Remote Sensing
(or Satellite Imaging)

Ch. 1 Introduction

1.1 What is Remote Sensing

"**Remote**" : far away.

"**Sensing**" : detecting a property or characteristics

➔ "**Remote sensing**" means detecting a property of things from a distance.

Of our five senses we use three as remote sensors when we: (A) **watch** a football game from the stands (sense of sight). (B) **smell** freshly baked bread in the oven (sense of smell) (c) **hear** a telephone ring (sense of hearing).

What are our other two senses and why aren't they used remotely? ➔ **touch** and **taste**

Definition

"**Remote sensing** is **<u>the science of acquiring information about the Earth's surface without actually being in contact with it</u>**. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

1.1 What is Remote Sensing

In the world of **science**, “remote Sensing” means **<u>observing the Earth with sensors from high above its surface</u>**. They are like cameras except that they use not only **visible light** but also other bands of the electromagnetic spectrum such as **infrared**, **radar** and **ultraviolet**. Because they are so high up, these sensors can make images of a very large area, sometimes a whole province.

Today, remote sensing, also known as **Earth observation**, is often done **from space using satellites**. Hundreds of images are sent every day from the satellites to receiving stations on Earth. The Earth’s entire surface is imaged every week or so. Can you imagine how these images could be used?

1.1 What is Remote Sensing

What Can You See on a Satellite Image?

In the downtown Vancouver, British Columbia, you can see:

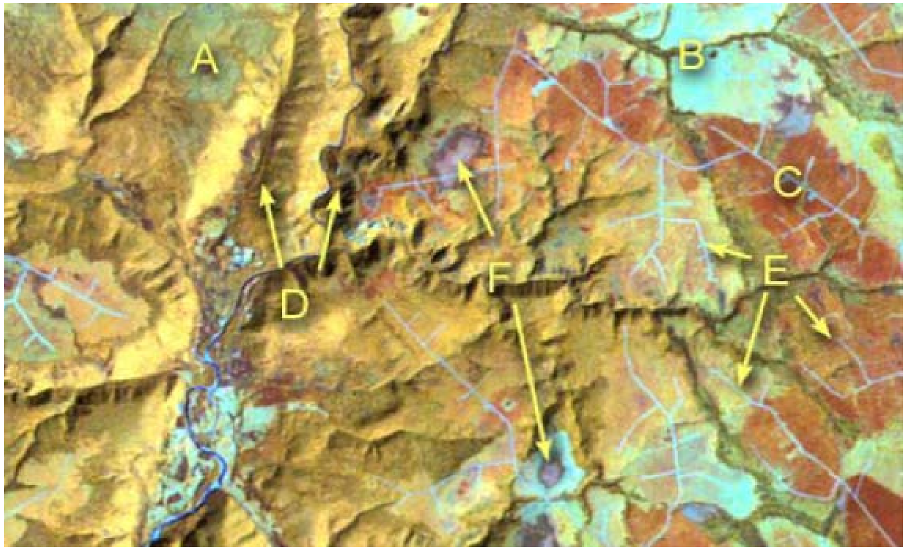
A. Tall buildings and their shadows
B. Bridges
C. Residential street patterns
D. A large stadium
E. Marinas for small boats
F. A ship and its wake

Near Prince Albert, Saskatchewan, you can see:

A. A large river
B. A small, meandering river
C. Farm fields with crops
D. Farm fields showing bare ground
E. Forest **F**. Roads **G**. Small ponds

1.1 What is Remote Sensing

In the Cape Breton Highlands of Nova Scotia, you can see:
A. Standing forest
B. Recent forest clearcut
C. Older forest clearcut
D. Deep river valley
E. Logging roads **F**. Swamp



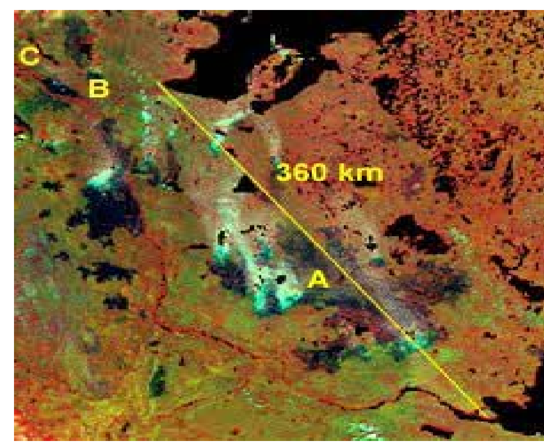
In the Minas Basin of Nova Scotia, you can see:
A. A river carrying sediment into the Basin
B. Shallow water areas
C. Deep water areas
D. Clouds and their shadows
E. Forests

1.1 What is Remote Sensing

Who Uses Remote Sensing and Why?

- **the meteorologist,** who gets immediate **information on climate** and **weather conditions** from remote sensing satellites. Images over time allow us to predict weather behavior;

- **the geographer**, who looks for **changes on the Earth's surface** that need to be mapped;



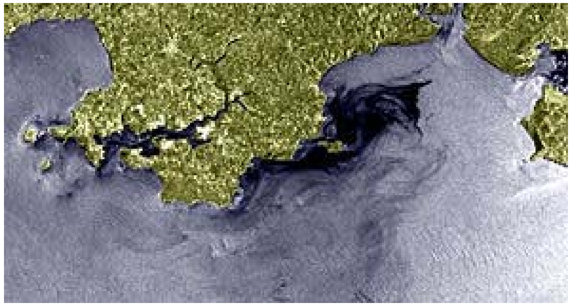
- **the forester**, who needs **information about what type of trees are growing** and if they have been affected by disease, fire or pollution;

- **the firefighter**, who sends out his crews based on **information about the size** and **movement of a forest fire.**

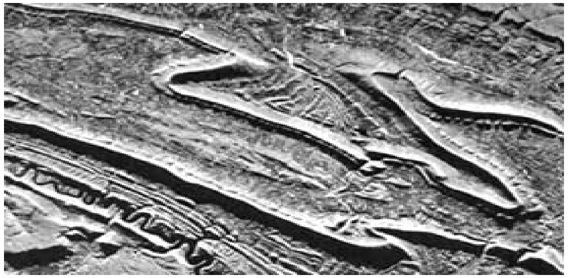
1.1 What is Remote Sensing

Who Uses Remote Sensing and Why?

• **the environmentalist**, who wants to detect, identify and follow **the movement of pollutants** such as oil slicks on the ocean;



• **the geologist**, who is interested in finding **valuable minerals** and **mapping faults, folds**, **lineaments** and **rock types**



• **the farmer**, who wants to keep an eye on **how his crops are growing** and if they've been affected by drought, floods, disease or pests;

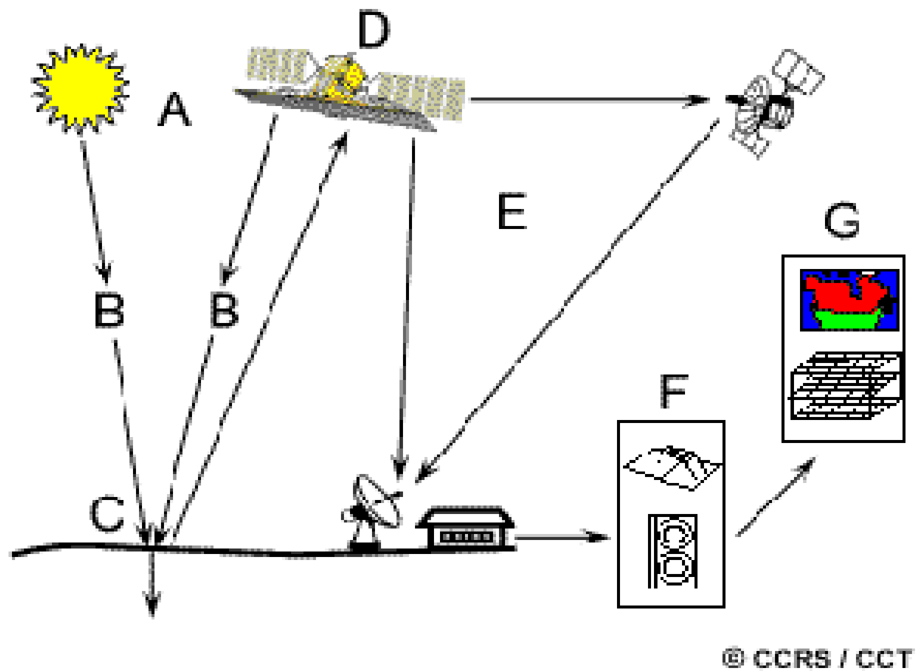
• **the ship captain**, who needs to **find the best route through the northern ice packs**;

--- And there are many more ways to use remote sensing. ---

1.1 What is Remote Sensing

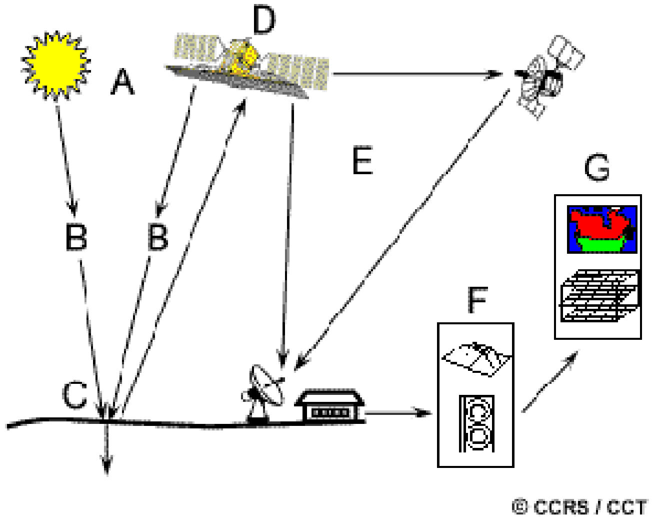
Seven(7) elements in the RS process

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



1.1 What is Remote Sensing

Seven(7) elements in the RS process



A. Energy Source or Illumination
an energy source which illuminates or provides **electromagnetic energy** to the target of interest.

B. Radiation and the Atmosphere
as the energy travels from its source to the target, it will come in contact with and **interact with the atmosphere** it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

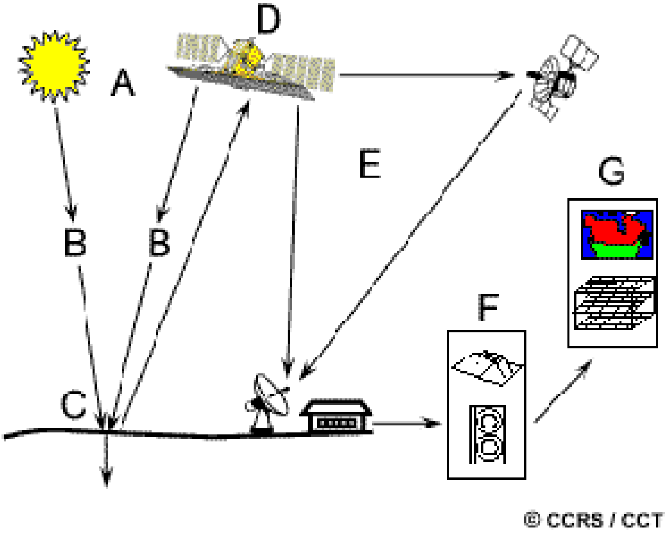
C. Interaction with the Target
once the energy makes its way to the target through the atmosphere, it **interacts with the target** depending on the properties of both the target and the radiation.

1.1 What is Remote Sensing

Seven(7) elements in the RS process

D. Recording of Energy by the Sensor
after the energy has been scattered by, or emitted from the target, we require a **sensor** (remote - not in contact with the target) to **collect and record the electromagnetic radiation**.

E. Transmission, Reception, and Processing
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).

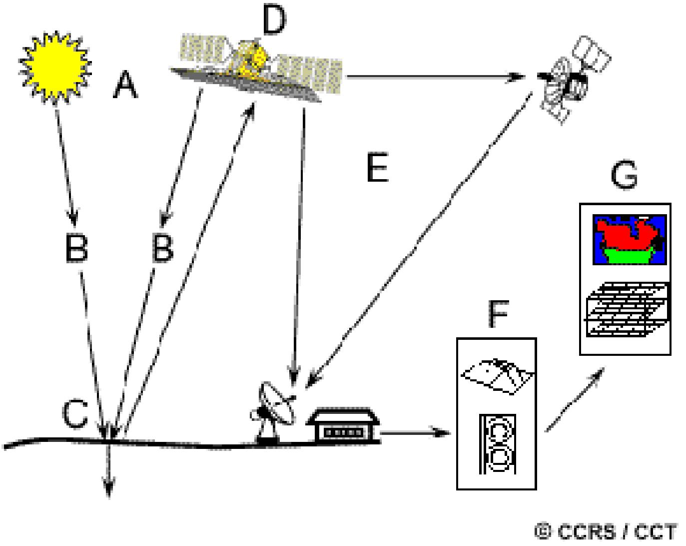


1.1 What is Remote Sensing

Seven(7) elements in the RS process

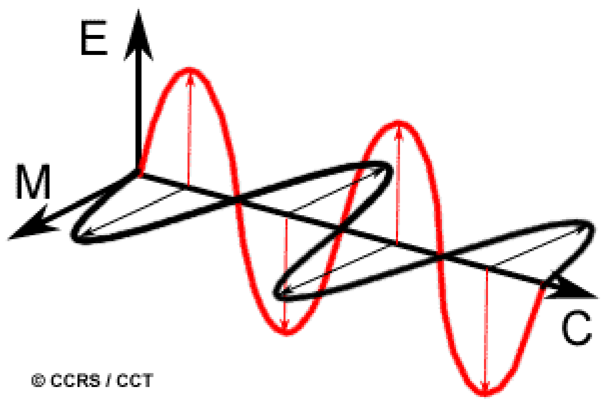
F. Interpretation and Analysis
the processed image is interpreted, visually and/or digitally or electronically, to **extract information** about the target which was illuminated.

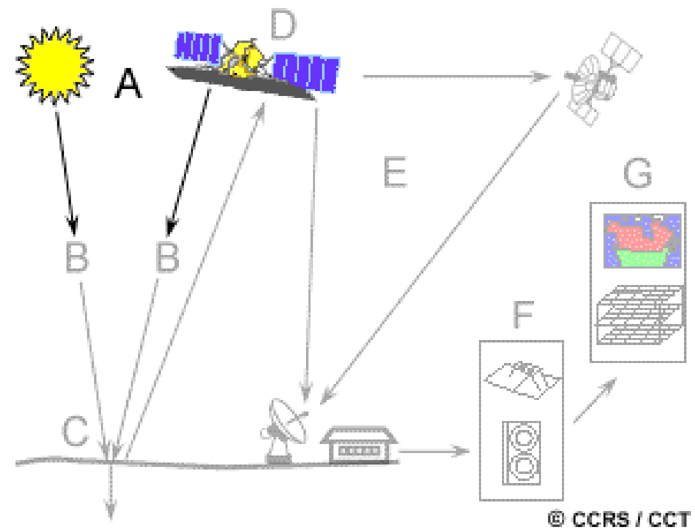
G. Application
the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to **better understand it**, reveal some **new information**, or assist in **solving a particular problem**.



1.2 Electromagnetic Radiation

A. Energy Source to illuminate the target (the first requirement for remote sensing) ➔ **electromagnetic radiation**

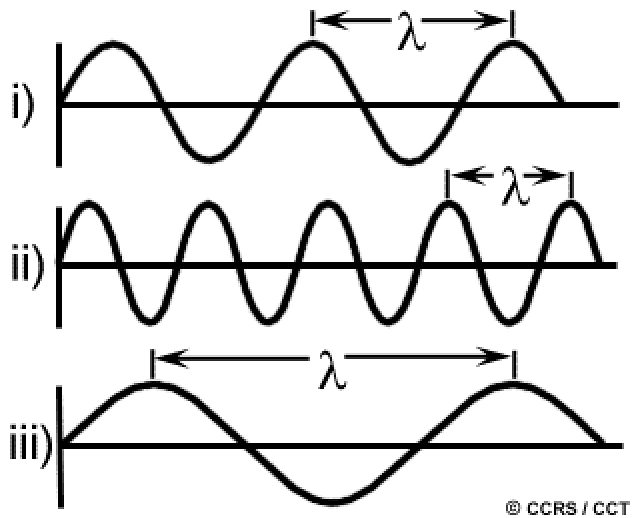




Electromagnetic (EM) radiation consists of an **electrical field(E)** which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a **magnetic field (M)** oriented at right angles to the electrical field. Both these fields travel at the speed of light (**C**).

1.2 Electromagnetic Radiation

Two important characteristics of EM radiation :
wavelength (λ) and **frequency (ν).**



$$\mathbf{c = \lambda \nu}$$

where

λ = **wavelength** (**m**)
ν = **frequency** (cycles per second, **Hz**)
c = **speed of light** ($\mathbf{3 \times 10^8 m/s}$)

1.2 Electromagnetic Radiation

Quiz 1 The first requirement for remote sensing is an energy source which can illuminate a target. What is the obvious source of EM energy that you can think of? What "remote sensing device" do you personally use to detect this energy?

ANS:

1.2 Electromagnetic Radiation

Quiz 1 The first requirement for remote sensing is an energy source which can illuminate a target. What is the obvious source of EM energy that you can think of? What "remote sensing device" do you personally use to detect this energy?

ANS: The most obvious source is **the sun**. The sun provides the initial energy source for much of the remote sensing of the Earth surface. The remote sensing device that we humans use to detect radiation from the sun is **our eyes**. Yes, they can be considered remote sensors - and very good ones - as they detect the visible light from the sun, which allows us to see. There are other types of light which are invisible to us...but more about that later.

1.2 Electromagnetic Radiation

Quiz 2 Assume the speed of light to be $3x10^8$ m/s. If the frequency of an EM wave is 500,000 GHz (GHz = gigahertz = 10^9 s^{-1}), what is the wavelength of that radiation? Express your answer in micrometers(μm).

ANS:

1.2 Electromagnetic Radiation

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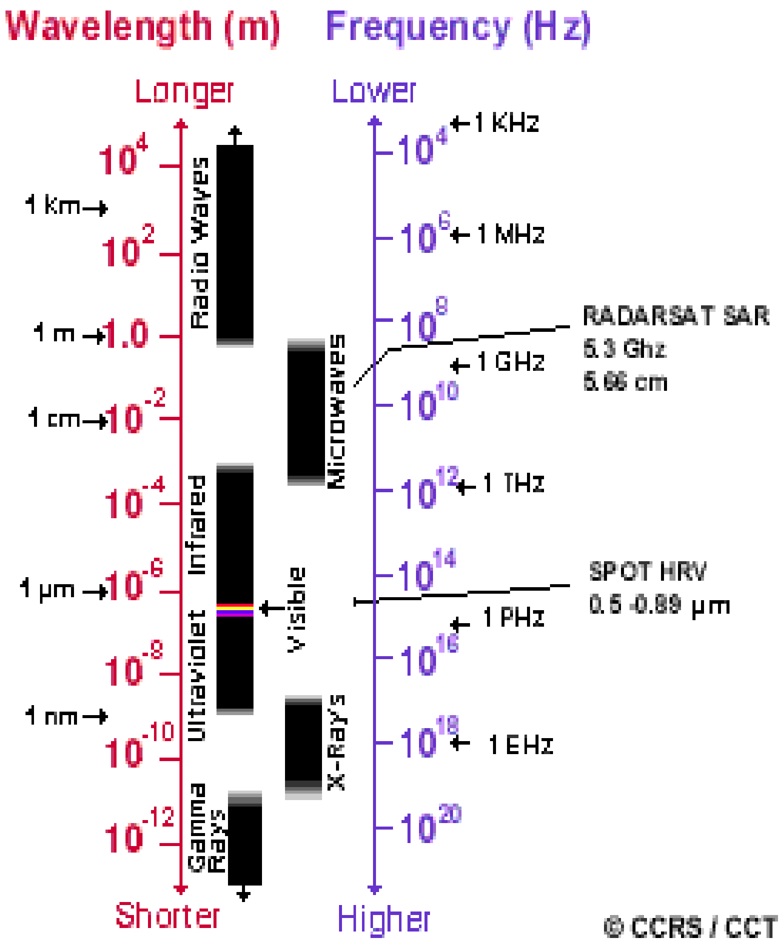
ANS: Using the equation for the relationship between wavelength and frequency, let's calculate the wavelength of radiation of a frequency of 500,000 GHz.

$$c = \lambda \nu$$
$$3x10^8 = \lambda(500{,}000x10^9)$$
$$3x10^8 = \lambda\ (5x10^{14})$$
$$3x10^8/5x10^{14} = \lambda$$
$$6x10^{-7}\ \text{metres} = \lambda$$

1.3 Electromagnetic Spectrum

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

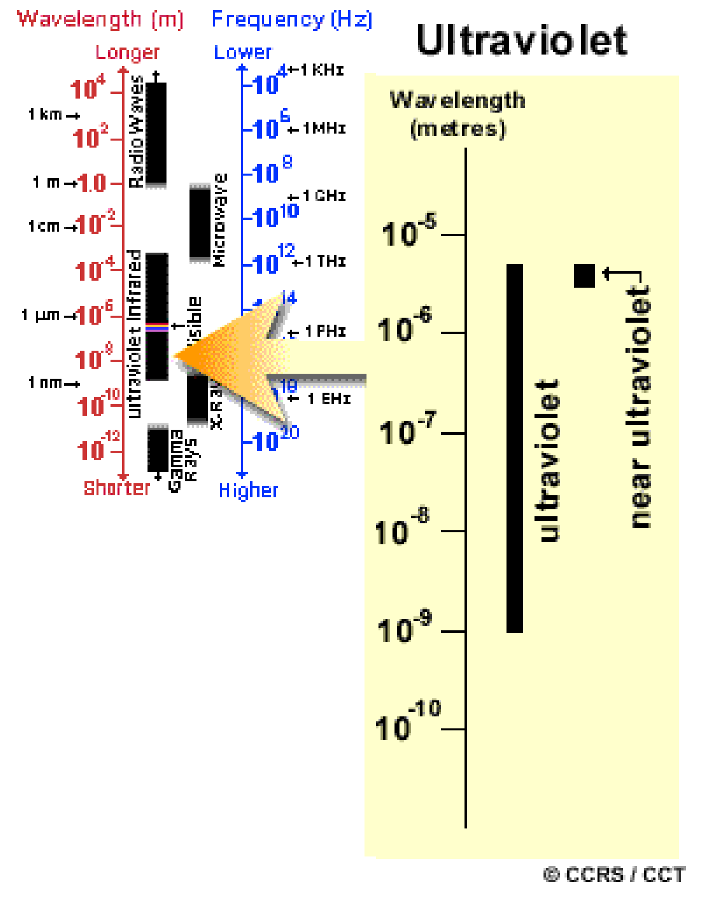
- **Ultraviolet (UV) : 1 nm ~ 0.4 μm.**
- **Visible : 0.4 μm ~ 0.7 μm.**
- **Infrared (IR) : 0.7 μm ~ 100 μm**
- **Microwave : 1 mm ~ 1 m.**



1.3 Electromagnetic Spectrum

Ultraviolet (UV)

- **1 nm ~ 0.4 μm**.
- The shortest wavelengths which are practical for remote sensing
- 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.

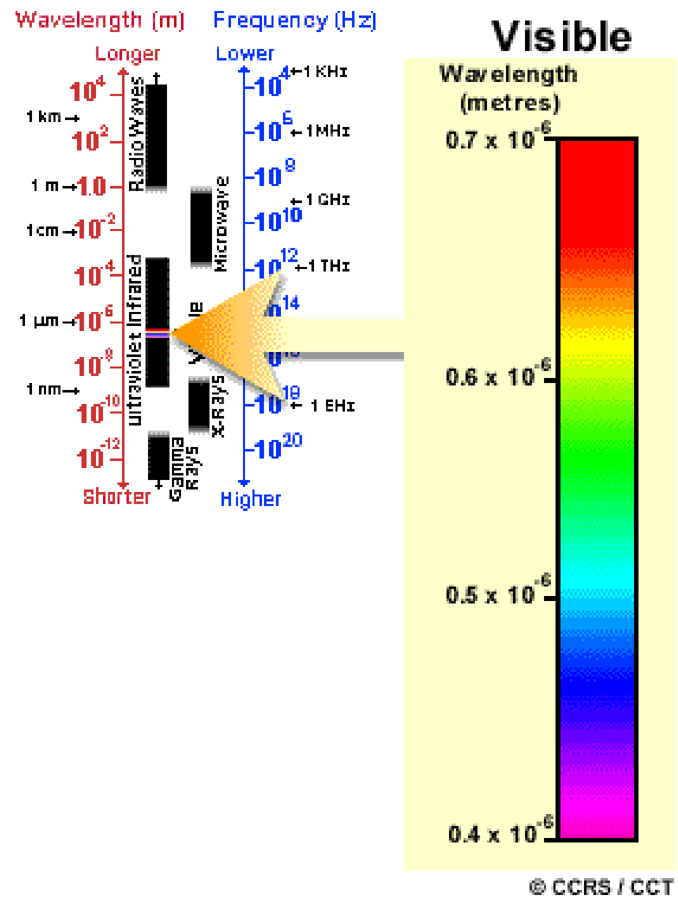


1.3 Electromagnetic Spectrum

Visible spectrum

- **0.4 μm (violet) ~ 0.7 μm (red)**
- The light which our eyes can detect
- Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum

  - **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**

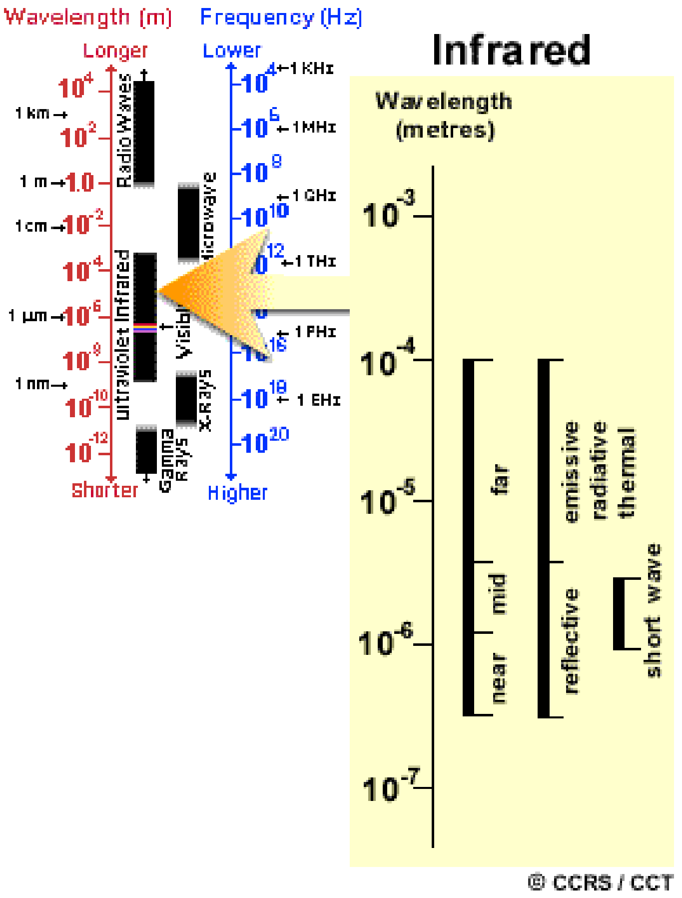


1.3 Electromagnetic Spectrum

Infrared (IR)

- **0.7 µm ~ 3 µm : reflected Infrared** 🡐 very similar to radiation in the visible portion

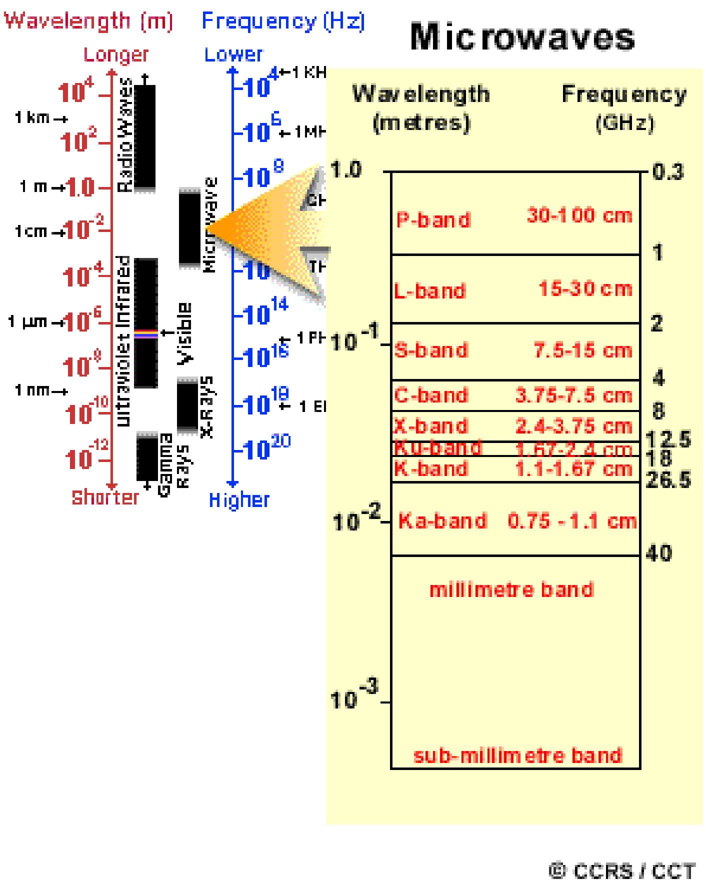
- **3 µm ~ 100 µm** : **emitted** (or **thermal**) Infrared 🡐 emitted from the Earth's surface in the form of heat



1.3 Electromagnetic Spectrum

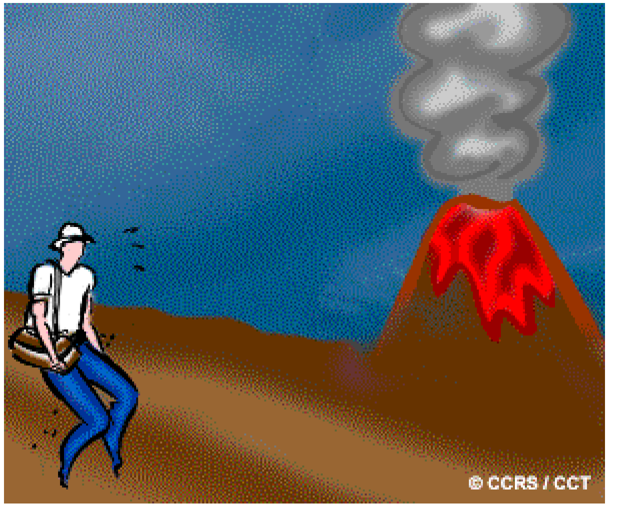
Microwave region

- **1 mm ~ 1 m** : the longest wavelengths used for RS.
- The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.
- The portion of the spectrum of **more recent interest** to remote sensing
- Because of the special nature of this region an entire chapter (Chapter 3) of the tutorial is dedicated to microwave sensing.



1.3 Electromagnetic Spectrum

Quiz The infrared portion of the EM spectrum has two parts: the reflective and the emissive. Can you take photographs in these wavelength ranges?

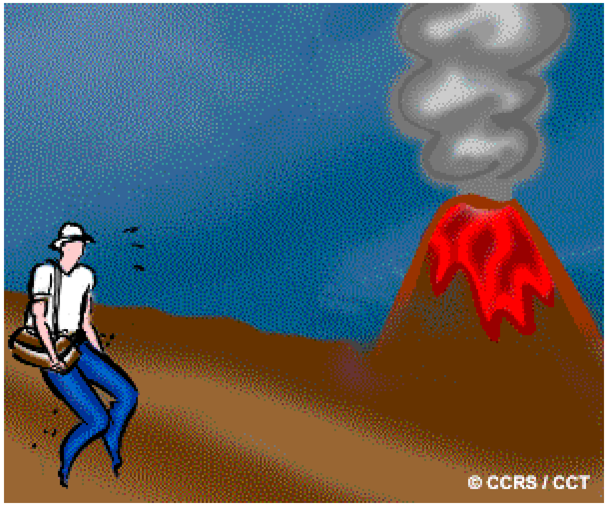


ANS

1.3 Electromagnetic Spectrum

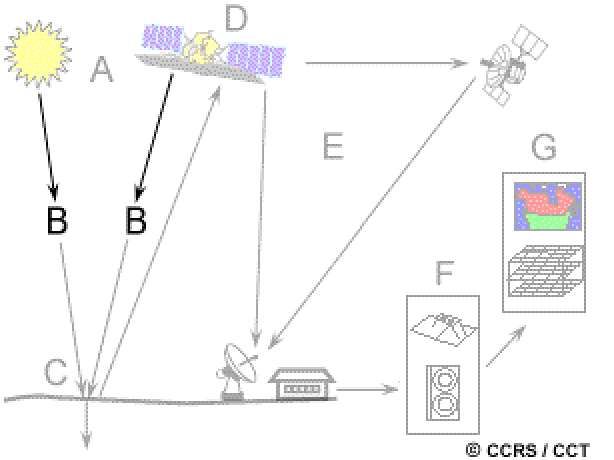
Quiz The infrared portion of the EM spectrum has two parts: the reflective and the emissive. Can you take photographs in these wavelength ranges?

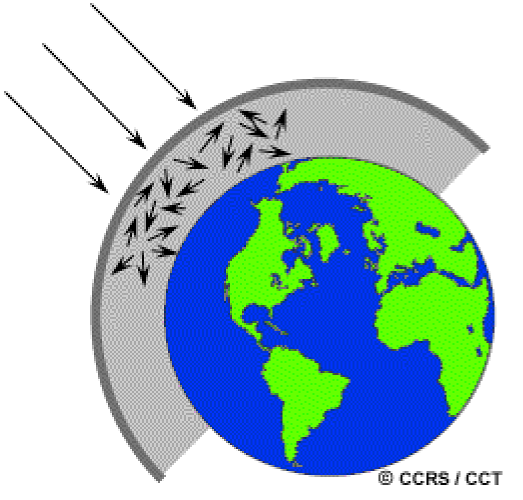
ANS **Yes** and **no**.
There are photographic films in black and white as well as color emulsions, which are sensitive to **the reflective portion of the infrared band** and these are used for scientific and artistic purposes too.
But no photographic films exist to directly record **emissive infrared (heat).** If they did, then they would have to be cooled (and kept very cold during use), which would be very impractical. However there are a number of electronic devices which detect and record thermal infrared images.



1.4 Interactions with the Atmosphere

Before radiation 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** and **absorption**.

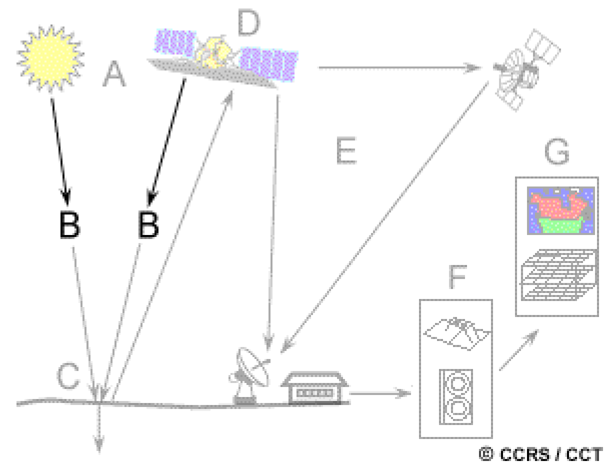


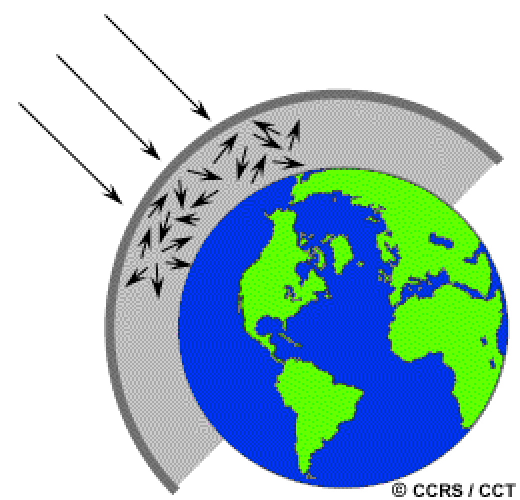


1.4 Interactions with the Atmosphere

Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the EM radiation to be redirected from its original path. **How much scattering** takes place depends on several factors including the **wavelength** of the radiation, the **abundance** of particles or gases, and the **distance** the radiation travels through the atmosphere. Three(3) types of scattering.

1. **Rayleigh scattering**
2. **Mie scattering**
3. **Non-selective scattering**





1.4 Interactions with the Atmosphere

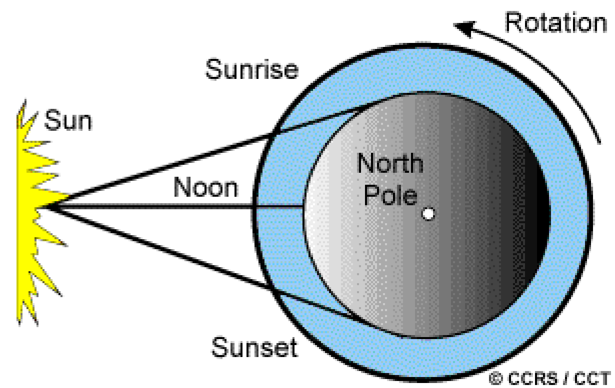
Rayleigh scattering (particle << wavelength)

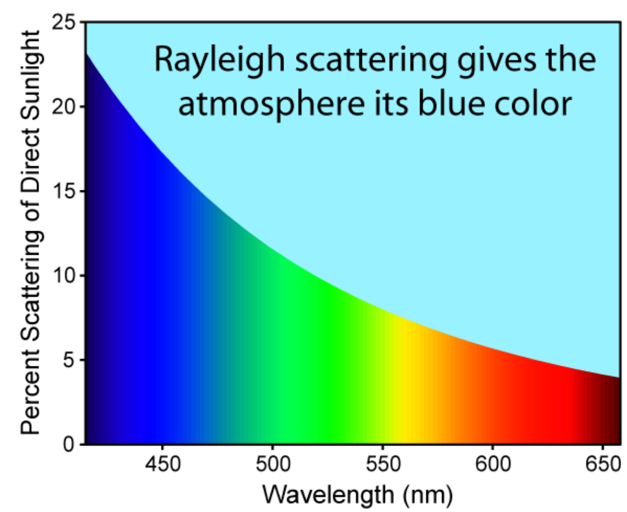
• occurs when **particles are very small compared to the wavelength** of the radiation. (small specks of dust / nitrogen / oxygen molecules)

• **shorter wavelengths** of energy to be **scattered much more** than longer wavelengths.

• 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. The result is that the human eye perceives blue when looking toward **parts of the sky other than the sun.**



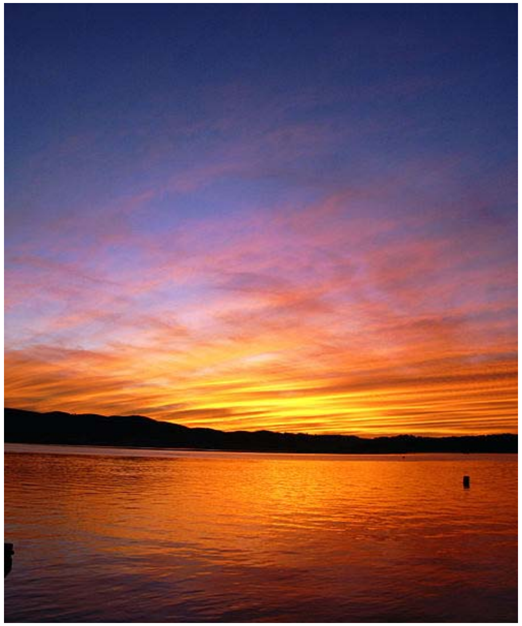


1.4 Interactions with the Atmosphere

Mie scattering (particle ~ wavelength)

• occurs when **the particles are just about the same size as the wavelength** of the radiation. (Dust, pollen, smoke and water vapor)
• affect **longer wavelengths** than those affected by Rayleigh scattering.
• mostly in the **lower portions of the atmosphere** where larger particles are more abundant, and dominates when cloud conditions are overcast.

• The change of sky color at sunset (**red** nearest the sun, **blue** furthest away) is caused by **Rayleigh scattering** by atmospheric gas particles which are much smaller than the wavelengths of visible light.
• The **grey/white color** of the clouds is caused by **Mie scattering** by water droplets which are of a comparable size to the wavelengths of visible light



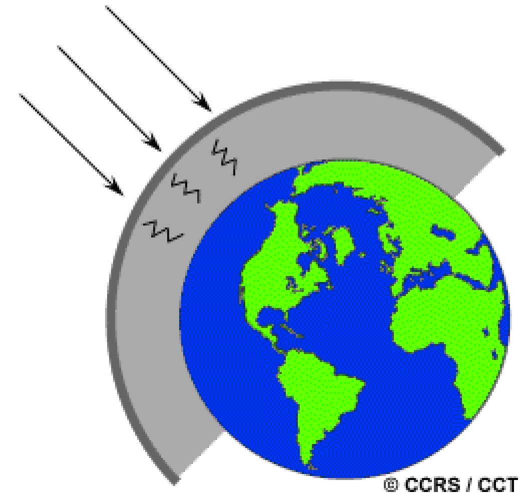
1.4 Interactions with the Atmosphere

nonselective scattering. **(particle >> wavelength)**

- when the **particles are much larger than the wavelength** of the radiation. (Water droplets and large dust particles)
- gets its name from the fact that all wavelengths are scattered about equally.
- 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).

1.4 Interactions with the Atmosphere

Absorption causes molecules in the atmosphere to absorb energy at various wavelengths. Three main atmospheric constituents which absorb radiation.



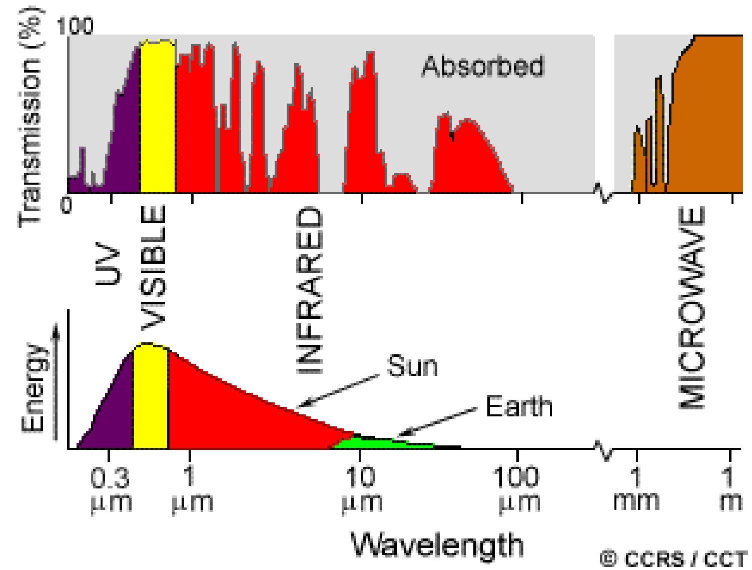
1. Ozone : absorbs the harmful (to most living things) **ultraviolet** radiation from the sun. Without this protective layer in the atmosphere our skin would burn when exposed to sunlight.

2. Carbon dioxide (greenhouse gas) : absorbs 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.

3. Water vapor : absorbs much of the incoming **longwave infrared** and **shortwave microwave** radiation (between 22 μm and 1mm). The presence of water vapor in the lower atmosphere varies greatly from location to location and at different times of the year. e.g. the air mass above a desert would have very little water vapor to absorb energy, while the tropics would have high concentrations of water vapor (i.e. high humidity).

1.4 Interactions with the Atmosphere

atmospheric windows : Because these gases absorb EM energy in very specific regions of the spectrum, they influence where we can "look" for remote sensing purposes. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.



By comparing the characteristics of the two most common energy/radiation sources (the sun and the earth) with the atmospheric windows available to us, we can define those **wavelengths that we can use most effectively for remote sensing**. The **visible portion** of the spectrum, to which our eyes are most sensitive, corresponds to both an atmospheric window and the peak energy level of the sun. Note also that heat energy emitted by the Earth corresponds to a window around **10 µm** in the **thermal IR portion** of the spectrum, while the large window at wavelengths **beyond 1 mm** is associated with the **microwave region**.

1.4 Interactions with the Atmosphere

Quiz Most remote sensing systems avoid detecting and recording wavelengths in the ultraviolet and blue portions of the spectrum. Explain why this would be the case.

ANS

1.4 Interactions with the Atmosphere

Quiz Most remote sensing systems avoid detecting and recording wavelengths in the ultraviolet and blue portions of the spectrum. Explain why this would be the case.

ANS

- **Difficult :** Detecting and recording the ultraviolet and blue wavelengths of radiation is difficult because of scattering and absorption in the atmosphere.
- **Absorption** : Ozone gas in the upper atmosphere absorbs most of the ultraviolet radiation of wavelengths shorter than about 0.25 μm.
- **Scattering** : Rayleigh scattering, which affects the shorter wavelengths more severely than longer wavelengths, causes the remaining UV radiation and the shorter visible wavelengths (i.e. blue) to be scattered much more than longer wavelengths, so that very little of this energy is able to reach and interact with the Earth's surface.

In fact, blue light is scattered about 4 times as much as red light, while UV light is scattered 16 times as much as red light!

1.4 Interactions with the Atmosphere

Quiz What do you think would be some of the best atmospheric conditions for remote sensing in the visible portion of the spectrum?

ANS

1.4 Interactions with the Atmosphere

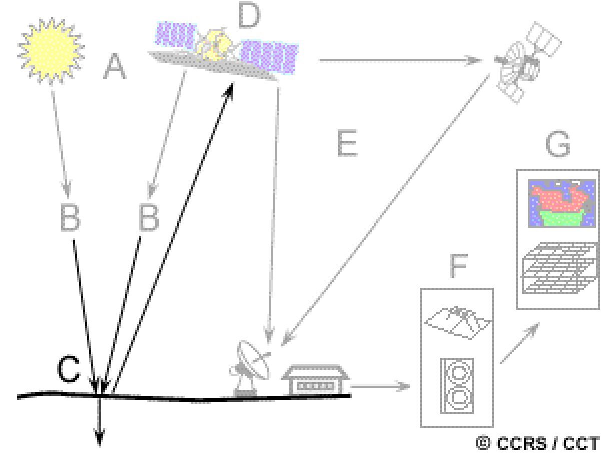
Quiz What do you think would be some of the best atmospheric conditions for remote sensing in the visible portion of the spectrum?

ANS

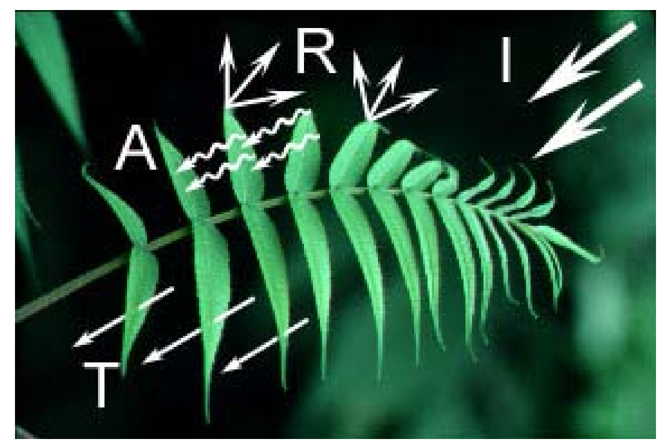
- Around *noon* on a *sunny*, *dry* day with *no clouds* and *no pollution* would be very good for remote sensing in the visible wavelengths.
- **At noo**n the sun would be at its most directly overhead point, which would reduce the distance the radiation has to travel and therefore the effects of scattering, to a minimum.
- **Cloud-free** conditions would ensure that there will be uniform illumination and that there will be no shadows from clouds.
- **Dry, pollutant-free** conditions would minimize the scattering and absorption that would take place due to water droplets and other particles in the atmosphere.

1.5 Radiation - Target Interactions

There are three (3) forms of interaction that can take place when energy is **incident (I)** upon the surface. These are **absorption (A)**, **transmission (T)** and **reflection (R)**. 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.

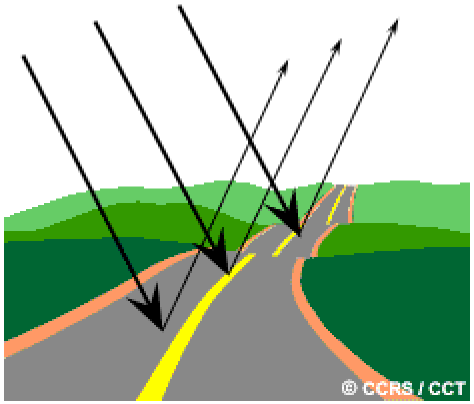


Absorption (A) : when radiation (energy) is absorbed into the target
Transmission (T) : when radiation passes through a target.
Reflection (R) : when radiation "bounces" off the target and is redirected.
➔ In remote sensing, we are most interested in measuring **the radiation reflected from targets**.



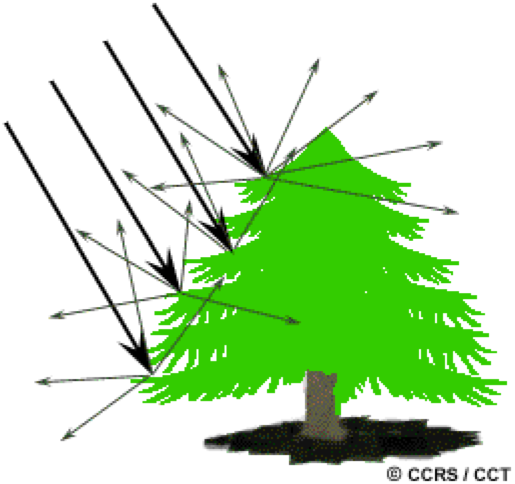
1.5 Radiation - Target Interactions

The two extreme ends of the way in which energy is reflected from a target: **specular reflection** and **diffuse reflection**.



specular (mirror-like) reflection : when a surface is **smooth** / where all (or almost all) of the energy is directed away from the surface in a single direction.

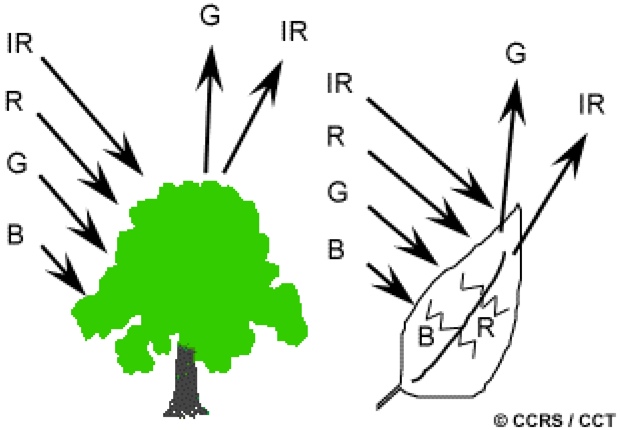
diffuse reflection : when the surface is **rough** / where the energy is reflected almost uniformly in all directions.



Most earth surface features lie somewhere between perfectly specular or perfectly diffuse reflectors. Reflection type depends on the surface roughness of the feature in comparison to the wavelength of the incoming radiation.

1.5 Radiation - Target Interactions

Examples of targets at the Earth's surface and interaction of energy at the visible and infrared wavelengths with them.
(1) Leaves and **(2) Water**



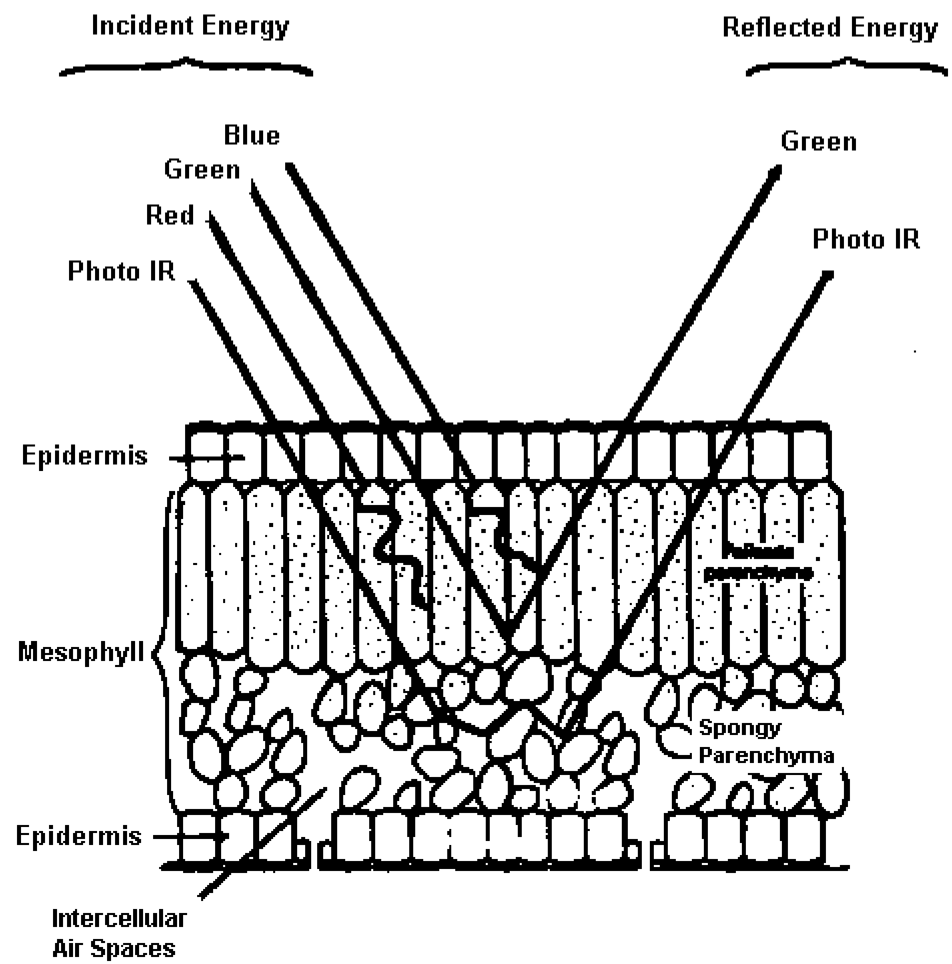
(1) Leaves

- A chemical compound in leaves called **chlorophyll** strongly *absorbs* radiation in the *red* and *blue* wavelengths but *reflects green* wavelengths.

- Leaves appear "**greenest**" to us in the summer, when chlorophyll content is at its maximum. In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear **red** or **yellow** (yellow is a combination of red and green wavelengths).

1.5 Radiation - Target Interactions

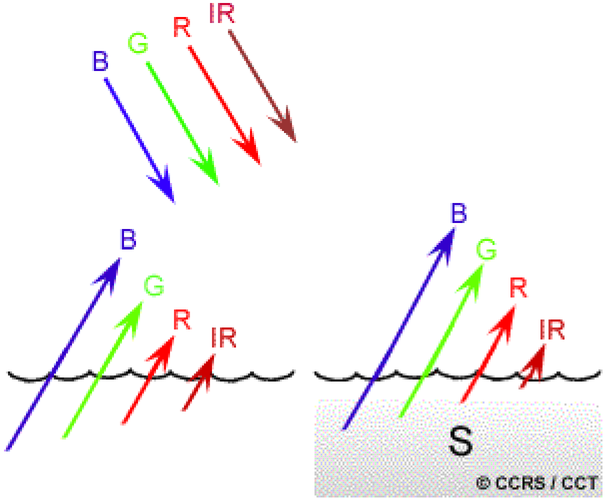
- The internal structure of healthy leaves act as **excellent diffuse reflectors of near-infrared wavelengths**. If our eyes were sensitive to near-infrared, trees would appear extremely bright to us at these wavelengths. In fact, measuring and monitoring the near-IR reflectance is one way that scientists can determine how healthy (or unhealthy) vegetation may be.



1.5 Radiation - Target Interactions

(2) Water

- Longer wavelength visible and near infrared radiation is absorbed more by water than shorter visible wavelengths. Thus water typically looks **blue** or **blue-green** due to stronger reflectance at these shorter wavelengths, and darker if viewed at red or near infrared wavelengths.

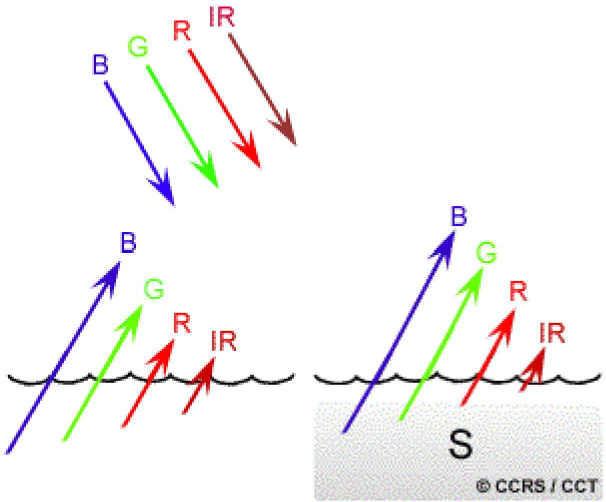


- If there is **suspended sediment** present in the upper layers of the water body, then this will allow better reflectivity and a **brighter** appearance of the water. The apparent color of the water will show a slight shift to longer wavelengths. Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar.

1.5 Radiation - Target Interactions

- **Chlorophyll in algae** absorbs more of the blue wavelengths and reflects the green, making the water appear **more green** in color when algae is present.

- The **topography of the water surface** (rough, smooth, floating materials, etc.) can also lead to complications for water-related interpretation due to potential problems of specular reflection and other influences on color and brightness.



1.5 Radiation - Target Interactions

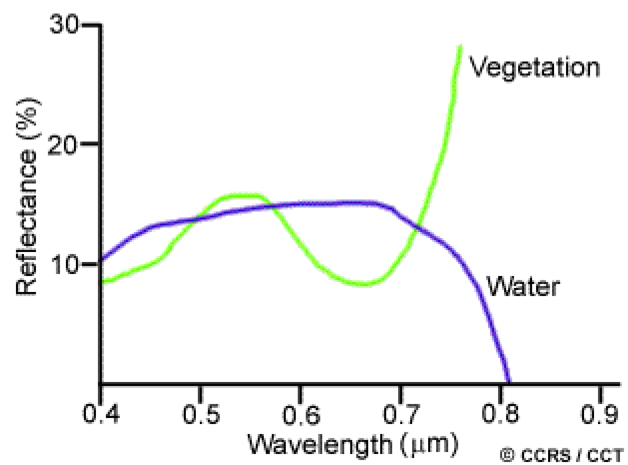
Spectral Response

- The amount of the **energy that is reflected** (or emitted) by targets on the Earth's surface **over a variety of different wavelengths**.

- By **comparing the response patterns** of different features we may be able to **distinguish** between them, where we might not be able to, if we only compared them at one wavelength.

Ex) water and vegetation may reflect somewhat similarly in the **visible** wavelengths but are almost always separable in the **infrared**.

- Knowing where to "look" spectrally and understanding the factors which influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.



1.5 Radiation - Target Interactions

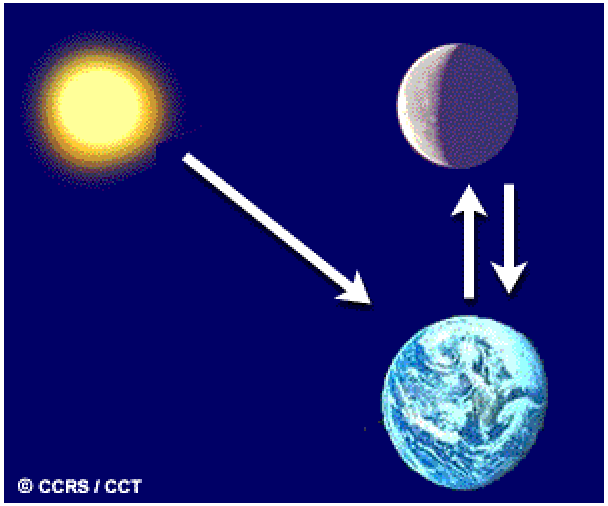
Quiz On a clear night with the crescent or half moon showing, it is possible to see the outline and perhaps very slight detail of the dark portion of the moon. Where is the light coming from, that illuminates the dark side of the moon?

ANS

1.5 Radiation - Target Interactions

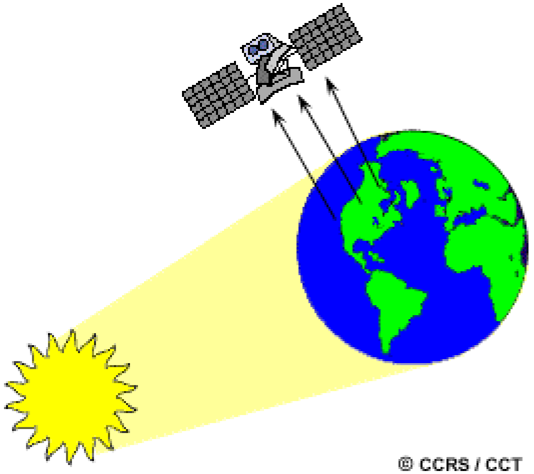
Quiz On a clear night with the crescent or half moon showing, it is possible to see the outline and perhaps very slight detail of the dark portion of the moon. Where is the light coming from, that illuminates the dark side of the moon?

ANS The light originates from the sun (of course), hits the earth, bounces up to the (dark side of the) moon and then comes back to the earth and into your eye. A long way around - isn't it?



1.6 Passive vs. Active Sensing

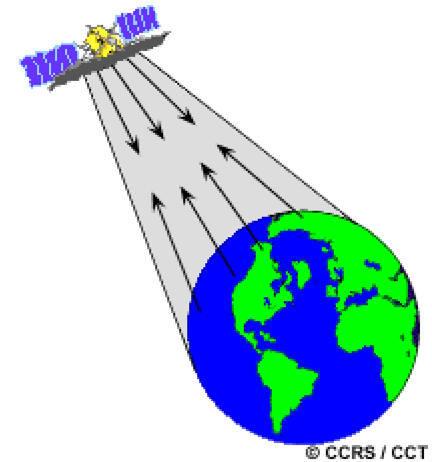
Passive sensors



- Remote sensing systems which measure energy that is naturally available (the Sun) .
- The sun's energy is either **reflected**, as it is for visible wavelengths, or absorbed and then **re-emitted**, as it is for thermal infrared wavelengths.
- 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.

1.6 Passive vs. Active Sensing

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.
- examples of active sensors : a laser fluoro sensor and a **synthetic aperture radar (SAR).**

1.7 Characteristics of Images

EM energy may be detected either **photographically** or **electronically**.

- The **photographic process** uses chemical reactions on the surface of light-sensitive film to detect and record energy variations. A **photograph** refers specifically to images that have been detected as well as recorded on **photographic film**. (e.g. The black and white photo to the right, of part of the city of Ottawa, Canada was taken in the visible part of the spectrum.)

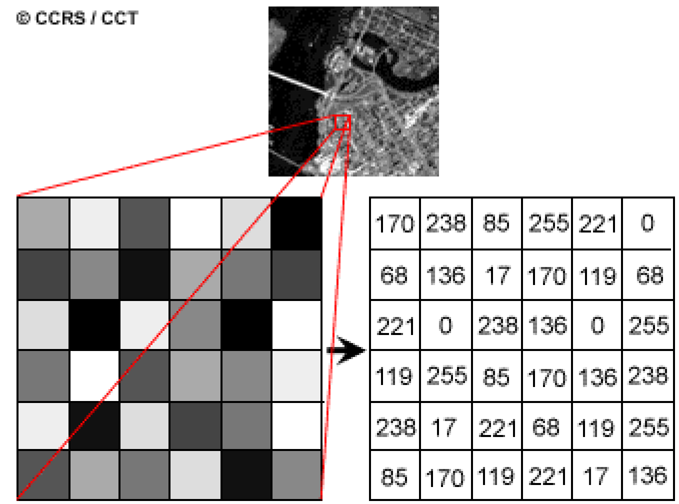
- Photos are normally recorded over the wavelength range from **0.3 μm** to **0.9 μm** (the visible and reflected infrared).

- An **image** refers to any pictorial representation, regardless of what wavelengths or remote sensing device has been used to detect and record the EM energy.

- Based on these definitions, we can say that all photographs are images, but not all images are photographs. Therefore, unless we are talking specifically about an image recorded photographically, we use the term image.

1.7 Characteristics of Images

- A photograph could also be represented and displayed in a **digital** format by subdividing the image into **pixels**, and representing the brightness of each area with a **digital number**. Indeed, that is exactly what has been done to the photo to the right. In fact, using the definitions we have just discussed, this is actually a **digital image** of the original photograph!



- The photograph was **scanned** and **subdivided into pixels** with each pixel assigned a digital number representing its relative brightness. The computer displays each digital value as different brightness levels.

- Sensors that record electromagnetic energy, electronically **record the energy as an array of numbers in digital format** right from the start.

- These two different ways of representing and displaying remote sensing data, either pictorially or digitally, are interchangeable as they convey the same information.

1.7 Characteristics of Images

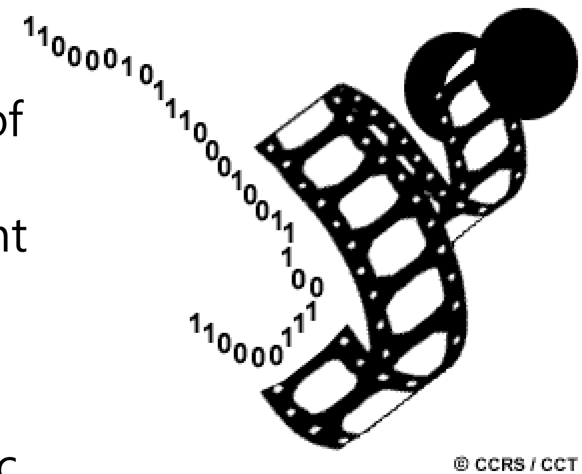
Can you imagine what the world would look like if we could only see very narrow ranges of wavelengths or colors? That is how many sensors work. The information from **a narrow wavelength range** is gathered and stored in a **channel**, also sometimes referred to as a **band**.

- **single channel display** : When we display a single channel or range of wavelengths, we are actually displaying that channel in a **black and white image**, showing various shades of gray from black to white.

- **multi-channel display** : When we display more than one channel each as a different primary color, then the brightness levels may be different for each channel/primary color combination and they will combine to form a **color image**.

1.7 Characteristics of Images

Did you know?

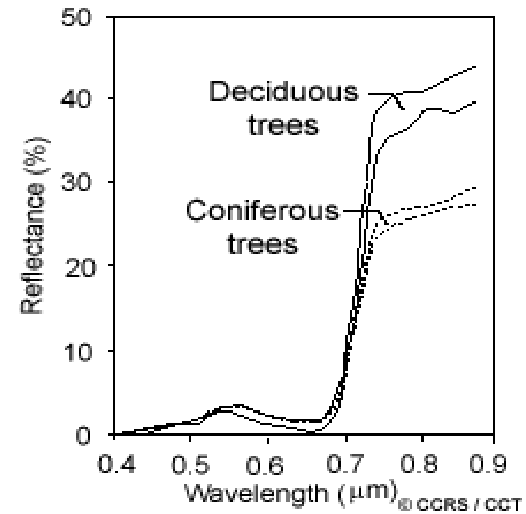


- **Photographic film** has the clear **advantage** of recording extremely **fine spatial detail**, since individual silver halide molecules can record light sensitivity differently than their neighboring molecules.

- But when it comes to spectral and radiometric qualities, **digital sensors** outperform film, by being able to use extremely **fine spectral bands** (for spectral 'fingerprinting' of targets), and recording up to **many thousands of levels of brightness**.

1.7 Characteristics of Images

Quiz 1 If you wanted to map the deciduous (e.g. maple, birch) and the coniferous (e.g. pine, fir, spruce) trees in a forest in summer using remote sensing data, what would be the best way to go about this and why? Use the reflectance curves illustrating the spectral response patterns of these two categories to help explain your answer



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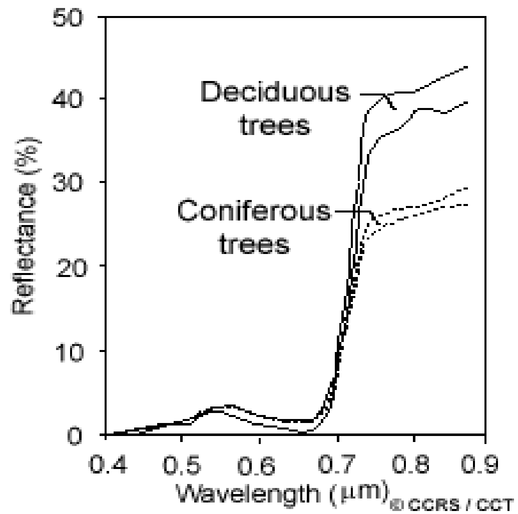

ANS

- Because both types of trees will appear as similar shades of green to the naked eye, imagery (or photography) using the **visible portion** of the spectrum may **not be useful**. Looking at the reflectance curves for the two types, it is clear that they would be **difficult to distinguish** using any of the **visible wavelengths**.
- However, in the **near-infrared**, although both types reflect a significant portion of the incident radiation, they are **clearly separable**. Thus, a remote sensing system, such as **black and white infrared film**, which detects the infrared reflectance around 0.8 μm wavelength would be ideal for this purpose.

1.7 Characteristics of Images

Quiz 2 What would be the advantage of displaying various wavelength ranges, or channels, in combination as color images as opposed to examining each of the images individually?

ANS

1.7 Characteristics of Images

Quiz 2 What would be the advantage of displaying various wavelength ranges, or channels, in combination as color images as opposed to examining each of the images individually?

ANS

- By combining different channels of imagery representing different wavelengths, we may **be able to identify combinations of reflectance** between the different channels which highlight features that we would not otherwise be able to see, if we examine only one channel at a time.
- Additionally, these combinations may manifest themselves as **subtle variations in color (which our eyes are more sensitive to),** rather than variations in gray tone, as would be seen when examining only one image at a time.