**Topic 1e - Wavebands and spectroscopy in remote sensing**

In terms of Sentinel-2, this satellite carries an instrument called MSI, or the Multispectral Imager. Emitted in 13 different wave bands, both within the visible part of the spectrum, but also outside of that, in the near infrared and extending into the shortwave infrared. Some of these are quite narrow and focused on particular vegetation properties-- for example, chlorophyll content or moisture content.

It also measures at a range of spatial resolution. So the red, green, and blue bands that we see with our own eyes at those wavelengths, they're taken at 10-metre spatial resolution, allowing you to pick out individual features of large buildings, like the Houses of Parliament, etc, that we see behind us. Certain of the other wave bands are measured at 20-metre spatial resolution.

And then you have some bands at 60-metre spatial resolution, which are mainly focused on atmospheric properties. The light that Sentinel-2 MSI measures is coming from the sun. It passes through the atmosphere. It's reflected from the earth's surface back out to the instrument orbiting, or the satellite, in space. And obviously the atmosphere has some impact on that light as it passes through. And so these atmospheric correction bands allow the data in the other optical channels to be corrected for this atmospheric impact.

Spectroscopy is all about measurements of light. So in order to best interpret the data we get from optical remote sensing satellites, it's really useful to have laboratory analogues of those measurements. So here we've got a field spectrometer, which allows us to measure the reflectors of different materials we might find on the Earth's surface, and how that reflectance changes at different wavelengths of light-- the same wavelengths as instruments such as MSI or Landsat Thematic Mapper, or any of these optical remote sensing measurements located on orbiting satellites allow us to study.

So here we're using a reflectance panel here, which is almost 100% reflecting. And we're using this light, here, as an analogue for the sun. So using these two things, we can get an understanding of how much light is coming from this lamp and is arriving onto the surface here, where we're going to place our targets.

Then we've got some soil here. This might represent an area, for example, in the satellite image, that's been cleared of vegetation due to deforestation or something. And here we've got a leaf that's been recently plucked from a healthy plant.

And you can imagine that a tree canopy might have a somewhat similar reflectance to this. Although obviously you've got lots of shadowing and different geometric structures in an overall canopy that you haven't got replicated here, with this leaf. Still, this allows us to look at the general optical properties of the vegetation itself. So what we're going to do is use this setup to measure the reflectance properties of this soil and this leaf.

And that would then allow us, if we see those similar reflected properties in data from MSI, for example, we would know then, that we're looking at a pixel that is mainly coloured by vegetation, for example, or bare soil. So if we use this reflectance panel to first measure the amount of incoming light, we can position this panel under the instrument. Just check it's located with the laser. And then just measure the reference here, using the computer.

This then provides us a measure at each of these wavelengths of light, of the amount of incoming light into the instrument from this lamp. Move that away. Now reposition the soil under the instruments in the instrument's field of view there. Click on Target, now.

So we can see that trace here. Over here is the blue part of the electromagnetic spectrum, through the green, into the red. And then this part is the near-infrared, beyond which our eyes see.

So this is just the amount of incoming light into the instrument, that that panel's reflecting at all these different wavelengths. Move that away. Now, reposition the soil under the instruments in the instruments field of view there. Click on Target, now.

So now we're going to get a measure of the amount of light from here that's being reflected by the soil into here. And we divide those two measurements. Divide this target measurement by that of the reference panel. And that will give us the percentage of that light that is coming into the instrument.

So you can see that each of these wavelengths here, along the bottom, we get a measurement of the amount of light, in terms of percentage, that the soil target is reflecting. So we a maximum of about 20% at near-infrared wavelengths over here. And a minimum, in the blue part of the spectrum down here, of about 4% or 5%.

If we replace the soil with the leaf, make the target measurement again, the optical setup is the same. So we don't need to remeasure the reference panel

Now we should see a very different-shaped reflectance spectrum. Clearly when we look at the leaf, it's a very different colour to our eyes than the soil. And here we have the leaf reflectance spectrum. So it's this yellow-orange line here.

This is the visible part the electromagnetic spectrum, that our eyes see. And this is the near-infrared part, the spectrum beyond which our eyes can see. But the instrument here can measure both.

What we can immediately see is it reflects much more light at certain wavelengths than does the soil. So up to 70%. And that's particularly in the near-infrared region of the electromagnetic spectrum. We can also see, when we get into the visible part of the spectrum here, the leaf reflects much, much less.

That's because it's absorbing light in the visible part of spectrum for photosynthesis, which is what drives parts to make new material. And you can see a little peek here, in the green part of the spectrum. That's because green wavelength radiation is not really used for photosynthesis.

And so the plant is reflecting more of that than blue or red wavelengths. And so we see plants as green, because they're reflecting more green light than the other lights of the visible part of the spectrum. And we see this little peak here as well, in the green wavelengths.

So vegetation has this very characteristic low reflectance in the visible part of the spectrum, high reflectance in the near-infrared part of spectrum. And we can see this feature here, which is called the red edge, where between the red wavelengths and the near-infrared wavelengths, where the reflectance rises a great deal in a very short wavelength region. And the MSI instrument on Sentinel-2 has a number of wave bands that are particularly targeting this region, which should provide increased information on vegetation status compared to previous instruments of that sort of class.

And compared to soil, where we see a much flatter reflectance spectrum, and overall much lower--particularly in the near-infrared region there. And you've basically got this slowly sloping increasing reflectance with wavelength. That's characteristic of soils. If we wetted that soil, typically what would happen is that soil reflectance would drop further.

And you can imagine that, in your own experience, if you pour water on soil and wet it, it looks darker. So it reflects even less light than when it's dry. So you can see that even if we have an instrument that's providing far less spectral detail than this. For example, the MSI instrument, or the Landsat Thematic Mapper, that would measure just a series of wave bands across this spectral region, rather than a huge number of wavelengths like this instrument measures, we could still easily tell the difference if we were looking at vegetation or soil, just by using a few different wave bands.