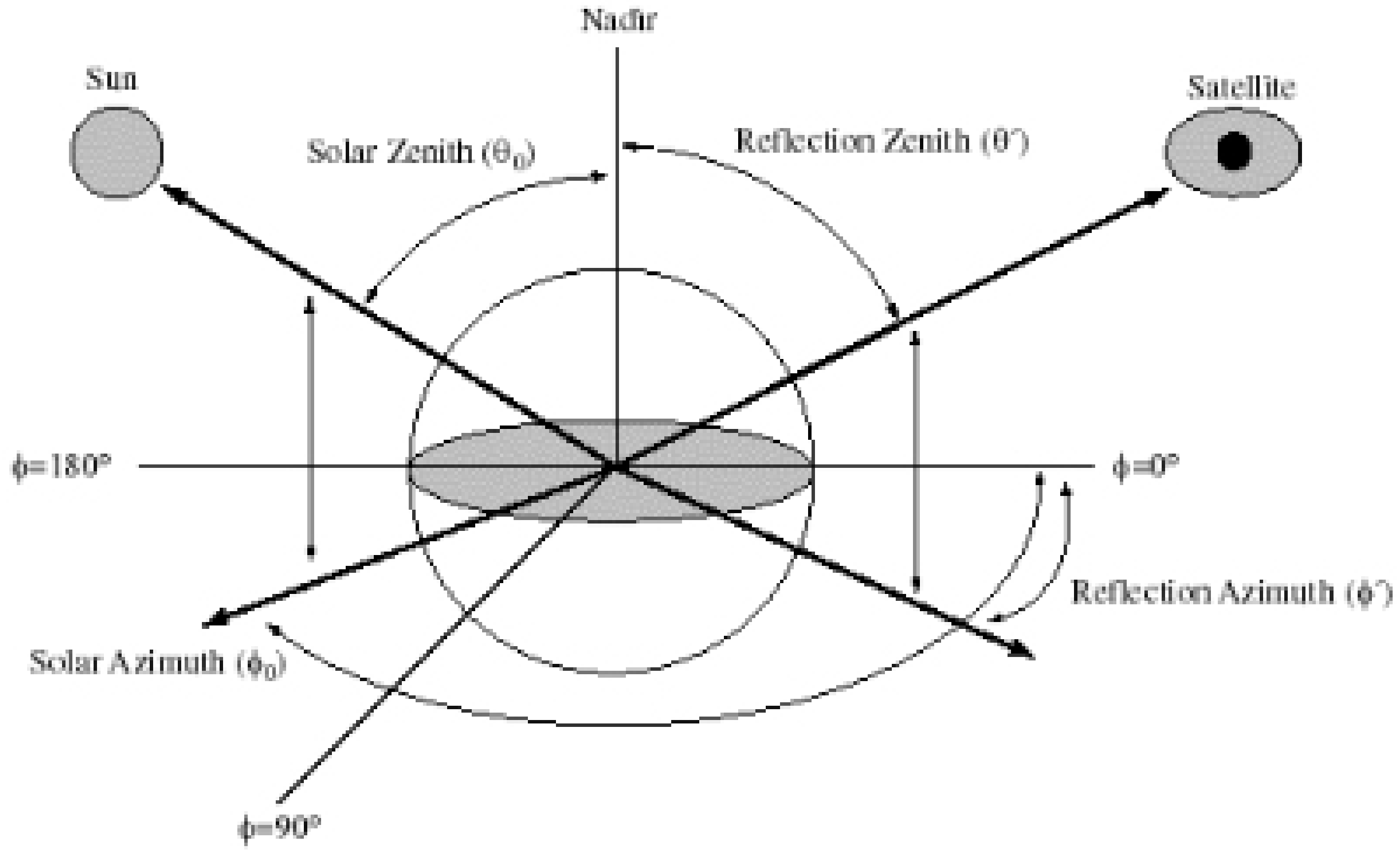
Visible, Near-Infrared and Shortwave Infrared Remote Sensing

Radiation Geometry

Just a quick review of some geometric factors applicable to remote sensing. When dealing with satellites we have to consider both plane and spherical geometry. In case you forgot, there are 2π radians in a circle (360°) which makes each radian equal to approximately 57.3° Additionally the steradian (ster or st) is a solid angle. It is a measure of Area/Radius^2 and in case you were wondering there are 4π steradians in a sphere.

The figure below illustrates the general case of source-target-sensor geometry. As you can see in remote sensing it is necessary to consider the angle from nadir of the source and the sensor as well as the directions the source and sensor are pointing. One additional term you will come across is Solar Elevation, which is the complement of the Solar Zenith Angle (SZA). Many high to moderate resolution sensors are primarily what we call nadir viewing, this means that they look essentially straight down and have what is termed a narrow field-of-view (FOV), that is to say that they only look over a few degrees from side to side. In this case, the problem is much simplified and only the Solar Zenith Angle and Azimuth are of interest.



One thing to be aware of is that it is rare that a system looks exactly perpendicular to the ground surface. In this case the actual area on the ground illuminating the sensor (As) is related to the area perpendicular to the sensor (Ap) in the following manner:

$$A_p = A_s \cos(\theta')$$

Radiation Quantities

Radiant Flux or Radiant Power (Φ, P^*) - time rate of flow of radiant energy. The unit of radiant flux is a watt (Joule sec^{-1}). Just to be complete 1 Joule = 1 N m = 1 kg m^2 sec^{-2}.

Irradiance (E, M, H) - radiation incident upon a surface (W m^{-2})

Emmittance and/or *Exitance* - radiation emitted from a surface (W m^{-2})

Intensity (I^*, J) - radiant flux emitted into a cone in a given direction divided by the solid angle of that cone (it assumes the radiation is emitted from a point source). The units are W ster^{-1}.

Radiance (L^*, N) - radiant flux per unit area per unit solid angle. The units are W m^{-2} ster^{-1}.

In remote sensing, the energy source is usually considered to be a point source. If an instrument's field-of-view (FOV) is filled that is termed an extended source.

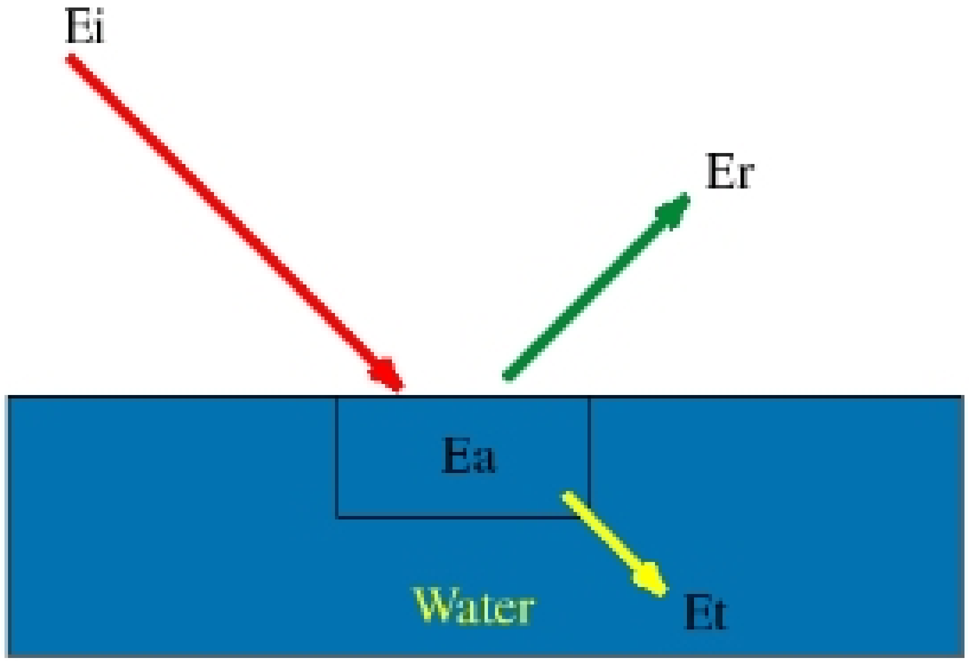
Wavelength Region of Interest

Generally speaking, the visible portion (VIS) of the spectrum runs from 0.4 to 0.7 micrometers. 0.4 to 0.5 ∝m is considered the blue, 0.5 to 0.6 ∝m is considered the green and 0.6 to 0.7 ∝m is considered the red. Obviously, there is a constant gradation of perceived color with wavelength. The near-infrared (NIR) is then 0.7 to 1.3 ∝m while the shortwave infrared (SWIR) runs from approximately 1.3 to 3.0 ∝m. Sometimes the visible and near-infrared are considered together to be theVNIR.

Basic Theory

When a photon is incident on any earth surface feature there are three possible interactions. Energy can be absorbed, transmitted, or reflected. And because energy must be conserved these three interactions must sum to unity.

$$E_i(\lambda) = E_a(\lambda) + E_t(\lambda) + E_r(\lambda) = 1$$



The proportions of the incident energy that is absorbed, transmitted and reflected varies greatly from one substance to another and from one wavelength to another (hence the dependency on wavelength in the equation above). The following figure illustrates the transmission, absorption and reflection of a leaf. As you can see the leaf appears green because it reflects slightly more light in the green portion of the visible spectrum than at other visible wavelengths.

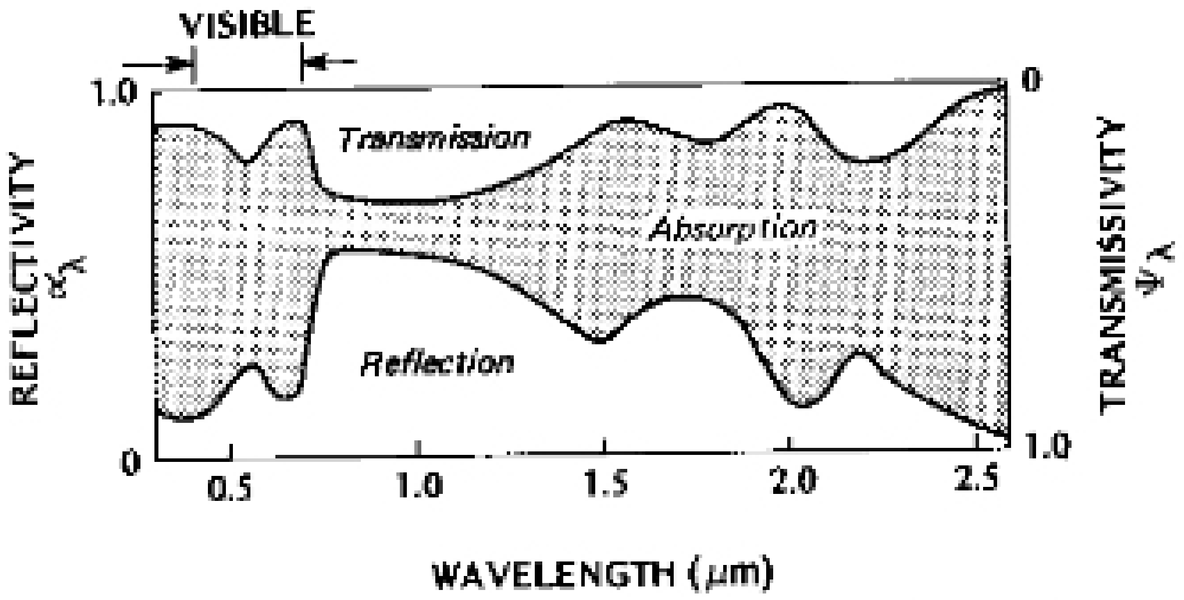


Figure 4.4 Idealized relation between wavelength and the reflectivity (α), transmissivity (Ψ) and absorptivity (ξ) of a green leaf (after Monteith, 1965a).

Spectral Reflectance

In remote sensing we are most interested in the reflectance from an object and this represents the component of the incident radiation that is detected by the instrument. In general terms, reflectance is simply the ratio of the reflected energy (E_r) to that incident upon the surface (E_i). For our purposes, reflectance is more narrowly defined. We are interested in *the spectral reflectance* of an object, that is to say the reflectance measured at a particular wavelength (λ). In addition both the incident and reflected radiation are measured plane parallel to the surface. Thus more concisely spectral reflectance is defined as:

$$\rho_\lambda = \frac{\rho_r(\lambda)}{\rho_i(\lambda)}$$

Another commonly used term is albedo. Albedo (α) is simply the ratio of reflected to incident energy measured in a surface-parallel plane and integrated over the entire spectrum or a portion thereof.

$$\alpha = \frac{\rho_r(\lambda)d\lambda}{\rho_i(\lambda)d\lambda}$$