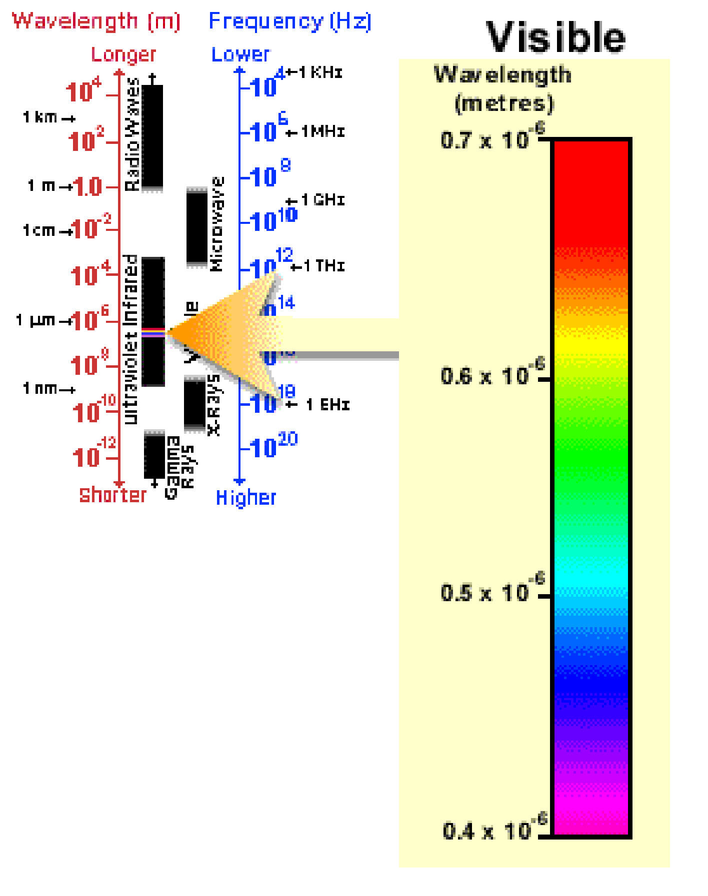
The Electromagnetic Spectrum

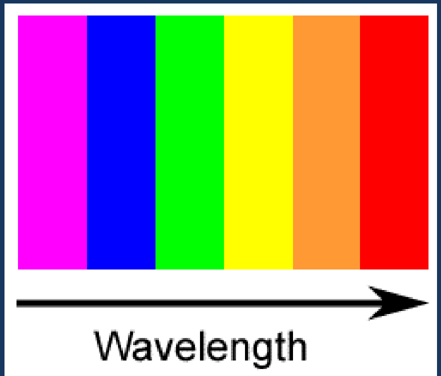
The Electromagnetic Spectrum *ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.*

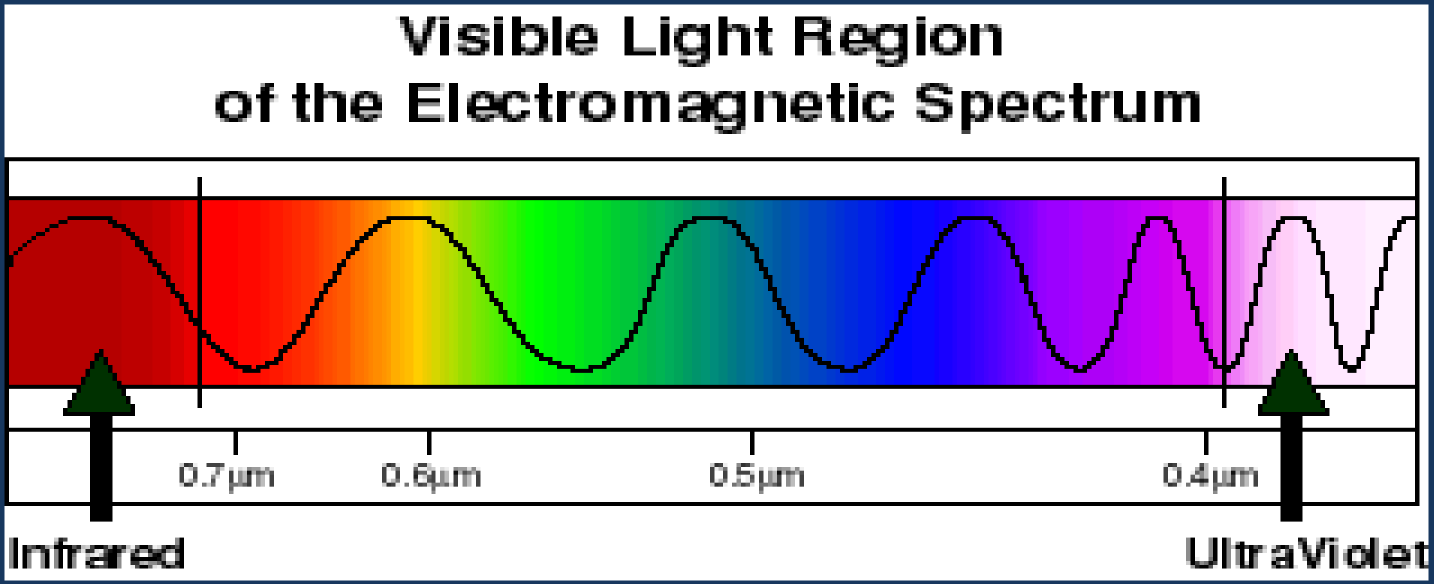
⇒ *The light which our eyes can detect is part of the visible spectrum (very narrow)*

⇒ *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*

⇒ *The visible wavelengths cover a range from approximately* ***0.4 to 0.7 µm*** *(violet to red)*



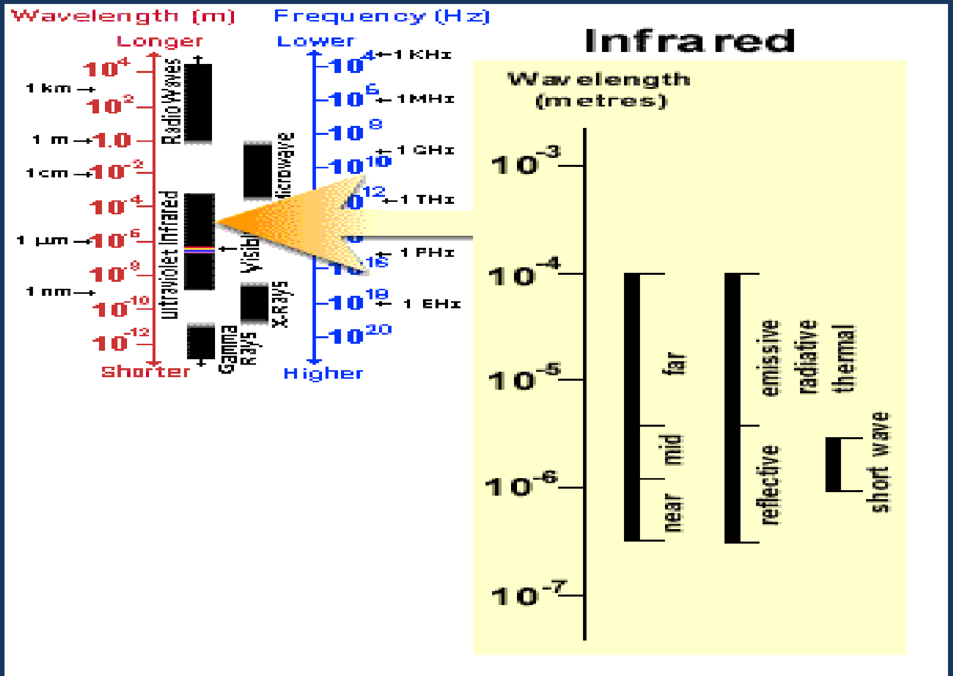




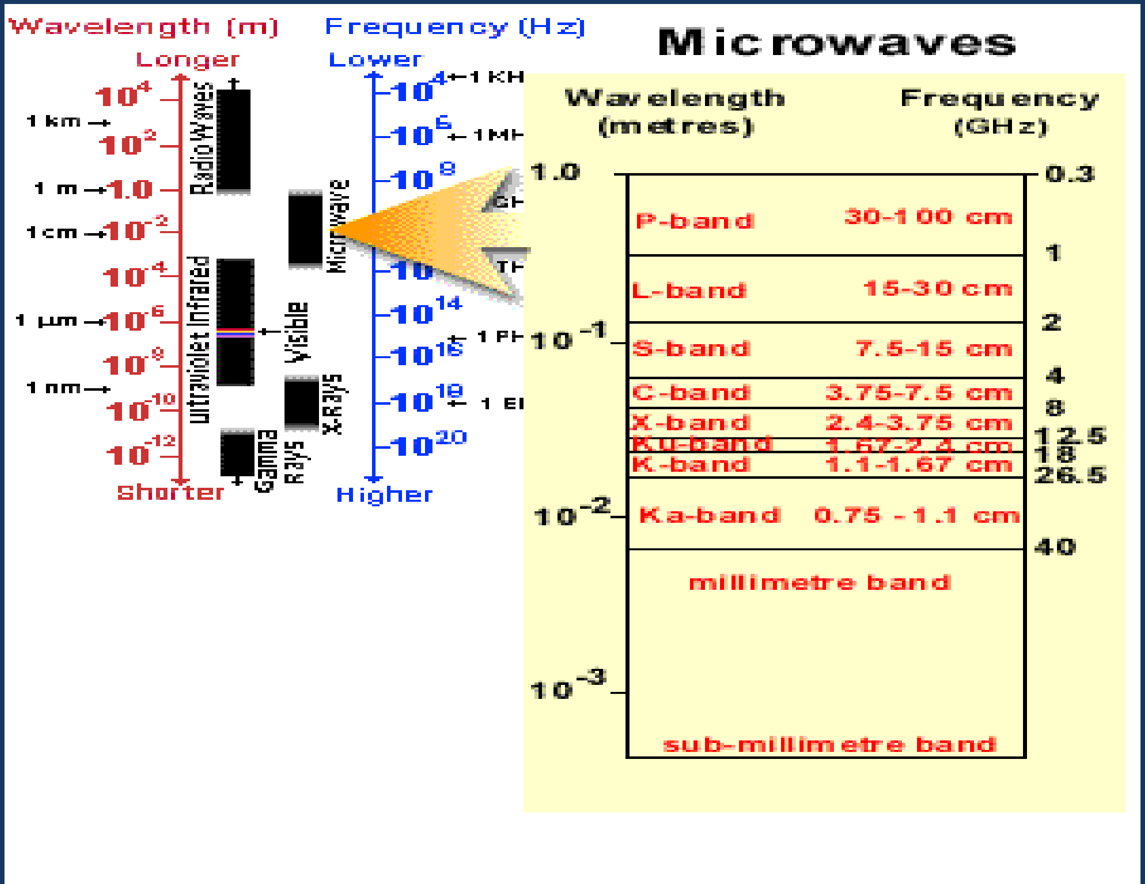
Visible light waves are the only electromagnetic waves we can see. We see these waves as the colors of the rainbow. Each color has a different wavelength. Red has the longest wavelength and violet has the shortest wavelength. When all the waves are seen together, they make white light

The next portion of the spectrum of interest is the **Infrared (IR)** region which covers the wavelength range from approximately **0.7 μm to 14 μm** - more than 100 times as wide as the visible portion!

The IR region can be divided into two based on their radiation properties - the reflected IR, and the emitted or thermal IR. Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 μm to 3.0 μm. The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 μm to 14 μm.



The portion of the spectrum of more recent interest to remote sensing is the **microwave** region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.



There are three forms of interaction that can take place when energy strikes, or is incident (I) upon the surface:

- Absorption (A) : radiation is absorbed into the target
- Transmission (T) : radiation passes through a target
- Reflection (R) : radiation "bounces" off the target and is redirected

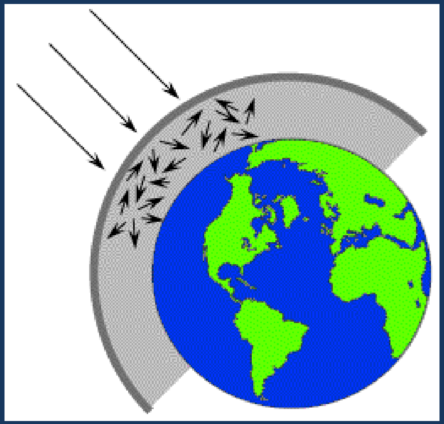
The proportions of each interaction will depend on the wavelength of the energy and the material and condition of the feature.

Interactions with the Atmosphere

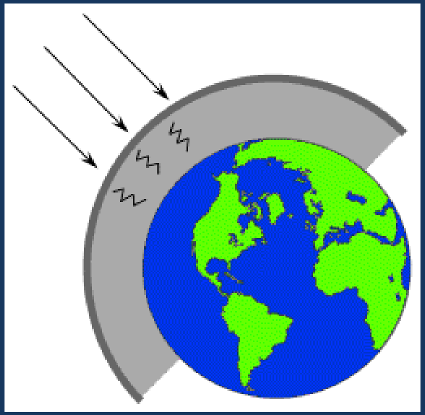
⇒ Before radiation used for remote sensing reaches the Earth's surface ***it has to travel through*** some distance of the Earth's atmosphere

⇒ ***Particles and gases*** in the atmosphere can affect the incoming light and radiation:

A) Scattering



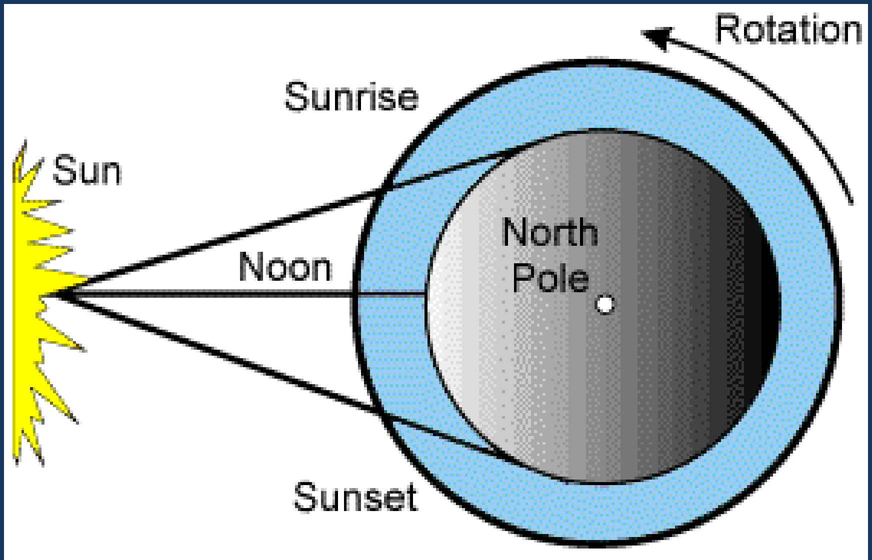
B) Absorption



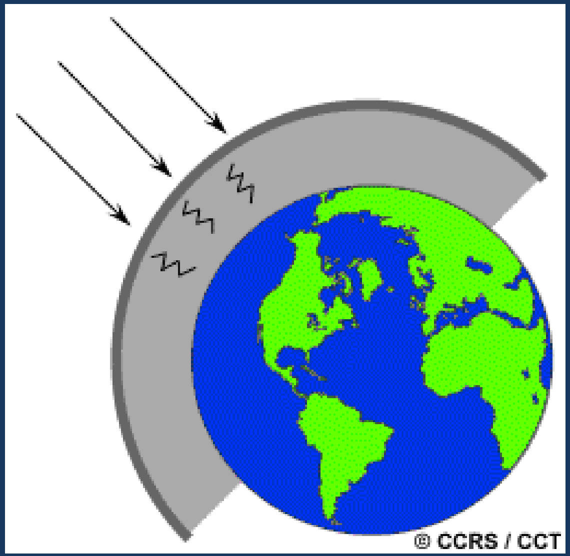
⇒ ***Scattering*** occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path

⇒ ***Absorption*** 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

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.



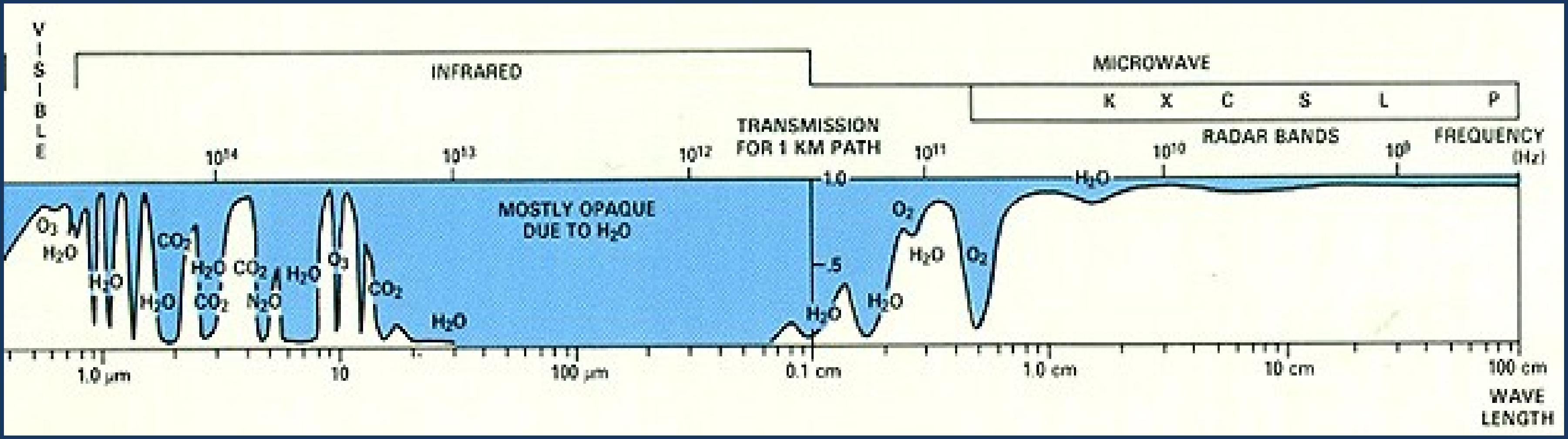
Absorption

The another 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.

Atmospheric Windows

⇒ Gases absorb electromagnetic energy in very specific regions of the spectrum → they influence where (in the spectrum) we can "look" for remote sensing purposes.

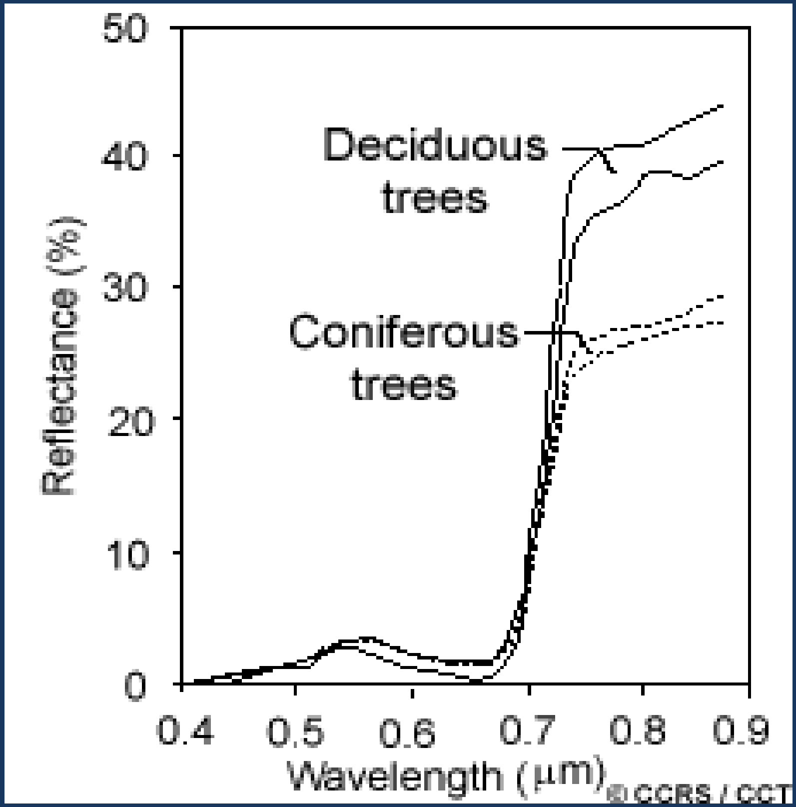
⇒ Those areas of the spectrum which are not influenced by atmospheric absorption and thus, are useful to remote sensors, are called ***atmospheric windows.***



For any given material, the amount of solar radiation that is reflected (absorbed, transmitted) will vary with wavelength.

This allows us to separate distinct cover types based on their response values for a given wavelength. When we plot the response characteristics of a certain cover type against wavelength, we define what is termed the spectral signature of that cover.

The graph of the spectral reflectance of an object as a function of wavelength is termed as *spectral reflectance curve*.

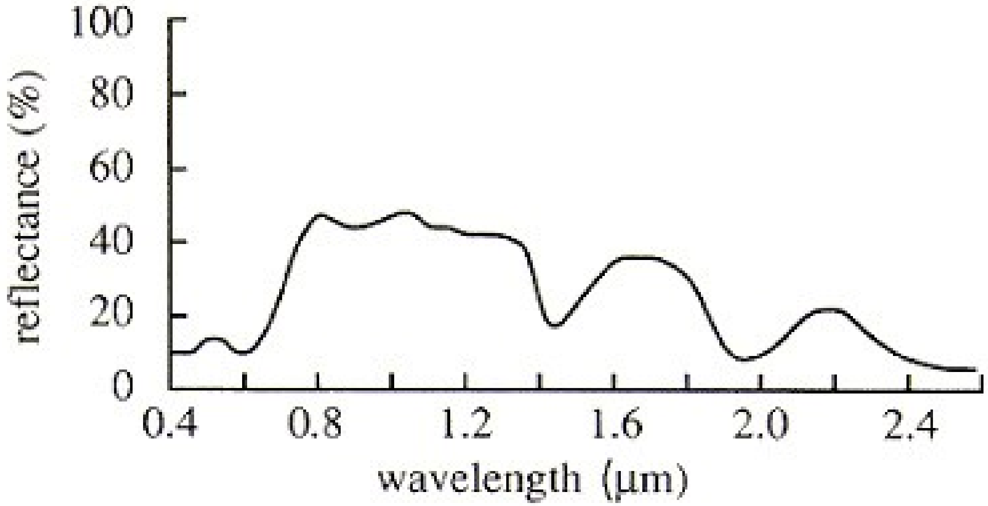


Usage of Spectral Reflectance Curve (SRC)

The configuration of SRC gives idea about the spectral characteristics of an object and helps to determine the suitable wavelength regions in which remote sensing data has to be acquired for a particular application.

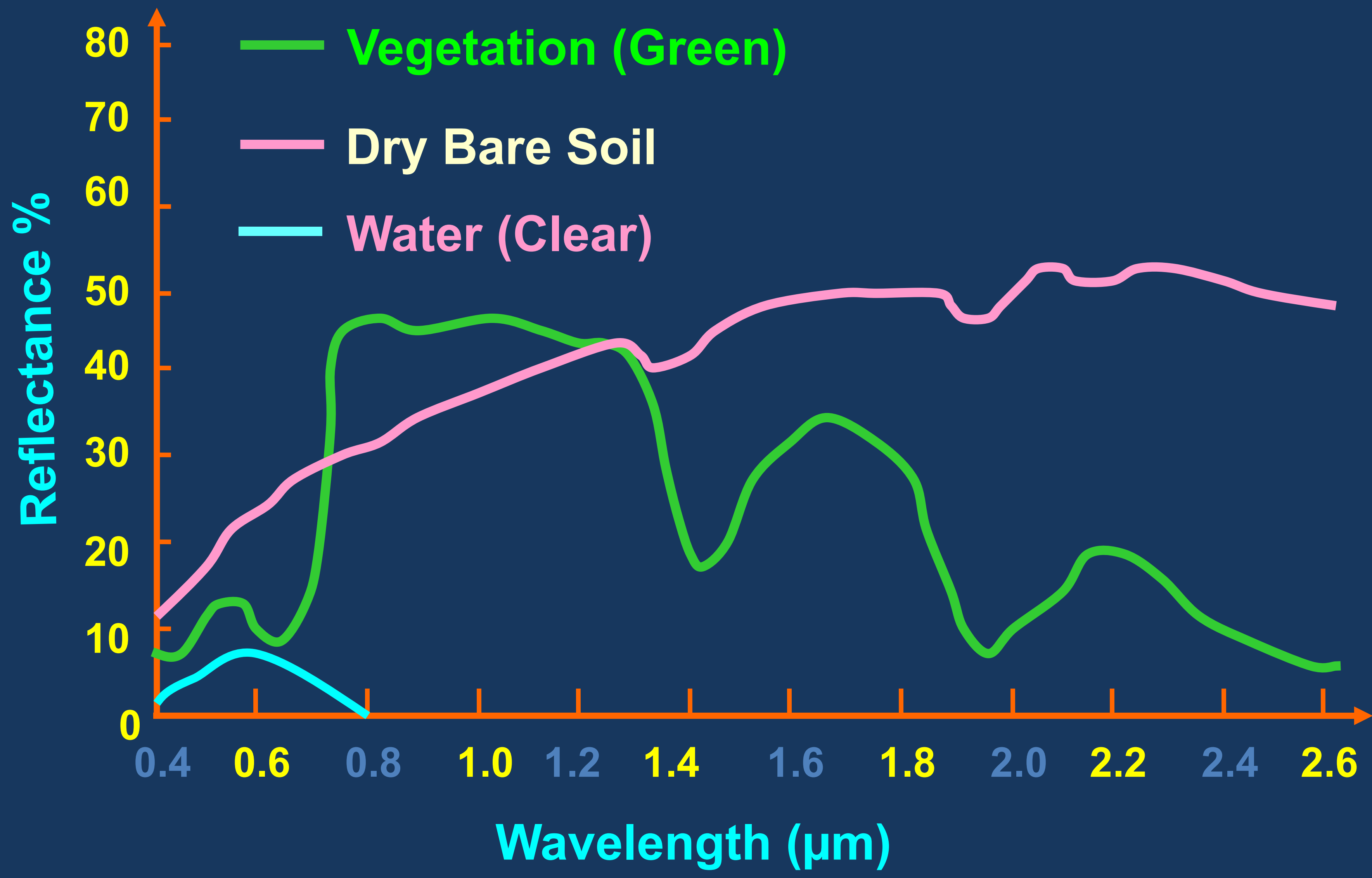
Spectral Reflectance

Reflectance with respect to wavelength is called spectral reflectance as shown for a vegetation example



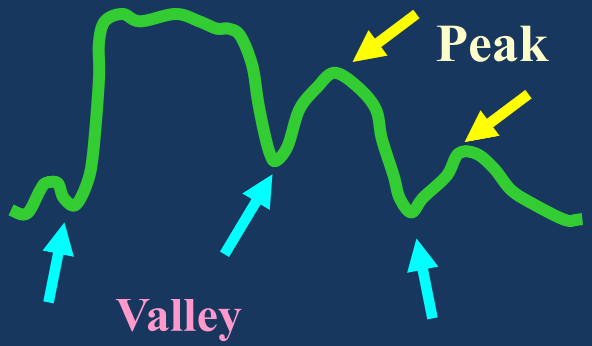
Spectral Reflectance of Vegetation

Spectral Reflectance

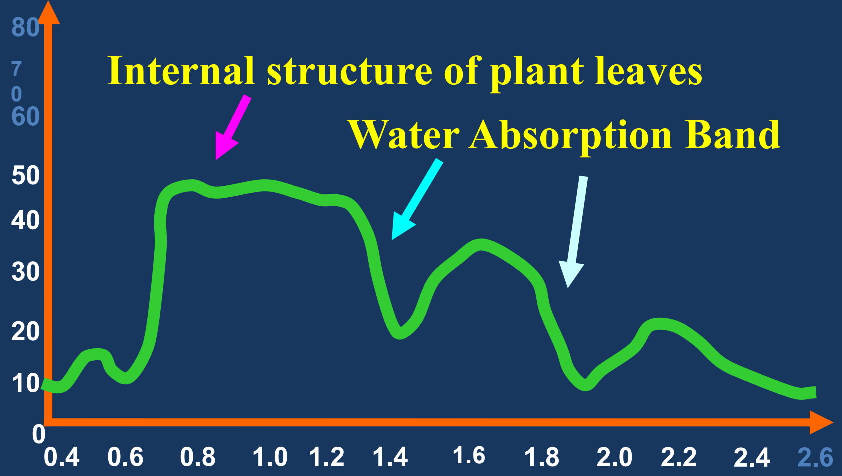


The lines in the above figure represent the *average* reflectance curves complied by measuring a large sample features. Though, the reflectance of individual features will vary considerably above and below the average, these curves demonstrate some fundamental points concerning spectral reflectance.

Spectral reflectance curves for healthy vegetation almost always manifest the "*Peak and Valley*" configuration.



The valleys in the visible portion of the spectrum are caused by the pigment in plant leaves. Chlorophyll strongly absorbs energy at 0.45 - 0.67 µm and called as chlorophyll absorption bands. Hence, we see healthy vegetation as green in color because of the very high absorption of blue and red wavelengths but strong reflectance of green wavelength. Whereas if the plant is subjected to some stress, decreases / ceases chlorophyll production it will result in the less chlorophyll absorption in the blue and red wavelengths and often results in the increase of red reflectance to the point that leave turn yellow (Green + Red).

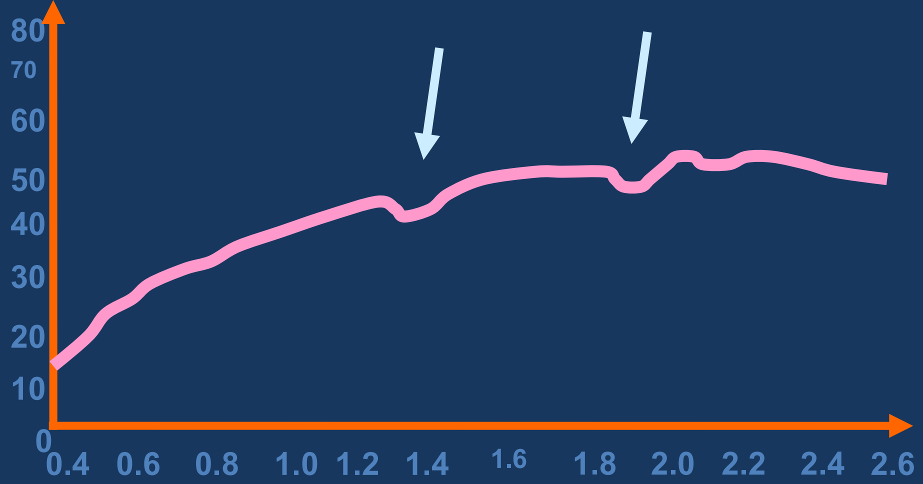


As we move from visible to near IR portion, the reflectance of healthy vegetation increases tremendously. In between ***0.7 - 1.3 μm***, a leaf reflects nearly ***40 - 50 %*** energy incident upon it. Most of remaining energy is transmitted whereas absorption is less than ***5%*** .

Reflectance in this wavelength region is induced by the internal structure of plant leaves. Because, internal structure of leaves is highly variable between different plant species, reflectance in this region permits us to discriminate different plant species. Even if they look similar in visible region. *Plant stresses alter the reflectance in this region*, hence this region is also used for detecting the vegetation stress.

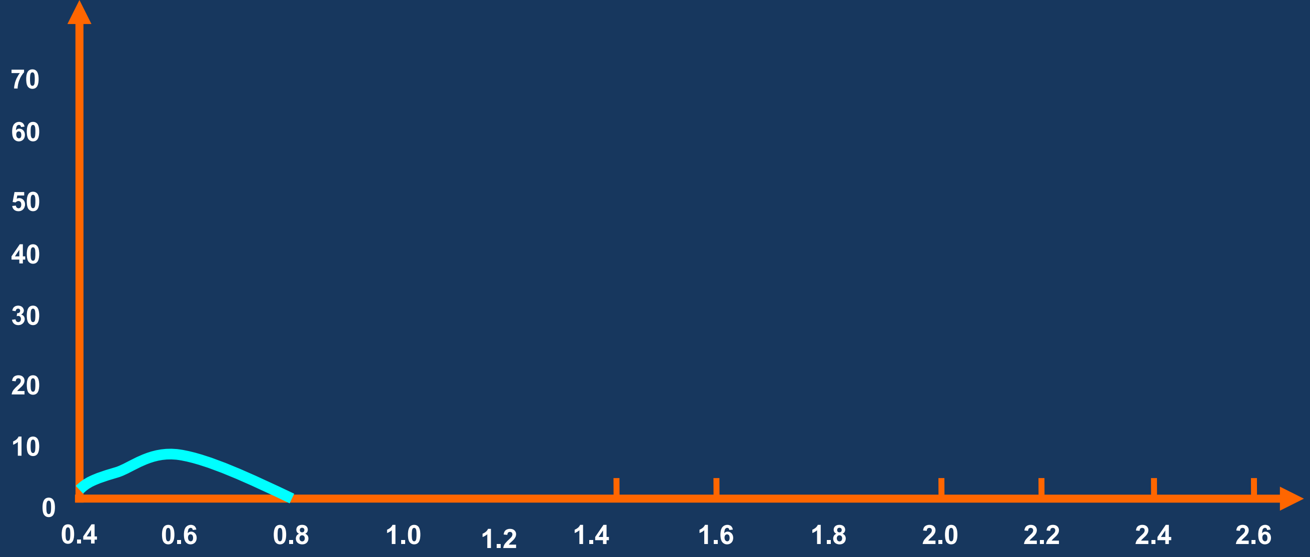
Beyond 1.3 *μm* energy incident upon vegetation is mainly absorbed or reflected with little or no transmittance.

Dips in reflectance occur at *1.4, 1.9, 2.7 μm* because water in the leaves strongly absorbs at these wavelengths *(Water Absorption Band).*



Soil curve shows less peak and valley reflection pattern. That is factors that influence soil reflectance act less specific spectral bands. Factors that influence soil reflectance are : 1. *Moisture content*, *2. Soil texture*, *(Proportion of Sand, Silt, and Clay)* *3. Surface roughness*, *4. Presence of iron oxide and organic matter.*

Presence of moisture in soil decreases reflectance. As with vegetation this effect is more in the water absorption bands (*1.4, 1.9, 2.7 μm*). Soil moisture is related to soil texture, coarse sandy soils are usually well drained and less in moisture content and have relatively high reflectance. In the absence of water, this tendency reverses coarse grained soil appears darker than fine grained soil.. Surface roughness and organic matter can also reduce soil reflectance. In addition, presence e of iron oxide will also significantly decrease soil reflectance.



Distinct characteristic of water is the energy absorption at near IR wavelengths and beyond. Water absorbs in these wavelengths whether it is contained in lake / streams or in vegetation or soil.

Hence, delineating water bodies is done more easily in near IR wavelengths because of these absorption property. At the same time, reflectance from the water body depends on the interaction with the water's surface (specular reflection), with material suspended in water, or with the bottom of the water body.

Thus, reflectance properties of a water body are a function of not only the water but also the material in the water.