Machine Learning for Soil and Crop Management
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Lecture 41
Hyperspectral Remote Sensing and ML Applications in Agriculture

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Welcome friends to this NPTEL online certification course of Machine Learning for Soil and Crop Management. And today, we are going to start our week 9 lectures and the topic of this lectures Hyperspectral Remote Sensing and Machine Learning Applications in Agriculture.

And so, in this week, we are going to learn in detail about what is hyperspectral remote sensing, we will be starting from the sampling the spectrum, we have already touched this hyperspectral spectroscopy in our previous week in our week 5.

And in this week, we are going to discuss about the hyperspectral remote sensing we are going to discuss some applications and also we are going to see how this machine learning can be useful for, for these hyperspectral remote sensing, based soil and crop characterization.

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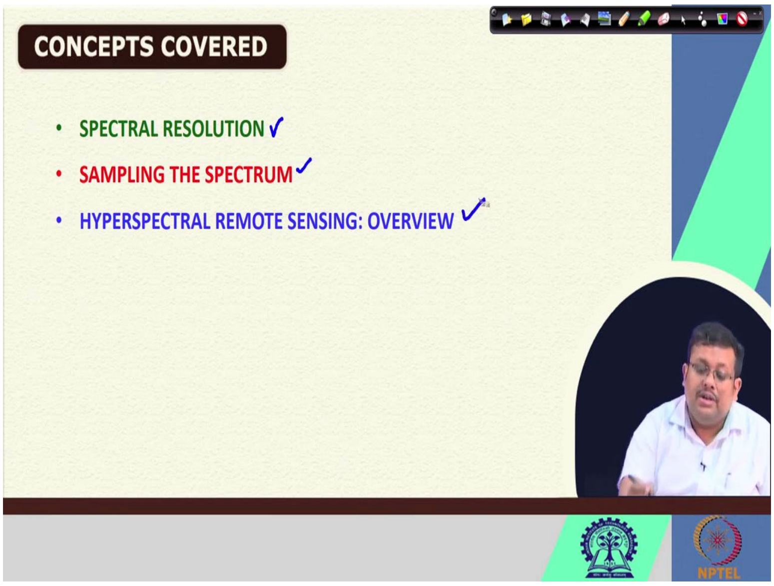

So, let us start in this first lecture our, these are the concepts which we are going to cover first of all, we are going to cover the what is spectral resolution, and then we are going to cover what sampling the spectrum and also we will try to cover the hyperspectral remote sensing the overview of hyperspectral remote sensing. So, these three are the major concepts of this week.

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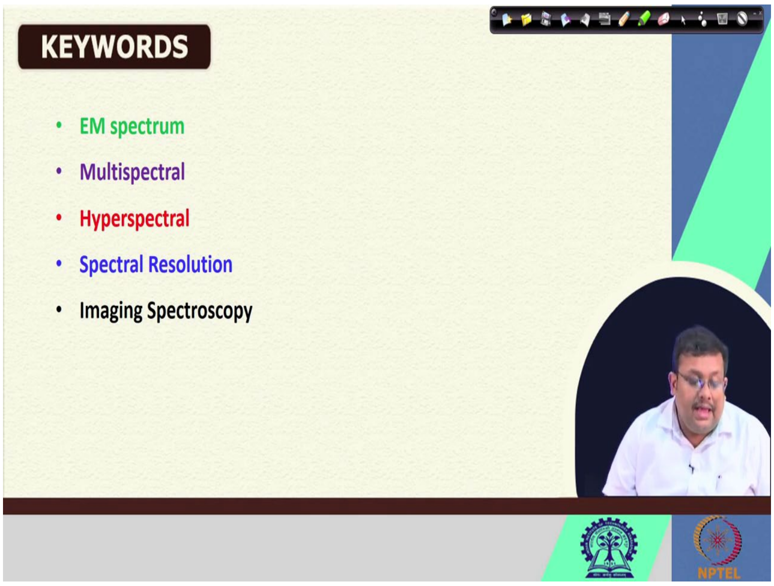

And these are the keywords. So, we are going to learn about this EM spectrum also or electromagnetic spectrum. Then we are going to discuss about the multispectral data hyperspectral data and also spectral resolution and imaging spectroscopy or hyperspectral remote sensing.

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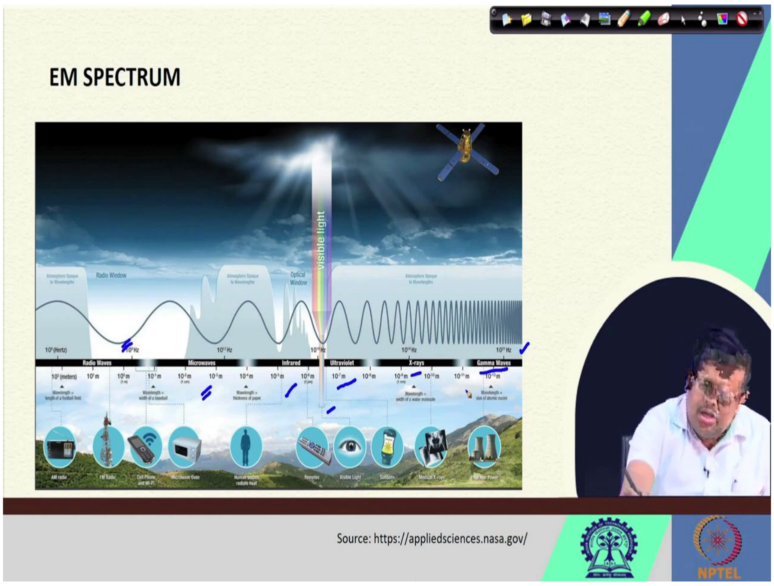

So, guys you already know what is electromagnetic spectrum. Now, this electromagnetic spectrum can be differentiated into different zones based on their wavelength and or wave number. And based on these wavelength and wave number they are divided into several types of wave, energies or they have named they have they have been named differently.

So, for example, if we start with the very high frequency component of this electromagnetic spectrum, this is called the gamma waves and then X rays and then comes the ultraviolet rays then a small window from 400 to 700 nanometer wavelength range is the visible range which you can see and then the infrared range then microwaves and then the radio waves.

So, you can see that as we are moving from gamma rays to the radio waves, the frequency is getting less and also the wavelength is continuously increasing. So, depending on, on which zone we are working different types of spectral methods have been developed so far, for characterization of soil and crop properties.

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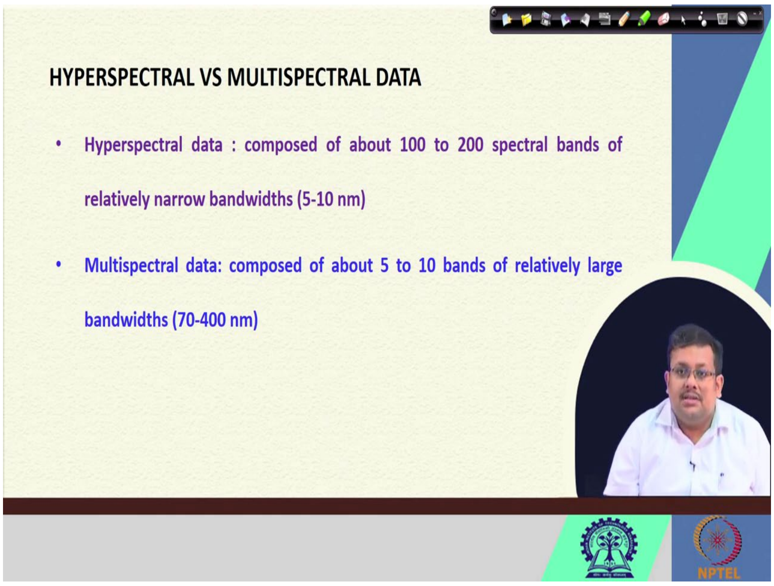

So, that next important thing comes to our mind what is hyperspectral and multispectral data. What is the difference between hyperspectral data and multispectral data? Remember hyperspectral data generally composed of about 100 to 200 spectral bands of relatively narrow bandwidths which generally varies from 5 to 10 nanometer.

Whereas, in case of multispectral data it is composed of about 5 to 10 bands of relatively large bandwidths and these bandwidths varies from 70 to 400 nanometers. So, you can see that hyperspectral data and multispectral data, the major differentiating factor is the number of bands and also the bandwidths. Of course, in case of multispectral data, the bandwidth is quite high and the number of bands are quite low as compared to hyperspectral data.

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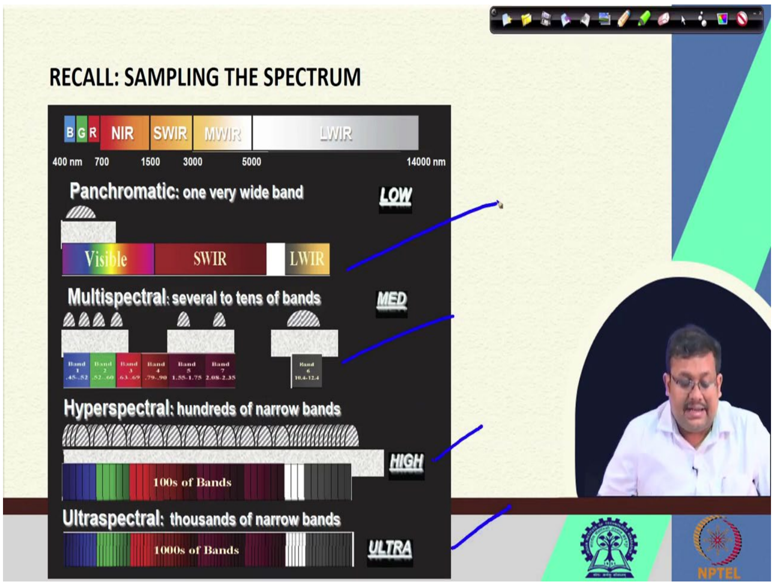

Now, if you recall one of our previous lecture we have discussed what is the difference between a panchromatic band and then multispectral data, hyperspectral data and ultraspectral data if you see the panchromatic band, the panchromatic band has one very wide band, whereas it is a multispectral you can see that they have several to tens of bands and hyperspectral has hundreds of narrow bands, and ultraspectral has thousands of narrow bands, of course.

So, ultraspectral has higher resolution than hyperspectral, so this is the hyperspectral with high resolution and this is the ultraspectral data and this is the this is the multispectral data you can see and this is the panchromatic data. So, these data have been used by different sensors for different types of application.

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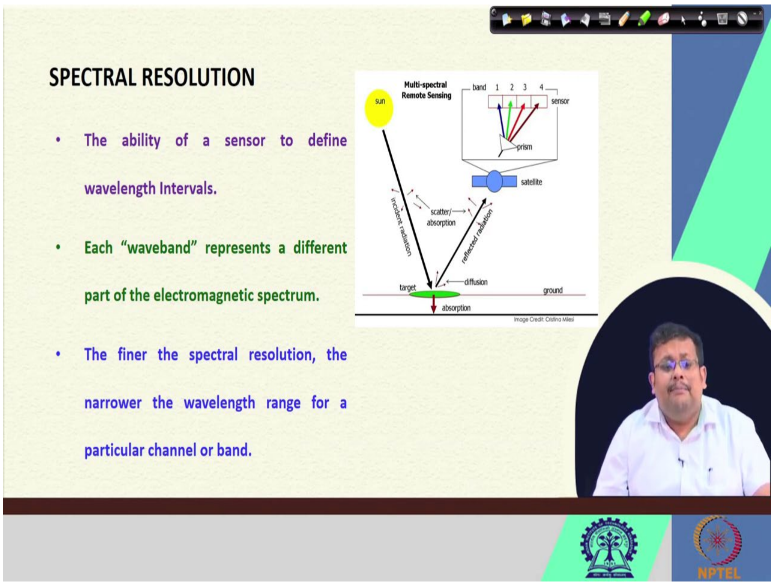

And the next term comes to our mind what is spectral resolution. Although, we have discussed that what is spectral resolution in our while discussing the hyperspectral spectroscopy. In a general sense the spectral resolution defines the ability of a sensor to define a wavelength interval. Higher resolution means lower wavelength intervals.

So, the finer the spectral resolution, the narrower the wavelength range for a particular channel or band. So, remember that each wave band represents a different part of the electromagnetic spectrum as you can see in this picture, when the sunlight comes and get reflected from any surface, and in this case, the ground surface and the satellite captures the images the satellite deflect that image through the prism into different bands or to the constituent bands. Now, these individual bands or wavebands represents different parts of the electromagnetic spectrum.

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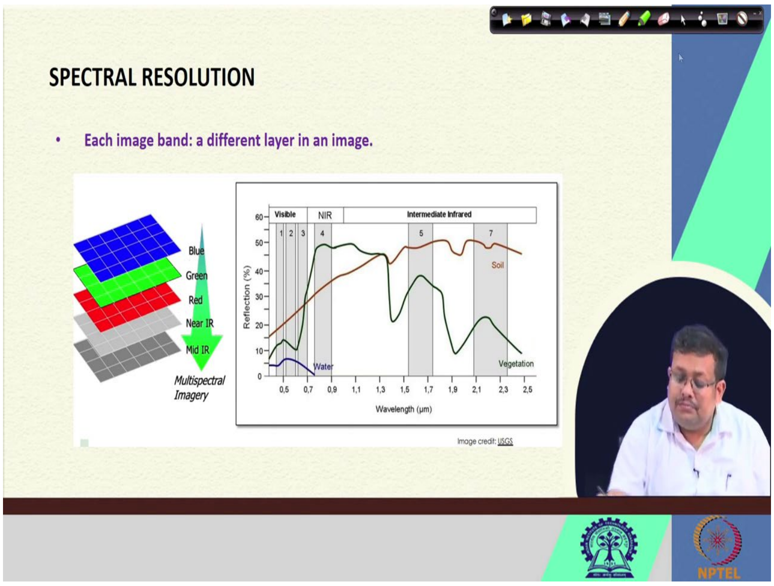

Now, if we consider the multispectral imagery, you can see that these blue green, red and near infrared, mid infrared these are considered as individual layers. So, basically each image band, a different, consider as a different layer in an image in case of multispectral imagery.

However, in case of hyperspectral data, they are contiguous and you can see clearly here this is, these are the different types of hyperspectral spectra, this is for vegetation this for soil and this for water and this is the hyperspectral spectra. And here, in the multispectral imagery and if we take these blue, green, red, near infrared, mid infrared at individual, layer they are considered as a combinely they are considered as a multispectral data.

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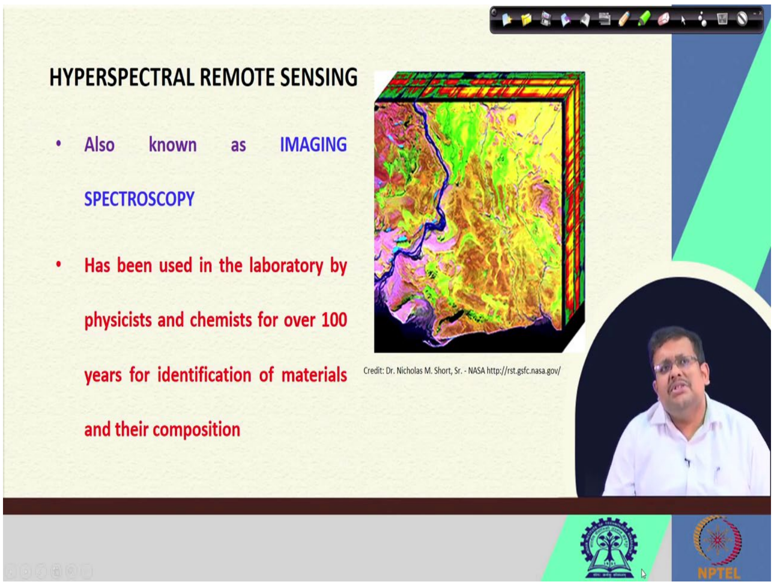

So, let us focus on hyperspectral remote sensing. So, what is hyperspectral remote sensing? Hyperspectral remote sensing is also known as the imaging spectroscopy. And this has been utilized in the laboratory by physicist and chemist for over 100 years for identification of materials and their composition.

As you can see this is a hyperspectral data cube and this hyperspectral data cube not only is having the spectral property of an, of a, of a individual pixel, but it covers the whole area to give a 3D view. So, that is why these image of this hyperspectral has 3 dimension x, y and z and that is why it is called the hyperspectral image cube. So, not only we are getting the spectral image, but also we are getting the spectral image for individual pixels.

So, an area can be divided into individual pixels and then for individual pixel, we will be getting the picture using individual wavebands, and then we are combined them together. So, we can consider a book as a image cube. And we can consider each page in that book as an image taken by a single wavelength of a hyperspectral sensor.

So, suppose a hyperspectral sensor is operating from 350 to 2500 nanometer wavelength range. So, if so, that means, they will take an image of a pixel using all these wavelengths starting from 350 to 2500 nanometers, and these individual images are considered as a page individual page of this book, and where we combine all these pages will get a 3D view of the book. So, this is like this data cube.

So, this hyperspectral remote sensing is utilized, because you can see not only we are getting the compositional variability, but also same time we are having a special coverage also. So, that is why we have combined these two terms imaging and spectroscopic together. So, this is an image taken by a spectral sensor. So, it is a basically combination of imaging as well as spectral scanning.

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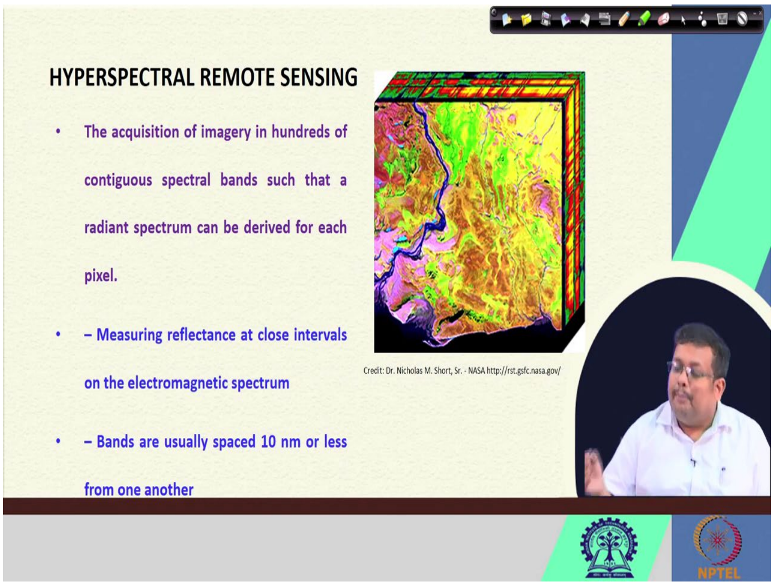

So, the acquisition of imagery in hundreds of contiguous spectral bands, such that irradiance spectrum can be derived for each of these pixel, that is what just I have told him, this just in our last slide. So, basically this hyperspectral remote sensing it measure reflectance at close intervals on the electromagnetic spectrum and bands that usually spaced 10 nanometer or less from one another. So, this is how this hyperspectral remote sensing operates. And we ultimately get these image data cube and these image data cube, these individual image has a bandwidth of 10 nanometers.

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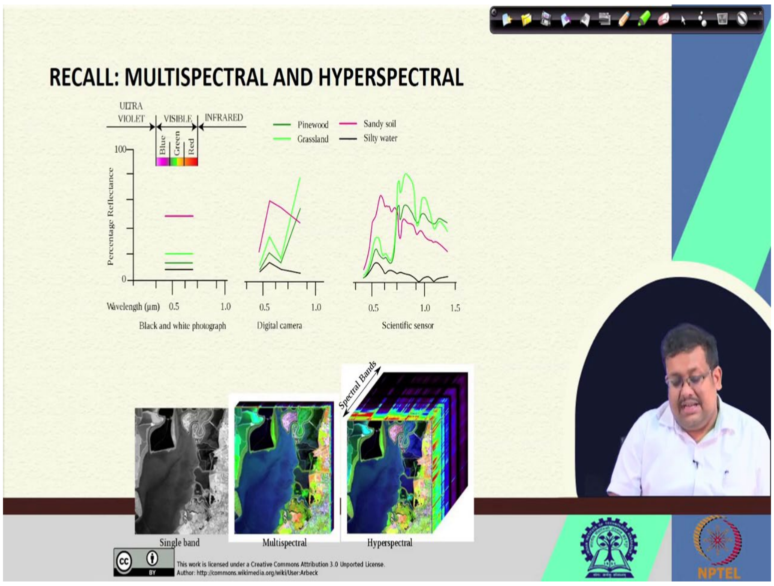

So, if we compare the, the the single band image as well as multispectral image and hyperspectral image, we will get this type of information of course, you can see that this is a black and white photograph, and this is digital camera that which is considered as a multispectral image, they have taken the image into RGB, RGB band, and then you can see here this is a hyperspectral band and one thing is very clear that as we go from a single band to multispectral band to hyperspectral, when we are getting more and more information.

For example, here we are not getting any spatial information, here we are getting some variation in the spectral response. However, here we are getting more and more spectral features. So, that means, when you go from single band image to multispectral data to hyperspectral data, we will get more and more information about the surface on which we are taking the image.

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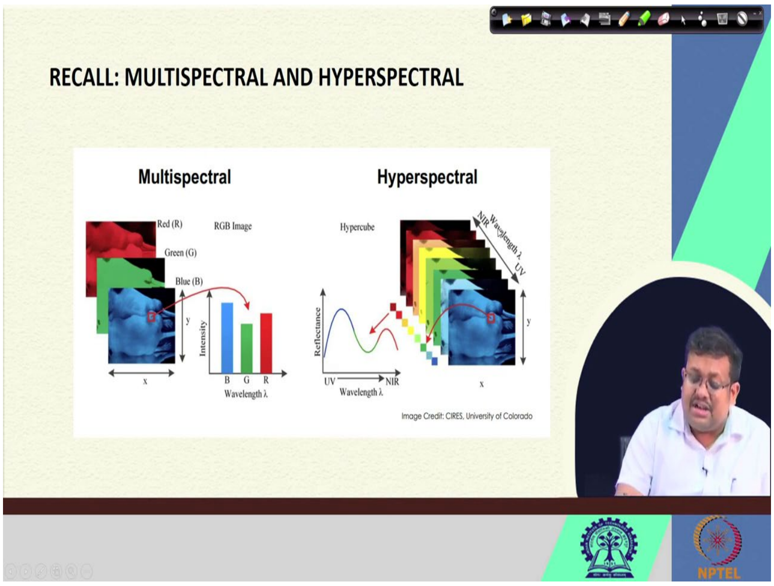

You can see a good, another good example here, you can see that this image can be consider as, these is an RGB image which has been for this, this pixel we can take this image in blue and green and red all these three bands. however, in case of hyperspectral, we can take the image using all the contiguous bands. If this is a UV and IR sensor, we can get the images for all these individual wavebands.

So, this is how this hyperspectral sensor basically works. And this is how and you can see the number of images are also getting increased. So, that means, here in this data cube, not only we are getting these x and y spatial information, but in the z direction, we are also getting the number of wavelengths. So, that is why it is called the data cube.

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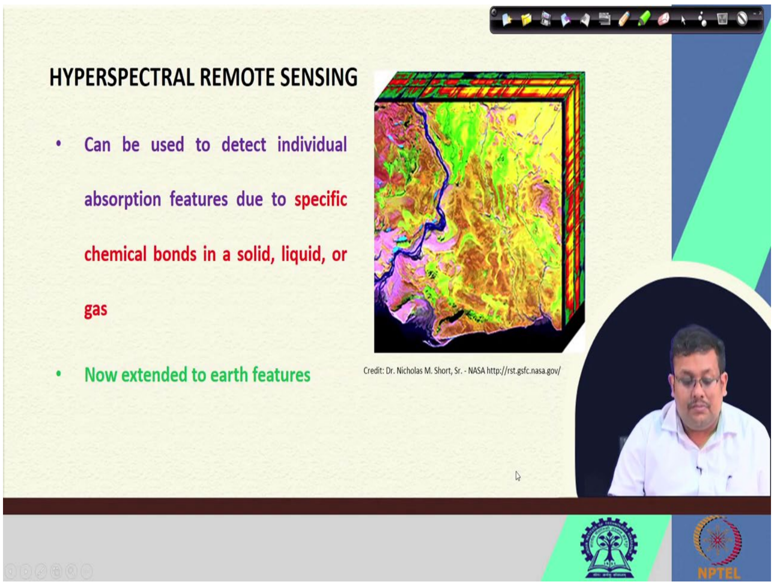

Now, this hyperspectral remote sensing can be used to detect the individual absorption features due to specific chemical bonds in solid, liquid and gas we know that. So, recently, last coup, in a couple of years, this hyperspectral remote sensing has been extended for mapping the earth features also. So, these while we have these earth features, while we can map these earth features, we can get more and more information about the surface.

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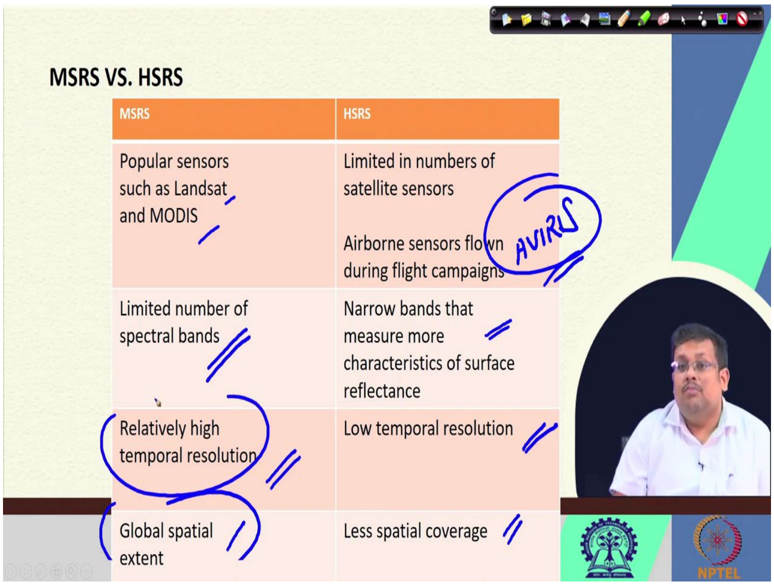

Now, if we want to differentiate between the multispectral remote sensing and hyperspectral remote sensing, these are some of the important points we have to think of. One is that the multispectral remote sensing has some popular sensors like Landsat, MODIS and hyperspectral remote sensors are very much limited and airborne sensor flown during flight campaigns like AVIRIS, AVIRIS we will be discussing this AVIRIS.

And also in case of multispectral remote sensing, there are a limited number of spectral bands as we have seen. However, in case of hyperspectral remote sensing, we have narrow bands that measure more characteristics of surface reflectance. And in case of multispectral remote sensing we have relatively high temporal resolution, but in case of hyperspectral remote sensing, we have low temporal resolution and the multispectral remote sensing has global spatial extent.

However, in case of hyperspectral remote sensing has less special coverage. But despite all these differences, despite all these benefits of this multispectral remote sensing, if you want to get more information, then obviously hyperspectral remote sensing is a better choice than multispectral remote sensing.

Of course, the image the storage cap, storage requirement for these images as well as the processing requirement, technical requirement for processing in case of hyperspectral data will be more as compared to the multispectral data but, but, but even then, the hyperspectral data will provide you more information than that multispectral data.

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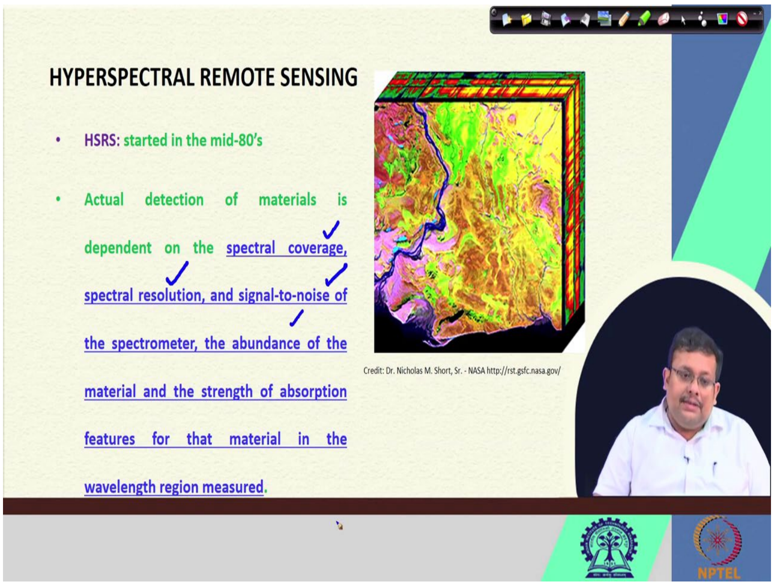

Now, this hyperspectral remote sensing started in the mid-80's and actual detection of matrial is basically using these hyperspectral remote sensing is dependent on the spectral coverage, then spectral resolution and signal to noise of the ratio of the spectrometer and the abundance of the material and the strength and absorption features for that materials in the wavelength region measured. So, the spectral coverage is one of the important point then spectral resolution more spectral resolution means more minuet features you can capture.

Signal to noise ratio means more signal higher signal to noise ratio, that means you are getting more and more desired in signals than that of the noise. So, always in case of spectral processing, we try to enhance the signal to noise ratio of the spectrometer and also the abundance of the material and the strength of absorption features are also important in the in the for the hyperspectral remote sensing. So, these are some of the important features for these hyperspectral remote sensing.

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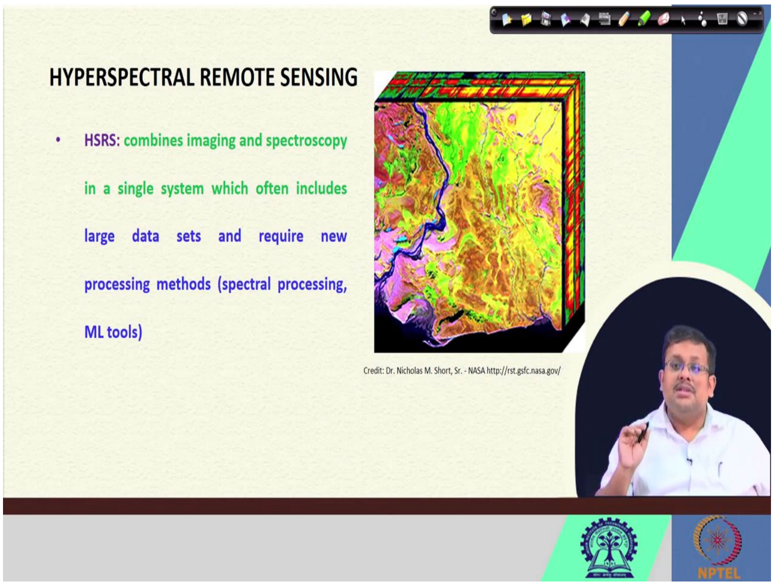

And these imaging spectroscopy or hyperspectral remote sensing combines as I have told you it combines both imaging and spectroscopy in a single system, which often includes large data sets and require new processing methods. So, we need different types of spectral processing. And also we require different types of machine learning tools to extract the information or the useful information for subsequent characterization of the surface.

So, we have already discussed in case of point spectroscopy or spectroradiometer. We have already discussed some of the important spectral processing like standard normal variate, then we have also we have also discussed the derivative spectroscopy we have already discussed then continuum removal all these different types of spectral processing we have discussed and apart from the spectrum.

So, most of these spectral processing is done, they are directed towards improving the signal to noise ratio. In other words, they are they try to remove the noise and enhance the spectral features, which are desired and subsequently they are being fed to the machine learning tools to extract the important information. We have seen several examples while discussing the hyperspectral, hyperspectral radiometer based modeling of soil properties and crop properties.

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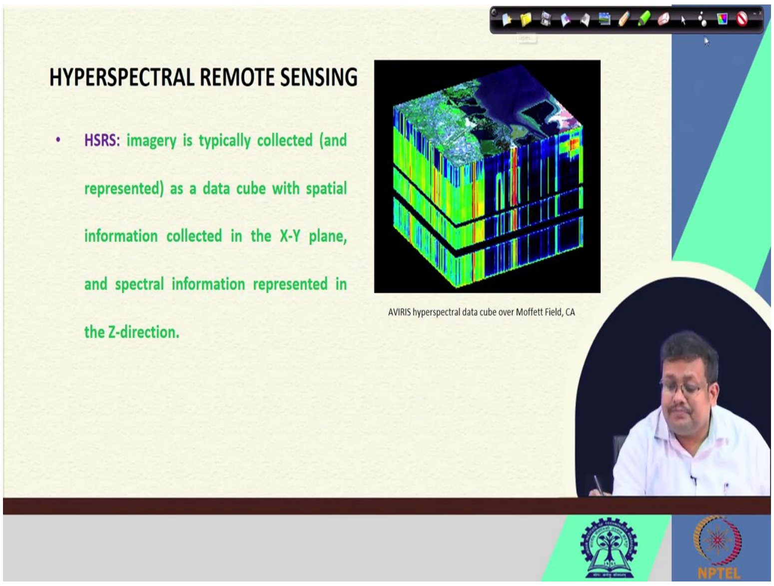

Now, in the HSRS or hyperspectral remote sensing imagery is typically collected and represented as a data cube just like these I have already discussed with spatial information collected in the X and Y plane and spectral information represented in the Z direction.

So, if we can see here, this is the X and Y information in the Z direction, we are getting the wavelength values or spectral information reflectance values for each of these wavelength with the wave bandwidth of around 10 nanometer. So, this is how this image data cube is generated and you can see here this is an AVIRIS hyperspectral data cube for California region.

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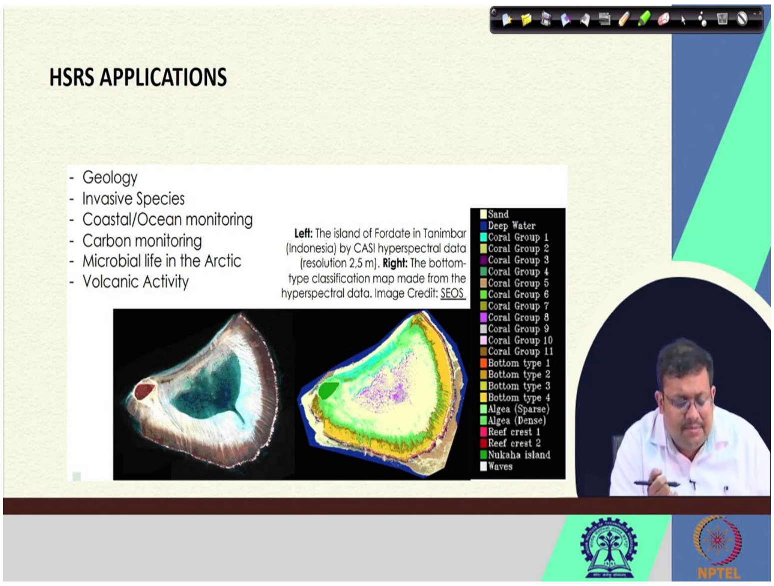

Now, what are the different types of application? Of course, as I have told you that hyperspectral remote sensing has been extensively used in geology, then identifying the invasive species then coastal and ocean monitoring, carbon monitoring, microbial life in the Arctic as well as volcanic activity. Nowadays it is being used extensively in different domains of agriculture.

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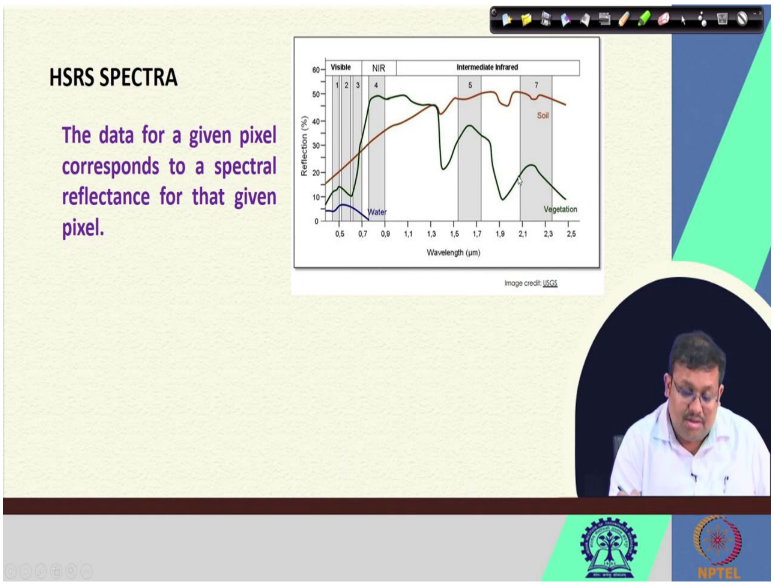

Now, if we consider the hyperspectral remote sensing spectra, it is basically n dimensional you can see that it is an n dimensional data and the data for a given pixel corresponds to the spectral reflectance for that given pixel, we have already discussed. One pixel one spectra and then we combine the, the spectral data for individual wavelengths.

So, here you can see these are the spectral reflectance values for different wavelengths starting from 0.4 to, to 2.5 nanometer, micrometer and we can see that these hyperspectral safe spectra are having huge amount of information, we are getting the spectral absorption features here. So, this is how this type of information we can exploit in case of hyperspectral remote sensing.

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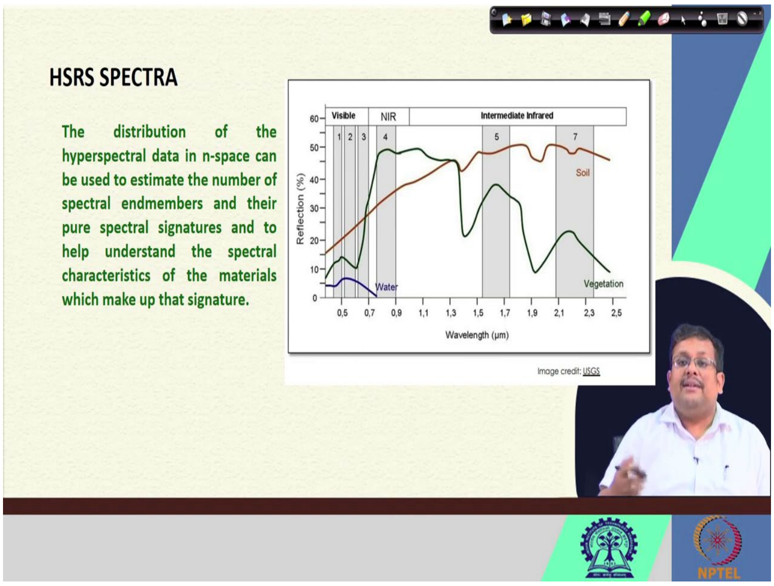

So, the distribution of the hyperspectral data in n space can be used to estimate the number of spectral endmembers. So, here the spectral endmember there are three spectral endmembers you can see water, vegetation and soil. So, if you see the spectral types or spectral pattern you can identify in that pixel we have both soil, vegetation and water.

So, the distribution of the hyperspectral data in n space can be used to estimate the number of spectral endmembers and their pure spectral signatures and to help understand the spectral characteristics of the materials which make up that signature. So, once you have the signature or spectral signatures or spectral pattern from an individual pixel, you will have an idea, these are the spectral endmembers in that particular area of interest or particular area.

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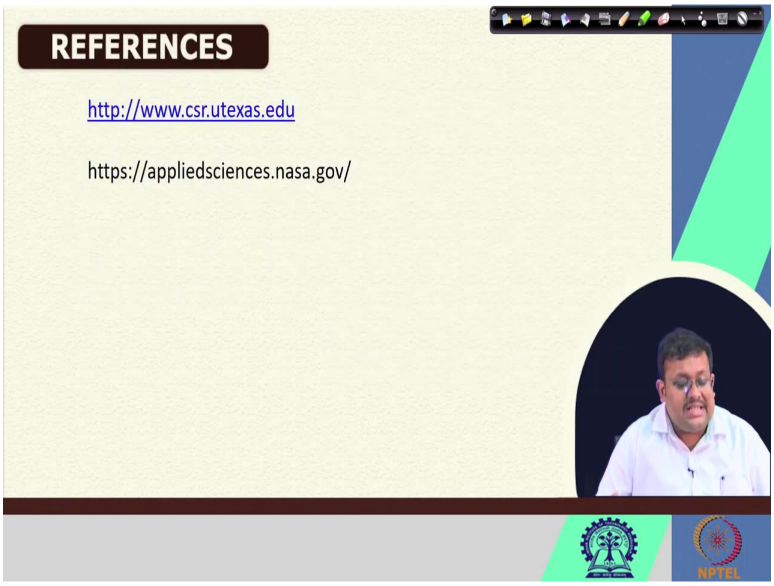

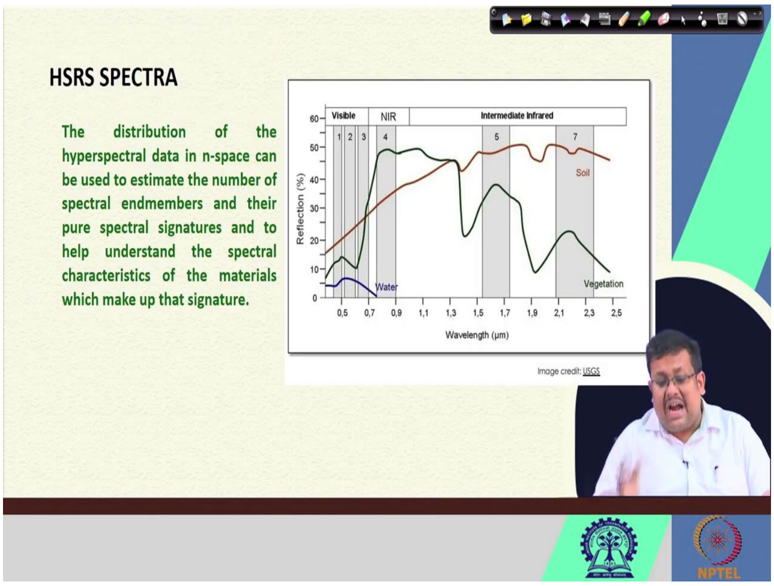

So, guys, I hope that these are some, we have got some knowledge from this lecture. And these are some basic overview of hyperspectral remote sensing, these are some of the references from which I have utilized some of the material some of the pictures, some of the figures. So, so, we will start from here in our next lecture, and we will go and discuss more about these hyperspectral remote sensing.

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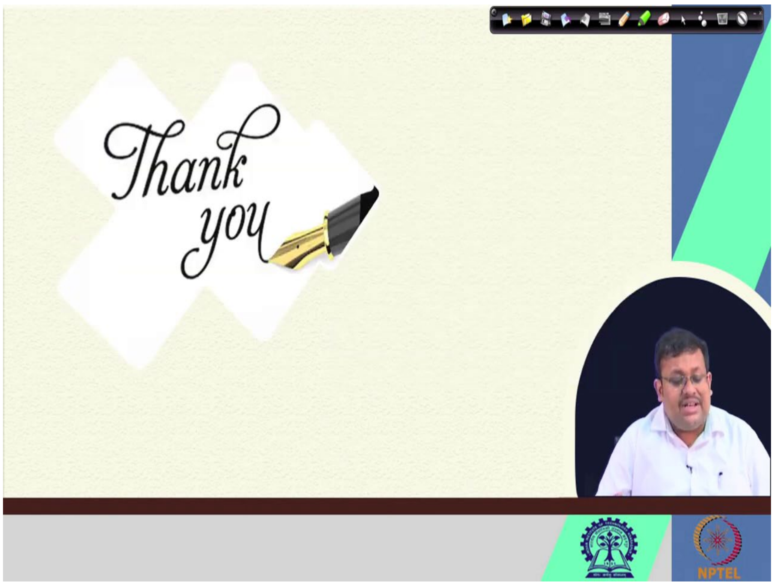

So, let us wrap up our lecture here, and we will meet in our next lecture. And we will start from here to discuss more about hyperspectral remote sensing, and then we will discuss how we can use the machine learning in combination with hyperspectral remote sensing for characterizing the soil and crop. Thank you.