BHARATHIDASAN UNIVERSITY
Tiruchirappalli - 620 024
Tamil Nadu, India

Programme : 6 year Integrated M.Tech in Geological Technology and Geoinformatics

Course title : Principles of Remote Sensing
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UNIT – II

Electro Magnetic Radiation (EMR)

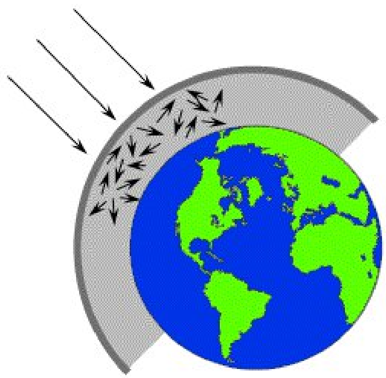
D.Ramesh, Ph.D
Associate Professor, Dept. of Remote Sensing

Interactions with the Atmosphere

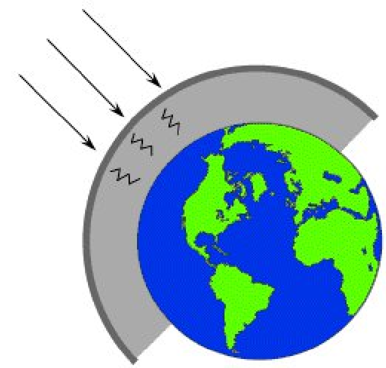
- **Before radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere**

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

A) Scattering



B) Absorption



Þ **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

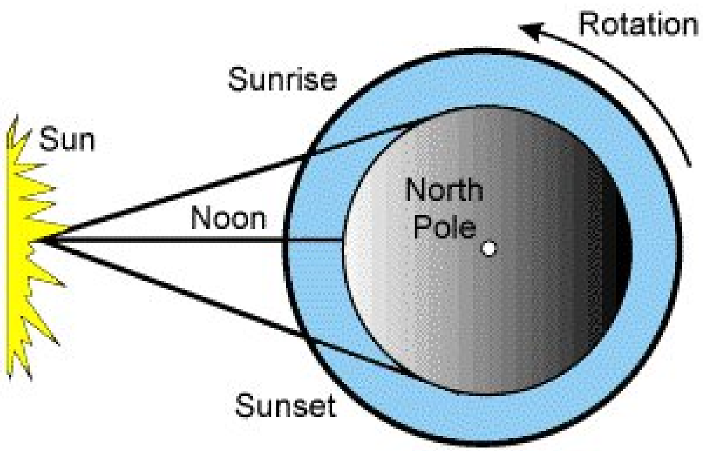
Þ **Absorption** causes molecules in the atmosphere to absorb energy at various wavelengths. Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation

Rayleigh scattering - when the 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.

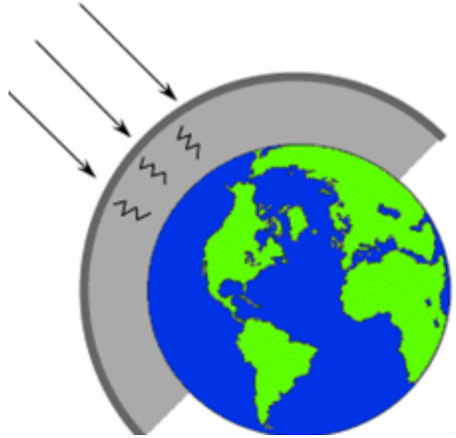
Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering.

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 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 = white light**).



Absorption

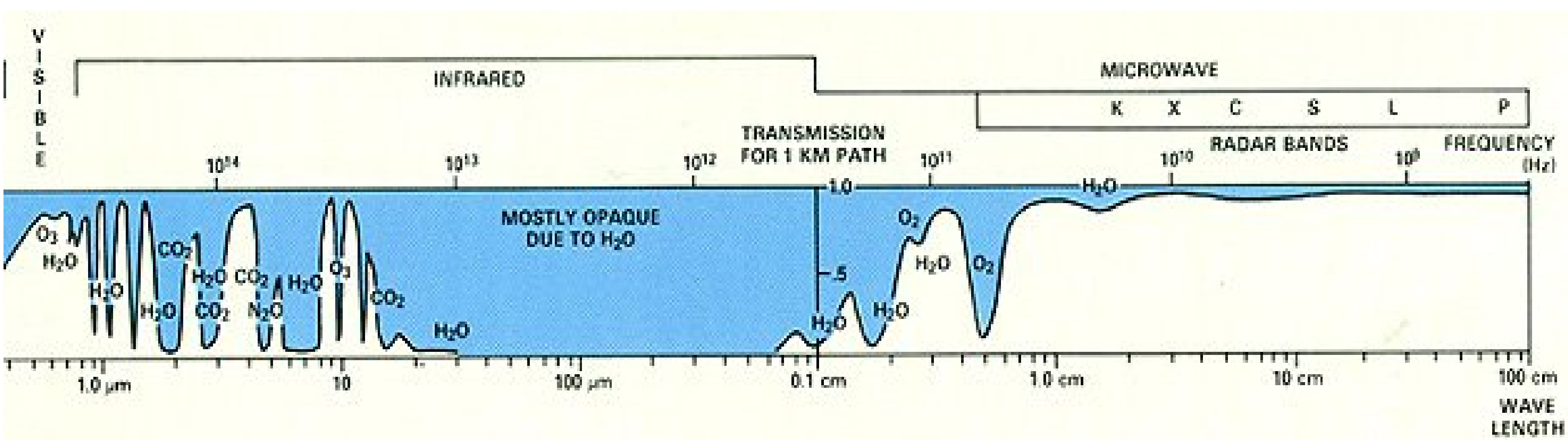
The another main mechanism at work when electromagnetic radiation interacts with the atmosphere.

In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths <u>Ozone, Carbon dioxide</u>, and <u>Water vapour</u> 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.**

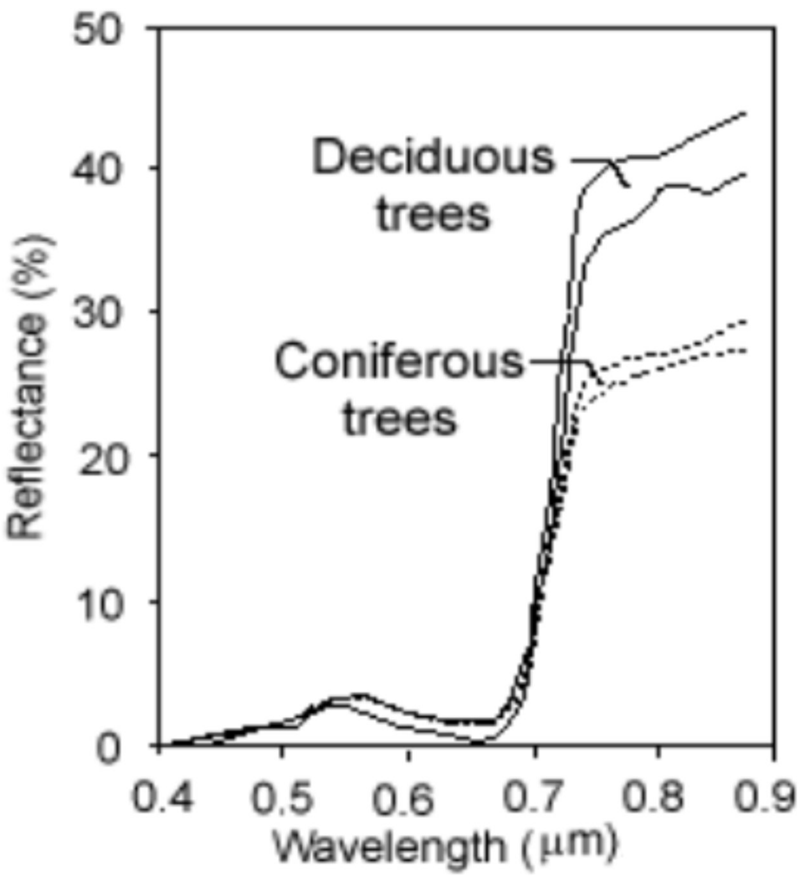


For any given material, the amount of solar radiation that is **reflected** / **absorbed** / **transmitted** will vary with the wavelength.

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**.

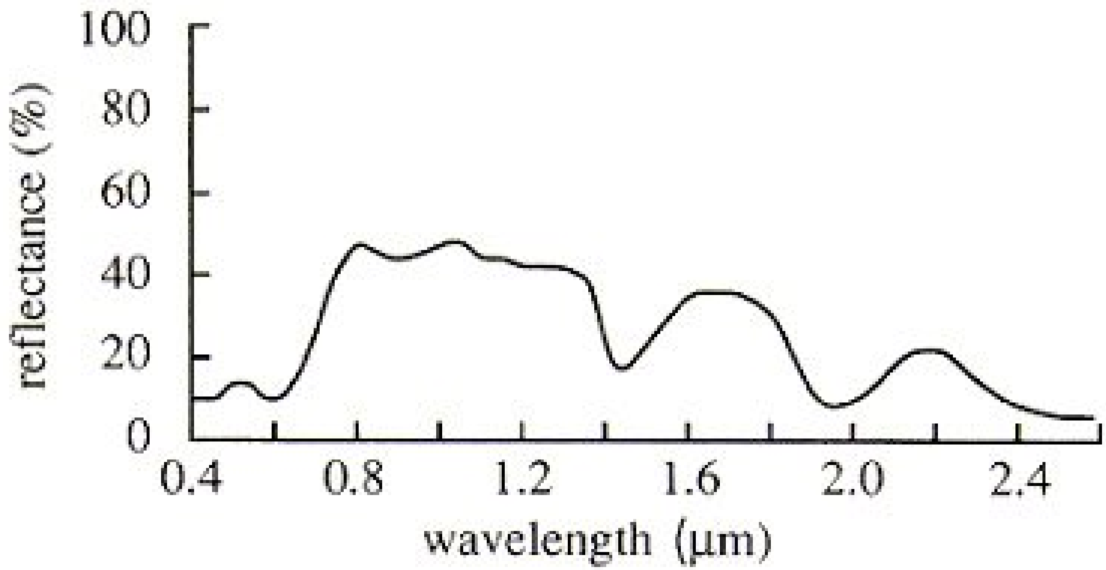


Usage of Spectral Reflectance Curve (SRC)

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.

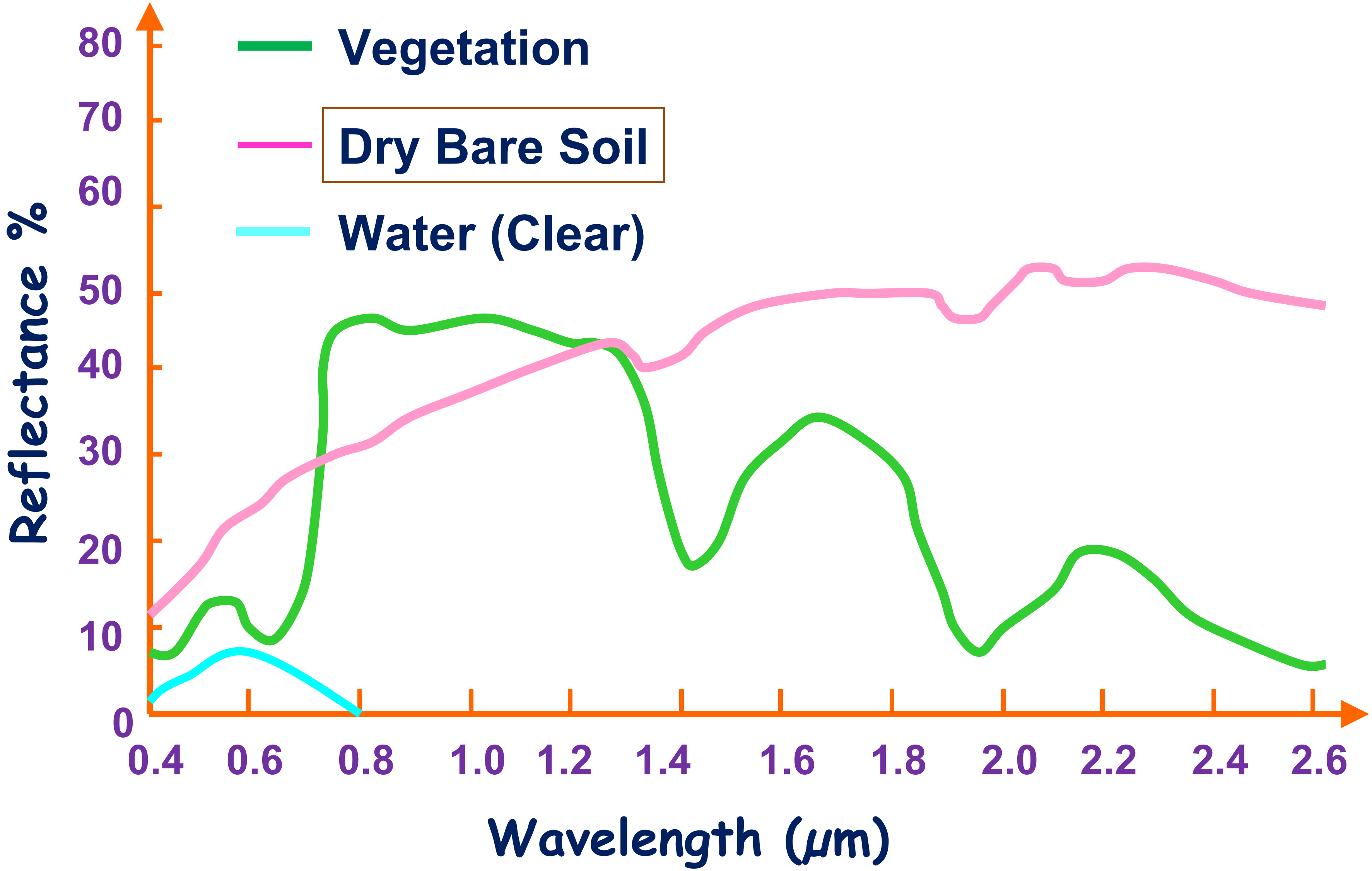
Spectral Reflectance

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



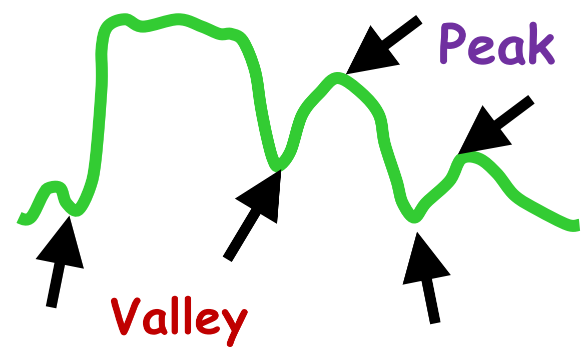
Spectral Reflectance of Vegetation

Spectral Reflectance

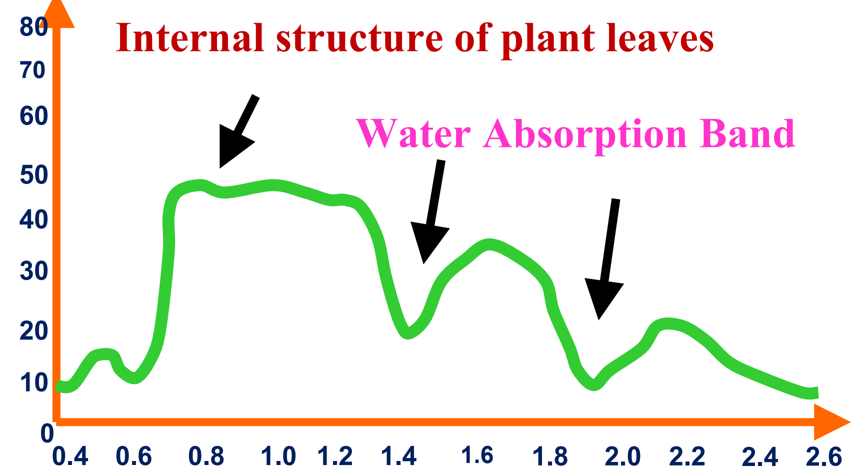


The lines in the figure represent the **average** reflectance curves complied by measuring a large sample features. Though, the reflectance of individual features will vary considerably above and below the average, these curves demonstrate some fundamental points concerning spectral reflectance. Spectral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

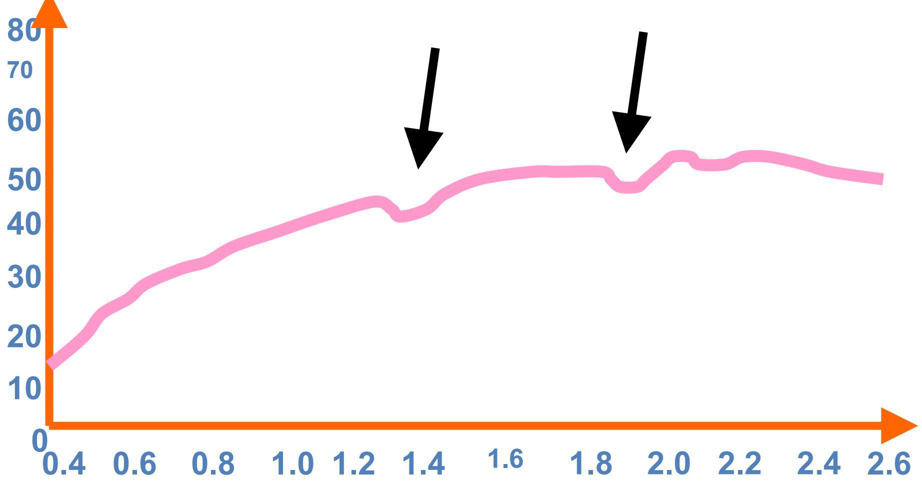


As we move from visible to near IR portion, the reflectance of healthy vegetation increases tremendously. In between 0.7 - 1.3 µm, a leaf reflects nearly 40 - 50 % energy incident upon it. Most of remaining energy is transmitted whereas absorption is less than 5% .

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.

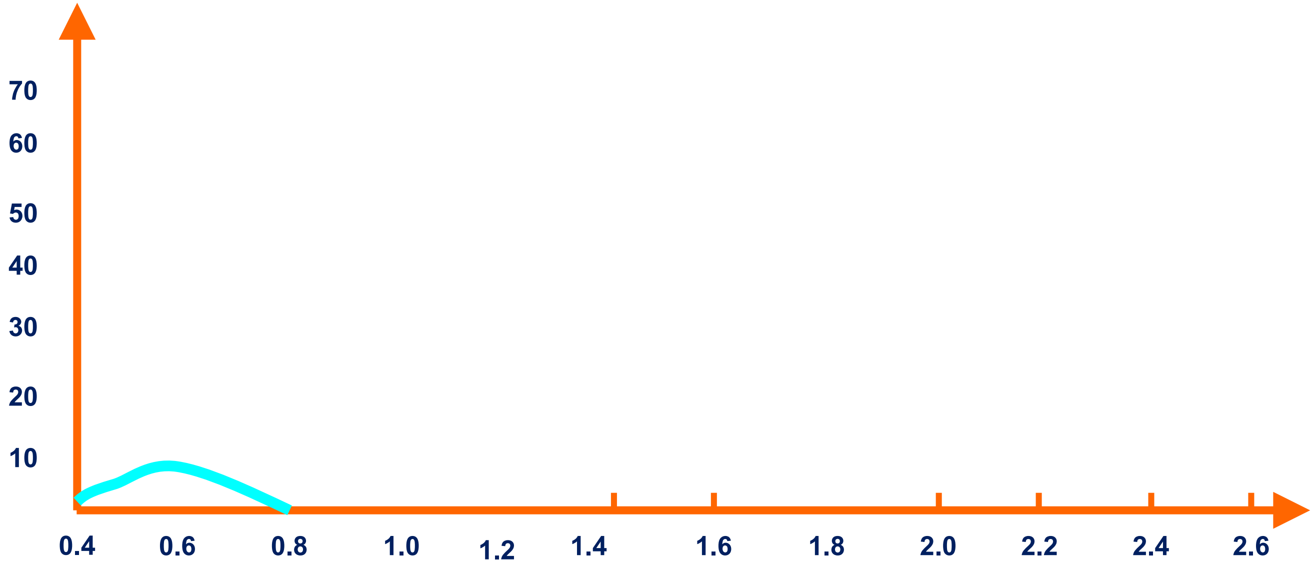
Dips in reflectance occur at 1.4, 1.9, 2.7 µm because water in the leaves strongly absorbs at these wavelengths (Water Absorption Band).



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 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.

Energy budgeting in Remote Sensing

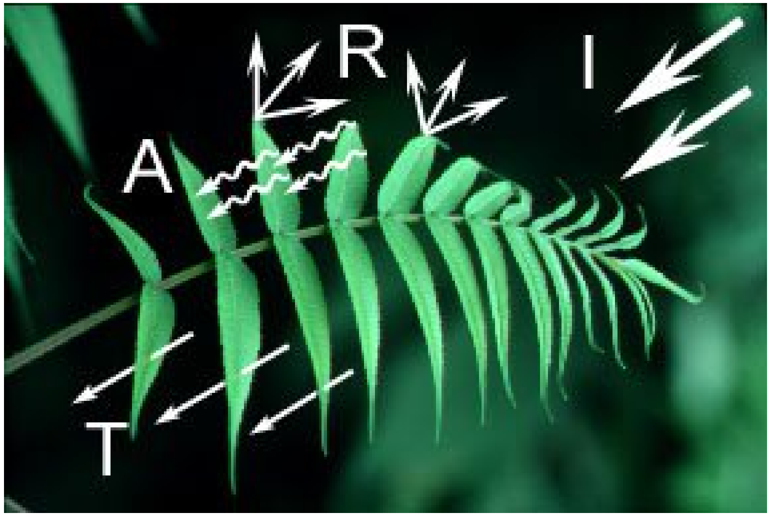
What happens to the electromagnetic energy when it encounters earth surface features?

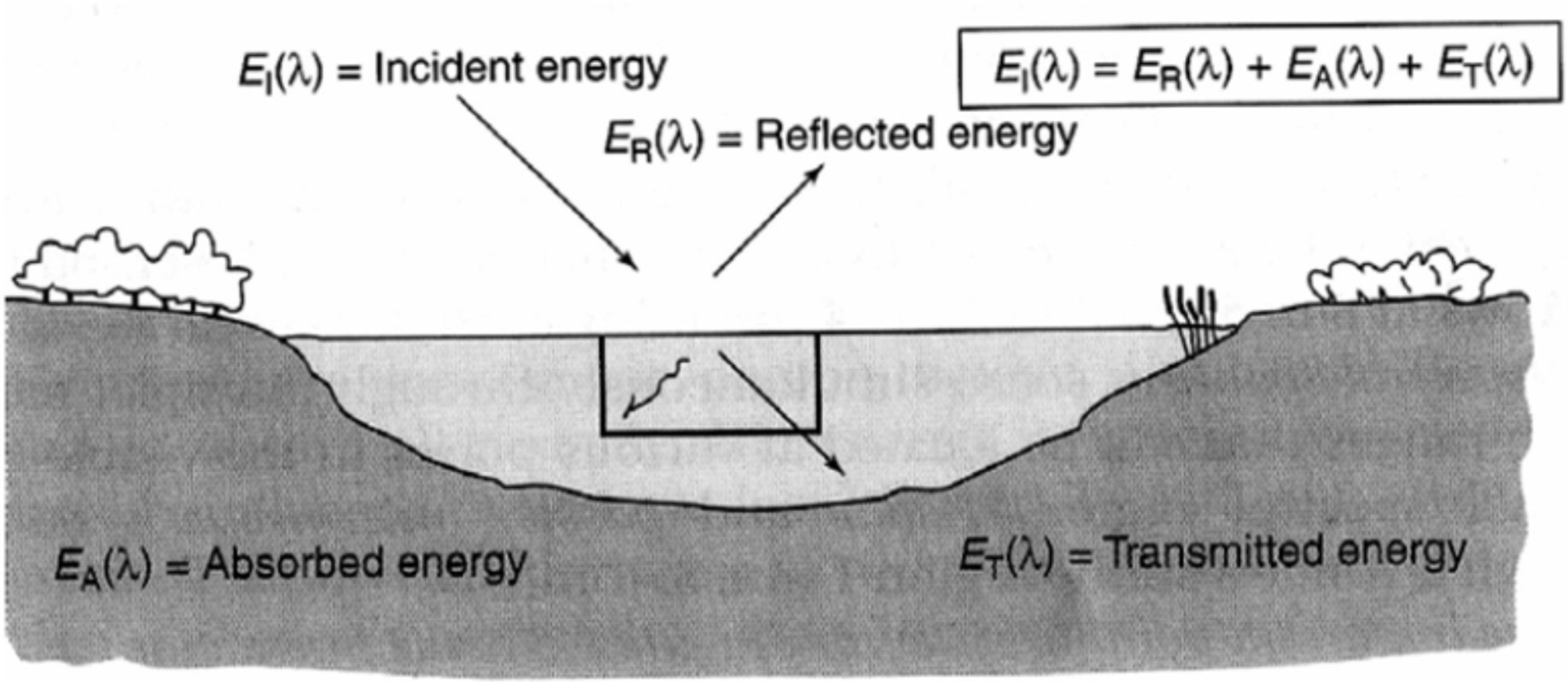
Three fundamental energy interactions with the features, are possible:

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.





Applying the principle of conservation of energy, we get

Incident energy = Reflected energy + Absorbed energy + Transmitted energy

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

All energy components are a function of the wavelength

Many remote sensing systems operate in the wavelength regions in which reflected energy predominates. Hence, the reflectance properties of earth features are very important.

So, let us restructure our energy balance equation in the following manner

Reflected energy = Incident energy – (absorbed energy + transmitted energy)

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

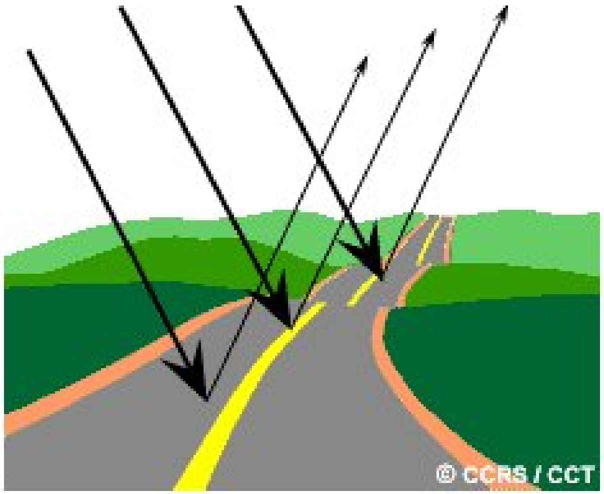
The reflectance characteristics of the earth surface features maybe quantified. This is measured as a function of wavelength and is called **spectral reflectance**.

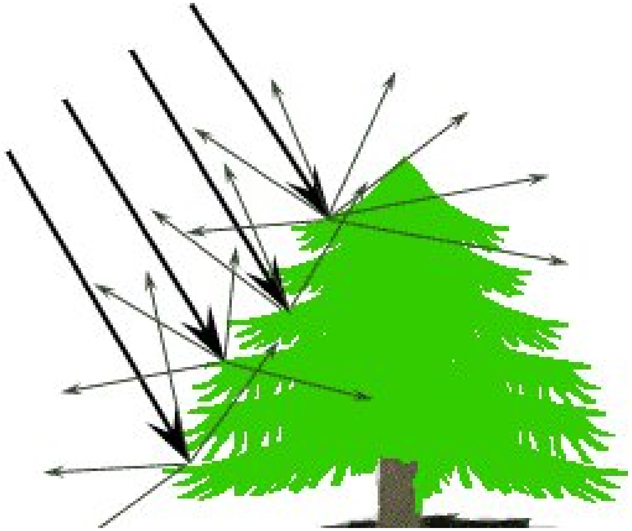
$$\rho_\lambda = E_R(\lambda) / E_i(\lambda) \times 100,$$

ρ_λ – expressed as a percentage

In remote sensing, we are most interested in measuring the radiation reflected from targets.

We refer to two types of reflection, which represent the two extreme ends of the way in which energy is reflected from a target: **Specular** reflection and Diffuse (Lambertian) reflection.

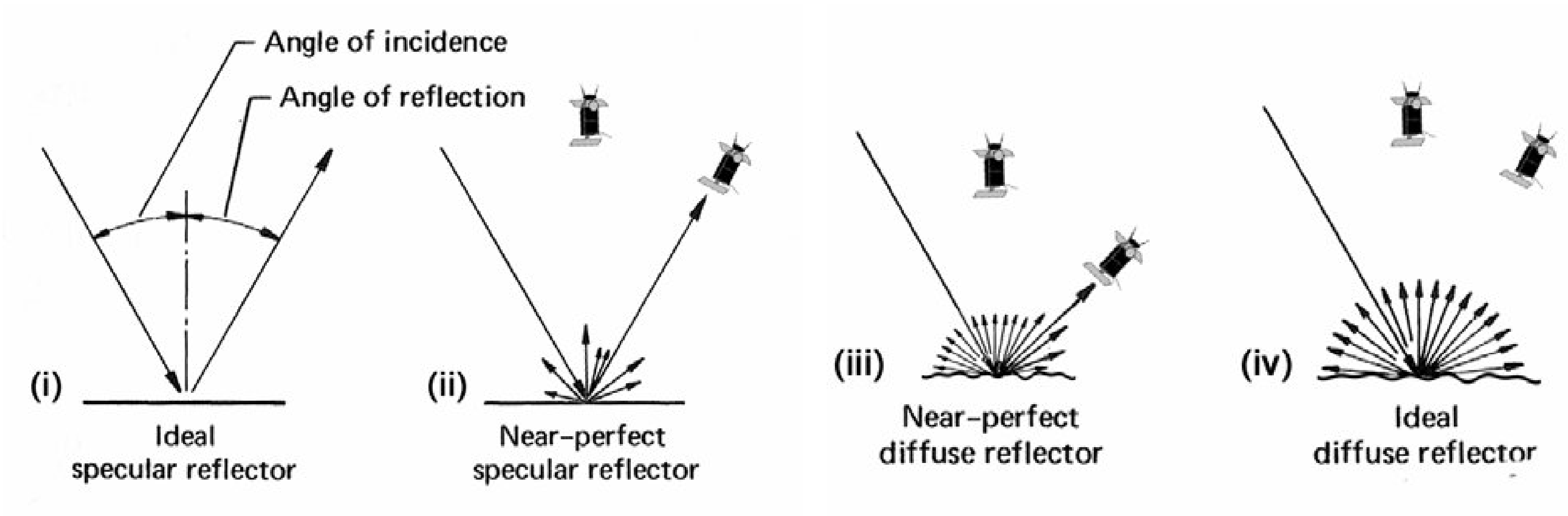




Most earth surfaces are neither perfectly specular nor diffuse reflectors.

We already know that the geometric manner in which an object reflects energy, varies. The variation is primarily a function of the surface roughness of the object relative to the wavelength.

Roughness depends on the relative wavelength in comparison to the surface of the objects.



Specular reflectors are flat relative to wavelength. These surfaces act like tiny mirrors on a large surface.

When the wavelength of the incident energy is large in comparison to the surface roughness or surface height variations, such a surface will act as a near-perfect specular reflector.

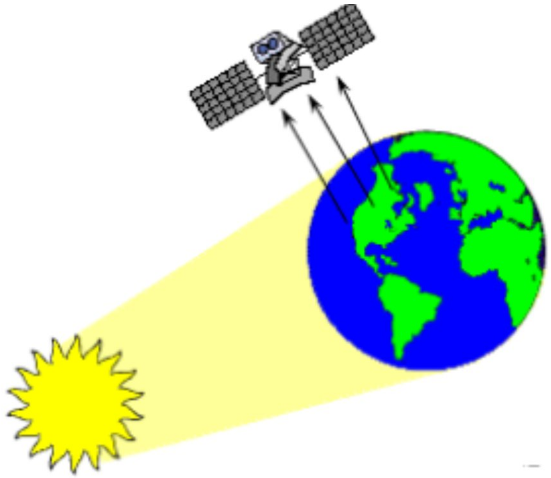
Diffuse reflectors are rough surfaces and reflect uniformly in all directions.

In contrast to specular reflection, here the wavelengths of the incident energy is much smaller than the surface height variations, that surface will act as a near-perfect diffuse reflector.

For example, in the relatively long wavelength microwave range, a sandy beach can appear smooth to incident energy and hence specular. But, in the visible portion of the spectrum, it appears rough and hence diffuse.

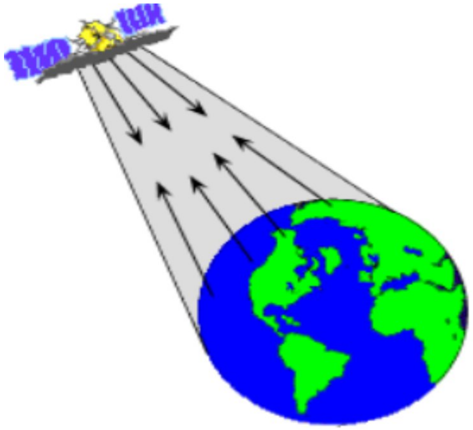
When the wavelength of incident energy is much smaller than the surface height variations or the particle sizes that make up a surface, the reflection from the surface is diffuse.

For visible and infrared (IR) waves, most features are diffuse reflectors.



The sun provides a very convenient source of energy for remote sensing. The sun's energy is either **reflected**, as it is for visible wavelengths, or absorbed and then **reemitted**, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called **passive sensors**.

Passive sensors can only be used to detect energy when the naturally occurring energy is available. For all reflected energy, this can only take place during the time when the sun is illuminating the Earth. There is no reflected energy available from the sun at night. Energy that is naturally emitted (such as thermal infrared) can be detected day or night, as long as the amount of energy is large enough to be recorded.



Active sensors, on the other hand, provide their own energy source for illumination.

The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor. Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season.