REMOTE SENSING

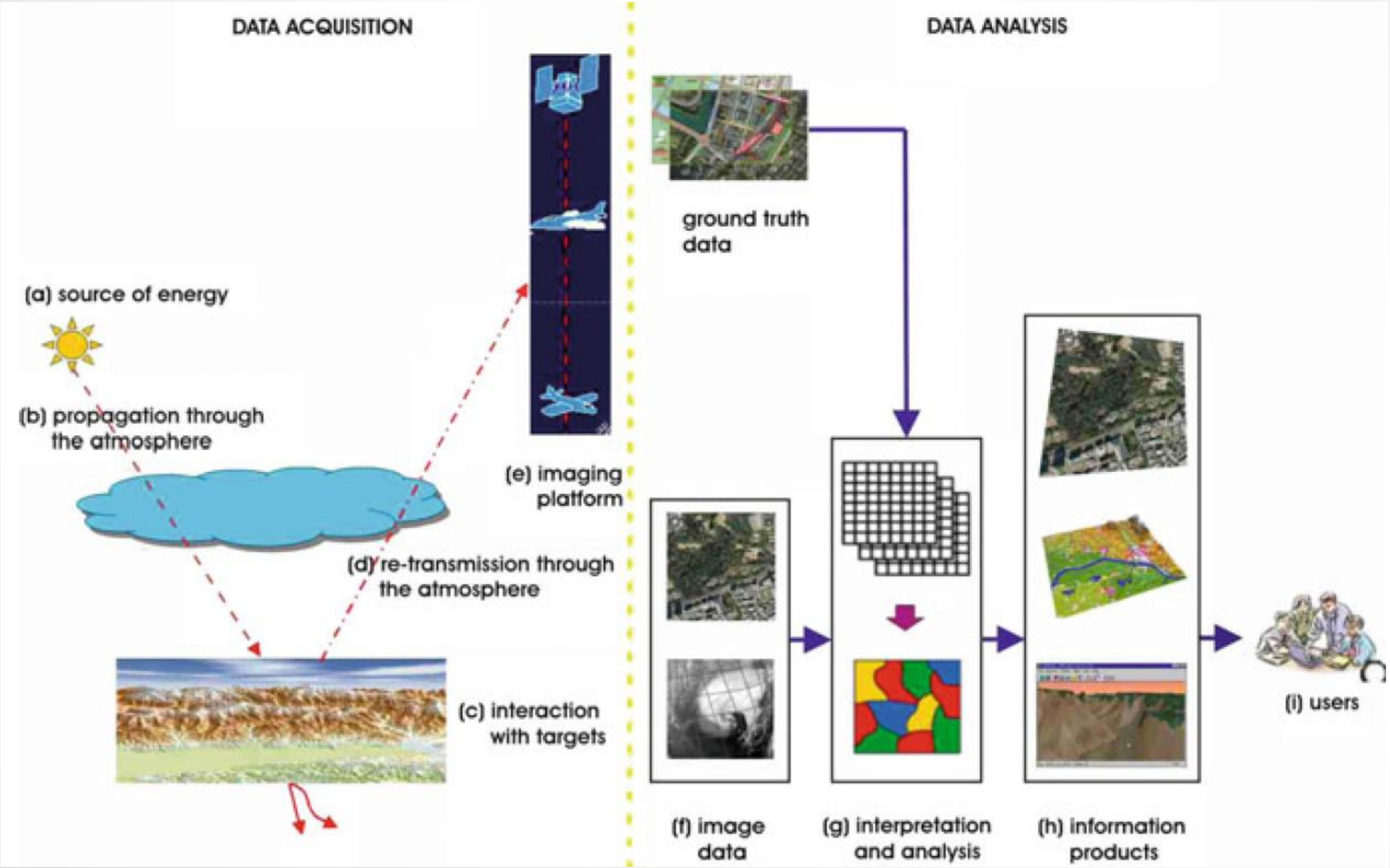
Electro-Magnetic Radiation

OVERVIEW

Terminology.
Nature of the electro-magnetic radiation.
Bands of the electro-magnetic radiation (wavebands):
- Radio waves.
- Microwaves.
- Infrared radiation.
- Visible light.
- Ultraviolet rays.
- X-rays.
- Gamma rays.

Special issues:
- Black body radiation.
- Solar emission.
- Radiation interaction with the atmosphere:
    - Scattering and absorption.
    - Radiation interaction with Earth surface features:
    - Surface roughness versus the wavelength of the incident radiation.
    - Specular versus diffuse/Lambertian surfaces.
    - Spectral reflection of vegetation, soil, and water.

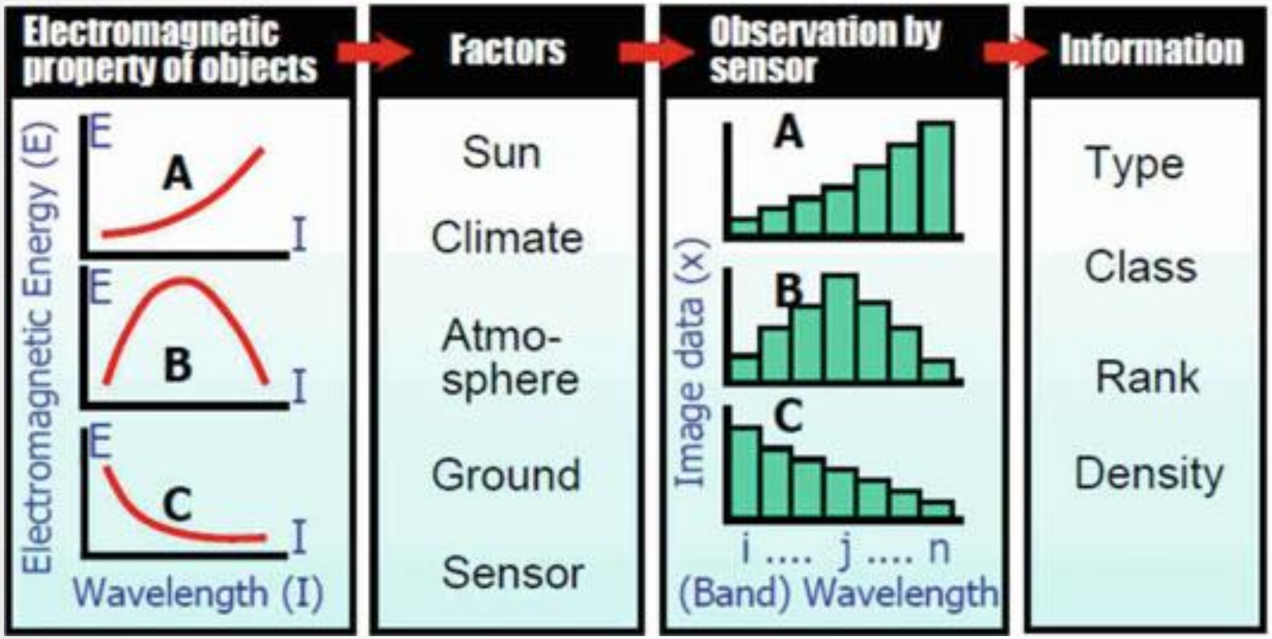
ELEMENTS OF REMOTE SENSING



ELEMENTS OF REMOTE SENSING

(a) an energy source or illumination is used to provide electromagnetic energy to the target of interest,
(b) Interactions between the electromagnetic radiation and the atmosphere,
(c) interaction between the target and the electromagnetic radiation,
(d) recording of reflected and emitted energy from the target by the sensor,
(e) transmission, reception, and processing of recorded energy into an image,
(f) Interpretation and analysis of the image to extract desired information and
(g) application of the information about the object or target in order to better understand it, reveal some new information or assist in solving a particular problem.

ELEMENTS OF REMOTE SENSING



Accordingly, each object has a unique spectral signature of reflection or emission dependent on the sun, climate, atmosphere, ground condition, and sensor among other factors. This allows the discrimination of the object ***type, class, rank or density*** to be made through image processing and analysis

TERMINOLOGY

Energy (*I*) is the capacity to do work.
It is expressed in *joules (J)*.
Radiant energy is the energy associated with electromagnetic radiation.
Radiant flux (*Φ*) is the rate of transfer of energy from one place to another (e.g., from the Sun to the Earth).
Radiant flux is measured in *watts* (*J/sec*).

$$\Phi = \frac{\partial I}{\partial t}$$

To understand the interaction between EM radiation and the surface of the Earth, we need to introduce the term **radiant flux density**.
- The radiant flux that is *incident upon* or is *emitted* by a surface per unit area.
- For incident radiation, we use the term **irradiance** (*E*) to denote the radiant flux density.
- For emitted radiation, we use the term **radiant emittance** (*M*) to denote the radiant flux density.
- Radiant flux density is measured in *watts per square meter* (*wm*-^{2}).

$$E/M = \frac{\partial \Phi}{\partial A}$$

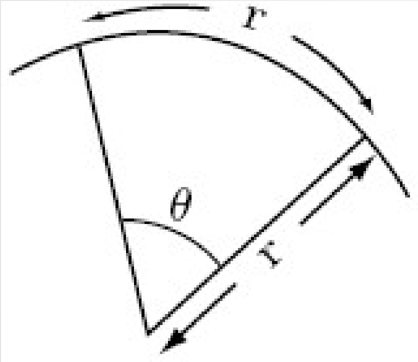
(A) refers to the area along the normal to the radiation direction

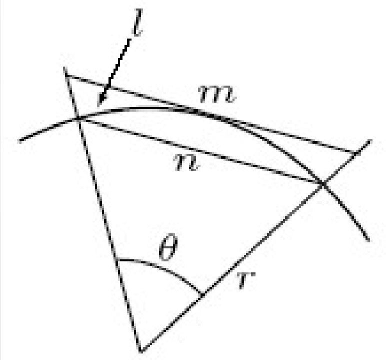
TERMINOLOGY

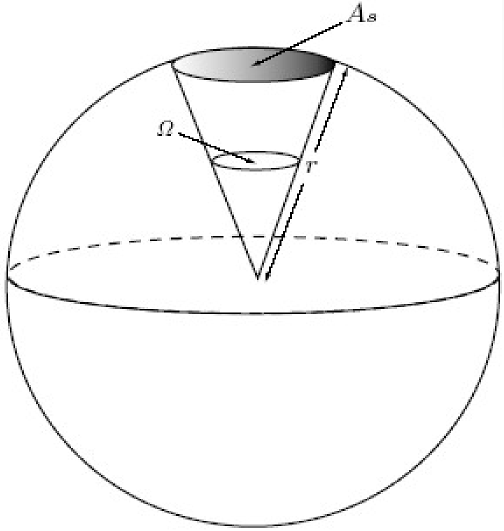
Radiance (*L*) denotes the radiant flux density transmitted from a small area and viewed through a unit solid angle (*steradians* - *sr*).
For an irradiance that is backscattered in all upward directions, the measured radiant exitance per unit solid angle is radiance.
- Radiance is measured in *watts per square meter per steradian* ($w\ m^{-2}\ sr^{-1}$).

$$L = \frac{\partial E}{\partial \Omega} = \frac{\partial^2 \Phi}{\partial \Omega \partial A}$$

This is what we measure by the sensor.



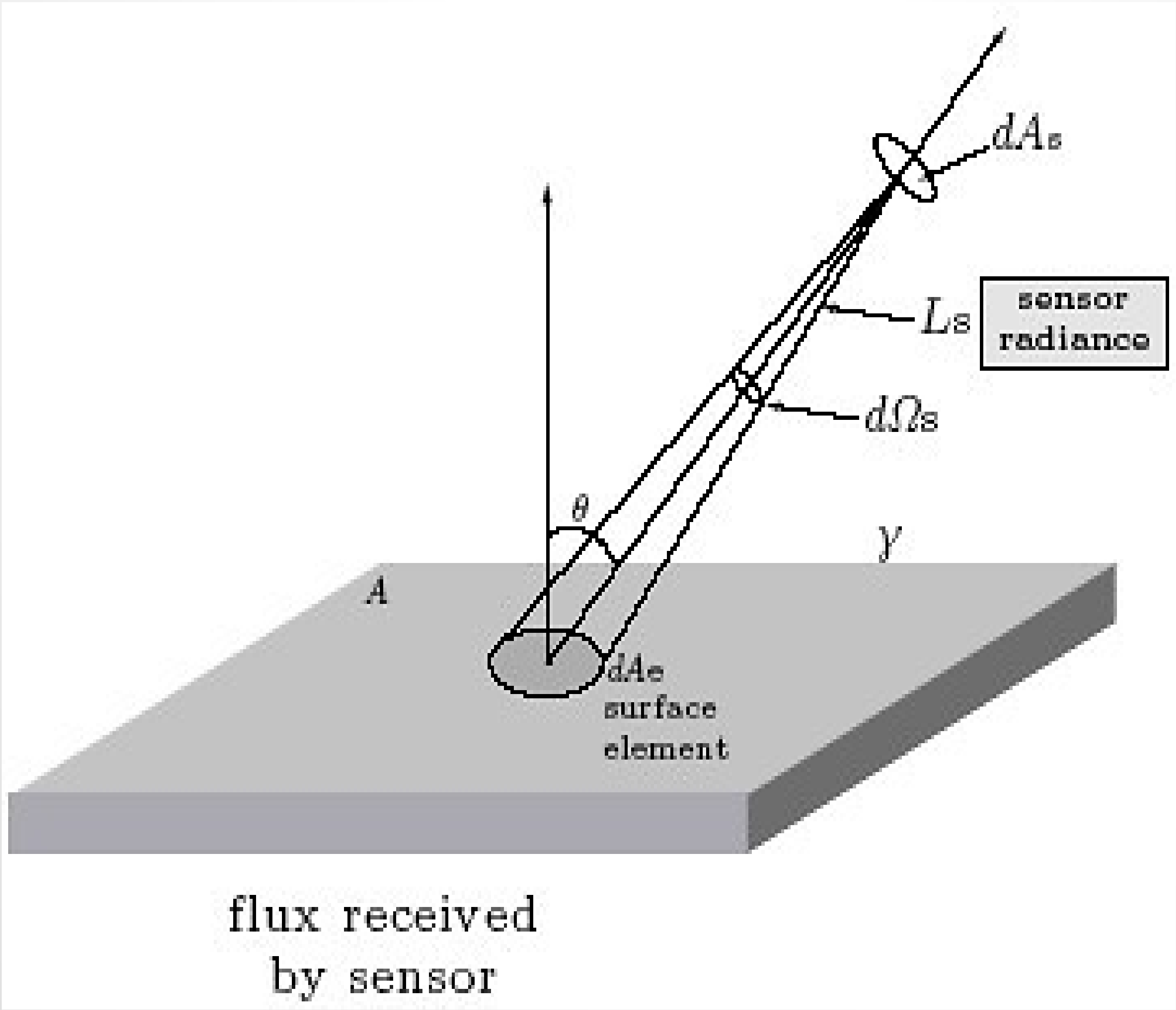




- Angle in radians (θ) = arc length/radius.
- For small angles:
  - (θ) = l/r ≈ m/r ≈ n/r.
    - m = tangent.
    - n = chord.

- Solid angle (*Ω*) = Area on sphere (A_s) / r^2.
- Total solid angle subtended by a point:
  - $4\pi r^2 / r^2 = 4\pi$ (*sr*).
- Solid angle above a point on a flat surface = 2 π (*sr*).
- For small solid angles, we can use either chord plane

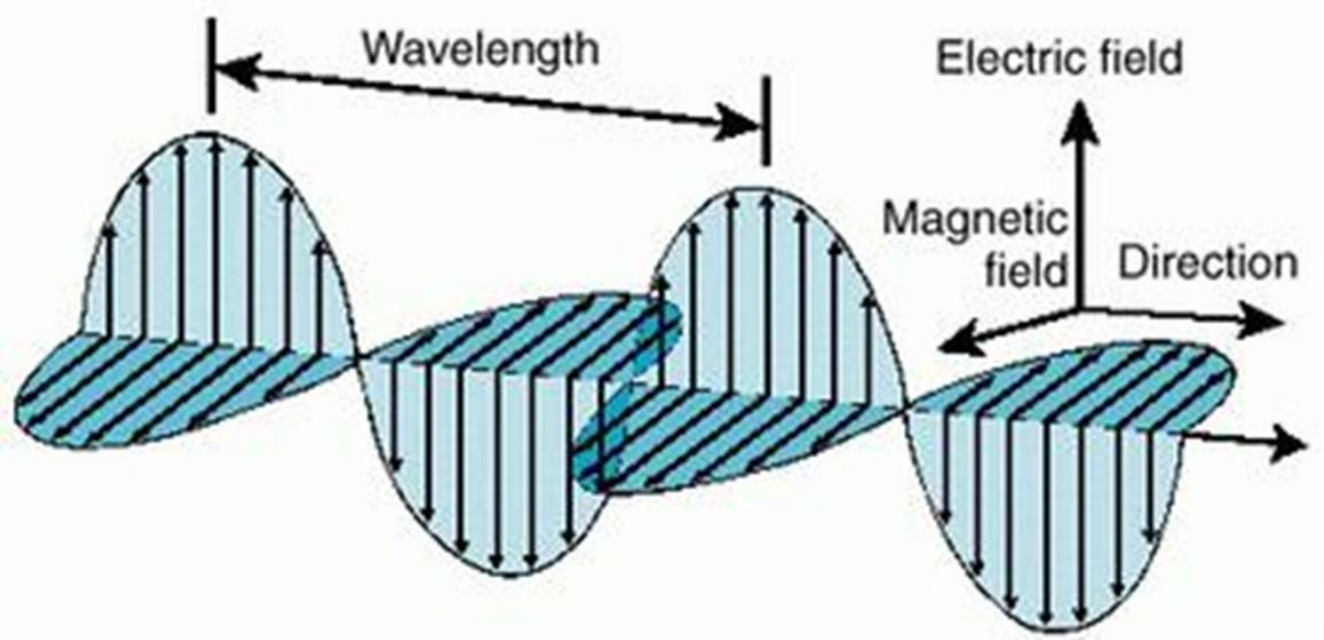
MEASURED SENSOR RADIANCE



LIGHT? WHAT DO WE KNOW ABOUT IT?

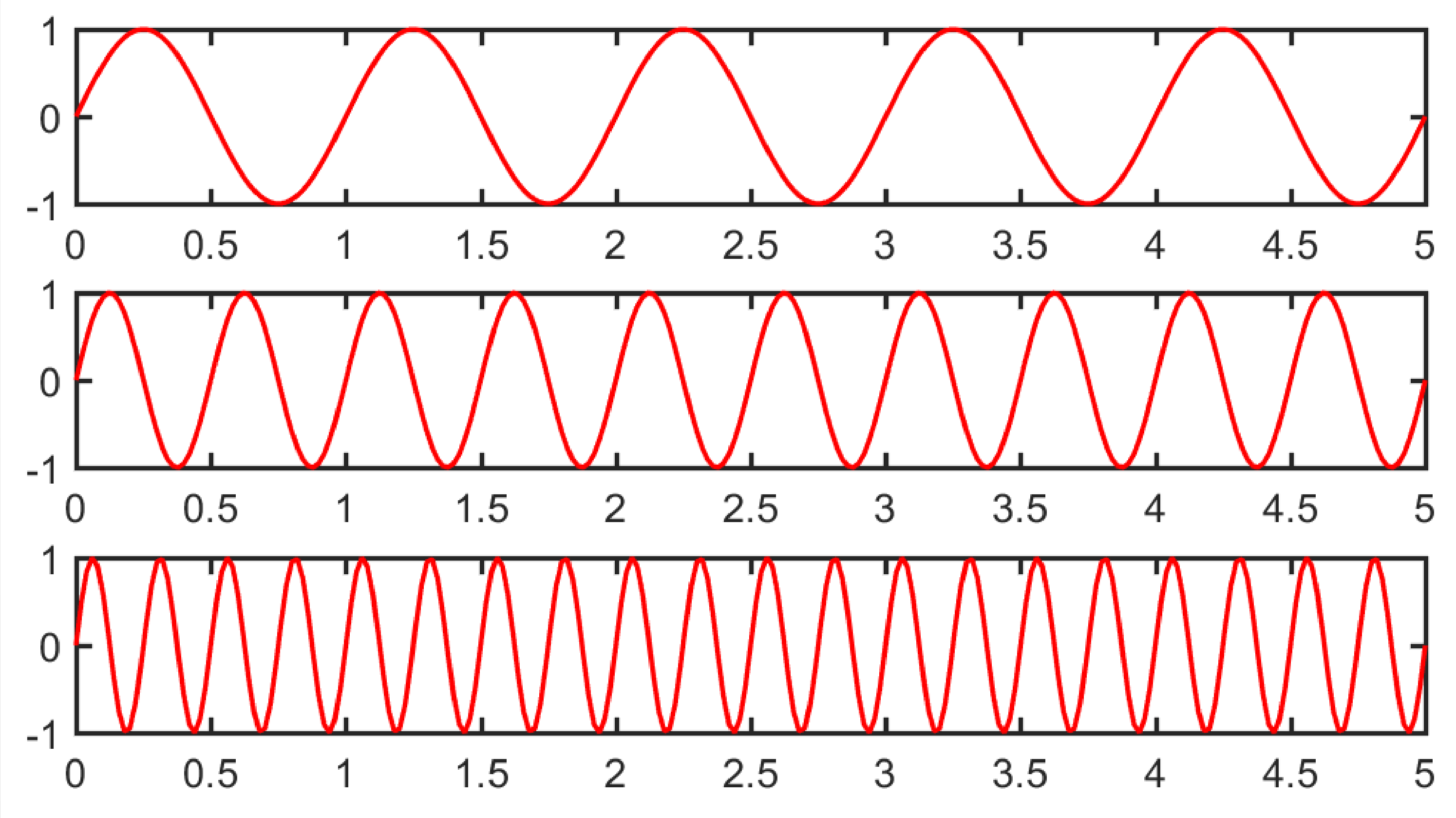
It travels 300,000 km/s
Sunlight takes about 8 minute to travel from the Sun to the Earth

Light → Electromagnetic wave
Photons



WAVELENGTH AND FREQUENCY

Frequency, f = number of cycle per second



1 Hz = 1 Cycle/second

One Period (p) = time that one wave has moved

Velocity = λ/p Velocity = $\lambda * f$ Speed of light (c) = $\lambda * f$

RADIATION ENERGY

- The shorter the wave length, the higher the energy that is carried by the radiation.
- The amount of energy of a single photon is defined as:

I (*joule*) = *h* (*joule sec*) *f* (*sec*$^{-1}$).

  - *h* is Planck's constant (6.3 x 10^{-34} *joule sec*).

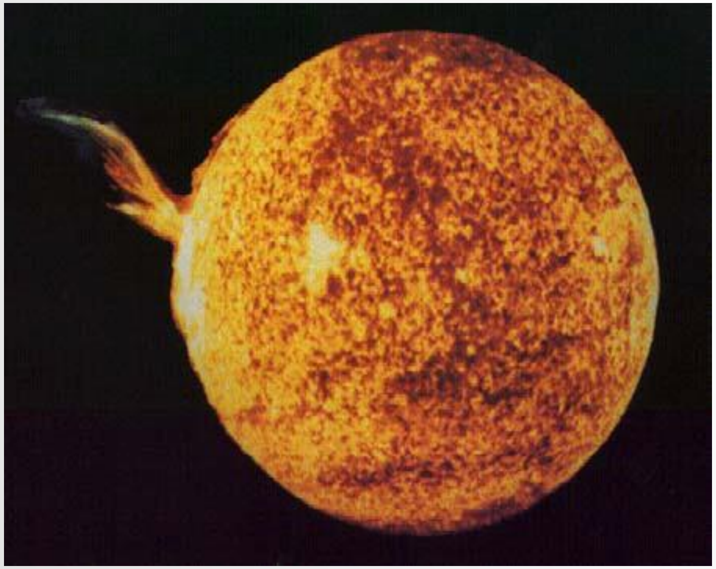
Energy of a photon $Q = \underbrace{h}_{\text{Planck's constant}} \times \underbrace{v}_{\text{frequency}} = h \times \frac{c}{\lambda}$

Speed

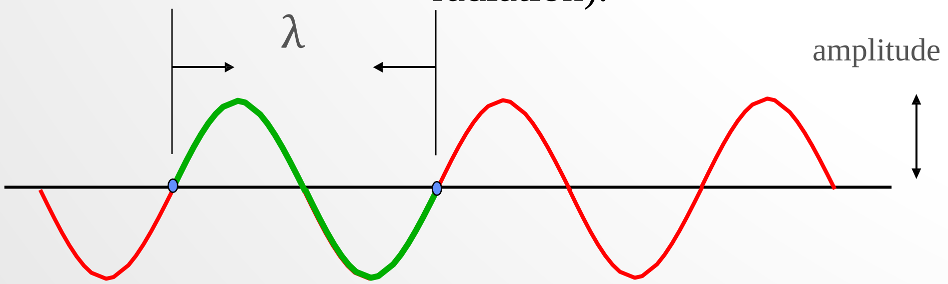
Wavelength

EM RADIATION SOURCE

The Sun: The common source of radiation



- Visible light is only one of the many forms of electromagnetic energy.
- Radio waves, heat, ultraviolet rays, and x-rays are other familiar forms.
- EM-radiation can be either considered as:
  - Stream of particles (photons).
    - Allow for a better understanding of the radiation interaction with the surface of the Earth and its atmosphere.
  - Wave form.
    - Allow for the distinction between the different manifestations of radiation (e.g., microwave and infrared radiation).



- The EM radiation travels in a vacuum with the speed of light.
- The relationship between the speed, frequency, and wavelength of the radiation is defined by:

$$c\ (m/sec) = \lambda\ (m) * f\ (sec^{-1})$$

  - (c) speed of light = 3×10^8 m/sec.
  - *(f)* frequency of the radiation (cycles/sec).

SOURCES OF EM RADIATION

Any object whose temperature is greater than 0° Kelvin (-273° C) emits radiation.

The distribution of the emitted energy at each wavelength is not uniform.

The distribution of the emitted energy in different regions of the spectrum depends upon the temperature of the source.

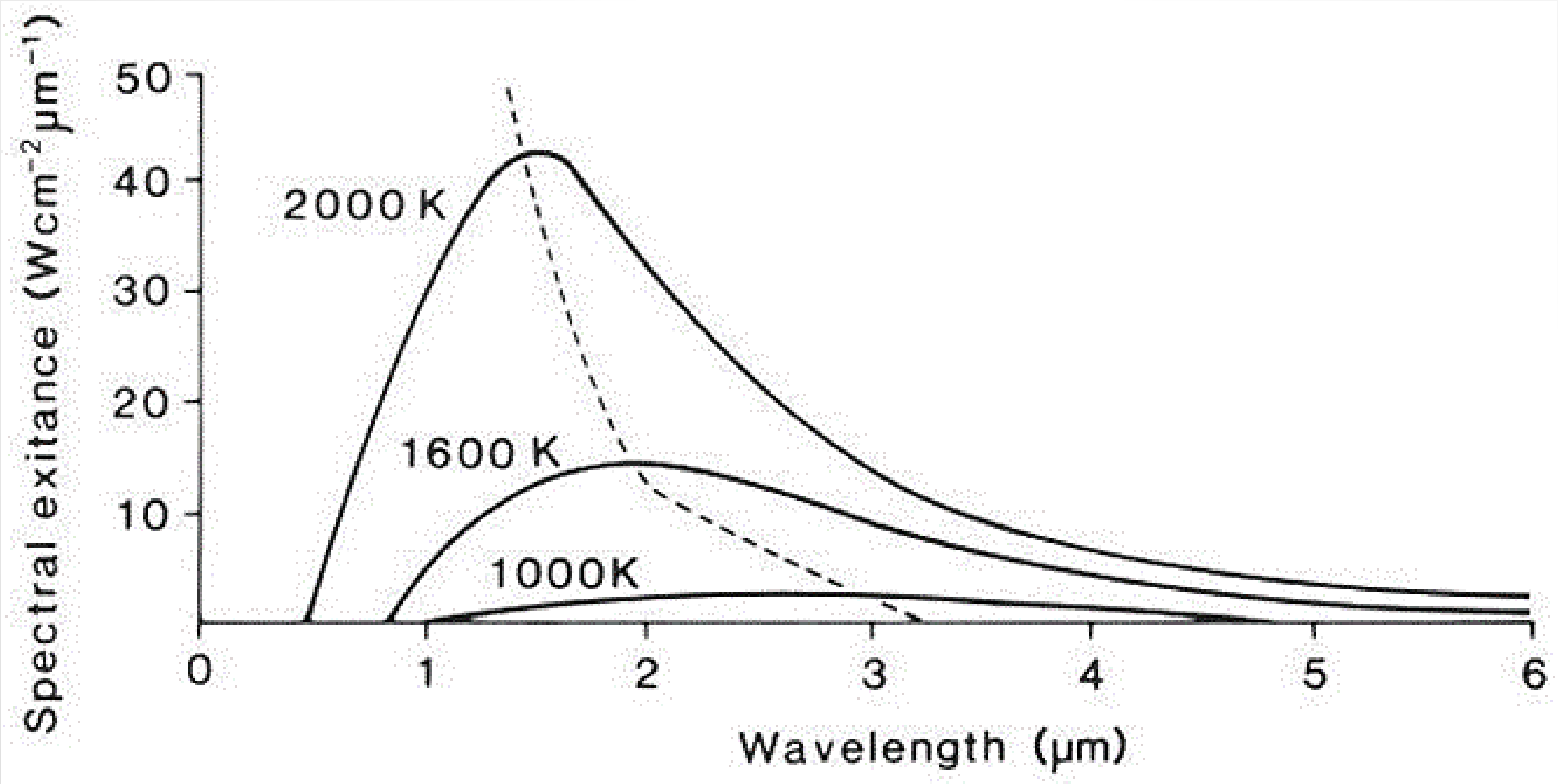
Black material absorbs all radiation that reaches it (a perfect absorber is referred to as a 'blackbody').

A blackbody transforms absorbed heat into radiant energy according to Planck's law of spectral exitance:

$$M_\lambda = \frac{c_1 \pi \lambda^{-5}}{\left(e^{c_2/\lambda T} - 1\right)}$$

- $c_1 = 3.742 \times 10^{-16}$ ($W\,m^2$)
- $c_2 = 1.4388 \times 10^{-2}$ ($m\,K$)
- λ = wavelength (m)
- T = Temperature (K)
- M_λ = Spectral exitance per wavelength ($Wm^{-2}m^{-1}$)

BLACK BODY RADIATION



EM RADIATION SOURCE

The integrated radiance (area under the curves) increases as T increases.
The peak radiance shifts towards shorter wavelengths as T increases.
The peak of the spectral exitance curve is governed by Wein's Displacement Law:

$$\lambda_{\max} = c_3 T^{-1}$$

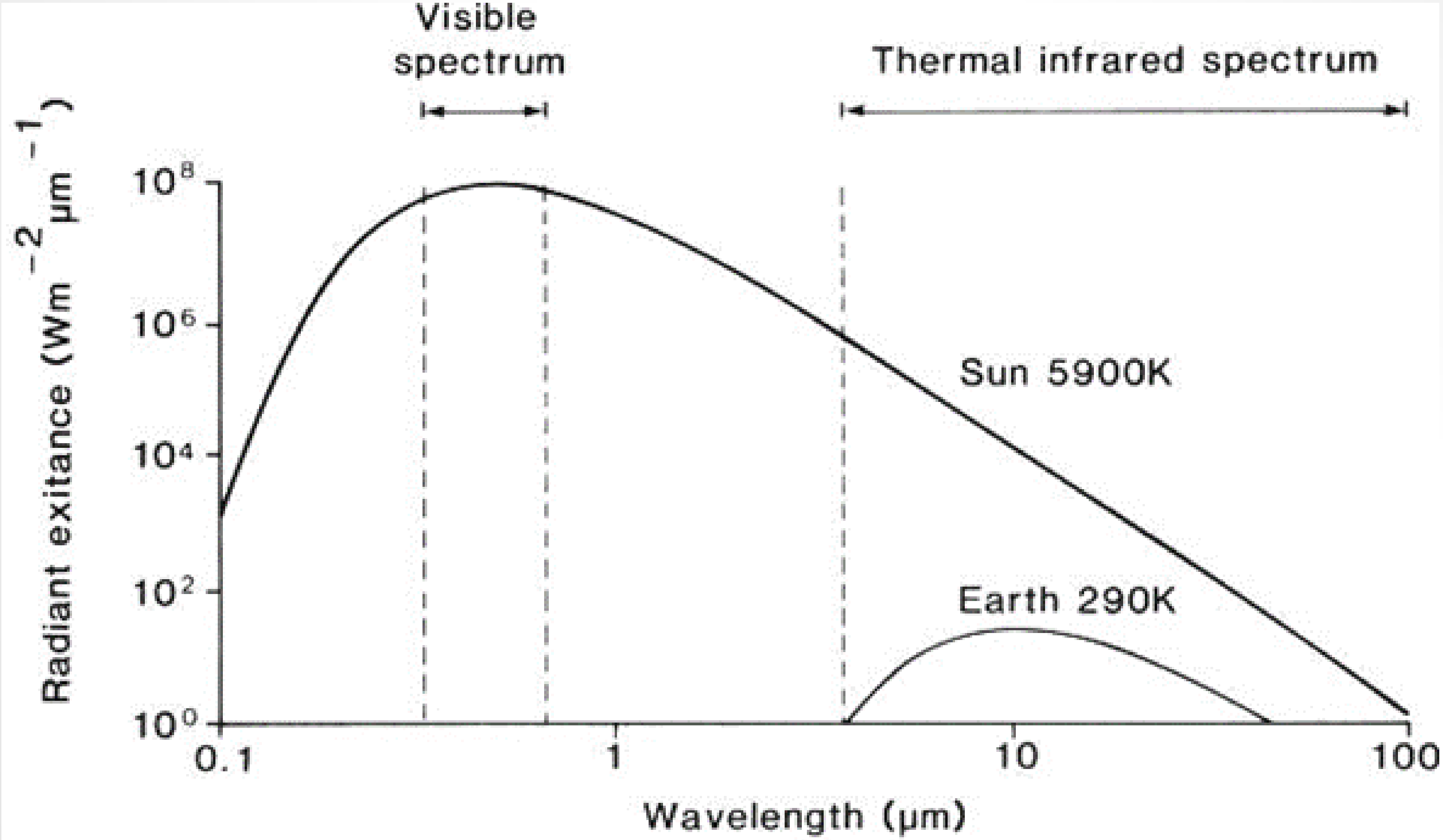
$$c_3 = 2.898 \times 10^{-3} \, (m\,K)$$

The total spectral exitance of a blackbody at temperature T is given by the Stefan-Boltzmann Law as:

$$M = \sigma T^4 \; (W\, m^{-2})$$

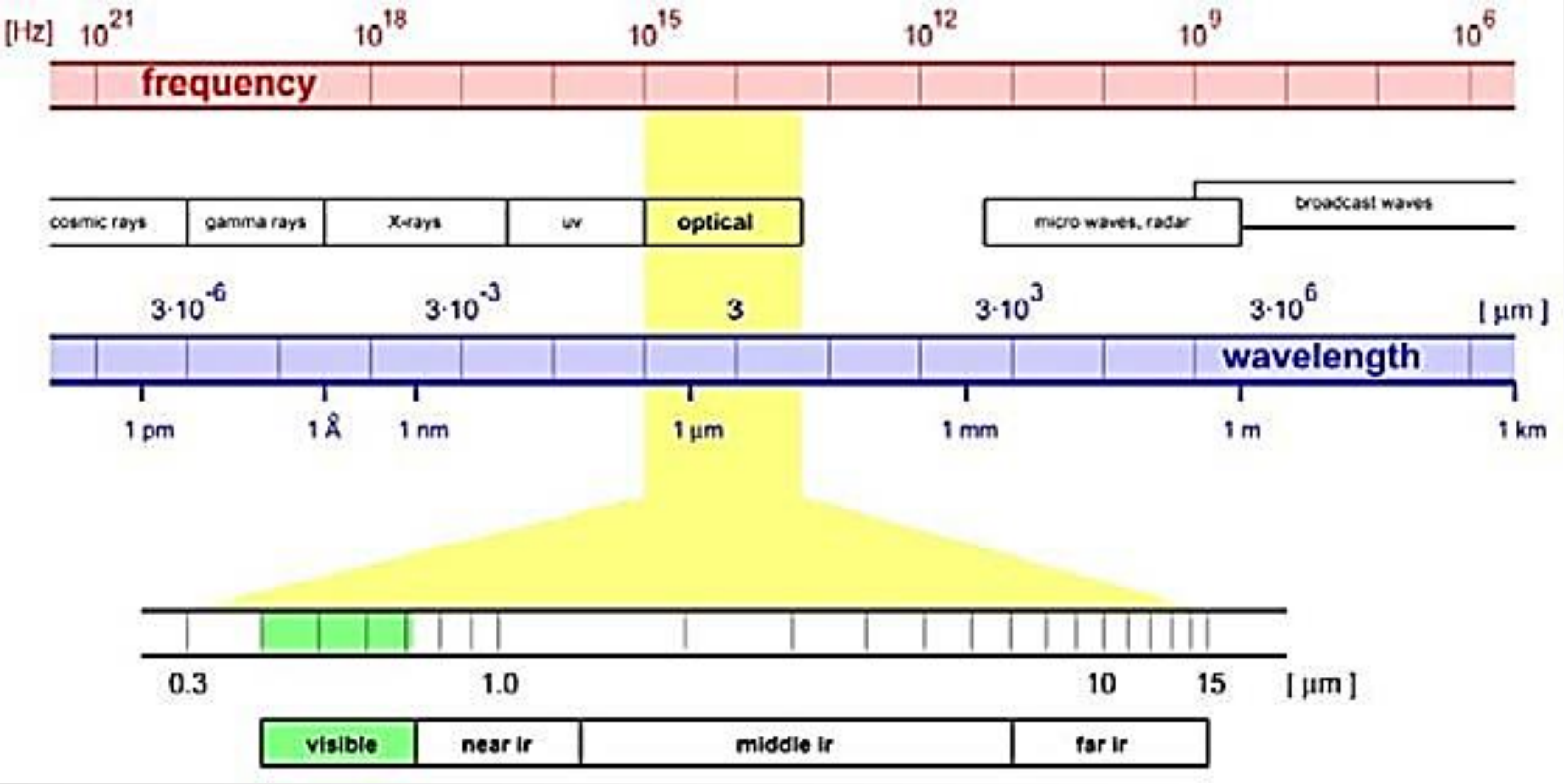
$$\sigma = 5.6697 \times 10^{-7} \, (\mathrm{W}\, m^{-2} K^{-4})$$

SUN/EARTH RADIATION



The distribution of the spectral exitance at 5900° K closely approximates the Sun's spectral exitance.
The Earth approximately acts as a blackbody with a temperature of 290° K.
The maximum solar radiation takes place in the visible spectrum ($\lambda max = 0.47\mu m$).
– 46% of the Sun's total energy falls into the visible waveband (0.4 - 0.76 µm)

EM RADIATION WAVEBANDS



Because of the spectral absorption characteristic of atmospheric molecules in certain regions of the atmosphere, otherwise referred to as the ***blocking effect***, only certain parts of the electromagnetic spectrum are useful in remote sensing. These regions represent the principal atmospheric windows and define the bands employed in remote sensing

EM RADIATION WAVEBANDS

Radio Waves

- They are used to transmit radio and TV signals.
- Wave length ranges from less than centimeters to hundreds of meters.
- FM radio waves are shorter than AM radio waves.
- Natural objects do not emit radio waves!
- Radio waves are used in remote sensing to exchange information between satellites and ground stations.

Microwave

- It has a wavelength that extends from 1mm – 300 cm.
  - This radiation can penetrate clouds (a valuable region for remote sensing).
- Microwaves are emitted from:
  - Earth surface,
  - Cars,
  - Planes, and
  - Atmosphere.
- The emitted microwave is a function of the object’s temperature.
  - The emitted energy is too small for high-resolution remote sensing.

EM RADIATION WAVEBANDS

Active Microwave

For applications with high resolution requirements, we use active microwave remote sensing systems (RADAR): RAdio Detection And Ranging.

Advantages of RADAR include:

- All weather, day-night systems.
- Radiation is not scattered or absorbed by clouds.
- Detect roughness, slope, and electrical conductivity information.

They do not detect color and temperature information.

Infrared (IR)

It has a wavelength that extends from 0.7µm → 1 mm.

Near IR (0.7 µm – 1.5µm) behaves like visible light and can be detected by special photographic films.

Mid IR (1.5µm – 3.0µm) is of solar origin and is reflected by the surface of the earth.

Thermal/Far IR (3.0µm – 15µm) is emitted by the Earth’s surface and can be sensed as heat.

The amount of emitted energy depends on the temperature of the target.

Much of the emitted energy is absorbed by the atmosphere (it heats the atmosphere).

Sub-millimeter IR (15µm – 1mm).

EM RADIATION WAVEBANDS

Visible Light

It has a wavelength ranging from:
– 0.4 μm to 0.7 μm.
It contains the Blue, Green, and Red portions of the electromagnetic spectrum.
This portion of the spectrum is sensed by the human eye and most photographic films.

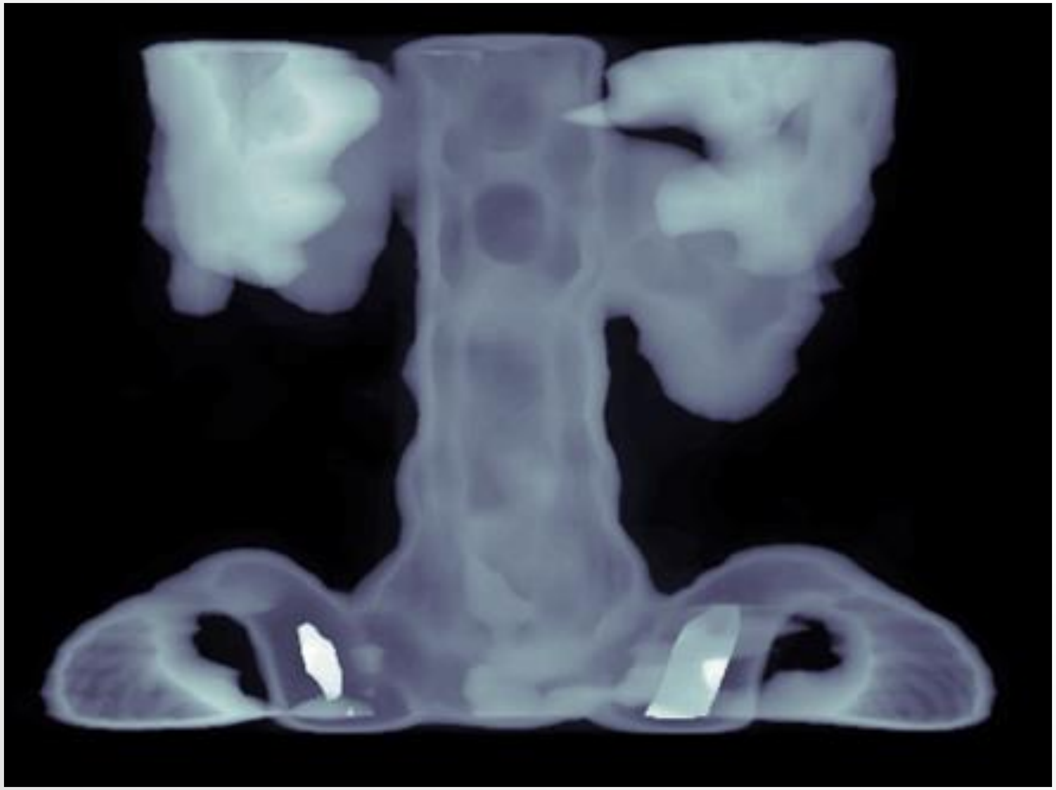
Ultraviolet

It has a wavelength ranging from:
– 0.01 μm to 0.4 μm.
It is a portion of the sunlight that can burn the skin and cause skin cancer.
This portion of the spectrum should be blocked by the ozone in the earth’s upper atmosphere.
– It is not used in satellite remote sensing.

EM RADIATION WAVEBANDS

X-Rays

Wavelength ranging from:
– 0.01 μm to 10-5 μm.
Short wavelength → High energy content → high penetration power.
Extensively used in medical applications.

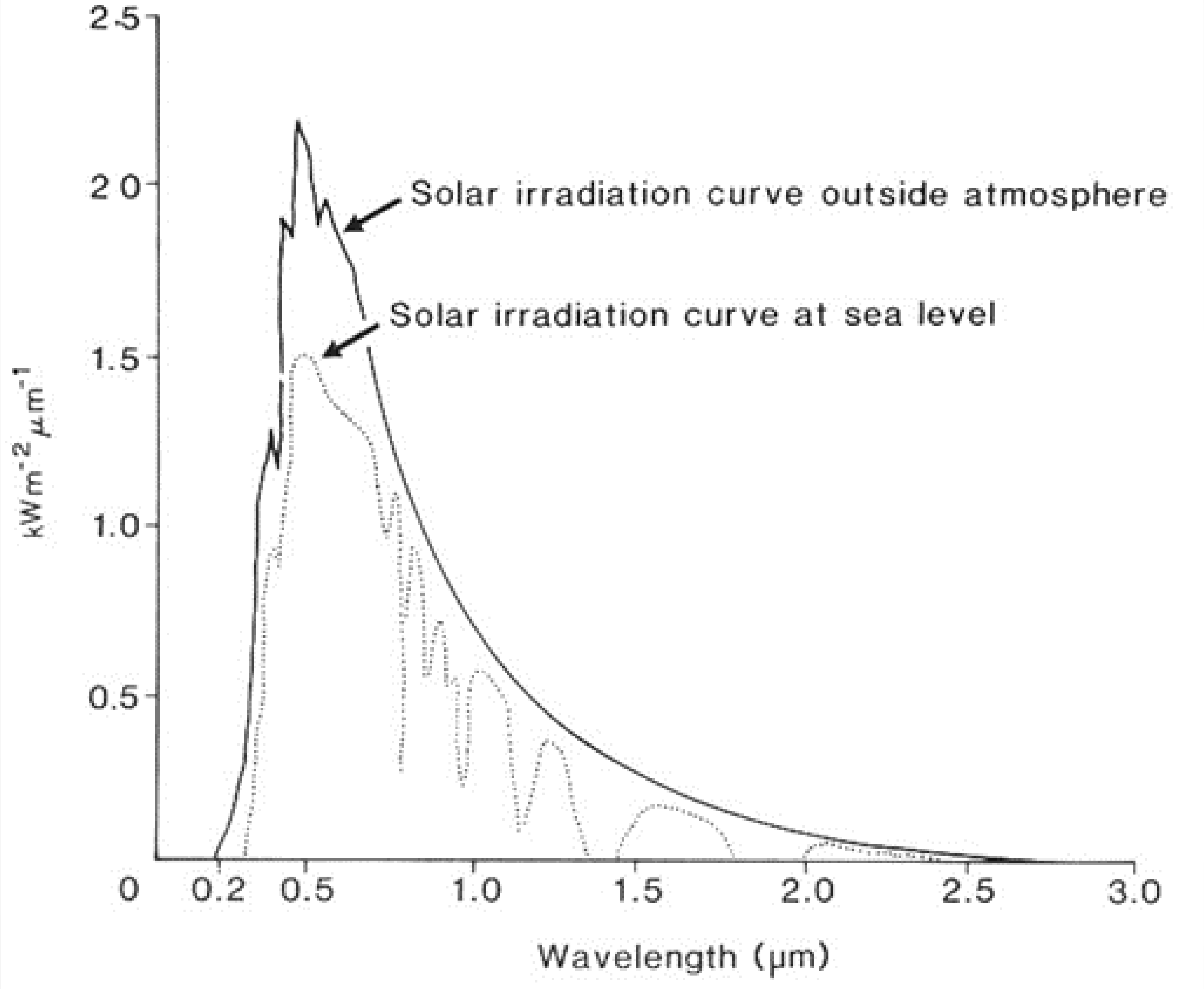


EM RADIATION WAVEBANDS

Gamma Rays

The wavelength of approximately 3* 10-6 μm.
More penetrating power than X-Rays.
They are generated by radioactive atoms and nuclear explosions.
Gamma rays from radioactive material can be recorded by low-flying aircraft.
Due to atmospheric scattering and absorption, gamma rays can not be detected by satellite sensors.
They are in use in some medical applications.

EM RADIATION: INTERACTION WITH THE ATMOSPHERE



ATMOSPHERIC EFFECTS ON EM-RADIATION

The atmospheric effect on the EM-radiation can be viewed either as:

- A source of disturbance that alters the emitted and/or the reflected energy.

  This would be the case when investigating the reflectance properties of targets.

- A source of information about the composition of the atmosphere.

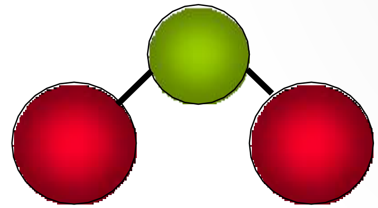
  This would be the case for weather forecasting applications.

Someone’s noise is someone’s signal.

COMPOSITION OF THE ATMOSPHERE

Rain drops, snow, ice crystals

Aerosols



Gas Molecules

The atmosphere is a mixture of:

Various gases (O_3, O_2, CO_2, N_2, Ar, etc.),

Suspended particles (aerosols, fumes, etc.), and

Water particles (water droplets, ice crystals, rain drops, snow, etc.).

ATMOSPHERIC GASES (MOLECULES)

Constituent	% by volume	Variable constituents	% by volume
Nitrogen (N_2)	78.08	Water vapour	0 to 4
Oxygen (O_2)	20.95	Ozone	0-12 x 10^-4
Argon (Ar)	0.93	Ammonia (NH_3)	0.004 x 10^-4
Carbon dioxide (CO_2)	0.033	Sulphur dioxide (SO_2)*	0.001 x 10^-4
Neon (Ne)	18.2 x 10^-4	Nitrogen dioxide (NO_2)*	0.001 x 10^-4
Helium (He)	5.2 x 10^-4	other gases	trace amounts
Krypton (Kr)	1.1 x 10^-4	aerosols, dust, gases	highly variable
Xenon (Xe)	0.089 x 10^-4		
Hydrogen (H_2)	0.5 x 10^-4		
Methane (CH_4)	1.5 x 10^-4		
Nitrous Oxide (N_2O)*	0.27 x 10^-4		
Carbon monoxide (CO)*	0.19 x 10^-4		

Principal gases (99.98 % of atmospheric volume).
Other important Gases.
* Gases concentration close to the terrestrial surface.

NATURAL SOURCES OF AEROSOLS

Pinatubo Volcanic eruption, June 1991

Forest Fire

HUMAN SOURCES OF AEROSOLS

Industry

Cars

Burning oil field, Kuwait (1991)

EM RADIATION INTERACTION WITH THE ATMOSPHERE

Water Vapor

Water vapor plays a major part in the process of emission and absorption of EM radiation.

Sources: Evaporation and perspiration of the plants.

Absorbs certain spectral bands in the visible, IR, and microwave bands of the spectrum.

Atmospheric Gases

O_3 concentration varies with latitude, altitude, and time.

Generated and destroyed by photochemical reactions, or sometimes destroyed by dissolving in water or reacting with the plants.

Absorbs Ultraviolet radiations, IR, and microwaves.

CO_2 has a relatively constant concentration with altitude.

The principal sources of CO_2 are the combustion of fossil fuels, breathing of the alive beings, and volcanic activities.

99% of CO_2 is dissolved in the oceans.

CO_2 is one of the gases responsible for the greenhouse effect.

Absorbs certain wavelengths in the visible and IR portions of the EM spectrum.

EM RADIATION INTERACTION WITH THE ATMOSPHERE

- The density of the elements within the atmosphere changes with the temperature and spatial location.
- These elements are responsible for:
  - Refraction,
  - Scattering (diffusion)
    - Non-selective scattering.
    - Rayleigh scattering.
    - Mie scattering.
  - Absorption.

REFRACTION

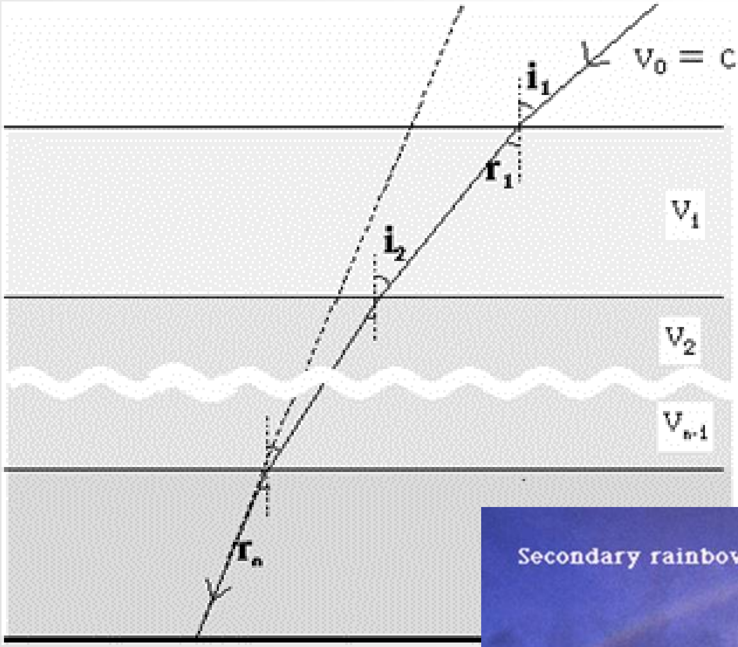
Refraction is caused by variations in temperature, pressure, and humidity within the layers of the atmosphere.

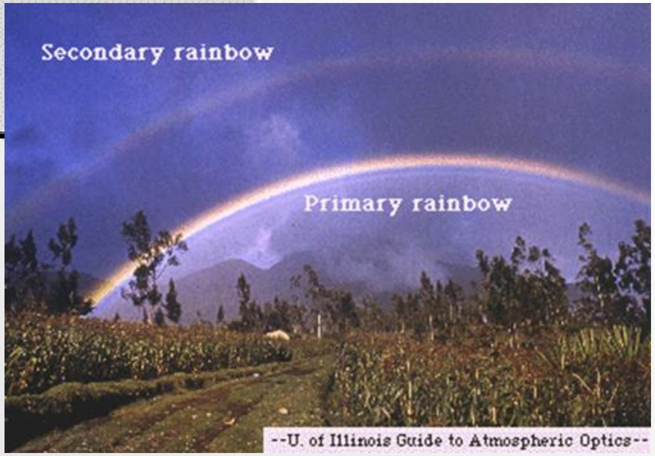
Refraction varies with space and time.

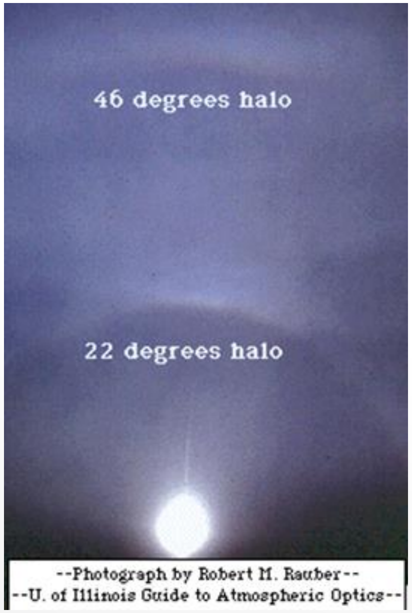
Refraction is governed by Snell's law:

- $n_1 \sin i = n_2 \sin r$

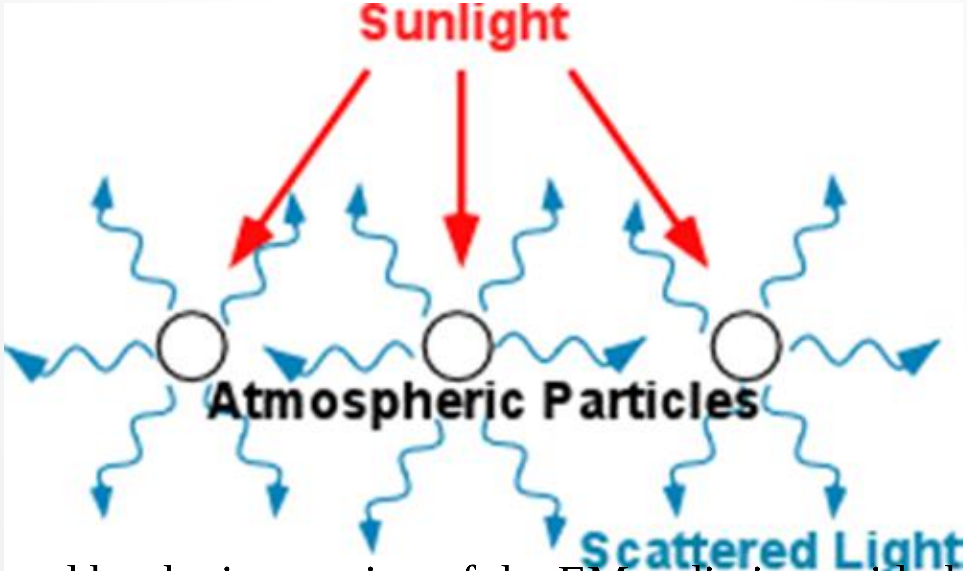
EM wave propagation EM is not a straight line. The way traversed by waves EM is longer than the shortest distance between the target and the sensor; Refraction degrades the spectral resolution and causes geometric distortions in the location of the recorded imagery.







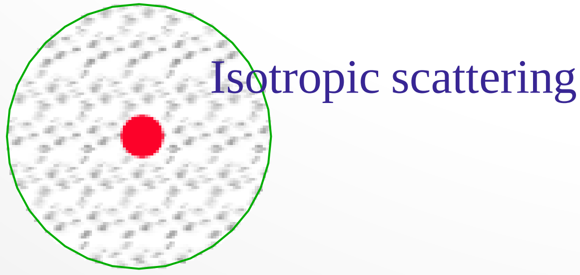
SCATTERING



- Scattering is caused by the interaction of the EM radiation with the following:
  - Gas molecules (size 10^{-8} cm);
  - Solid aerosols (0.1 μm < size < 1 μ m);
  - Water droplets (1 μ m < size < 10 μ m);
  - Ice crystals (1 μ m < size < 100 μ m);
  - Hail (size up to 10 cm).
- Scattering contributes to the attenuation of EM radiation.
- There are two types of scattering:
  - Selective scattering.
    - Rayleigh scattering
    - Mie Scattering.
  - Non-selective scattering.

NON-SELECTIVE SCATTERING

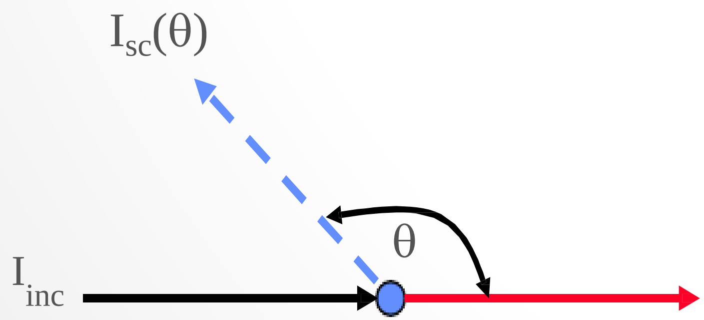
- Takes place in the lower atmosphere.
- Caused by particles with a size larger than the wavelength of the incidental radiation.
- Non-selective scattering is independent of the wavelength of the incident radiation.
- Non-selective scattering is isotropic.
- Non-selective scattering is responsible for fog.



SELECTIVE SCATTERING: RAYLEIGH SCATTERING

- Takes place in the upper atmosphere (9-10 Km).
- Caused by gas molecules and particles with a size smaller than the wavelength of the incident spectrum.
- Rayleigh scattering is inversely proportional to the wavelength of the incident radiation.

$$I_{sc}(\theta) = \alpha \, I_{inc} \, (1 + \cos^2\theta) \, / \, \lambda^4$$

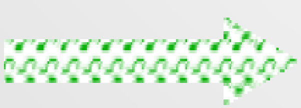


- Rayleigh scattering along the direction of the radiation ($\theta = 0°$ & $\theta = 180.0°$) is two times more than that in the direction perpendicular to the incident radiation.

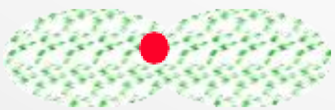
$$I_{sc}(0°) = I_{sc}(180.0°) = 2 \, \alpha \, I_{inc} \, / \, \lambda^4$$

$$I_{sc}(90.0°) = \alpha \, I_{inc} \, / \, \lambda^4$$

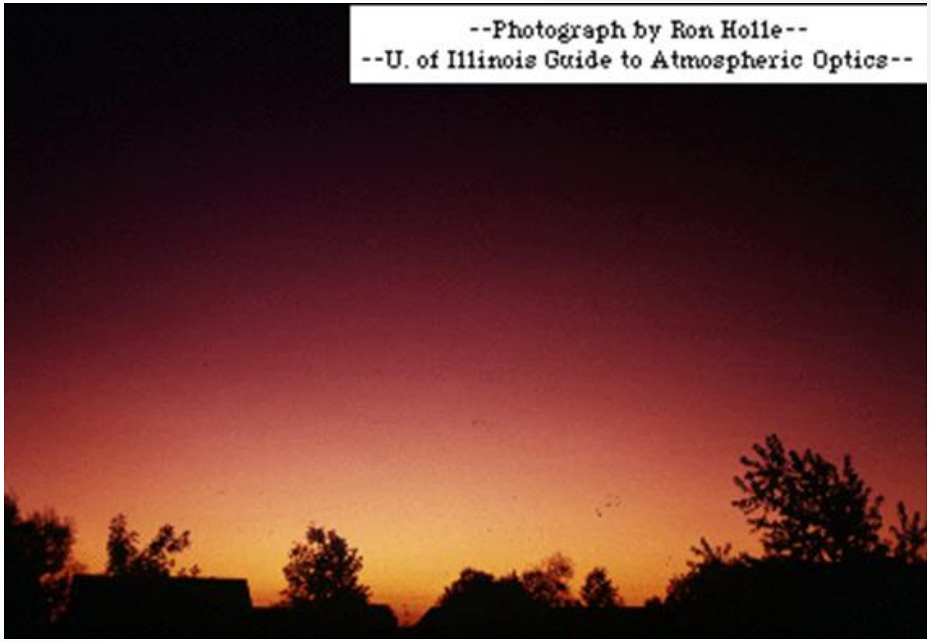
Incident radiation



Rayleigh scattering



RAYLEIGH SCATTERING



The previous formula explains the blue sky at midday.
– Blue radiation is scattered 4 times more than red radiation.

The formula also explains the red sky at sunset

MIE SCATTERING

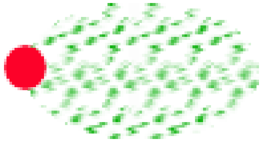
- Mie scattering takes place in the lower part of the atmosphere (0 to 5 km).
- It is caused by aerosols whose size is similar to the wavelength of the incident radiation.
- Mie Scattering is concentrated forward.

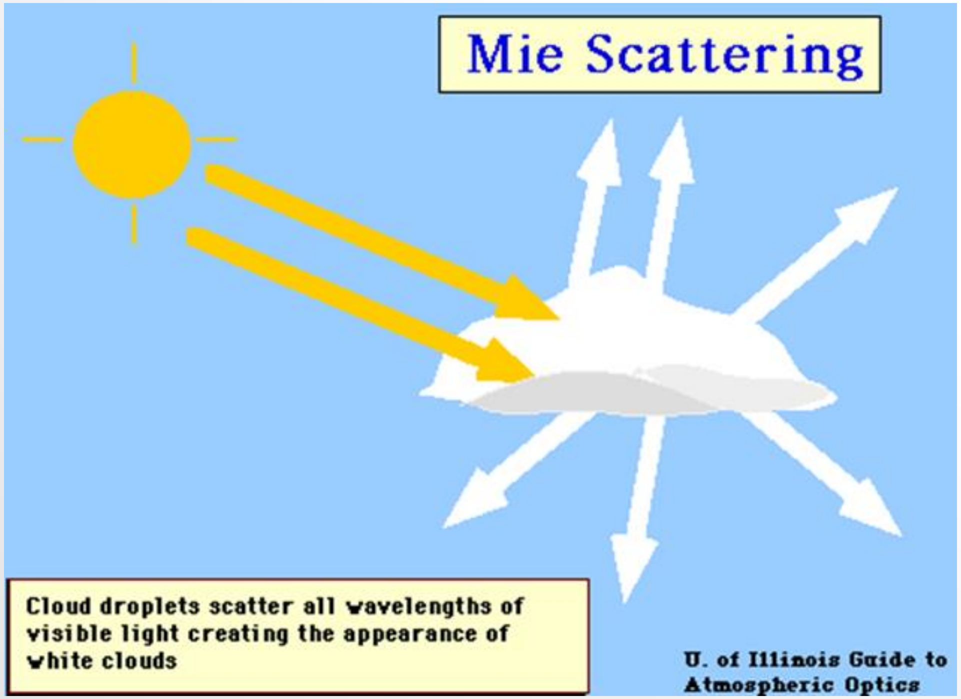
$$I_{sc} = f(\lambda^{-t}, I_{inc})$$

$$t \sim 0.7 - 2.0$$

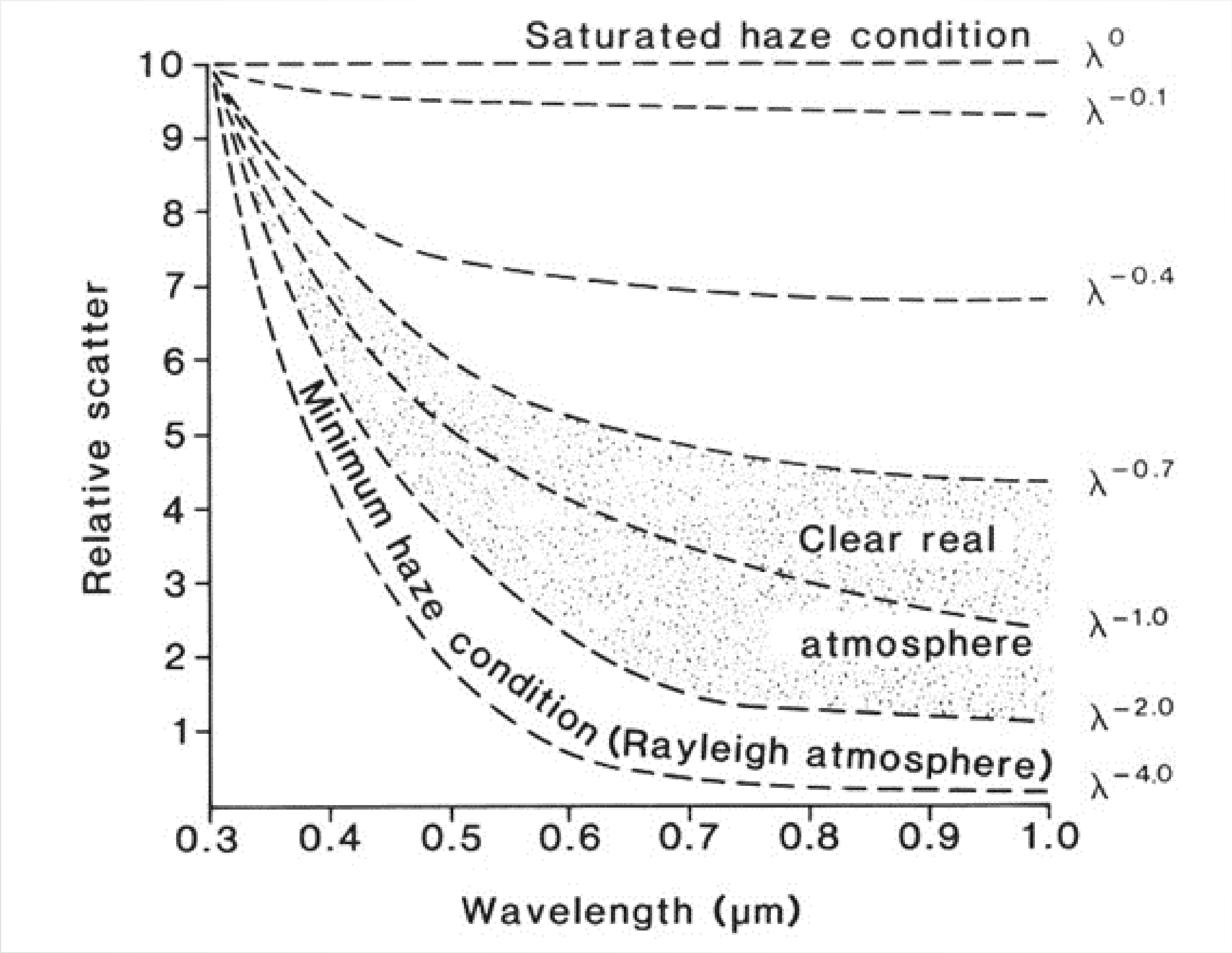
Incident radiation

Mie Scattering

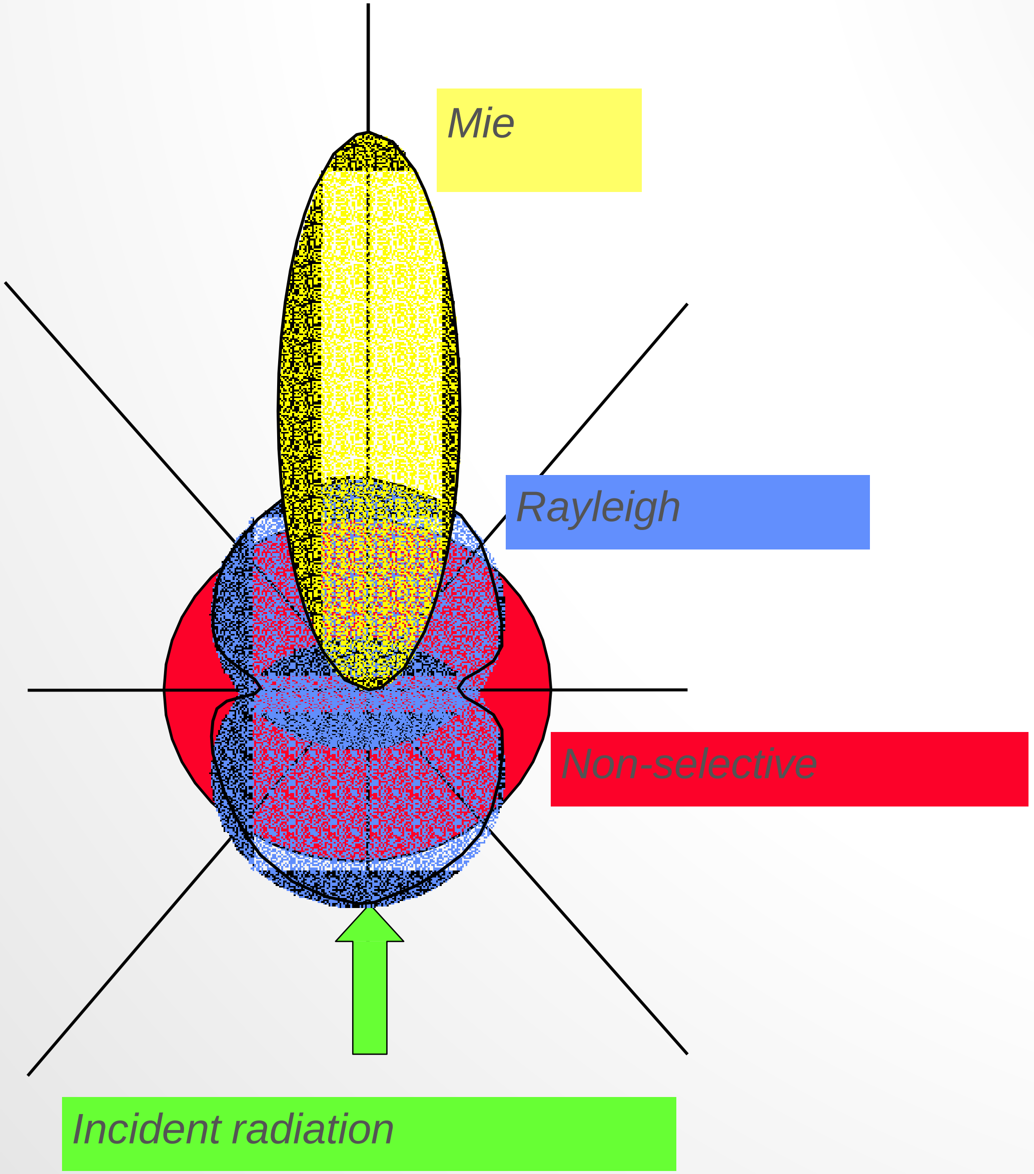




SCATTERING AS A FUNCTION OF WAVELENGTH



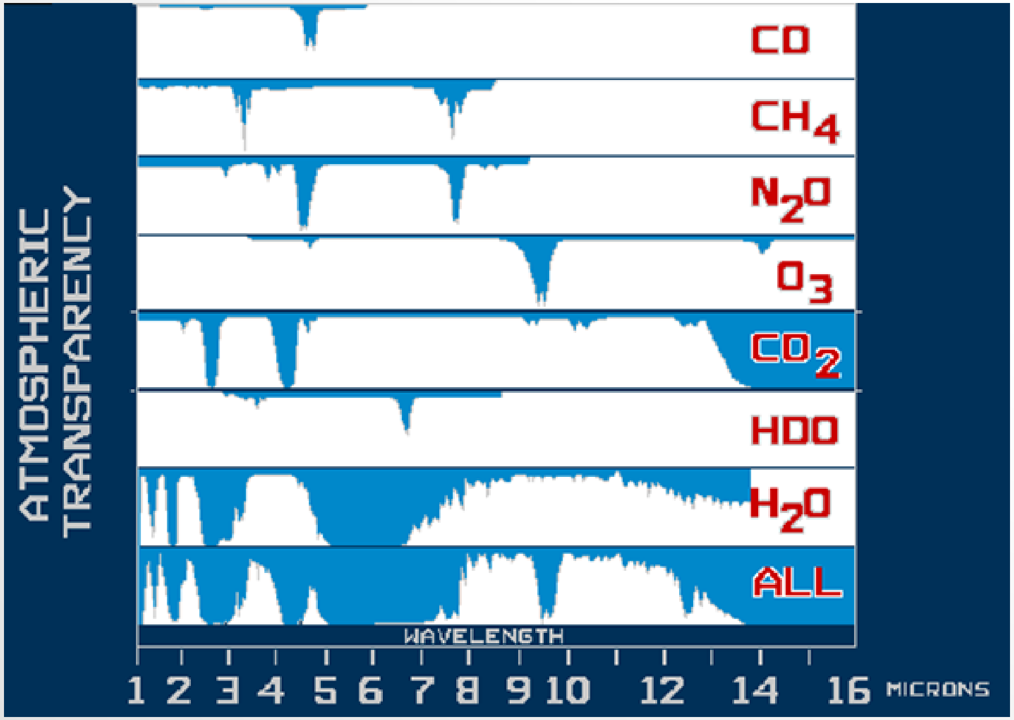
SCATTERING: FINAL REMARKS



Scattering is direction dependent

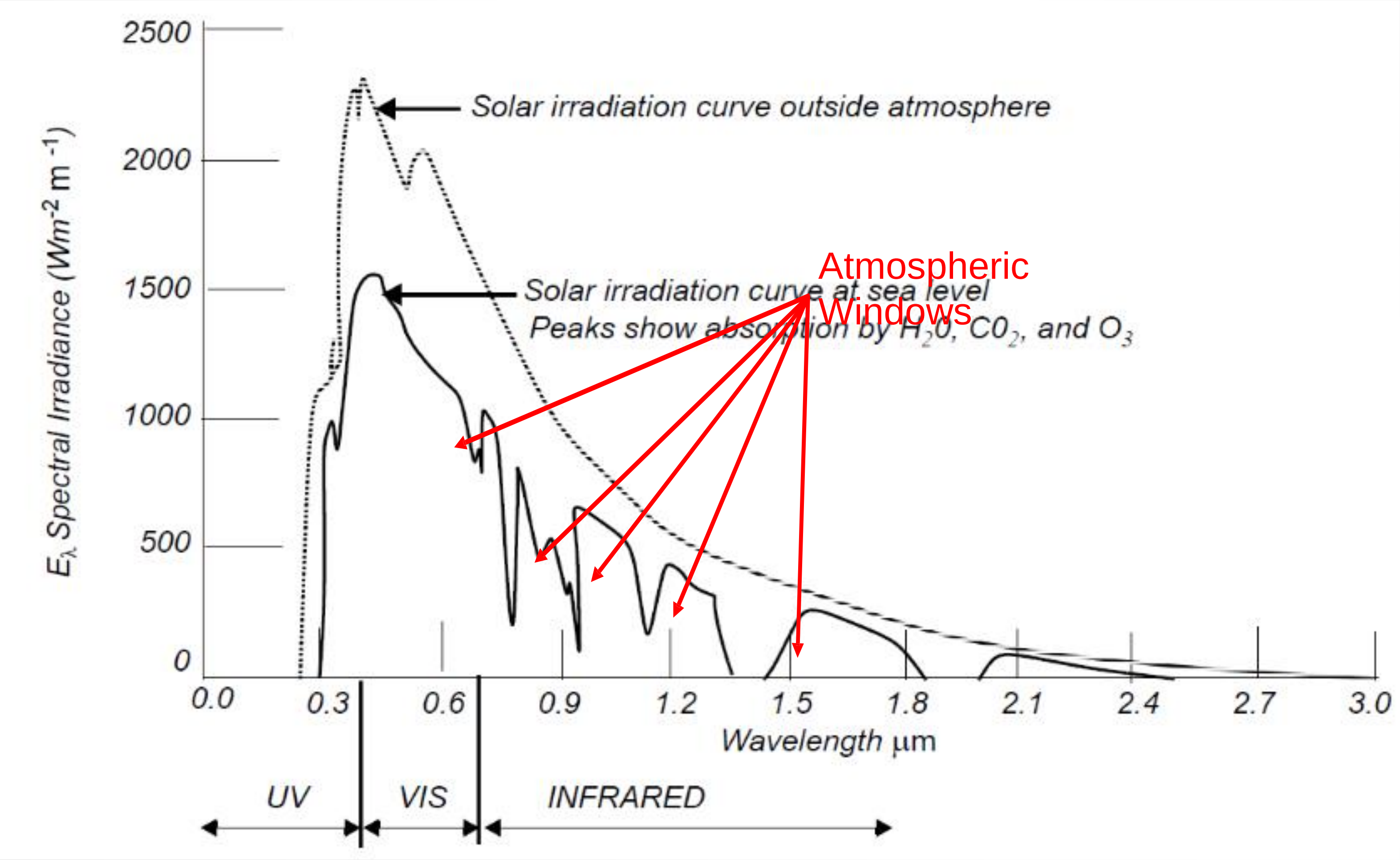
ABSORPTION

- Radiant energy is converted into molecular energy.
- Contributes to the attenuation of EM radiation.
- Principal absorption bands in:
  - Visible: O_3 (600 Nm), H_2O (718 Nm), O_2 (760 Nm).
  - Infra-red: O_3 (9.6 μm), H_2O (1.45, 1.9, 2.7 - 3.7, and 6.3 μm), CO_2 (2.9 μm, 4.3 μm).
  - Opaque atmosphere for wavelengths between 22 μm to 1 mm.
  - Microwave: O_2 (2.5 and 5 mm), H_2O (1.6 and 13.5 mm).
  - Transparent atmosphere for wavelengths beyond 3 cm.



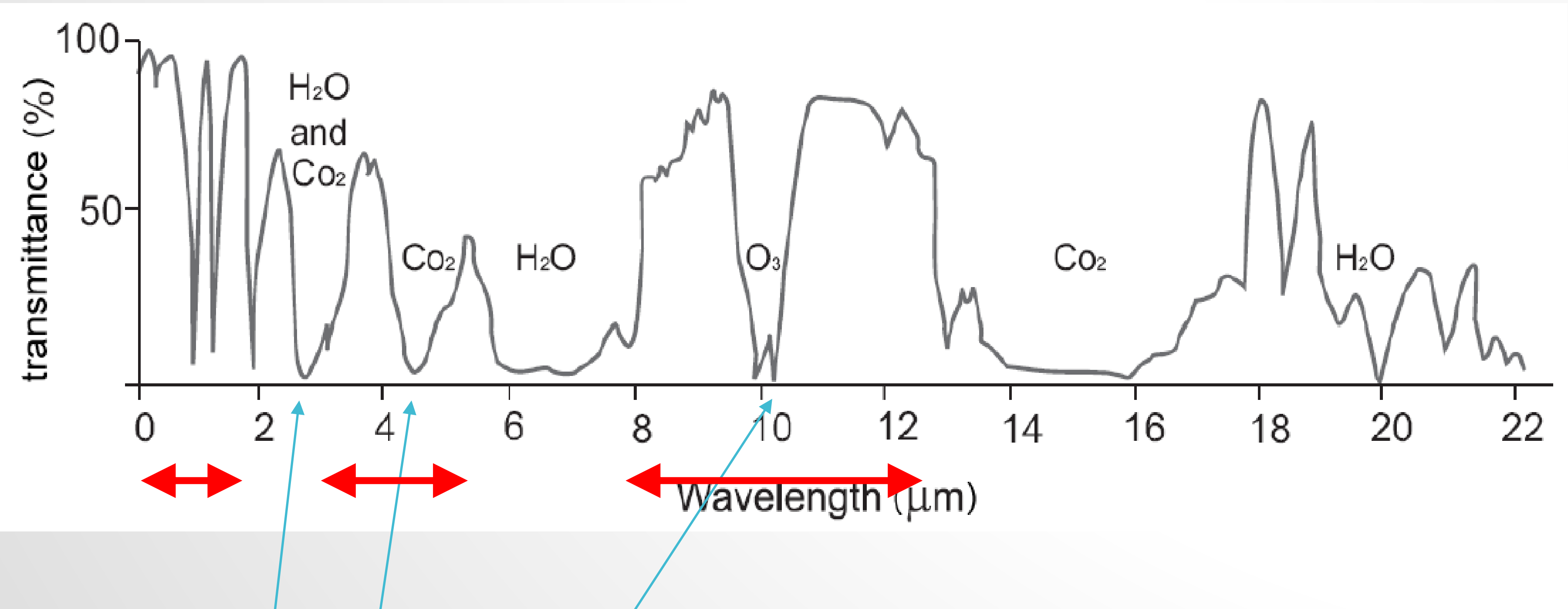
Major components (H_2O & CO_2)

ATMOSPHERIC WINDOWS



ATMOSPHERIC WINDOWS

Ozone (O3), water vapor (H2O) and Carbon Dioxide (CO2) Absorption



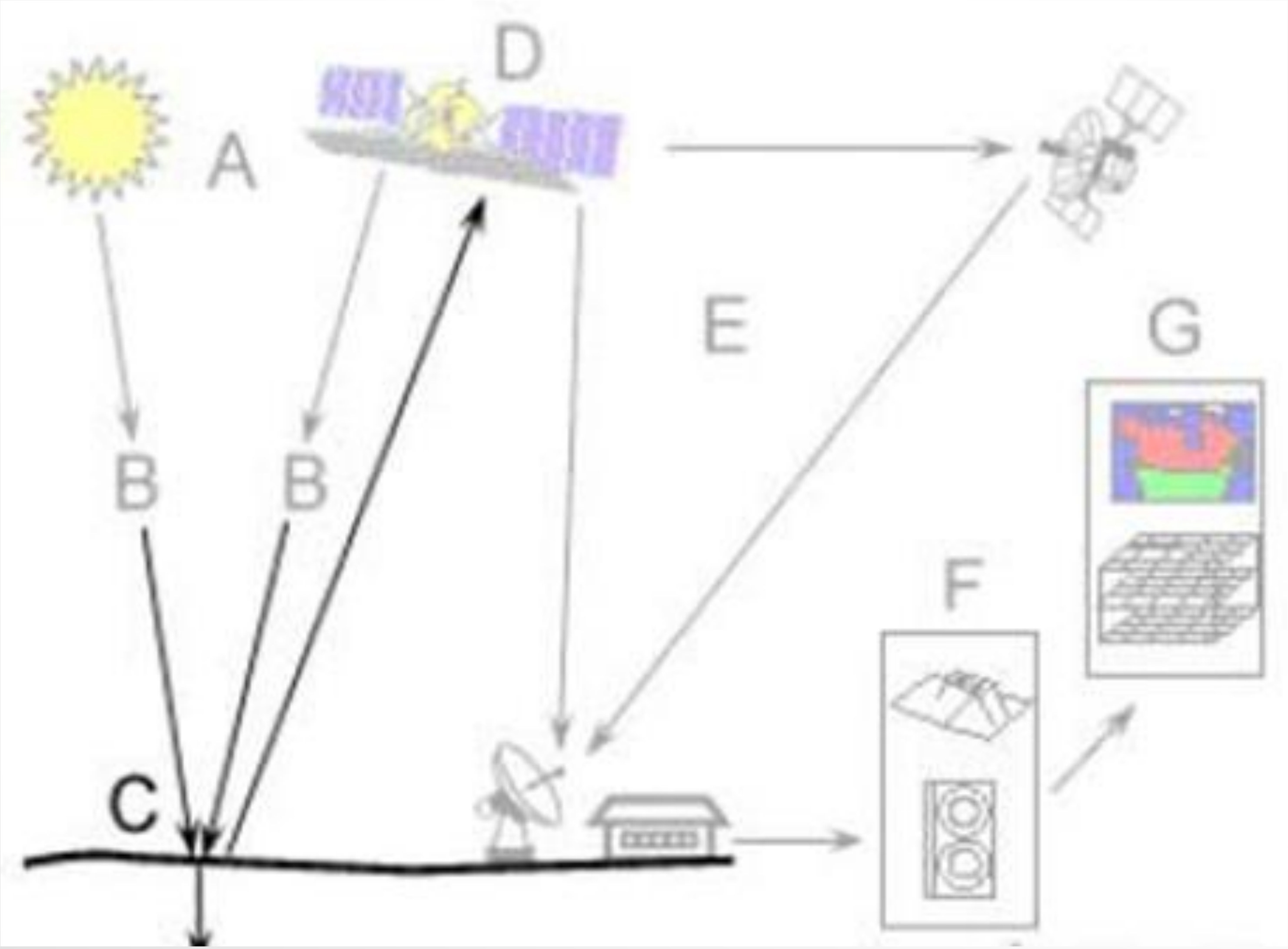
Not good for remote sensing wavelength

ABSORPTION BANDS & ATMOSPHERIC WINDOWS

- Gases such as water vapor, carbon dioxide, and ozone absorb particular regions of the EM radiation spectrum.
  - These regions are called ***absorption bands***.
- Remote sensing in the absorption bands is impossible.
- Other regions (i.e., other than the absorption bands) in the EM radiation spectrum are called ***atmospheric windows***.

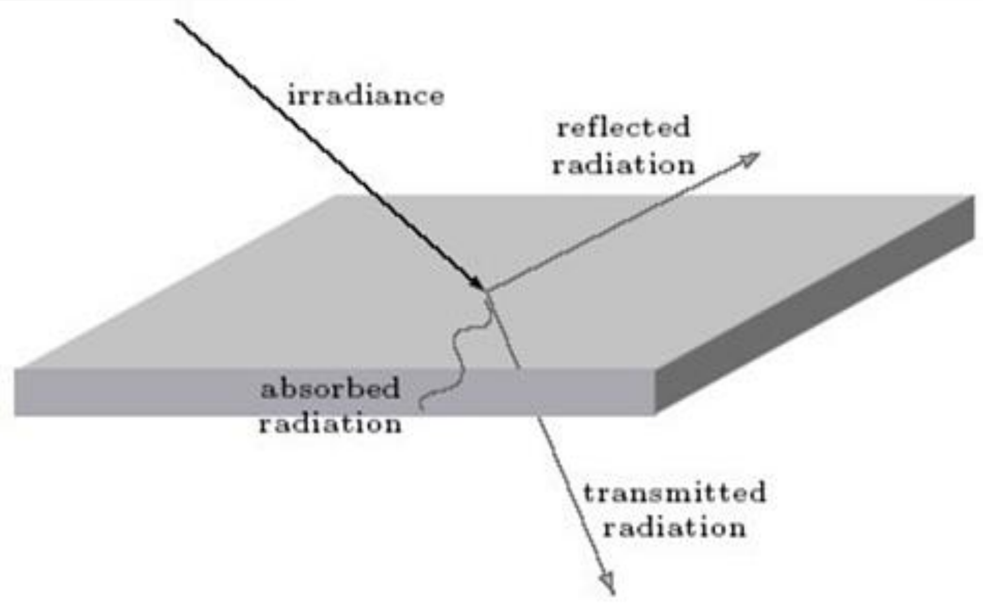
- Atmospheric windows are these portions of the EM radiation spectrum with low absorption/high transmission.
- Following are some examples of atmospheric windows:
  - (0.3 – 1.3 μm): Visible/near-infrared window.
  - (1.5 – 1.8, 2.0 – 2.5, and 3.5 – 4.1μm): Mid-infrared window.
  - (7.0 – 15.0 μm): Thermal/far infrared window.

INTERACTION WITH THE TARGET



EM RADIATION: INTERACTION WITH TARGETS

Irradiance that falls on the material is either reflected, transmitted through the material, or absorbed by the material.



$$\text{reflectivity} = \frac{\text{reflected exitance}}{\text{irradiance}} = r$$

$$\text{transmissivity} = \frac{\text{transmitted exitance}}{\text{irradiance}} = t$$

$$\text{absorptivity} = \frac{\text{absorbed irradiance}}{\text{irradiance}} = a$$

- Due to conservation of energy:
  - $r + t + a = 1$

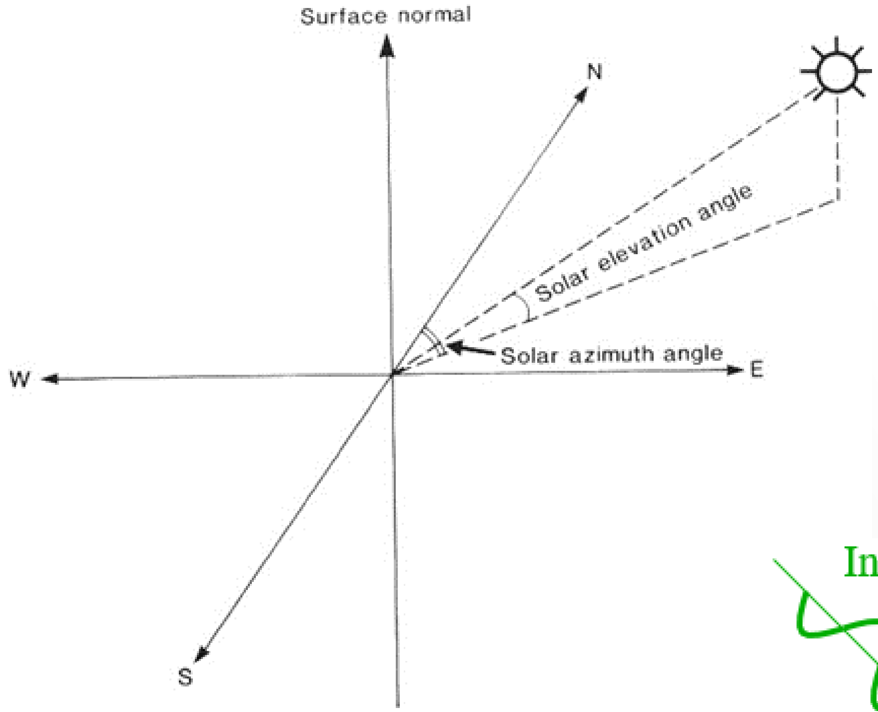
REFLECTED ENERGY

- Reflected energy travels upward through, and interacts with, the atmosphere.
- The part of the reflected energy that enters the field of view of the sensor is detected and converted into numerical values (digital sensor).
- The amount and the distribution of the reflected energy are used to infer the nature of the reflecting surface.
  - This is the main objective of remote sensing activities.
- *Spectral reflectance curve* describes the spectral response of the target.

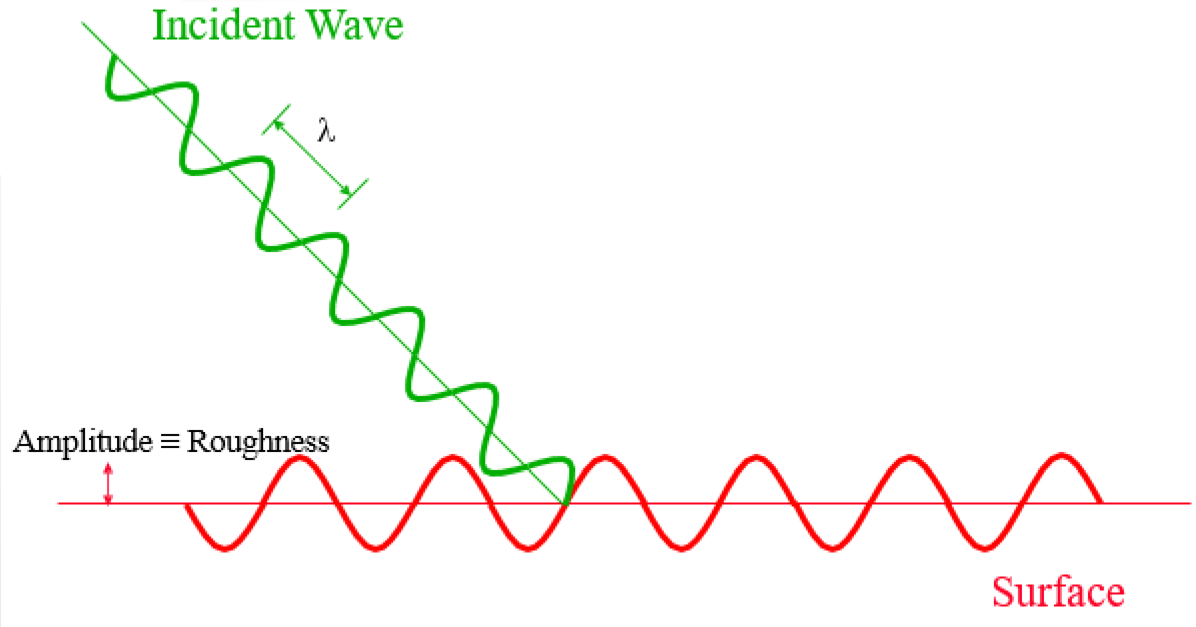
- For the same material, the reflectance response curve might be time-dependent.
  - Vegetation: Leafing stage, growth, maturity, and senescence.
- For the same material, the reflectance curve depends on:
  - The orientation of the Sun (solar azimuth),
  - The height of the Sun in the sky (solar elevation angle).
  - The direction that the sensor is pointing relative to the solar azimuth (look angle).

REFLECTED ENERGY

Solar Azimuth & Elevation Angle



Surface Roughness

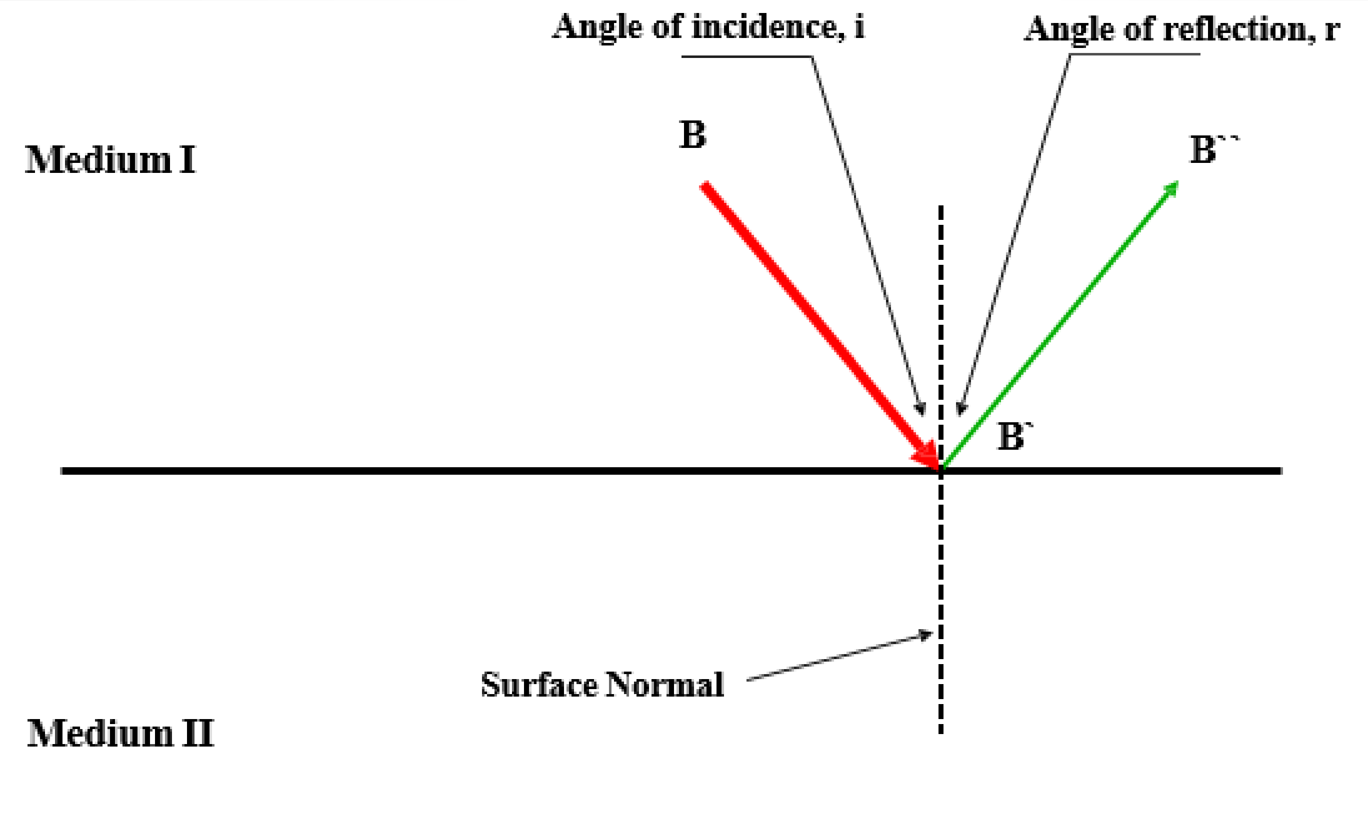


Surface classification (rough & smooth) depends on the wavelength of the incident radiation.

SPECULAR VERSUS DIFFUSE REFLECTANCE

- There are two kinds of reflectance that can occur at a surface.
- ***Specular reflection***: reflected energy leaves the reflecting surface without being scattered.
  - The angle of reflectance equals the angle of incidence.
- Specular reflectance is expected to take place when the target is smooth relative to the wavelength of the incident energy.
  - Surface roughness is smaller than the wavelength of the incident energy.

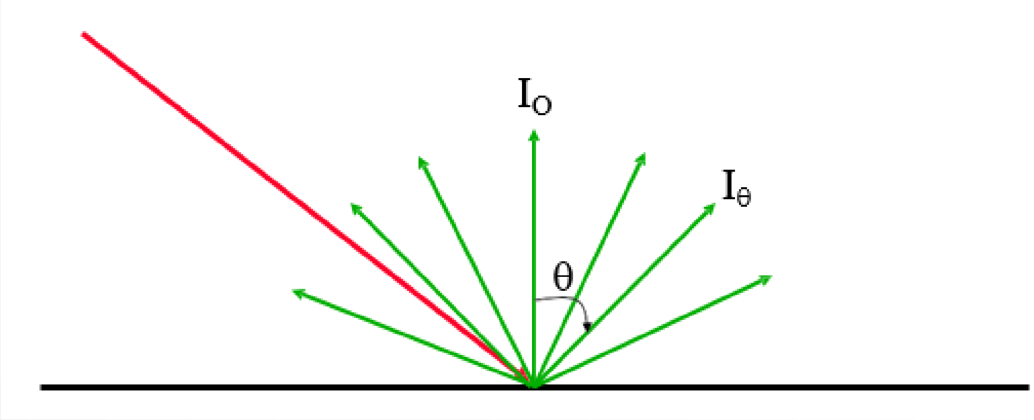
SPECULAR REFLECTANCE



- The Specular reflectance law controls the path (BB`B``).
- The Specular reflectance law states that:
  - –The incident ray, the surface normal, and the reflected ray all lie in the same plane.
  - –The incident angle (i) = the reflection angle (r).

DIFFUSE REFLECTANCE

- Diffuse reflectance occurs when the reflecting surface is rough relative to the wavelength of the incident energy.
- In this case, the incident energy is scattered in all directions.
- In the visible portion of the EM spectrum:
  - All terrestrial targets are diffuse reflectors.
  - A calm water can act as a Specular reflector.
- In the microwave portion of the EM spectrum:
  - Some terrestrial targets will act as Specular reflectors.

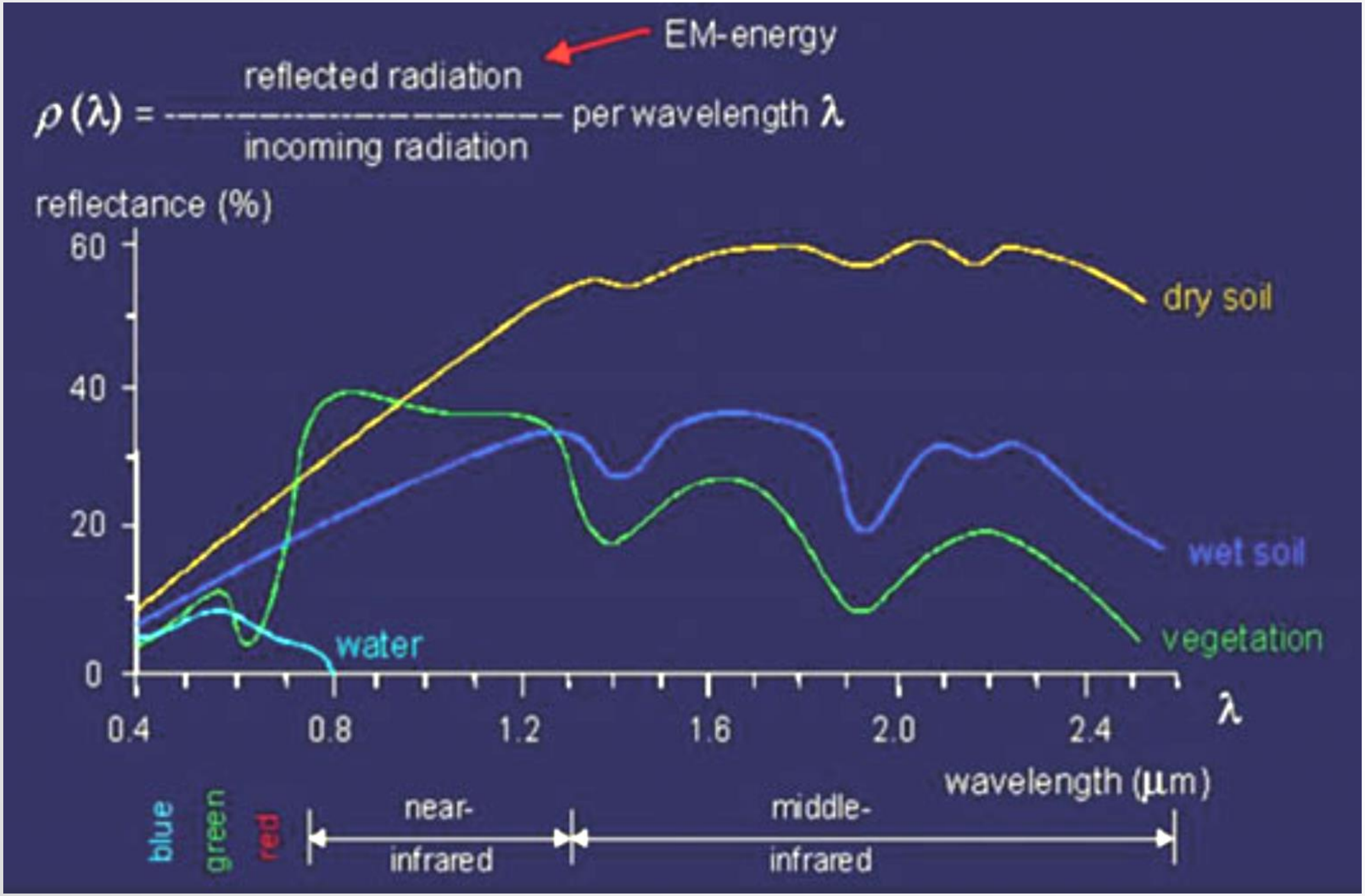


- Lambertian Surface:
  - Radiant exitance observed at an angle (θ) is the same as the detected exitance at a view angle (0) adjusted for the fact that the projection of the unit surface at a view angle (θ) is proportional to cos(θ).
  - $I_\theta = I_O \cos(\theta)$

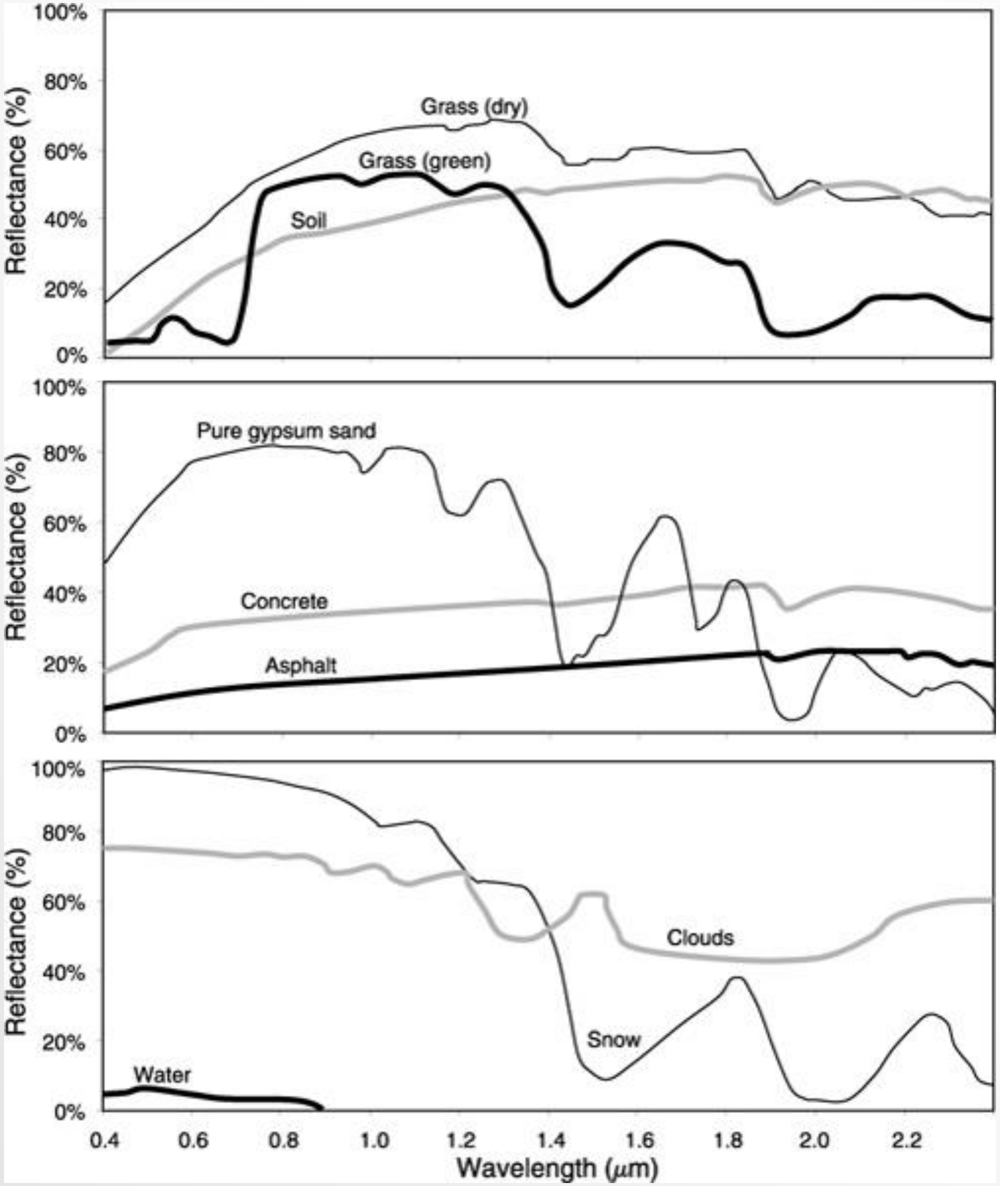
MEASUREMENT OF REFLECTED ENERGY

- Remote sensing sensors do not observe and detect all the reflected energy from a ground target over the entire hemisphere.
  - Rather, they record the reflected energy from the ground target that is returned at a particular angle.
  - The distribution of the radiance in all possible observation and illumination angles is defined by the bidirectional reflectance distribution function (BRDF).
- The reflectance of a surface depends on:
  - The direction of the irradiating flux.
  - The direction along which the reflected flux is detected.

SPECTRAL REFLECTANCE OF EARTH-SURFACE MATERIALS



SPECTRAL REFLECTANCE OF EARTH-SURFACE MATERIALS



SPECTRAL REFLECTANCE OF VEGETATION

- Vigorous vegetation show relatively low values in the red and the blue portions of the visible spectrum with a peak in the green spectral band.
  - The chlorophyll and other pigments absorb 70-90% of the red and blue portions (for photosynthesis).
  - The reflectance peak in the green band is the reason for growing vegetation to appear green.
- The reflectance rises sharply in the region of 0.75 μm (red edge).
- The reflectance remains high in the region (0.75 – 1.35 μm).

- The leaf water content is responsible for the dib in the reflectance curve at 1.45μm and 1.9μm.
- *As the plant ages*, the level of reflectance in the near-infrared region (0.75-1.35μm) declines at first.
  - The reflectance in the visible portion of the spectrum is not significantly affected.
  - As senescence continues, the relative peak in the green portion declines as the leaf losses its greenness.
- Stress caused by drought or the presence/absence of particular minerals in the soil can produce a spectral response that is similar to senescence.
  - The use of geo-botanical anomalies is being used to determine mineral deposits.

SPECTRAL RESPONSE OF VEGETATION

- The spectral reflectance response can be used to discriminate among different vegetation species.
- There is no single, ideal spectral reflectance curve for any particular vegetation type.
  - As mentioned earlier, the recorded reflectance depends on the illumination and viewing angles as well as other variables (e.g., number of leaf layers, the geometry of crop canopy, nature of ground).

SPECTRAL RESPONSE OF ROCKS (GEOLOGY)

- 70% of the Earth's land surface is vegetated.
  - Remote sensing analysis of geo-botanical anomalies can be used to study the underlying rocks.
    - For example, peculiar or unexpected species distribution, stunted growth, reduced cover, altered leaf pigmentation (yellowing), early senescence, or late leafing.
- In semi-arid and arid areas, the spectral reflectance curves of rocks and minerals may be used.
  - Rock-forming minerals have unique spectral reflectance curves.
  - The presence of absorption features in these curves is diagnostic of the presence of certain mineral types.

- Clay minerals have a decreasing spectral reflectance beyond 1.6μm.
- Carbonate and silicate mineralogy can be inferred from the presence of absorption bands in the mid-infrared region, particularly (2.0 – 2.5 μm).
- Effects of weathering cause problems with the identification of rocks.
  - Spectral reflectance of a rock is determined by the mineralogy of the upper 50 μm layer.
  - Weathering produces a surface layer that is different in composition from the parent rock.

SPECTRAL RESPONSE OF WATER BODIES

- Spectral reflectance curve for water shows a general reduction in reflectance with increasing wavelength.
  - The near-infrared reflectance of deep clear water is virtually zero.
- Spectral reflectance of water is affected by dissolved and suspended organic and inorganic material as well as the depth of the water body.
- Radiance levels over water are low compared with those observed over land
- The proportion of information contained in the signal received by the sensor can be as low as 20%.
- The major contributor to the noise is the atmosphere.
- Oceanographic remote sensing community has been most active in developing methodologies for the removal and/or the reduction of atmospheric effects from remotely-sensed imagery.

SPECTRAL RESPONSE OF SOILS

- Spectral reflectance curves of soils rise as the wavelength increases.
  - The opposite of the spectral response reflectivity of water.
- Reflectance in the visible wavebands is affected by the presence of organic matter and soil moisture.
  - The soil water content is responsible for the dib in the reflectance curve at 1.45µm and 1.9µm.
  - Soil reflectance is usually greatest in the region between these two water absorption bands.