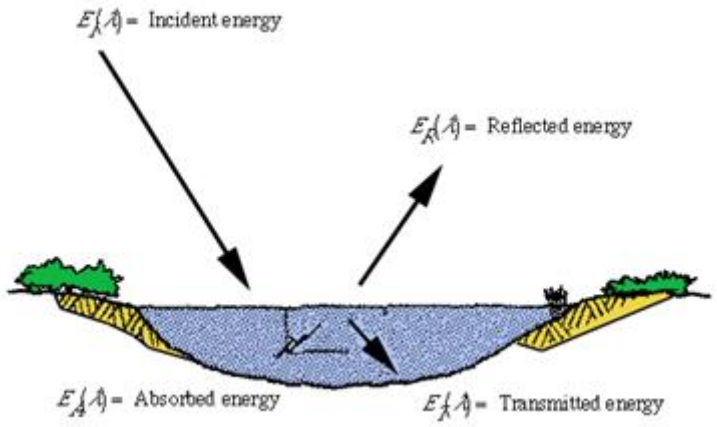
Interaction of EMR with Earth's Surfaces

Introduction

When electromagnetic energy reaches the Earth's surface there are three possible energy interactions with the surface feature:

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

As we know from the principle of energy conservation, energy can neither be created nor destroyed, but it can be transferred:



$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$$

Where:

$E_I(\lambda)$ = Incident energy (from sun)

$E_R(\lambda)$ = Reflected energy

$E_A(\lambda)$ = Absorbed energy

$E_T(\lambda)$ = Transmitted energy

The proportion of energy reflected, absorbed and transmitted will vary depending on the surface material, condition and wavelength of the energy. For example: Vegetation and soils can

reflect approximately 30-50% of the incident energy (across the entire EM spectrum) while water on the other hand reflects only 10% of incident energy. Water reflects most of this in the visible range, minimal in the NIR and beyond 1.2 µm (mid-infrared) water absorbs nearly all energy.

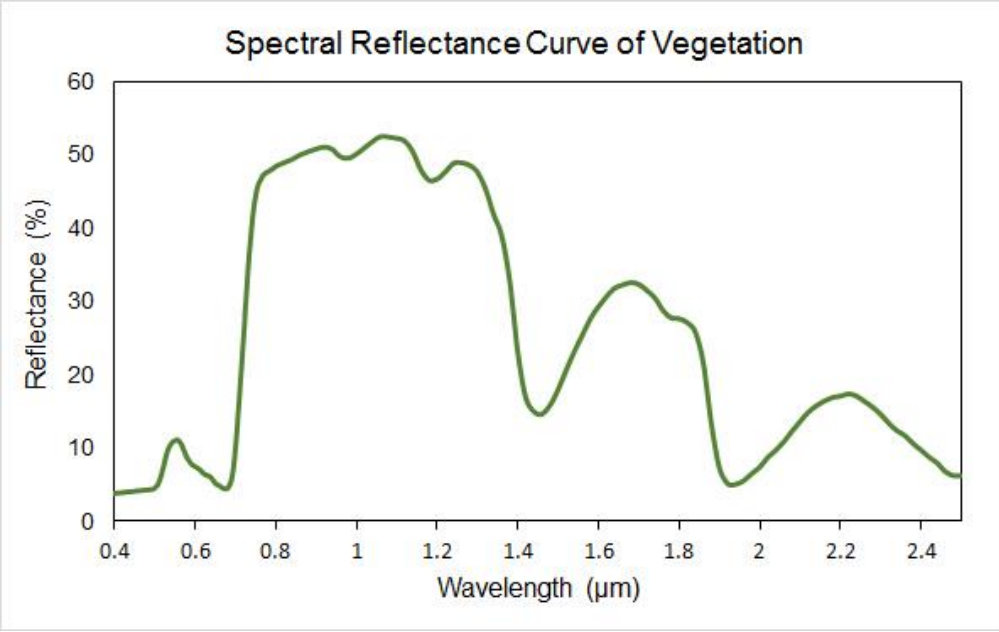
Reflectance

Reflection occurs when incoming energy bounces off a surface and is reflected back. The amount of reflection varies with:

- Wavelength of Energy
- Geometry of the Surface
- Surface Materials

The color of an object is actually the wavelengths of the light reflected while all other wavelengths are absorbed.

Spectral Reflectance



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 analyzing their spectral reflectance signatures. **Spectral reflectance curves** graph the reflectance (in percent) of objects as a function of wavelengths.

Spectral Reflectance of Earth Surface Features

Vegetation

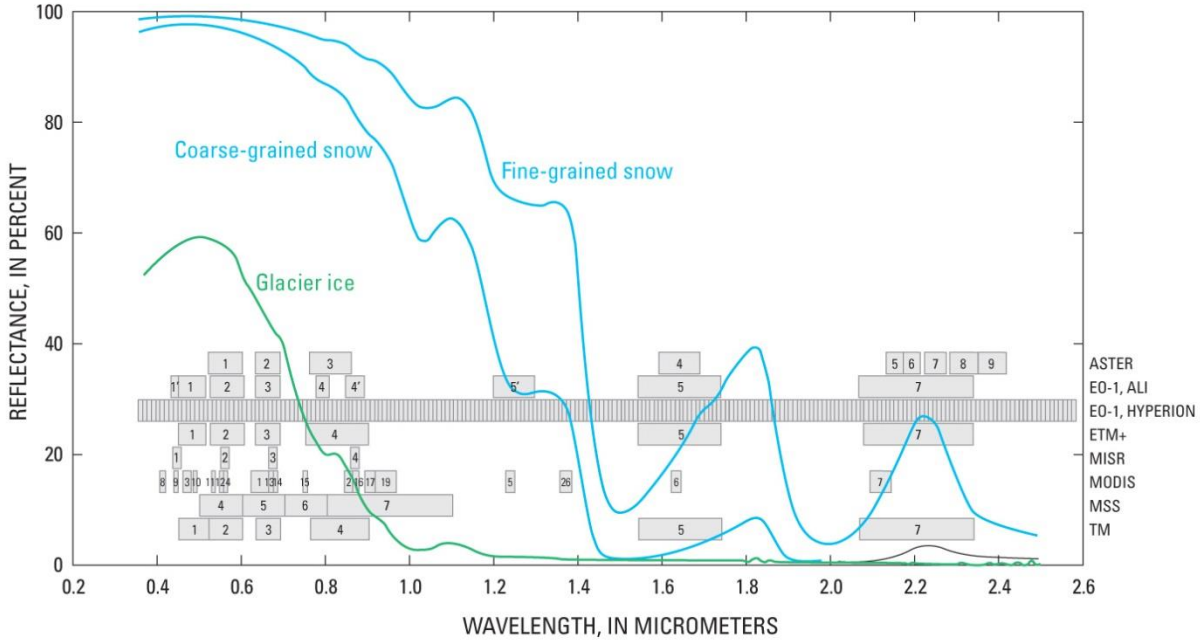
In general, healthy vegetation is a very good absorber of electromagnetic energy in the visible region. Chlorophyll strongly absorbs light at wavelengths around 0.45 (blue) and 0.67 µm (red) and reflects strongly in green light, therefore our eyes perceive healthy vegetation as green. Healthy plants have a high reflectance in the near-infrared between 0.7 and 1.3 µm. This is primarily due to healthy internal structure of plant leaves. As this internal structure varies amongst different plant species, the near infrared wavelengths can be used to discriminate between different plant species.

Water

In its liquid state, water has relatively low reflectance, with clear water having the greatest reflectance in the blue portion of the visible part of the spectrum. Water has high absorption and virtually no reflectance in near infrared wavelengths range and beyond. Turbid water has a higher reflectance in the visible region than clear water. This is also true for waters containing high chlorophyll concentrations.

Ice and Snow

Ice and snow generally have high reflectance across all visible wavelengths, hence their bright white appearance. Reflectance decreases in the near infrared portion and there is very low reflectance in the SWIR (shortwave infrared). The low reflection of ice and snow in the SWIR is related to their microscopic liquid water content. Reflectance differs for snow and ice depending on the actual composition of the material including impurities and grain size.



Spectral reflectance curves of bare glacier ice, coarse-grained snow, and fine-grained snow. Spectral bands of selected sensor on Earth-orbiting satellites are shown in gray. The numbers in the gray boxes refer to the associated band numbers of each sensor. Image Credit: USGS

Soil

Bare soil generally has an increasing reflectance, with greater reflectance in near-infrared and shortwave infrared. Some of the factors affecting soil reflectance are:

- Moisture content
- Soil texture (proportion of sand, silt, and clay)

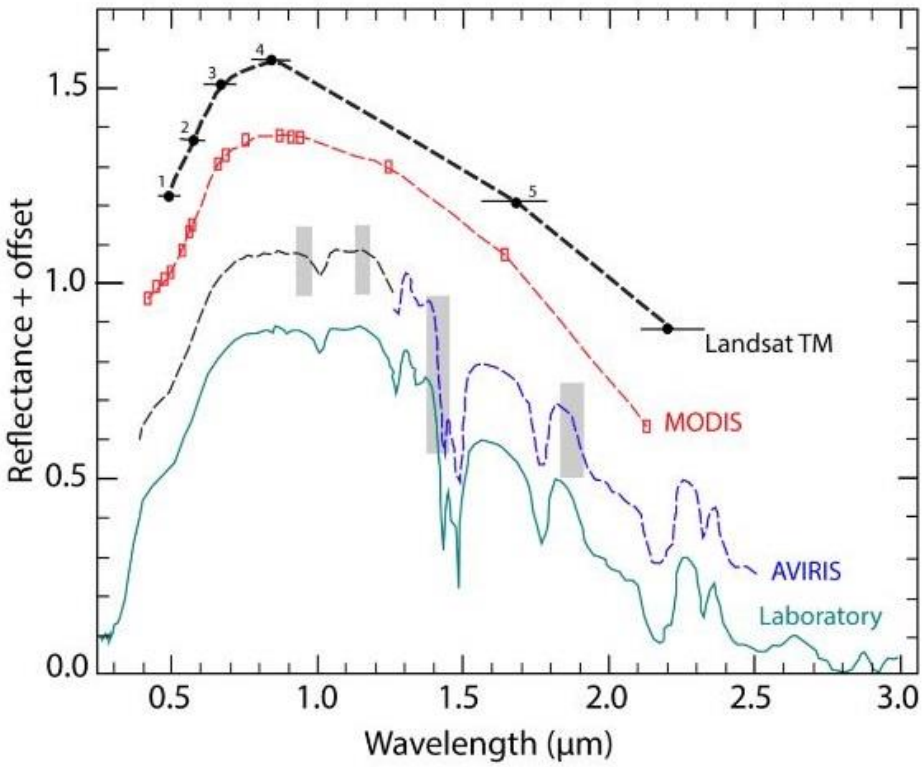
- Surface roughness
- Presence of iron oxide
- Organic matter content

Measuring Spectral Reflectance

There are many different ways that the spectral reflectance pattern of an object or surface can be recorded. Reflectance measurements can be made in the laboratory, in the field using a field spectrometer or captured by other remote sensors including those mounted on aircraft and satellite.

Collection of field spectral reflectance measurements for the USGS Spectral Library. Image Credit: USGS

The level of detail of the reflectance curve (number of data points collected) depends on the *spectral resolution* of the sensor. Laboratory and field spectrometers typically collect hundreds of data points, measuring the percent reflectance of a material at hundreds of wavelengths. The Landsat 8 OLI (Operational Land Imager) only measures reflectance at nine different bands (or specific wavelengths) between 400 to 2500 nanometers, while advanced hyperspectral sensors like Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) measure 224 bands in the same wavelegnth range.



Comparison of spectral reflectance curves for alunite from four sensors (Landsat TM, MODIS, AVIRIS and laboratory sensor) with different spectral resolutions. Image Credit: USGS

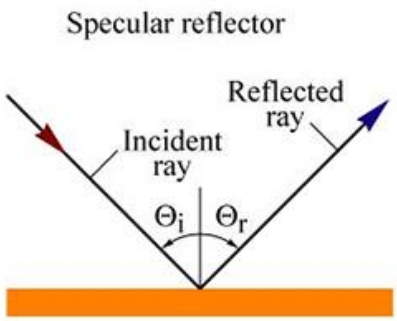
In the above image, the Landsat Thematic Mapper (TM) has only six bands in the visible to shortwave-infrared spectrum which isn't sufficient resolution to detect any absorptions typical in minerals. AVIRIS, however, has sufficient spectral range and resolution to resolve many common absorption bands found in a wide variety of minerals and other compounds.

Geometry

The surface geometry of an object is an important consideration when discussing reflectance. This is primarily a function of the surface roughness of an object.

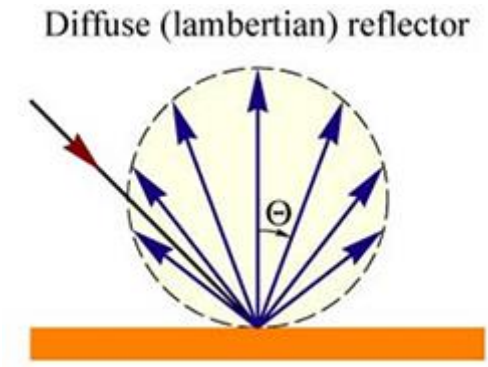
Specular Reflectors

Specular reflectors are flat surfaces that produce mirror like reflections. Mirrors and calm surfaces of lakes are specular reflectors and produce mirror-like reflections. On an ideal specular reflector the angle of incidence is equal to the angle of reflection.



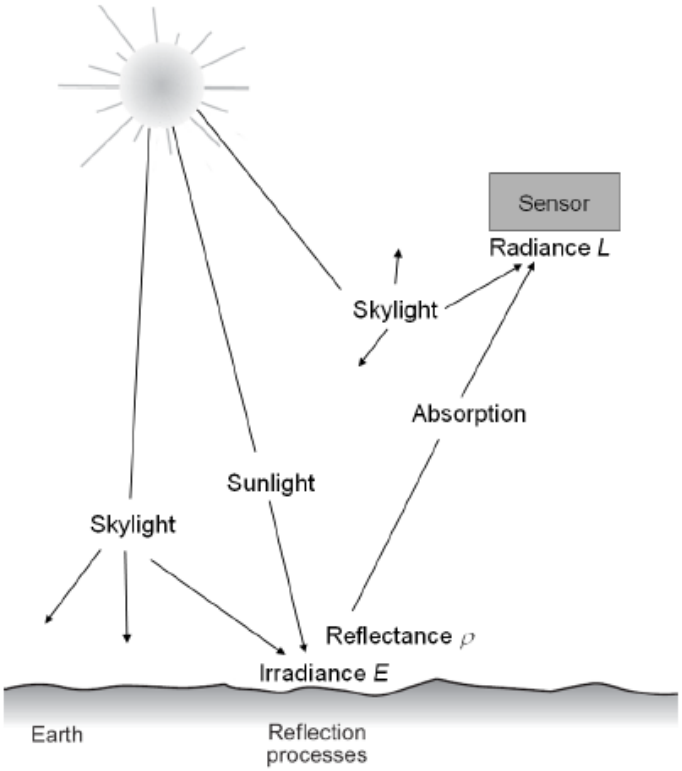
Diffuse or Lambertian Reflectors

Diffuse or Lambertian reflectors are rough surfaces that reflect uniformly in all directions. Most surfaces are idealized diffuse or lambertian reflectors.



Most of the surfaces on earth are neither perfectly specular or diffuse reflector but their characteristics are somewhere in between.

Irradiance vs Radiance vs Reflectance



The total quantity of incoming energy (light) from the sun is known as irradiance. Satellites measure radiance (brightness), or the amount of light. Objects on the ground are often characterized by their reflectance, or the percentage of the total energy that is reflected. The atmosphere affects the radiance received by the sensor in two ways:

1. It can reduce (or attenuates) the energy
2. Atmosphere itself is a reflector, adding energy or "path radiance" to the signal detected by the sensor

In remote sensing we are generally interested in the reflectance characteristics of surface features. **Reflectance is the percent of incoming incident energy that is reflected.** This is always measured as a function of wavelength and is given as a percent.

Spectral Reflectance

$\rho_\lambda = E_R(\lambda) / E_I(\lambda)$

OR

% Reflectance = Amount of Reflected Energy/Total Energy x 100

Reference:

http://gsp.humboldt.edu/OLM/Courses/GSP_216_Online/lesson2-1/surface.html