

Slide 1 – Title Slide

Hello and welcome to Week 9, part 5 of EGM310: Spectral properties. In this lesson, we'll cover how the reflectance of different objects changes with wavelength, which in turn helps us identify objects in remote sensing images. This is the final lesson for week 9 – after this, you can get started on the first practical – the materials are all in the Practicals section on blackboard.

Slide 2 – Spectral properties

Recall from the last lesson that the reflectance of an object, or the ratio of the energy that it reflects to the energy that falls on it, depends on its surface properties such as its roughness. It also depends on the chemical composition, or what molecules make up the surface, but also the viewing angle and angle of illumination. We talked about two examples – how healthy, chlorophyll-producing plants appear green because they absorb red and blue wavelengths of light, reflecting green wavelengths; and how water preferentially absorbs longer wavelengths, causing it to look bluer and bluer as it gets deeper.

All of this is to say – objects or surfaces reflect differently at different wavelengths.

Slide 3 – Some definitions

Before we start, we have to lay out some definitions. First, the spectral reflectance of an object or a surface, ρ_λ , is the reflectance of an object for a given wavelength λ – this is similar to how we defined the spectral radiance or irradiance of an object as the radiance or irradiance for a given wavelength. The spectral signature of an object or surface is just the pattern of spectral reflectance across the electromagnetic spectrum. We can display an object's spectral signature as a spectral response curve, several examples of which are shown here. We see here that in the visible wavelengths, these different plants, oak, lawn grass, and conifer, all have similar spectral signatures, just perhaps at different brightness levels. But, the plants all look quite different to the concrete, or the snow, which have somewhat similar reflectances across red, green, and blue wavelengths. Moving into the infrared wavelengths, we see that concrete has a fairly even reflection, while the pattern of our different vegetation types is quite distinctive. We can also see that water has a pretty low reflection across the electromagnetic spectrum. We can use spectral signatures to help differentiate between surfaces and objects, potentially allowing us to map things like vegetation, or snow, or water bodies, or anything else we might be interested in.

Slide 4 – Measuring spectral properties

In order to use the spectral properties of different objects, though, we have to measure them. In the field, or in the lab, we use an instrument called a spectrometer. A spectrometer, seen here in action somewhere in Arizona, takes the incoming light and breaks it into its individual spectral components, similar to how a prism works. It then records the reflectance of the object at those different wavelengths – in other words, it records a bunch of spectral reflectances. We often need to take multiple measurements of multiple samples, as even the same material can have variable spectral

signatures – remember again that the amount of energy reflected depends on surface properties, as well as illumination angle or viewing angle. Instead of a field spectrometer, we can also use a hyperspectral camera – an instrument that records radiation in a large number of wavelengths. We can also use some satellite images – some sensors record in a large number of wavelength ranges, or bands – if we know exactly what we’re looking at in a given image, we can use this information to estimate the object’s spectral signature.

Slide 5 - “True-colour” image

From here, we’re going to look at the same image in a number of different ways. Obviously, this is an image showing a portion of Northern Ireland – we have Derry/Londonderry here in the lower right, or southwest, portion of the image; Lough Foyle is here, with Magilligan Point; Coleraine is here in the more eastern part of the image, and Portrush and Portstewart here along the coast. This image is what is known as a “true-color” or “natural color” image – it’s displayed with the red wavelengths recorded by the sensor displayed as red on the computer screen; green wavelengths displayed as green; and blue wavelengths displayed as blue. You can see also our spectral curve plot here in the corner, with the different bands highlighted.

In this image, we see lots of green – no big surprise, as it was acquired in the summer months, with lots of agricultural land and crops growing in the region, everything tends to be quite green. But we can also pick out some other things – the cities and towns tend to look a bit more gray, there’s some darker bands of forest here in the middle of the image, and we see some other patterns in the agricultural fields over here north of Limavady, which might indicate different crops, or fields that haven’t been planted.

Slide 6 - “False-colour” image

If we then change the color combination to what is known as a false-color image, the image is now displayed so that the near-infrared recorded by the sensor is displayed as red on the computer screen; red is displayed as green; and green is displayed as blue. And what we can see is – everything has flipped from green to red. If you look at the spectral curve over here, you can maybe understand why – the different vegetation types all have very high reflectance in the near-infrared – much higher than in the red or the green, which means that the image appears red overall. We can also see that the water appears mostly black, blue, or green – water reflects very little in the near-infrared, so we don’t have any red coloring in this image. The cities we looked at before appear mostly blue-gray, indicating that they’re fairly bright across the three bands, but maybe a bit higher in the green.

Slide 7 – Visible Blue

Next, we’ll look at some single-band images – images corresponding to a single wavelength range. At the top of the slide, I’ve indicated the wavelength range recorded by the sensor – here, it’s between 450 and 510 nm, corresponding to visible blue light. You can see that the brightest parts of the image are along the coast on the nice white sand beaches, in some of the fields we noted earlier, and in the cities.

We can also see the different sediment patterns in the Lough, indicating that there's some transmission of blue light through the water.

Slide 8 – Visible Green

Next up, we're seeing the visible green wavelengths recorded by the sensor. You see that the land is much brighter here, as the different plants we noted earlier reflect more radiation in green wavelengths. We can also see the sediment patterns in the Lough, but note that the bands of forest here in the middle of the scene are quite dark – remember how they were very dark green in the true-color image – this indicates a much lower level of reflection from the trees here than for the other types of vegetation we can see in the image.

Slide 9 – Visible Red

Moving on to the visible red wavelengths, we see how the agricultural lands we noted earlier are a bit darker. We can still see the sediment patterns in the Lough, though they're significantly darker than in the green and blue wavelengths. Note that the cities haven't changed significantly through the visible wavelengths – in the true-color image, they were more of a gray color, indicating relatively even reflection in red, blue, and green wavelengths.

Slide 10 – Near Infrared

In the near infrared, all of the vegetation that we saw earlier is extremely bright – note the large peaks for the different vegetation types in the spectral curves. Note also that the Lough, where we could see sediment patterns earlier, is completely black. Liquid water absorbs nearly all radiation in the near-infrared, and so there is very little reflection or transmission. Even the bands of forest that we saw earlier are quite bright, though not as bright as the other green plants. Finally, the cities are somewhat darker than the vegetation, something we could also see in the false-color image, where the cities all appeared blue-gray.

Slide 11 – Shortwave Infrared 1

In the shortwave infrared around 1600 nm, the water is still very dark, while the vegetation is still bright, though a bit less bright than before. The exception is the bands of forest here in the middle of the image, which are again quite dark. You can also see that the cities are still fairly bright, corresponding to the mostly flat curve for concrete shown in the plot up here.

Slide 12 – Shortwave Infrared 2

Finally, in the shortwave infrared around 2200 nm, the picture looks fairly similar to 1600 nm, but a bit dimmer – you can see from the spectral curves that most surfaces reflect a bit less as we move to longer wavelengths.

Slide 13 – Summary

In this lesson, we've discussed how a surface's spectral signature is the pattern of reflectance it has across different wavelengths of the electromagnetic spectrum.

By measuring spectral reflectance and spectral signatures in the field, we can try to differentiate between different surfaces and objects – we'll talk more about this in the coming weeks.

Finally, as you will see in practical 1, and as we will discuss more next week, different combinations of wavelengths, or the use of multiple wavelengths or bands help us interpret the things we can see in satellite images.

Slide 14 – Additional Resources

Once again, you can read more about the concepts we've covered in this lesson in the textbooks, Chapter 1 of Lillesand, Kiefer & Chipman; and Chapter 2 of Campbell & Wynne. I've also included links for two videos that cover similar concepts to what we have discussed in this lesson – the first, mapping the invisible, is about how we can use remote sensing to study vegetation; the second talks a bit more about the satellite that I used in this lesson, Landsat 8. That's all for this lesson – I hope you found it interesting, and you have any questions, please don't hesitate to e-mail me or post in the discussion forum on blackboard. Bye!