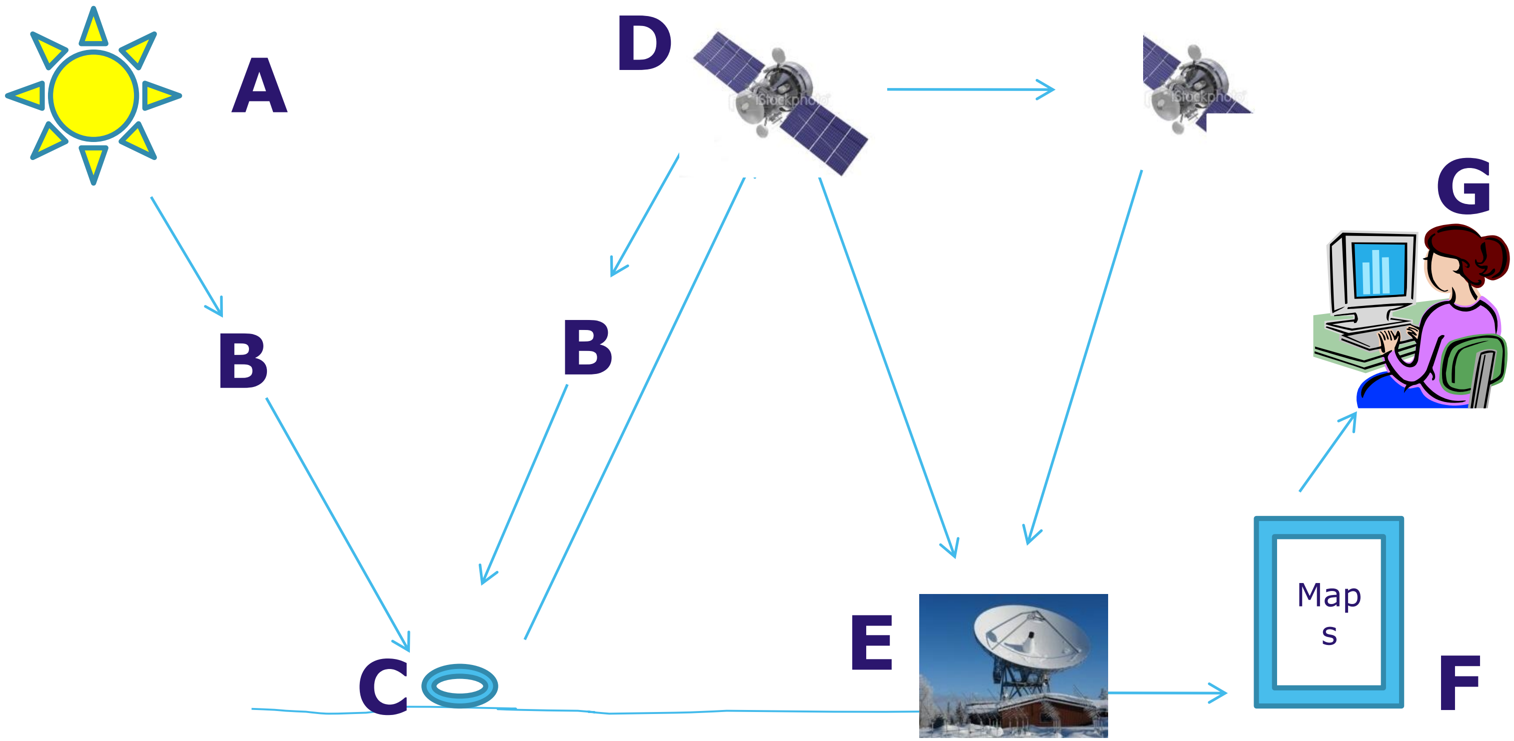
ELECTRO MEGNETIC RADIATION

M.H. Mohamed Rinos

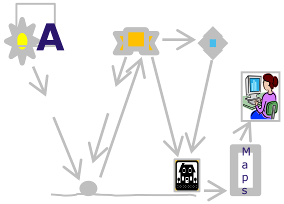
Remote sensing Process



A – Energy Source or Illumination
B – Radiation & the Atmosphere
C – Interaction with the Target
D- Recording of Energy by the Sensor
E – Transmission, Reception & Processing
F – Interpretation and Analysis
G - Applications

Electromagnetic Radiation

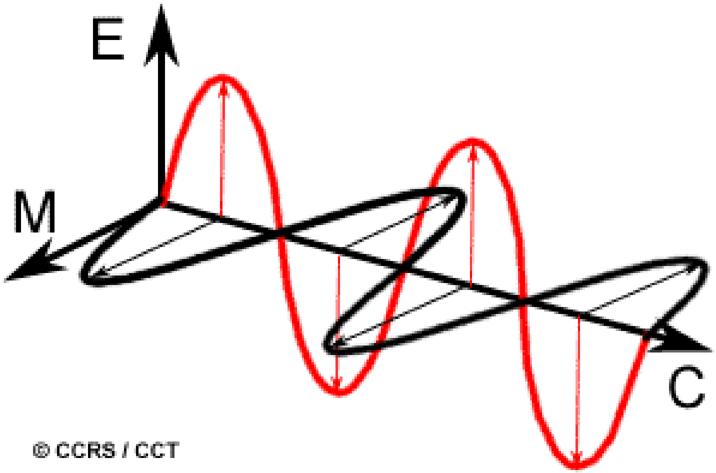
❖First requirement of RS is to have an energy source to illuminate the target.



❖This energy is in the form of electromagnetic radiation

❖ER Transverse waves without a medium. (They can travel through empty space)

❖They travel as vibrations in electrical and magnetic fields.



❖Have some magnetic(ability to travel through space) and some electrical (ability to push Particles) properties to them.

❖Speed of electromagnetic waves =300,000,000 meters/second (Takes light 8 minutes to move from the sun to earth {150 million miles} at this speed.)

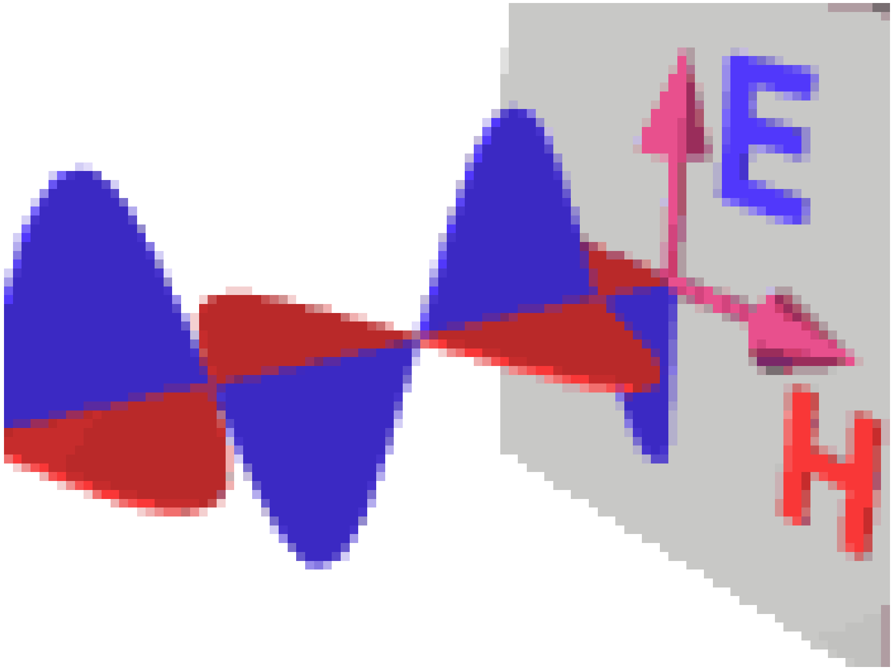
Electromagnetic Radiation

Electromagnetic radiation consists of an,

•Electrical field(E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling.

•Magnetic field (M) oriented at right angles to the electrical field.

•Both these fields travel at the speed of light (c).



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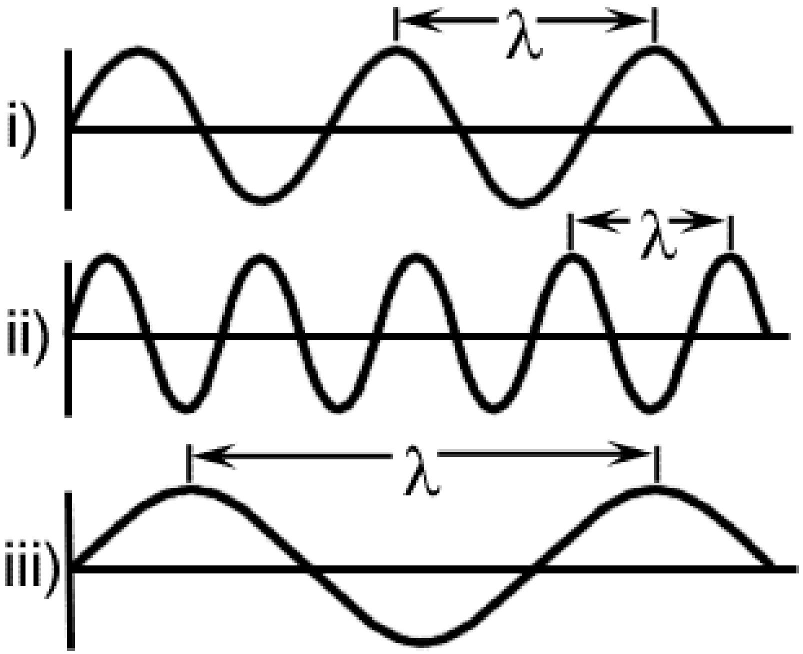
Electromagnetic Radiation

Important characteristics of electromagnetic radiation in RS



Wavelength

Wavelength is the length of one wave cycle which can be measured as the distance between successive wave crests.

Measured in meters or some factors of meters (nano meters, micrometers)

Frequency

Number of cycles of a wave passing a fixed point per unit of time.

Measured in hertz (Hz).

Electromagnetic Radiation

$$C = \lambda V$$

λ – wavelength (m)

V – Frequency (cycles per second , Hz)

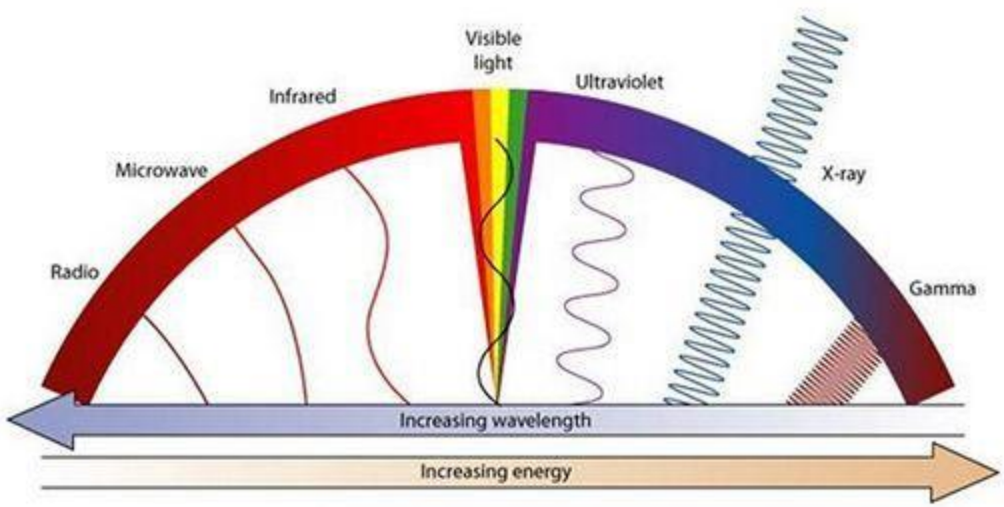
C – Speed of light ($3*10^8$ m/s)

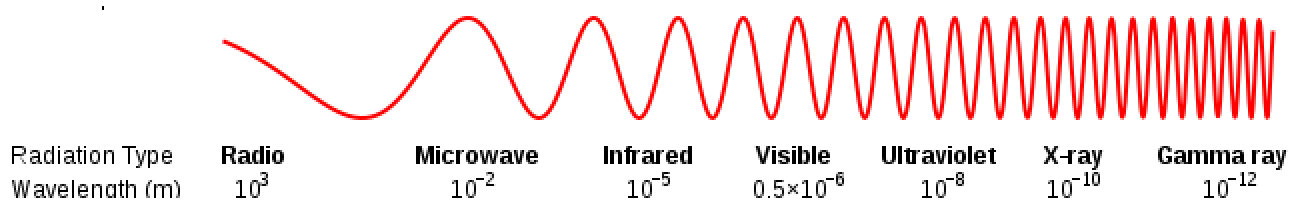
❖The wavelength & the frequency are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency.

❖Understanding the characteristics of electromagnetic radiation in terms of their <u>wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data</u>

Electromagnetic Spectrum

Electromagnetic Spectrum is ranges the all possible Frequencies in the electromagnetic radiation.

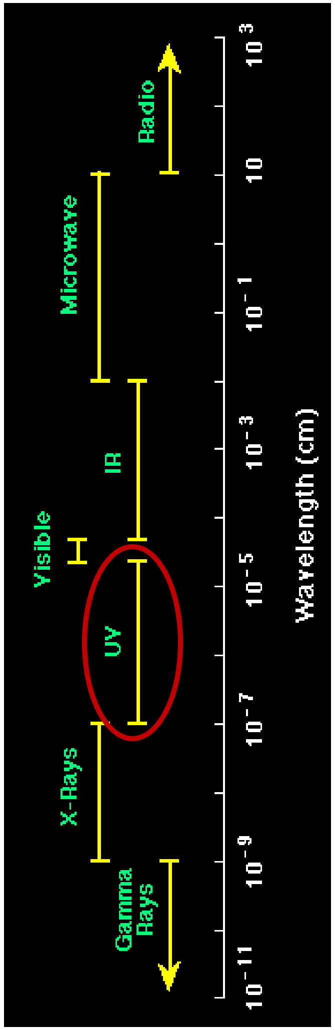




Electromagnetic Spectrum

Spectrum of Electromagnetic Radiation				
Region	Wavelength (Angstroms)	Wavelength (centimeters)	Frequency (Hz)	Energy (eV)
Radio	$> 10^9$	> 100	$< 3 \times 10^9$	$< 10^{-5}$
Microwave	$10^9 - 10^6$	10 0- 0.1	$3 \times 10^9 - 3 \times 10^{12}$	$10^{-5} - 0.01$
Infrared	$10^6 - 7000$	$0.01 - 7 \times 10^{-5}$	$3 \times 10^{12} - 4.3 \times 10^{14}$	0.01 - 2
Visible	7000 - 4000	$7 \times 10^{-5} - 4 \times 10^{-5}$	$4.3 \times 10^{14} - 7.5 \times 10^{14}$	2 - 3
Ultraviolet	4000 - 10	$4 \times 10^{-5} - 10^{-7}$	$7.5 \times 10^{14} - 3 \times 10^{17}$	$3 - 10^3$
X-Rays	10 - 0.1	$10^{-7} - 10^{-9}$	$3 \times 10^{17} - 3 \times 10^{19}$	$10^3 - 10^5$
Gamma Rays	< 0.1	$< 10^{-9}$	$> 3 \times 10^{19}$	$> 10^5$

Electromagnetic Spectrum - Ultraviolet



•Wavelengths < 0.3 mm are completely absorbed by the Ozone

•The **ultraviolet or UV** portion of the spectrum has the shortest wavelengths which are not used for remote sensing applications.

•Shorter wavelength and higher frequency than visible light

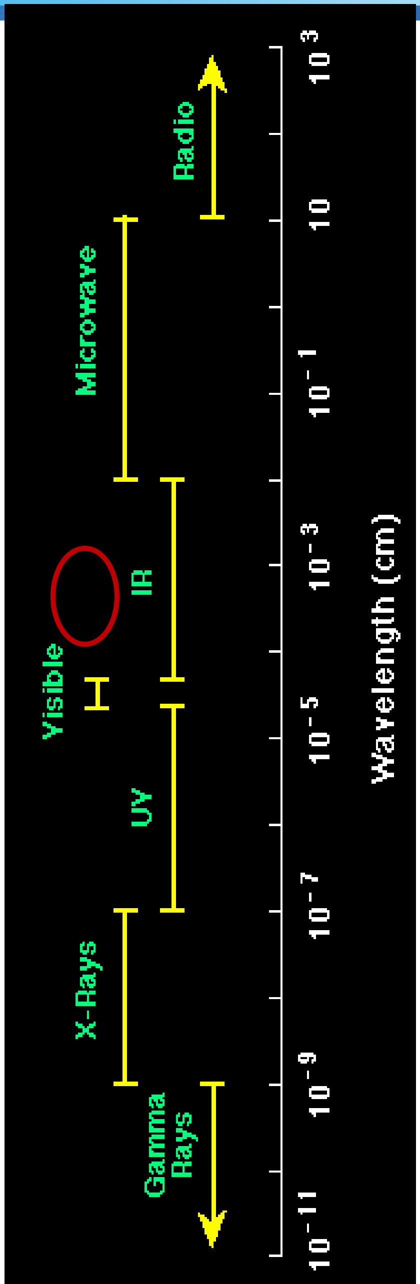
•Carry more energy than visible light

•This radiation is just beyond the violet portion of the visible wavelengths, hence its name.

•Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated by UV radiation.

•Too much can cause skin cancer. Use sun block to protect against (UV rays)

Electromagnetic Spectrum - Visible

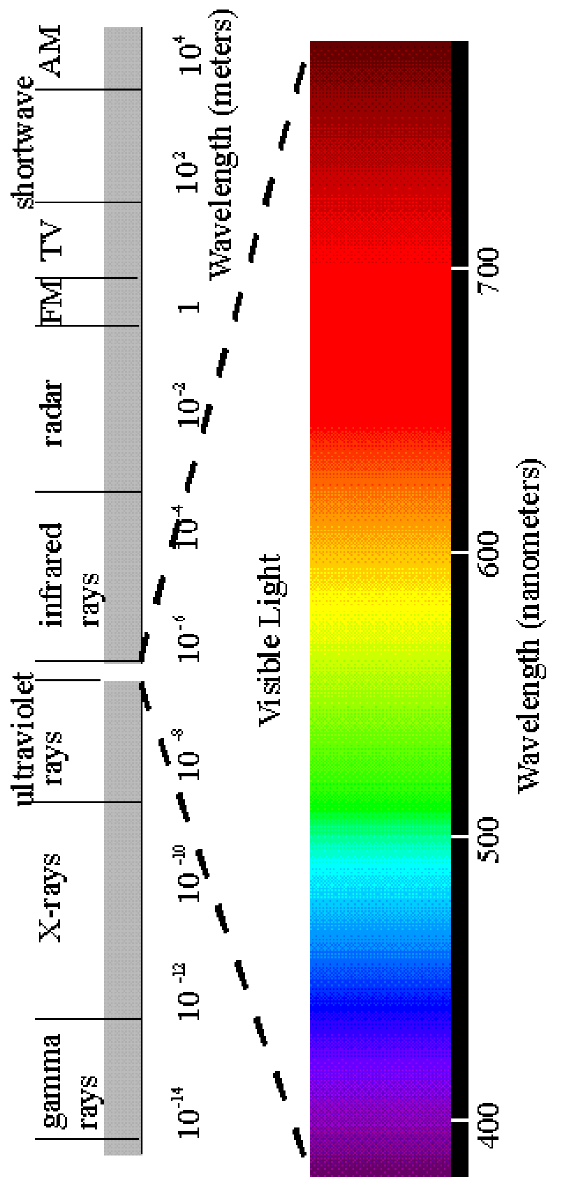


The light which our eyes - our "remote sensors" - can detect is part of the **visible spectrum. It is important to recognize how** small the visible portion is relative to the rest of the spectrum.

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.**

Electromagnetic Spectrum - Visible



Violet: 0.4 - 0.446 µm

Blue: 0.446 - 0.500 µm

Green: 0.500 - 0.578 µm

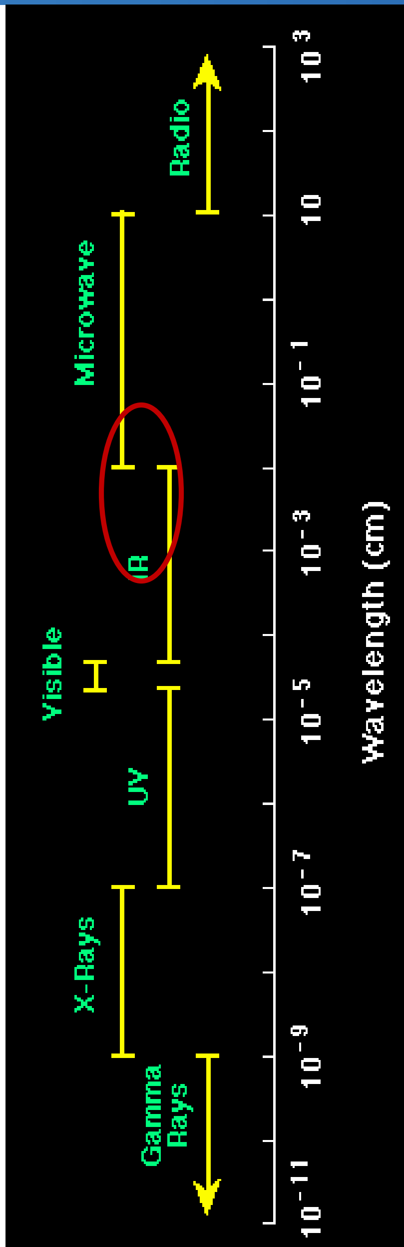
Yellow: 0.578 - 0.592 µm

Orange: 0.592 - 0.620 µm

Red: 0.620 - 0.7 µm

Blue, green, and red are the primary colours or wavelengths of the visible spectrum. They are defined as such because no single primary colour can be created from the other two, but all other colours can be formed by combining blue, green, and red in various proportions

Electromagnetic Spectrum - Infared



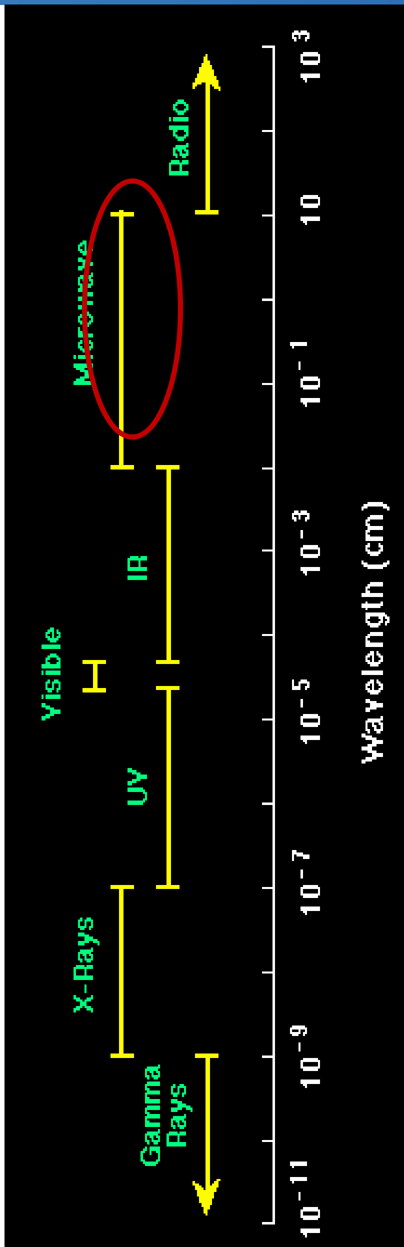
The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range **from 0.7 µm- to 100 µm**

Can be divided into five portions

NIR	-0.7 µm to 1.3 µm
SWIR	-1.3 µm to 3 µm
Intermediate IR	– 3 µm – 8 µm
Thermal IR	– 8 µm -14 µm
Far IR	– 14 µm– 0.1mm.

Radiation in the NIR & SWIR region is used for remote sensing purposes in ways very similar to radiation in the visible portion

Electromagnetic Spectrum – Micro Waves



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.

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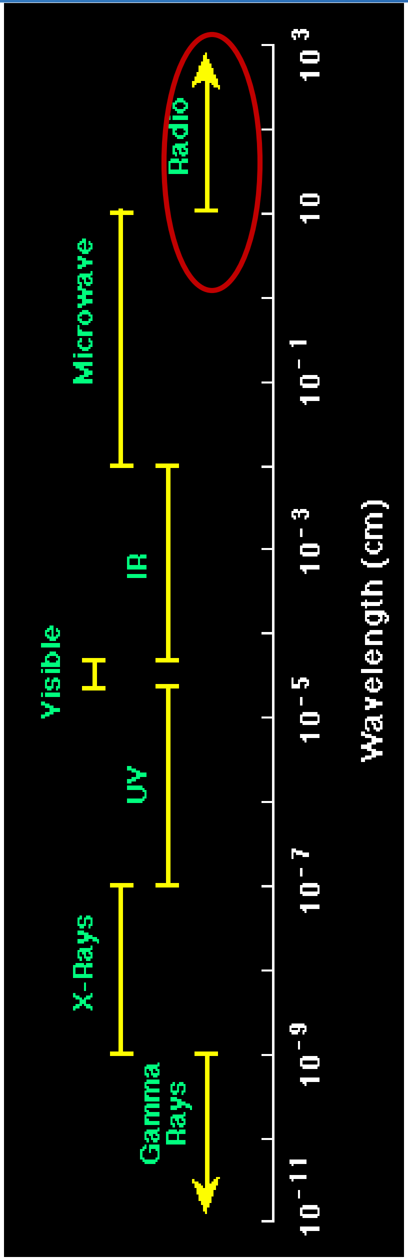
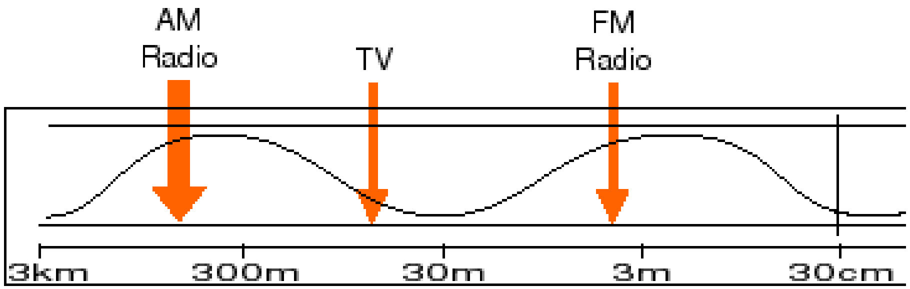
Electromagnetic Spectrum – Radio Waves



❖Have the longest wavelengths and lowest frequencies of all the electromagnetic waves.

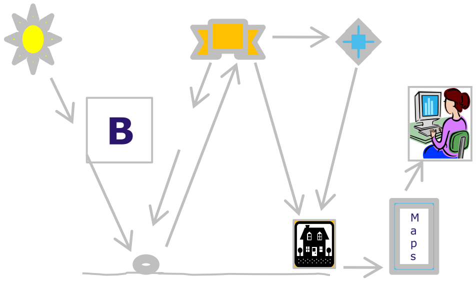
❖We use radio waves extensively for communication.

❖A radio picks up radio waves through an antenna and converts it to sound waves.



Radio Wave Region of the Electromagnetic Spectrum

B. Interaction with Atmosphere



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

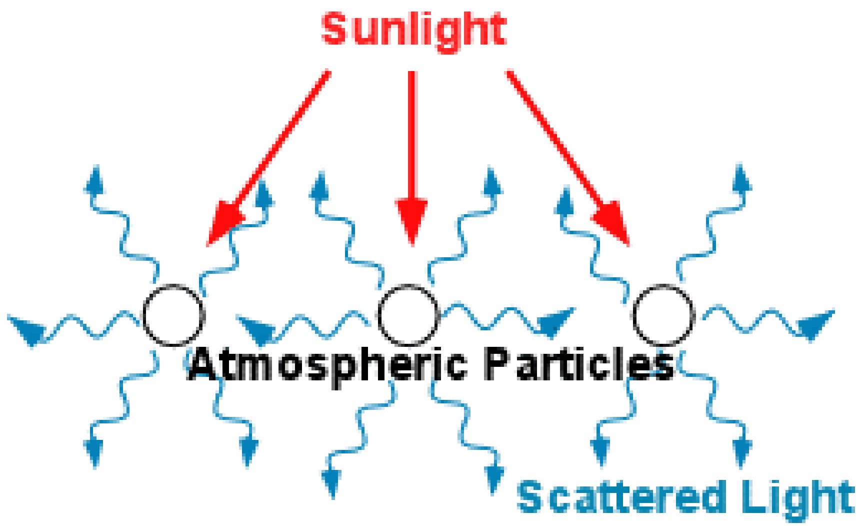
Particles and gases in the atmosphere can affect the incoming light and radiation.

These effects are caused by the mechanisms of

Scattering

Absorption

B. Interaction with Atmosphere - Scattering



❖**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

- the wavelength of the radiation,
- the abundance of particles or gases,
- the distance the radiation travels through the atmosphere.

There are three (3) types of scattering which take place.

- Rayleigh Scattering
- Mie Scattering
- Non Selective Scattering

B. Interaction with Atmosphere - Scattering

Rayleigh Scattering

❖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 / nitrogen and oxygen molecules.

❖This causes shorter wavelengths of energy to be scattered much more than longer wavelengths.

❖This is the dominant scattering 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 the sunset sky appears as red.

B. Interaction with Atmosphere - Scattering

Mie Scattering

This 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.

Non Selective 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.

❖This 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).

B. Interaction with Atmosphere - Absorption

❖**Absorption is the other main mechanism at work** when electromagnetic radiation interacts with the atmosphere.

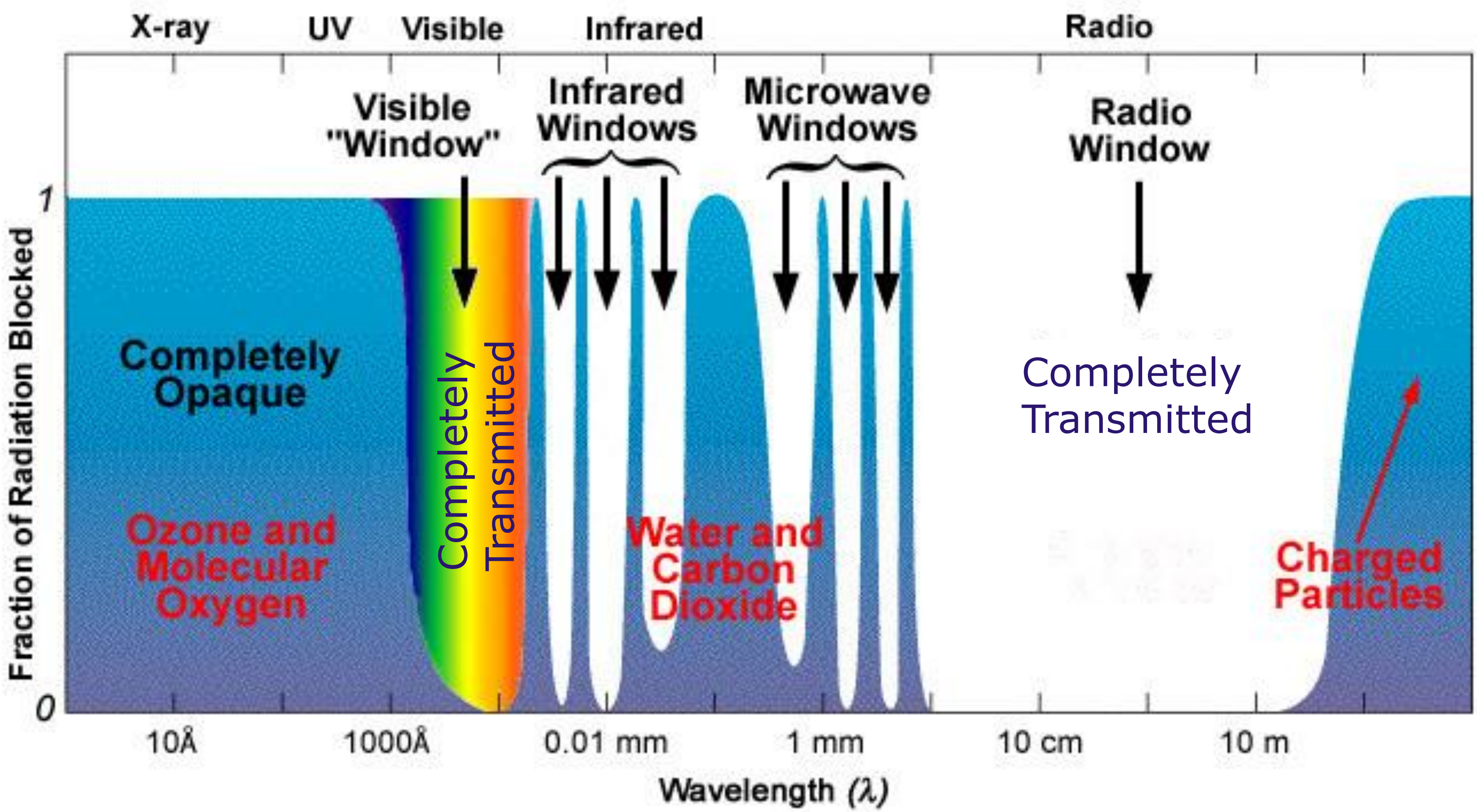
❖In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths.

Ozone, carbon dioxide, and water vapour are the three main atmospheric constituents which absorb radiation

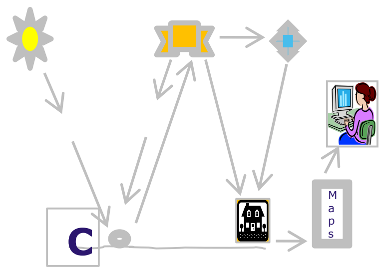
Ozone –
absorb the harmful **ultraviolet** radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

carbon dioxide (greenhouse gas)-
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-
absorbs much of the incoming long wave infrared and shortwave microwave radiation (between 22μm and 1m).


X-ray
UV
Visible
Infrared
Radio
Visible "Window"
Infrared Windows
Microwave Windows
Radio Window
1
0
Fraction of Radiation Blocked
Completely Opaque
Ozone and Molecular Oxygen
Completely Transmitted
Water and Carbon Dioxide
Completely Transmitted
Charged Particles
10Å
1000Å
0.01 mm
1 mm
10 cm
10 m
Wavelength (λ)

C. Interaction with Target

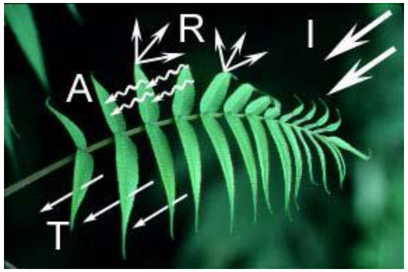


Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface.

There are three (3) forms of interaction that can take place when energy strikes, or is incident (I) upon the surface.

These are:

- ❖ **Absorption – radiation absorbed by the target**
- ❖ **Transmission – radiation passes through the target**
- ❖ **Reflection - radiation bounces off the target & redirected**

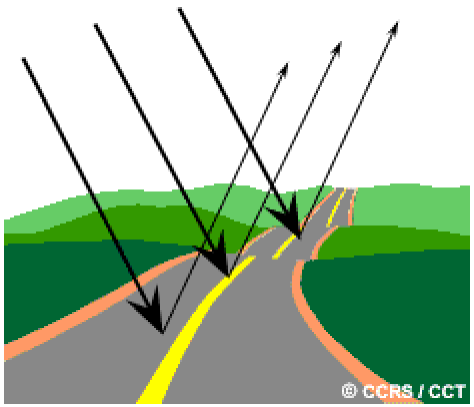


The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the Feature.

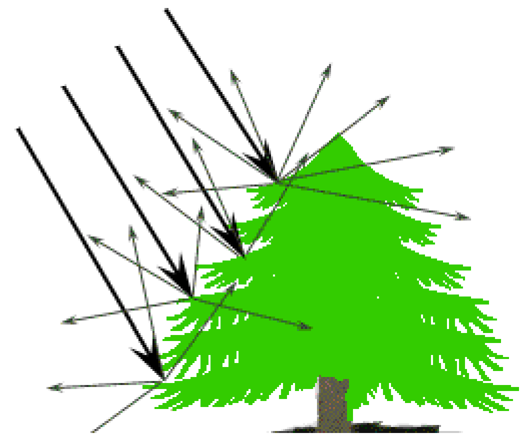
C. Interaction with Target

In RS, we are most interested in measuring the radiation **reflected from targets.**

There are two extreme ends in reflected of the way in which energy is reflected from a target



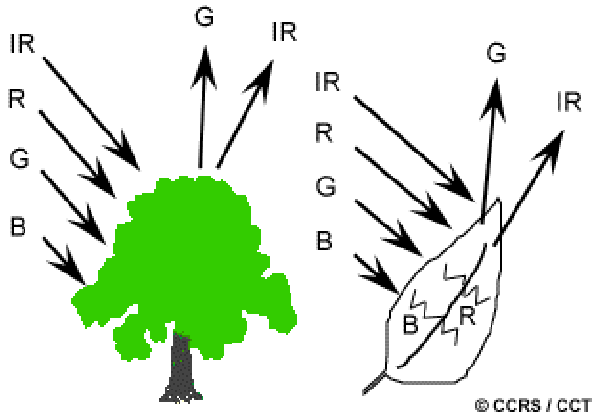
Specular (mirror-like reflection)
All of the energy is directed away from the surface in a single direction



Diffuse reflection
occurs when the surface is rough and the energy is reflected almost uniformly in all directions

C. Interaction with Target

Ex: Leaves



The spectral characteristics of vegetation vary with wavelength.

A compound in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflect green wavelength.

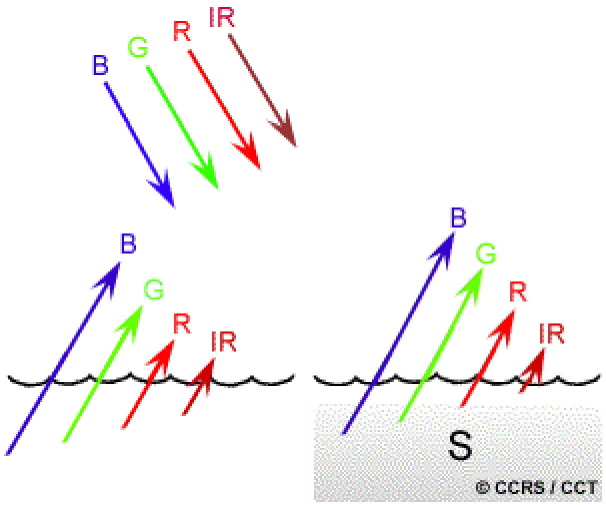
The internal structure of healthy leaves act as diffuse reflector of near-infrared wavelengths.

Measuring and monitoring the infrared reflectance is one way that scientists determine how healthy particular vegetation may be.

Leaves appear greenest to us in summer and become red or yellow with decrease in chlorophyll content in autumn.

C. Interaction with Target

Ex: Water



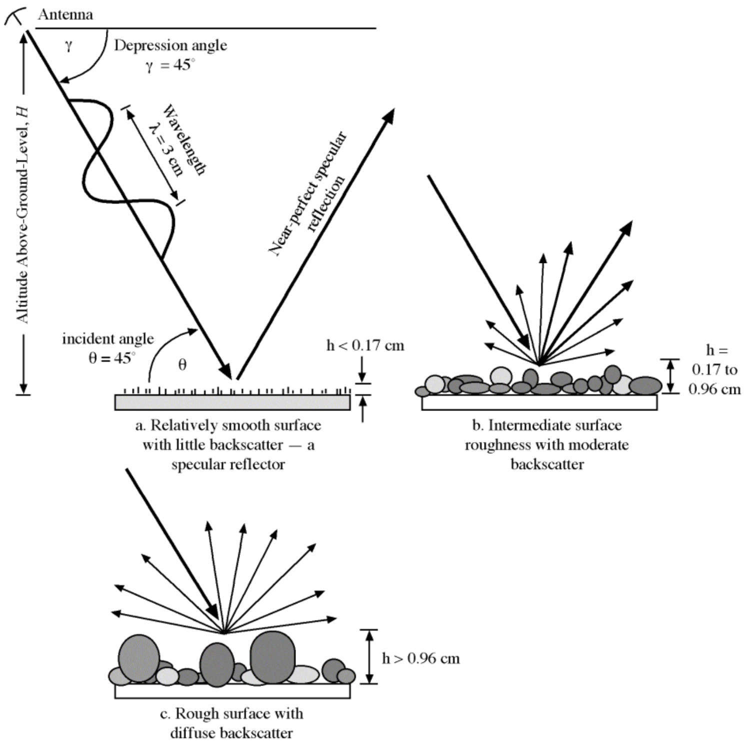
Spectral Reflectance of Water
Majority of the radiation incident upon water is not reflected but either is absorbed or transmitted.

Longer visible wavelengths and near-infrared radiations are absorbed more by water than the visible wavelengths.

Thus water looks blue or blue-green due to stronger reflectance at these shorter wavelengths and darker if viewed at red or near-infrared wavelengths.

The factors that affect the variability in reflectance of a water body are depth of water, materials within water and surface roughness of water.

C. Interaction with Target



Spectral Reflectance of Soil

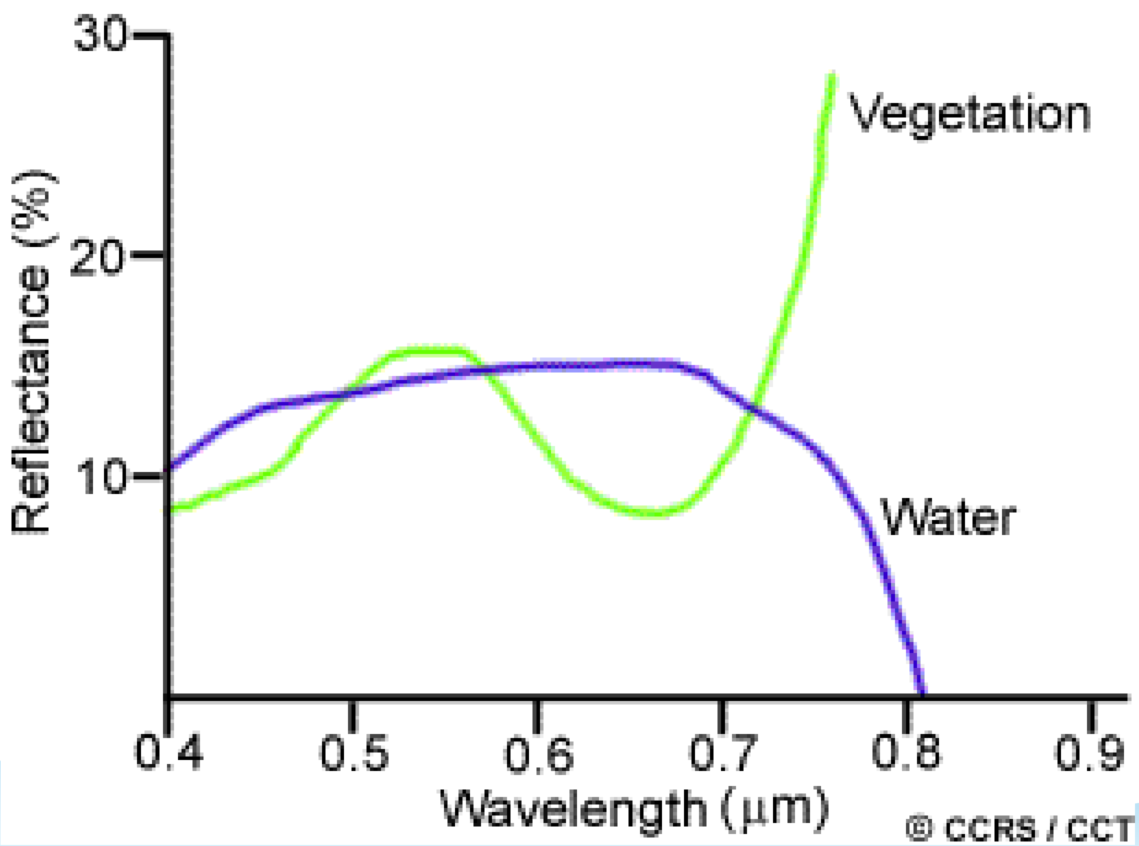
The majority of radiation on a surface is either reflected or absorbed and little is transmitted.

The characteristics of soil that determine its reflectance properties are its moisture content, texture, structure iron-oxide content.

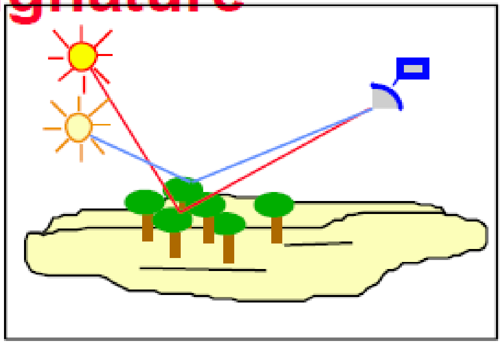
The soil curve shows less peak and valley variations. The presence of moisture in soil decreases its reflectance.

C. Interaction with Target

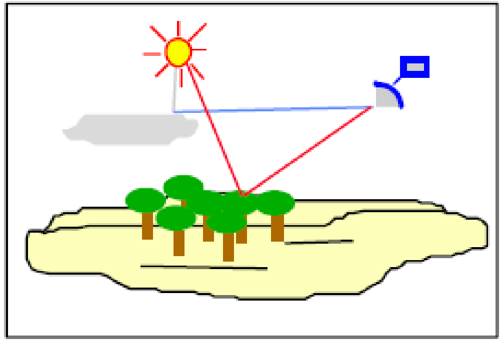
By measuring the energy that is reflected by targets on earth's surface over a variety of different wavelengths, a spectral signature for that object can be made. And by comparing the response pattern of different features we may be able to distinguish between them.



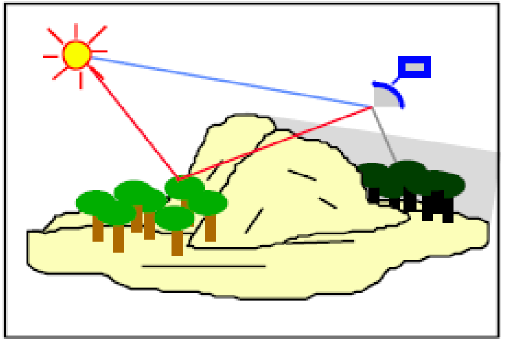
Factors influencing the spectral signature



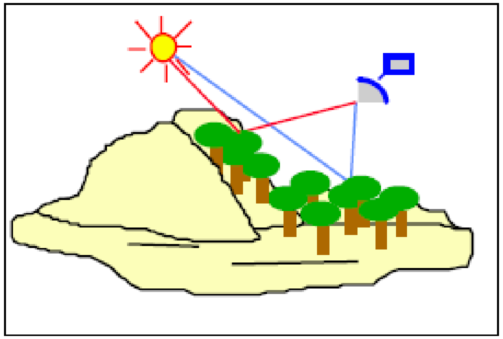
Heigth of the sun
(date, time)



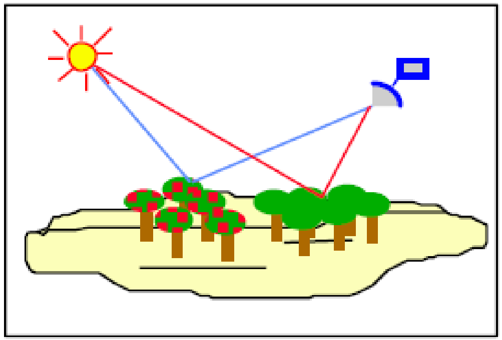
Atmospheric conditions



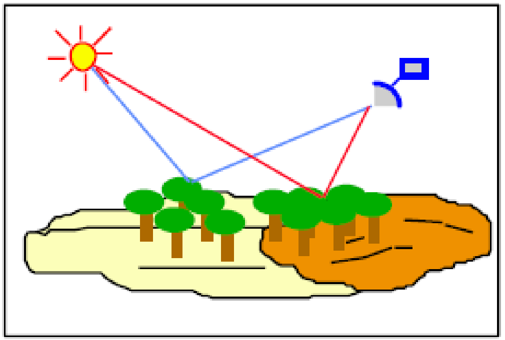
Relief (shadow)



Relief (slope)

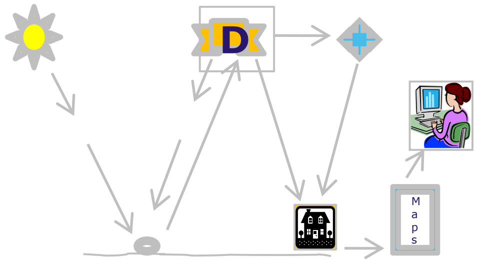


Phenology, disease



Environment

D. Recording Sensor – Passive Sensor



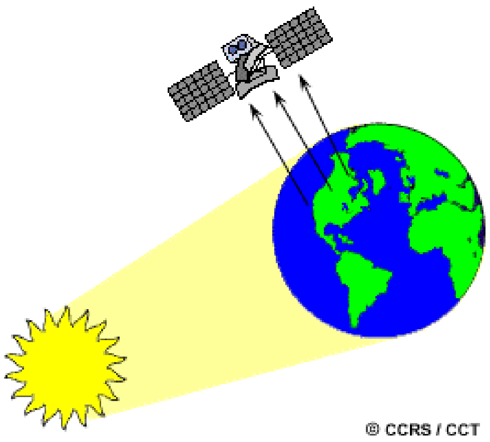
The sun provides a very convenient source of energy for RS.

Remote sensing systems which measure energy that is naturally available are called **passive sensors.**

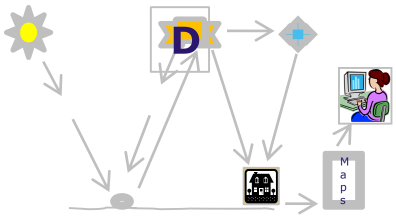
Passive sensors can only be used to detect energy when the naturally occurring energy is available.

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.



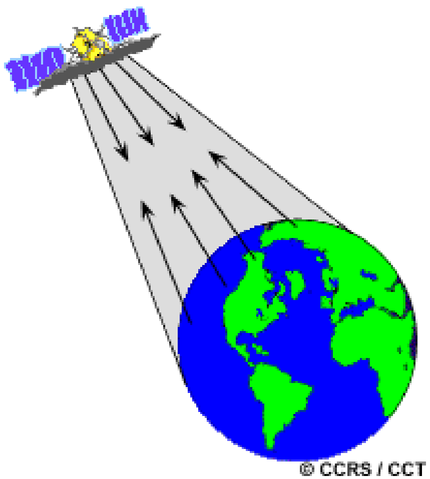
D. Recording Sensor Active Sensor



❖Active sensors, provide their own energy source for illumination.

❖ The sensor emits radiation which is directed toward the target to be investigated.

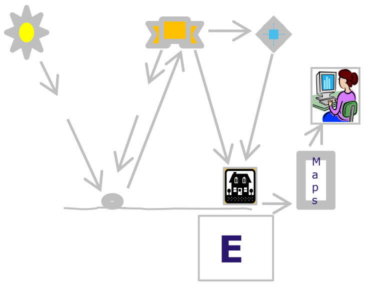
❖The radiation reflected from that target is detected and measured by the sensor.



❖Advantages for active sensors include the **ability to obtain measurements anytime, regardless of the time of day or season**. Active sensors can be used for examining wavelengths that are not sufficiently provided by the sun, such as microwaves, or to better control the way a target is illuminated.

❖However, active systems require the generation of a fairly large amount of energy to adequately illuminate targets.

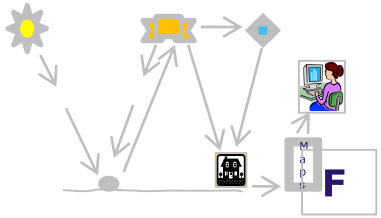
E. Transmission, Reception & Processing



Transmission, Reception, and Processing (E) –

the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

F. Interpretation and Analysis



- ❖Image Enhancement
- ❖Image Preprocessing
- ❖Transformations
- ❖Image Interpretations
- ❖Image Classifications & Accuracy Assessment
- ❖GIS Integration

Remote Sensing Vs GIS

❖GIS (Geographic Information System) enables:

- The collection of spatial data from different sources (RS being one of them).
- Relating spatial and tabular data.
- Performing tabular and spatial analysis.
- Symbolize and design the layout of a map.
- can handle both vector and raster data

❖Remote Sensing analysis has been done, its results are usually combined within a GIS or into database of an area, for further analysis (overlaying with other layers, etc)

Remote Sensing Vs Eyesight

As humans, we are intimately familiar with remote sensing in that we rely on visual perception to provide us with much of the information about our surroundings. As sensors, however, our eyes are greatly limited by

1) sensitivity to only the visible range of electromagnetic energy;
2) viewing perspectives dictated by the location of our bodies
3) the inability to form a lasting record of what we view.

Because of these limitations, humans have continuously sought to develop the technological means to increase our ability to see and record the physical properties of our environment

Advantages of Remote Sensing

1. Relatively *cheap* and *rapid* method of acquiring *up-to-date* information over a *large* geographical area.

2. It is the only practical way to obtain data from *inaccessible* regions,

3. At small scales, regional phenomena which are invisible from the ground are clearly visible. Examples: geological structures.

4. Cheap and rapid method of constructing base maps in the absence of detailed land surveys.

5. Easy to manipulate with the computer, and combine with other geographic coverages in the GIS.

Disadvantages of remote sensing

They are not direct samples of the phenomenon, so must be calibrated against reality.

They must be corrected geometrically and georeferenced in order to be useful as maps,

Distinct phenomena can be confused if they look the same to the sensor, leading to classification error. Example: artificial & natural grass in green light (but infrared light can easily distinguish them).

Phenomena which were not meant to be measured (for the application at hand) can interfere with the image and must be accounted for. Examples for land cover classification: atmospheric water vapor, sun vs. shadow (these may be desirable in other applications).

Resolution of satellite imagery is too coarse for detailed mapping and for distinguishing small contrasting areas.

Thank You