Remote sensing; the Physical basis

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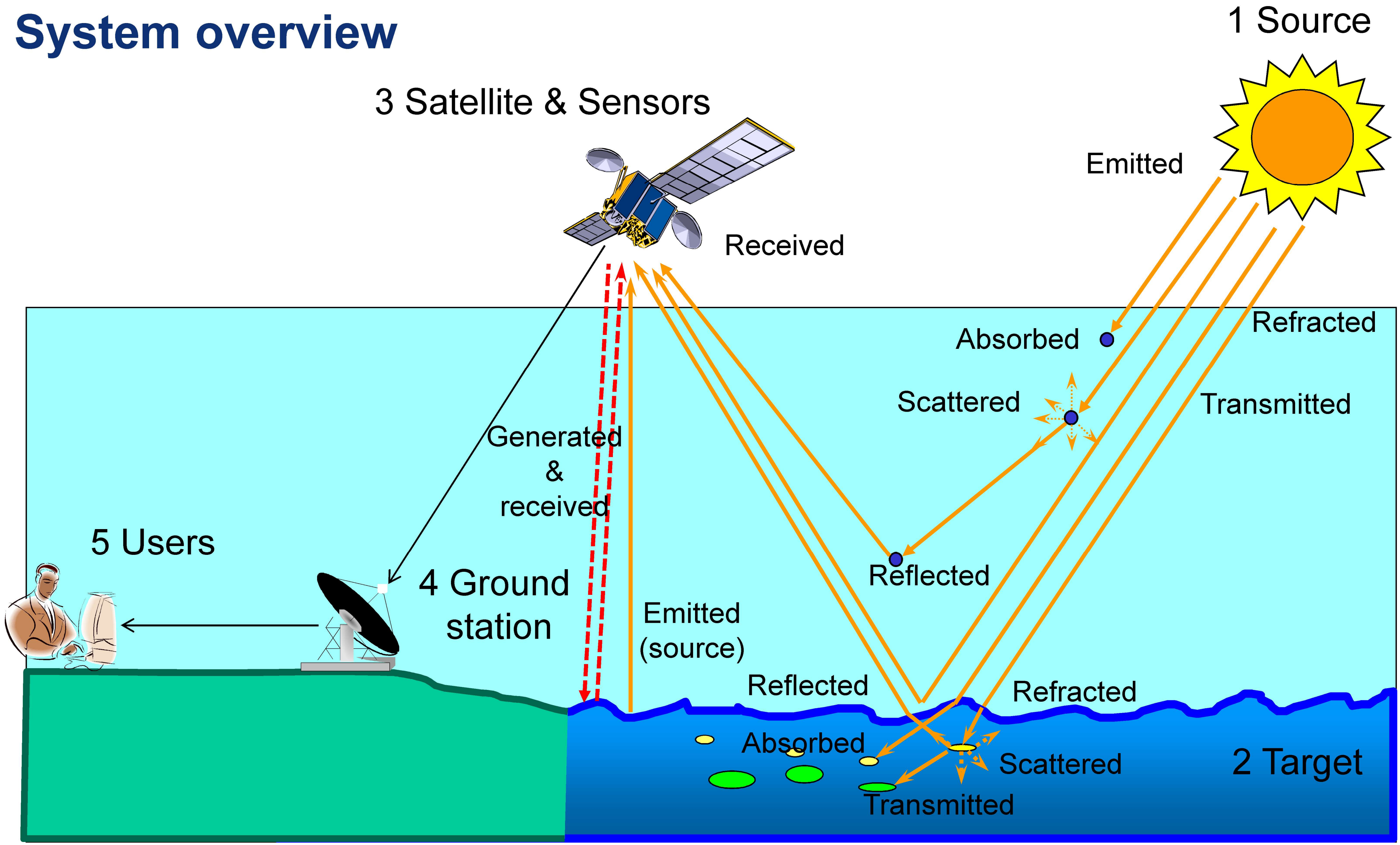
http://ec.europa.eu/dgs/jrc/index.cfm/

System overview

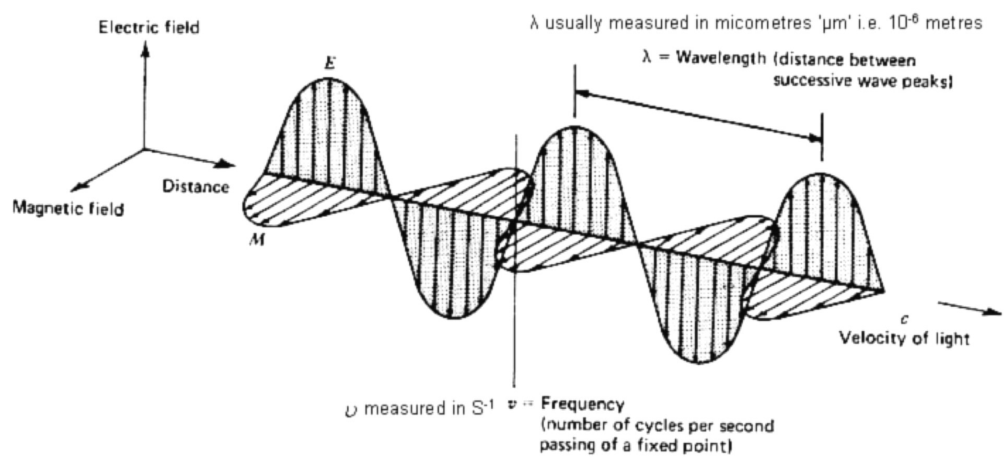


Sources of EMR – not just the Sun

- Everything in our Universe with a temperature above absolute zero 0° Kelvin (-273° C) emits electromagnetic radiation (EMR)
- Two models describe this energy – waves and particles
- Light waves are energy in the form of electric and magnetic fields
- The smallest packet of EMR is the photon
- Photons are subatomic particles of radiation, with no mass, which move in waveform at the speed of light (in a vacuum):
  - 299,792.46 km/sec (rounded to 3 x 10^8 ms-1 and denoted by c)

$$\lambda \upsilon = c$$

λ lamda denotes wavelength
v nu denotes frequency
c denotes speed of light



Lillesand, Kiefer and Chipman, 2008, Remote Sensing and Image Interpretation 6th edition (Wiley & Sons)

Electromagnetic radiation and the electromagnetic spectrum

- The speed of light is constant and is related to wavelength and frequency:

$$\lambda \upsilon = c \qquad \nu = \frac{c}{\lambda} \qquad (1)$$

- The energy carried by each photon Q is determined:

$$Q = h\upsilon \qquad (2)$$

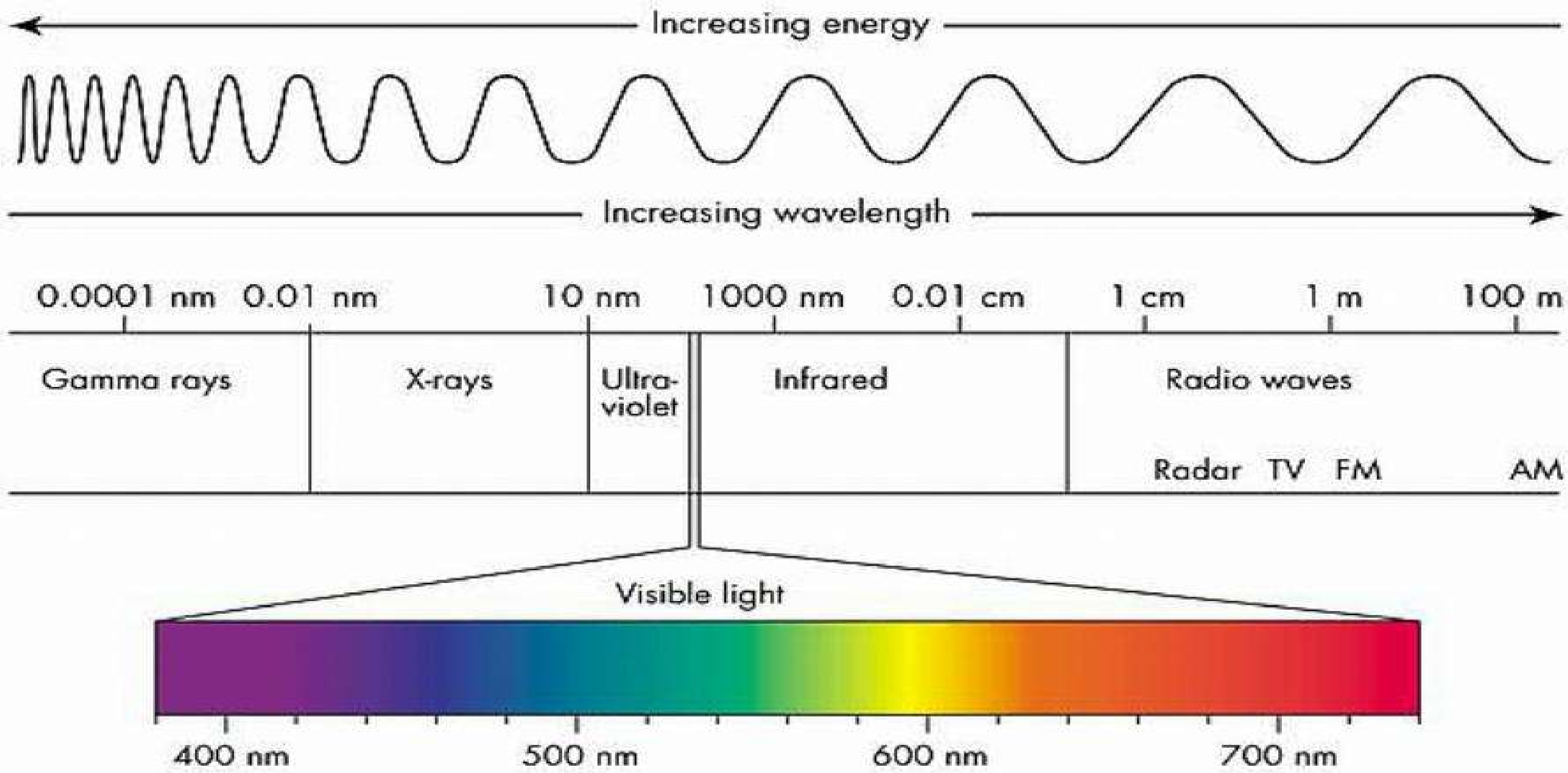
H is Planck's Constant and has a value of 6.626 x 10^{-34} Js

- The two equations combine to give:

$$Q = \frac{hc}{\lambda} \qquad (3)$$

The electromagnetic spectrum

The shorter the wavelength the greater the energy



Micrometre µm equals to 1/1,000,000 of a meter
Nanometre nm equals to 1/1,000,000,000 of a meter

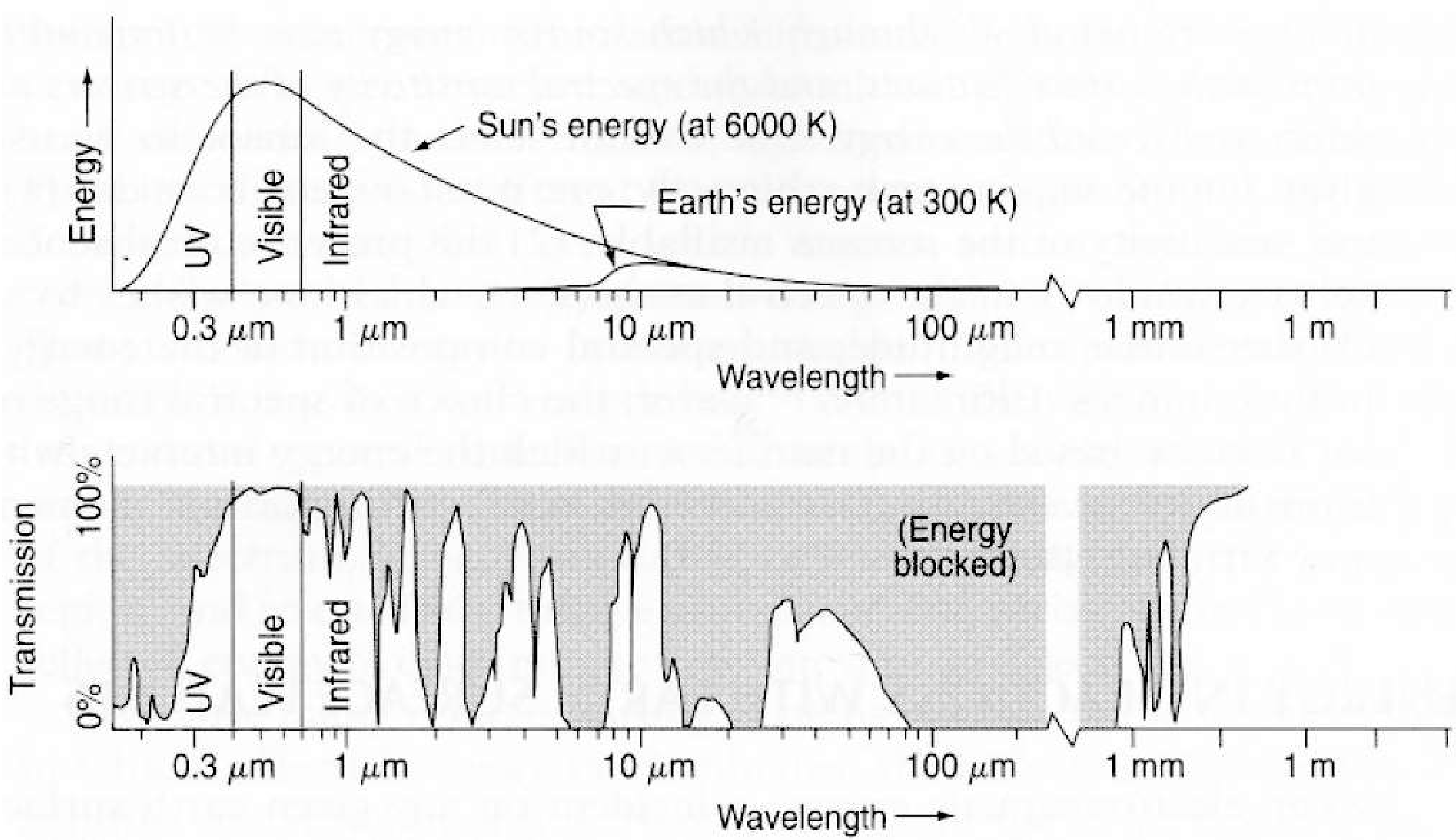
1 µm = 0.001 mm

http://www.antonine-education.co.uk/

Lillesand, Kiefer and Chipman, 2008, Remote Sensing and Image Interpretation 6th edition (Wiley & Sons)

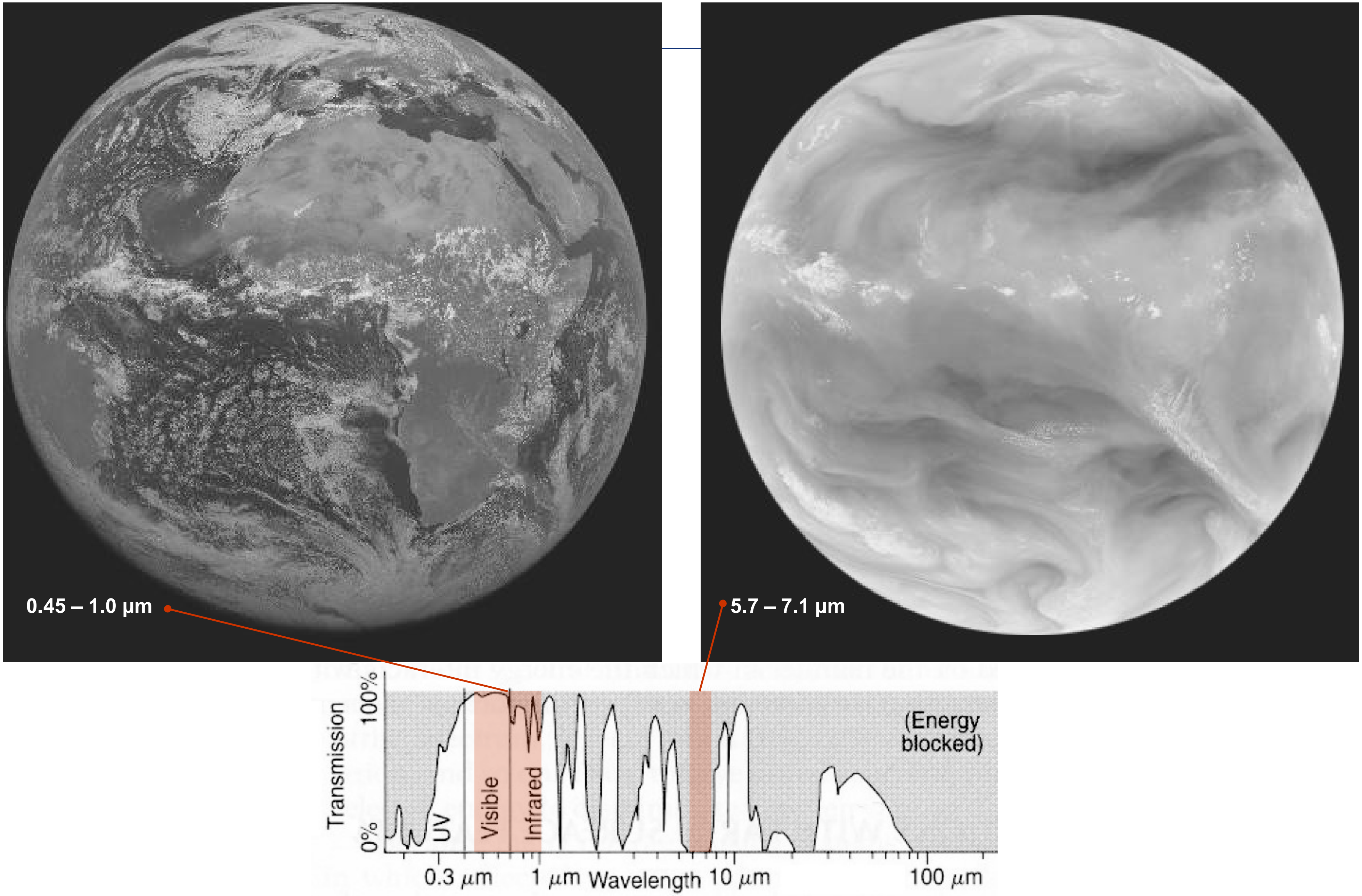
Interactions in the atmosphere; absorption and scattering

- Atmospheric attenuation (CO_2, H_2O, O_3)
- Atmospheric windows



http://www.eduspace.esa.int
Meteosat images visble and water vapour

Absorption



Scattering

- Scattering occurs as gas molecules, dust particles, water droplets reflect or refract EMR, which deviates from its original straight line of travel – there is no energy transformation, just a change in spatial distribution
  - Selective scattering, or Rayleigh (wavelength is larger than the size of the scatterer – mainly gas molecules)
  - Mie (wavelength is of the same order of magnitude as the size of the scatterer, or much smaller – mainly water vapour and aerosols)
  - Non-selective (wavelength is much smaller than the size of the scatterer – mainly water droplets)

Rayleigh scattering

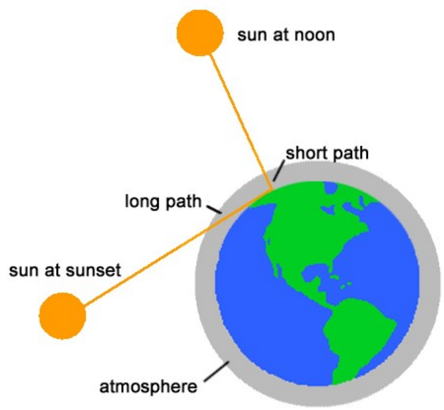
No atmosphere = black sky

Atmospheric scattering = blue sky moving to white

http://optics.kulgun.net/Blue-Sky/

Interactions in the atmosphere; absorption and scattering

- Short wavelengths are scattered more strongly than long
  - Blue skies, red sunsets

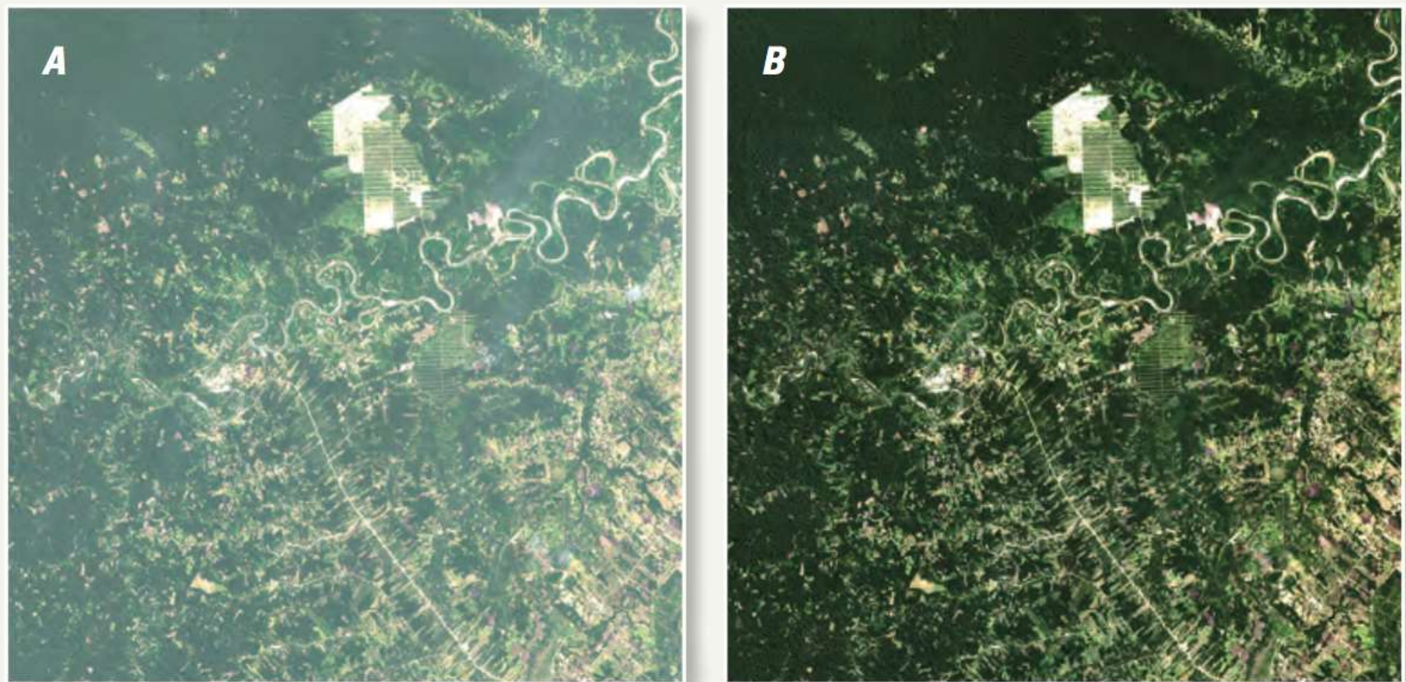


http://scifun.chem.wisc.edu/homeexpts/Graphics/bluesky.gif

- The effects of Rayleigh and Mie scattering decrease as EMR wavelength increases

http://eol.jsc.nasa.gov/sseop/EFS/
Earth from Space (Astronaut Photography from Space)
International Space Station May 18th 2002

Figure 3. Landsat 8 images acquired May 11, 2014, showing a portion of rain forest in Peru, and displaying the differences in *A*, standard Level 1 data and *B*, surface reflectance (SR) data.



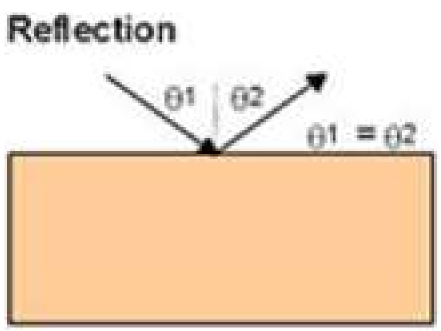
Landsat fact sheets
http://pubs.usgs.gov/fs/2013/3060/

http://rst.gsfc.nasa.gov/Intro/Part2_3.html

Energy conservation

Incident EMR = reflected plus absorbed plus transmitted

Incident EMR =



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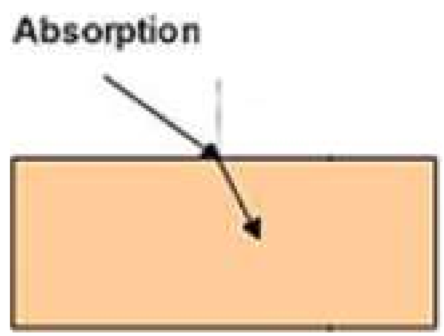

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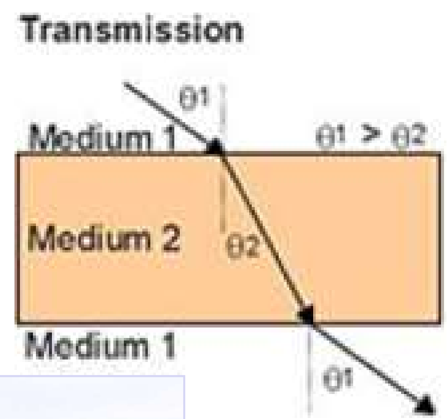
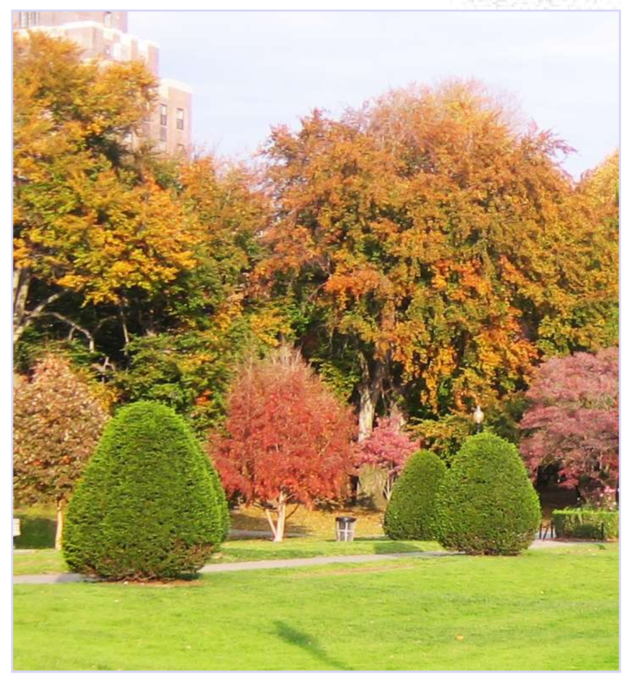


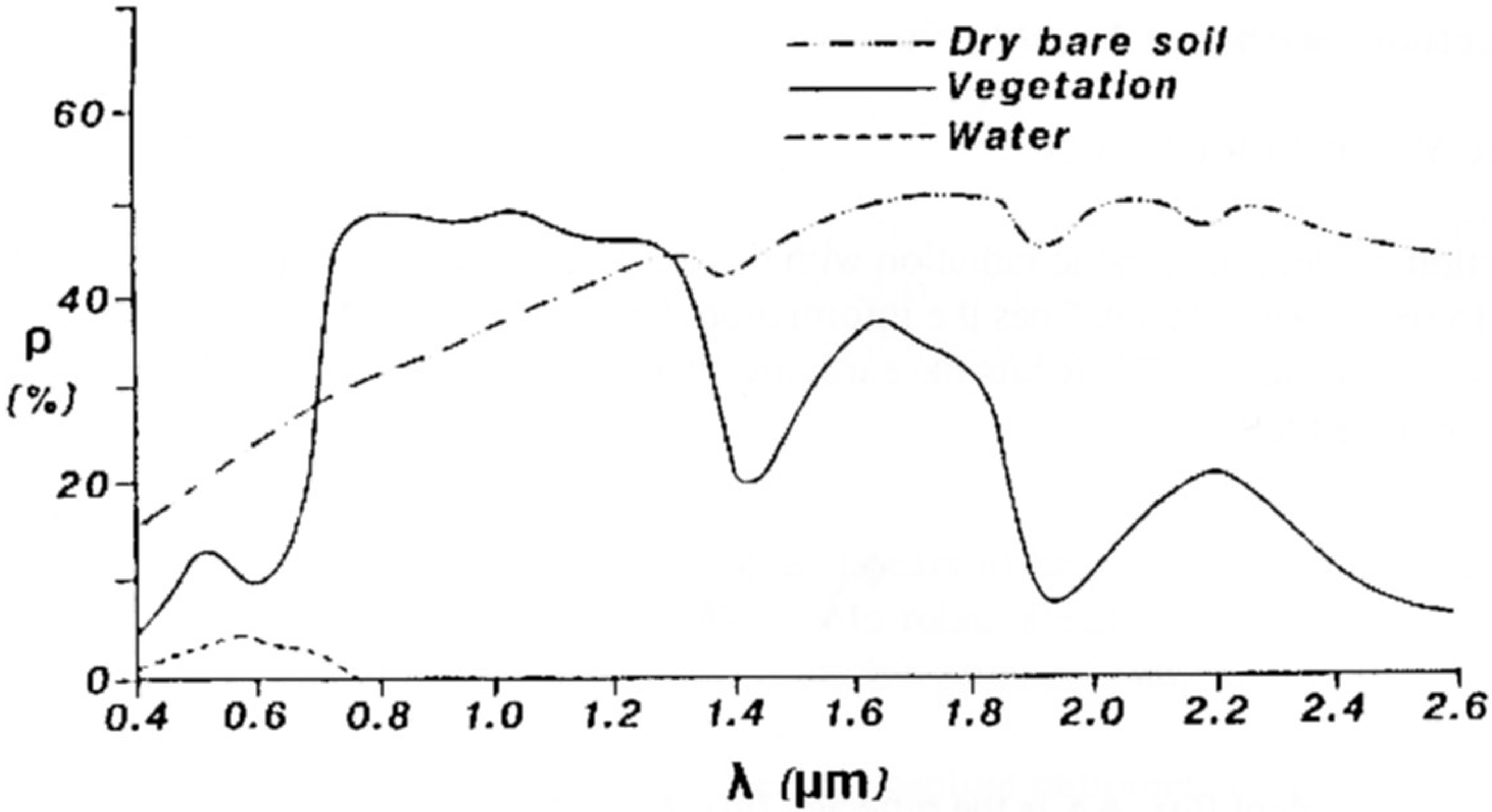
Reflected EMR = incident minus absorbed plus transmitted

Spectral reflectance is a physical property of an object



Remote Sensing and Geographical Information Systems for Resource Management in Developing Countries
edited by A. S. Belward and C. R. Valenzuela (Kluwer Academic: Dordrecht) 1991

Spectral response – spectral reflectance curves



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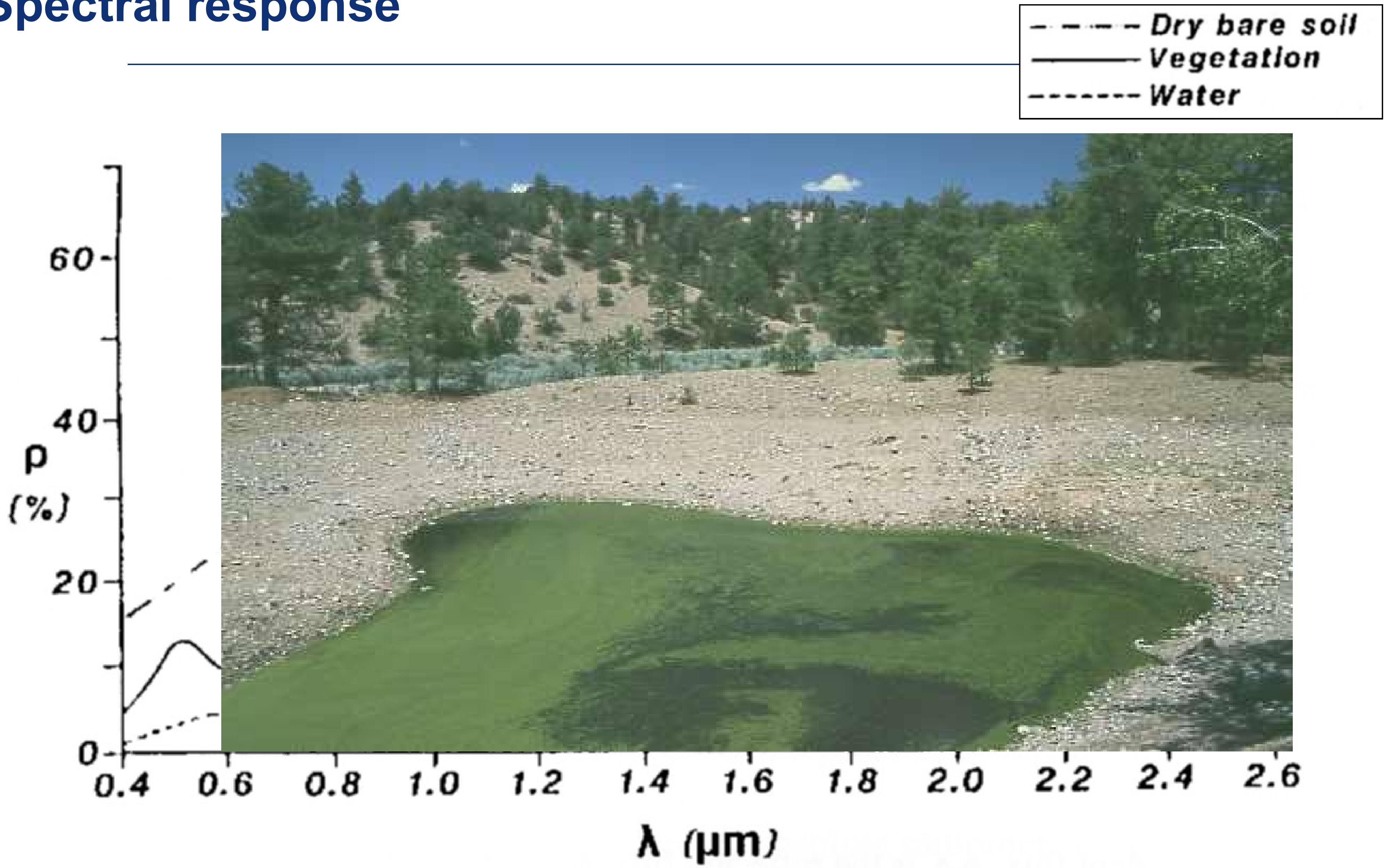


Temperature as a controlling factor

- temperature affects amount of energy emitted at any given wavelength
- the overall amount of energy increases with temperature
- the wavelength at which maximum energy is emitted moves to shorter wavelengths as temperature increases

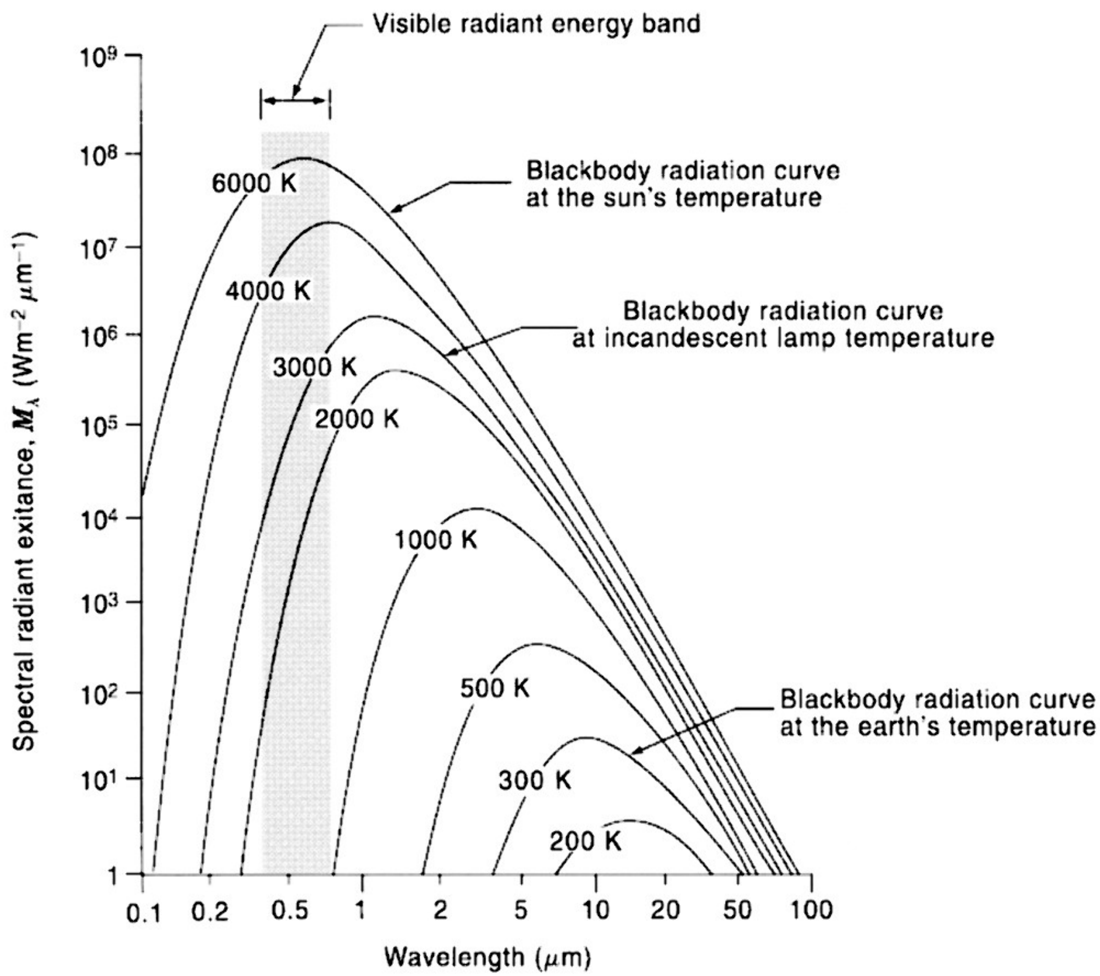


Figure 1.4 Spectral distribution of energy radiated from blackbodies of various temperatures. (Note that spectral radiant exitance M_λ is the energy emitted per unit wavelength interval. Total radiant exitance M is given by the area under the spectral radiant exitance curves.)

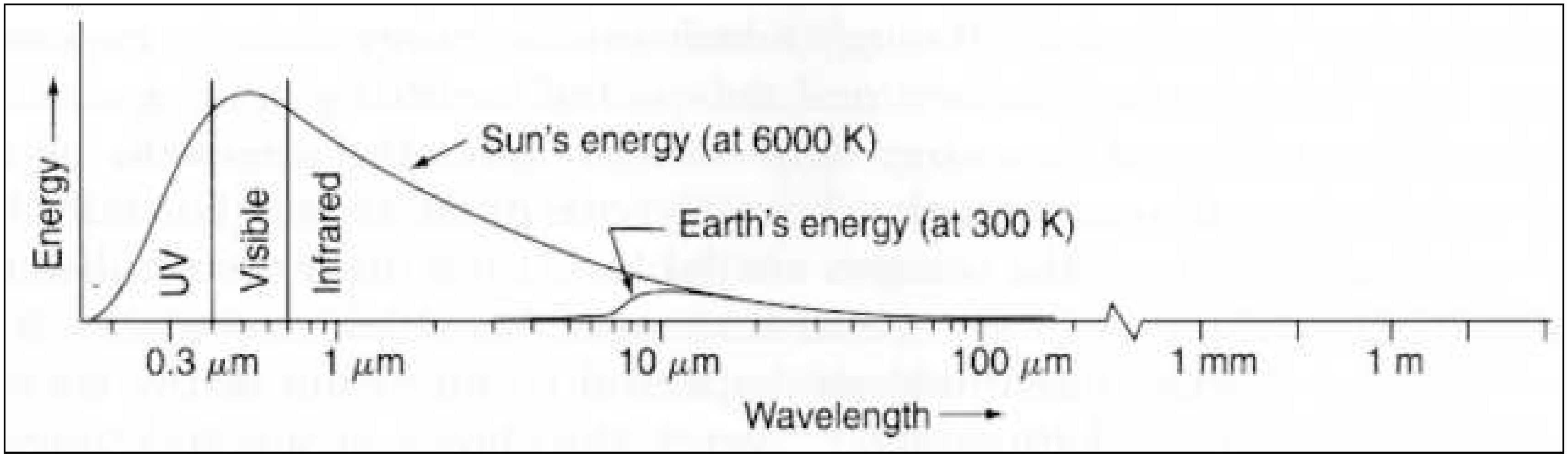
Wien's Displacement Law

T = temperature degrees Kelvin K
A = 2898 μmK
λ_{max} decreases as T increases

$$\lambda_{\max} = \frac{A}{T}$$

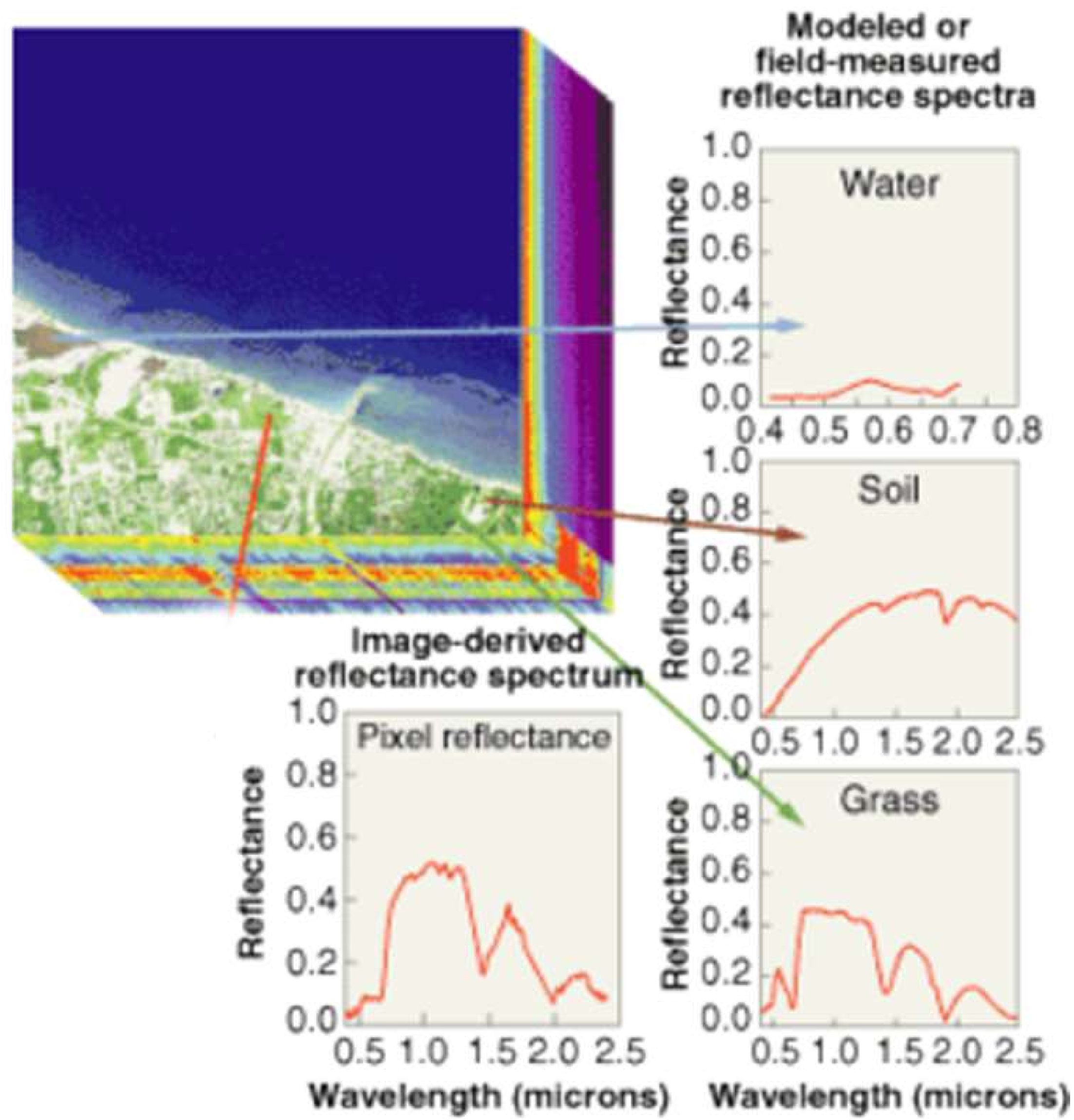
Reflected or Emitted EMR?

- Much of the time the remotely sensed image you work with is a measurement of EMR that has been emitted from the Sun, has passed through the atmosphere, been reflected from some Earth surface feature, has passed through the atmosphere again and arrived at the sensor
- but, don't forget… the Earth also emits EMR

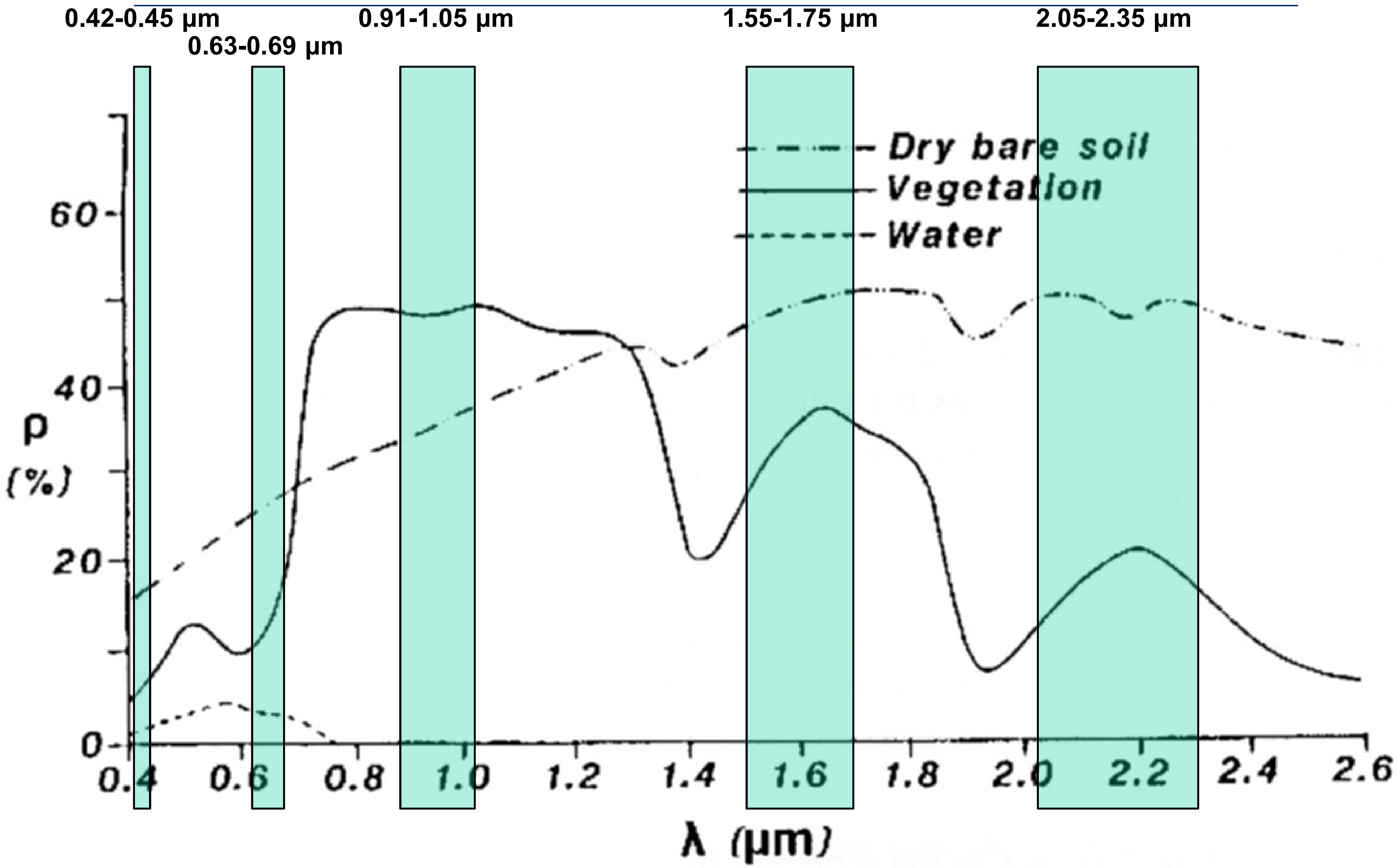


Measuring/ recording spectral reflectance

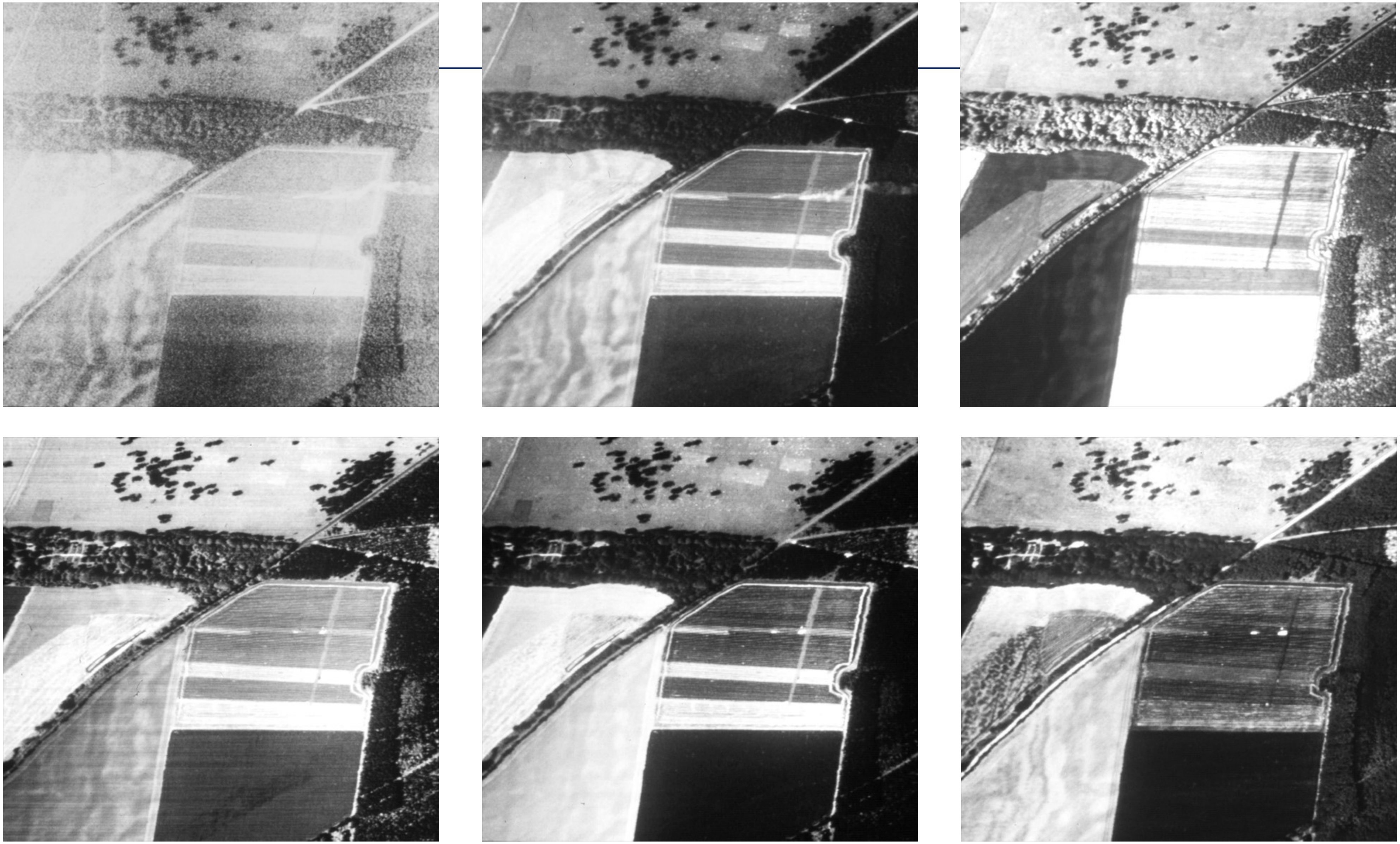
- **Cameras** integrate over the entire visible spectrum to generate a 2 dimensional image
- **Spectrometers** continuously sample over a predetermined wavelength range and generate spectral reflectance curves
- **Radiometers** measure over narrow, predetermined ranges to generate 2 dimensional images at specific wavelengths



Multi spectral images – sampling spectral reflectance



0.42-0.45 µm **0.63-0.69 µm** **0.91-1.05 µm**



1.55-1.75 µm **2.05-2.35 µm** **8.50 -13.0 µm**

Summary

- EMR is a continuous phenomenon…we give names to particular regions of this continuous spectrum for convenience
- Everything in the Universe (with a temperature above absolute zero, 0 degrees Kelvin (-273° C)) emits electromagnetic radiation (EMR)
- EMR is energy moving at a constant speed
  - (c.a. 3×10^8 ms^{-1})… the fastest thing in the Universe
- Hot objects emit more EMR than cold
- Wavelength at which maximum energy is emitted moves to shorter wavelengths as temperature increases
- Energy increases as wavelength decreases

Summary 2: EMR Interaction with objects

- Everything in our Universe reflects, absorbs or transmits EMR in a selective manner - depending on the nature of the object and the wavelength of the incident EMR

$$\Phi_{r\lambda} = \Phi_{i\lambda} - (\Phi_{a\lambda} + \Phi_{t\lambda})$$

- Spectral reflectance is a physical property of an object
- Measuring spectral properties at different wavelengths gives us information about the object, area, or phenomenon of interest
- Any measurement made at wavelengths less than 2.5 µm are likely to be reflected solar radiation – except for very hot surfaces where you may measure emitted terrestrial radiation
- For detecting hot spots move to shorter wavelengths, typically 2 to 4 µm range…
- For general thermal remote sensing use the 8 – 14 µm range