REMOTE SENSING FOR NATURAL HAZARD STUDIES

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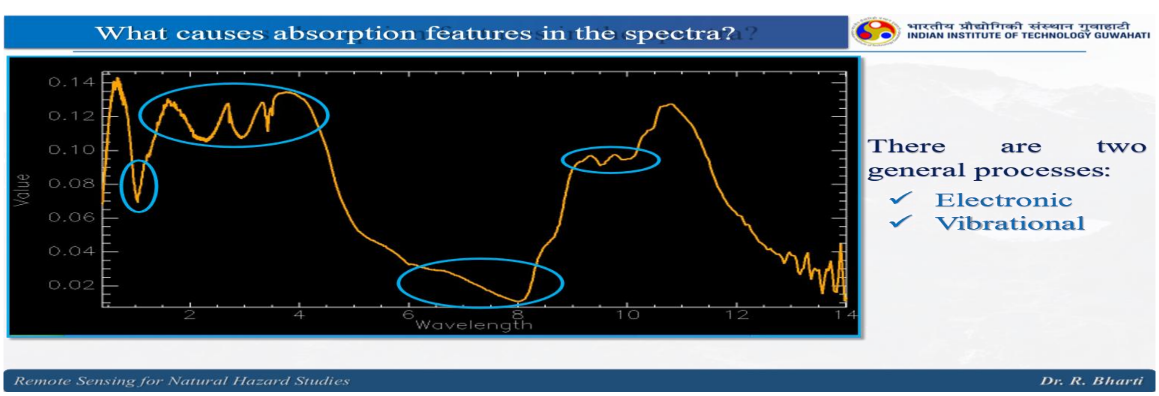
Lec 7a: Hyperspectral Data Acquisition and Processing-Part A

Hello everyone, today we will start the third module, and this is the seventh lecture of remote sensing for natural hazard studies. Today, we will talk about hyperspectral data acquisition and processing. So, as usual, this lecture will be divided into two parts. So, this is the first part. So, I hope you remember that hyperspectral remote sensing; the basic definition is that we should have contiguous bands, the number of bands should be more, and the bandwidth should be very narrow. So, with that, what we do is try to generate the spectra of each pixel.

So, each pixel of the acquired image has an associated spectrum, which means that for each pixel, this is the pixel. Or this is the pixel for which we will have associated spectra. So, this spectrum will help you analyze and gain the compositional information about the target material. So, here we consider this as 1 pixel, and we have derived this spectrum.

So, this is a hypothetical case where we have this spectrum, and this spectrum will help you gain information about the target material based on its absorption position. So, here it says the distribution of electromagnetic radiation emitted or absorbed by a particular object. So, whether it is emitted, reflected, or absorbed, we can observe this kind of spectral behavior in the target material. We understand that the internal atomic structure and composition are the reasons for absorption features because, if we have the target and this is the sensor, it is looking at this particular area with the fixed IFOV. It is generating pixel information.



So, the energy that is reflected, emitted, or absorbed by this particular area or pixel will be recorded, and we will have this kind of spectral behavior. So, it depends on the material's composition and the internal atomic structure. How they will behave and how they will provide you with the characteristic absorption feature that we are able to use to characterize them. So, trough are the places where things are happening; I hope you remember my first example that if we take the example of vegetation, this is basically your green band, and our eyes are sensitive from here to here; this is 400 to 700 nanometers.

So, since our eyes have limited vision, this green color, which is reflected from the target, is getting detected by our eyes. But if we look at this IR region, NIR or SWIR, you can see that this reflectance is much greater than that of the green. But since our eyes are not able to detect this wavelength, we see vegetation as green. But if our eyes are sensitive to this, we would have seen this vegetation in a different color. So, keeping this in mind, you can just try to understand that if a particular wavelength is not interacting with the target, it is getting reflected.

If it is interacting with the target, that means that it is getting absorbed by the target. So, these particular absorption features will give you more information compared to those, indicating that this target is x, y, or z. Here is an example of quartz. So, quartz has this kind of emissivity spectrum. And remember, this is a function of wavelength.

Now, when we talk about imaging spectroscopy to acquire spectroscopic information over a large area, it has both the power of spectroscopy and imaging. So when we talk about spectroscopy, it is instrument-based and capable of generating the spectra of a given material, but it will not have the spatial distribution. So, it will not cover a large area; it will cover only a small portion of the sample that we do in XRD, XRF, and ICP. So, everything works on the principle of spectroscopy. So, here when we talk about imaging spectroscopy, we are simultaneously measuring the spectroscopic information for a larger area.

So, this imaging spectroscopy has both the power to generate the image and to generate the spectra. So, here you can see if we take the example of this field spectroradiometer. So, this field spectroradiometer can generate this kind of spectrum. So, what we do is, with this kind of pointer, place it over the sample, or we have a different setup through which we will target or focus on the fiber optic cable, as you can see here. So, this we will target and this cable will have a IFOV, and it will look at this particular area.

So, it can be centimeter, meter, or millimeter, depending on the height of the instrument, or this is the target, and this is the sensor. So, what are the height and the field of view that will decide how much area you will capture in one spectrum? This kind of measurement will provide you with the spectra of the material in such a way. So, here you can see again that we have some absorption positions and some reflected areas, which are very, very high. So, which one should we consider? We should consider the absorption feature whenever we are getting the absorption positions. That will tell you about the material characteristics rather than looking at this particular position.

Now this kind of instrument will help you upscale the ground information to the satellite scale. Because what happens if you generate an image or if you generate a hyperspectral image like this, because of the uncertainties and the error introduced by the topography, by the atmosphere, by the instrument itself, you will not be able to prove it. That this behavior is purely because of the target. So, in that case, what we do is rely on this kind of ground measurement; this instrument is taken to the field, and then we measure the spectra, considering this the pure spectra of that particular target. Which we covered in the field, and once we have this information from the field, what we do is try to correlate it with the same pixel spectra of this image, and then we see how much matching there is.

Based on that, we will be able to say that this is the accuracy of my satellite image results, which are produced by some processing steps. So, this kind of instrument will help you to upscale the ground information to the satellite scale. Please remember this is very, very important. Whenever you go for hyperspectral data processing, you will have to have some ground measurement or some way to validate your results; otherwise, you will not be able to justify that your results are accurate or precise. So, here I hope you remember this is the basics, so from here we are illuminating the target, and then the reflected emitted energy will be received by the sensor, and this sensor will provide you with this kind of spectra, and you will also have a few bands. That can be called hypercube or hyperspectral data.

So let us talk about the field of spectroscopy. So here we will talk about spectroradiometers. So a spectroradiometer is an optical instrument that uses a detector to measure the distribution of radiation in the visible, near infrared, and shortwave infrared wavelength regions. So, if you see, this is one type of spectroradiometer, this is another type of spectroradiometer, and this is another type of spectroradiometer.

Please remember I am not advertising for any company; this is just for example. I have put photographs of the most popular spectroradiometers available on the market, but many such instruments are available. So, for example, how will you identify whether this instrument can generate the data you need to check the data sheet for your objective? So, here for this instrument, it is designed by ASD, and the wavelength range measured by this instrument is 350 to 2500 nanometers, and the spectral sampling refers to how frequently you are generating the data in wavelength. So, for every 1 nanometer, you will have 1 measurement. So, remember 1 nanometer, and you have 350 to 2500 nanometers; how many data points will you be generating across the wavelength that you can calculate? Collection time is the minimum time required to measure 1 spectrum, which is

0.1 seconds per spectrum. And here we are using 2 different sets of detectors: one is a silicon photodiode that works from 0.35 to 1 micrometer, and the other is Indium Gallium Arsenide, which works from 1 to 2.5 micrometers. So, these 2 detectors are used in this instrument to generate data from 350 to 2500 nanometers, and the field of view is 25 degrees, but such an instrument comes with an option where you can change the field of view. So, it can also be 4 degrees, 16 degrees, or 25 degrees

So, this kind of additional attachment comes with this instrument so that you can focus on your target more precisely. So, these instruments are capable of measuring spectral reflectance, spectral transmittance, spectral absorbance, spectral radiance, and spectral irradiance. Now, why are we talking about this parameter in the spectral domain? Because we are generating the information, let us say, the first spectroradiometer example. So, the wavelength we are using to generate spectral reflectance is from 350 to 2500 nanometers. So, the first one is reflectance, so we have to consider the radiance and irradiance.

Remember, for every 1 nanometer, you have 1 measurement for that spectroradiometer. So, the first measurement will be 350, then you will have 351, 352, 353, and so on until you reach 2500 nanometers. So, in the same way, when we are measuring this radiance, you will have individual measurements across these wavelengths. When we measure the irradiance, we will have all these measurements; then, what we do is calculate the reflectance using this particular formula, and then you will have the spectral reflectance. So, this is why we call it spectral reflectance.

In the same way, we will measure the transmittance, absorbance, radiance, and irradiance that we have already discussed. So, all these measures can be done with the spectroradiometer, which is available on the market; it can be ASD, GAR, or any other company. So, remember this is just for the example; I am referring to their name; I am not validating, nor am I advertising their instruments. Now, this is one thing that is very important: the spectral panel. This spectral panel is used to measure the irradiance as well as the white reference.

We will see why we need this spectroradiometer. So, remember I told you that if we have a satellite that is looking at a particular area, it is generating one single pixel with one detector. So, this pixel, when we measure from here, is the reflected energy. So, we measure the radiance initially, we measure the DN value, then we convert it to radiance, and then we should also have irradiance. Once you have the irradiance, we calculate the reflectance radiance by irradiance.

So, here if we have the same instrument, we can put it over the ground, focusing towards the sun because the sun is our source of light in this condition. So, this will provide you the irradiance. But this is not possible because these instruments, which are sent to space, are different and have the same wavelength. You can measure different instruments, but different instruments will have different problems and advantages according to their detectors or configurations. So, what we do is when we talk about the spectroradiometer, this spectroradiometer is the main instrument and this is the fibre optic cable, which allows the energy to pass through, coming from the surface or the target, entering this and then through this fibre optic cable it goes to the main instrument. So the light is falling on this, then it is entering into this, and then it is getting transferred from here to this instrument, and here this will measure depending on what your target is. Whether you are focusing on the sun or whether you are focusing on the surface, you will measure the radiance and irradiance. So, this is how we measure the radiance and irradiance, but when we try to focus on the sun, what happens is that your instrument will get saturated. From the sun, this is the incoming radiation; most of the time, it gets saturated.

Because this energy is too high to be handled by this particular instrument when we are directly focusing on the sun or the source. So, what we do is put this kind of panel, which is a specular panel. So, this is isotropic in nature. So, it has a property whatever energy falls on this, it will be equally reflected in all directions.

And, it does not absorb. So, now if your instrument is here. So, this is looking at this particular portion of the panel. So, here you will have the irradiance measurements. So, when this kind of setup, we refer when we have a spectral panel on the ground which reflects the energy coming from the sun, and it is measured by the spectroradiometer.

So, this is called downwelling radiance. So, this is also radiance, but this is the downwelling radiance. So, actually, when we refer to downwelling radiance, this is our irradiance. So, downwelling radiance is your irradiance. Now, you remove this speculant panel, and then this particular sensor will focus on the ground, which is your target, and then you will measure your radiance. So, now you have both measured radiance and irradiance, and then you can calculate the reflectance.

I hope this concept is clear. So, this kind of isotropic material is used to measure the downwelling radiance, which is nothing but the irradiance; only the style of measurement is different. Instead of focusing on the sun, we are placing it on the ground, and then we are measuring the radiance. And actually, the property of this particular panel is that it reflects an equal amount of energy in all directions. So, this will give you the incoming radiation, and this is called irradiance. But when we refer to a spectral panel to measure irradiance, we call it downwelling irradiance.

Please remember this; it is very, very important. Now, there are factors that affect spectral measurement. So, atmospheric characteristics and stability are important because whenever we go for the measurement, when we have a spectroradiometer with us and when we go to the field to measure the spectra, we try to see what parameters can influence the measurement.

So, the atmospheric characteristics are one of them. Because every moment the atmospheric characteristics are changing, clouds are moving from one place to another.

So, the irradiance coming from the sun will change very frequently, and the wind speed will also affect your measurement sampling, viewing, and illumination geometry. So, how are you looking at the ground with your spectroradiometer, whether it is nadir or off nadir, and how are you going to utilize this information, whether you are going to upscale it to satellite scale? If a satellite has a 5-degree off-nadir measurement, then it is suggested that you should also have a 5-degree off-nadir measurement at the field level. Only then will you be able to correlate these two values. So, one value coming from the satellite, one value coming from the spectroradiometer, and then you will be able to correlate them. Source of illumination means what your source is, whether it is the sun or a tungsten halogen lamp, which is characterized, and you have the full characteristics of that particular lamp.

So that can be seen here. The instrument's field of view is basically how much area the spectroradiometer is covering to generate one value. So, because the spectroradiometer is looking at this particular area at this height, this IFOV is fixed; let us say this is 25 degrees and this is 1 meter. You can easily calculate what the footprint on the ground will be. Now, once you have this information, whether you want to cover a part of the sample, let us say this is an exposed rock, and you want to measure this particular portion of the sample. So, you need to adjust your height because the IFOV is fixed.

So, you need to adjust your height so that you will actually be covering this particular portion of this sample in the field. So, this is very, very important to check how much area my instrument is covering, what my target sample is, and how you are going to correlate it with the satellite measurement. Now it's instrument scanning time, so remember I told you that one of the instruments has 0.1 seconds per spectrum. So, if I move my hand very frequently and if it is less than 0.1 seconds, my spectra will not be captured perfectly. So, we need to hold the fibre optic cable for a minimum of 0.1 seconds at that particular position so that it will actually generate the spectral behavior of that sample. Next is the sample characteristic, whether it has a rough or very smooth surface; depending on that, you will have to adjust the measurement. Then wind speed comes the steps involved in the measurement. So, I told you that the previously mentioned spectral panel we are going to use in the field for the spectroradiometer.

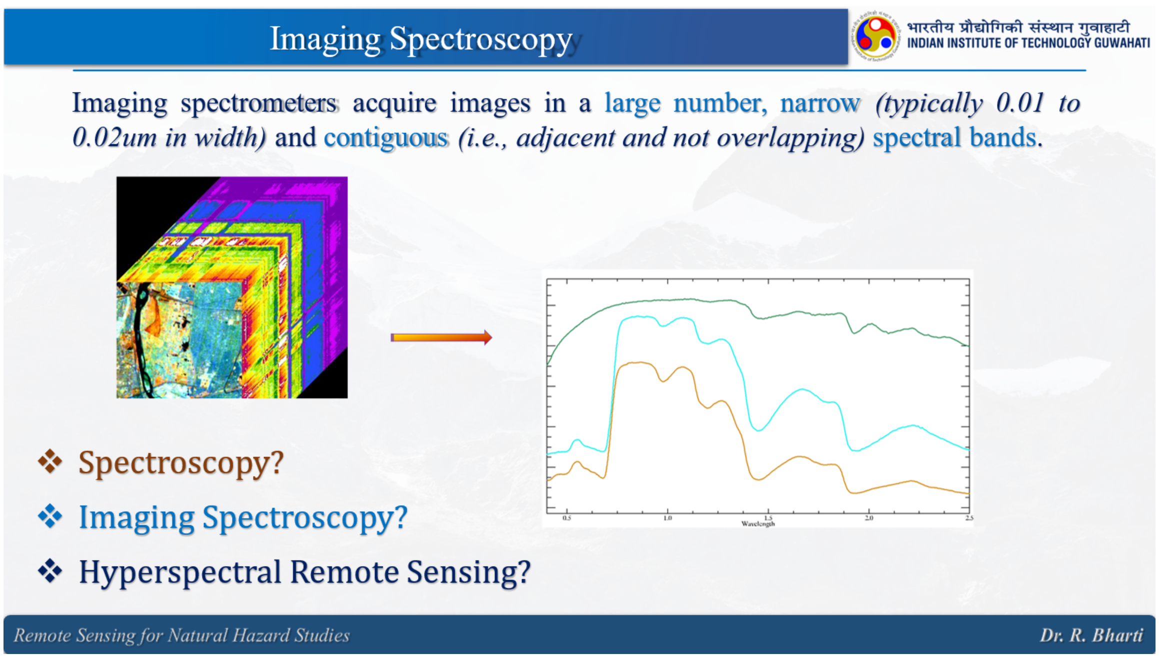
So, the first thing we need to measure is the dark current. So, the dark current, then next is the white reference, and then the target spectra. So, this white reference is basically your irradiance, which is nothing but the downwelling radiance, and this target spectrum is basically your radiance. So, when you have these two measurements, you can calculate the reflectance. But what is this dark current? This dark current is related to the instrument.

Dark current refers to the current generated within a detector in the absence of any external photons. So, what happens if this is the spectroradiometer, this is the slit from where you have the fiber optic cable connected, which has a field of view of 25 degrees, and it is looking at the ground? You have different detectors; remember the silicon and indium gallium arsenide that were there. So, they are arranged in such a way that when light enters here, it will be sensed by these detectors. So, when we close this slit, let's say we have closed it. So, when we close this, these instruments are turned on it is measuring the signal, but without any external energy.

This particular detector, we will see whether it is receiving any kind of energy or photons. So, in general, when you turn on any electronic device, the instrument gets heated, and once you have heat generation, you will have photons. So, that will be the additional information that is coming from the sensor itself. So, we need to subtract from the measurement of irradiance and radiance. So, that is why this dark current measurement is very important.

It measures the radiation or energy generated by the detector itself in the absence of any external photons. Now comes the white reference, a material with approximately 100 percent reflectance across the entire spectrum, called a white reference panel or white reference standard. So, this white reference standard, I showed you one example here. So, you have a spectral panel; this is also called a white reference panel. So, this white reference is used to measure the downwelling radiance, which is nothing but irradiance.

Now, my instrument is ready to measure the radiance and once you have these two measurements, you can have the reflectance, which is radiance coming from here, and irradiance, which we use from the white reference panel, and we call it downwelling radiance, which is coming from the white reference, and then we will have the spectral reflectance. I hope this is clear. So imaging spectrometers acquires images in a large number narrow typically 0.01 to 0.02 micrometer in width, that is your bandwidth. So, I told you that 10 to 20 nanometers are allowed when we talk about hyperspectral remote sensing. And they should be contiguous in nature, which means they should be adjacent to each other between 2 bands; there should not be any gap in the wavelength. So, when you are using this kind of measurement, you will be calling it hyperspectral remote sensing or imaging spectroscopy, which are both the same. So, here we are generating these bands, and then for each pixel, you will have this kind of measurement, and here is the characteristic absorption feature that will be studied, which we will call material x, y, or z.



So, this is very, very important. So, spectroscopy is when we have only this kind of measurement coming from the spectroradiometer. But when we talk about the satellite images with the hyperspectral remote sensing configuration, we call it imaging spectroscopy or hyperspectral remote sensing. I hope the difference between spectroscopy, imaging spectroscopy, and hyperspectral remote sensing is clear. So, this is different here; you have only one spectral measurement, and these two are the same: imaging spectroscopy and hyperspectral. Here, you have images like this, and these images' pixels will have this kind of information.

So, this is imaging spectroscopy. So, we will continue this course in the next lecture. So, with this, I will stop here.

Thank you very much.