EM energy and Remote Sensing

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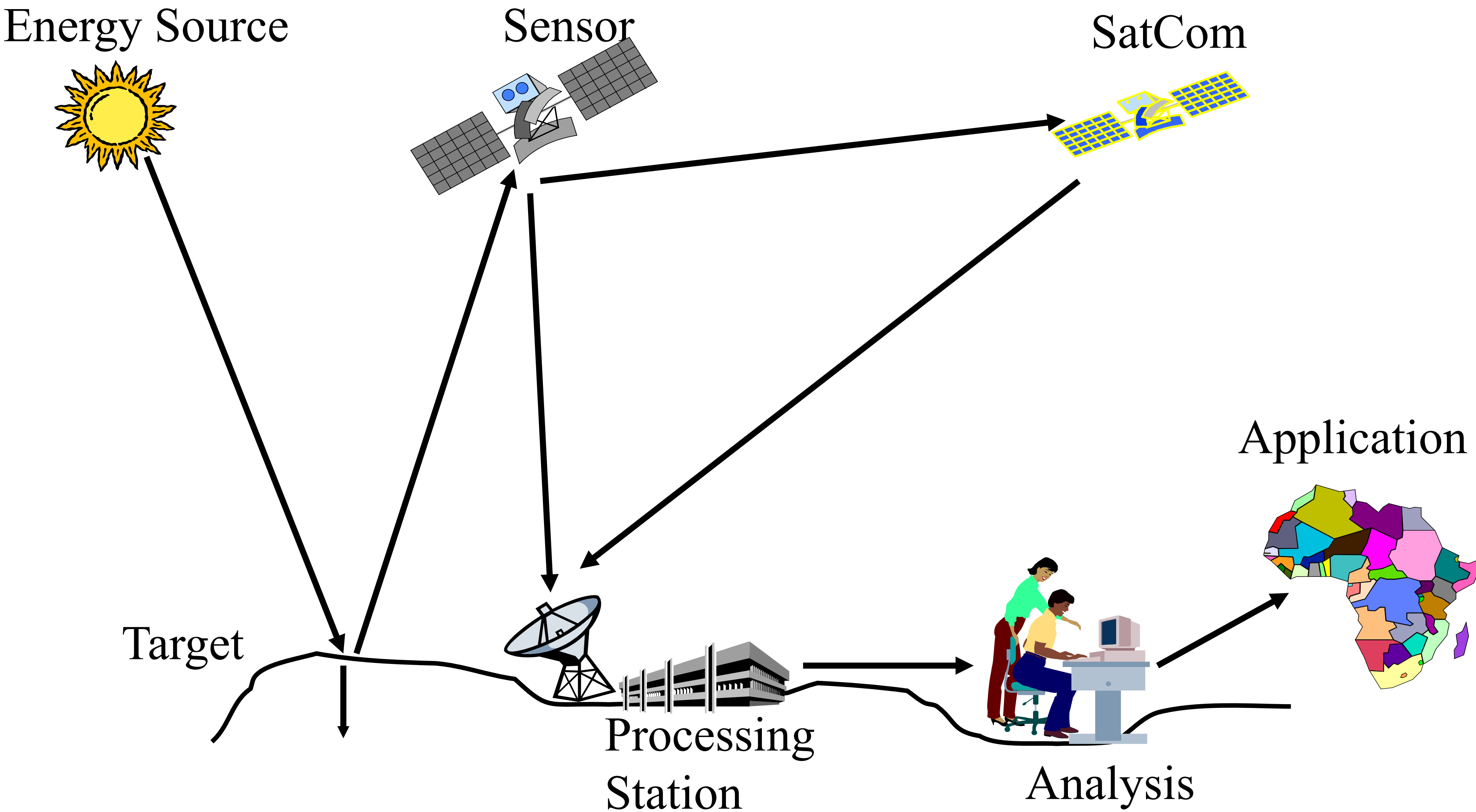
Definitions (serious and *not so serious*)

- Remote Sensing **is the science of acquiring, processing and interpreting images that record the interaction between electromagnetic energy and matter. (Sabins, 1996)**
- Remote Sensing **is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. (Lillesand and Kiefer, 1994).**
- Remote Sensing **is the instrumentation, techniques and methods to observe the Earth's surface at a distance and to interpret the images or numerical values obtained in order to acquire meaningful information of particular objects on Earth. (Buiten and Clevers, 1993)**
- ***(An alternative definition: Staying as far away from the problem as possible. - G. Archer, World Bank)***

The Remote Sensing Process

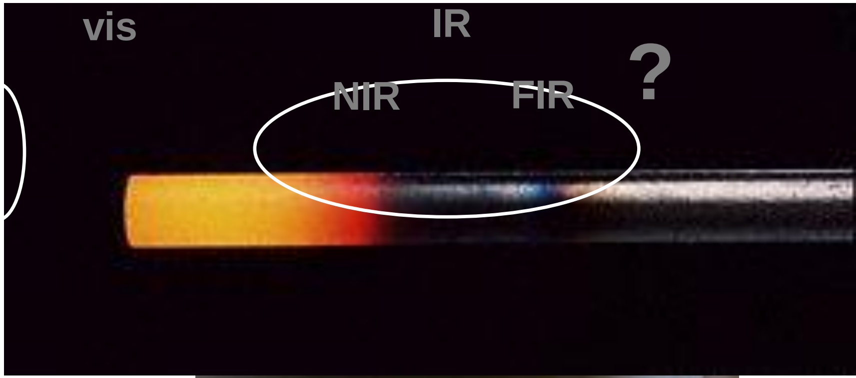


What we see

- At the temperature of the earth's surface (27°C), λ_{max} is 9.7μm, which is heat (TIR).
- At the temperature of the sun (6000°K), λ_{max} is at the range of 0.4μ -0.7μ, around the visible range.

Examples:

- hot steel shifts to λ_{max} of orange (~0.5μ-0.7μ)
- The blue region in a flame is hotter than the yellow region in a flame



Theory of Light

- Discovery of infrared light
  - Herschel (1800)
- Discovery of ultraviolet light
  - Ritter (1801)
- Infrared light like visible light
  - Fizeau and Foucault (1847)
- Theory of electromagnetic energy
  - Maxwell (1873)

ELECTROMAGNETIC RADIATION AND THE ELECTROMAGNETIC SPECTRUM

EM energy can be modeled in 2 ways:

- by waves
- by photons (energy bearing particles)

Wave model

- Electromagnetic energy travels as sinusoidal waves
- Waves are characterized by 2 fields: E and M
- The 2 fields vibrate perpendicularly to each other and to the direction of travel
- Waves travel with speed of light, $c = 3 * 10^8 ms^{-1}$

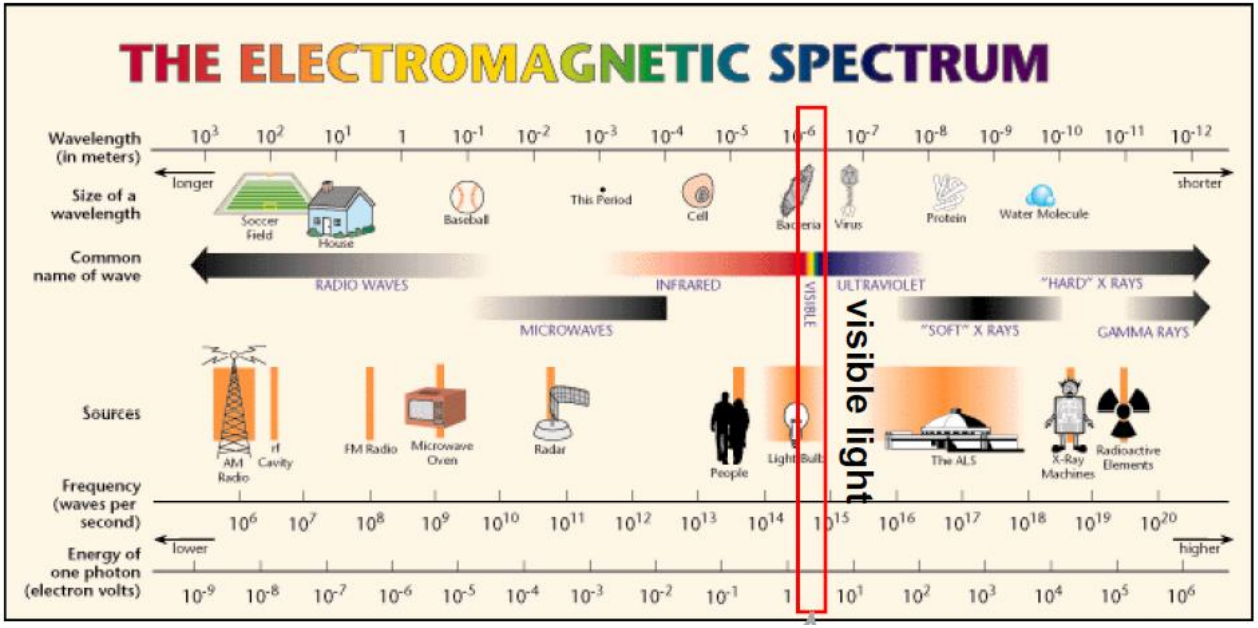
Particle model

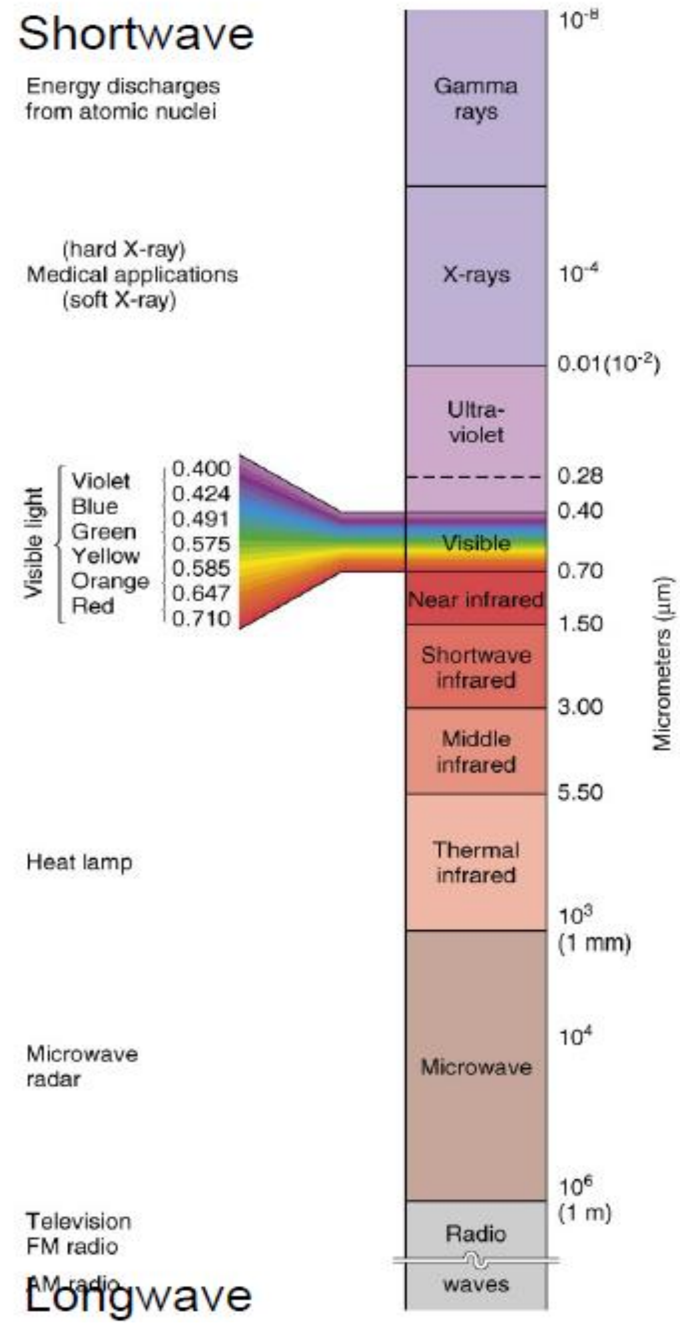
- Particle theory: EM energy is composed of particles called **photons**
- Particle theory is useful for describing the amount of energy measured by the sensor
- $$Q = h * v$$
- *Q = amount of energy per photon (J)*
- *h = Planck's constant 6.3 10^{-34} J s*

Electromagnetic spectrum

- All matter with a temperature above 0 K radiates electromagnetic waves of various wavelengths
- Total range of wavelengths: **electromagnetic spectrum**
- Optical part of the EM spectrum: **part where optical laws can be applied**
- Visible part of the EM spectrum: **light**

The EM spectrum





Bands in Satellite Images

• Remote sensors can capture radiation in one or more "bands" of the
EM spectrum (Spectral resolution: λ's to which a RS system is sensitive)

• Panchromatic – one B/W band capturing reflectance in the (narrow) visible range of wavelengths

• Multispectral systems – divides the spectrum into relatively broad bands (e.g., 1 micron). Examples: Landsat, SPOT, IRS

• Hyperspectral systems – divides spectrum into many small bands and allows more complete coverage of reflectance

Sensing of EM energy

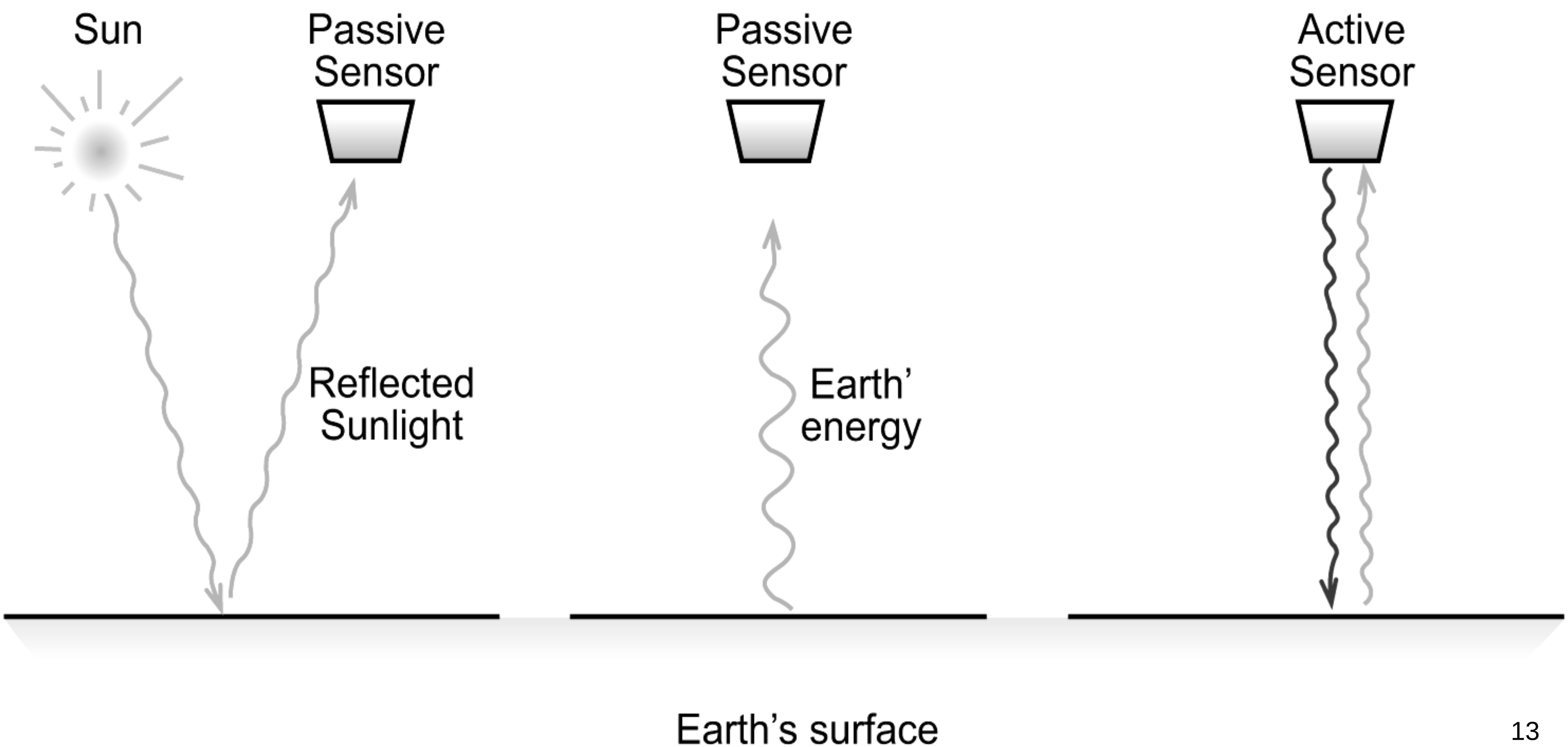
- Passive systems depend on other energy sources (daylight, heat)
  - example of passive sensors:
    - aerial camera
    - thermal scanners

- Active systems generate their own source of energy (“illumination”)
  - example of active sensors:
    - radar (micro waves)
    - laser scanners

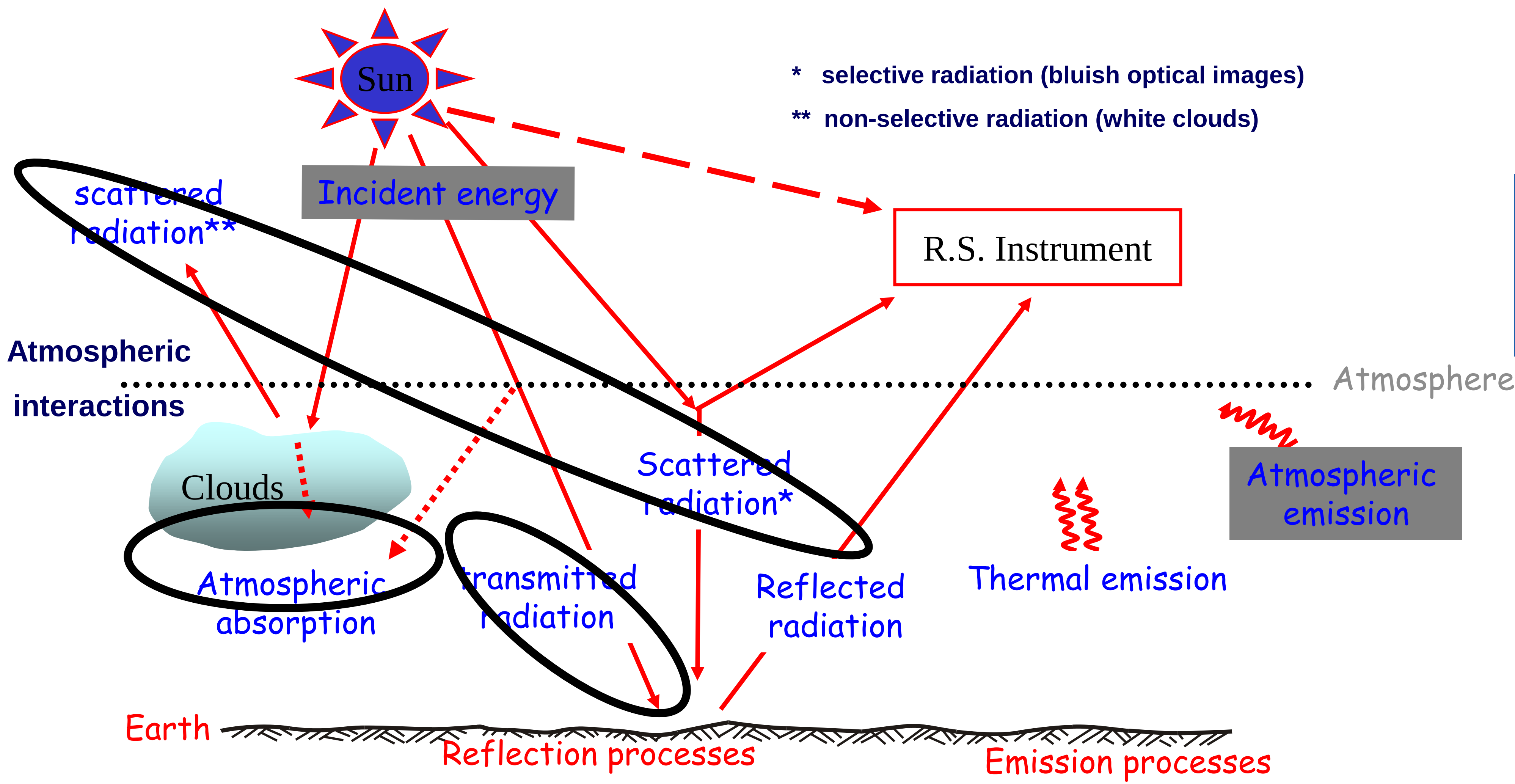
Sensing of EM energy

Remote sensor:

A device that detects, quantifies and records EM energy



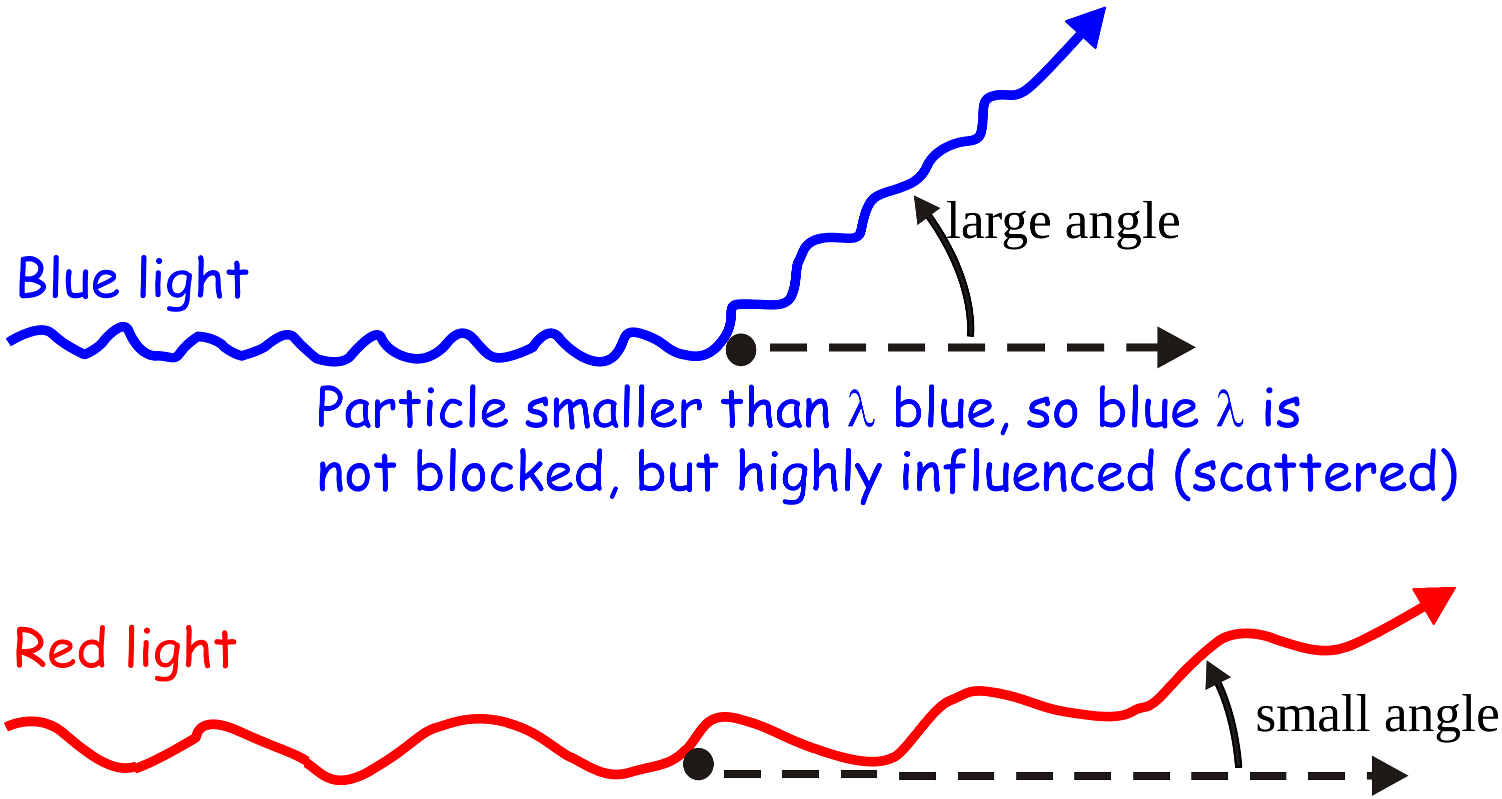
Interaction in atmosphere and on land



Atmospheric scattering

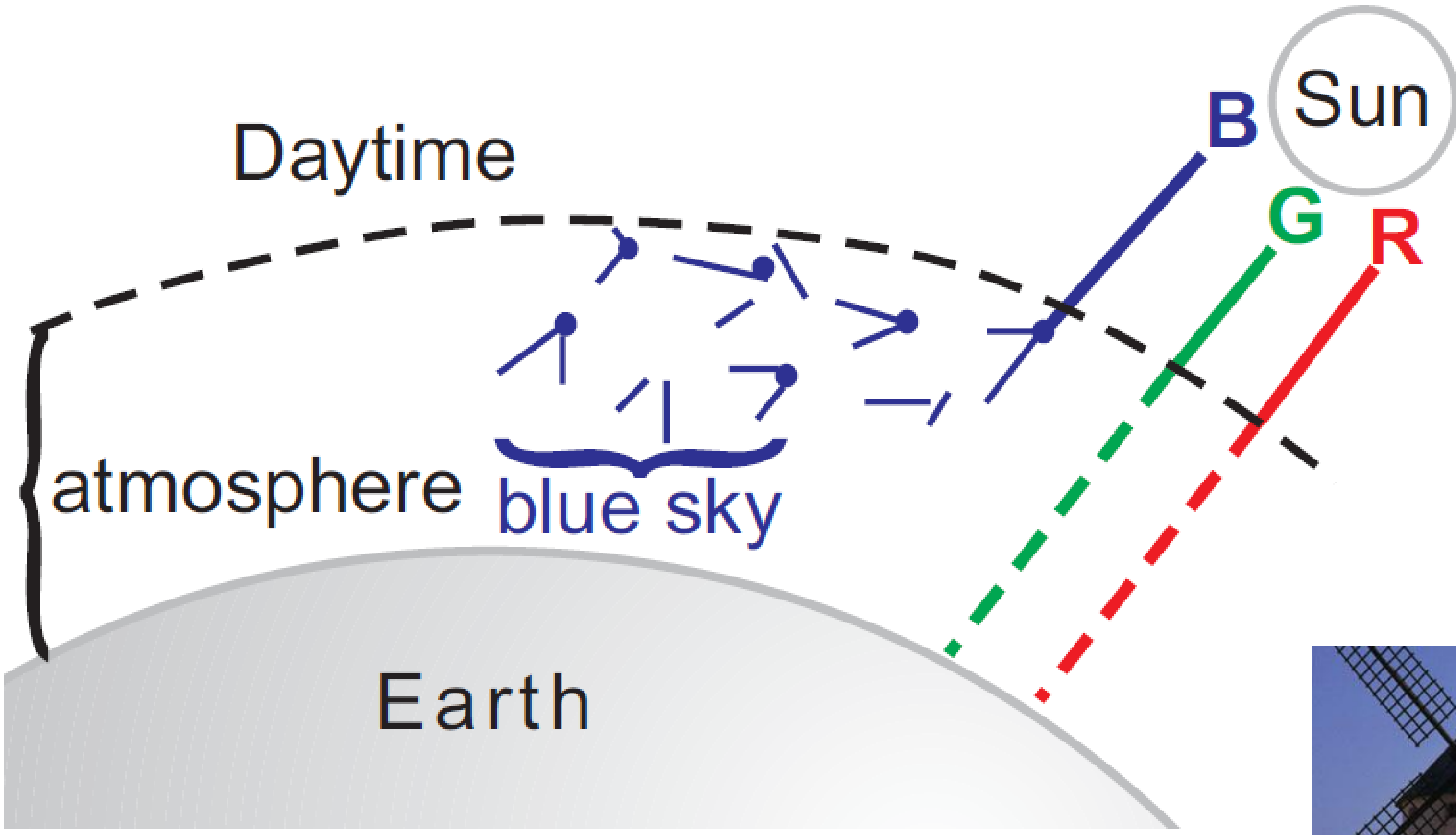
- Particles or gas molecules in the atmosphere cause EM waves to change direction
- The amount of scattering depends on wavelength, size and amount of particles & gases, distance through atmosphere

Selective (Rayleigh) scattering

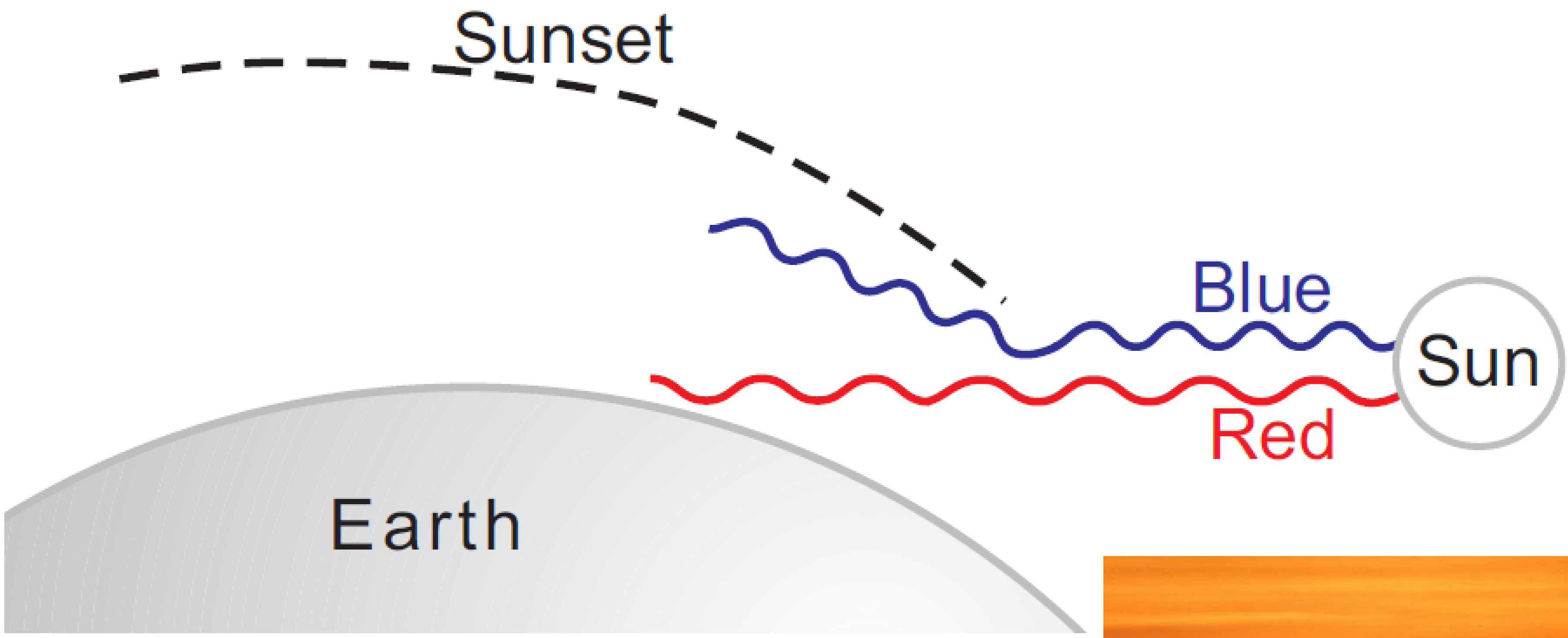


- The shorter λ, the greater the scattering effect.
- Scattering is mostly done by aerosols.

Selective (Rayleigh) scattering



Selective (Rayleigh) scattering



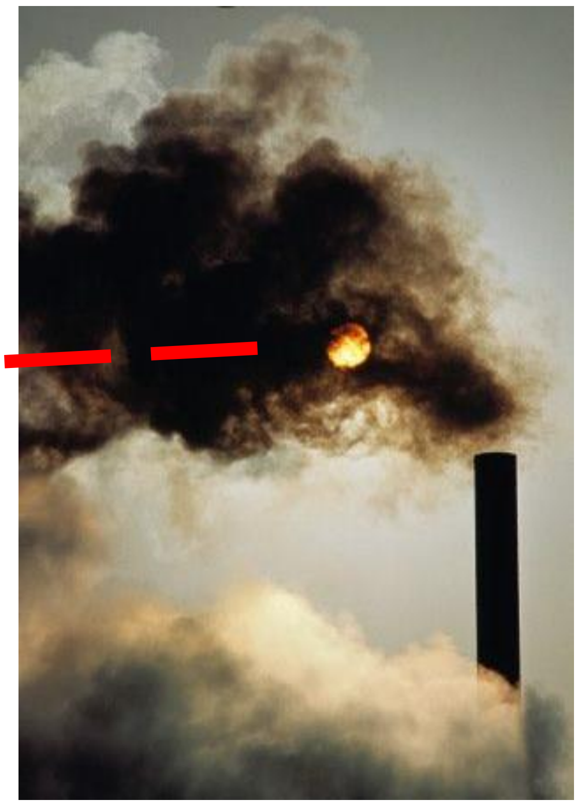
Selective (Rayleigh) scattering

Are shadows darker or lighter on the moon?

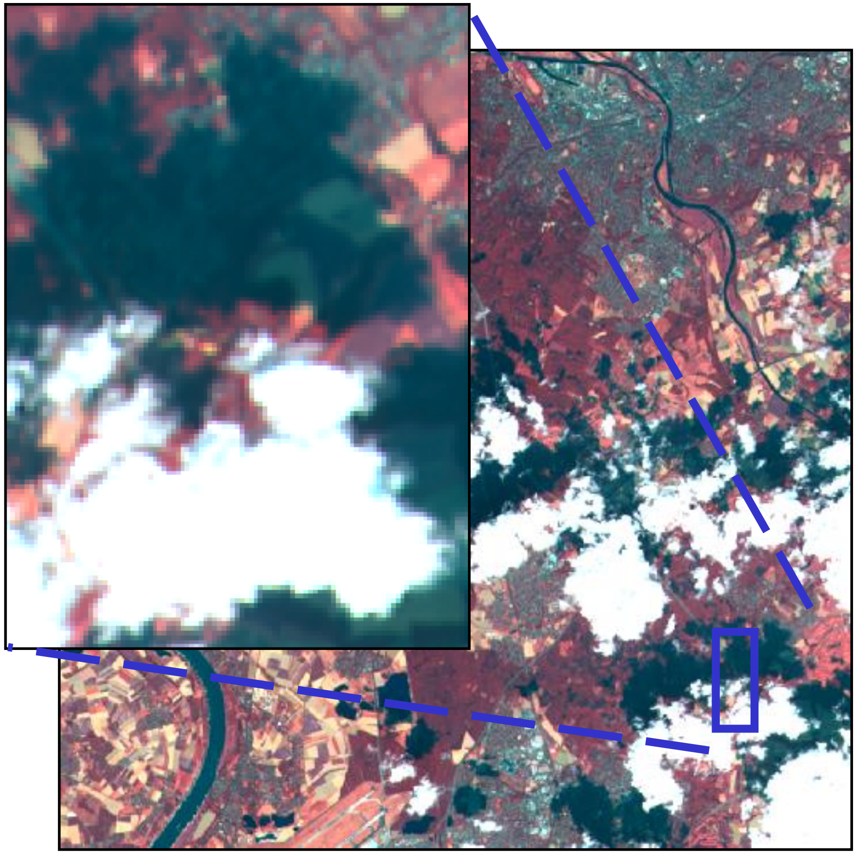
Why?

Selective (Mie) scattering

- Occurs when λ is equal to the particle size (usually bigger particles than those of Rayleigh scattering) .
  - Example: Sun and Smoke.



Non - selective scattering

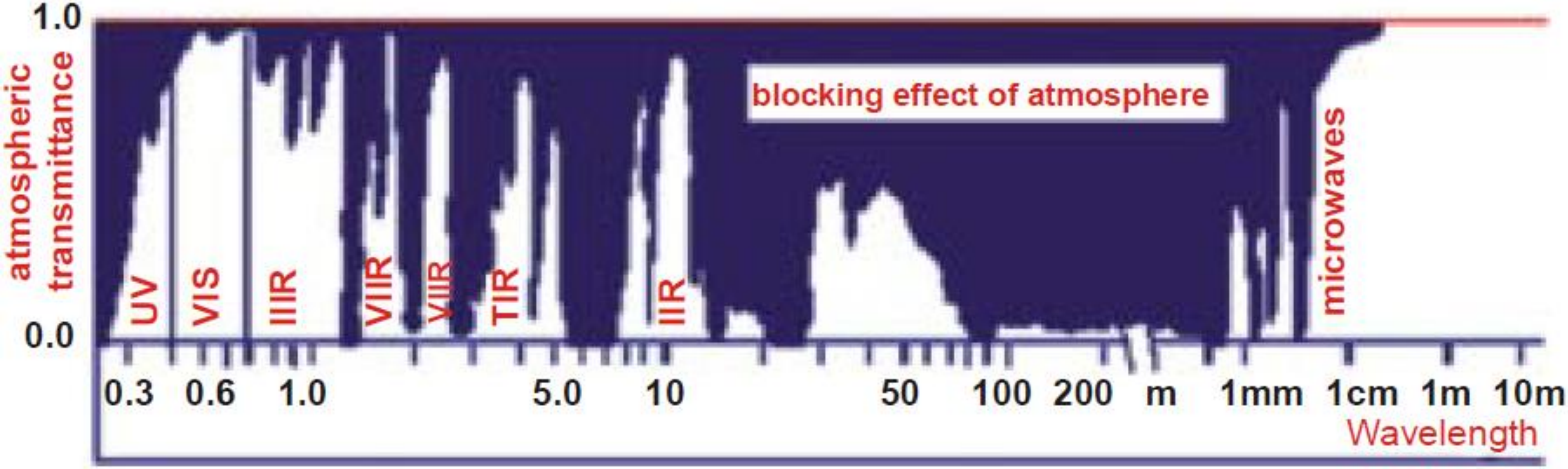


SPOT
Germany
1999

- no λ's pass through.
- The shadows of clouds are not black. (Why?)

- **Break - 10mins**

Atmospheric windows- absorption

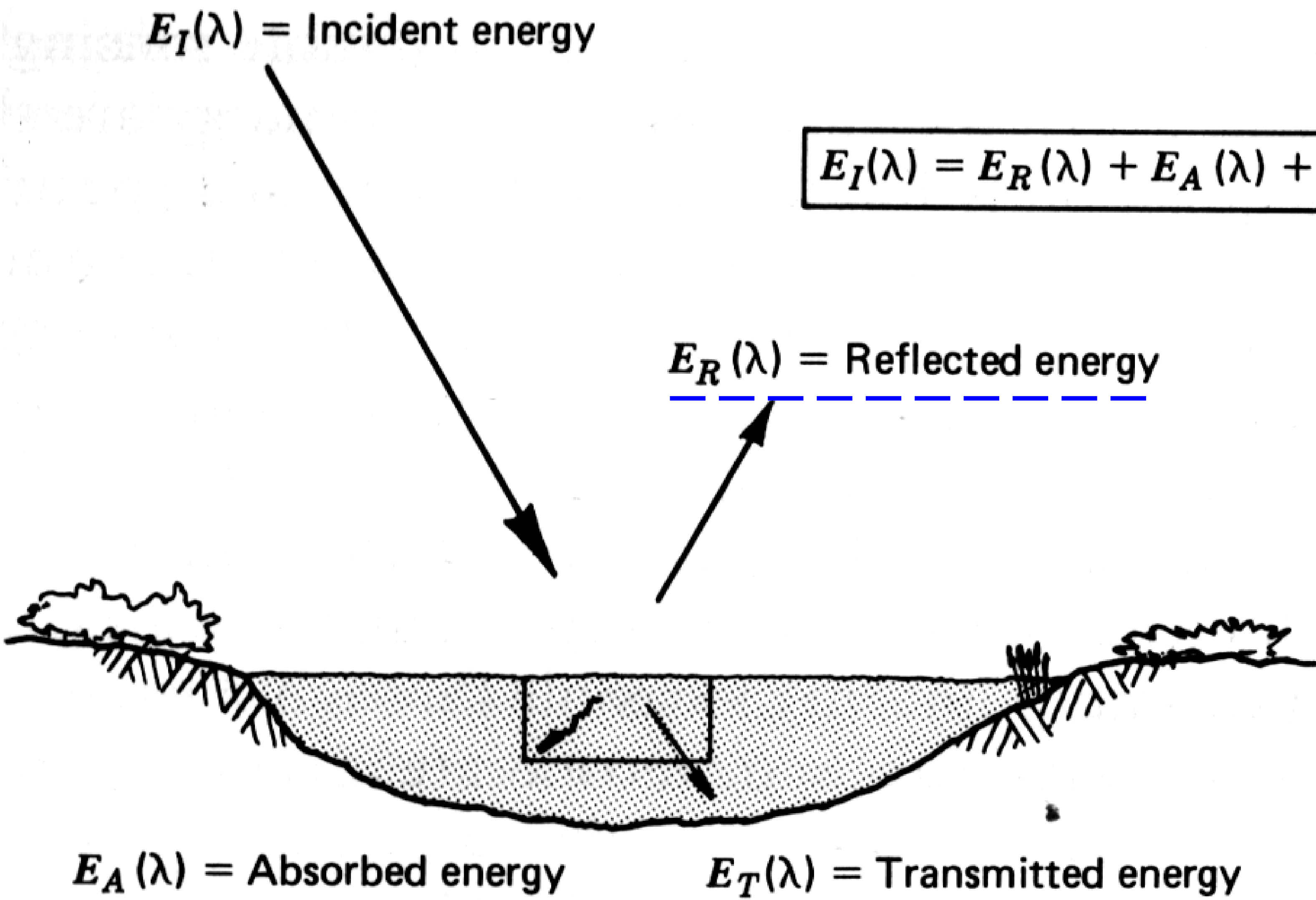


Refraction

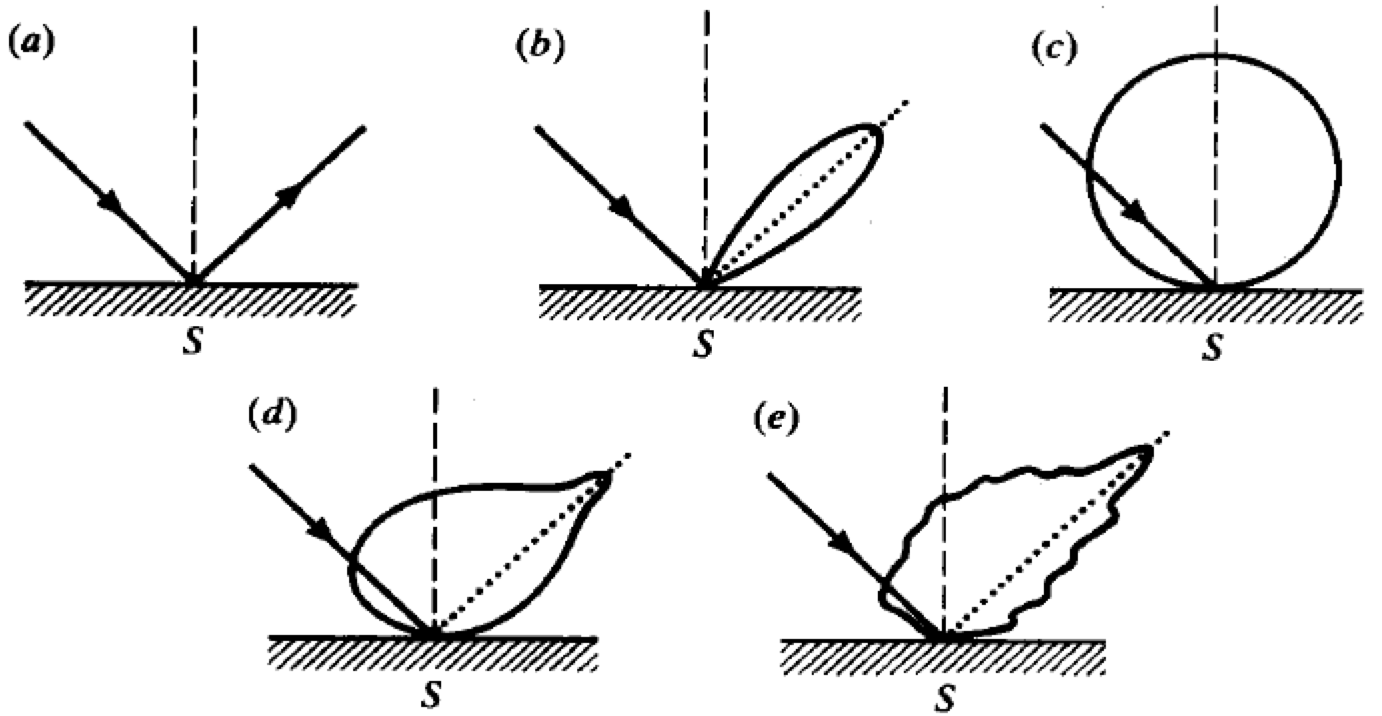
Refraction

The phenomenon of refraction, that is bending of light at the contact between two media, also occurs in the atmosphere as the light passes through the atmospheric layers of varied clarity, humidity and temperature. These variations influence the density of atmospheric layers, which in turn, causes the bending of light rays as they pass from one layer to another. The most common phenomena are the mirage like apparitions sometimes visible in the distance on hot summer days.

Interactions with the surface



Surface Reflections



(a)Perfect specular reflector (b) Near perfect specular reflector (c) Lambertian
(d) Quasi-Lambertian (e) Complex

Specular reflection - example

Spectral reflectance curves

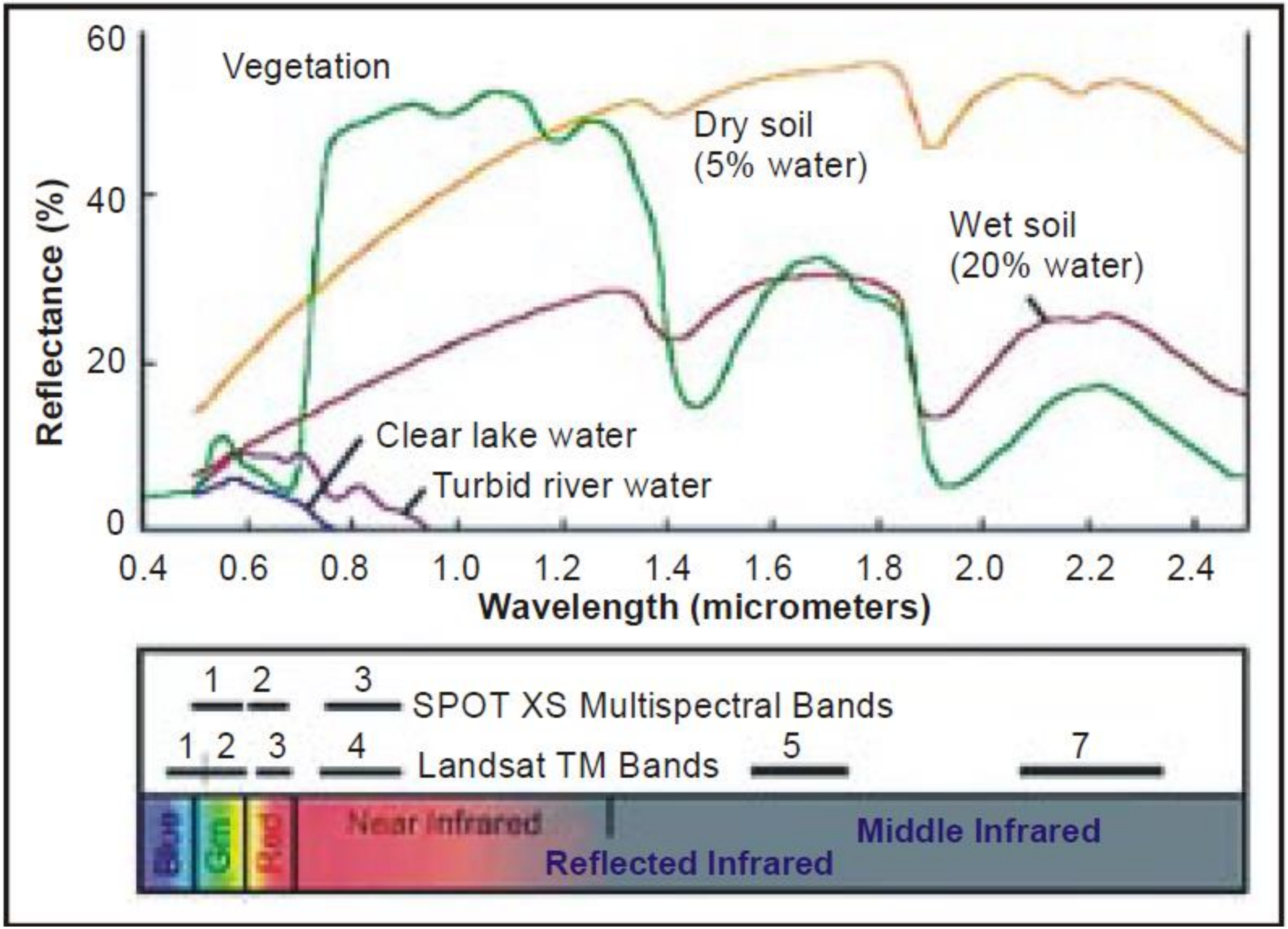
- Energy reaching the surface: irradiance (Wm^{-2})
- Energy reflected by the surface: radiance(Wm^{-2})
- Reflectance curve: fraction of irradiance that is reflected as a function wavelength
- Reflectance curves are material specific

Example

Visible λ

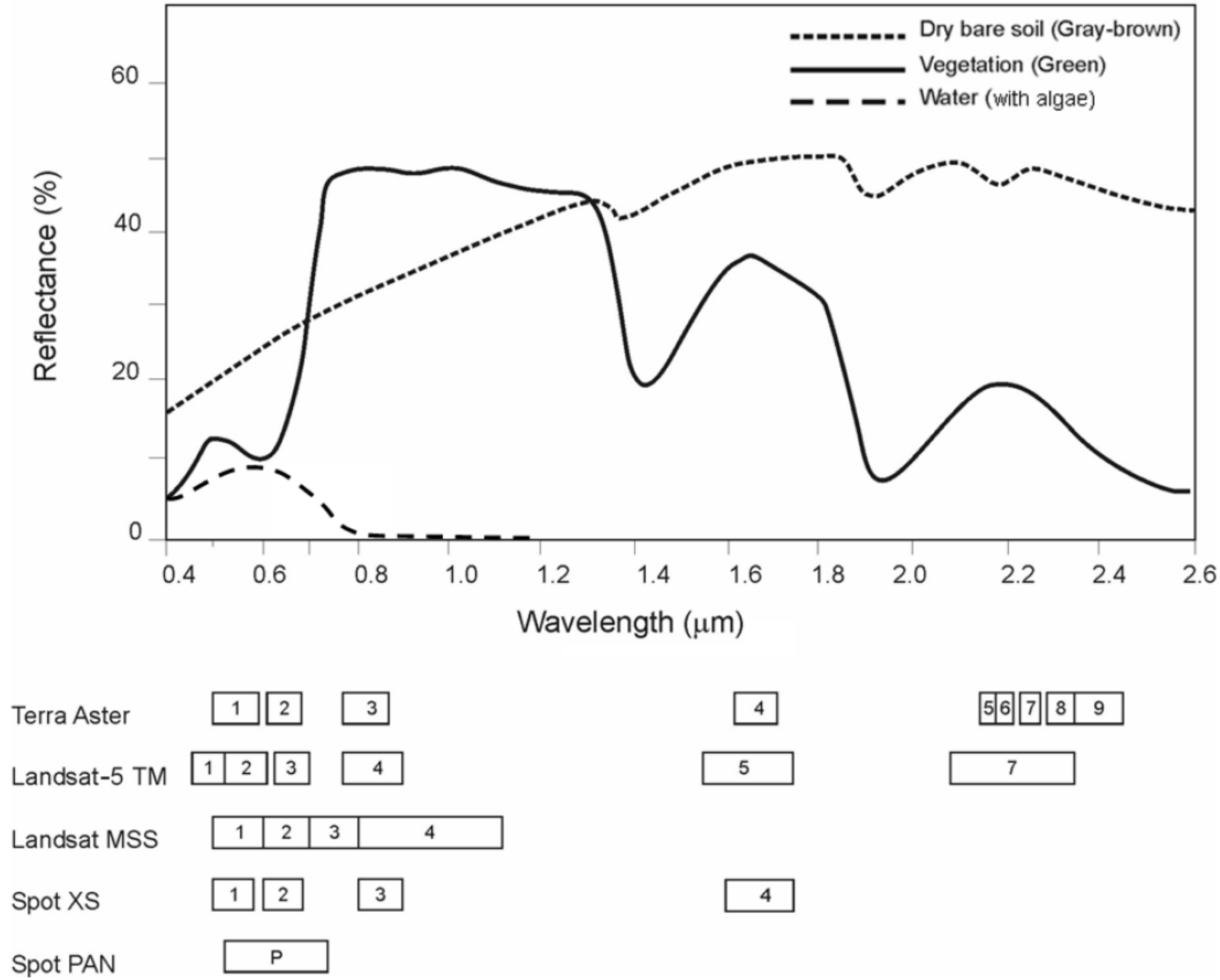
IR λ

Spectral Signature



Sensing of EM energy

Radiance recorded by the sensor is a "spectral band" not a single wavelength



Sensing of EM energy

Sensing in several spectral bands allows relating properties

Combining reflection in “red” and “NIR” bands can tell something about photosynthetic activity (biomass) and plant health - (NDVI)

NDVI

- NDVI = Normalized DifferenceVegetation Index
- Formula: (NIR - Red) / (NIR + Red)
- Interpretation
  - Values range from -1.0 to +1.0
  - Higher values indicate healthy green vegetation
  - Values for unhealthy vegetation are lower
  - Lowest values are for non-vegetated areas

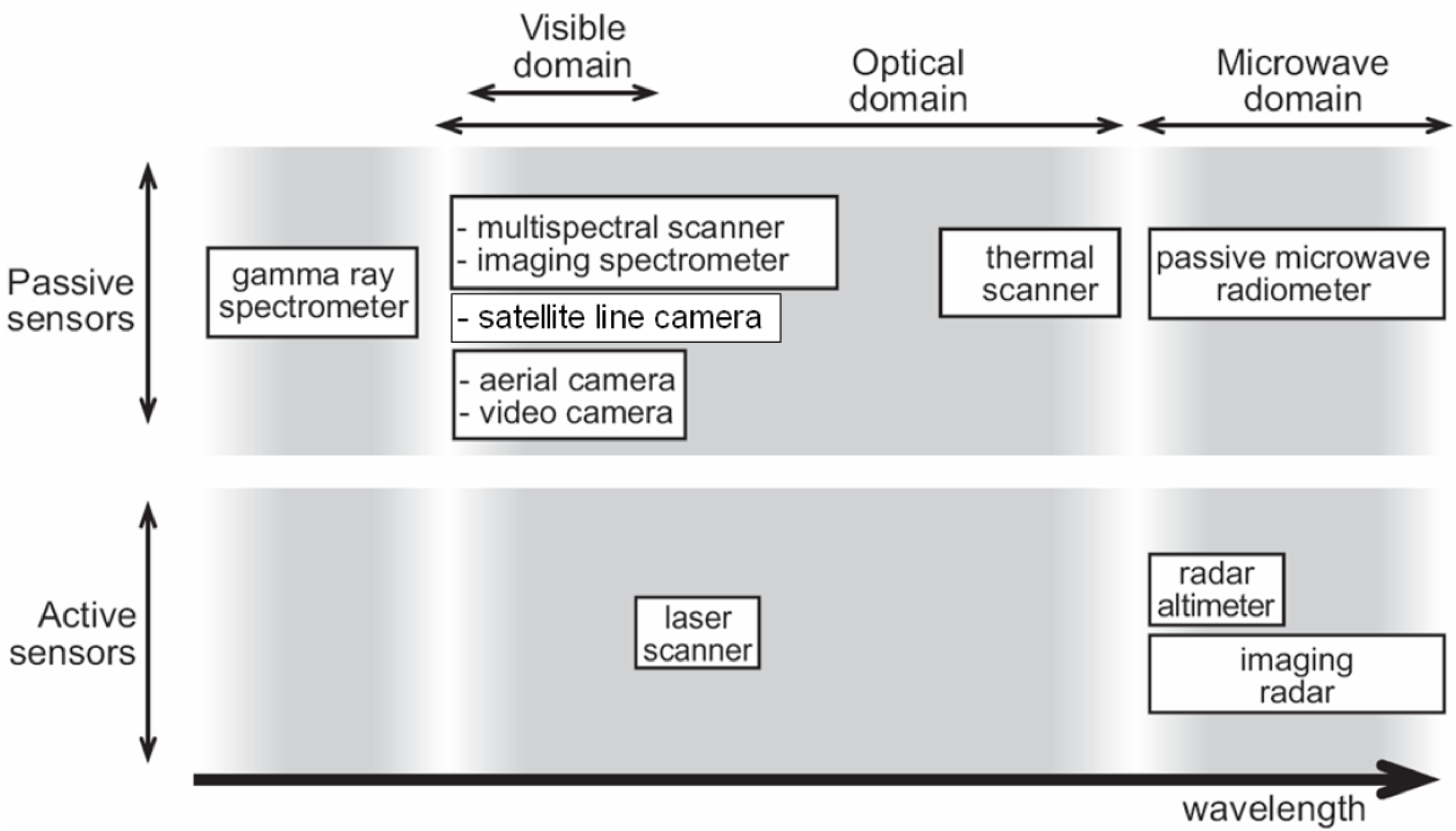
Classification of sensors

Different types of sensors:

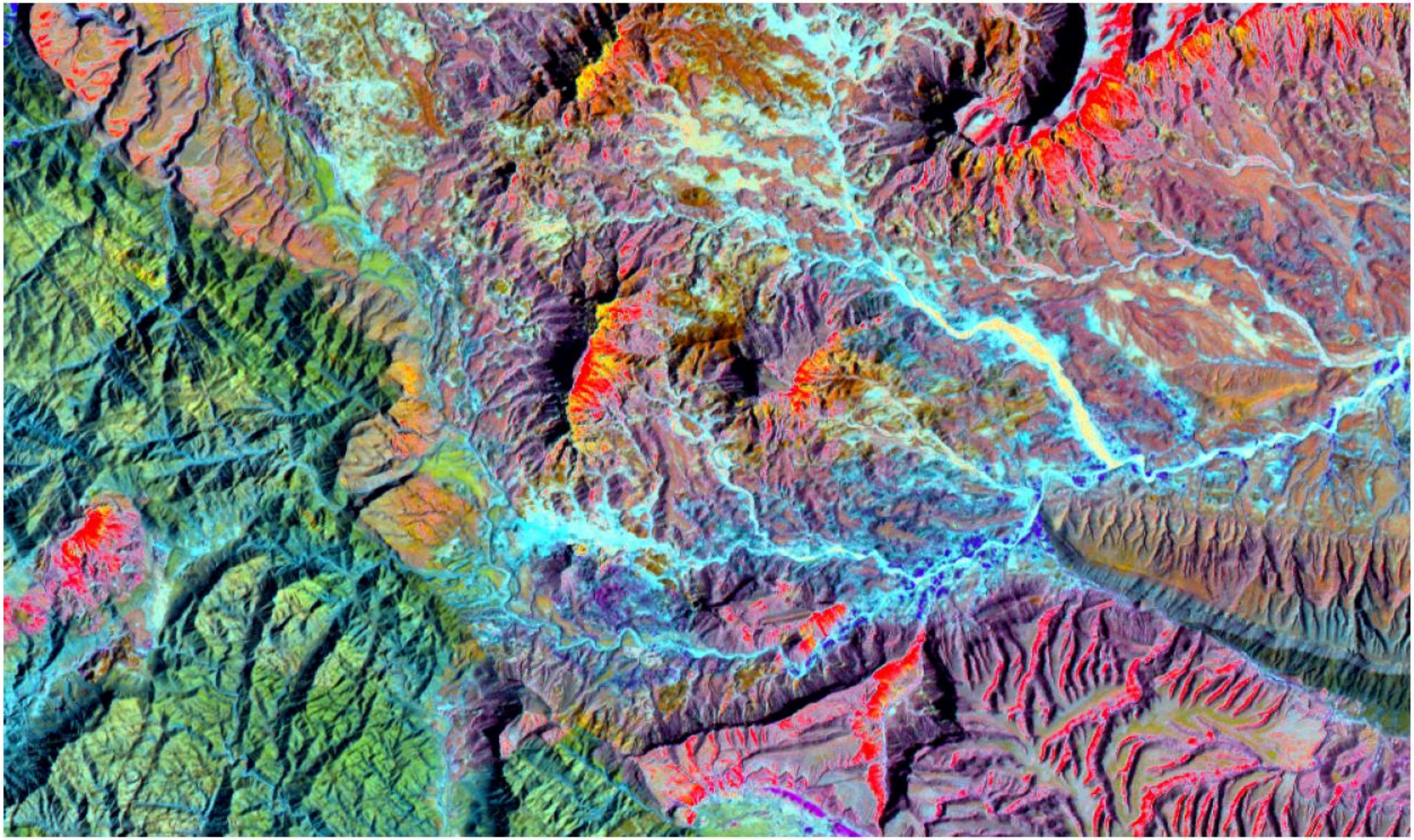
Altimiter	(no images but info on elevation)
Radiometer	(one or few broads with high sensitivity)
Spectrometer	(many bands, high spectral resolution)

Gamma ray spectrometer
Film camera, digital camera, video camera
Multispectral scanners
Imaging spectrometers
Thermal scanners
Microwave radiometers
Laser scanners
Imaging radar
Radar altimeters
Sonar

Classification of sensors

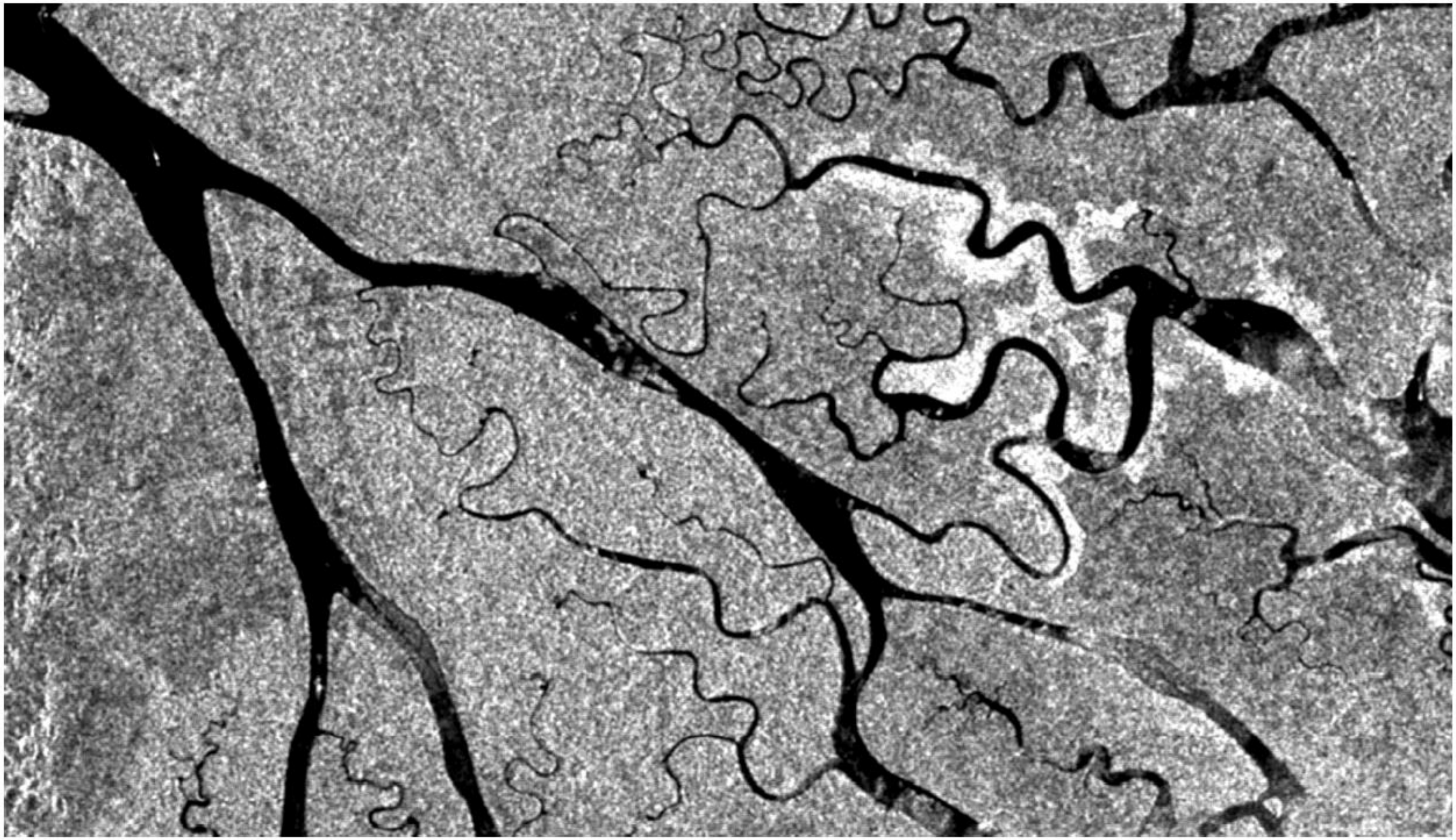


Classification of sensors



Landsat-5 TM false colour composite of an area of 30 by 17 km

Classification of sensors



ERS-1 SAR image of a delta on Kalimantan

Summary

- RS based on detecting electromagnetic (EM) energy
- Waves & photons
- Blackbody radiance & emissivity
- EM spectrum
- Interaction in the atmosphere
- Interaction on the surface
- Atmospheric windows
- Spectral reflection curves (‘spectral signatures’)
- DN values