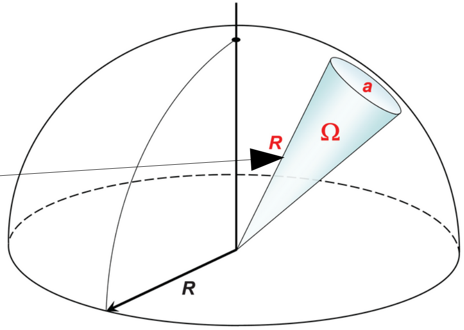
EGM703 – Advanced Active and Passive Remote Sensing

Week 1, Part 2: More Principles of Thermal Remote Sensing

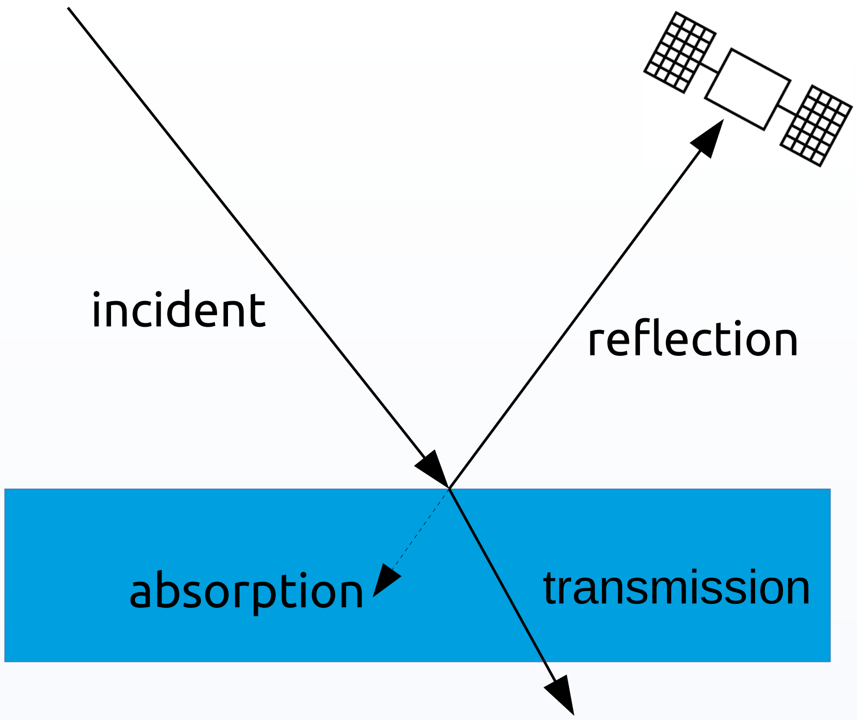
Recall: definitions

- Radiant energy (Q, [J]): the amount of energy
- Radiant flux (Φ, [W] [J s^{-1}]): energy per unit time
- Radiant intensity (I, [W sr^{-1}]): radiant flux per solid angle
- Radiance (L, [W sr^{-1} m^{-2}]): flux per solid angle per area
- Radiant emittance (M, [W m^{-2}]): radiant flux emitted from surface
- Irradiance, (E, [W m^{-2}]): radiant flux onto a surface
- Radiosity (J, [W m^{-2}]): radiant flux leaving a surface (emitted, reflected, transmitted)
- Spectral radiance (L_λ, [W sr^{-1} m^{-3}]): Radiance per wavelength unit
- Spectral irradiance (E_λ, [W m^{-3}]): Irradiance per wavelength unit



EMR and Earth Surface

- EMR interacts with Earth surface similar to atmosphere:
  - Reflection
  - Absorption
  - Transmission
- How, and how much, depends on:
  - Properties of surface
  - Wavelength
  - Angle of illumination (incidence)



$$\Phi_i = \Phi_r + \Phi_a + \Phi_t$$

EMR and Earth Surface

- If we normalize (divide) by Φ_I:

$$\frac{\Phi_I}{\Phi_I} = \frac{\Phi_A}{\Phi_I} + \frac{\Phi_R}{\Phi_I} + \frac{\Phi_T}{\Phi_I}$$

- Next, define:
  - Absorptance, $\alpha(\lambda) = \Phi_A / \Phi_I$
  - Reflectance, $\rho(\lambda) = \Phi_R / \Phi_I$
  - Transmittance, $\tau(\lambda) = \Phi_T / \Phi_I$
- Then:

$$\alpha(\lambda) + \rho(\lambda) + \tau(\lambda) = 1$$

Kirchoff's radiation law

- For an arbitrary body emitting and absorbing in thermodynamic equilibrium:

$$\varepsilon(\lambda)=\alpha(\lambda)$$

- Most objects are opaque in thermal infrared (i.e., $\tau(\lambda) = 0$), so:

$$\varepsilon(\lambda)+\rho(\lambda)=1$$

- In other words:
  - Low reflectance $\rightarrow$ high emissivity (like a blackbody!)
  - Low emissivity $\rightarrow$ high reflectance

Emissivity

- Most objects emit only a fraction of “ideal” blackbody
- (Spectral) emissivity, ε_λ:

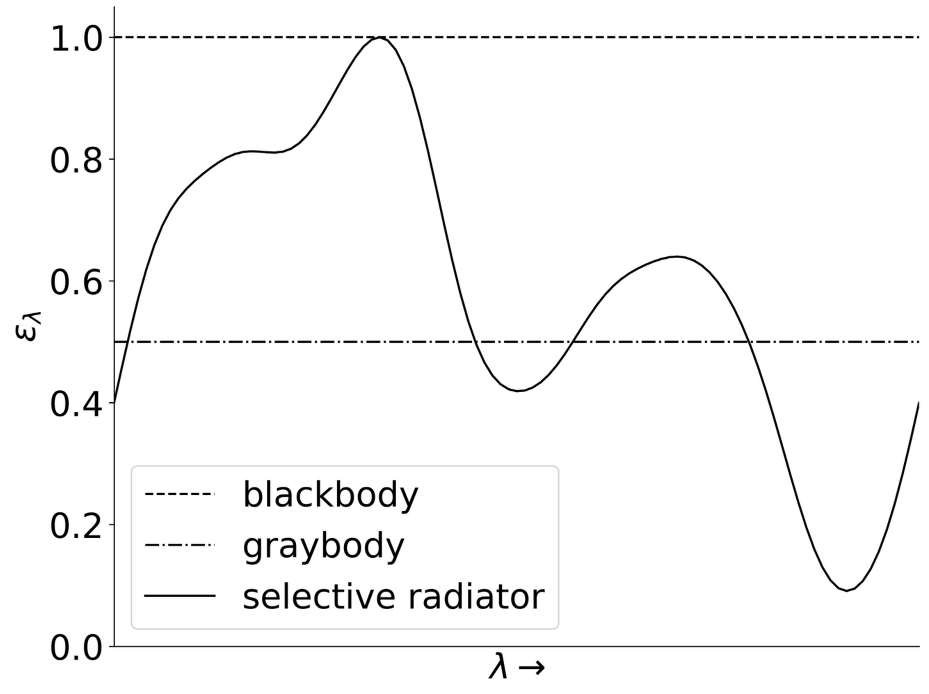
$$\varepsilon_\lambda = \frac{L_\lambda(object)}{L_\lambda(blackbody)}$$

- Or:

$$L_\lambda = L(\lambda, T) = \frac{2\pi h c^2}{\lambda^5}\left(\frac{1}{\pi(e^{hc/\lambda k T} - 1)}\right)\varepsilon_\lambda$$

The non-ideal world

- Graybody: constant $\varepsilon_\lambda < 1$, independent of λ
- Selective radiator: $\varepsilon_\lambda < 1$ varies with λ
- Objects can behave like blackbodies over narrow bandwidths
  - e.g., (clear) water, 6 µm – 14 µm



More on emissivity

- Emissivity can vary with:
  - Temperature
  - Surface conditions
  - Viewing angle
- We can use this!
  - Estimating emissivity in at different λ can help identify materials (more on this later)

Summary

- For the most part, sensors measure (spectral) radiance
- If we know the incident radiation, we can figure out the proportion that is reflected/absorbed/transmitted
- For thermal infrared, emissivity (≈ absorption) is most important
- Emissivity (often) varies with wavelength, surface properties – this can be useful

Additional resources

- Lillesand, Kiefer & Chipman – Chapter 1.4, 4.9
- Campbell & Wynne – Chapter 2, 9.6
- Sobrino et al., 2008 [IEEE Trans. Geosci. Rem. Sens.]
- Hook et al., 1994 [J. Geophys. Res. Solid Earth]
- Christensen et al., 2001 [Space Science Rev.]
- Meerdink et al., 2019 [Remote Sens. Env.]
- MODIS UCSB Emissivity Library [UCSB]