UNIVERSITY OF TWENTE.

Training Course

CENN Caucasus Environmental NGO Network

Remote Sensing - Basic Theory & Image Processing Methods

19 – 23 September 2011

Introduction to Remote Sensing

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ITC FACULTY OF GEO-INFORMATION SCIENCE AND EARTH OBSERVATION

Overview

- **Electro Magnetic (EM) energy**
- **Waves & photons**
- **EM wave & photon theory**
- **Sources of EM energy**
- **EM spectrum**
- **Energy interactions in atmosphere and with the surface**

Remote Sensing

Remote Sensing **is the art, science and technology of observing an object scene, or phenomenon by instrument-based techniques.**

Remote: **because observation is done at a distance without physical contact with the object of interest**

Sensing: **Detection of energy, such as light or another form of electromagnetic energy**

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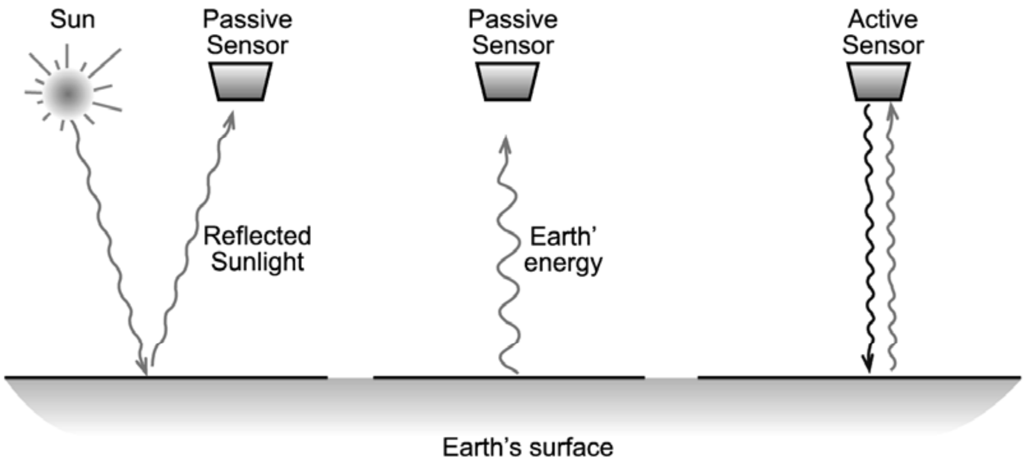
Electromagnetic Energy

Remote Sensing relies on the measurement of ElectroMagnetic (EM) energy.

The most important source of EM energy is the sun

Some sensors detect energy emitted by the Earth itself or provide their own energy (Radar)

See also Chapter 2.5



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Electromagnetic Energy

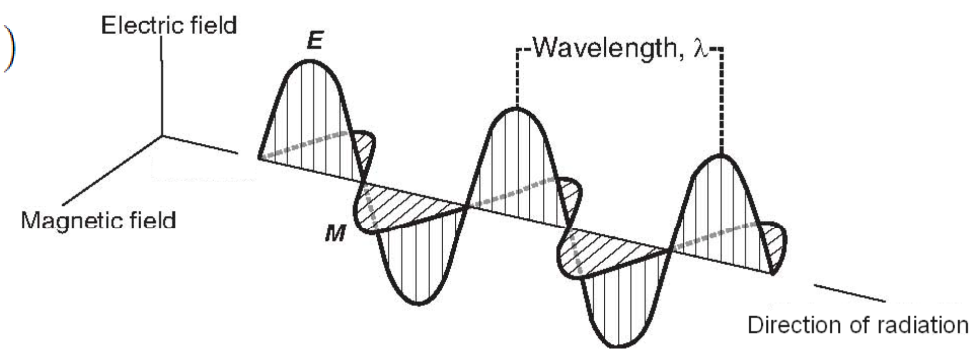
Characteristics of sinus waves

EM energy **can be modelled by (1) waves or (2) energy bearing particles called photons**

The waves are characterized by electrical (*E*) and magnetic (*M*) energy (see picture below)

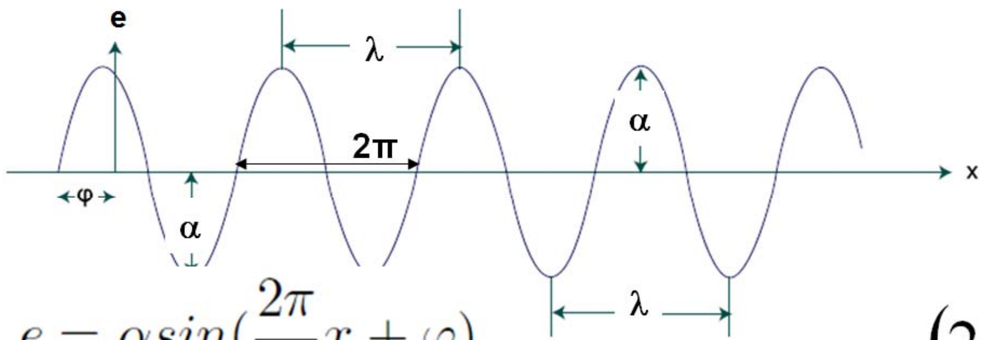
Both components interact; an instance of positive electrical energy interacts coincides with a moment of negative magnetic energy

$$e = \alpha sin(\frac{2\pi}{\lambda}x + \varphi)$$



Electromagnetic Energy

Characteristics of sin wave



$$e = \alpha sin(\frac{2\pi}{\lambda}x + \varphi)$$

- e → Y direction
- α → Amplitude
- $\frac{2\pi}{\lambda}$ → Wave number
- x → Distance from origin
- φ → Phase (between 0 - 2π)

$(2\pi/\lambda)$

Wave number
2π : one full cycle

Electromagnetic Energy

Characteristics of sinus waves

Frequency of wave (ν) : number of cycles per second

wavelength (λ) and frequency (ν) have inverse relationship

$$c = \lambda \cdot \nu$$

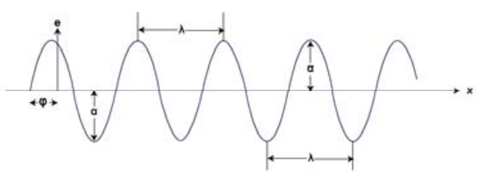
$$\frac{meters}{second} = \frac{meters}{cycle} \cdot \frac{cycles}{second}$$

C = speed of EM energy (light) =

$$3 \cdot 10^8 \, m \cdot s^{-1} = 300{,}000 \, km/\sec$$

λ = wavelength $[m]$

ν = frequency $[cycles \cdot s^{-1}]$



Electromagnetic Energy

<u>EM Photon theory</u>

Light travels as discrete particles ("<u>Photons</u>")

Photon energy (Q) and frequency (ν) have a <u>positive</u> relationship

$$Q = h \cdot \nu$$

Q = energy of 1 photon [J]

h = Plank's constant = $6.6 \cdot 10^{-34} [J \cdot S^{-1}]$

ν = frequency $[cycles \cdot s^{-1}]$

Electromagnetic Energy

EM Photon theory

λ and Q have inverse relationship (since h and c are constant)

$$c = \lambda \cdot \nu \longrightarrow \nu = \frac{c}{\lambda}$$

$$Q = h \cdot \nu = h \cdot \frac{c}{\lambda}$$

The longer the wave length

λ,

the lower its energy content

Q

Electromagnetic Energy

Radiometric units

Amount of ***radiant emittance*** expressed as **Watt / m^2**

Spectral ***radiant emittance*** : **Watt / m^2 / µm**

↘ Radiant emittance per wavelength

Radiance (L) : **Watt / m^2 / angle**

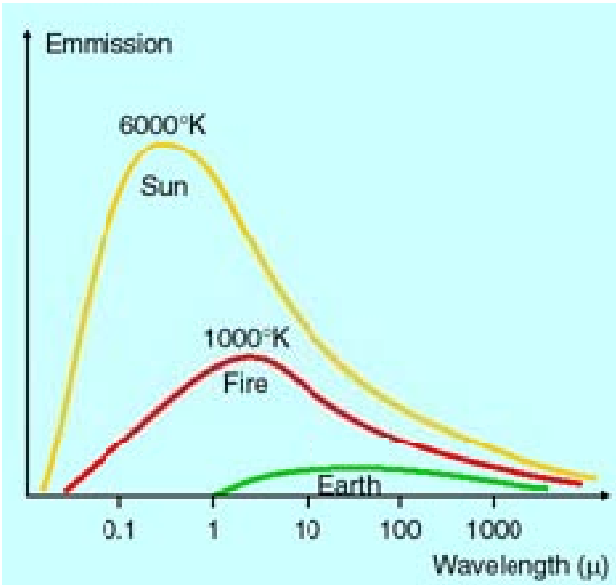
↘ Amount of energy emitted or reflected from an particular area per unit angle and per unit time

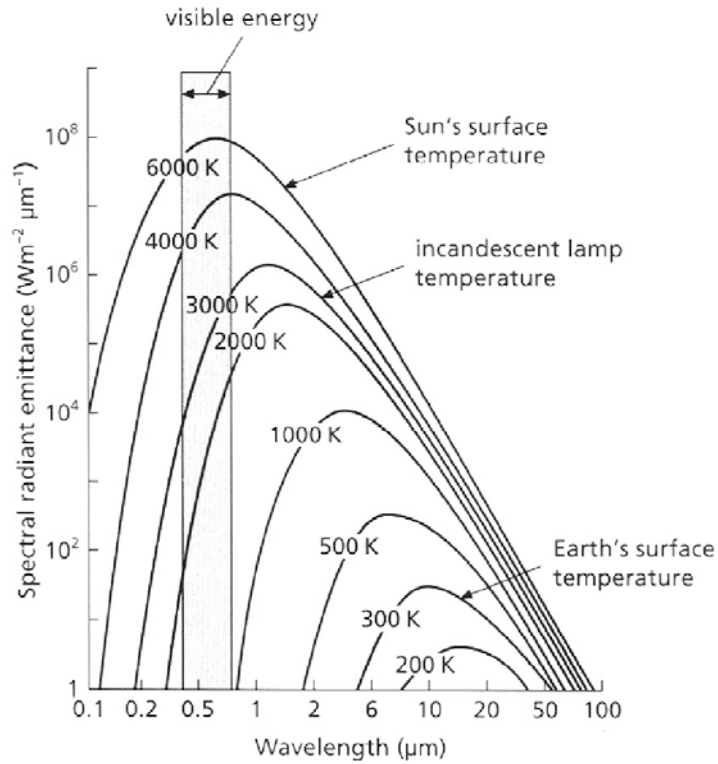
Irradiance (E) : **Watt / m^2**

↘ Amount of incident energy on a surface per unit area and per unit time

Earth surface temperature

Earth's surface ~ 27 º Celcius = **27ºc +273º = 300º Kelvin**





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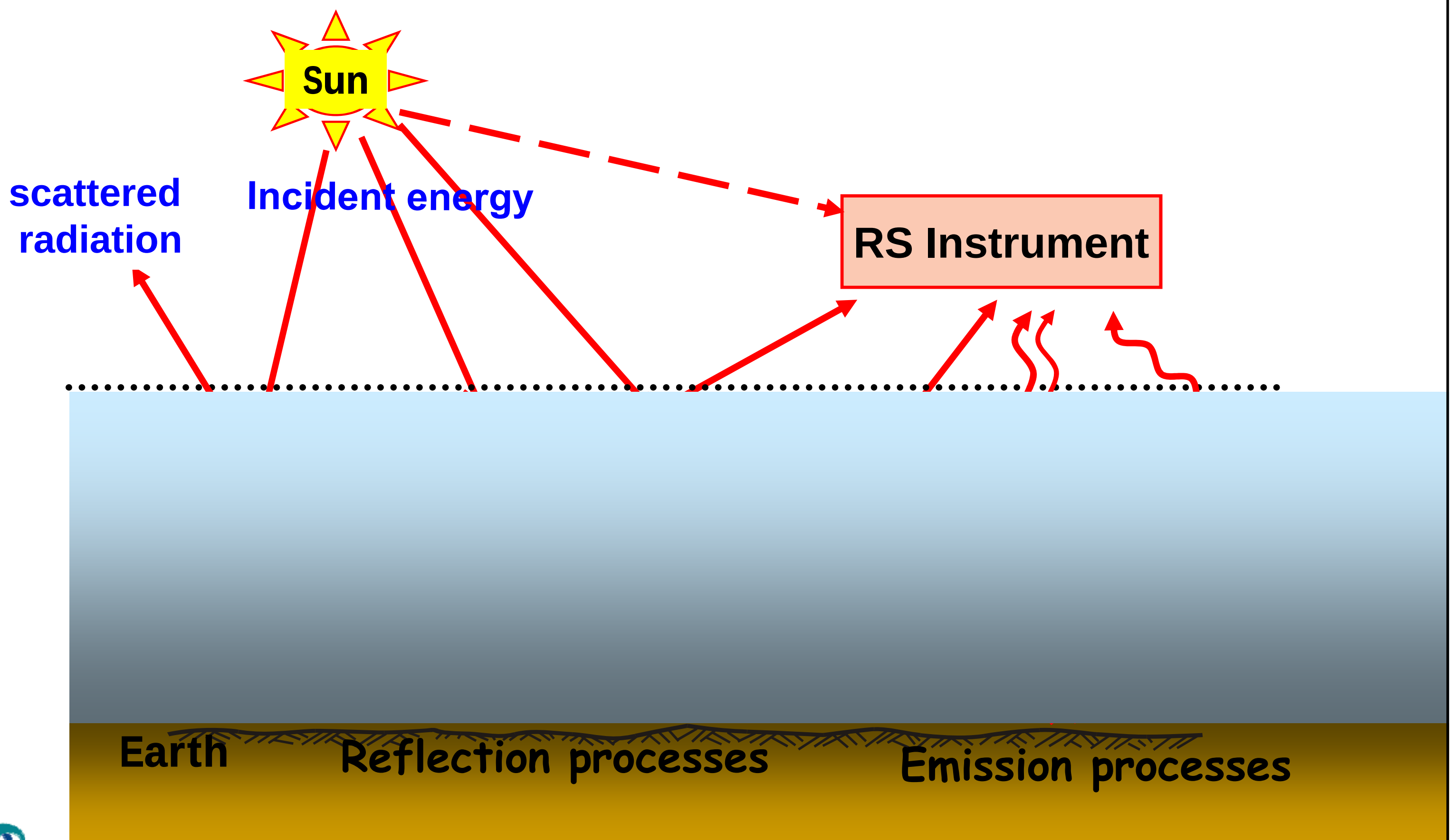
Energy interactions with atmosphere and earth surface



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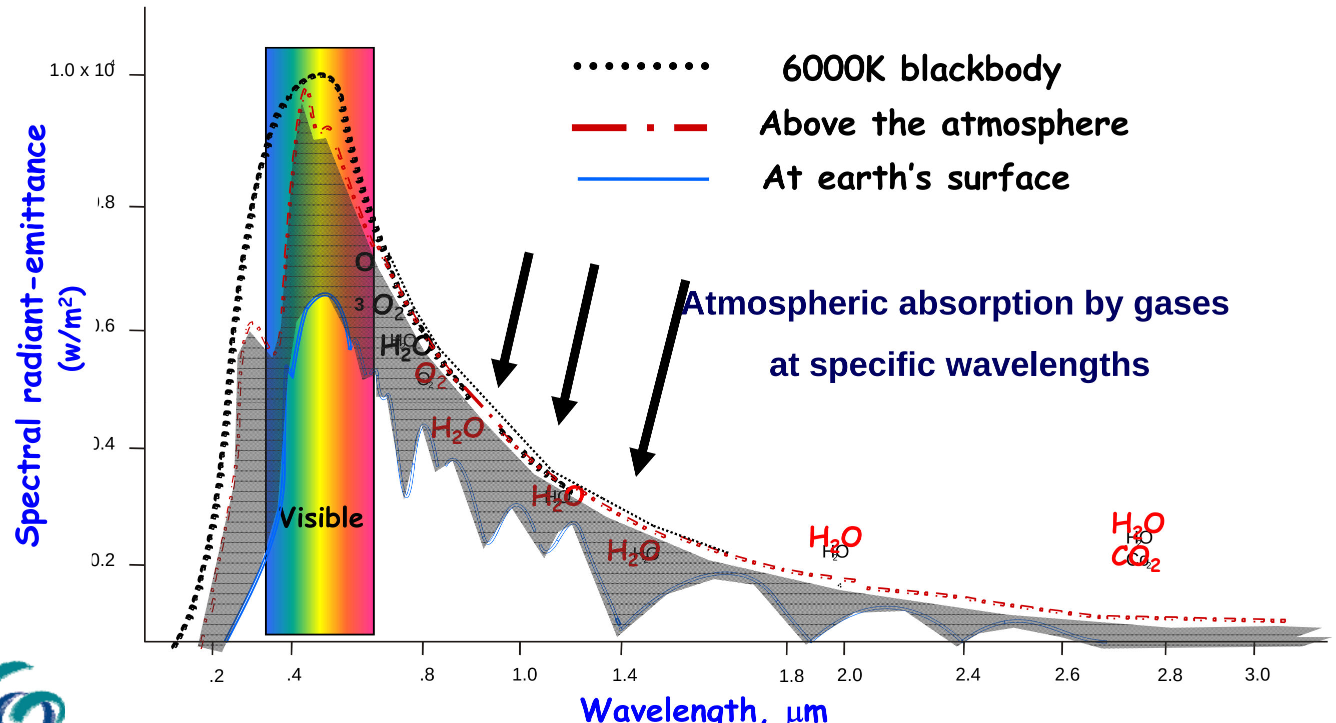
Energy interactions with atmosphere

EM spectrum of sun as observed with / without the influence of atmosphere



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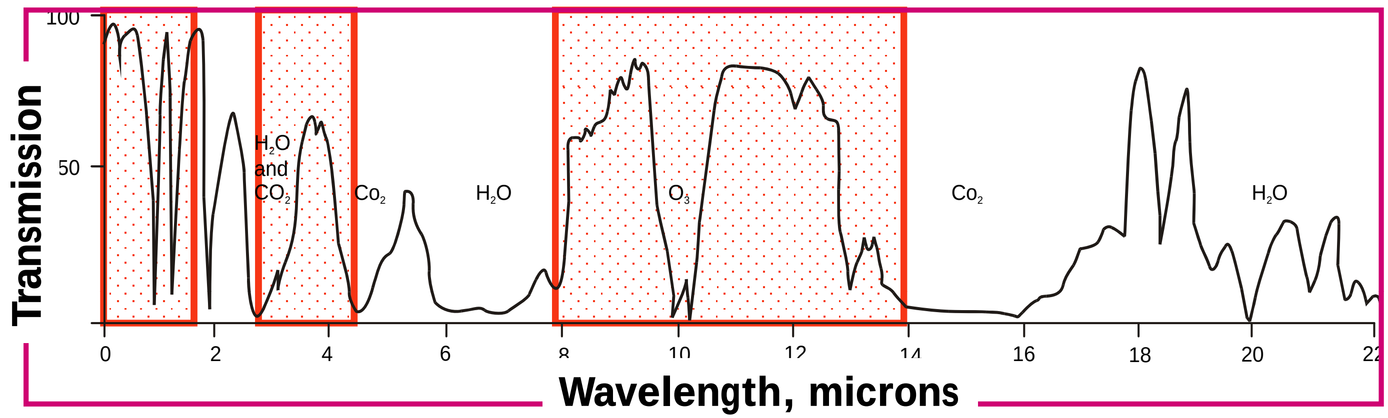
Atmospheric absorption of solar radiation

Most efficient absorbers of solar radiation are:
Ozone O_3 - Water vapors H_2O - Carbon dioxide CO_2



- **Atmospheric transmission windows ?**

Atmospheric scattering

This occurs when the particles of gaseous molecules in the atmosphere cause the EM waves to be redirected from the original path

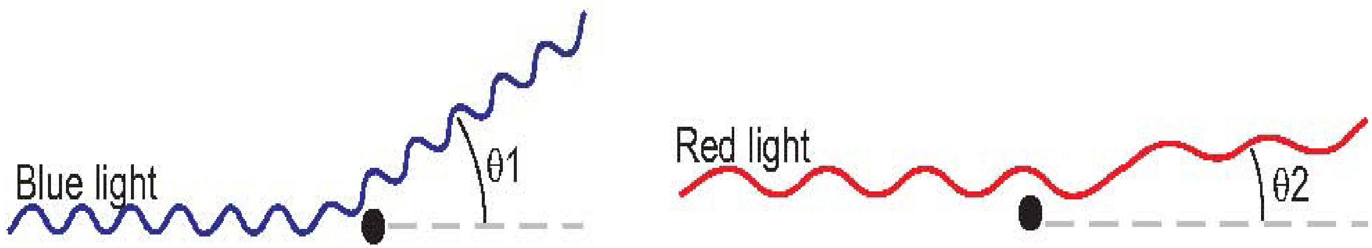
- *Raleigh scattering* : size atmospheric particles < than the wavelengths of incoming radiation
- *Mie scattering* : size atmospheric particles ~ than the wavelengths of incoming radiation
- *Non-selective scattering* : size atmospheric particles > than the wavelengths of incoming radiation

Atmospheric scattering

Raleigh scattering **: size atmospheric particles < than the wavelengths of incoming radiation**

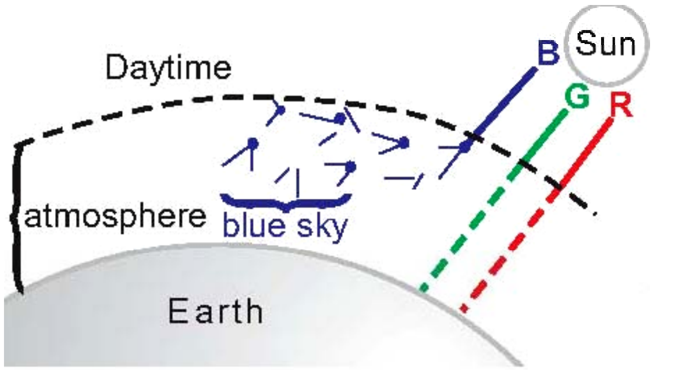
Examples: Small dust particles and NO_2 & O_2 molecules

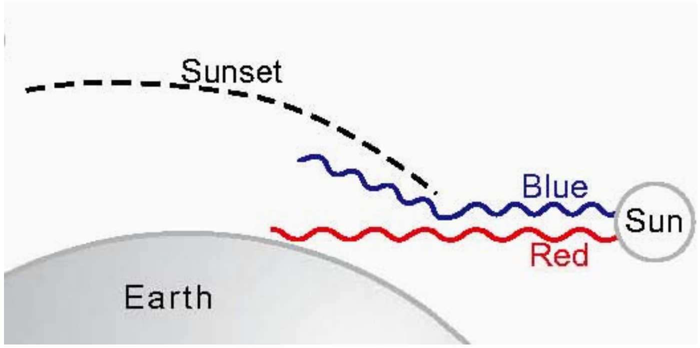
Shorter wavelengths (blue) are scattered more than longer wavelengths (red)



Atmospheric scattering

Selective (Rayleigh) scattering





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Atmospheric scattering

Mie scattering : size atmospheric particles ~ than the wavelengths of incoming radiation

- Mainly caused by aerosols : mixture of gases, water vapor and dust
- It may influence the entire spectral region

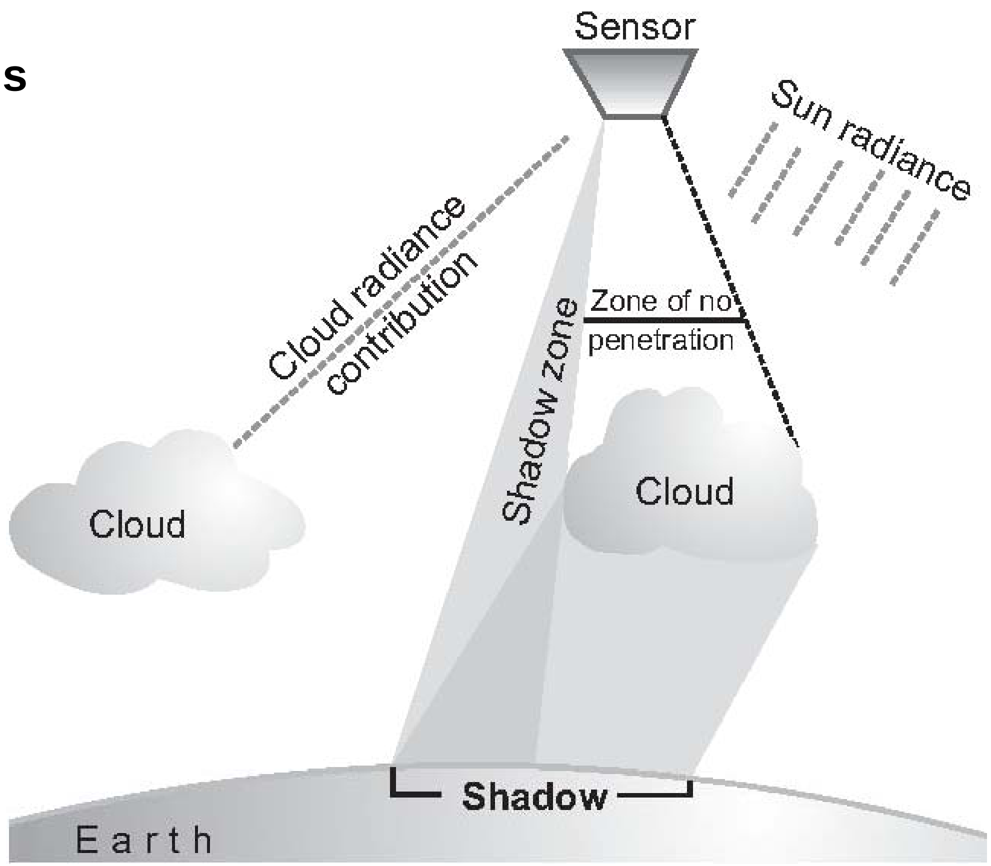
Non-selective scattering : size atmospheric particles > than the wavelengths of incoming radiation

- Examples: Water droplets and larger dust particles
- It is independent from wavelength – all wavelengths scatter about equally :

Clouds appear white !!

Atmospheric scattering

Effect of clouds



Energy interactions with Earth surface

Reflection **occurs when radiation "bounces" off the target and is then redirected**

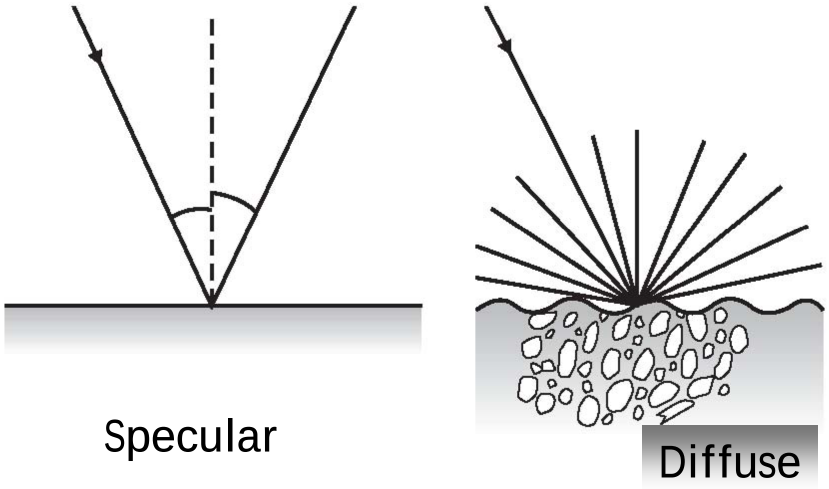
Absorption **occurs when radiation is not reflected**

Specular **reflection :**

smooth surface

Diffuse **reflection :**

rough surface

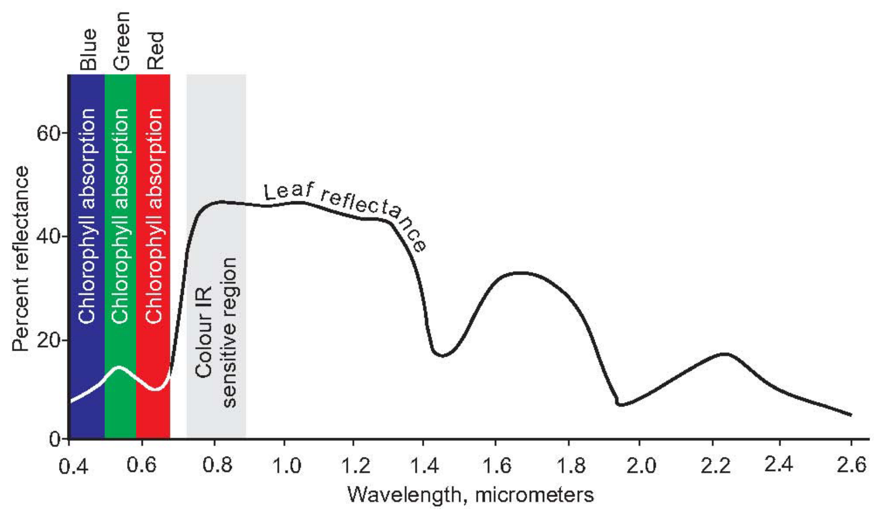


Spectral reflectance curves

For each type of material a specific reflectance curve can be established

They show the fraction of incident radiation that is reflected as a function of wavelength

Spectral libraries



Ideal reflectance curve for healthy vegetation

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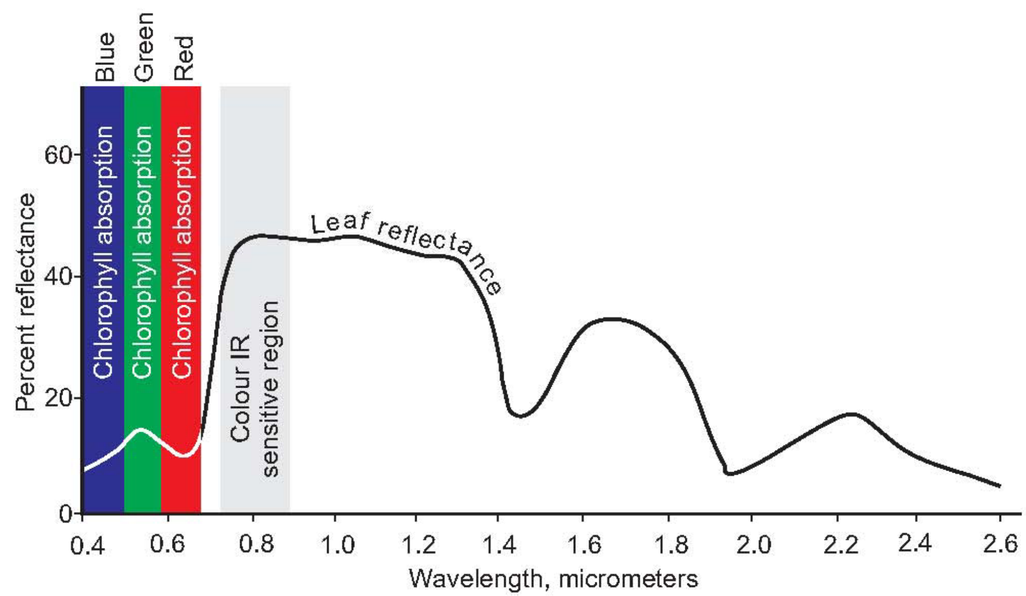
Spectral reflectance curves

Vegetation

Reflection depends on properties of leaves

- **Pigmentation**
- **Thickness**
- **Cell structure**
- **Water content**



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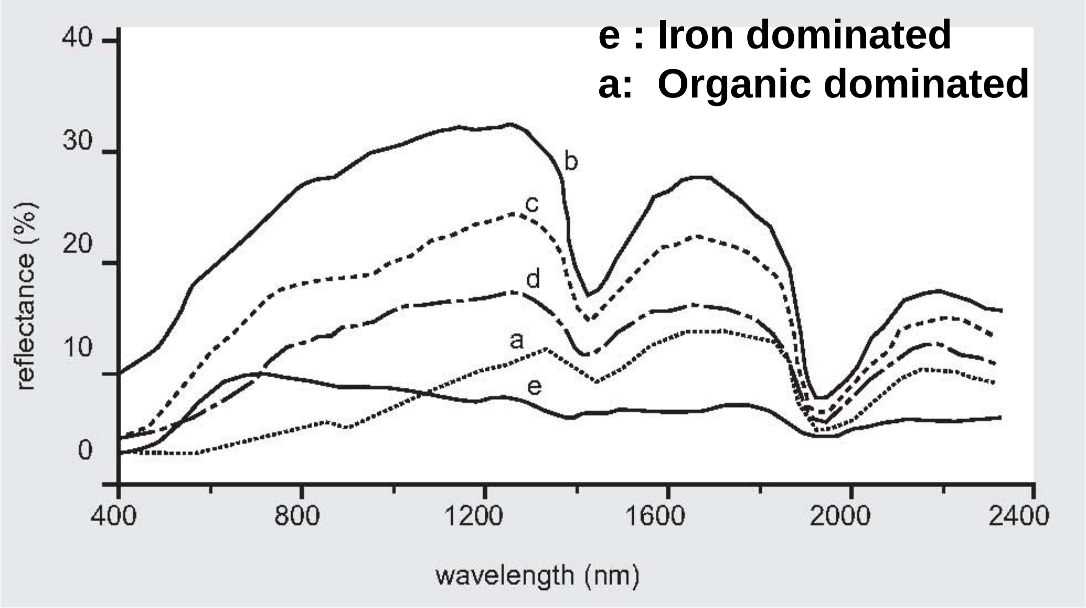
Spectral reflectance curves

Bare soil

Reflection depends on various properties

- **Color**
- **Moisture**
- **Carbonates**
- **Iron oxides**
- **Organic material**



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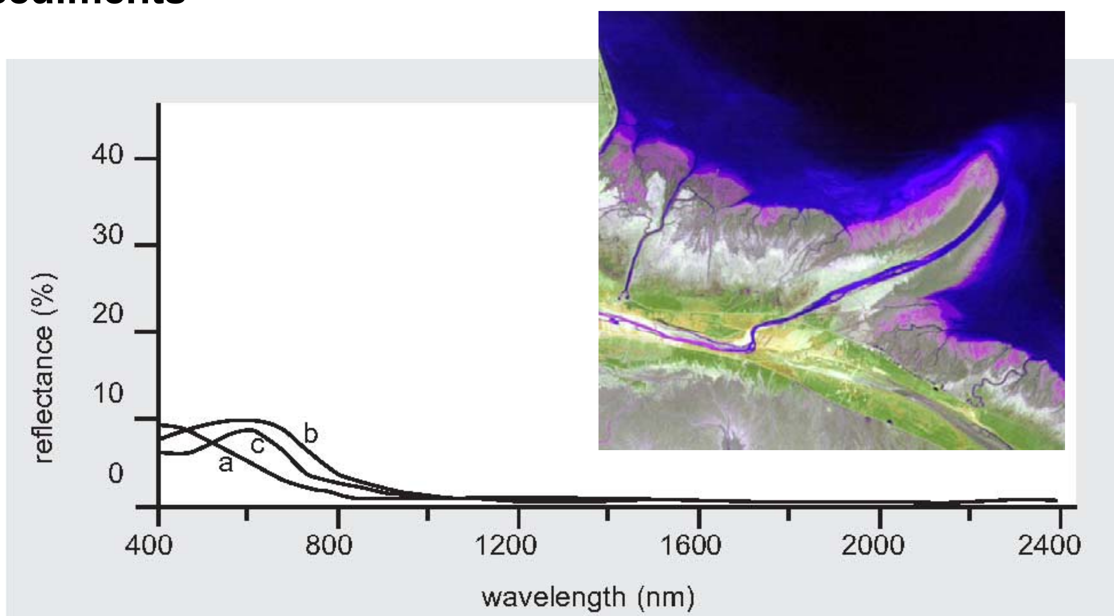
Spectral reflectance curves

Water

Reflection depends on various properties

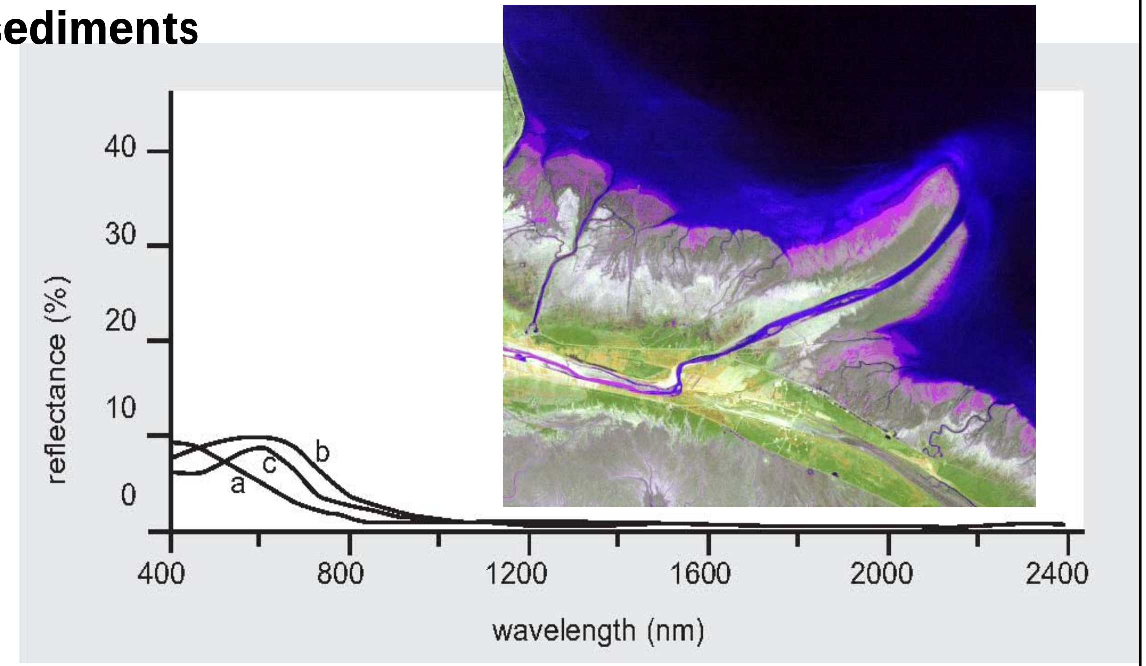
- **Suspended sediments**
- **Turbidity**
- **Chlorophyll**



Spectral reflectance curves - Water

Reflection depends on various properties

- **a : Suspended sediments**
- **b : Turbidity**
- **c : Chlorophyll**



Summary

- RS sensors measure EM energy
- Most important source of EM energy the sun
- Radar provides own source of energy
- Sensor characteristics based on atmospheric transmission windows
- Interaction with atmosphere: scattering
- Interaction with earth surface: reflection & absorption
- Different reflection curves for vegetation, bare soil, water, etc.

Questions

- **What type of earth surface are you interested in ?**
- **What is the most important atmospheric disturbance in your country in respect to RS ?**