Introduction to Remote Sensing
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Lecture 18
Hyperspectral Remote Sensing

Hello everyone and welcome to the 18th topic of introduction to remote sensing course and in topic, we are going to discuss very upcoming part of remote sensing, branch of remote sensing which is called hyperspectral remote sensing. As you know that so far we have been discussing the passive remote sensing, also we have discussed the active sensing but this is though it is a passive remote sensing but it is hyperspectral has got many applications which are very specific and it is going to be very popular technique for certain types of applications of remote sensing.

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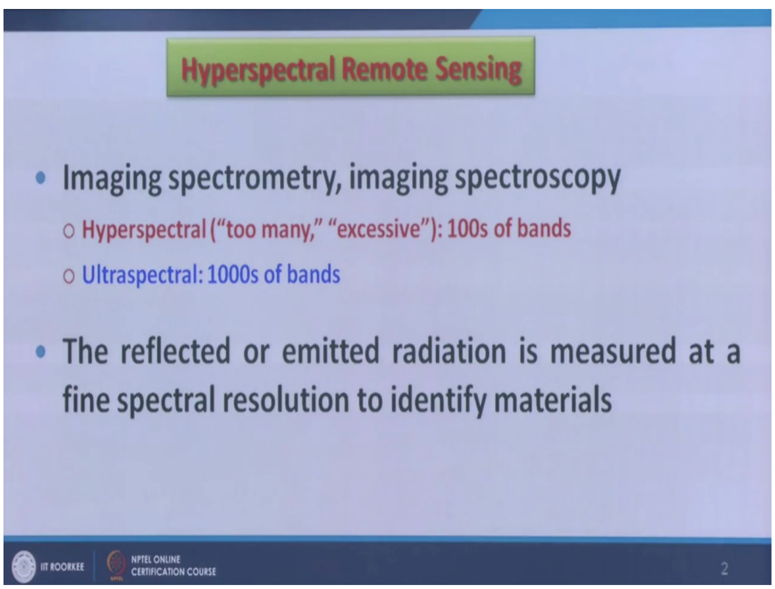

So what basically hyperspectral sensing earlier we used to have spectrometers and used to take in the field to create the spectral curves of different objects, different rocks, different minerals which are present on the surface of the earth. But now it is possible to even create these spectral curves using hyperspectral remote sensing as well plus finding out other mineral resources alteration zones and changes in vegetation, stresses, conditions, different stress conditions in the vegetation and so and so forth. So this is becoming very very popular, very important branch of remote sensing which is upcoming so its hyperspectral term may be used when we are having too many or excessive bands so we like (in) (in) initially like we had when Landsat MSS, we had only 4 bands.

Now, in Landsat OLI series we we are having 11 bands so we have progressed only that much but now it is possible to have 100s of bands. We will see some example of currently operational satellites or in hyperspectral region which are having more than 200 channels so may be in future, we instead of having hyperspectral remote sensing, we might be even thinking of ultraspectral remote sensing of 100s of bands within 1 sensor but 1 thing one has to be remember more the number of bands are there, more the data has to be handled and this is really huge datasets which is being generated nowadays under this hyperspectral.

This this because this is also a passive remote sensing so it's reflected or emitted radiation whatever during daytime, solar radiation or emitted radiation which can be measured at very fine spectral resolution so it's a continuous and that means there is there are no gaps like if I take example of Landsat ETM plus sensor or in OLI series Landsat 8 that there are gaps between 1 brand and another brand because of atmospheric windows and other reasons were there or absorptions but now in hyperspectral, there is no gap.

One bands, 1 band ends, another starts so it's a continuous data which is being collected so very (fi) fine spectral resolution that means may be in nanometers or in 0.1 micrometer or something like that and to identify different materials which are present on the surface of the earth and can can so we this would be also able to create if it is flying or if image (bel) is of belonging to a known area, there we know that what kind of materials are present then we can make spectral curves as well for other purposes in other fields of remote sensing. So basically 2 purposes to identify different materials which are present on the earth, create a spectral library for future use.

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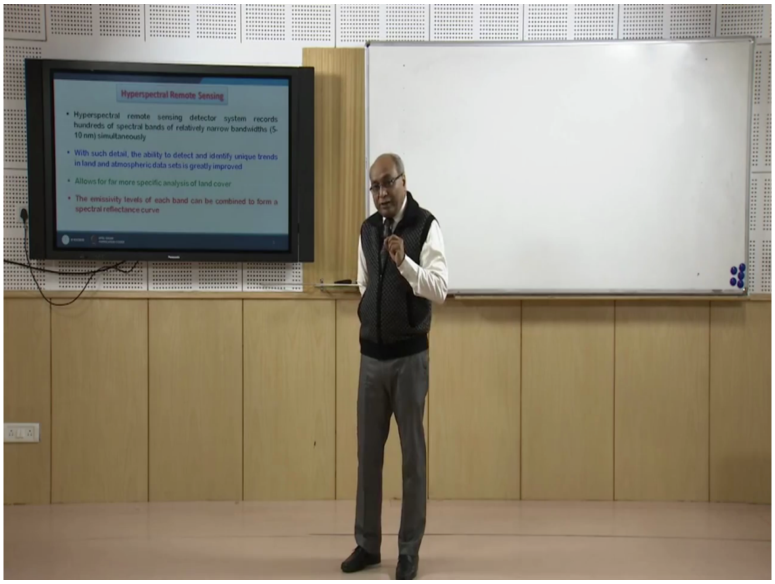

Hyperspectral remote sensing basically detector records 100s of spectral bands or relatively very nano nano width, maybe 5 to 10 nano simultaneously on this all this data has been collected huge data with such detail, the ability to detect and identify unique trends in land and atmospheric datasets is greatly improved so that each and every variations within each and every object which are present on the earth can be recorded very accurately including part of atmosphere.

Because (glo) more focus is going on nowadays on the atmosphere as well because global changing and other things and it is it is hyperspectral remote sensing also allows to have specific analysis for a particular type of land cover and emissivity levels of each band can be combined to form a spectral reflectance curve, this is what I said that another purpose of this that spectral reflectance can also be created earlier the curves which we will see very soon or we have also seen some like curve for vegetation, curve for water body, bare soil, rocks and other things were were taken at only at certain points and then rest of the things were connected but here in hyperspectral remote sensing, for each um nanometer, you are having 1 value and therefore you are having a continuous curve and not interpolated one so that is the another advantage of hyperspectral.

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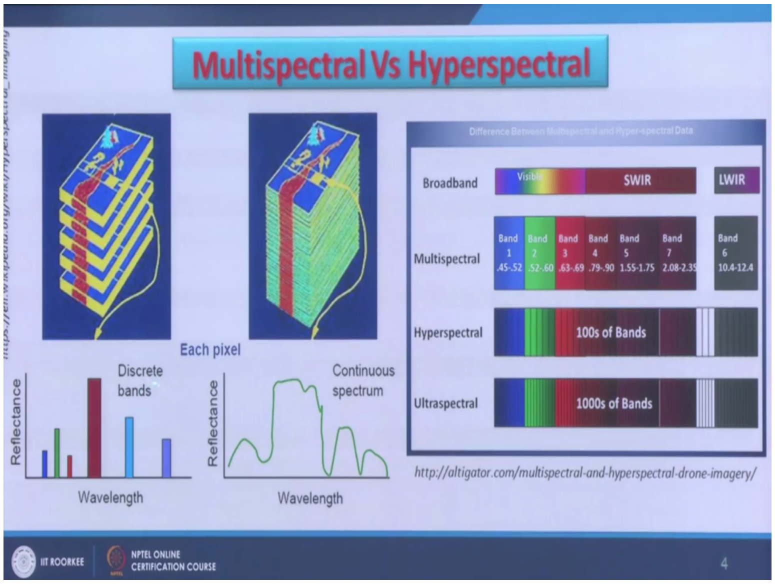

If we compare simple multispectral then you are having gaps between 1 band and another but in hyperspectral, all bands are continuous so here, this was if we say the these were the discrete bands, not continuous bands and here you are having continuous bands so therefore if I have to make curve then all top and in between the interpolation was required basically but here now each wavelength I am having, 1 value of reflectance and therefore continuous curve, reflection curve or emission curve can be generated.

Same way here that broad band, we used to have very broad band, still we carry a broad in visible part in panchromatic sensors are there even on Landsat 8 there is a broad, relatively quite broad band, invisible and the short wave infrared, long wave infrared, all these were very broad brands. When we came for the multispectral then these brands, this visible part has been divided in 3 parts. Short wave was also divided in 3 parts, later on later in the hyperspectral, you are having continuous and 100s of such brands are there.

And of course if we go for ultraspectral may be in future then we will have 1000s of bands and you can think that the the handling of data would be really (expo) exponential in in terms of their processing but anyway the processing tools and the computer hardware, software everything is developing so it would be possible even today like to handle 100s of bands data, in future may be

1000s of bands data and we will have very accurate spectral curves and the analysis of different materials which are present on the surface of the earth.

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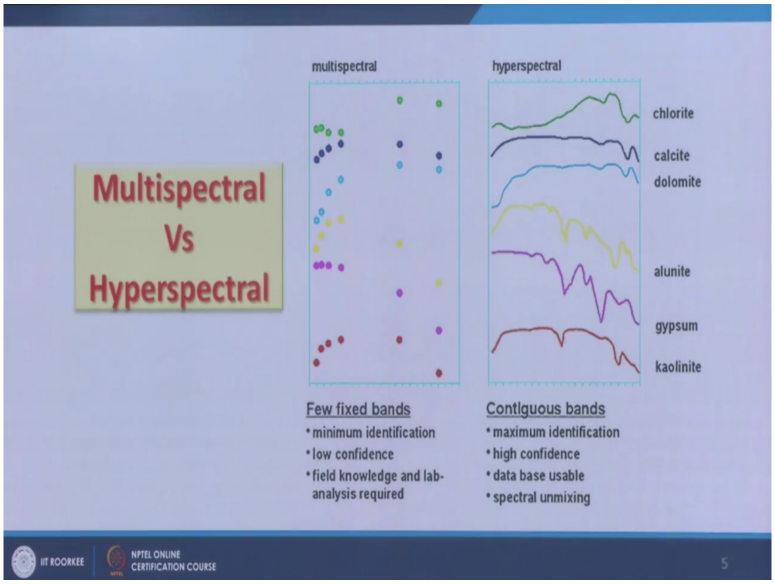

like in multispectral we used to have just point data against certain wavelength but here in a continuous so minimum identification was possible in multispectral and low confidence we had, here in case of hyperspectral, it's a maximum identification, everything could be identified, a slight change in a spectral curve can be correlated in different parts of EM spectrum, high confidence is there and here, the field knowledge and level analysis was required but here in future, we will have have these standard curves for different materials like here for different minerals, kaolinite, gypsum, alunite, dolomite, calcite, chloride, all these are having different spectral curves so these can be used to classify a hyperspectral images very easily without having any prior field knowledge so that can be also possible in future as well.

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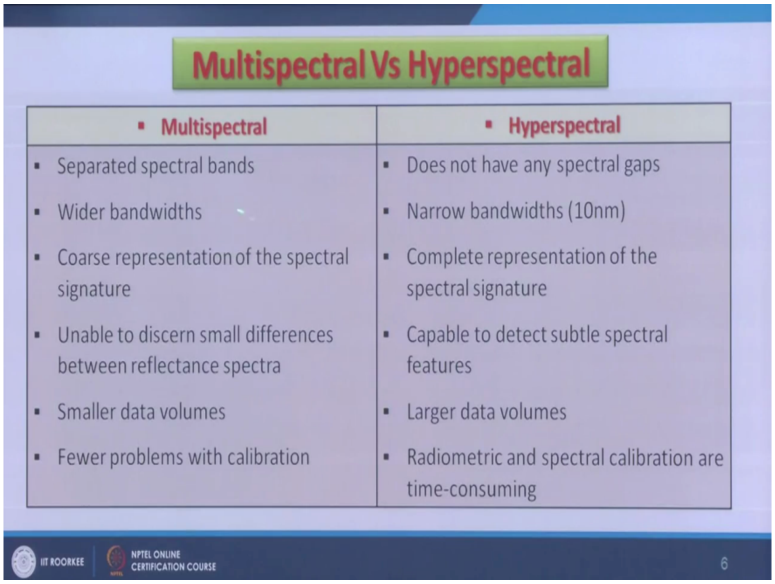

Now we continue on this multispectral versus hyperspectral. as we know that if they are separated spectral bands, there were gaps between 1 band to another whereas in case of hyperspectral does not have any spectral gaps, say continuous data, here is the (con) (diconti) discrete brands, here continuous brands, wider bandwidth we had initially like between 0.4 to 0.5 so this was now considered as wider bandwidth whereas here you are having a nanometer, narrow bandwidth data is there so very high spectral resolution.

A coarse representation of a spectral signatures, a complete representation of spectral, it was a discontinuous spectral curves, here is a continuous spectral curve unable to understand small differences between reflectance spectra but here, it is capable to detect suitable spectral features. Smaller data volume, not much in today's terms, it was not much data but at that time of course, it was huge data and because now computers and our storage capacity has increased many (for) so today's reference, it looks a smaller datasets.

But nowadays, even as per today's standards, hyperspectral data is larger data volumes so the in that way, it's a minus point but it is providing a completely continuous dataset and fewer problems with calibrations, calibration problems, we are very limited but now we have to because we are having data of very narrow bandwidth of 10 nanometer and therefore radiometric and spectral calibration are very much required and it these are very time consuming processes.

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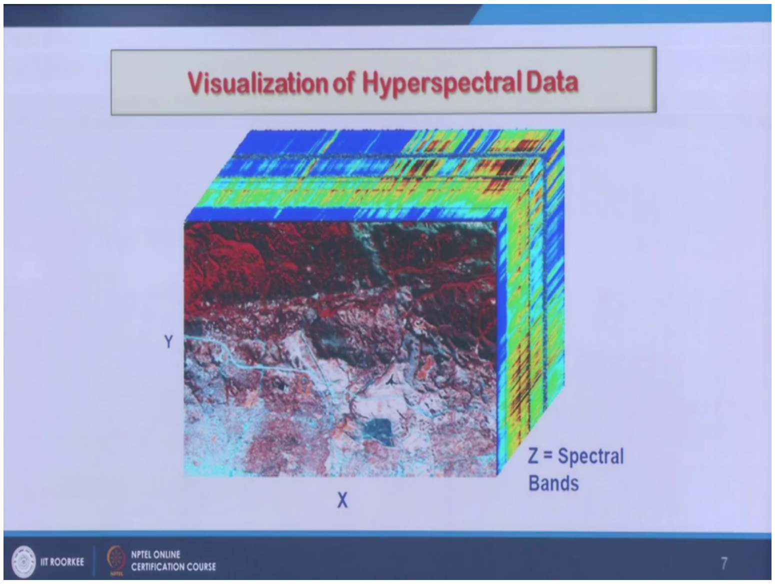

As can be seen here is that suppose this is one (mult) this false color composite but in 3D in when we are having 100s of bands then like here Z equal to spectral bands then as can be seen for in the sides, you will have these not really slices but continuous depth of information, a reflection or emission information about an area, earlier we used to have just 1 color composite, not we we can have a complete cube of information so you say it has definitely added a one more dimension to standard remote sensing.

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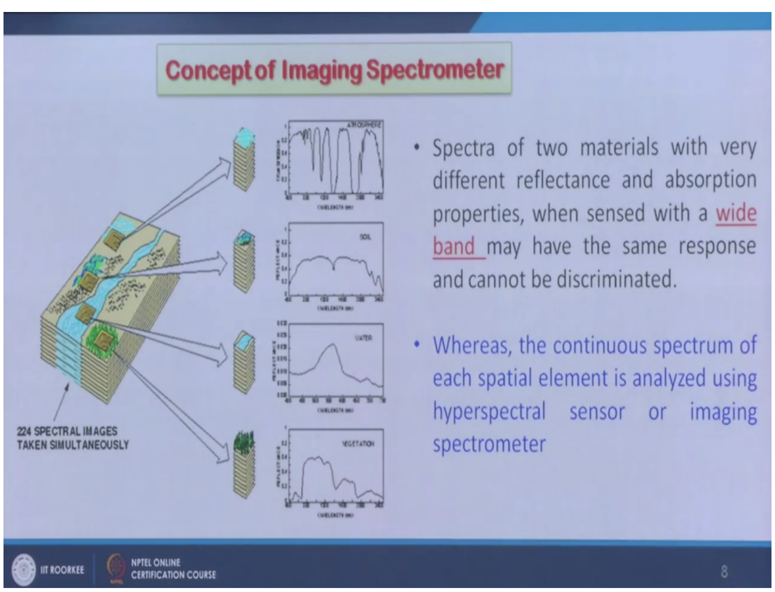

And this how this this spectrometer is, there as you can realize that there are some sensors which we will discussing soon having 224 spectral images taken simultaneously so we can we can we can detect each objects and their corresponding responses in throughout this 224 spectral images. Like here, immediately it becomes very easy to make a spectral curve if I am I am having some prior information that this area is (cum) 100% having vegetation so then I can say that this is the spectral curve.

Automatically also, when the pixel by pixel data is collected or images are generated then using these standard curves that, once the standard curves are generated then classification can be done very easily so likewise water, soil and everything, these things can be done. As you see that the vegetation, water and soil curves are very easy to interpret. We know that where (the) there is higher reflection, where is a less reflection or absorptions but in case of atmosphere, it's a complex thing so anyway that that has to be also looked into and hyperspectral remote sensing also providing that kind of information as well.

So spectra of 2 materials with very with very different (differe) reflection and absorption properties and sense with a wide band in a normal remote sensing like Landsat MSS or Tm or IRS, Liss 3, Liss 4, may have the same response and cannot be discriminated but in case of when we are having continuous spectra, we will find that place between these 2 objects in ther (res) respective spectral curves where these these can be differentiated so this is what is meaning here. That the whereas the continuous spectra if I am having, each spectral element is analyzed using hyper spectral sensor or amazing ray spectrometer so that is the biggest advantage of having hyperspectral.

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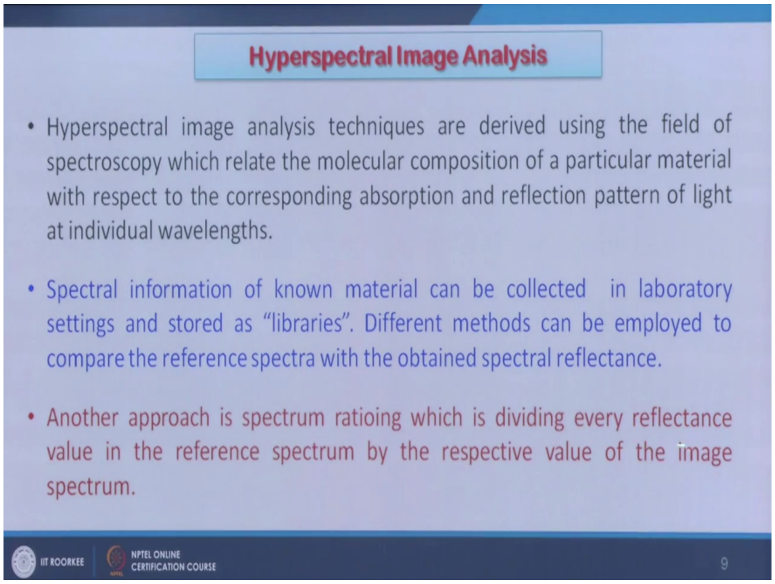

Hyperspectral image analysis techniques can drive using the field spectroscopy which related a molecular composition of a particular material with respect to corresponding absorption, reflection pattern of light at individual wavelength the advantage here, you are having continuous spectra, not a discrete one and therefore it is easy to detect the slightest changes in 2 objects very easily.

A spectral information of known material can be collected in laboratory settings and then these (spe) spectral libraries can be used further as we mentioned also earlier that different methods can be employed to compare the (ref) (ref) reference spectra with obtained spectral curves and these another approach is in spectra that we create a ratio which is dividing every reflection value to a difference in spectrum by respective value of image so once the that data is collected then further processing is also possible.

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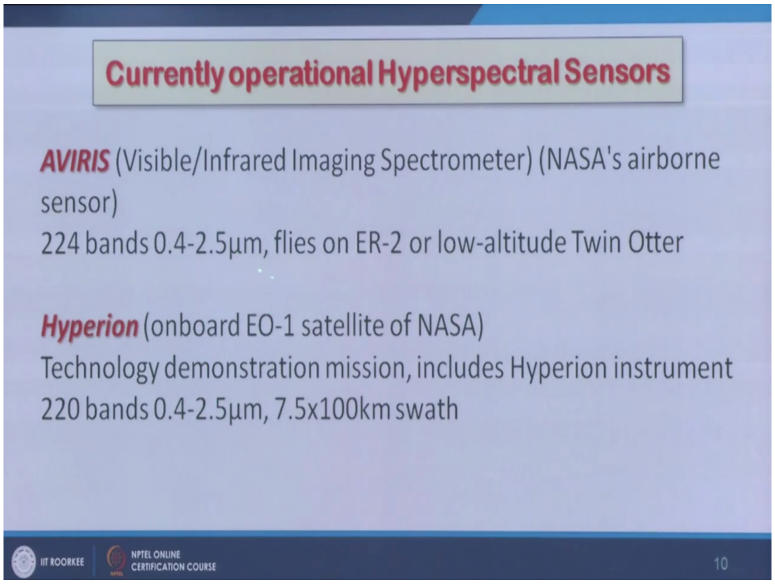

This Aviris was one of the sensors which was designed about 20 years or more and it as a airborne sensor, Aviris which which was covering visible and infrared part of electromagnetic spectrum but it was continuous, it was hyperspectral category, it had 224 bands, huge number of bands, just compare Landsat 8 data, just 11 bands. 224 bands and 0.4 to 2.5 micrometer so it's covering almost the same way EM spectrum as in Landsat 8 and except the thermal, flies on this ER2 or low altitude to an OTA.

So this was since it was airborne so that data, wherever they felt, they flown the aircraft and collected the data and of course it developed the concept and everything and later one once it was realized that now the similar kind of sensors can be sent on a satellite so it becomes a space borne rather than airborne and then you will have continously data for all parts of the globe and this is what is has done. By putting a hyperion sensor onboard of a earth observing satellite 1 of NASA and this had almost the same same kind of bands another thing which we will see.

This was the main purpose is to demonstrate the technology so this was a technology demonstration mission includes hyperion instruments and it has 220 bands because everything, for a decade, everything were tested in Averis which was airborne and almost same number of things were there and of course then number of bands were little reduced, 220 bands, this (EM) the bandwidth, or the total bandwidth coverage was remain same because in experiment, it was found it is alright and then swath of course is is little different.

It’s a tiny strip of just 7.5 kilometer and the lengthwise 100 kilometers so 1 scene is covering a very tiny strip and the reason is of course the huge data, it has to scan in 220 bands and same time, it has to send towards the earth or record onboard and however for many development and validation studies, still hand held sensors are used so you go in the field spectrometers and collect the data but this is a very good development has taken place that data is available for some part of the earth.

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Now on further we will see hyperion imaging spectrometer on board of NASA EO 1 satellite which was a demonstration purpose mainly. It has a it is a push broom sensor and of having the altitude of 7.5 kilometer, the swatch width is 7.6 kilometer which is a relatively very narrow and it has a 98 degree inclination flying information with reference to Landsat 7 just 1 minute apart so that it can be also checked along with the Landsat 7.

Spectral range was as mentioned earlier 0.4 to 2.5 or 2.4 and each band had the 10 nanometer bandwidth, there were 220 spectral bands, spatial resolution is not as that high as one would like to have to because now we are talking 30 centimeter but still 30 meter spatial resolution is quite good, it is comparable with the Landsat and latest series so that for corresponding bands where

Landsat is also having can be compared here as well so with this and this radiometric resolution is also very high. A 12 bit data so huge data of 220 band, bands at 12 bit is being generated for all parts of the globe.

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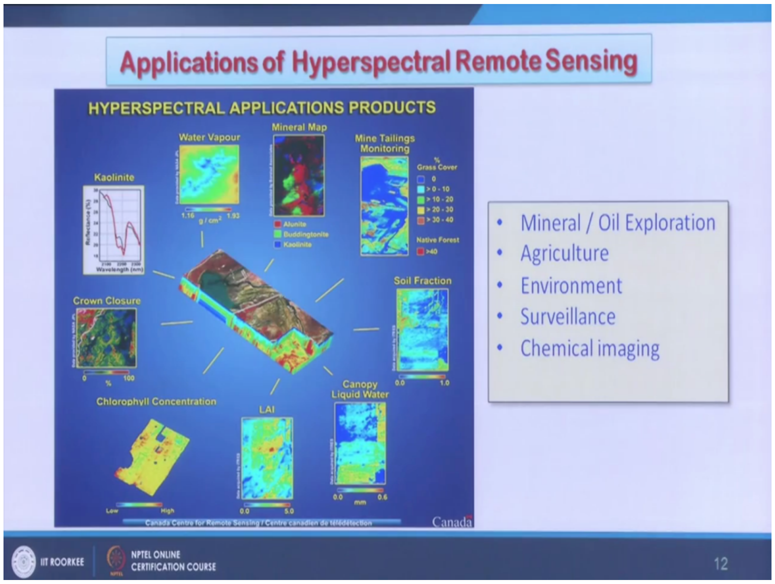

Now when we look the applications, some of the applications I have already discussed, the applications the major one which are coming so let's start from top, the mineral mapping, doing a mineral mapping, doing a searching for alteration zones, slight change in mineral properties can now it is possible to detect by using hyperspectral remote sensing. Of course it has has to be, it has to be exposed. If it is covered with vegetation of soil then it's a different thing. Even in the soil property, slight change in soil properties can also be discriminated so hyperspectral remote sensing can play major role in mineral mapping, mines train tailings monitoring.

This is again because mines create lot of output and those things can also be monitored. Now soil fractions, soil mapping overall, soil mapping, very accurate mapping and other things can also be done, can it be liquid water whether there is plants are having stress due to the water or not or trees or agriculture fields are having the same thing can also be accessed here and leaf area index can also be measured using hyperspectral remote sensing which will help in agriculture and it will tell that whether (pla) the (agri) the crop is under water stress or not. Those things can be assessed very easily.

Chlorophyll concentration again related with the health of vegetation, whether high (cul) chlorophyll concentration is there or less which part is having, which more. These all these things can be measured or sensed by the hyperspectral remote sensing the crown closure of plants, kaolinite which is again soil mapping and water vapor, water vapor you know the the atmospheric can also be used in that application, the hyperspectral remote sensing so lot of applications are there, mineral and oil exploration, overall in agriculture, environment water vapor and other things.

Surveillance, in surveillance also in chemical imaging especially for water bodies here, some affluent or pollutant water is coming so where because you are having a continuous spectra so you can really detect individual probably individual elements or concentration of different pollutants can also be measured with this one. Of course the spatial resolution is 30 meters but it doesn't matter, still in lake water or in seawater, such concentrations of a chemicals or sediments can be measured very easily.

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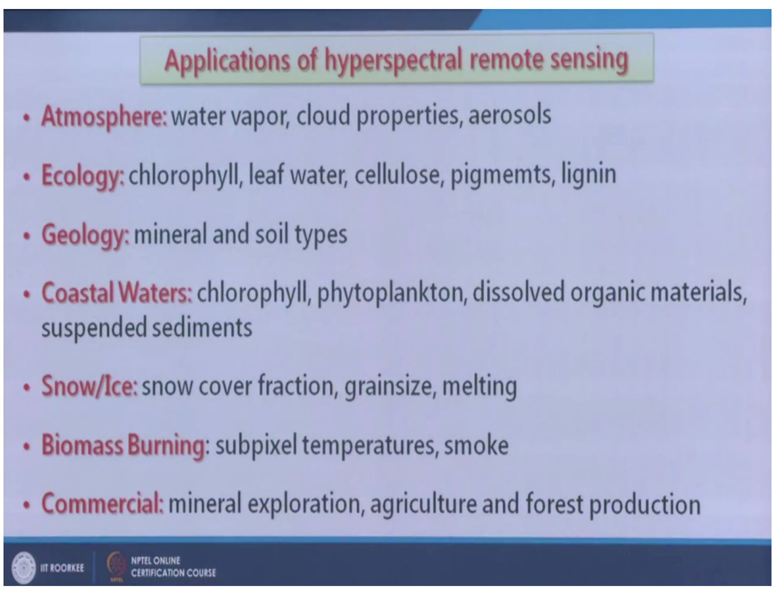

Further applications overall in atmosphere water vapor, cloud properties, aerosols, aerosols because of increasing pollutants, aerosols has become very important to study so in hyperspectral remote sensing it is possible. Ecology, Chlorophyll, leaf area, cellulose, pigment and and legnin. Earth sciences in geology in mineral and soil types, rock types and lithology can be discriminated. In coastal water, as I have said, Chlorophyll, phytoplankton, dissolved organic material, suspended sediments, all these are important to map.

And then snow and ice also and that a what is a snow cover fraction within whether it's a complete ice or complete snow or some part of a snow and so thing, grain size and and melting and other things and biomass burning, this is becoming a big issue that you know that we can have even a surficial temperature or smoke detection and other things and because of whether that smoke is coming because of biomass or a smoke is coming from coal burning that too can be detected because both smoke might have a different spectral which can be only detected through hyperspectral remote sensing. So likewise it is adding to many applications, mineral exploration, I have already covered agriculture forest production and so on.

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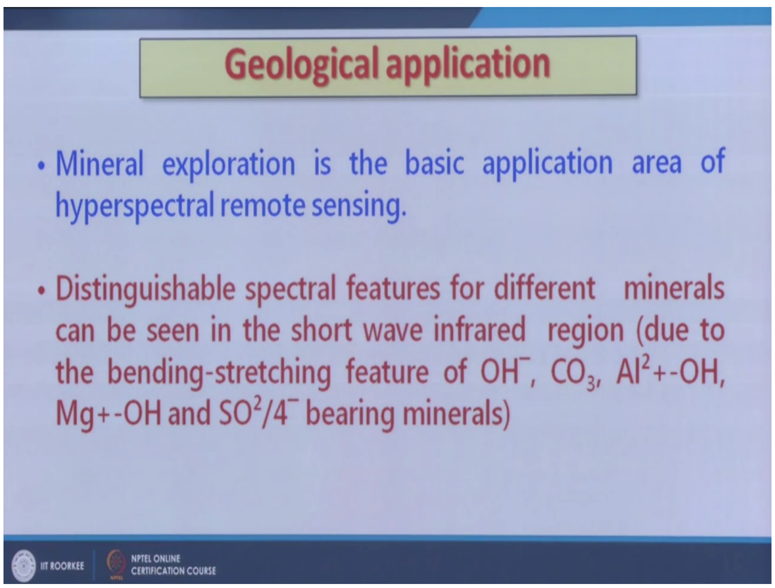

There are some specific geologic (operatio) applications, mineral exploration is the basic application area of hyperspectral remote sensing and the purpose here is to distinguish spectral features of different minerals and so that in short wave infrared region so that the band so different a mineral or bearings of different thing whether they are having water or other things, they can be detected very easily.

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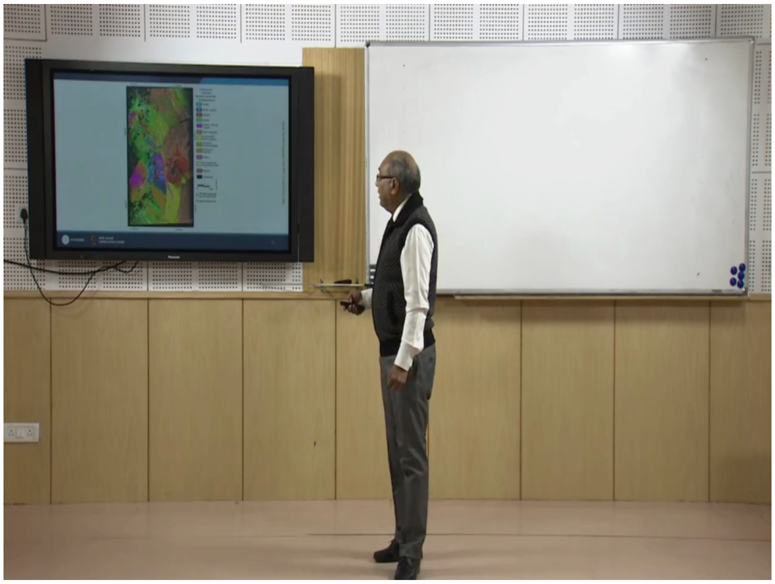

And likewise an area can be classified based on this is the example of Aviris data application. So different types of iron bearing minerals were classified like chloride, goethite, hematite, jarosite and pyroxene and then of course, some places we had not detection but it it has become only possible because of hyperspectral data but one thing as I have already mentioned, it’s too much data to handle even with today’s systems image processing software’s available with the standard installations, it is not that easy to handle but anyway, in future, this, this has got future, this will develop few more applications areas.

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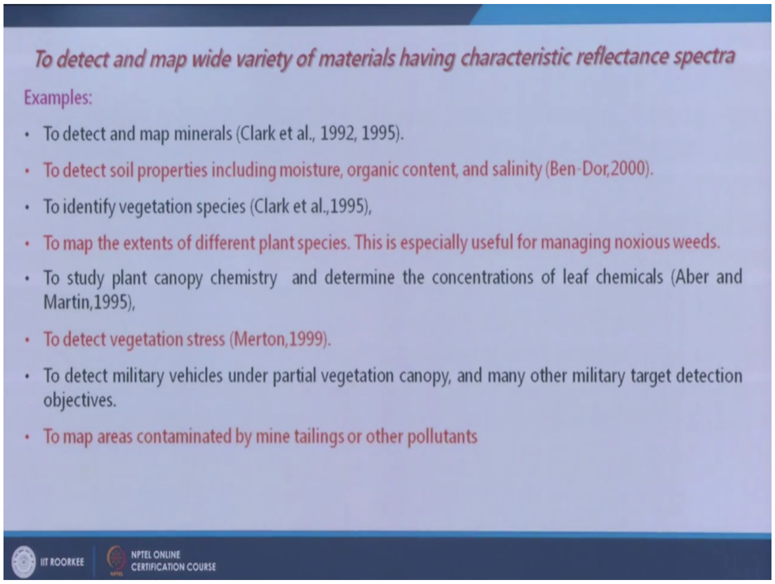

So wide variety of minerals can be detected, they can be mapped and people have done different kind of works, to detect soil properties, to detect vegetation species, to map extent of different plant species to study plant canopy, chemistry and to detect vegetation stress that is very very important application especially in agriculture whether crop is suffering from water stress or crop is suffering from certain types or disease or other things or the efficiency of certain minerals, fertilizers that can be detected and of course, it has got some military applications and to map areas contaminated by mine tailing or pollutions. And so water color to determine which micro organs are present and locate the pollution source so wide applications are there for hyperspectral remote sensing. People have already done some work using Aviris data on this.

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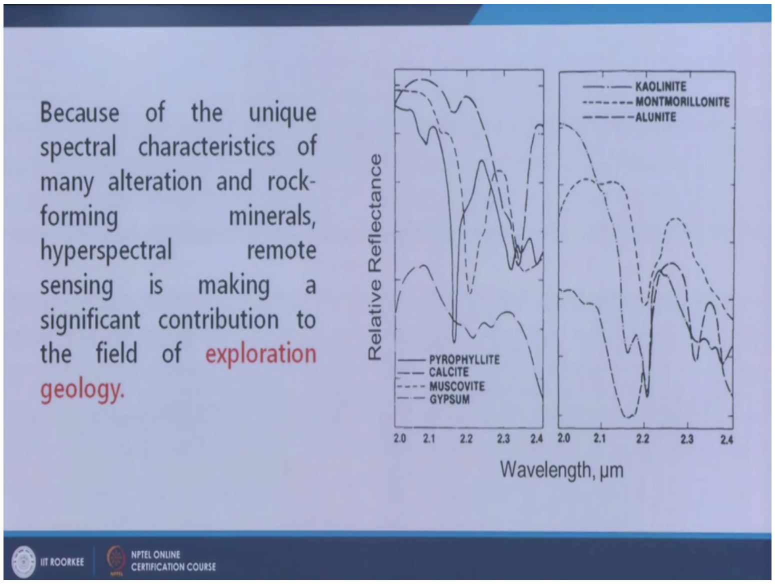

And similarly like for a minerals, mineral expression which I have already covered that different spectral curve for pyrophyllite, muscovite, calcite, gypsum can be detected very easily because you are having continuous curves same with different types of kaolinite, montmorillonite, alunite, all these can also be detected.

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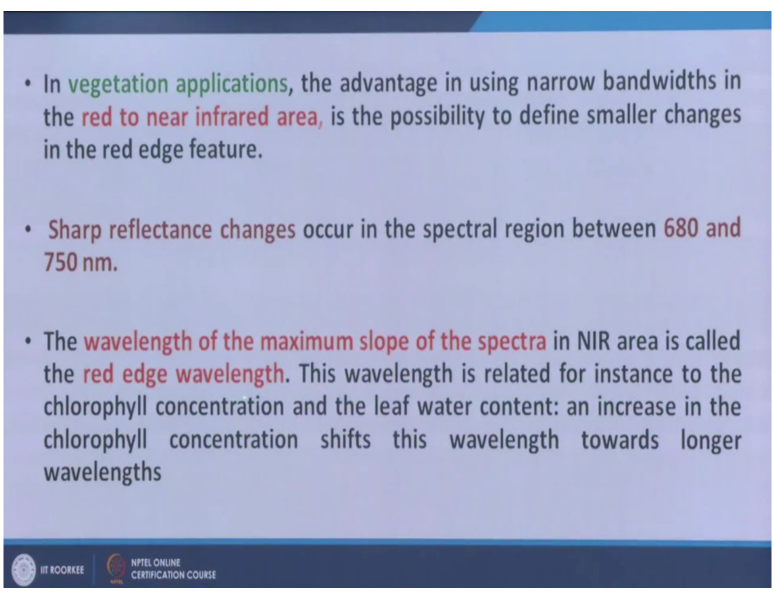

In vegetation basically if a plant is suffering from some stress because of water or some reason, the spectral curve will shift towards the left means towards the red edge and that can be detected in hyperspectral remote sensing. And then sharp reflection changes occur in this spectral region between this and this since we are having bands at almost every 10 nanometer so these things can be detected very easily and this red edge of a shift in red edge towards red edge can be detected in case of vegetation, in case of crops and other things.

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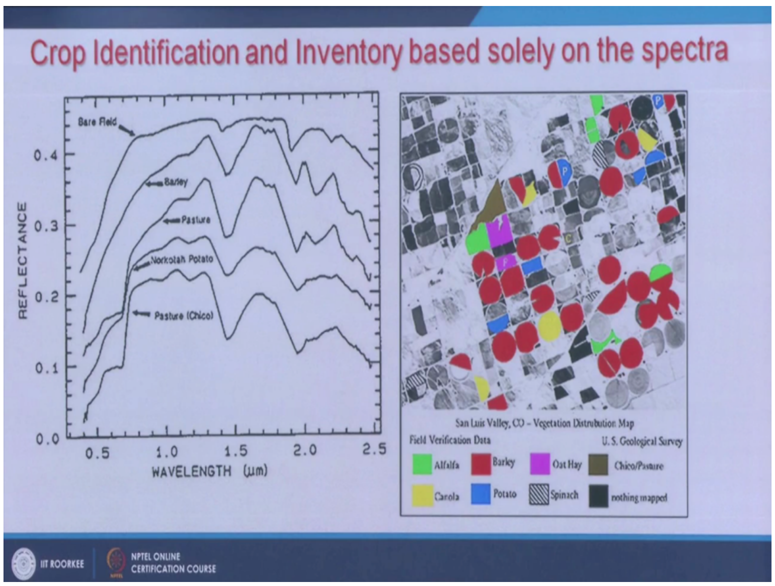

So crop identification and which can be done solely on the spectral curves which be developed in future standard spectrum curve is compared automatically by the computer based on the new input image and classification can be done and then you know that whether what kind of crop it is, whether it is having healthy conditions or not, those things can be detected very easily.

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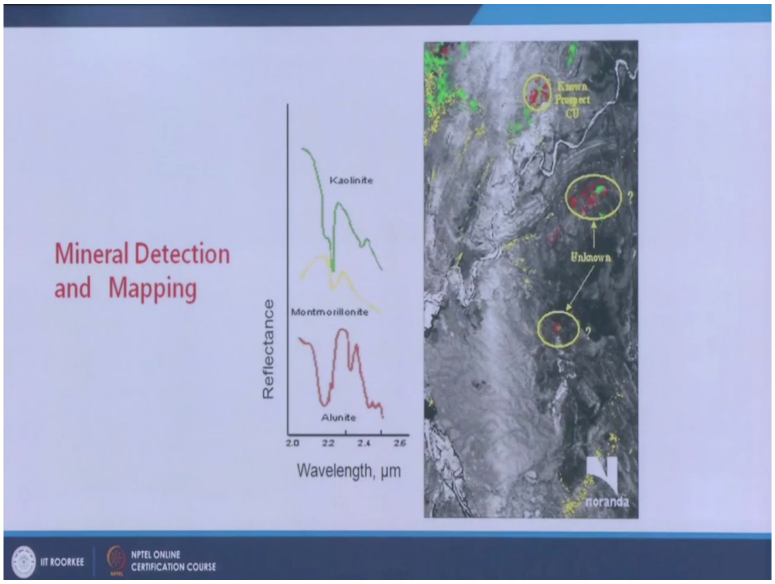

Same in the mineral detection and mapping can be done so it got really wide applications and future applications will also come so far only 1 sensor onboard, a satellite is there but very soon hopefully we will have more more data handling capabilities, more types of analytical tools would be available and this will serve a lot of purpose.

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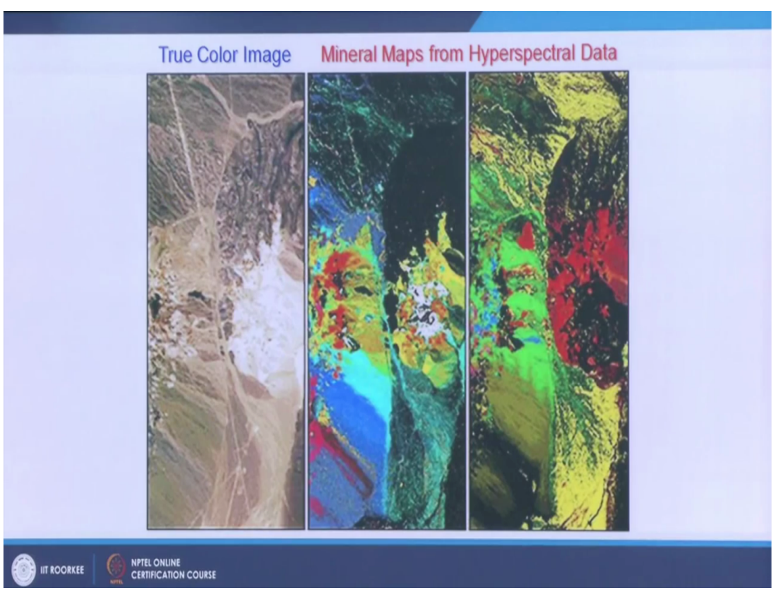

So this is a just an example of like a true color image, this is what you see, this much only discrimination is possible but in hyperspectral remote sensing, this kind of detection is possible.

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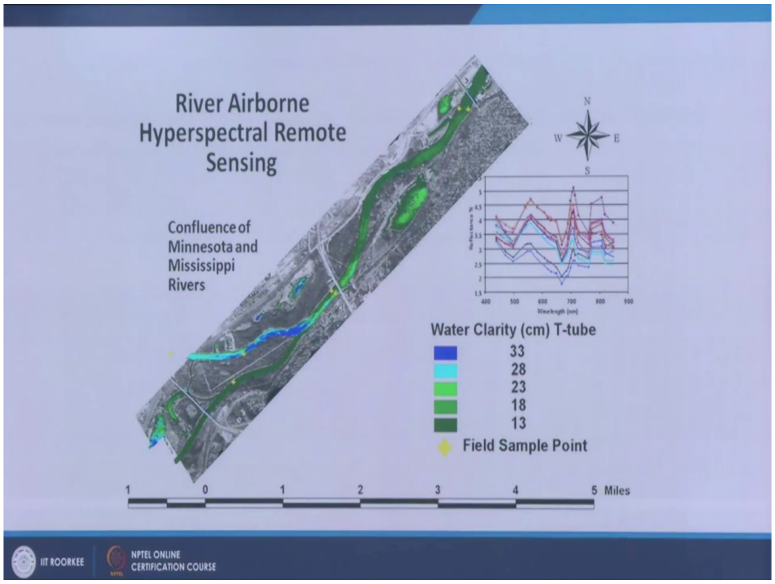

So this brings basically to this water quality also it can be done as I was mentioning in the river water or lake water this thing can be done so this brings to the end of this presentation. Thank you very much.