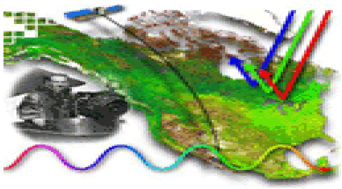


Section-3

(1-3) Interactions with the Atmosphere

Before radiation used for remote sensing reaches the Earth's surface, it has to travel through 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.

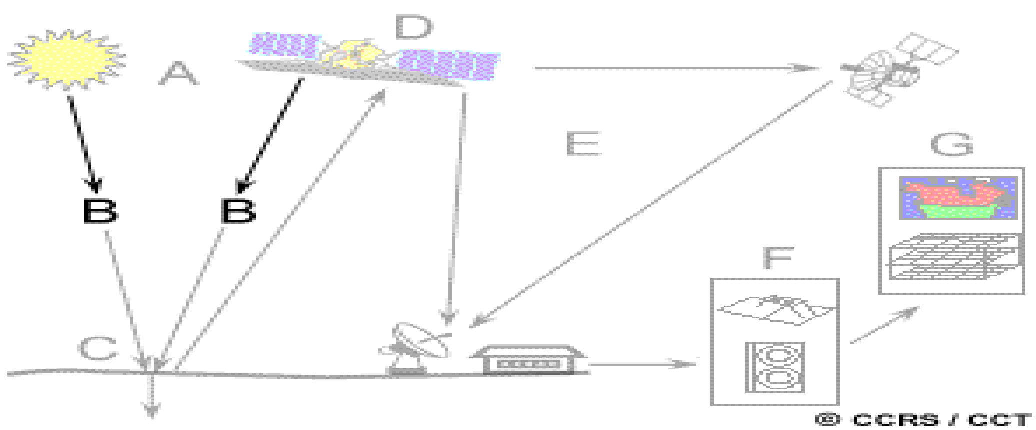
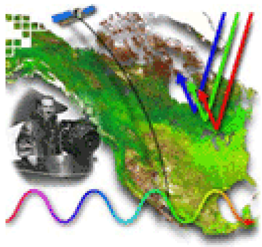


Fig. (1-3-1) Interactions of radiation with the Atmosphere

(1-3-1) 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 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 take place.



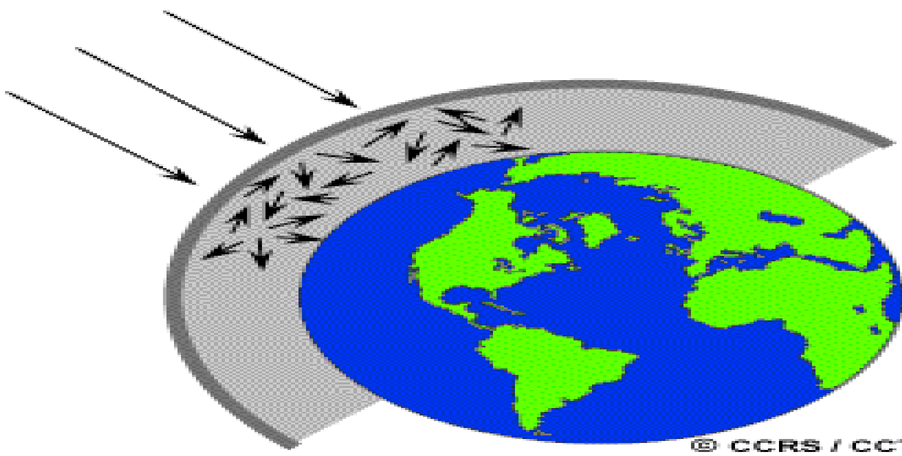


Fig. (1-3-2) The scattering

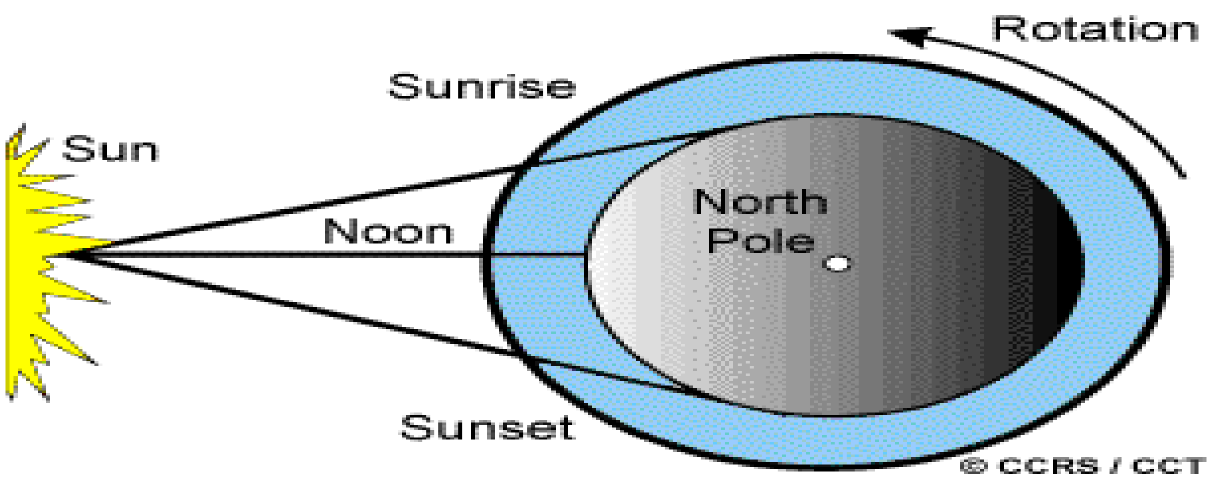
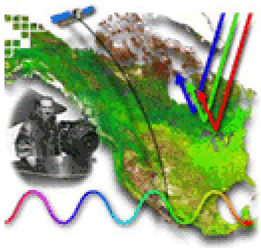


Fig. (1-3-3) The Sunrise and Sunset



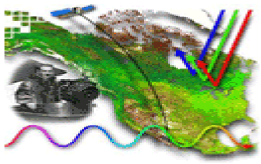
(1-3-1a) Rayleigh scattering occurs when particles are very small compared to the wavelength of the radiation. These could be particles such as specks of dust or nitrogen and oxygen molecules. Rayleigh scattering causes shorter wavelengths of energy to be scattered much more than longer wavelengths. 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.

(1-3-1b) 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 it dominates when cloud conditions are overcast.

(1-3-1c) 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 light = white light).

Fig. (1-3-4) nonselective scattering



(1-3-2) 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 that absorb radiation.

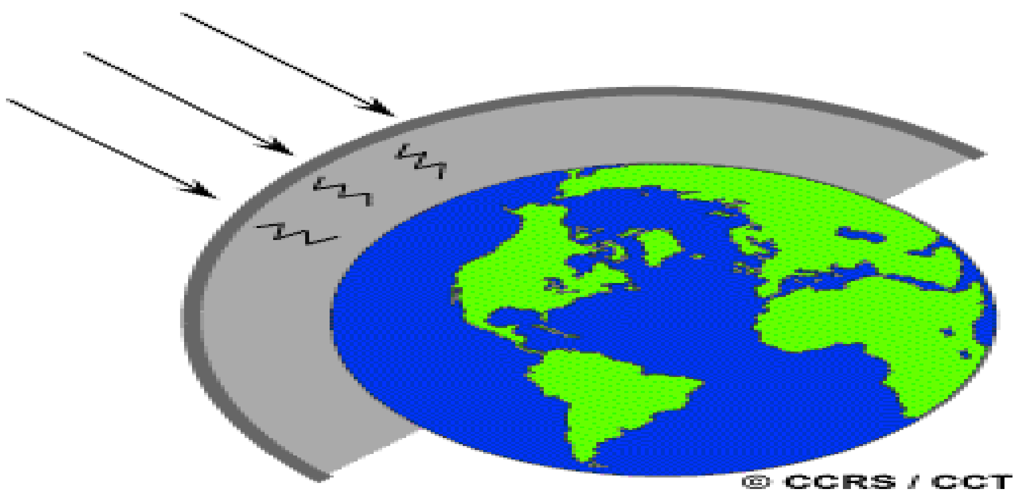
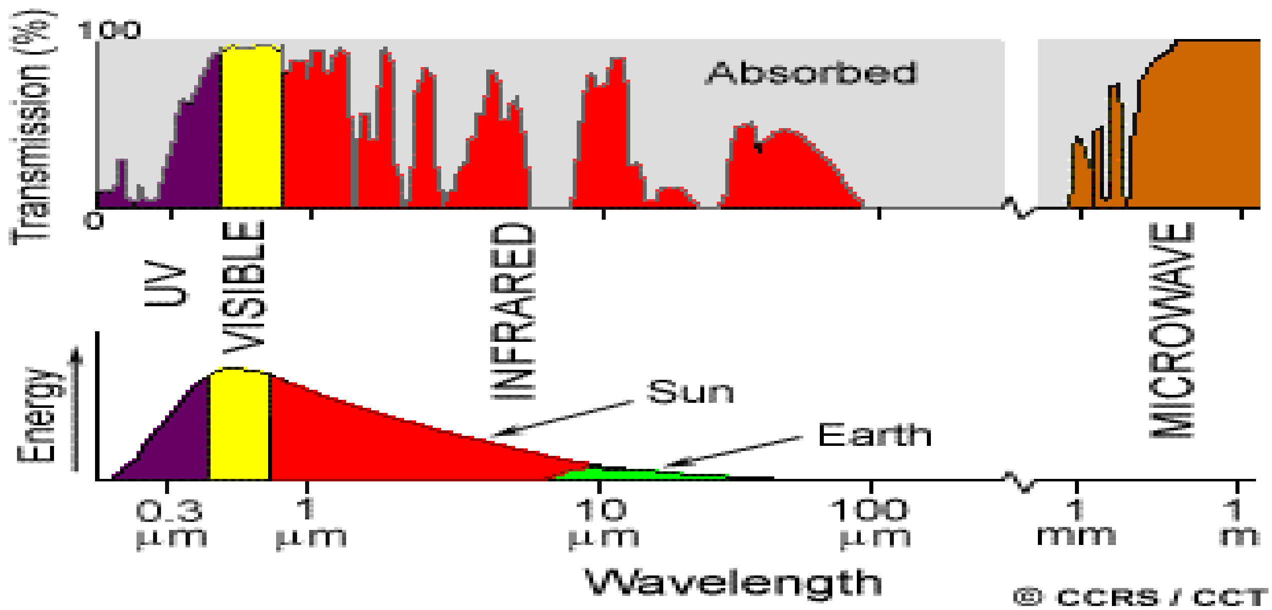


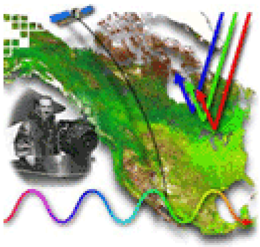
Fig. (1-3-4) Absorption mechanism

Ozone serves to absorb 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.

You may have heard carbon dioxide referred to as a greenhouse gas. This is because it tends to absorb radiation strongly in the far infrared portion of the spectrum - that area associated with thermal

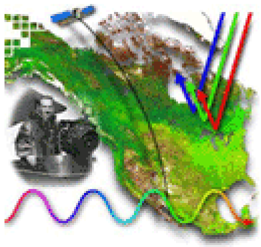
heating - which serves to trap this heat inside the atmosphere. Water vapour in the atmosphere absorbs much of the incoming long-wave infrared and short-wave microwave radiation (between 22µm and 1m). The presence of water vapour in the lower atmosphere varies greatly from location to location and at different times of the year. For example, the air mass above a desert would have very little water vapour to absorb energy, while the tropics would have high concentrations of water vapour (i.e. high humidity).





Because these 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 that 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.

Now that we understand how electromagnetic energy makes its journey from its source to the surface (and it is a difficult journey, as you can see), we will discuss in the next section what happens to that radiation when it does arrive at the Earth's surface.?



Section-4

(1-4) RADIATION - TARGET INTERACTIONS

Radiation that is not absorbed or scattered in

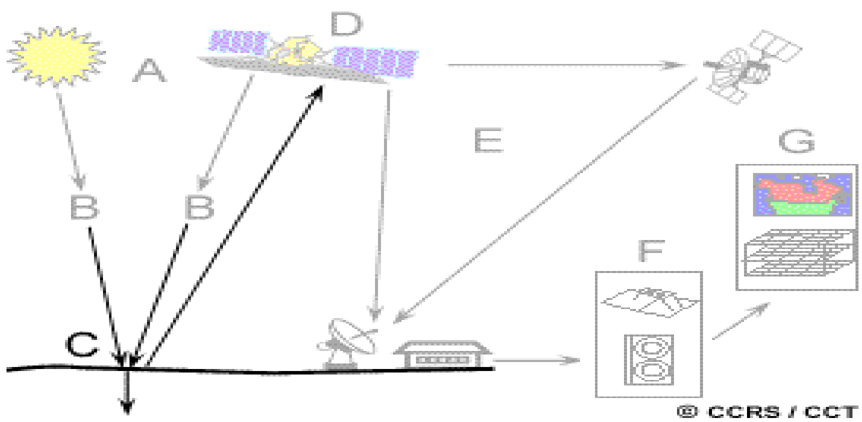
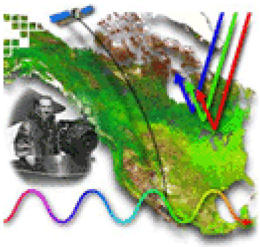


Fig. (1-4-1) RADIATION - Target Interactions

The atmosphere can reach and interact with the Earth's surface. Three (3) forms of interaction can take place when energy strikes, or 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.



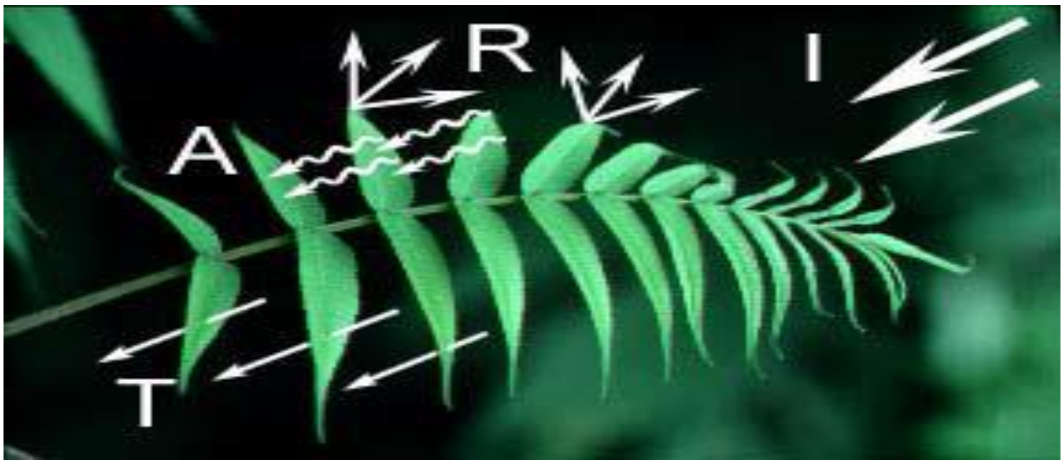
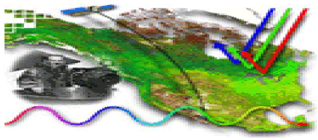


Fig. (1-4-2) Three forms of Radiation - Target Interactions

Absorption (A) occurs when radiation (energy) is absorbed into the target, while transmission (T) occurs when radiation passes through a target. Reflection (R) occurs when radiation "bounces" off the target and is redirected. 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 reflection.



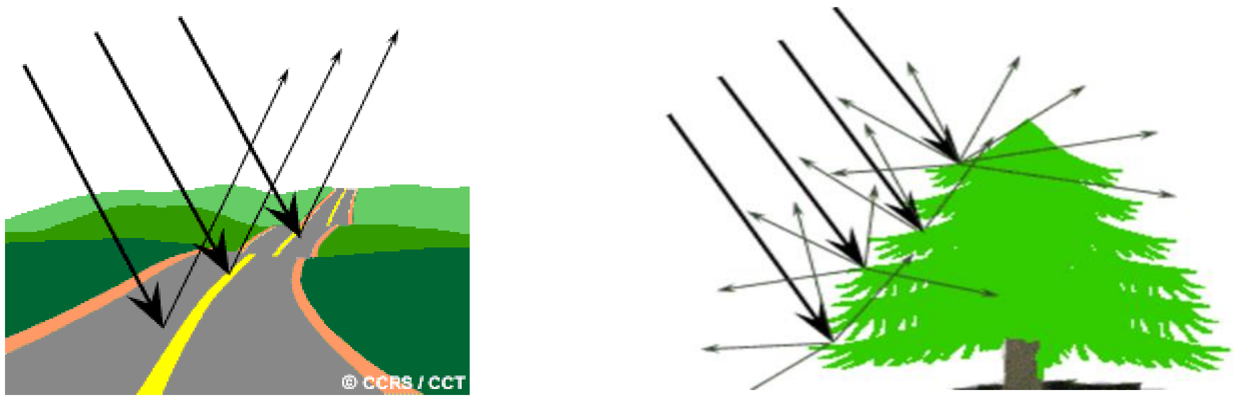
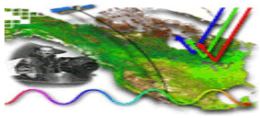


Fig. (1-4-3) Specular or mirror and Diffuse reflection

When a surface is smooth, we get a specular or mirror-like reflection where all (or almost 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. Most earth surface features lie somewhere between perfectly specular and perfectly diffuse reflectors. Whether a particular target reflects specularly or diffusely, or somewhere in between, depends on the surface roughness of the feature in comparison to the wavelength of the incoming radiation. If the wavelengths are much smaller than the surface variations or the particle sizes that make up the surface, diffuse reflection will dominate. For example, fine-grained sand would appear fairly smooth to long-wavelength microwaves but would appear quite rough to the visible wavelengths.



Let's take a look at a couple of examples of targets at the Earth's surface and how energy at the visible and infrared wavelengths interacts with them.

(1-4-1) 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). The internal structure of healthy leaves acts as an excellent diffuse reflector 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.**

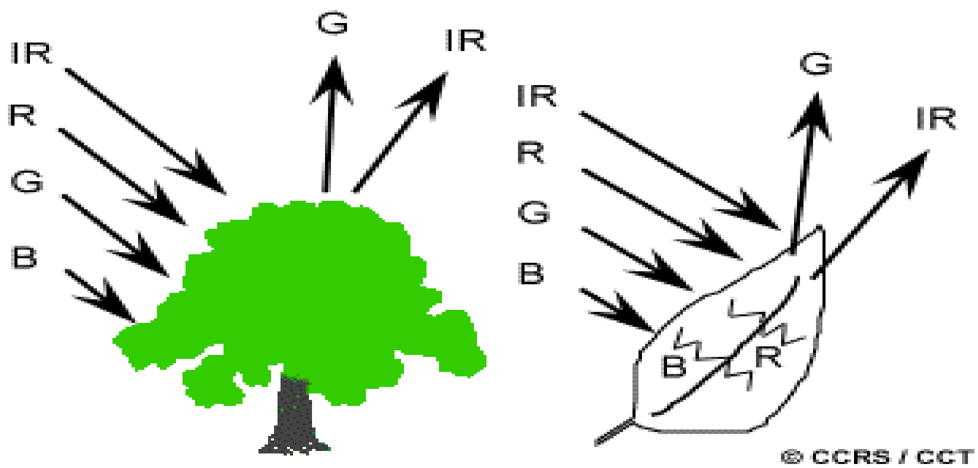
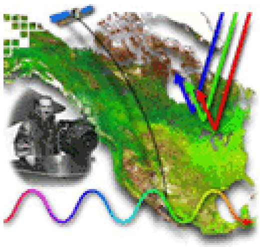


Fig. (1-4-4) Reflectance of Leaves



(1-4-2) 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 colour of the water will show a slight shift to longer wavelengths.

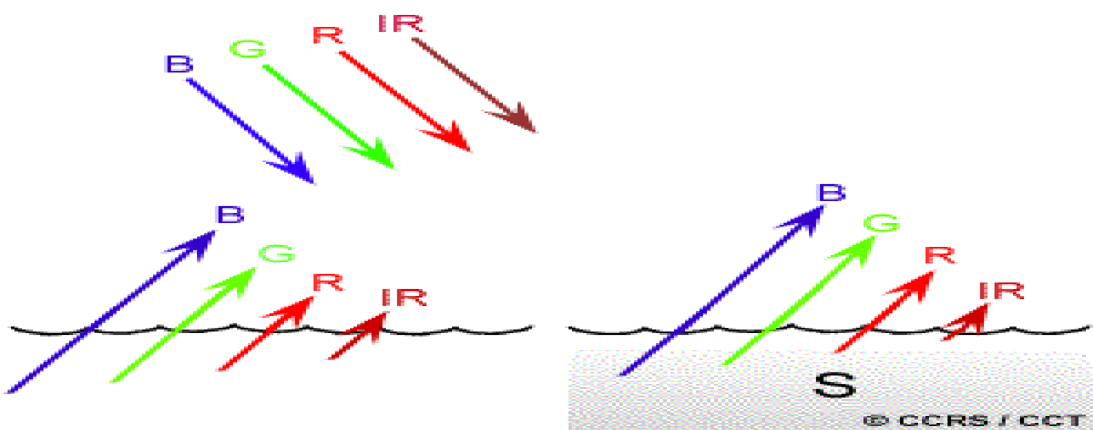
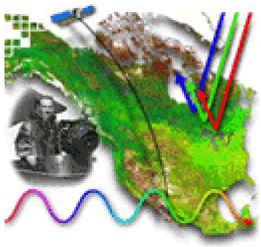


Fig. (1-4-5) Reflectance of Water



Suspended sediment (S) can be easily confused with shallow (but clear) water, since these two phenomena appear very similar. Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear greener in colour 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 colour and brightness.

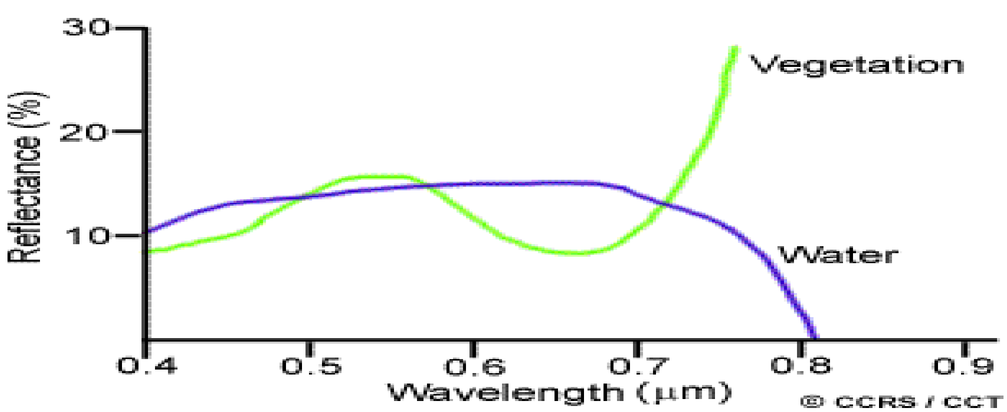
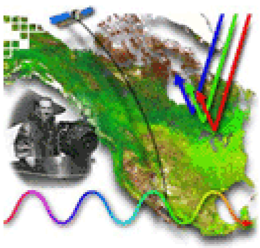
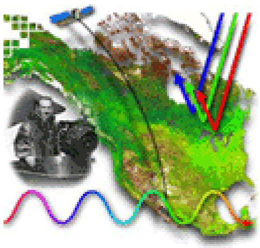


Fig. (1-4-6) Scheme of Reflectance with wavelength



We can see from these examples that, depending on the complex make-up of the target that is being looked at, and the wavelengths of radiation involved, we can observe very different responses to the mechanisms of absorption, transmission, and reflection. By measuring the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths, we can build up a spectral response for that object. 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. For example, water and vegetation may reflect somewhat similarly in the visible wavelengths, but are almost always separable in the infrared. Spectral response can be quite variable, even for the same target type, and can also vary with time (e.g., "green-ness" of leaves) and location. Knowing where to "look" spectrally and understanding the factors that influence the spectral response of the features of interest are critical to correctly interpreting the interaction of electromagnetic radiation with the surface.

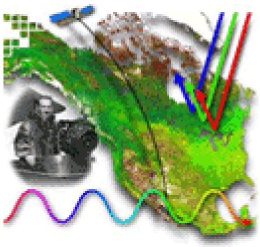


Section-5

(1-5) CHARACTERISTICS OF IMAGES

Before we go on to the next chapter, which looks in more detail at sensors and their characteristics, we need to define and understand a few fundamental terms and concepts associated with remote sensing images.

Electromagnetic 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. It is important to distinguish between the terms' images and photographs in remote sensing.



An image refers to any pictorial representation, regardless of what wavelengths or remote sensing device has been used to detect and record the electromagnetic energy. A photograph refers specifically to images that have been detected and recorded on photographic film. The black and white photo to the left, 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. 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.

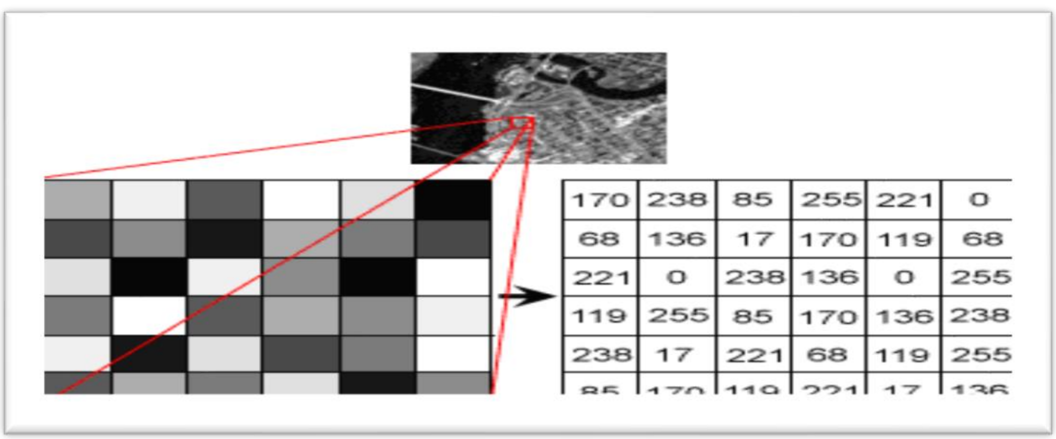
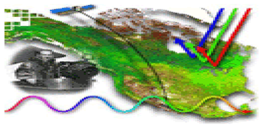


Fig. (1-5-1) The black and white photo of part of the city of Ottawa, Canada.

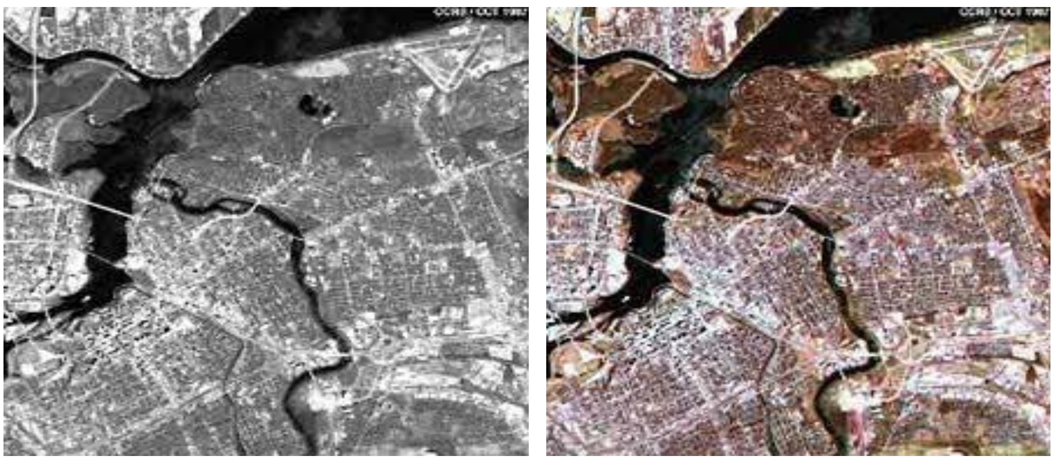


A photograph could also be represented and displayed in a digital format by subdividing the image into small, equal-sized and shaped areas, called picture elements or pixels, and representing the brightness of each area with a numeric value or digital number. Indeed, that is exactly what has been done to the photo to the left. 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 in 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 (although some detail may be lost when converting back and forth).

In previous sections, we described the visible portion of the spectrum and the concept of colours. We see color because our eyes detect the entire visible range of wavelengths, and our brains process the information into separate colors. 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. We can combine and display channels of information digitally using the three primary colours (blue, green, and red). The data from each channel is represented

as one of the primary colors and, depending on the relative brightness (i.e., the digital value) of each pixel in each channel, the primary colors combine in different proportions to represent different colors.



When we use this method to display a single channel or a range of wavelengths, we are actually showing that channel through all three primary colors. Because the brightness level of each pixel is the same for each primary color, they combine to form a black and white image, showing various shades of grey from black to white.

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