Slide 1 – Title Slide

Hello and welcome to Week 1, part 2 of EGM703: More Principles of Thermal Remote Sensing. In this lesson, we'll spend some more time refreshing how electromagnetic radiation interacts with the Earth's surface.

Slide 2 – Recall: definitions

I apologize in advance for the wall of text on this page, but before we keep going I think it's important to set out some definitions for the ways that objects interact with electromagnetic radiation. I'm not going to read through each of these, but they're here to serve as a reference for you. I will, however, highlight one definition, Spectral radiance – this is the one we're going to spend the most time covering this week.

Slide 3 – EMR and Earth Surface

Similar to what we discussed for the atmosphere, electromagnetic radiation interacts with the Earth's surface by either being reflected, absorbed, or transmitted. How it interacts with the surface depends on the properties of the surface, the wavelength of the electromagnetic radiation, and the angle of illumination, or incidence.

It's important to note that these are not mutually exclusive – an object can transmit some incident radiation, absorb some, and reflect the rest – or, it can completely absorb, or completely reflect, the incident radiation. In any case, the incident radiant flux, Φ_i, is the sum of the radiant flux that is reflected, absorbed, and transmitted.

Slide 4 – EMR and Earth Surface

Taking the equation from the previous slide, we can normalize (or divide) this by the incident radiant flux, Φ_i. We can then define the following: the absorptance, $\alpha(\lambda)$ – here, the λ in parentheses denotes that this varies with wavelength – is the ratio of the radiant flux that is absorbed to the incident radiant flux; the reflectance, $\rho(\lambda)$, is the ratio of the radiant flux that is reflected to the incident radiant flux – this should be very familiar to you; finally, the transmittance, $\tau(\lambda)$, is the ratio of the radiant flux that is transmitted to the incident radiant flux. If we put all of this together, then the absorptance, reflectance, and transmittance of a surface (or object) should sum to 1.

Slide 5 – Kirchoff's radiation law

Kirchoff's radiation law states that for an arbitrary body emitting and absorbing in thermodynamic equilibrium, the emittance, $\varepsilon(\lambda)$, of the object is equal to the absorptance. By thermodynamic equilibrium, what we mean is that there is no net flow of energy between the object and its environment. This assumption generally holds for most large objects, meaning objects larger than molecules, at least most of the time. In addition to this, we also know that most objects are opaque in the thermal infrared – that is, the transmittance is equal to zero, and so the equation from the previous slide becomes this: the emittance plus the absorptance is equal to one. In other words, objects that have a low reflectance have a high emissivity, like an idealized blackbody; and of course, conversely, objects with low emittance have a high reflectance.

Slide 6 – Emissivity

Of course, most objects only emit a fraction of what an ideal blackbody does. As we have seen, the emissivity is the ratio of the object's radiance to the radiance emitted by a blackbody at the same temperature. We normally refer to the spectral emissivity and the spectral radiance, meaning these are measured for a particular wavelength or wavelength band. Planck's radiation law gives us the spectral radiance for a blackbody of a given temperature, so we can write the spectral radiance for our non-ideal object like this – as the emissivity multiplied by the blackbody radiance. We'll come back to this more when we talk about how to estimate temperature using radiance.

Slide 7 – The non-ideal world

Because we live in a non-ideal world, we have different ways of describing how objects differ from ideal blackbodies. The first one, a graybody, is an object with an approximately constant emissivity – that is, its emissivity does not depend on wavelength. In the figure here, this is shown by the dash-dot line at about 0.5. Next, a selective radiator, shown in the figure as a solid black line, is an object whose emissivity does vary, sometimes significantly, with wavelength. Often, objects or surfaces can behave like blackbodies over very narrow bandwidths, or wavelength ranges – as an example, clear water has a very high emissivity in the thermal infrared, meaning that its emissivity in this region is very nearly equal to one.

Slide 8 – More on emissivity

In addition to wavelength, emissivity can also vary with the temperature of the object or surface, different surface conditions such as moisture content – wet soil has a different emissivity to dry soil, and the viewing angle. This is often a very useful thing! For example, we can use this to help differentiate or distinguish objects or materials, especially if we have a sensor that has multiple channels in the thermal infrared.

Slide 9 – Summary

For the most part, sensors are measuring radiance – to be slightly more precise, spectral radiance.

If we know the incident radiation on an object or surface, we can figure out what proportion of that radiation is reflected, absorbed, or transmitted by the object.

In the thermal infrared, emissivity, which is approximately equal to the absorption of an object, is the most important of these properties.

Emissivity often varies with wavelength or surface properties, which is something that we can use to help identify or study different surfaces or materials.

Slide 10 – Additional resources

You can read more about the topics we've discussed here in the two textbooks – Lillesand, Kiefer & Chipman, Chapters 1.4 and 4.9, or Cambpell & Wynne, Chapters 2 and 9.6. I've also included links to a number of different papers that go into more depth about emissivity, how we can measure emissivity using different sensors, and different emissivity mapping missions on both Earth and Mars. Finally, there are links to a few spectral libraries, where you can actually measured emittance values for different surfaces and materials. 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!