**2.4** **Energy Interactions**

**Reading material**

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| We know that when light comes into contact with an object it scatters. In the previous session, we learned that a signal from a satellite is part of an electromagnetic wave, and this scattering also applies to a signal from satellites.  In this third session, you will learn about energy interactions, and the mechanisms of scattering and absorption. |
| **Interactions with the Atmosphere**  Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere. Particles and gases in the atmosphere can affect the incoming light and radiation. These effects are caused by the mechanisms of scattering and absorption.  Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.  How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere. |
| There are three (3) types of scattering which take place:   * Rayleigh scattering * Mie scattering * Nonselective scattering   Scattering  Source: Canada Centre for Remote Sensing (CCRS) |
| **Rayleigh scattering** occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as small specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. Rayleigh scattering is the dominant scattering mechanism in the upper atmosphere. The fact that the sky appears "blue" during the day is because of this phenomenon. As sunlight passes through the atmosphere, the shorter wavelengths (i.e., blue) of the visible spectrum are scattered more than the other (longer) visible wavelengths. At sunrise and sunset, the light has to travel farther through the atmosphere than at midday and the scattering of the shorter wavelengths is more complete; this leaves a greater proportion of the longer wavelengths to penetrate the atmosphere.  **Mie scattering** occurs when the particles are just about the same size as the wavelength of the radiation. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering. 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 final scattering mechanism of importance is called **nonselective scattering**. This occurs when the particles are much larger than the wavelength of the radiation. 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 (blue + green + red light = white light).    Source: John R. Jensen (2014): Remote Sensing of the Environment: An Earth Resource Perspective |
| **Absorption** is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation.  Absorption  Source: Canada Centre for Remote Sensing (CCRS) |
| **Ozone** serves to absorb the harmful (to most living things) ultraviolet radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.  You may have heard carbon dioxide referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming longwave infrared and shortwave microwave radiation (between 22µm and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e., high humidity). |
| Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called atmospheric windows. By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the **atmospheric windows** available to us, we can define those wavelengths that we can use most effectively for remote sensing. 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. Note also that 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. |
| Wavelengths that we can use most effectively  Source: Canada Centre for Remote Sensing (CCRS) |
| Energy-Matter interactions with the terrain: |
| **Spectral Reflectance**  The wavelengths of EMR always vary based on the nature of distant objects, and thus create different spectral signatures. Remote sensing sensors play important roles to identify these spectral signatures. The recorded radiation (or datasets) is then used to analyse the object (e.g., features of Earth’s surface) and for mapping purposes.    Source: YouTube video: Spectral Reflectance Curves - What is Remote Sensing? (8/9) - YouTube |
| Different surface features reflect and absorb the sun's electromagnetic radiation in different ways. The reflectance properties of an object depend on the material and its physical and chemical state, the surface roughness as well as the angle of the sunlight. The reflectance of a material also varies with the wavelength of the electromagnetic energy. The amount of reflectance from a surface can be measured as a function of wavelength, this is referred to as spectral reflectance.  Spectral Reflectance is a measure of how much energy (as a percent) a surface reflects at a specific wavelength. Many surfaces reflect different amount of energy in different portions of the spectrum. These differences in reflectance make it possible to identify different earth surface features or materials by analysing their spectral reflectance signatures.  **Spectral reflectance curves** graph the reflectance (in percent) of objects as a function of wavelengths.    Source: YouTube video: Spectral Reflectance Curves - What is Remote Sensing? (8/9) - YouTube  \* Mesophiyll is the soft chlorophyll-containing tissue of a leaf between the upper and lower layers of epidermis: involved in photosynthesis |

**Exercise materials and tasks**

**Quiz questions**

Instructions: As a recap and deepening of the previous session’s content, we have prepared this quiz. Have fun!

1. Impact of the atmosphere – which statement is correct?

1. All parts of electromagnetic radiation are affected by the atmosphere in the same strength.
2. **Increasing portions of water vapor increase the transmissivity in the atmosphere.**
3. Where the atmosphere exhibits high transmissivity for specific wavelength, atmospheric windows can be found.

2. Scattering mechanisms – which image represents Mie scattering?

1. **red sunset**
2. white clouds
3. blue sky

3. Scattering mechanisms – which image represents Rayleight scattering?

1. red sunset
2. white clouds
3. **blue sky**

4. Which part of electromagnetic radiation (EMR) is absorbed the most?

1. **Visible**
2. Near-infrared (IR)
3. Shortwave infrared (SWIR)