Ch-1- Introduction to Remote Sensing

Inst. Biruk G. (MSc)
March 2020

Introduction

- Earth Observation is the gathering of information about planet Earth's physical, chemical and biological systems via remote sensing technologies supplemented by earth surveying techniques, encompassing the collection, analysis and presentation of data.

Introduction

The nine societal benefit areas of RS

- Natural and human-induced **disasters**;
- Environmental factors affecting **human health and well-being**;
- Improving the management of **energy resources**;
- Understanding, assessing, predicting, mitigating, and adapting to **climate variability and change**;

Introduction

- Improving **water resource management** through better understanding of the water cycle;
- Improving **weather** information, forecasting and warning;
- Improving the management and protection of terrestrial, coastal and marine **ecosystems**;
- Supporting sustainable **agriculture** and combating **desertification**;
- Understanding, monitoring and conserving **biodiversity**.

Introduction

Remote Sensing:

- Art, science and technology of observing an object, scene or phenomenon by instrument-based techniques without physical contact
- Remote sensing is the observation of an object from a distance.
- This is done by sensing and recording ***reflected or emitted*** energy and processing, analyzing, and applying that information.
- Examples are Aerial Photography and the use of satellites to observe the Earth.

Introduction

Key Words While defining RS

- Information is collected by a **device (sensor)** that is not in contact with the objects being measured.
- Information transfer is accomplished by use of **electromagnetic radiation** (EMR).
- Concerned not only with data collection but also extracting information via different techniques.

Q#1

- **Which humans sense organ is remote sensor and which is not?**

Introduction

Why Earth Observation (EO) by RS

- Synoptic view- observations that give a broad view of a subject at a particular time.
- Large areas, dense data
- Synergy with in situ measurements
- High repeatability (temporal resolution)
- Global, inaccessible/secure areas
- Multi purpose
- Cost effective (can be)
- Data collection without disturbance

Introduction: History of RS

- 1826 The invention of photography
- 1850's Photography from balloons
- 1873 Theory of electromagnetic energy by J. C. Maxwell
- 1909 Photography from airplanes
- 1910's World War I: aerial reconnaissance
- 1920's Development and applications of aerial photography and photogrammetry
- 1930's Development of radar in Germany, USA, and UK
- 1940's World War II: application of Infrared and microwave regions
- 1950's Military Research and Development

Introduction: History of RS

- 1960’s The satellite era: Space race between USA and USSR.
- 1960 The first meteorological satellite (TIROS-1)
- 1960’s First use of term “remote sensing”
- 1960’s Skylab remote sensing observations from the space
- 1972 Launch of the first earth resource satellite (Landsat-1)
- 1970’s Rapid advances in digital image processing
- 1980’s Landsat-4: new generation of Landsat sensors
- 1986 Launch of French earth observation satellite (SPOT-1)
- 1980’s Development of hyperspectral sensors
- 1990’s Launch of earth resource satellites by national space agencies and commercial companies

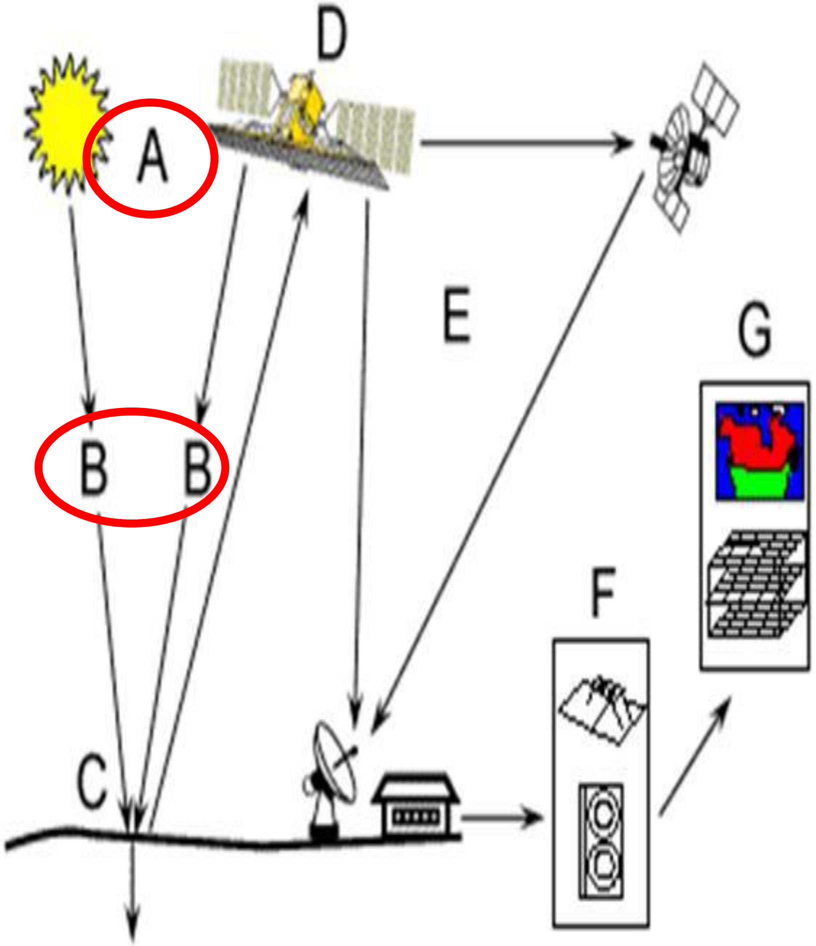
Major Components Remote Sensing Technology

- **Energy Source**
  - Passive System: sun, irradiance from earth's materials;
  - Active System: irradiance from artificially generated energy sources such as radar.
- **Platforms**: (Vehicle to carry the sensor) (truck, aircraft, space shuttle, satellite, etc.)
- **Sensors**: (Device to detect electro-magnetic radiation) (camera, scanner, etc.)
- **Detectors**: (Handling signal data) (photographic, digital, etc.)
- **Processing**: (Handling Signal data) (photographic, digital etc.)
- **Institutionalization**: (Organization for execution at all stages of remote-sensing technology: international and national organizations, centers, universities, etc.).

Remote Sensing Process

Energy Source or Illumination (A) –the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

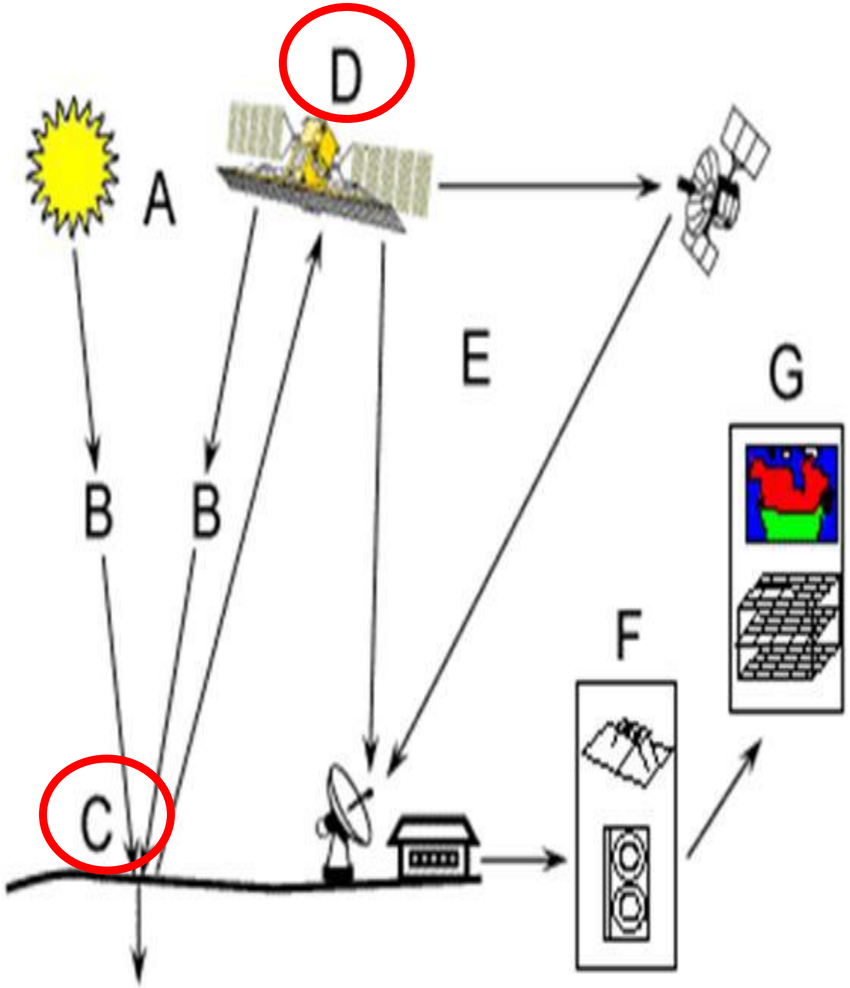
Radiation and the Atmosphere (B) – as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.



Remote Sensing Process

Interaction with the Target (C) - 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.

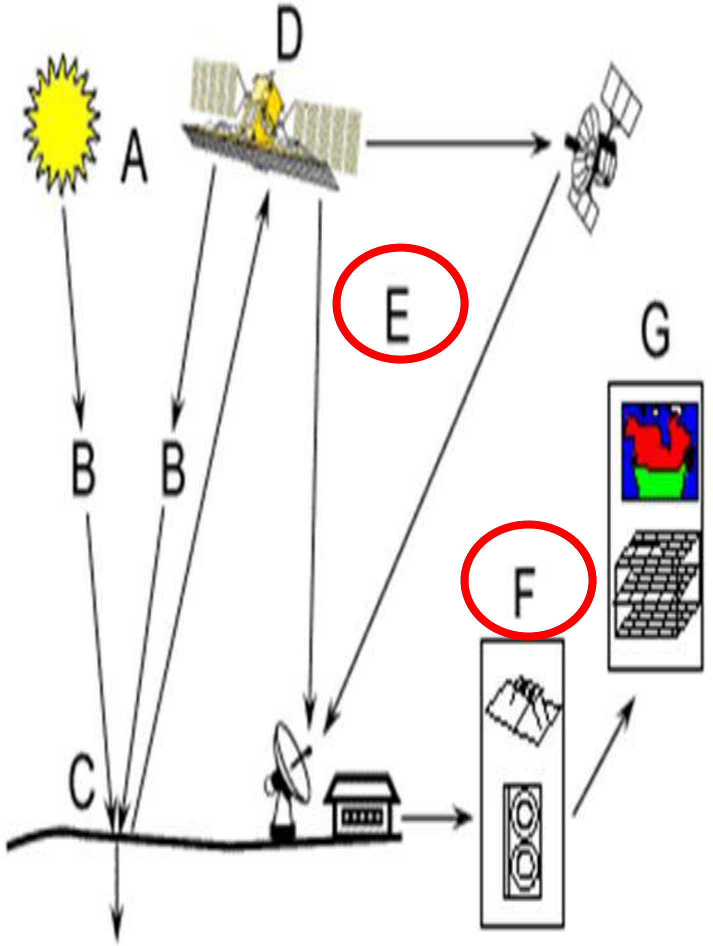
Recording of Energy by the Sensor (D) - after the energy has been *scattered by*, or *emitted from the target,* we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation



Remote Sensing Process

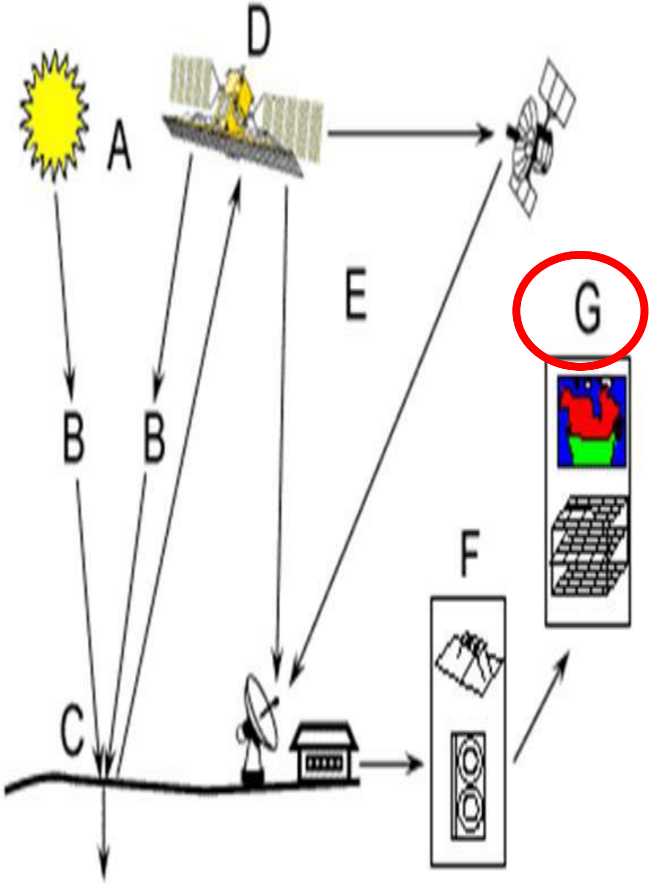
Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, *to a receiving and processing station* where the data are *processed into an image (hardcopy and/or digital).*

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

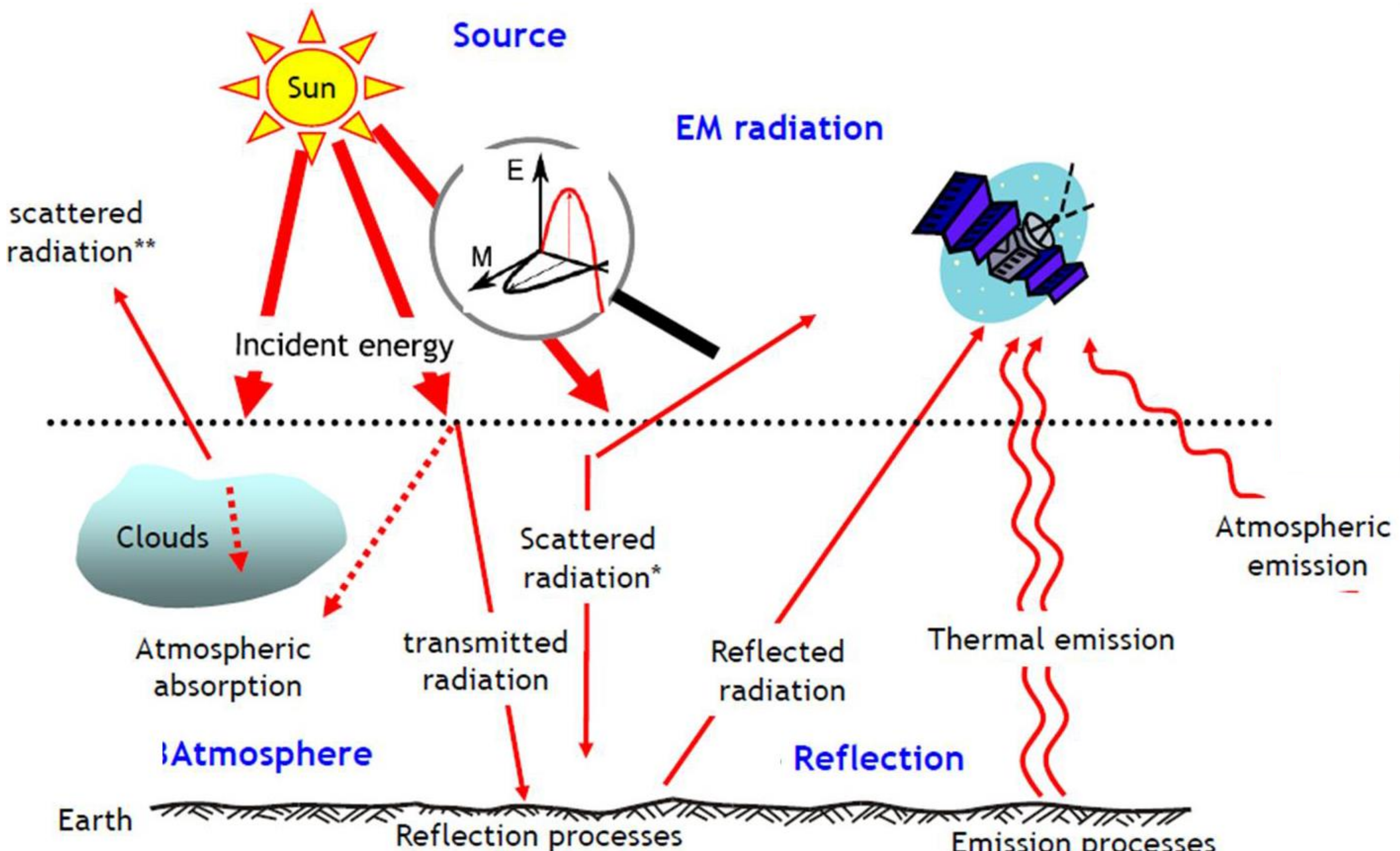


Remote Sensing Process

Application (G) - 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.*



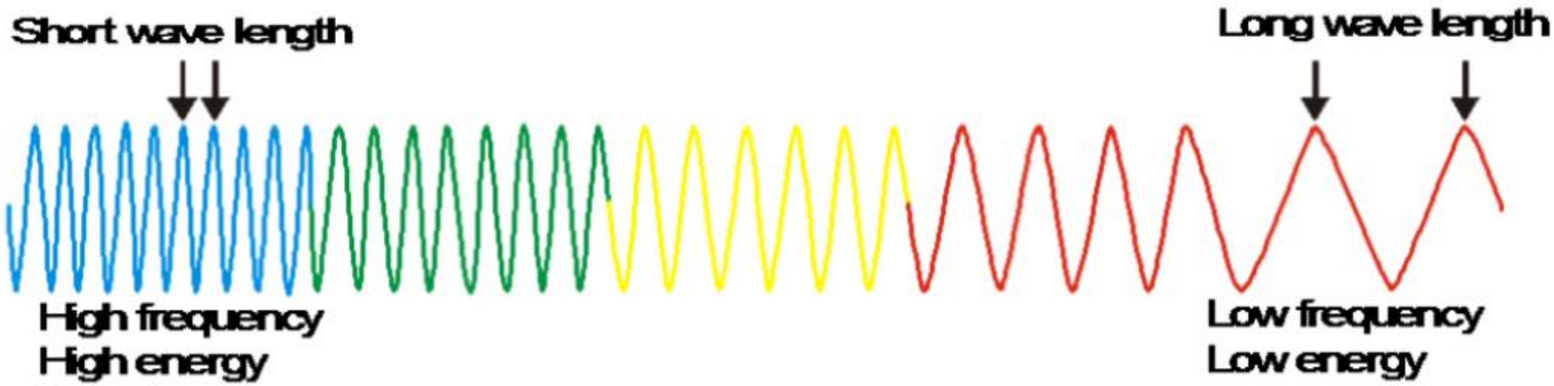
Remote Sensing Process, EMR

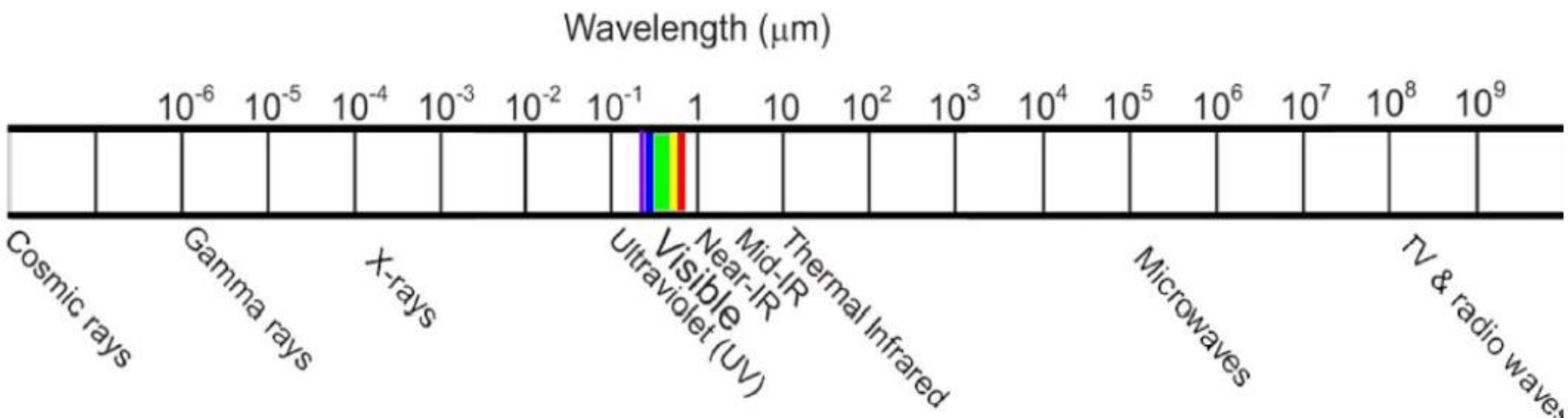


Electromagnetic radiation

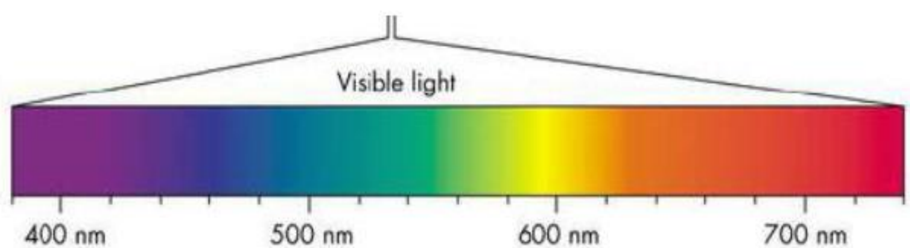
- EMR is a form of energy that reveals its presence by the ***observable effects it produces when it strikes the matter***.
- The sun is the most obvious source of EMR for remote sensing,
- Light is Electromagnetic (EM) radiation
- Electromagnetic energy can be discussed in terms of its energy distribution, or the spread of energy over a range of wavelengths.

- This distribution of energy is also known as the spectral distribution.
- EM-Spectrum is the entire range of wavelengths of electromagnetic radiation.
- The **electromagnetic spectrum** extends from below the low frequencies used for modern **radio** communication to gamma radiation at the short-wavelength (high-frequency)
- ***Most sensors operate in the visible, infrared, and microwave regions of the spectrum.***

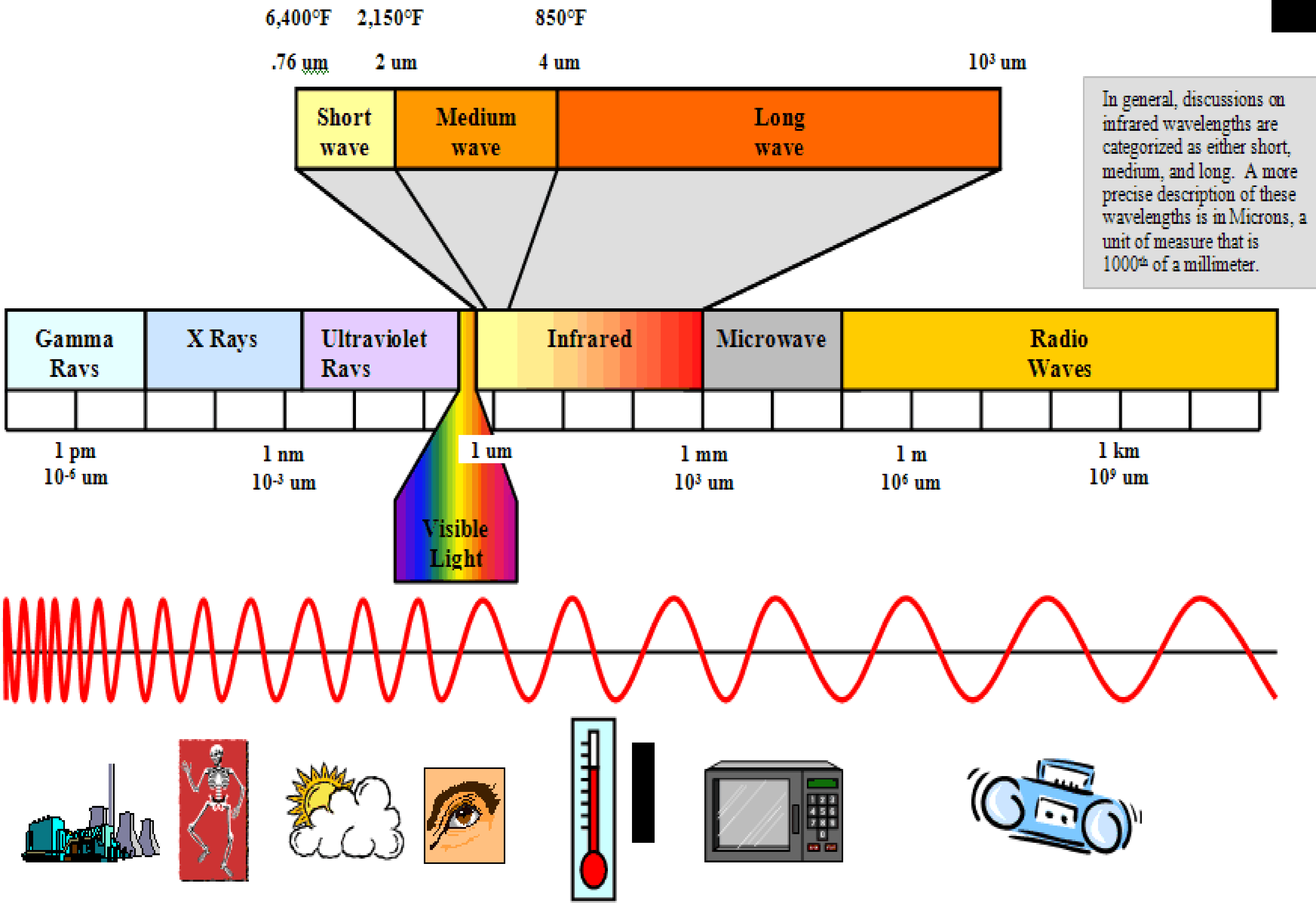




Violet: 0.4 00 - 0.446 mm
Blue: 0.446 - 0.500 mm
Green: 0.500 - 0.578 mm
Yellow: 0.578 - 0.592 mm
Orange: 0.592 - 0.620 mm
Red: 0.620 - 0.700 mm



[redacted]

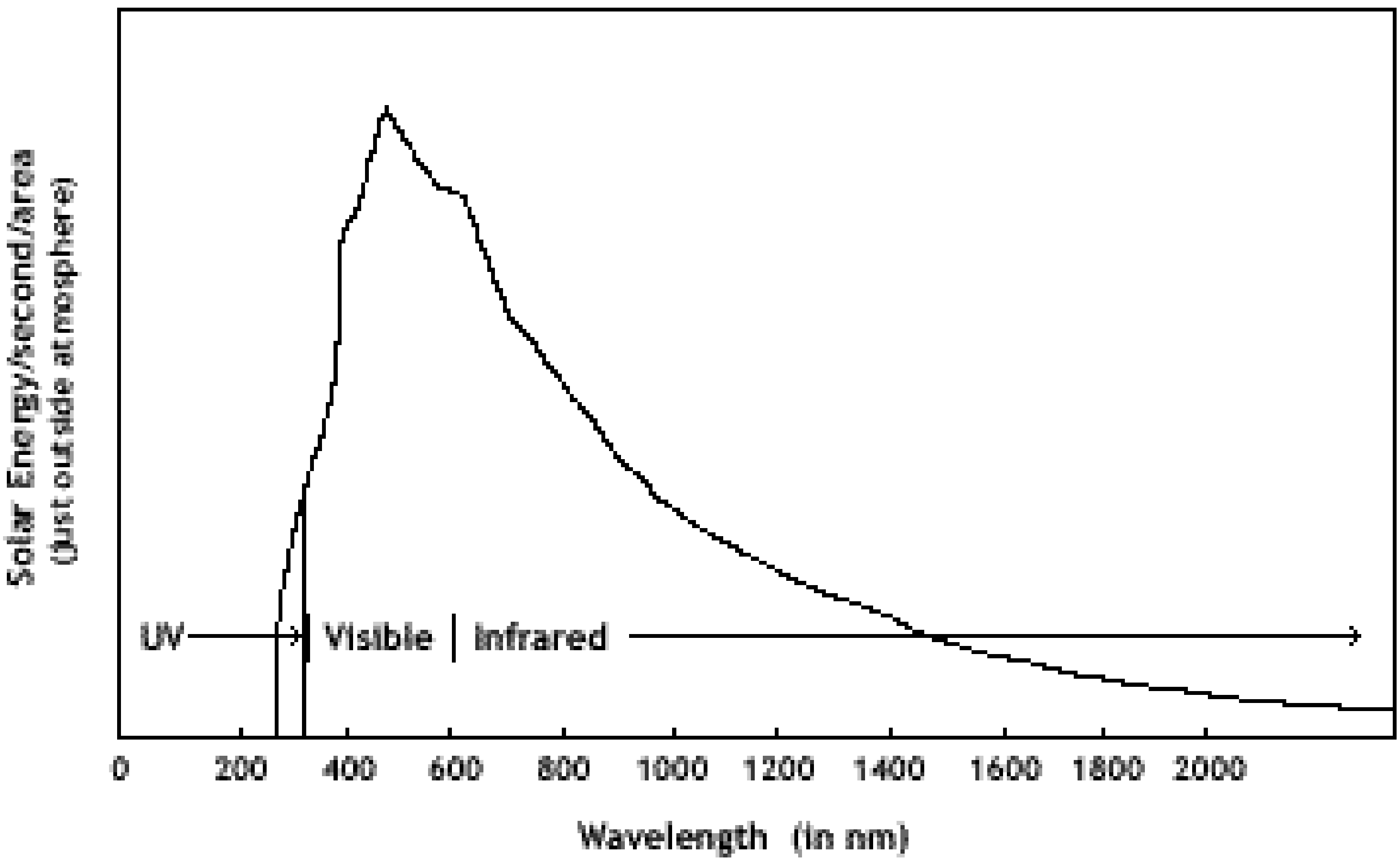


6,400°F
2,150°F
850°F
.76 um
2 um
4 um
10³ um
Short wave
Medium wave
Long wave
In general, discussions on infrared wavelengths are categorized as either short, medium, and long. A more precise description of these wavelengths is in Microns, a unit of measure that is 1000th of a millimeter.
Gamma Rays
X Rays
Ultraviolet Rays
Infrared
Microwave
Radio Waves
1 pm
10-6 um
1 nm
10-3 um
1 um
1 mm
10³ um
1 m
10⁶ um
1 km
10⁹ um
Visible Light

Solar Spectrum

- The range of electromagnetic energy emitted by the sun is known as the **solar spectrum**, and lies mainly in three regions:
  - ultraviolet,
  - visible, and
  - infrared.
- The solar spectrum extends from about 0.29 μm (or 290 nm) in the longer wavelengths of the ultraviolet region, to over 3.2 μm (3,200 nm) in the far infrared.

Solar spectrum



Ultraviolet:

- Has short wavelengths (0.3 to 0.4 μm) and high frequency.
- Used in geologic and atmospheric science applications (tracking changes in the ozone layer).

Visible Light

- Radiation detected by human eyes.
- The only portion of the spectrum that can be perceived as colors.
- Ranges from approximately 0.4 to 0.7μm.
- Applicable in manmade and natural feature identification and study.

Infrared:

- Ranges from approximately 0.7 to 1000 µm.
- It is 100 times as wide as the visible portion.
- Based on their radiation properties, IR can be the *reflected* IR (0.7 to 3.0 µm) and the emitted or *thermal* IR (3.0 to 1000 µm)

Reflected Infrared

- Shares radiation properties exhibited by the visible portion.
- Valuable for delineating healthy verses unhealthy or fallow vegetation, and
- For distinguishing among vegetation, soil, and rocks.

Thermal Infrared

- Radiation that is emitted from the Earth's surface in the form of thermal energy.
- Useful for monitoring temperature variations in land, water and ice

Microwave

- Ranging on the spectrum from 1000µm to 1 m.
- The longest wavelength used for remote sensing.
- Used in the studies of ***meteorology, hydrology, oceans, geology, agriculture, forest and ice and for topographic mapping.***
- Microwave emission is influenced by moisture content, it is useful ***for mapping soil moisture, sea ice, currents, and surface winds.***

Examples:

Different molecules absorb different regions of electromagnetic energy preferentially.

Water molecule preferentially ***absorbs certain wavelengths in the microwave region*** of the electromagnetic spectrum. This preference is the basis of the efficient cooking of food by microwave ovens.

Calcium, a primary constituent of bones, ***absorbs energy in the x-ray region*** more strongly than do the water or carbon in the cells of ordinary tissue, allowing for the use of x-rays to generate images that show unevenness such as broken bones or tumors.

The chlorophyll molecule in green plants absorbs mostly ***ultraviolet*** (and also some blue violet, and red light) and uses this energy for photosynthesis. Most of the green light in sunlight is reflected by leaves, making them appear green to our eyes.

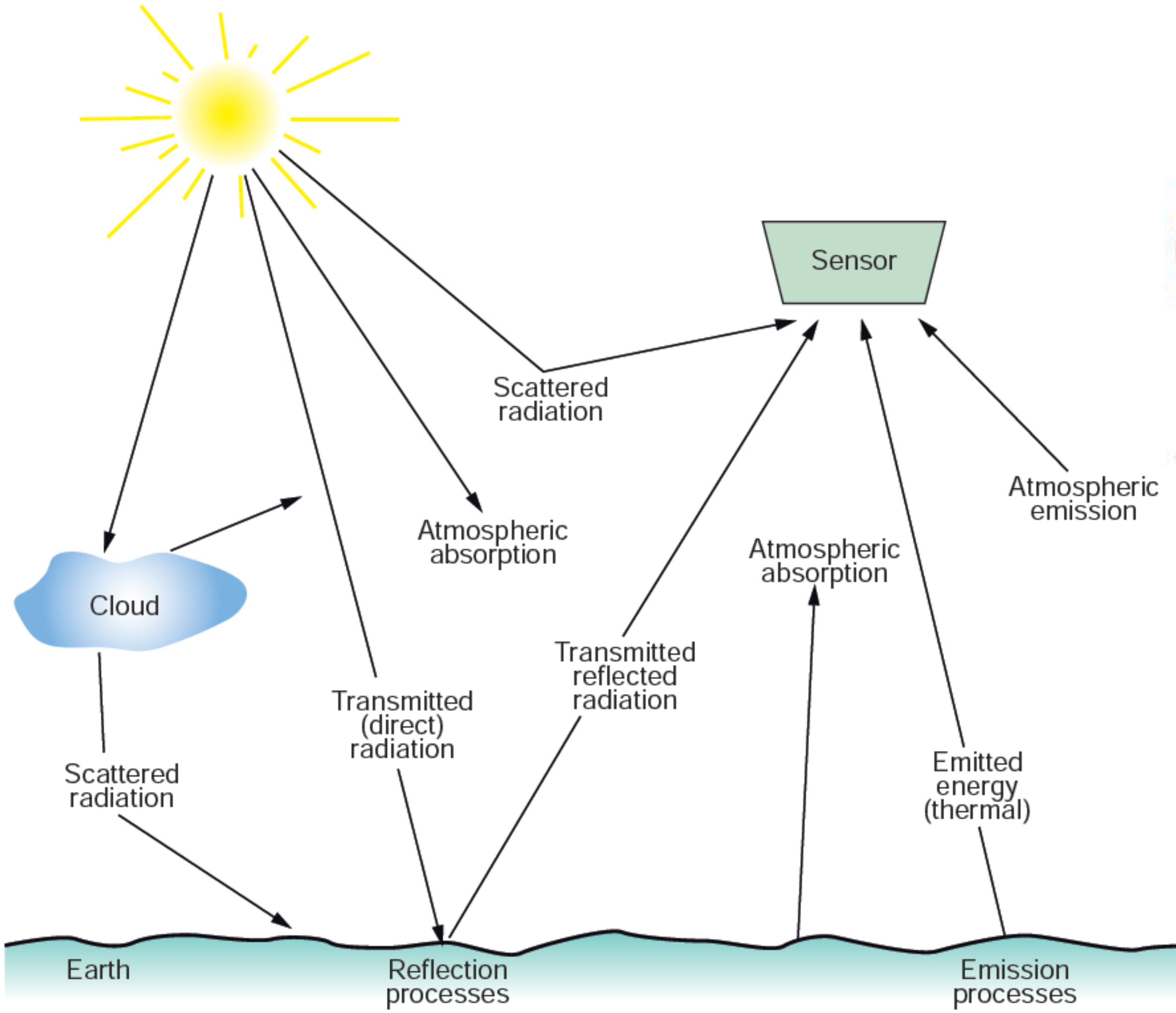
Interaction

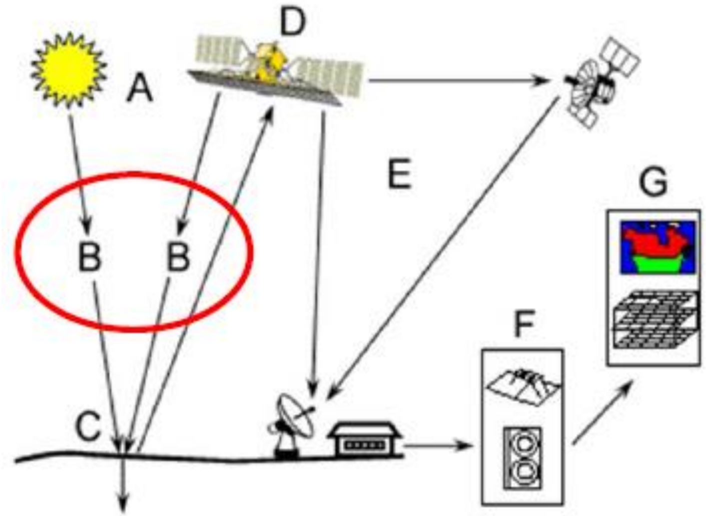
- The interaction could be surface and/or volume phenomena.
- The surface and volume interactions with matter can produce a number of changes in the incident EMR:
  - magnitude,
  - direction,
  - wavelength,
  - polarization and phase.
- RS technology detects and records these changes.
- The resulting images and data are ***interpreted to identify remotely the characteristics of the matter that produced the changes in the recorded EMR.***

A. EM Interaction with Atmosphere

- **Absorption, transmission, and scattering.**
- The transmitted radiation is then either absorbed by the surface material or reflected.
- The **reflected** radiation is also subject to scattering and absorption in the atmosphere before reaching a remote sensor
- **Gases** mainly absorb EM energy
  - known concentrations and location enable to predict influence
- **Aerosols** mainly scatter EM energy
  - variable and difficult to model (human and natural changing influence)
- Either way sensor sense less than what reached the Earth's atmosphere

A. EM Interaction with Atmosphere…contd





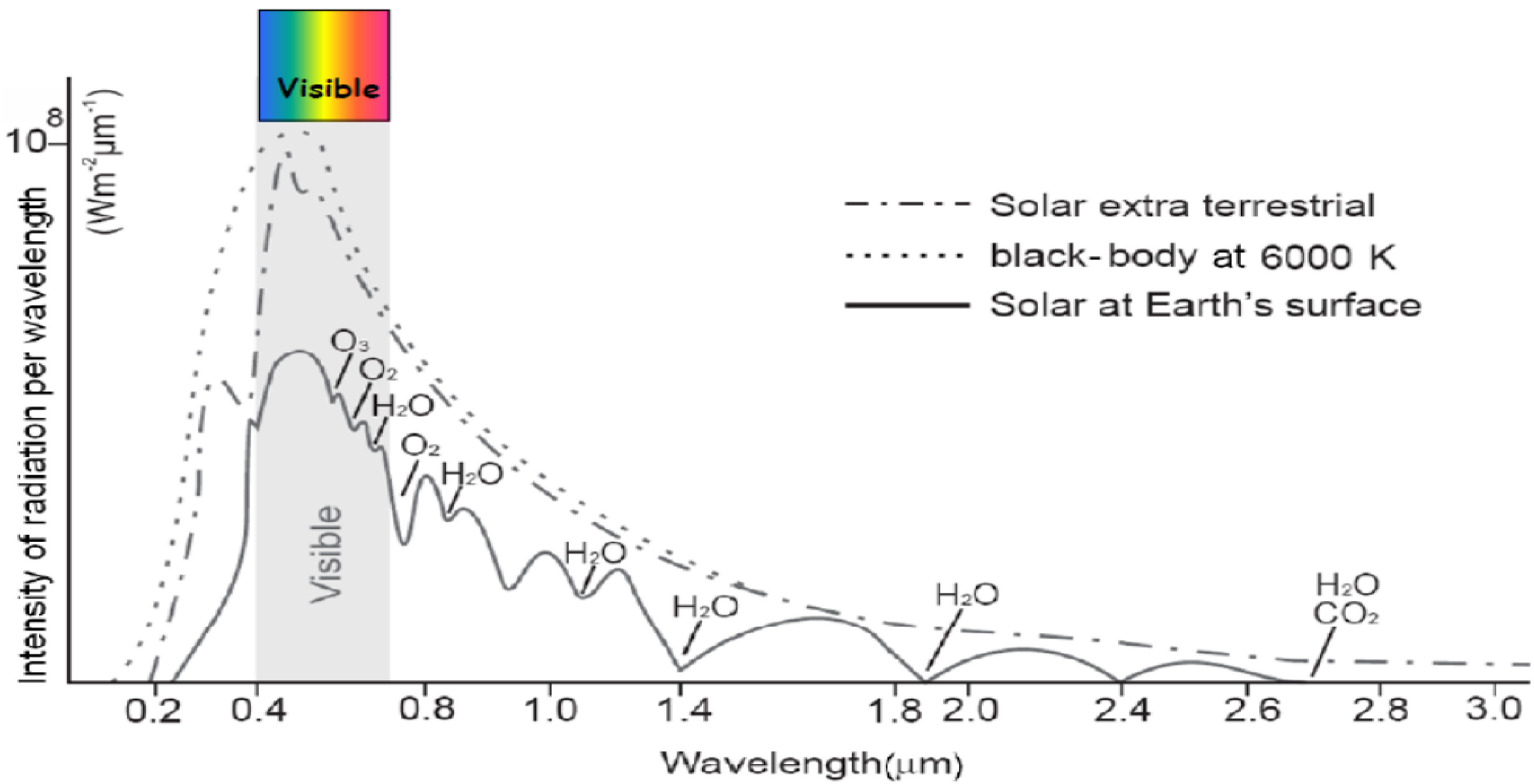
A. EM Interaction with Atmosphere…contd

Absorption

- As it moves through the atmosphere, EM radiation is partly absorbed by various molecules. The most efficient absorbers of solar radiation in the atmosphere are **ozone (O_3), water vapour (H_2O) and carbon dioxide (CO_2).**
- From below fig. it can be seen that many of the wavelengths are not useful for remote sensing of the *Earth's surface*, simply because the corresponding radiation cannot penetrate the atmosphere. *Only the wavelengths outside the main atmospheric transmission absorption ranges of the atmospheric gases can be used for remote sensing ES.*

A. EM Interaction with Atmosphere…contd

EM Spectrum (Absorption)



A. EM Interaction with Atmosphere…contd

- **Absorption-Global Warming**
- Most of the atmosphere consists of nitrogen (78%) and oxygen (21%), other gases account for the remaining 1%.
- Water vapor (can vary highly in concentration), carbon dioxide (0.035%), methane, and nitrous oxide (N_2O) are called **greenhouse gases**.
- These gases (mainly water vapor and carbon dioxide) have the ability to absorb ***long wave radiation emitted by the Earth*** and ***reemit it from much colder levels to the outer space***. They are able to store heat in the atmosphere and keep the **Earth warm**. It looks like the Earth is surrounded by a thermal blanket. This phenomenon is called the **greenhouse effect**.

A. EM Interaction with Atmosphere...contd

- What is negative is the enhanced greenhouse effect. As Temperature of atm > Temperature earth, it leads to the increase in the Earth temperature. The more the concentration of greenhouse gases, the higher the temperature of the atmosphere.
- *Atmospheric Window-Good for Sensing Ground Surface*
- The EM-Spectrum for which the atmosphere is relatively transparent.
- The atmosphere selectively transmits energy of certain wavelengths.

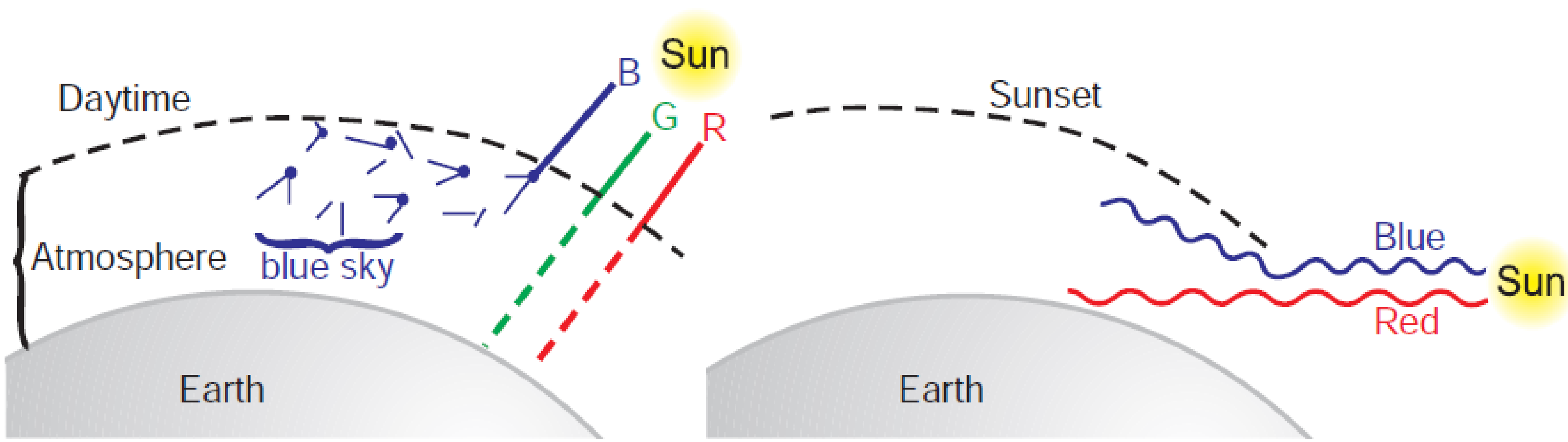
A. EM Interaction with Atmosphere…contd

Scattering (*Many Direction reflection*)

- Atmospheric scattering occurs when particles or gaseous molecules present in the atmosphere cause EM radiation to be *redirected from its original path.*
- The amount of scattering depends on several factors
  - **The wavelength of the radiation**
  - **The size and amount of particles and**
  - **The distance the radiation travels through the atmosphere.**
- Three types of scattering occurs in the atmosphere depending on the size of particles in the atmosphere causing it. They are of different relevance to RS.
- ***Rayleigh Scattering, Mie scattering*** and ***Non-selective scattering***

A. EM Interaction with Atmosphere…contd

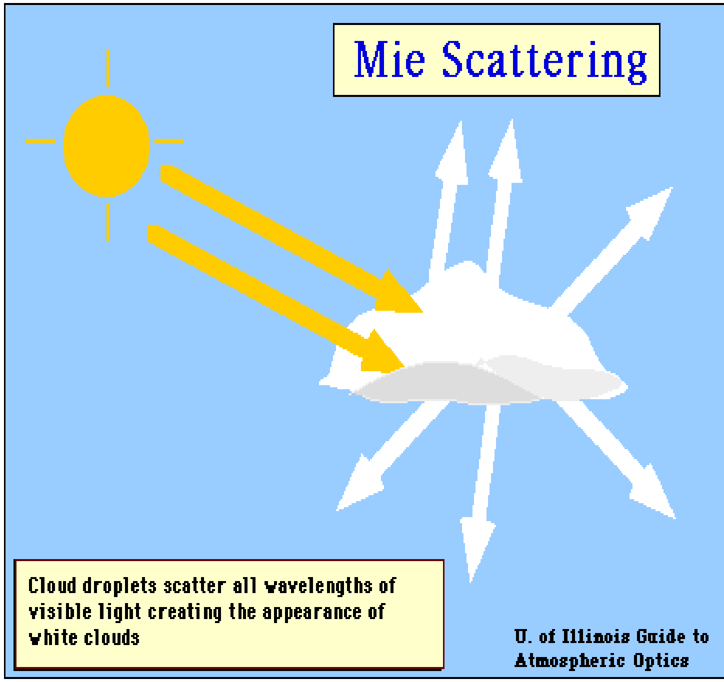
- **Rayleigh** scattering dominates where electromagnetic radiation interacts with particles *<u>that are smaller than the wavelengths of light.</u>* Eg. of such particles are tiny Rayleigh scattering specks of dust, and nitrogen (NO_2) and oxygen (O_2) molecules. Light of shorter wavelength(e.g. blue) is scattered more than light of a longer wavelength (e.g. red)



A. EM Interaction with Atmosphere…contd

Mie scattering occurs when the wavelength of EM radiation is *similar in size to particles in the atmosphere*. *The most important cause of Mie scattering is aerosols*: a mixture of gases, water vapour and dust.

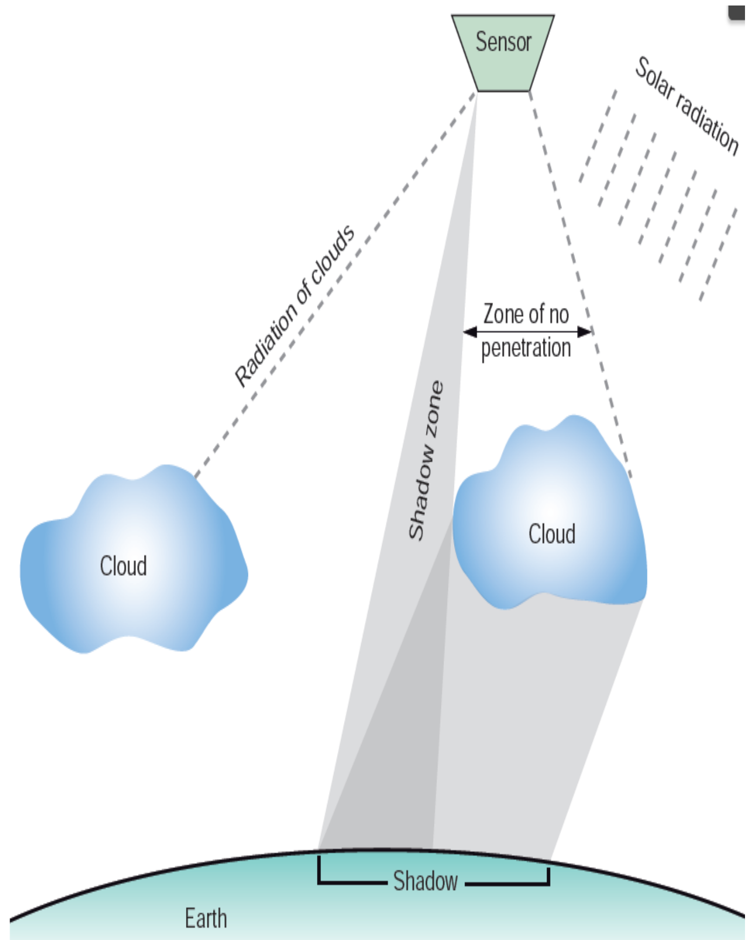
- Mie scattering is generally restricted to the **lower atmosphere**, where larger particles are more abundant, and it dominates under overcast, cloudy conditions.
- Mie scattering influences the spectral range from the **near-UV up to mid-IR**, and has a greater effect on radiation of longer wavelengths than Rayleigh scattering.



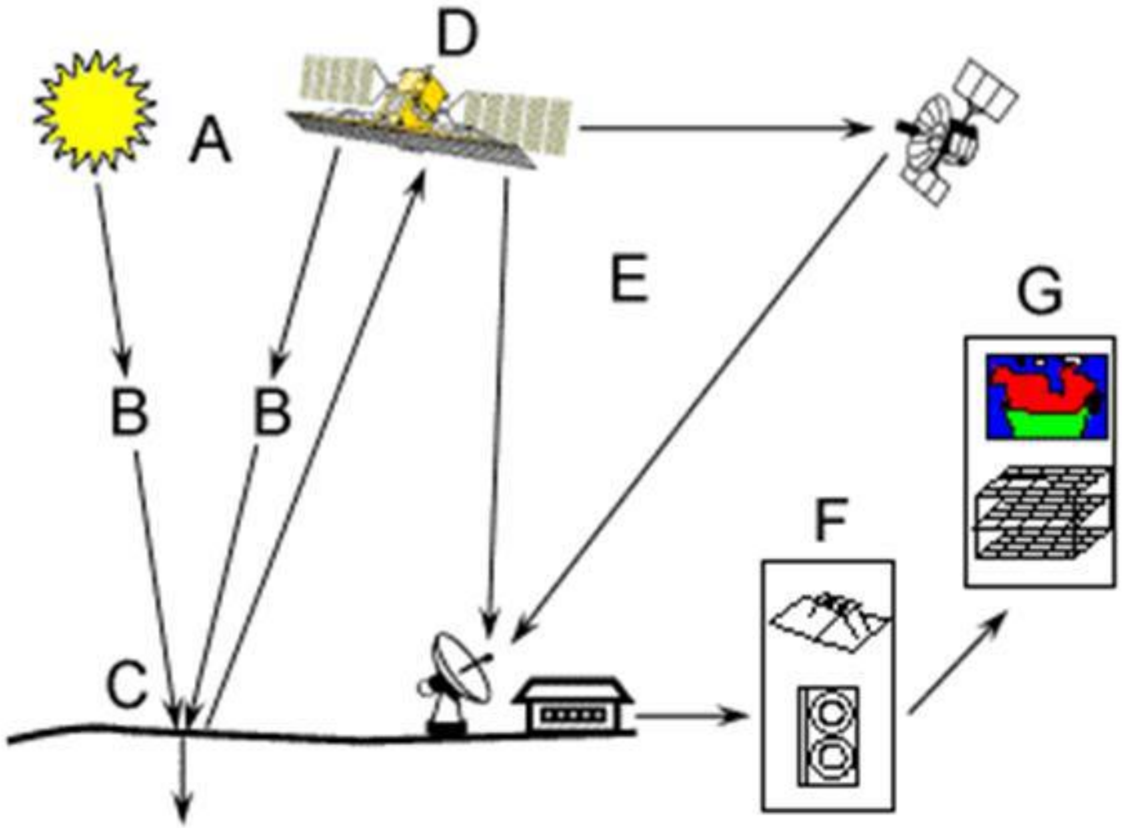
A. EM Interaction with Atmosphere...contd

Non-selective scattering occurs *when particle sizes are much larger than the radiation wavelength.* Typical particles responsible for this effect are water droplets and larger dust particles.

Non-selective scattering is independent of the wavelength within the optical range. The most prominent example of non-selective scattering is that we see clouds as white bodies. A cloud consists of water droplets; since they scatter light of every wavelength equally, a cloud appears white. Moreover, clouds have a further limiting effect on optical RS



B. EM Interaction with surface (Earth)

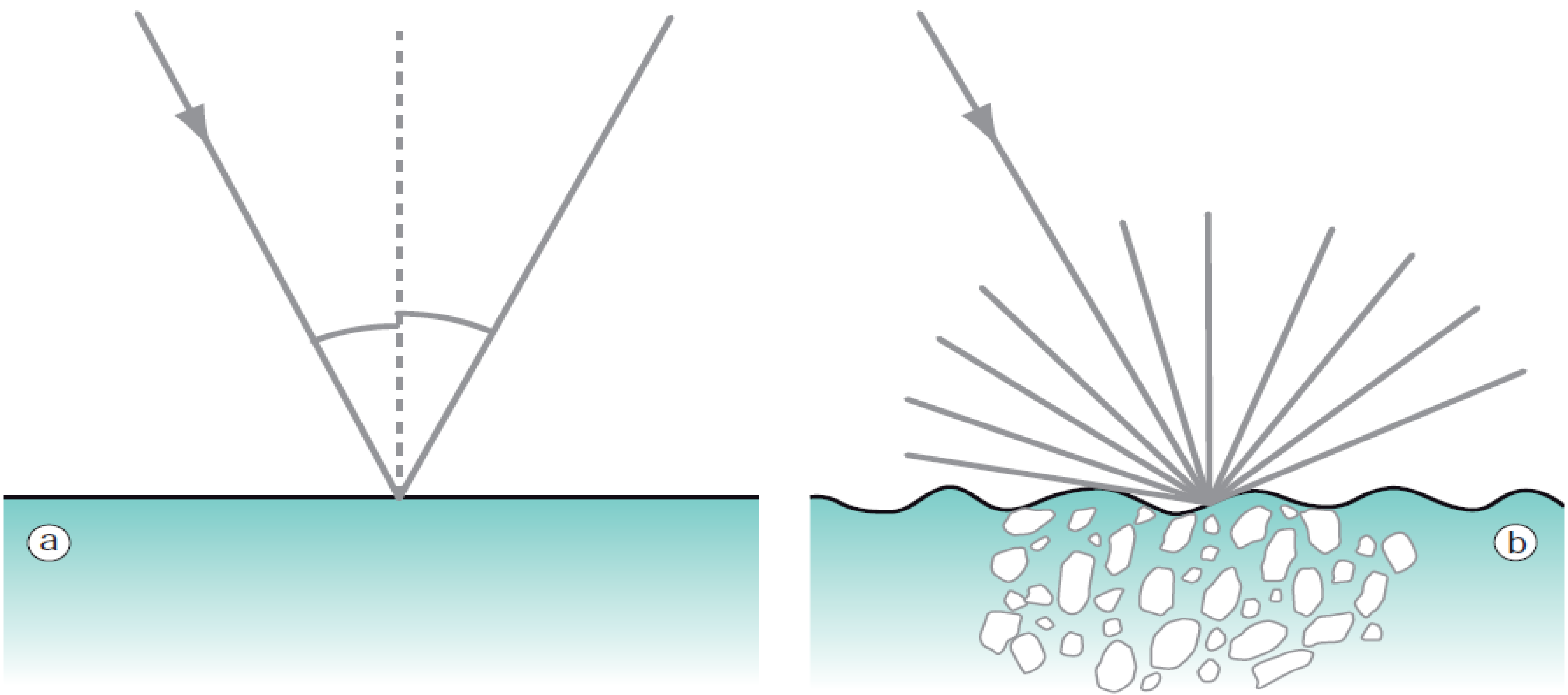


B. EM Interaction with surface…contd

- In "**land and water applications**" of remote sensing, we are most interested in **reflected solar radiation** because this tells us much about surface characteristics.
- **Reflection** occurs when radiation bounces off the target and is thus redirected.
- **A target** is defied as an object on the Earth surface, being detected or sensed.
- Not all solar radiation is reflected by water and land surfaces; some of it may be **absorbed and some even transmitted** (through a water body, for example, the sea floor).
- **The proportion of reflected-absorbed-transmitted radiation** will vary with *wavelength and material type*

B. EM Interaction with surface…contd

- Two types of reflection by a target: “**specular reflection” and “diffuse** reflection”.
- In the real world, usually a combination of both types is found.



B. EM Interaction with surface…contd

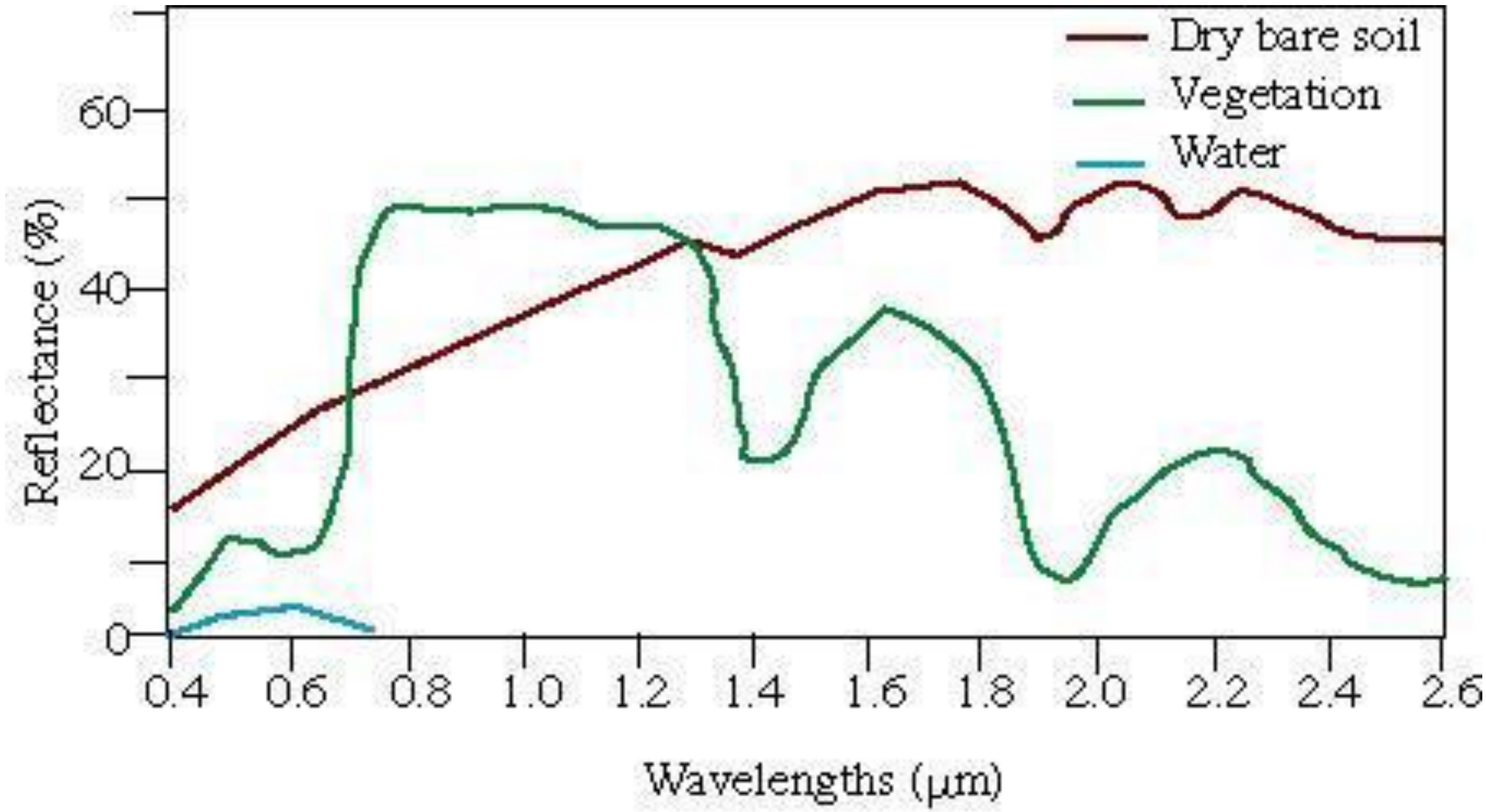
- Various materials of the earth's surface have different spectral reflectance characteristics (*used to discriminate different features)*
- It is *unique for different features/objects regardless of the sum of the incoming radiation.*
- The spectral reflectance is dependent on wavelength, it has different values at different wavelengths for a given terrain feature.
- Unique objects reflect differently, while similar objects only reflect differently *if there has been a physical or chemical change*

B. EM Interaction with surface…contd

Spectral reflectance curves

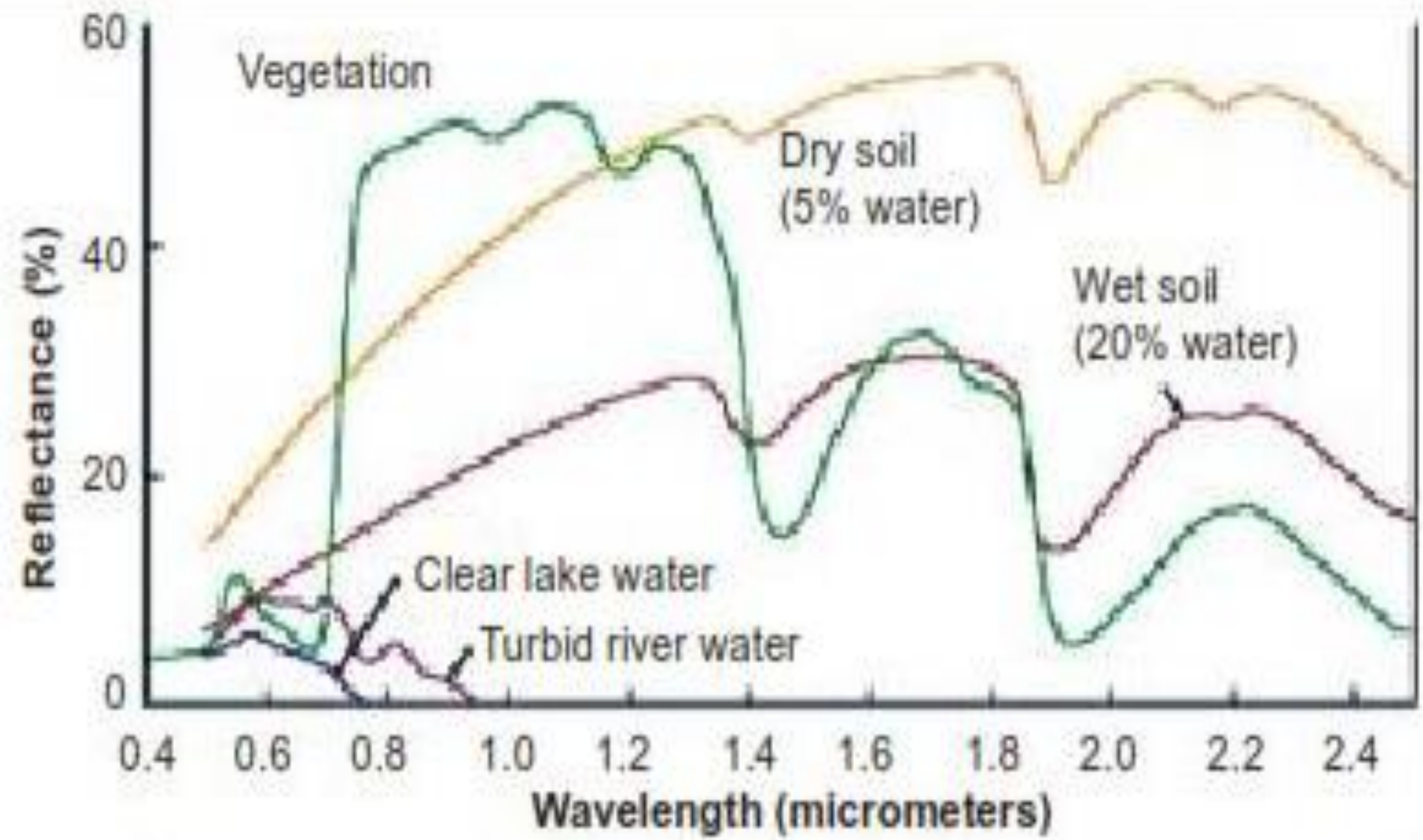
- Surface feature can be characterized by the percentage of incoming EME it reflects at each wavelength across the electromagnetic spectrum.
- This is said to be spectral reflectance curve or "spectral signature"
- SRC: is a curve which shows the portion of the incident radiation that is reflected as a function of wavelength
- Each type of material of interest has *its own reflectance property/ curve.*
- Reflectance measurements can be carried out in a laboratory measurements or in the field using a field spectrometer.

B. EM Interaction with surface…contd



Typical spectral reflectance curves for vegetation, soil, and water.

B. EM Interaction with surface…contd

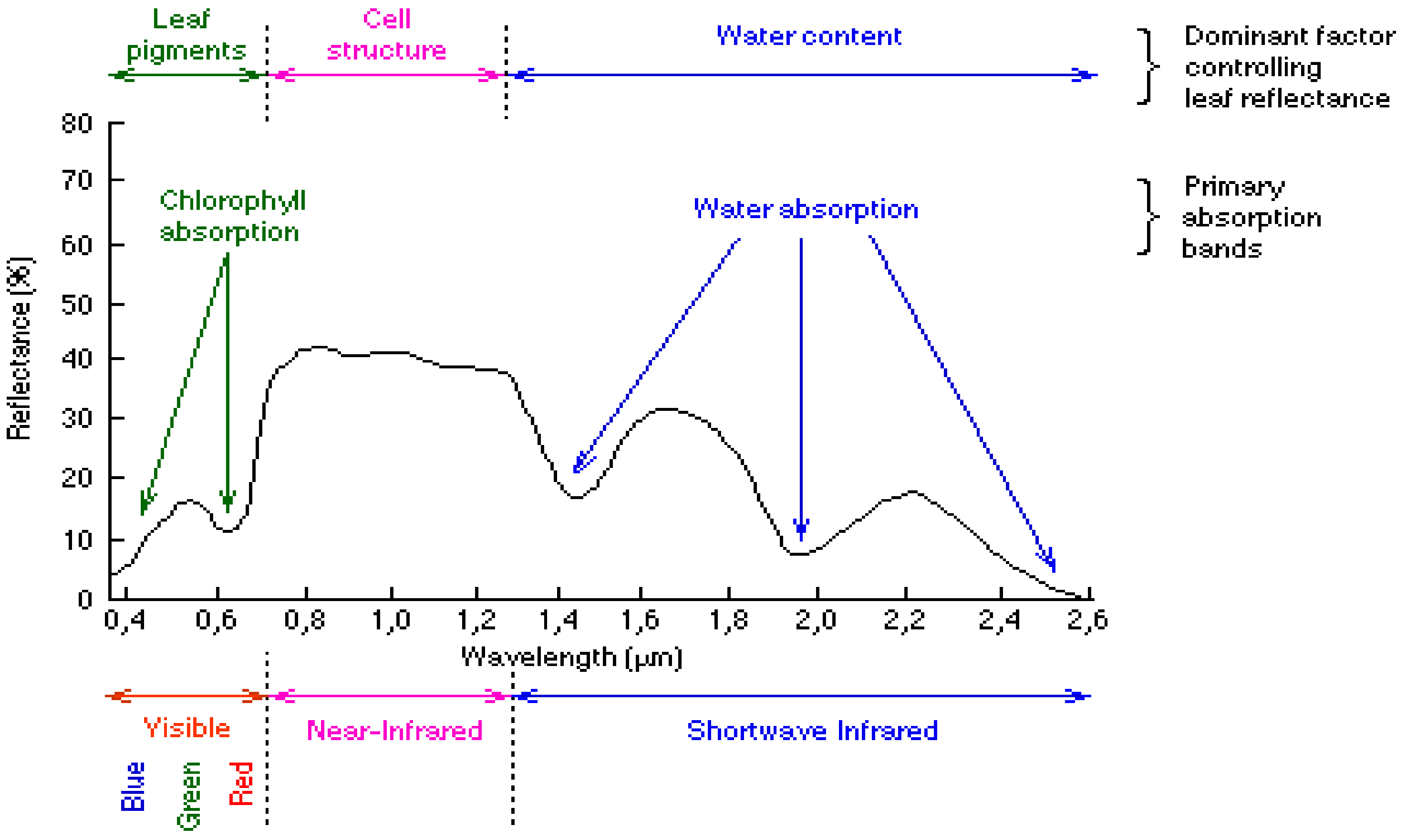


B. EM Interaction with surface…contd

Reflectance of vegetation

- The spectral characteristics of vegetation vary with wavelength.
- Plant pigment in leaves called chlorophyll strongly absorbs radiation in the red and blue wavelengths but reflects green wavelength.
- The internal structure of healthy leaves acts as diffuse reflector of near infrared wavelengths.
- Measuring and monitoring the near infrared reflectance is one way that scientists determine how healthy particular vegetation may be.

B. EM Interaction with surface…contd

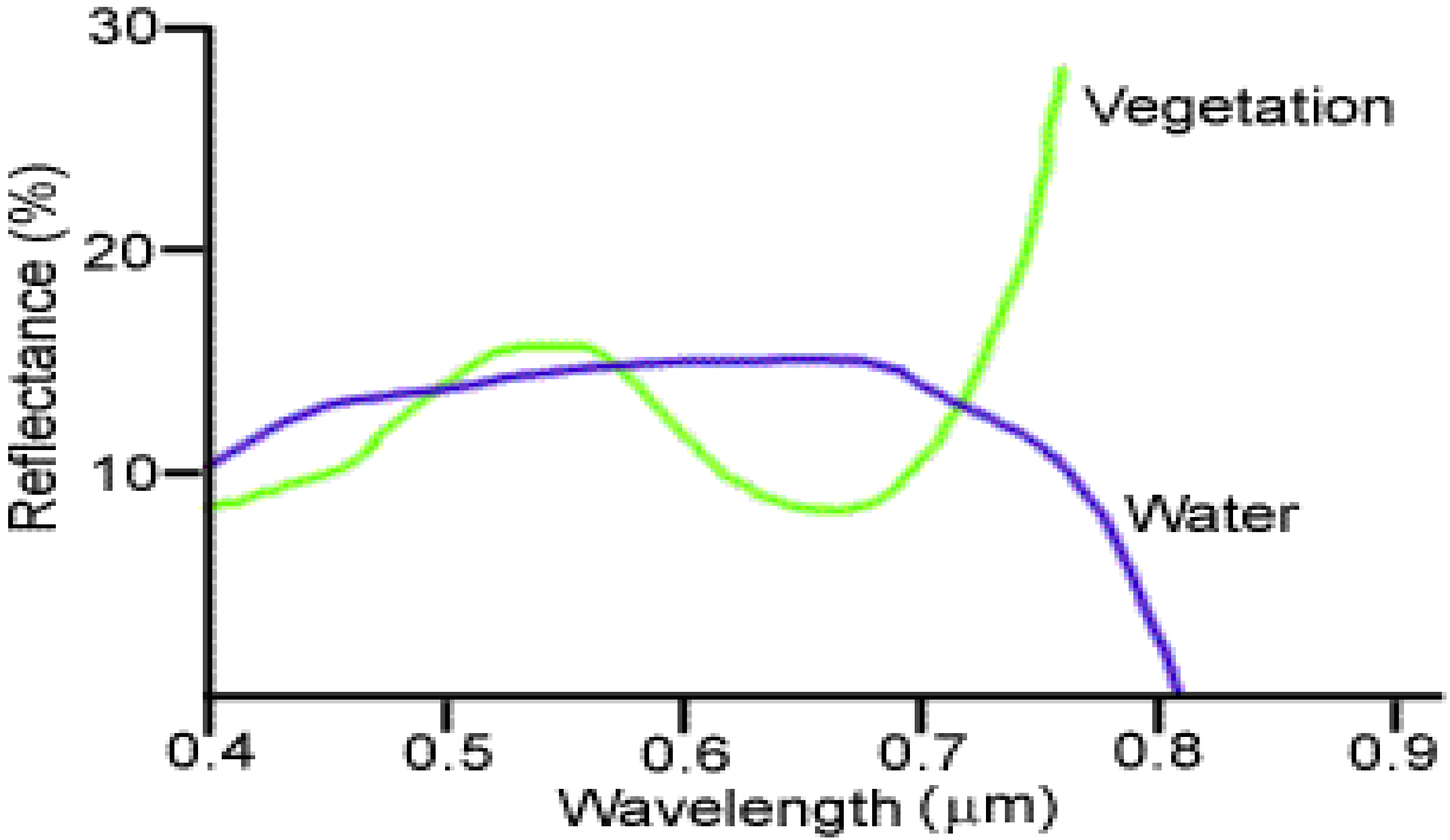


B. EM Interaction with surface…contd

Reflectance of water

- Majority of the radiation incident upon water is not reflected but is either absorbed or transmitted.
- Longer visible wavelengths and near infrared radiation is absorbed more by water than by 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.*

B. EM Interaction with surface…contd

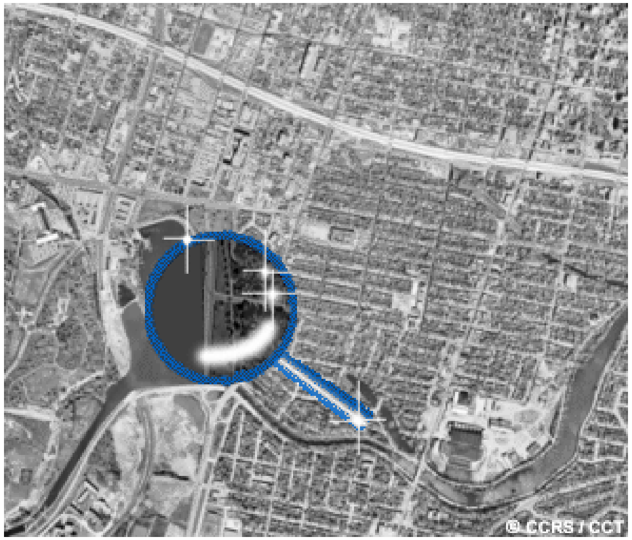


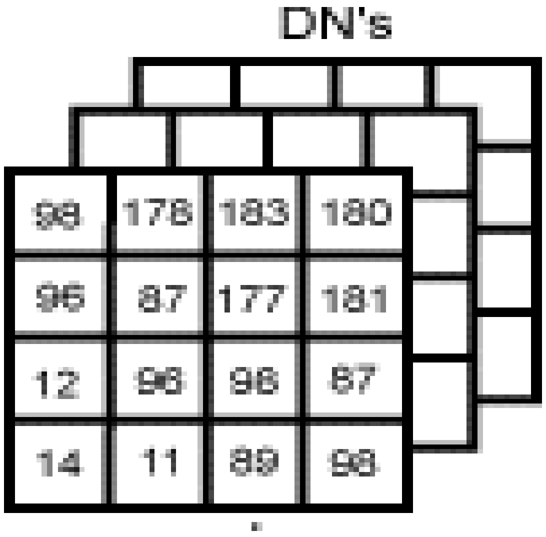
Digital image preprocessing and visual interpretation

- Interpretation and analysis of remote sensing imagery involves the identification and/or measurement of various targets in an image in order to extract useful information about them.
- Targets in remote sensing images may be any feature or object which can be observed in an image, and have the following characteristics:
- Targets may be a point, line, or area feature.
- This means that they can have any form, from a bus in a parking lot or plane on a runway, to a bridge or roadway, to a large area of water or a field.
- The target must be distinguishable
- It must contrast with other features around it in the image.

Digital image preprocessing…cont

- Much interpretation and identification of targets in remote sensing imagery is performed ***manually or visually***, i.e. by a human interpreter.
- Remote sensing images can also be represented in a computer ***as arrays of pixels***, with each pixel corresponding to a *digital number, representing the brightness level of that pixel* in the image.
  - In this case, the data are in a digital format.





Digital image preprocessing…cont

- Both analogue and digital imagery can be displayed as black and white (also called monochrome) images, or as colour images by combining different channels or bands representing different wavelengths.
- When remote sensing data are available in digital format, digital processing and analysis may be performed using a computer.
- Digital processing may be used to enhance data as a preface to visual interpretation.
- Digital processing and analysis may also be carried out to automatically identify targets and extract information completely without manual intervention by a computer interpreter.

Digital image preprocessing…cont

- However, rarely is digital processing and analysis carried out as a complete replacement for manual interpretation.
- Often, it is done to supplement and assist the human analyst.
- Manual interpretation requires little, if any, specialized equipment, while digital analysis requires specialized, and often expensive, equipment.
- Manual interpretation is often limited to analyzing only a single channel of data or a single image at a time due to the difficulty in performing visual interpretation with multiple images.

Digital image preprocessing…cont

- The computer environment is more amenable to handling complex images of several or many channels or from several dates
- Manual interpretation is a subjective process, meaning that the results will vary with different interpreters.
- Digital analysis is based on the manipulation of digital numbers in a computer and is thus more objective, generally resulting in more consistent results.
- However, determining the validity and accuracy of the results from digital processing can be difficult.
- Both methods have their merits. In most cases, a mix of both methods is usually employed when analyzing imagery

Elements of Visual/Manual/ Interpretation

- Recognizing targets is the key to interpretation and information extraction.
- Observing the differences between targets and their backgrounds involves comparing different targets based on any, or all, of the visual elements of:
  - shape,
  - size,
  - pattern,
  - texture,
  - shadow,
  - association.

- Association takes into account the relationship between other recognizable objects or features in proximity to the target of interest.
  - E.g commercial properties may be associated with proximity to major transportation routes, whereas residential areas would be associated with schools, playgrounds


THANK YOU