GE 113 – REMOTE SENSING

Topic 2. Electromagnetic Radiation Principles

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Outline

• Part 1. Basics of Electromagnetic Radiation (EMR)
  – Review of the Remote Sensing Process
  – Role of Energy Sources
  – Definition of EMR
  – Characteristics of EMR (wavelength, frequency)
  – The Electromagnetic Spectrum

• Part 2. Electromagnetic Radiation Interactions in the Atmosphere
  – Refraction
  – Scattering
  – Absorption

• Part 3. Electromagnetic Radiation Interactions with Earth Surface Features
  – Reflection
  – Transmission
  – Absorption
  – Spectral signatures
Expected Outcomes

• The students would be able to:
  – Identify the role of electromagnetic radiation in the remote sensing process
  – Describe how electromagnetic energy interacts in the atmosphere
  – Describe how electromagnetic energy interacts with earth surface features
  – Identify the different responses of earth surface features to electromagnetic energy.
  – Relate how spectral signatures can aid in identifying objects from a remotely-sensed data.
PART 1. BASICS OF ELECTROMAGNETIC RADIATION
A. **Energy Source or Illumination**

B. **Radiation and its Interaction with the Atmosphere**

C. **The Interaction of the Radiation with the Target of Interest**

D. **Recording of the Reflected/Emitted Energy by the Sensor**

E. **Transmission, Reception and Processing**

F. **Interpretation and Analysis**

G. **Application**
Why we need to study electromagnetic radiation as an energy source in the Remote Sensing process:

- Energy recorded by a Remote Sensing system undergoes fundamental interactions that should be understood to properly interpret remotely sensed data (e.g. images)

  - Example: Sun as an energy source:
    - Energy is radiated by atomic particles at the source
    - It travels through the vacuum of space at the speed of light ($3 \times 10^8$ m/s)
    - It interacts with the atmosphere
    - It interacts with the Earth’s surface
    - It interacts with the Earth’s atmosphere once again, and
    - It finally reaches the remote sensor

- It is helpful to examine each of these fundamental interactions that electromagnetic energy as it progresses from its source to the remote sensing system

Source: www.slideshare.net/SISPL/remote-sensing-34027477
Review of Basic Energy Concepts (1)

- Energy = the ability to do work
- In the process, Energy is often transferred:
  - from one body to another
  - from one place to another
- Three (3) basic ways in which energy can be transferred:

Source: http://cookwilkie11.wikis.birmingham.k12.mi.us/Conduction,+Convection,+Radiation
Review of Basic Energy Concepts (2)

• Energy = the ability to do work
• In the process, Energy is often transferred:
  – from one body to another
  – from one place to another
• Three (3) basic ways in which energy can be transferred:
  – **Conduction**: occurs when one body transfers its kinetic energy to another by colliding with it
  – **Convection**: occurs when kinetic energy of bodies is transferred from one place to another by physically moving the bodies
  – **Radiation**: occurs when kinetic energy of a body is emitted or transmitted (i.e., transferred) to another body in the form of waves or particles through space or through a material medium
• In Remote Sensing: transfer of energy by **electromagnetic radiation is of primary interest**
Electromagnetic Radiation

- the radiant energy released by certain electromagnetic processes.
  - Radiant = “glowing”, “beaming”
  - Direct transfer of energy by electromagnetic waves

- a kind of radiation including visible light, radio waves, gamma rays, and X-rays, in which electric and magnetic fields vary simultaneously.

Electromagnetic Radiation (2)

- Based on wave theory, EMR travels in a harmonic, sinusoidal fashion at the "velocity of light," $c$.

- consists of an electrical field ($E$) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field ($M$) oriented at right angles to the electrical field.
Characteristics of EMR

- Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing.
  - wavelength ($\lambda$)
  - frequency (f)

- **Wavelength** = The length of one wave cycle, which can be measured as the distance between successive wave crests.
  - Usually measured in **micrometers** (μm) or **nanometers** (nm)

- **Frequency** = frequency refers to the number of cycles of a wave passing a fixed point per unit of time.
  - A wave that sends one crest by every second (completing one cycle) is said to have a frequency of one cycle per second or **one hertz** (1 Hz)

\[ c = \lambda f \]

where
\[ c = \text{speed of light} \]
\[ c = 3 \times 10^8 \text{ m/s} \]
Relationship of Wavelength and Frequency

• Frequency is inversely proportional to wavelength

• The longer the wavelength, the lower the frequency

• The shorter the wavelength, the higher the frequency

• The speed of light and wavelength change while the frequency remains the same when electromagnetic radiation passes from one substance to another

$$c = \lambda f$$

where

$c = \text{speed of light}$

$c = 3 \times 10^8 \text{ m/s}$
Wavelengths are usually expressed in the metric or SI system, since having multiples of 10 are more convenient. Wavelengths can range from many kilometers long to extremely short lengths or fractions of a meter.

<table>
<thead>
<tr>
<th>Name</th>
<th>Meters</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 km (kilometer)</td>
<td>1000 m (meters)</td>
<td>1*10^3 m</td>
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<tr>
<td>1 m</td>
<td>1 m</td>
<td>1 m</td>
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<td>1 cm (centimeter)</td>
<td>0.01 m</td>
<td>1*10^-2 m</td>
</tr>
<tr>
<td>1 mm (millimeter)</td>
<td>0.001 m</td>
<td>1*10^-3 m</td>
</tr>
<tr>
<td>1 μm (micrometer or micron)</td>
<td>0.000001 m</td>
<td>1*10^-6 m</td>
</tr>
<tr>
<td>1 nm (nanometer)</td>
<td>0.000000001 m</td>
<td>1*10^-9 m</td>
</tr>
<tr>
<td>1 Å (Angstrom)</td>
<td>0.1 nm</td>
<td>1*10^-10 m</td>
</tr>
</tbody>
</table>
Wavelength and Frequency Standard Units of Measurement (2)

Frequencies

Frequencies are measured in hertz (Hz), which means cycles or wave crests per second. You can write the frequency with the symbol versions, as a large number or as an exponent.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Number</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Hz (hertz)</td>
<td>1 Hz</td>
<td>1 Hz</td>
</tr>
<tr>
<td>1 kHz (kilohertz)</td>
<td>1000 Hz</td>
<td>$1\times10^3$ Hz</td>
</tr>
<tr>
<td>1 MHz (megahertz)</td>
<td>1,000,000 Hz</td>
<td>$1\times10^6$ Hz</td>
</tr>
<tr>
<td>1 GHz (gigahertz)</td>
<td>1,000,000,000 Hz</td>
<td>$1\times10^9$ Hz</td>
</tr>
</tbody>
</table>
The Electromagnetic Spectrum

- Used to categorize electromagnetic radiation by their wavelength location

Source: www.mpoweruk.com
The Electromagnetic Spectrum (2)

Source: http://1.bp.blogspot.com
Regions of the EMR Spectrum Useful for Remote Sensing (1)

- **Ultraviolet or UV portion of the spectrum**
  - has the shortest wavelengths which are practical for remote sensing.
  
  - This radiation is just beyond the violet portion of the visible wavelengths, hence its name.

- Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.
Regions of the EMR Spectrum Useful for Remote Sensing (2)

• **Visible Spectrum**
  – The light which our eyes - our "remote sensors" - can detect
  – The visible wavelengths cover a range from approximately 0.4 to 0.7 µm.
  – The longest visible wavelength is red and the shortest is violet.

• It is important to recognize how small the visible portion is relative to the rest of the spectrum.
  – There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage.
More on the Visible Spectrum

• Common wavelengths of what we perceive as particular **colors** from the visible portion of the spectrum are:
  
  - **Violet**: 0.4 - 0.446 μm
  - **Blue**: 0.446 - 0.500 μm
  - **Green**: 0.500 - 0.578 μm
  - **Yellow**: 0.578 - 0.592 μm
  - **Orange**: 0.592 - 0.620 μm
  - **Red**: 0.620 - 0.7 μm

• **Blue**, **green**, and **red** are the **primary colors** or wavelengths of the visible spectrum.

• They are defined as such because no single primary color can be created from the other two, but all other colors can be formed by combining blue, green, and red in various proportions.

• It is important to note that this is the only portion of the spectrum we can associate with the concept of **colors**.
More on the Visible Spectrum

• Although we see sunlight as a uniform or homogeneous color, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum.

• The visible portion of this radiation can be shown in its component colors when sunlight is passed through a prism, which bends the light in differing amounts according to wavelength.
Regions of the EMR Spectrum Useful for Remote Sensing (3)

- **The Infrared (IR) Region**
  - Covers the wavelength range from approximately 0.7 μm to 1000 μm (or 1 mm)
  - The region useful for RS is approximately from 0.7 μm to 14 μm
    - can be divided into two categories based on their radiation properties:
      - the reflected IR
      - the emitted or thermal IR
More on the Infrared Region

• **Reflected IR Region**
  – Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion.
  – covers wavelengths from approximately $0.7 \, \mu m$ to $3.0 \, \mu m$.

• **Thermal IR Region**
  – the radiation that is emitted from the Earth's surface in the form of heat.
  – covers wavelengths from approximately $3.0 \, \mu m$ to $14 \, \mu m$. 
Regions of the EMR Spectrum Useful for Remote Sensing (3)

• The Microwave Region
  – Covers the wavelength range from approximately 1 mm to 1 m.
    – Longer wavelength microwave radiation can penetrate through cloud cover, haze, dust, and all but the heaviest rainfall as the longer wavelengths are not susceptible to atmospheric scattering which affects shorter optical wavelengths.
    – This property allows detection of microwave energy under almost all weather and environmental conditions so that data can be collected at any time.
Relationship between Energy and Frequency

• Based on particle theory, EMR is composed of many discrete units called **photons** or **quanta**

• The energy (Q) of a quanta is given as:

\[ Q = hf \]

  - Q is in Joules (J)
  - \( h = \) Planck’s constant = \( 6.626 \times 10^{-34} \) J seconds
  - \( f = \) frequency

• *Since \( c = \lambda f \), then \( Q = \frac{hc}{\lambda} \)*
  - The energy of a quantum is inversely proportional to its wavelength
    - The longer the wavelength, the lower its energy content
    - This suggests that it is more difficult to detect longer wavelength energy being emitted at thermal infrared wavelengths than those at shorter visible wavelengths
• Questions or clarifications?
Reading Assignment

• Download/Read Fundamentals of Remote Sensing (Online Tutorial).
  – Available at http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309
  – Or search “Fundamentals of Remote Sensing Tutorial” in Google
  – **Focus on Chapter 1, Section 1.4 to 1.7**
PART 2. ELECTROMAGNETIC RADIATION INTERACTIONS IN THE ATMOSPHERE
Review: 7 Elements of the Remote Sensing Process

A. Energy Source or Illumination

B. Radiation and its Interaction with the Atmosphere

C. The Interaction of the Radiation with the Target of Interest

D. Recording of the Reflected/Emitted Energy by the Sensor

E. Transmission, Reception and Processing

F. Interpretation and Analysis

G. Application
Review of Basic EMR Concepts (1)

- **EMR:**
  - travels in a harmonic, sinusoidal fashion at the “velocity of light,” \( c \)
  - consists of an electrical field (\( E \)) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (\( M \)) oriented at right angles to the electrical field.

- **Wavelength (\( \lambda \)), Frequency (\( f \)) and Energy (\( Q \))**
  - Frequency is inversely proportional to wavelength
    - *The longer the wavelength, the lower the frequency*
    - *The shorter the wavelength, the higher the frequency*
  - When electromagnetic radiation passes from one substance to another, the speed of light and wavelength change while the frequency remains the same
  - The energy of a quantum/photon (light particle) is inversely proportional to its wavelength
    - *The longer the wavelength, the lower its energy content*

\[ c = \lambda f \]
\[ Q = hf \]
\[ Q = \frac{hc}{\lambda} \]

\( Q \) is in Joules (J)
\( h \) = Planck’s constant = \( 6.626 \times 10^{-34} \) J s
\( \lambda \) = wavelength
\( f \) = frequency
\( C \) = speed of light, \( 3 \times 10^8 \) m/s
Review of Basic EMR Concepts (2)

• The EMR Spectrum

- Regions/Portions of EMR Spectrum useful for RS
  - Ultraviolet (UV) Region: 10 nm to <400 nm (0.1 to <0.4 µm)
  - Visible (VIS) Region: 400 to 700 nm (0.4 to 0.7 µm)
  - Reflected Infrared (IR) Region: 0.7 to 3 µm
  - Thermal Infrared Region: 3 to 14 µm
  - Microwave (MW) Region: 1 mm to 1 m
Review: 7 Elements of the Remote Sensing Process

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EMR and Its Interaction with the Atmosphere

• Once EMR is generated, it is propagated through the Earth’s atmosphere almost at the speed of light in a “vacuum”.
  – In a vacuum, light travels at a speed of $3 \times 10^8$ m/s

• But the atmosphere is not like a vacuum.
  – The atmosphere is composed of particles and gases that can affect:
    • The speed of radiation
    • Its wavelength
    • Its intensity
    • Its spectral distribution (the power per unit area per unit wavelength of an illumination)
      • It may also be diverted from its original direction

• Three (3) kinds of interactions:
  – Refraction
  – Scattering
  – Absorption
Atmospheric Refraction (1)

- Refraction takes place when EMR encounters substances of different density

- **Refraction** = the **bending** of light when it passes from one medium to another of different density.
Atmospheric Refraction (2)

• **Index of Refraction, \( n \)**
  - Measure of the optical density of a substance
  \[ n = \frac{c}{c_n} \]
  - \( c = \) speed of light in a vacuum
  - \( c_n = \) speed of light in a substance
  - Since \( c_n \) can never be greater than \( c \), \( n > 1 \).

• \( n \) of atmosphere = 1.0002926
• \( n \) of water = 1.33

• Light travels more slowly through water because of its higher density compared to the atmosphere.
Atmospheric Refraction (3)

• Refraction can be described by Snell’s law
  - “For a given frequency of light, the product of the index of refraction and the sine of the angle between the ray and a line normal to the interface is constant.”

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
Atmospheric Refraction (4)

- Snell’s Law:
  \[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

- The amount of refraction is a function of the angle made with the vertical (\( \theta \)), the distance involved, and the density of the air involved.

- Serious error in location due to refraction can occur in images formed from energy detected at high altitudes or at acute angles.

- If one knows the incident angle (\( \theta_1 \)), the index of refraction of medium \( n_1 \) and \( n_2 \), it is possible to predict the amount of refraction that will take place in medium \( n_2 \) using Snell’s law.
Atmospheric Scattering

• “The **unpredictable dispersal** of radiation by particles in the atmosphere”

• Differs from “**refraction**” or “**reflection**” because the direction associated with scattering is **unpredictable**.

• Three (3) Types:
  - **Rayleigh**
  - **Mie**
  - **Non-selective**

• The type of scattering is dependent on:
  - Wavelength of the incident EMR
  - Diameter of the atmospheric particles (gases, water vapors, and/or dusts)
Rayleigh Scattering

- Also called "**Molecular scattering**";
  - Takes place in the atmosphere 2 to 8 km above ground

- Occurs when the effective **diameter** of the matter (usually air molecules such as oxygen and nitrogen in the atmosphere) are many times smaller (usually < 0.1) than the wavelength of the incident EMR

- All scattering is accomplished through absorption and re-emission of radiation by atoms or molecules
  - It is impossible to predict the direction in which a specific atom or molecule will emit a photon
  - The energy required to excite an atom is associated with powerful short-wavelength, high frequency radiation

**Shorter wavelengths scattered more; longer wavelengths scattered less**
Rayleigh Scattering (2)

- Blue light is scattered about 5 times more than red light.

- Rayleigh scattering is responsible for the blue appearance of the sky.
Why is the sky blue? (AVP)

Watch the video here:

https://www.youtube.com/watch?v=0b1fqodmZJ0
Mie Scattering (1)

- Also called “non-molecular or aerosol particle scattering”

- Occurs when the particles are just about the same size as the wavelength of the incident EMR.

- Takes place in the lower 4.5 km of the atmosphere
  - Present in this portion are many spherical particles with diameters approximately equal to the size of the wavelength of the incident EMR
  - Actual size of the particles may range from 0.1 to 10 times the wavelength of the incident EMR
Mie Scattering (2)

- Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering.
  - Wavelengths that are scattered and reached our eyes are longer

- Mie scattering occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast.

- The greater the amount of smoke and dust particles in the atmospheric column, the more the violet and blue light will be scattered away and only the longer orange and red wavelength light will reach our eyes

This type of scattering explains:
- Beautiful sunsets and sunrises in urbanized cities due to air pollution (not to be confused with Rayleigh scattering during sunrise and sunset!)

- the reddish hues of the sky following a forest fire or volcanic eruption.
Group Discussion/Recitation

- On a sunny day, the clouds appear white. What could be the explanation behind this?
Non-selective Scattering

- This occurs when the particles are much larger than the wavelength of the radiation (>10 times)

- Water droplets and large dust particles can cause this type of scattering.

- Nonselective scattering gets its name from the fact that all wavelengths are scattered about equally.

- This type of scattering causes fog and clouds to appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities:
  \[
  \text{blue} + \text{green} + \text{red light} = \text{white light}
  \]
Why are rain clouds gray or dark?
Why are rain clouds gray or dark?

• Because of their thickness, or height.

• That is, a cloud gets thicker and denser as it gathers more water droplets and ice crystals — the thicker it gets, the more light it scatters, resulting in less light penetrating all the way through it.

• The particles on the underside of the rain cloud don't have a lot of light to scatter to your eyes, so the base appears gray as you look on from the ground below.

This effect becomes more pronounced the larger the water droplets get — such as right before they're large enough to fall from the sky as rain — because they become more efficient at absorbing light, rather than scattering it.
Atmospheric Scattering Effects on Remote Sensing Images

• It severely reduce the information content of remotely sensed data
  – The imagery **loses contrast**
    • It becomes difficult to differentiate one object from another.
  – Image **blurring**

• The EMR scattered by the atmosphere towards the sensor without first reaching the ground produces a **hazy** appearance of the image.
  – This effect is particularly severe in the blue end of the visible spectrum due to the **stronger Rayleigh Scattering for shorter wavelength radiation**.
Atmospheric Absorption

- In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths.

- Absorption = the process by which incident EMR is absorbed and converted into other forms of energy

- Reduces the amount of EMR reaching the Earth’s surface
Atmospheric Absorption (2)

- Main atmospheric constituents which absorb radiation:
  - Water vapour
  - carbon dioxide
  - Oxygen
  - Ozone
  - nitrous oxide

- The cumulative effect of the absorption by the various constituents can cause the atmosphere to "close down" completely in certain regions of the spectrum.

- Portions of the spectrum where absorption is minimal and transmit EMR effectively are called atmospheric windows.
  - These portions are being taken advantage by Remote Sensing
Atmospheric Windows (1)
Atmospheric Windows

- The visible portion of the spectrum, to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun.

- Heat energy emitted by the Earth corresponds to a window around 10 μm in the thermal IR portion of the spectrum, while the large window at wavelengths beyond 1 mm is associated with the microwave region.
• Questions or clarifications?
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G. **Applications**

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EMR Interaction with a Target

- Radiation that is **not absorbed or scattered** in the atmosphere **can reach** and **interact** with the Earth's surface.
- The interaction is dependent on the properties of both the target and the radiation.

- **Three (3) forms of interactions:**
  - Absorption
  - Transmission
  - Reflection

- The total incident energy will interact with the surface in **one or more of these three ways.**
Absorption vs. Transmission vs. Reflection

- **Absorption (A)** occurs when radiation (energy) is absorbed into the target.
- **Transmission (T)** occurs when radiation passes through a target.
- **Reflection (R)** occurs when radiation "bounces" off the target and is redirected.

In Remote Sensing, we are most interested in measuring the radiation reflected from targets.
Types of Reflection

- **Specular Reflection**
  - “mirror-like” reflection
  - occur when incident EMR interacts with a **smooth surface** and all (or almost all) of the energy is directed away from the surface in a **single direction**.

- **Diffuse Reflection**
  - occurs when incident EMR interacts with a **rough surface** and the energy is reflected **almost uniformly** in all directions.
  - The ideal form of diffuse reflection is called **Lambertian reflectance**
Specular Reflection Illustrations
Diffuse Reflection Illustrations
Specular vs Diffuse: Which one will dominate? (1)

- Most earth surface features lie somewhere **between** perfectly specular or perfectly diffuse reflectors.

- 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.
Specular vs Diffuse: Which one will dominate? (2)

• **Diffuse reflection** → if the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface

Example:

• **fine-grained sand** would appear quite rough to the visible wavelengths but would appear fairly smooth to long wavelength microwaves.
Role of Reflection, Absorption & Transmission in Remote Sensing of Earth Features (1)

- Various fractions of the energy incident (I) on the surface features are reflected (R), absorbed (A), and/or transmitted (T).

\[ E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda) \]

- all energy components are a function of wavelength (\( \lambda \)).

- The proportions of energy reflected, absorbed, and transmitted vary for different earth features, depending on their material type and condition.

- These differences permit us to distinguish different features on an image.
Role of Reflection, Absorption & Transmission in Remote Sensing of Earth Features (2)

• the **wavelength dependency** means that, even within a given feature type, the proportion of reflected, absorbed, and transmitted energy will vary at different wavelengths.

• This important property makes it possible to identify different features and separate them by their **spectral signatures**.

![Graph showing reflectance percentage against wavelength for different materials: Water, Soil, and Green vegetation in visible and near-infrared regions.](image-url)
Spectral Signature and Spectral Reflectance

- **Spectral signature** - the difference in the reflectance characteristics with respect to wavelengths.
- **Spectral reflectance** ($\rho$):
  - the ratio of reflected radiation to incident radiation as a function of wavelength.

$$\rho(\lambda) = \left( \frac{E_R(\lambda)}{E_I(\lambda)} \right) \times 100$$

Spectral reflectance has different values at different wavelengths for a given feature.
Spectral Reflectance of Vegetation (1)

- The spectral characteristics of vegetation vary with wavelength.

- Plant pigment in leaves called **chlorophyll** strongly **absorbs** radiation in the **red** and **blue** wavelengths but **reflects** **green** wavelength.

- The internal structure of healthy leaves acts as **diffuse reflector** of **near infrared** wavelengths.

- Measuring and monitoring the **near infrared reflectance** is one way that scientists determine how healthy particular vegetation may be.
Spectral Reflectance of Vegetation (2)

• Plant reflectance in the **0.7 to 1.3 \( \mu m \)** range results primarily from the internal structure of plant leaves.
  - Because this structure is highly variable between plant species, reflectance measurements in this range often permit us to discriminate between species, even if they look the same in visible wavelengths.

• Beyond 1.3 \( \mu m \), energy incident upon vegetation is essentially absorbed or reflected, with little to no transmittance of energy.

• Throughout the range beyond 1.3 \( \mu m \), leaf reflectance is approximately inversely related to the total water present in a leaf.
  - This total is a function of both the moisture content and the thickness of a leaf.

• Dips in reflectance occur at 1.4, 1.9, and 2.7 \( \mu m \) because water in the leaf absorbs strongly at these wavelengths.
  - Wavelengths in these spectral regions are referred to as **water absorption bands**.
Spectral Reflectance of Water

- Majority of the radiation incident upon water is not reflected but is either absorbed or transmitted.

- Longer visible wavelengths and near infrared radiation is absorbed more by water than by the visible wavelengths.
  - water looks **blue or blue green** due to stronger reflectance at these shorter wavelengths and **darker** if viewed at red or near infrared wavelengths.

- Factors that affect the variability in reflectance of a water body are depth of water, materials within water and surface roughness of water.
Spectral Reflectance of **Soil**

- The majority of radiation incident on a soil surface is either reflected or absorbed and little is transmitted.

- The soil reflectance curve shows less peak and valley variations.

- The presence of moisture in soil decreases its reflectance.

The characteristics of soil that determine its reflectance properties are:

- moisture content
- organic matter content
- Texture
- structure
- iron oxide content.
Important Notes:

- Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g. "green-ness" of leaves) and location.

- Knowing where to "look" spectrally and understanding the factors which influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.

- By measuring the energy that is reflected by targets on earth’s surface over a variety of different wavelengths, we can build up a spectral signature for that object.

- And by comparing the response pattern of different features we may be able to distinguish between them, which we may not be able to do if we only compare them at one wavelength.
• Questions or clarifications?
References/Further Reading


