LA502 Special Studies Remote Sensing

Electromagnetic Radiation (EMR)

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Overview

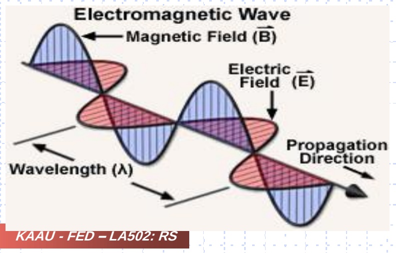
- What is Electromagnetic Radiation (EMR)?
- Atmospheric interaction
  - Scattering
  - Absorption
- Surface interaction
  - Transmission
  - Reflection
  - Absorption

What is EMR?

- Electromagnetic Radiation is a **form of energy**.
- Visible light is only one of the many forms of electromagnetic energy.
- Radio waves, heat, ultraviolet rays, and x-rays are other familiar forms.
- EM-radiation can be either considered as:
  - **Wave form**.
    - Allow for the distinction between different manifestation of radiation (e.g., microwave and infrared radiation).
  - **Stream of particles** (photons).
    - Allow for a better understanding of the radiation interaction with the surface of the Earth and its atmosphere.

Electromagnetic Waves

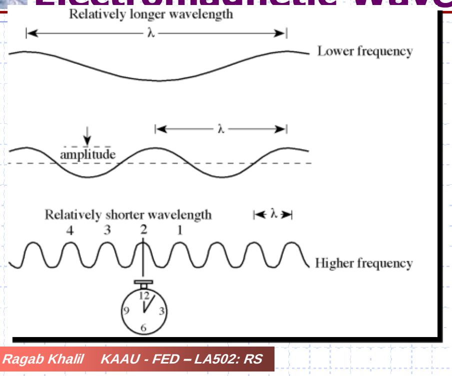
The waves propagate through time and space in a manner rather like water waves, but oscillate in all directions perpendicular to their direction of travel.



Electromagnetic Waves

- A wave is characterized by two principal measures: wavelength and frequency:
  - The wavelength (λ) (lambda) is the distance between successive crests of the waves and is normally measured in micrometers (μm) or nanometers (nm).
  - The frequency (η) (nu) is the number of wavelengths that pass a point per unit time (second). One cycle per second or one hertz, abbreviated 1 Hz

Electromagnetic Waves



Wavelength and Frequency

- Wavelength and frequency are related by the following formula:

  $$c = \lambda . \nu$$

Where

C = speed of light ($3x10^8$ m/s)

λ = wave length (m)

ν = frequency (cycle/s , Hz)

Electromagnetic Spectrum

Wave theory and quantum theory can be related to each other because the energy of a photon is:

$$Q = hv$$

where:

Q = The energy of a photon,

h = Planck's constant, and

v = frequency.

Electromagnetic Spectrum

Even if you are confused by the equation, understand that *wavelength and energy are inversely proportional*:

- Shorter wavelengths contain more energy (and are produced by more energetic (hotter) sources), and
- Longer wavelengths contain less energy (and we therefore required more photons to produce any physical or chemical reaction based on their energy content).

Electromagnetic Spectrum

One important consequence of the fact that longer wavelength photons are less energetic than photons with shorter wavelength is that remote sensor systems that acquire data at these wavelengths must either:

- Be exposed to radiation for a longer period of time to capture sufficient data, or
- Have larger detector elements (and consequently, lower image resolution).

Electromagnetic Spectrum

The Stefan-Boltzmann law describes the relationship between the temperature of an object and the rate at which it radiates electromagnetic radiation:

$$M = \sigma T^4$$

where

M = total radiant exitance in watts/m^{-2}

σ = Stefan-Boltzmann constant

T = Absolute temperate in degrees Kelvin

Electromagnetic Spectrum

The important relationships revealed by the Stefan-Boltzmann law are:

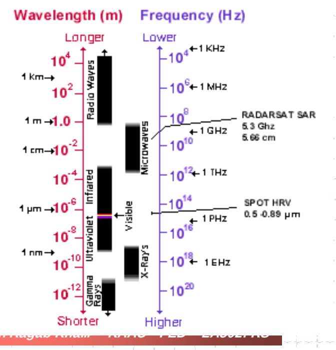
- Hotter objects emit radiation more rapidly than cooler objects, and
- Even small increase in temperature produce much higher radiation rates because the rate is dependent on the 4th power of the temperature (i.e. rates increase at an ever increasing rate at higher temperatures).

Review of concepts

A short review of concepts:

- Objects warmer than absolute zero emit electromagnetic radiation,
- Hotter objects emit more radiation with higher energy photons,
- Hotter objects emit photons with shorter wavelengths,
- The sun's energy peaks in the green portion of the visible light spectrum, but it emits significant ultraviolet energy and considerable infrared energy,
- The Earth emits thermal infrared energy.

Electromagnetic Spectrum

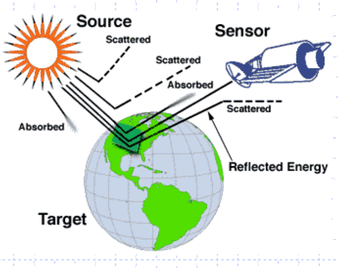


Regions of the Electromagnetic Spectrum

• gamma ray	<0.03 nanometers
• X-ray	0.03 - 3 nanometers
• Ultraviolet	3 nanometers - 0.4 micrometers
• Visible	0.4 - 0.7 micrometers
• near infrared	0.7 - 1.3 micrometers
• mid-infrared	1.3 - 3.0 micrometers
• far infrared	3.0 - 100 micrometers
• Microwave	0.1 - 100 centimeters

Atmospheric Interactions

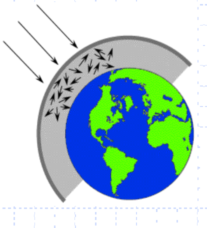
Atmospheric Interactions



Electromagnetic radiation “may” scattered or absorbed

Scattering

- The redirection of electromagnetic energy by particles suspended in the atmosphere, or by large molecules of atmospheric gasses.
  - This redirection of light can be in any direction



Three Types of Scattering

(1) Rayleigh Scattering
(2) Mie Scattering
(3) Non-selective Scattering

Scattering

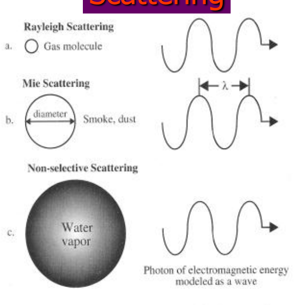
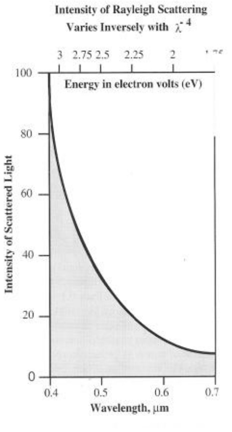


Figure 2-13 Types of scattering encountered in the atmosphere. The type of scattering is a function of 1) the wavelength of the incident radiant energy, and 2) the size of the gas molecule, dust particle, and/or water vapor droplet encountered.



Rayleigh scattering

- Upper atmosphere scattering, sometimes called clear atmosphere scattering.
  - Consists of scattering from atmospheric gasses
  - Is wavelength dependent
  - Scattering increases as the wavelength becomes shorter.
  - Atmospheric particles have a diameter smaller than the incident wavelength.
  - Dominant at elevations of 9 to 10 km above the surface.
  - Blue light is scattered about four times as much as red light and UV light about 16 times as red light.
  - Causes the blue color of the sky and the brilliant red colors at sunset.

Rayleigh Scattering

Mie scattering

- Lower atmosphere scattering (0-5km)
  - Caused by dust, pollen, smoke and water droplets.
  - Particles have a diameter roughly equal to the incident wavelength.
  - Effects are wavelength dependent and affect EMR mostly in the visible portion.

Non-selective scattering

- Lower atmosphere
  - Particles much larger than incident radiation
  - Scattering not wavelength dependent
  - Primary cause of haze

Non-Selective Scattering

Because scattering is nonselective, fog and clouds appear white (a color resulting from the presence of equal amounts of red, green and blue photons).

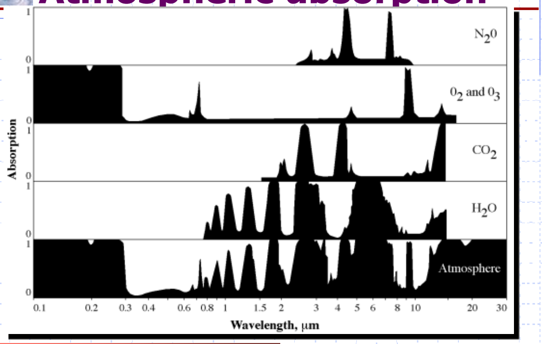
General effects of scattering

- Causes skylight (allows us to see in shadow).
- Directs light normally outside the sensor's field of view toward the sensors aperture decreasing the spatial detail (fuzzy images)
- Tends to make dark objects lighter and light objects darker (reduces contrast)

Atmospheric absorption

- Mostly caused by three atmospheric gasses
  - **OZONE (O3)** - absorbs UV
  - **CARBON DIOXIDE (CO2)** - Lower atmosphere absorbs energy in the 13 - 17.5 micrometer region.
  - **WATER VAPOR (H2O)** -Lower atmosphere. Mostly important in humid areas, very effective at absorbing in portions of the spectrum between 5.5 and 7 micrometer and above 27 micrometer.

Atmospheric absorption

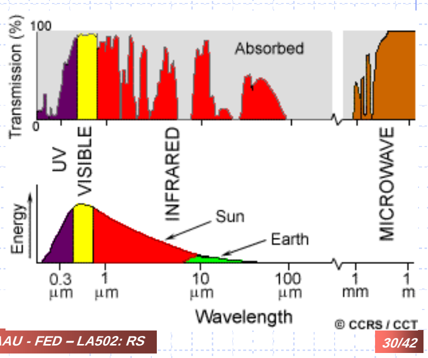


Atmospheric windows

- Portions of the EM spectrum that can pass through the atmosphere with little or no attenuation.
- The next figure shows areas of the spectrum that can pass through the atmosphere without attenuation (peaks) and areas that are attenuated (valleys)

Atmospheric window: It refers to the relatively transparent wavelength regions of the atmosphere

Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.



Surface Interactions

(1) Transmission
(2) Reflection
(3) Absorption

Transmission

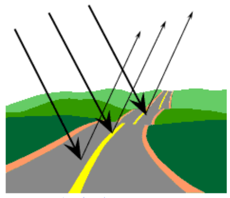
- The movement of light through a surface .
- Transmission is wavelength dependent
- Transmittance is measured as the ratio of transmitted radiation to the incident radiation.
- Transmittance therefore is the proportional amount of incident radiation passing through a surface.

Reflection

- In our usage reflection is the bouncing of electromagnetic energy from a surface.
- The term reflectance is defined as the ratio of the amount of electromagnetic radiation, usually light, reflected from a surface to the amount originally striking the surface.
- Reflection may be specular or diffuse.

Specular Reflection

- When a surface is smooth we get specular or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction.



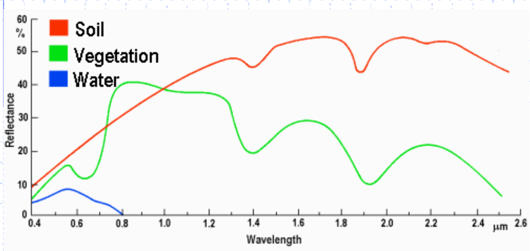
Diffuse Reflection

- Occurs when the surface is rough and the energy is reflected almost uniformly in all directions.

Reflection

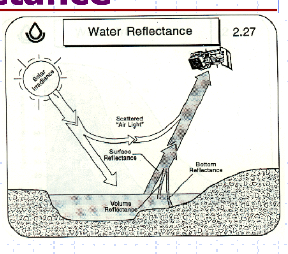
- Whether a particular target reflects specularly or diffusely, or somewhere in between, depends on the surface roughness of the feature *in comparison to the wavelength of the incoming radiation*.
- If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate.
- Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors.

Spectral Signatures

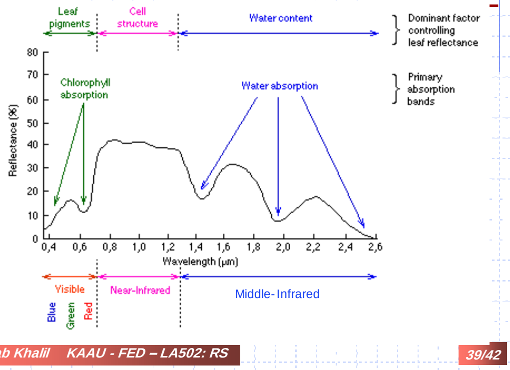


Water reflectance

- There are three types of possible reflectance from a water body - surface
  - Surface reflectance,
  - bottom reflectance, and
  - volume reflectance (Figure 2.27).



Vegetation reflectance



Soil reflectance

- The spectral reflectance of soil is controlled, for the most part, by six variables:
  - moisture content
  - organic matter content
  - particle size distribution
  - iron oxide content
  - soil mineralogy, and
  - soil structure.
- Of these variables, moisture content is the most important due to its dynamic nature and large overall impact on soil reflectance.

Absorption

- Some radiation is absorbed through electron or molecular reactions within the medium ;
- A portion of this energy is then re-emitted (as emittance), usually at longer wavelengths, and some of it remains and heats the target;

Summary

- What is EMR?
- Atmospheric interactions
  - **Scattering**
    - **Rayleigh Scattering**
    - **Mie Scattering**
    - **Non-selective Scattering**
  - **Absorption**
- Surface interactions
  - Transmission
  - Reflection
    - Specular
    - Diffuse
  - Absorption