BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024,
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Programme: M.Sc., Environmental Science and Sustainable Management

Course Title : Remote Sensing and GIS
Course Code : 21PGCC03

Module-I

# History of Remote Sensing, EMR and Interactions

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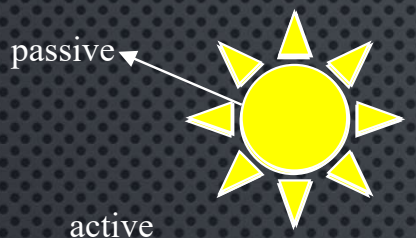
# BASIC OF REMOTE SENSING

# ELEMENTS OF REMOTE SENSING

- ENERGY SOURCE
- THE ATMOSPHERE
- THE OBJECTS ON THE EARTH'S SURFACE
- PLATFORMS
- SENSOR SYSTEMS
- RECORDING SYSTEMS

# Remotely Sensed Data ???




1

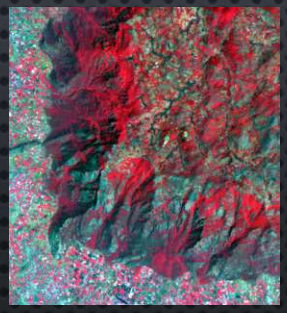
2


4

5 (Film)

6

7



Stage-1 Source of energy

Stage-2. Transmission of EMR towards the Object

Stage-3. Interaction of EMR with the Object

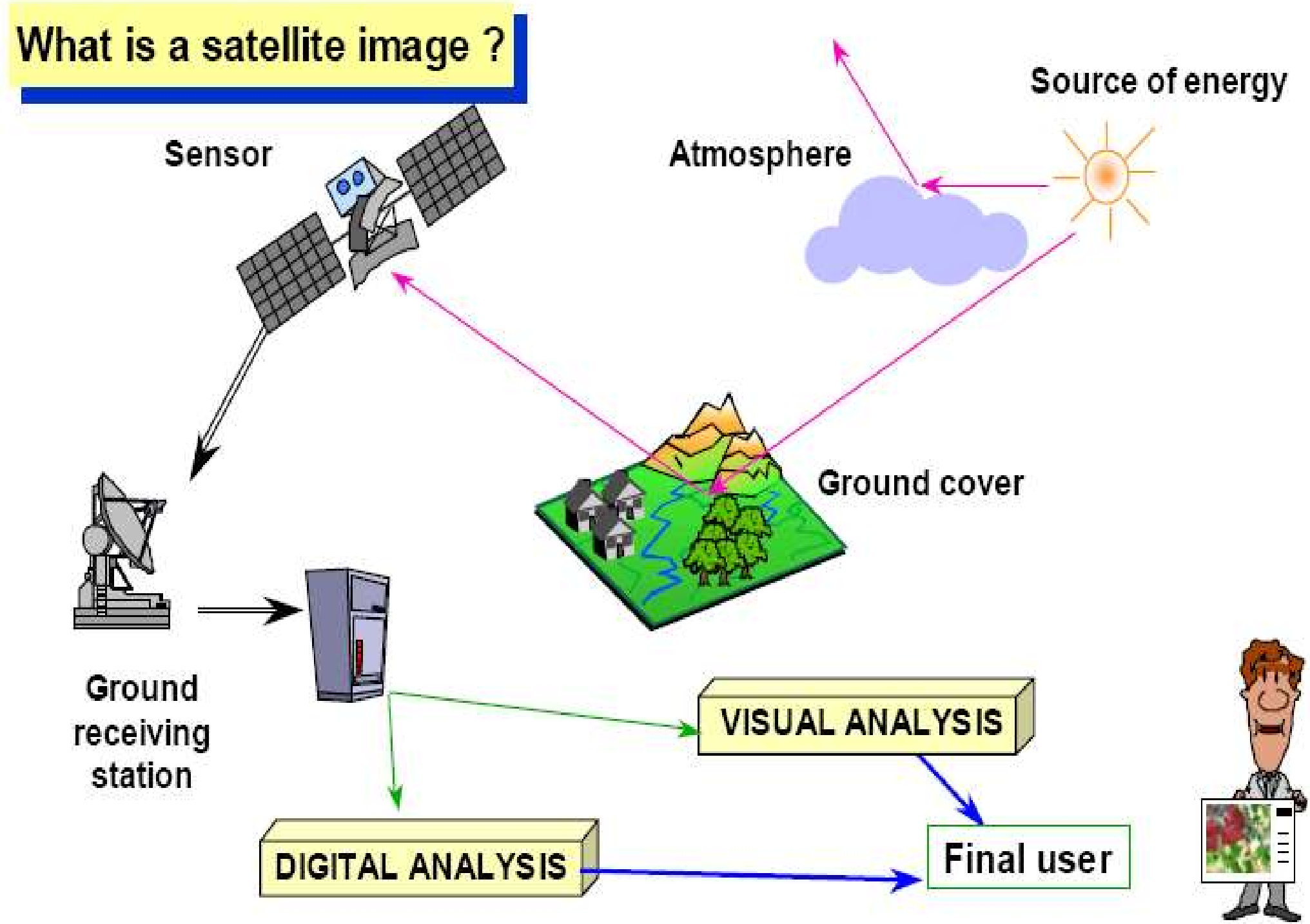
Stage-4. Transmission of Interacted EMR towards the Sensor

Stage-5 Recording of the Image by the Detector

Stage-6. Relay to Ground Station

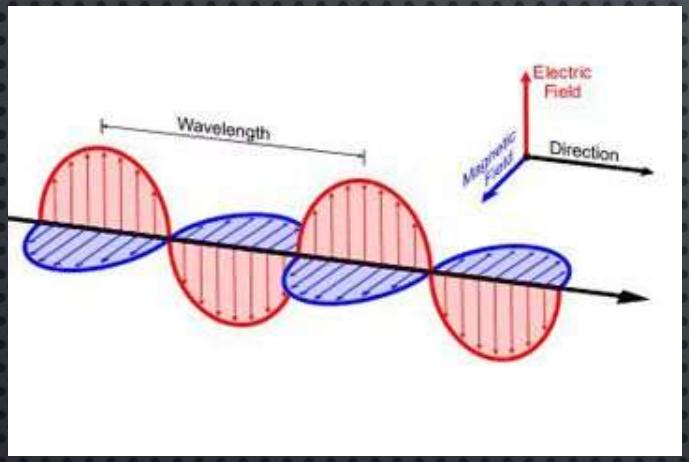
Stage-7. Analysis of the Imagery

# What is a satellite image ?

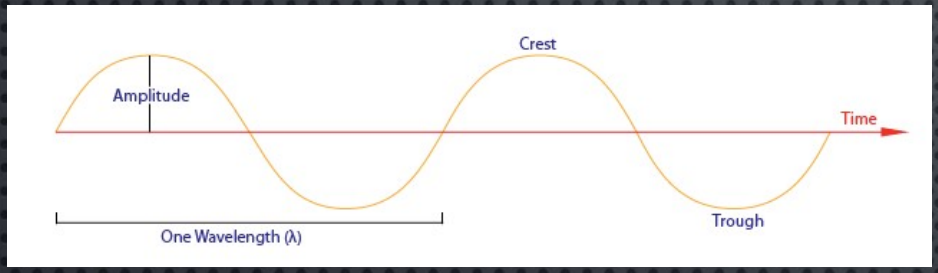



(E. Chuvieco, 1990)

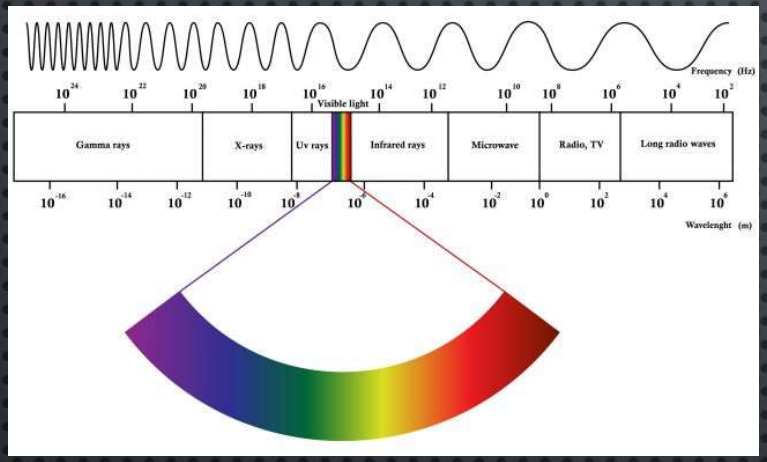
# ELECTRO MAGNETIC RADIATION




A wave has a *trough* (lowest point) and a *crest* (highest point). The vertical distance between the tip of a crest and the wave's central axis is known as its *amplitude*. This is the property associated with the brightness, or intensity, of the wave. The horizontal distance between two consecutive troughs or crests is known as the *wavelength* of the wave


Crest
Amplitude
Time
Trough
One Wavelength (λ)

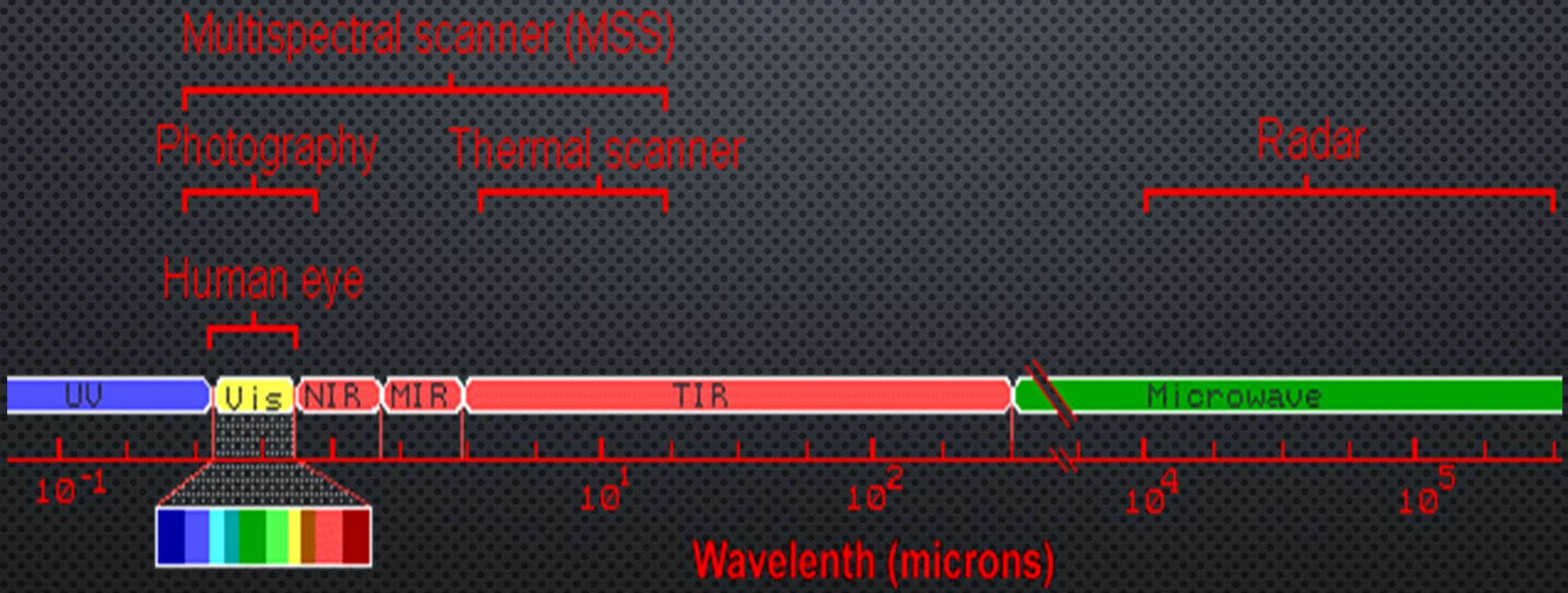
# ELECTRO MAGNETIC SPECTRUM



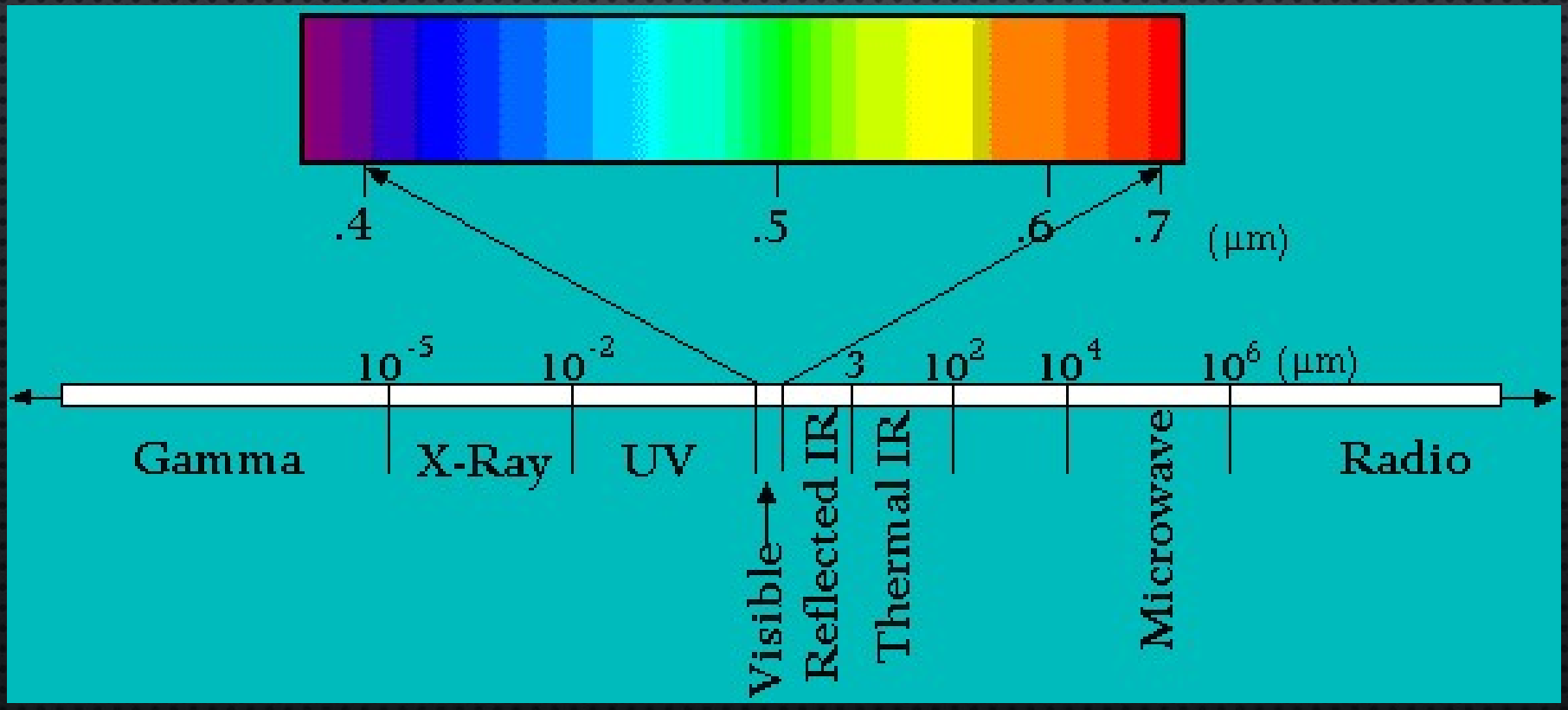
- **Radio waves**
- Radio waves are at the lowest range of the EM spectrum, with frequencies of up to about 30 billion hertz, or 30 gigahertz (GHz), and wavelengths greater than about 10 millimeters (0.4 inches). Radio is used primarily for communications including voice, data and entertainment media.
- **Microwaves**
- Microwaves fall in the range of the EM spectrum between radio and IR. They have frequencies from about 3 GHz up to about 30 trillion hertz, or 30 terahertz (THz), and wavelengths of about 10 mm (0.4 inches) to 100 micrometers (mm), or 0.004 inches. Microwaves are used for high-bandwidth communications, radar and as a heat source for microwave ovens and industrial applications.
- **Infrared**
- Infrared is in the range of the EM spectrum between microwaves and visible light. IR has frequencies from about 30 THz up to about 400 THz and wavelengths of about 100 mm (0.004 inches) to 740 nanometers (nm), or 0.00003 inches. IR light is invisible to human eyes, but we can feel it as heat if the intensity is sufficient.
- **Visible light**
- Visible light is found in the middle of the EM spectrum, between IR and UV. It has frequencies of about 400 THz to 800 THz and wavelengths of about 740 nm (0.00003 inches) to 380 nm (.000015 inches). More generally, visible light is defined as the wavelengths that are visible to most human eyes.
- **Ultraviolet**
- Ultraviolet light is in the range of the EM spectrum between visible light and X-rays. It has frequencies of about $8 \times 10^{14}$ to $3 \times 10^{16}$ Hz and wavelengths of about 380 nm (.000015 inches) to about 10 nm (0.0000004 inches). UV light is a component of sunlight; however, it is invisible to the human eye. It has numerous medical and industrial applications, but it can damage living tissue.

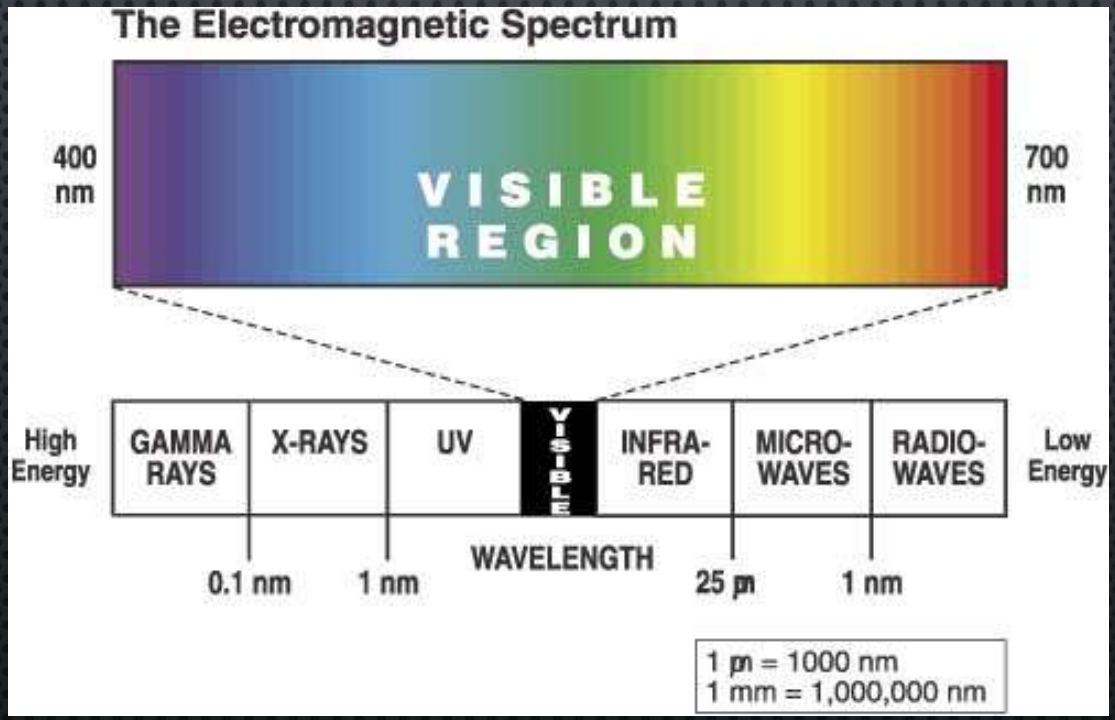
- **X-rays**
- X-rays are roughly classified into two types: soft X-rays and hard X-rays. Soft X-rays comprise the range of the EM spectrum between UV and gamma rays. Soft X-rays have frequencies of about $3 \times 10^{16}$ to about $10^{18}$ Hz and wavelengths of about 10 nm ($4 \times 10^{-7}$ inches) to about 100 picometers (pm), or $4 \times 10^{-8}$ inches. Hard X-rays occupy the same region of the EM spectrum as gamma rays. The only difference between them is their source: X-rays are produced by accelerating electrons, while gamma rays are produced by atomic nuclei.
- **Gamma-rays**
- Gamma-rays are in the range of the spectrum above soft X-rays. Gamma-rays have frequencies greater than about $10^{18}$ Hz and wavelengths of less than 100 pm ($4 \times 10^{-9}$ inches). Gamma radiation causes damage to living tissue, which makes it useful for killing cancer cells when applied in carefully measured doses to small regions. Uncontrolled exposure, though, is extremely dangerous to humans.

# REGIONS OF ELECTROMAGNETIC SPECTRUM



# ELECTROMAGNETIC SPECTRUM




The Electromagnetic Spectrum
400 nm
VISIBLE REGION
700 nm
High Energy
GAMMA RAYS
X-RAYS
UV
VISIBLE
INFRA-RED
MICRO-WAVES
RADIO-WAVES
Low Energy
WAVELENGTH
0.1 nm
1 nm
25 pm
1 nm
1 pm = 1000 nm
1 mm = 1,000,000 nm

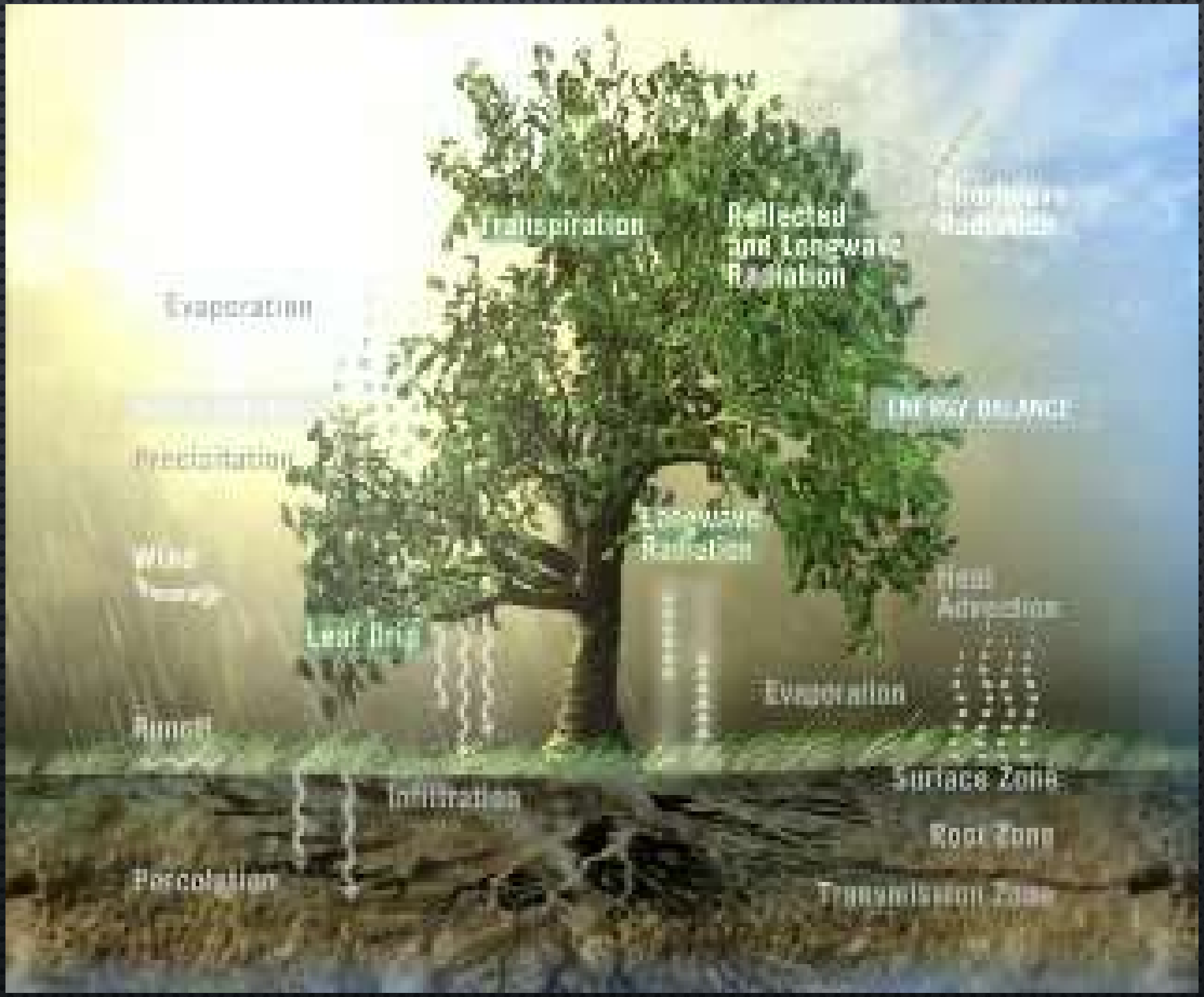
- **VISIBLE** : 0.4 - 0.8 µm
- Solar Reflection - Surface characteristics

- **INFRA RED** : 0.8 - 14 µm
- 0.8 - 1.3 µm : Near Infra Red (NIR) Solar Reflection
- 1.3 - 3 µm : Moyen Infra Rouge (MIR) Réflection and Emission (little)
- 3 - 5 µm et 8 - 14 µm : Thermal Infra Red (IRT): Emission
- 5 - 8 µm : Atmospheric Absorption

- **MICROWAVE** : 3 mm - 30 cm (100 - 1 GHz)
- Surface and Volume scattering

# REMOTE SENSING

# ENERGY INTERACTIONS WITH EARTH SYSTEMS


Transpiration
Reflected
and Longwave
Radiation
Evaporation
Wind
Leaf Drip
Runoff
Infiltration
Percolation
Evaporation
Surface Zone
Root Zone
Transmission Zone

# INTERACTIONS WITH THE ATMOSPHERE

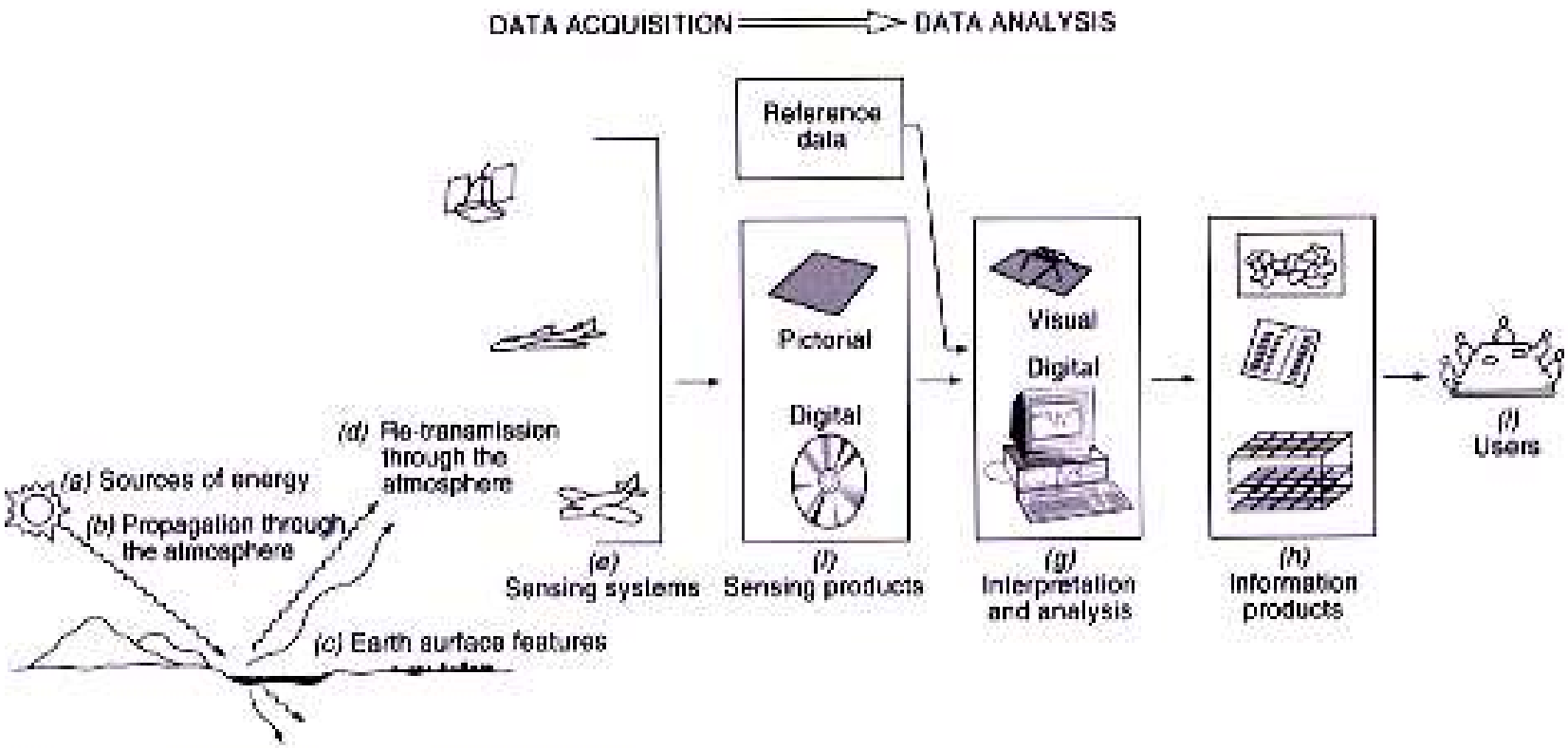


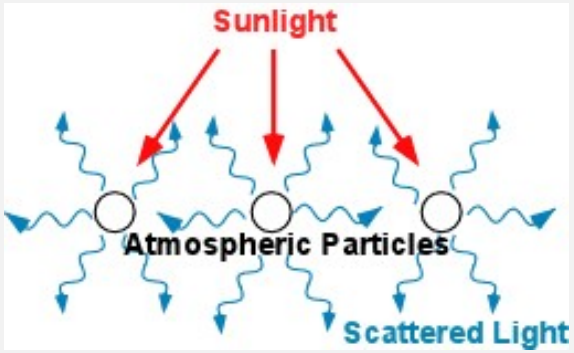

**Figure 1.1** Electromagnetic remote sensing of earth resources.

# Interactions with the atmosphere

- Scattering
- Refraction
- Absorption

# SCATTERING

- The redirection of EM energy by particles suspended in the atmosphere or large molecules of atmospheric gases

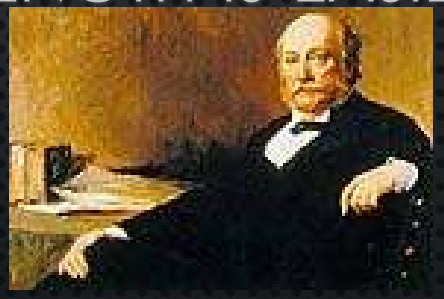



http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/opt/mch/sct.rxml

- Rayleigh scattering
- Mie scattering
- Nonselective scattering

# RAYLEIGH SCATTERING

- It occurs when atmospheric particles' diameters are much smaller than the wavelength of the radiation $D << \lambda$
- It is common high in the atmosphere
- Radiation with shorter wavelength is easier to be scattered
- Black vs. blue vs. red skies



http://www-phys.llnl.gov/Research/scattering/RTAB.html

# Mie scattering

- Particles' diameters are equivalent to the wavelength $D \approx \lambda$
- It is common in lower atmosphere
- It is wavelength dependent

# NONSELECTIVE SCATTERING

- Particles are much larger than the wavelength

  $D >> \lambda$

- All wavelength are scattered equally

Effects of scattering

- It causes haze in remotely sensed images
- It decreases the spatial detail on the images
- It also decreases the contrast of the images

**Types of Atmospheric Scatter in order of importance (Curran. 1988)**

| Type of Scatter of particles | Size of effective atmospheric particles | Type of effective atmospheric particles | Scatter of particles | Effect of scatter on visible and near visible wavelength |
|---|---|---|---|---|
| Rayleigh | Smaller than the wavelength of radiation. | Gas molecules | Molecule absorbs high energy radiation and re-emits. skylight scatter is inversely proportional to fourth power of wave length. | Affects short visible wave lengths, resulting in haze in photography, and blue skies. |
| Mie | Same size as the wavelength of radiation. | Spherical particles, fumes and dust | Physical scattering under overcast skies. | Affects all visible wave lengths |
| Non-selective | Larger than the wavelength of radiation. | Water droplets and dust. | Physical scattering by fog and clouds. | After all visible wave lengths equally, resulting white fog and clouds |
| Raman | Any | Any | Photon has elastic collision with molecule resulting in a loss or a gain in energy; this can decrease or increase wave length. | Variable |

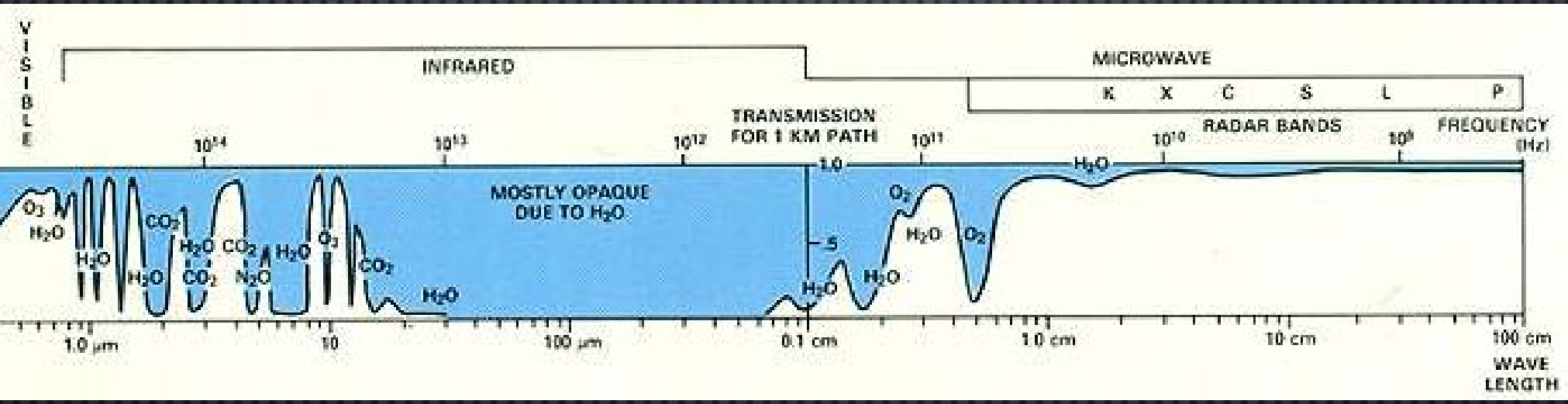
# REFRACTION

- THE BENDING OF LIGHT RAYS AT THE CONTACT BETWEEN TWO MEDIA THAT TRANSMIT LIGHT BUT WITH DIFFERENT DENSITY; WHEN LIGHT ENTERS THE DENSER MEDIUM, IT IS DEFRACTED TOWARD SURFACE NORMAL

# Absorption

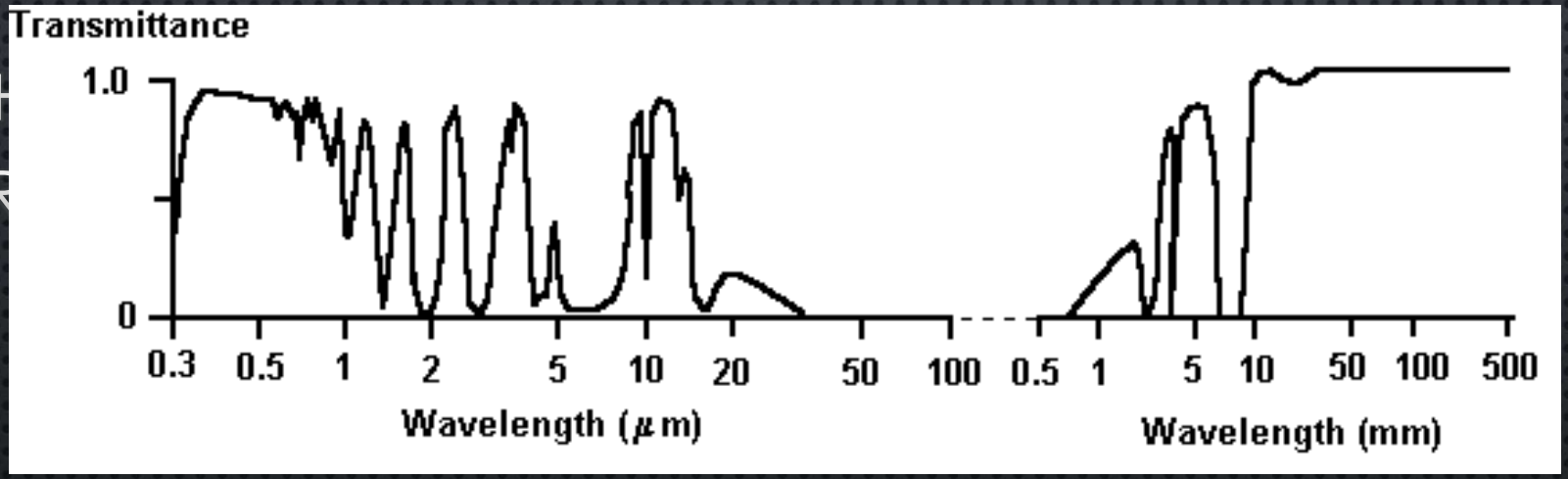
- The atmosphere prevents, or strongly attenuates, transmission of radiation through the atmosphere
- Three gases:
  - Ozone (O3): absorbs ultraviolet radiation high in atmosphere
  - Carbon-dioxide ($CO_2$): absorbs mid and far infrared (13-17.5microm) in lower atmosphere
  - Water vapor ($H_2O$): absorbs mid-far infrared (5.5-7.0, >27microm) in lower atmosphere

# ABSORPTION


VISIBLE
INFRARED
MICROWAVE
K X C S L P
RADAR BANDS
FREQUENCY (Hz)
TRANSMISSION FOR 1 KM PATH
MOSTLY OPAQUE DUE TO $H_2O$
$O_3$ $H_2O$ $CO_2$ $N_2O$ $O_2$
1.0 μm
10
100 μm
0.1 cm
1.0 cm
10 cm
100 cm
WAVE LENGTH

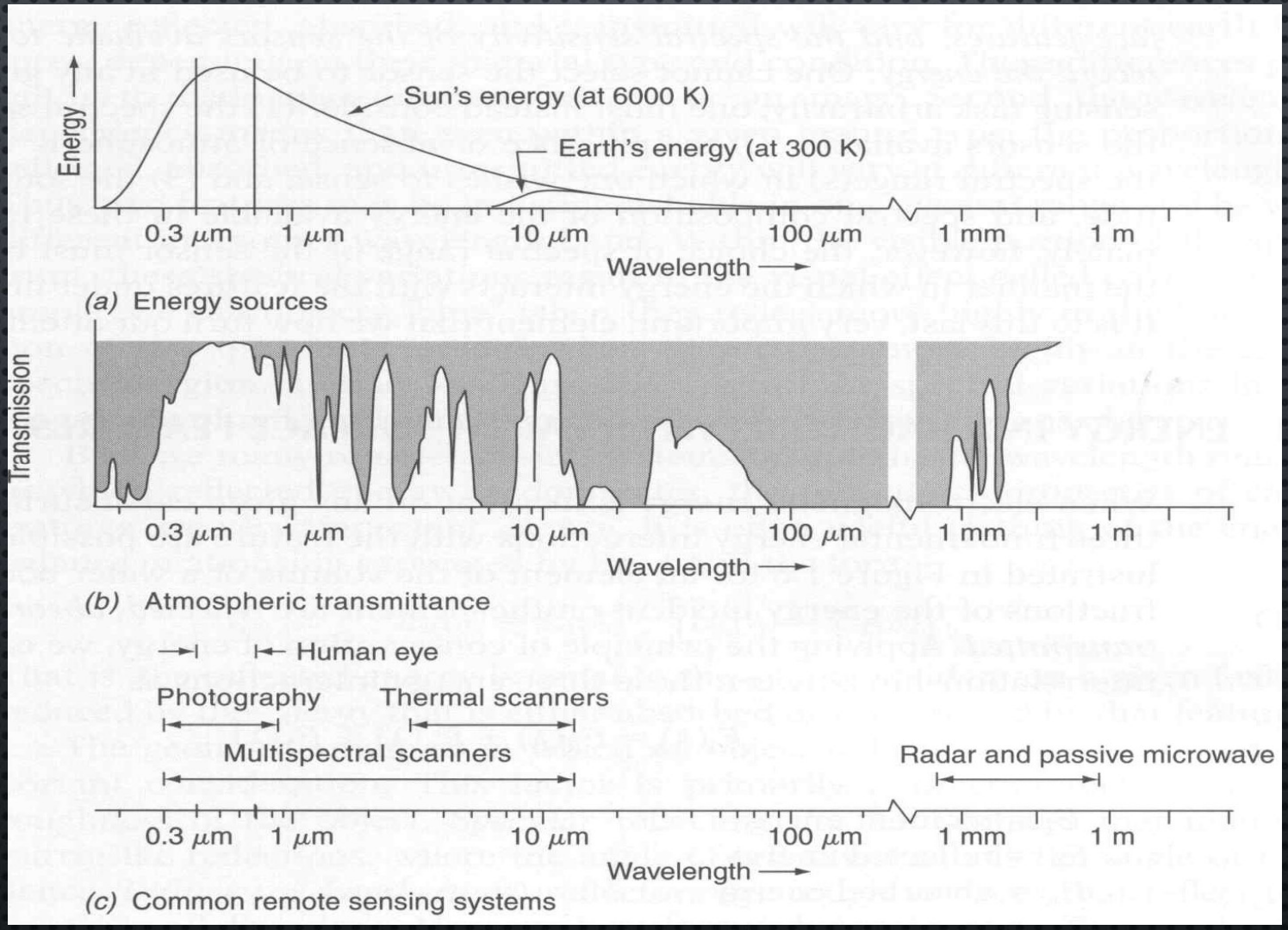
# ATMOSPHERIC WINDOWS

- TH
  TR




http://www.crisp.nus.edu.sg/~research/tutorial/atmoseff.htm#windows

# ATMOSPHERIC WINDOWS



# ATMOSPHERIC WINDOWS

- The windows:
  UV & visible: 0.30-0.75μM
  Near infrared: 0.77-0.91μM
  Mid infrared: 1.55-1.75μM, 2.05-2.4μM
  Far infrared: 3.50-4.10μM, 8.00- 9.20μM,
  10.2-12.4μM
  Microwave: 7.50-11.5mm, 20.0+mm

- The atmospheric windows are important for RS sensor design

# INTERACTION WITH FEATURES

## Reflection, absorption, and transmission

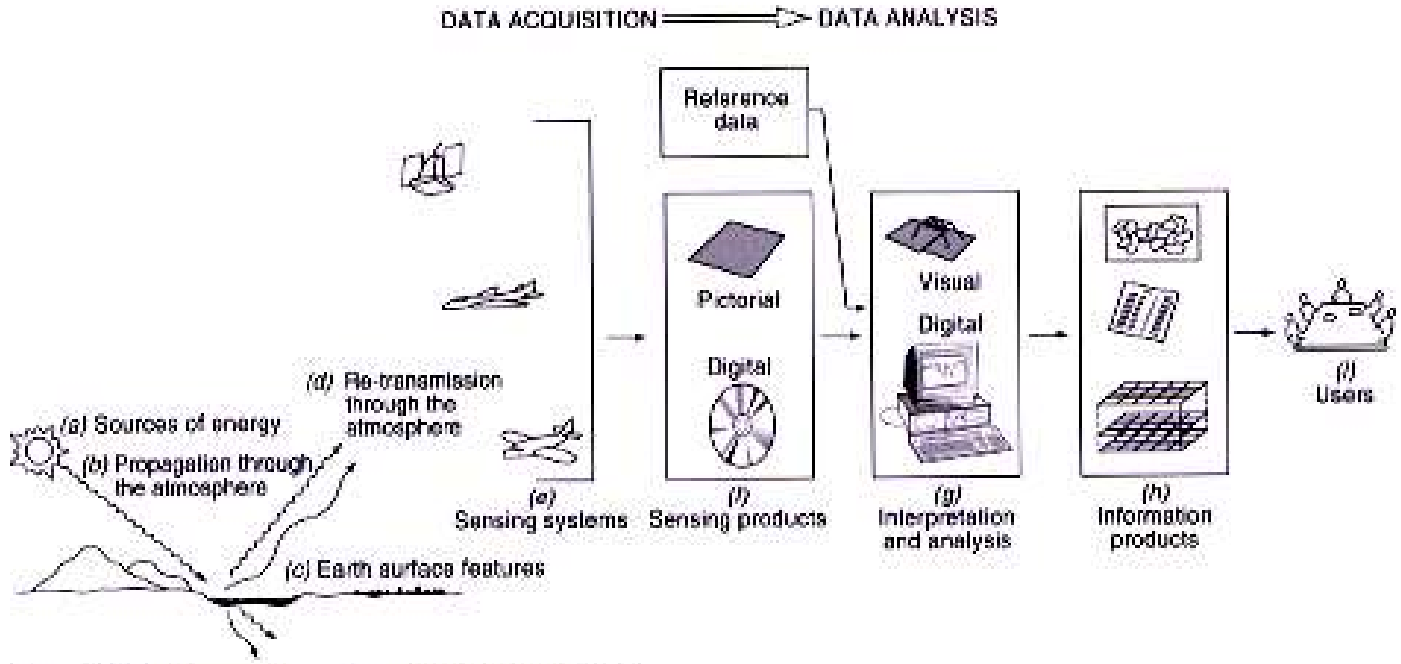
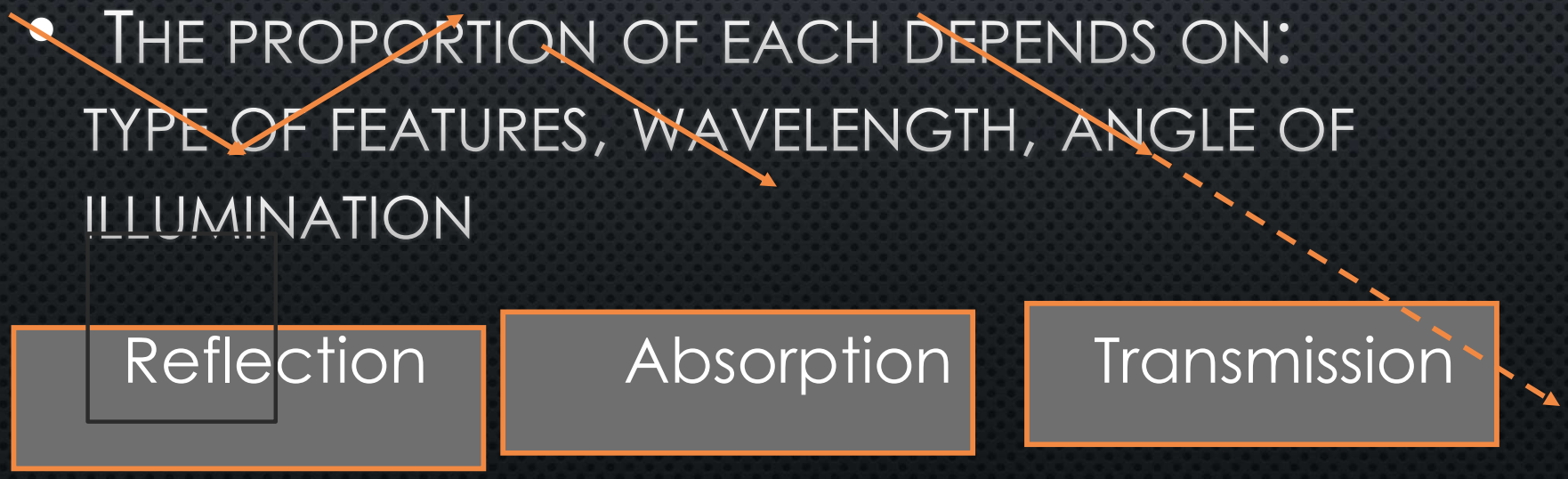



Figure 1.1 Electromagnetic remote sensing of earth resources.

# INTERACTIONS WITH SURFACE

- ALL EM ENERGY REACHES EARTH'S SURFACE MUST BE REFLECTED, ABSORBED, OR TRANSMITTED
- THE PROPORTION OF EACH DEPENDS ON: TYPE OF FEATURES, WAVELENGTH, ANGLE OF ILLUMINATION

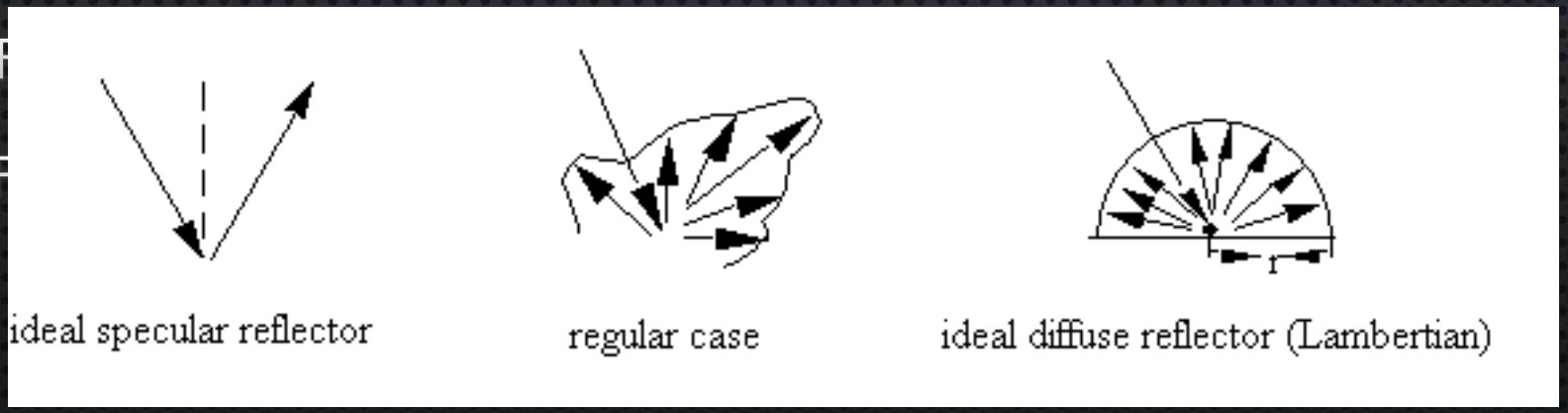


# REFLECTION

- LIGHT RAY IS REDIRECTED AS IT STRIKES A NONTRANSPARENT SURFACE
- SPECTRAL REFLECTANCE $\rho_\lambda = E_R(\lambda)/E_I(\lambda)$

= (E OF

(E OF



# Reflection

- Specular reflection

  When surface is smooth relative to the wavelength, incident radiation is reflected in a single direction
- incidence angle = reflection angle

- Diffuse (isotropic) Reflection
- When surface is rough relative to the wavelength, energy is scattered equally in all directions
- Lambertian surface

# TRANSMISSION

- RADIATION PASSES THROUGH A SUBSTANCE WITHOUT SIGNIFICANT ATTENUATION

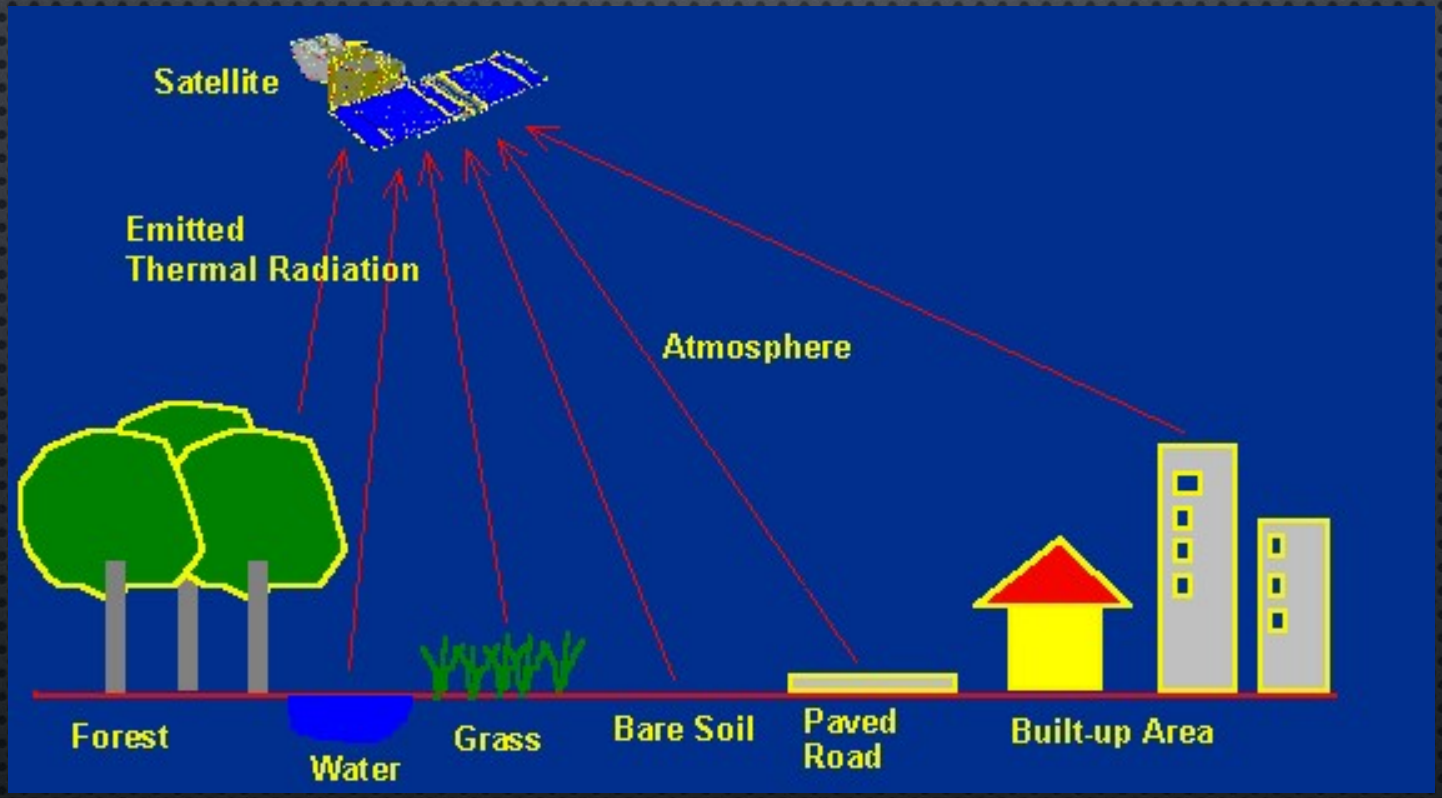
- TRANSMITTANCE (T):

$$T = \frac{\text{TRANSMITTED RADIATION}}{\text{INCIDENT RADIATION}}$$

# ABSORPTION

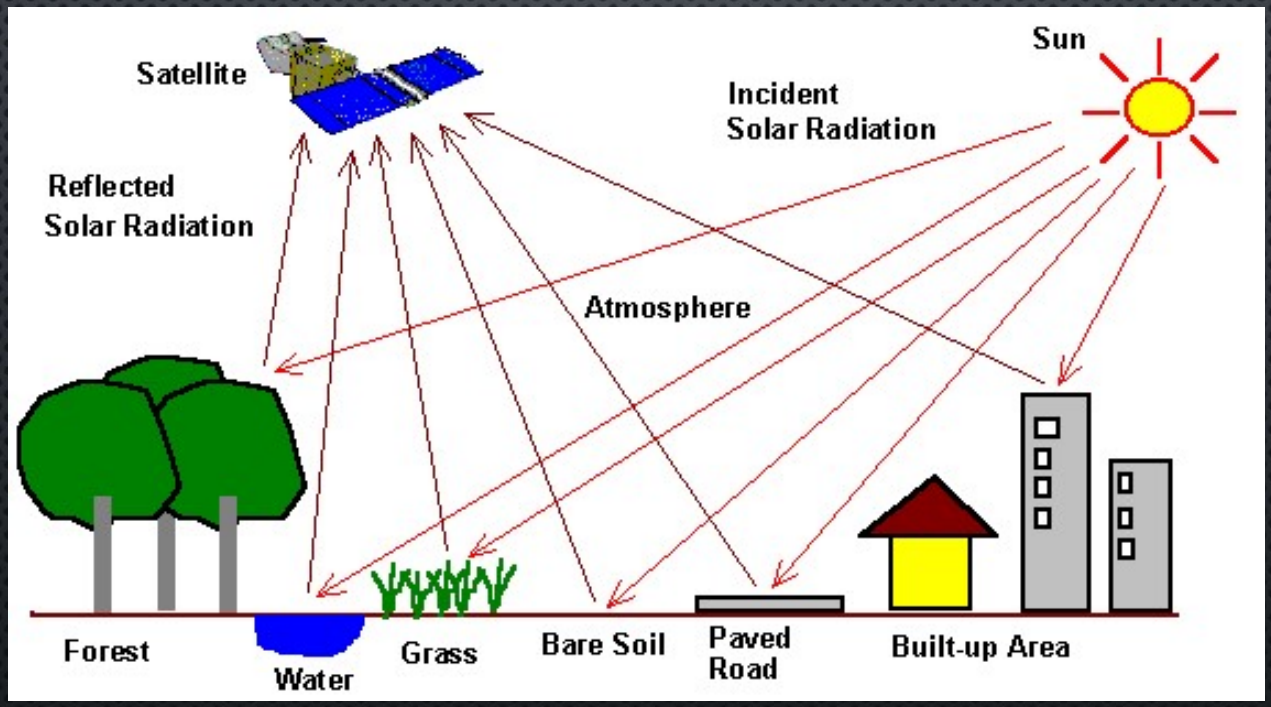
REFLECTION + TRANSMISSION + ABSORPTION = 100%

# EMISSION




http://www.crisp.nus.edu.sg/~research/tutorial/infrared.htm

# SPECTRAL CHARACTERISTICS OF FEATURES




http://www.crisp.nus.edu.sg/~research/tutorial/infrared.htm

# SPECTRAL REFLECTANCE CURVE

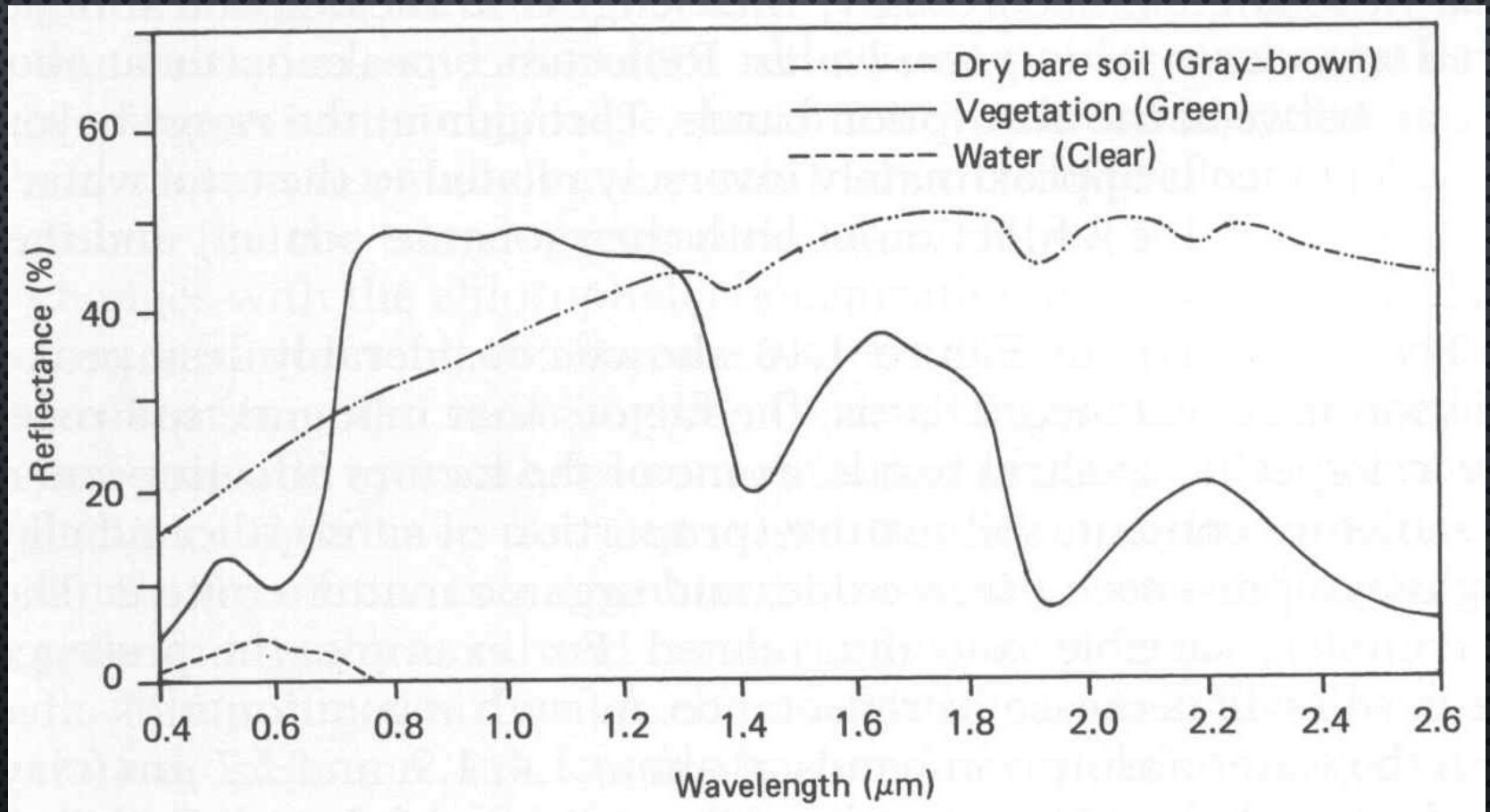



**Figure 1.10** Typical spectral reflectance curves for vegetation, soil, and water. (Adapted from Swain and Davis, 1978.)

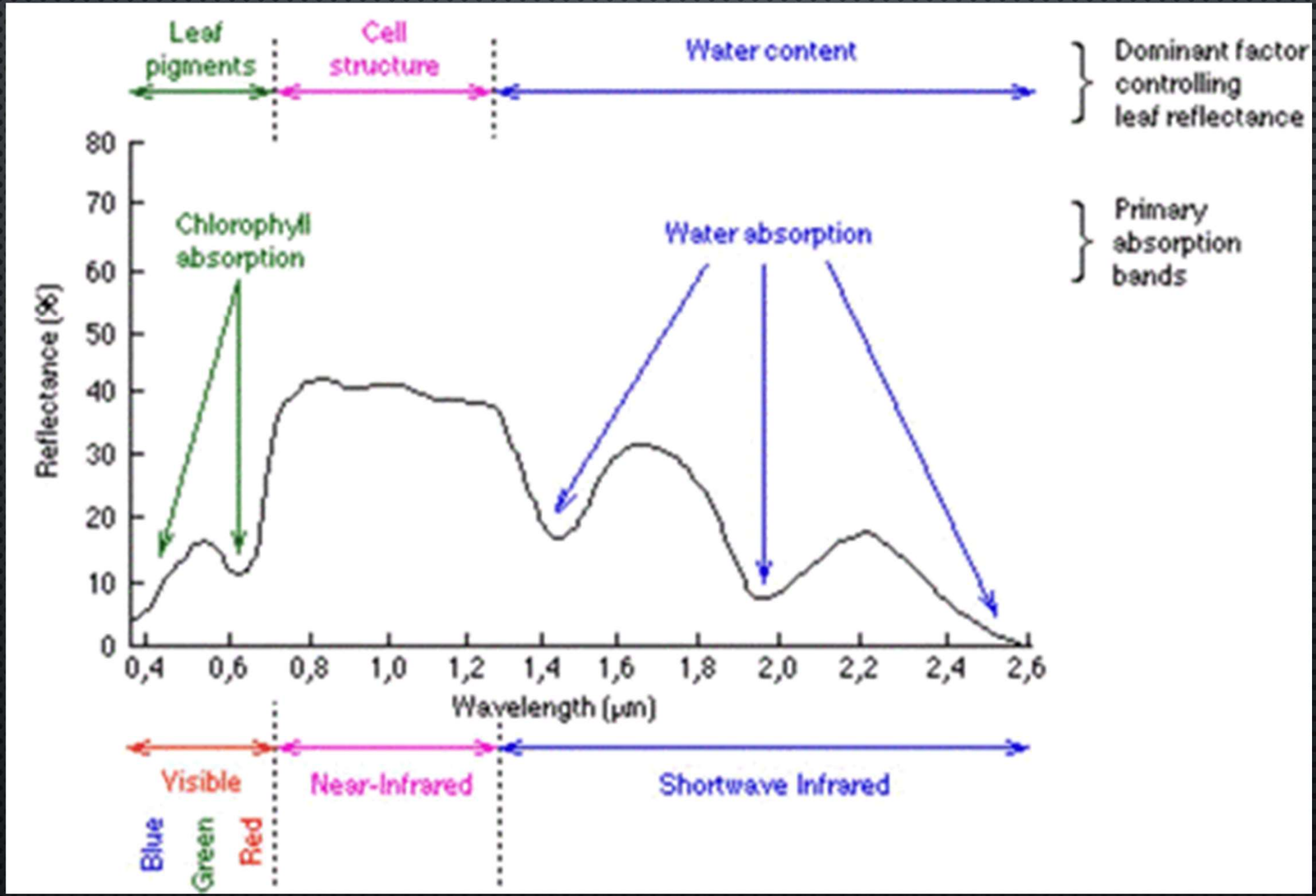
# VEGETATION

- Chlorophyll absorbs blue and red, reflects green
- Vegetation has a high reflection and transmission at NIR wavelength range
- Reflection or absorption at MIR range, the water absorption bands

From http://rst.gsfc.nasa.gov/Intro/nicktutor_I-3.html

# VEGETATION

- The palisade cells absorb blue and red light and reflect green light at a peak of 0.54mm
- The spongy mesophyll cells reflect near infrared light that is related to vegetation biomass because
  the intercellular air space of spongy mesophyll layer is where photosynthesis and respiration occur
- Vegetation moisture content absorbs mid infrared energy
- Jensen, J. R. "Biophysical Remote Sensing." Annals, 73:(1),111-132.

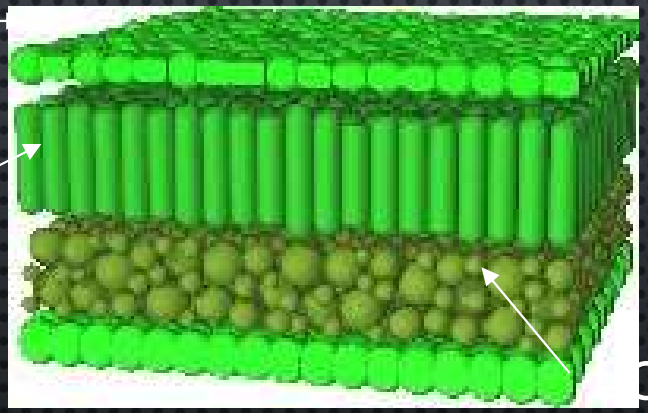

Leaf pigments
Cell structure
Water content
Dominant factor controlling leaf reflectance
Chlorophyll absorption
Water absorption
Primary absorption bands
Reflectance (%)
80
70
60
50
40
30
20
10
0
0,4
0,6
0,8
1,0
1,2
1,4
1,6
1,8
2,0
2,2
2,4
2,6
Wavelength (µm)
Visible
Near-Infrared
Shortwave Infrared
Blue
Green
Red

# BIOPHYSICAL SENSITIVITY OF SPECTRUMS ..

Upper epidermis

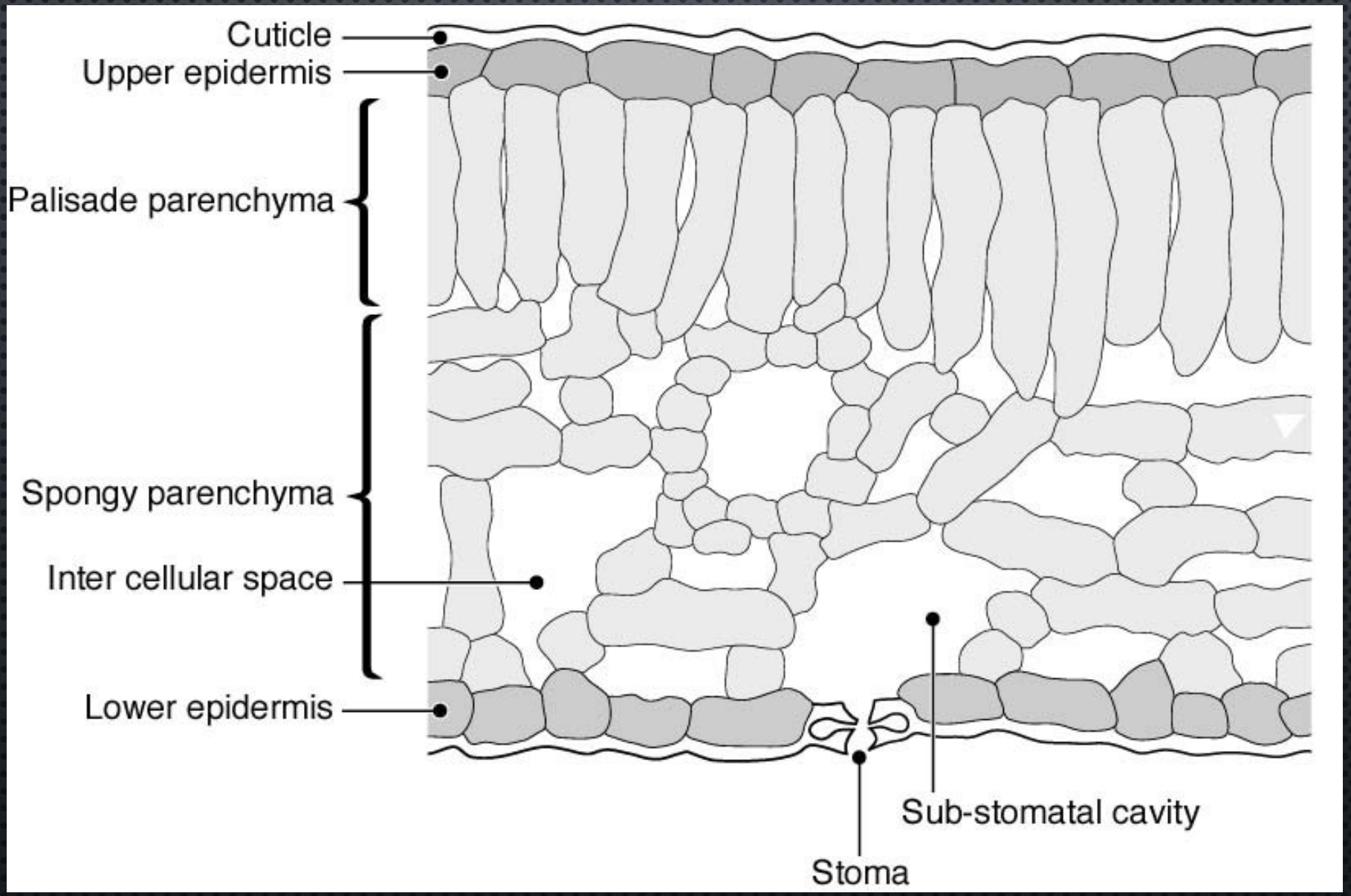
Palisade

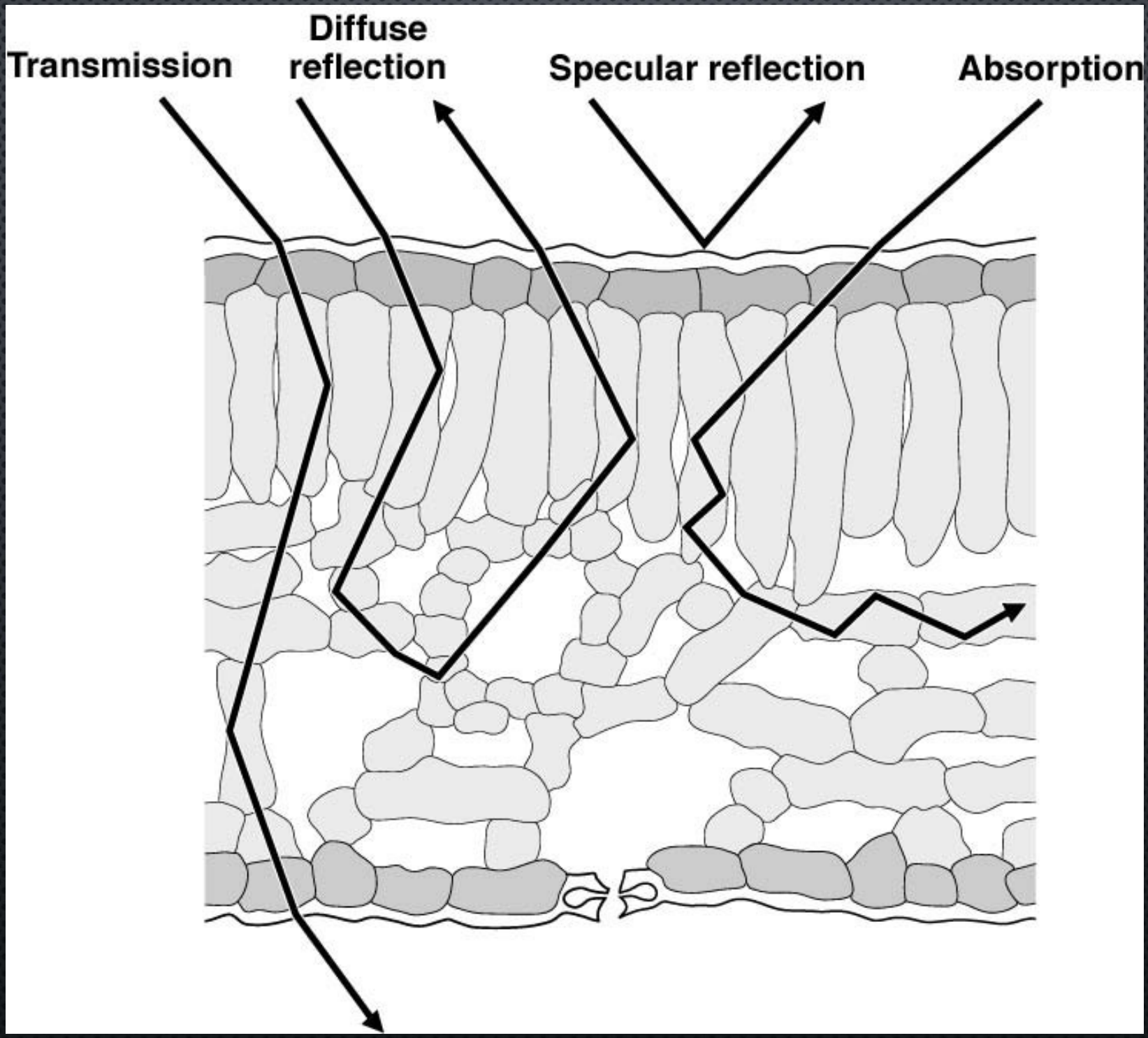
Spongy mesophyll



ower epidermis

http://www.cstars.ucdavis.edu/projects/modeling/


Cuticle
Upper epidermis
Palisade parenchyma
Spongy parenchyma
Inter cellular space
Lower epidermis
Sub-stomatal cavity
Stoma


Transmission
Diffuse reflection
Specular reflection
Absorption

# Energy Interactions with Earth Surface Features

- What happens to energy that hit surface features?
- One of three things.
  - Some of it is *absorbed*
  - Some of it is *reflected*
  - Some of it is *transmitted*


- This is known as *radiative transfer*.

# SOILS

- Soil moisture decreases reflectance
- Coarse soil (dry) has relatively high reflectance
- Surface roughness, organic matter, iron oxide affect reflectance

# WATER

- Transmission at visible bands and a strong absorption at NIR bands
- Water surface, suspended material, and bottom of water body can affect the spectral response