

Overview of EM remote sensing systems

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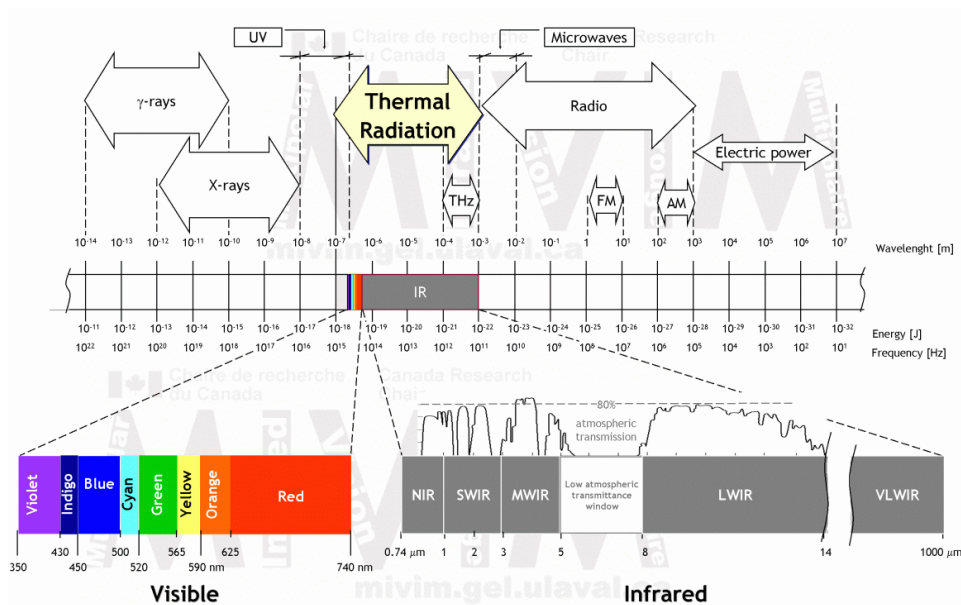
Overview of EM remote sensing

Overview

- Electromagnetic spectrum
- Black body radiation
- Classes of EM systems
 - By wavelength
 - Active/passive
 - Imaging/non-imaging
- Platforms
 - Airplanes
 - Satellites

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Electromagnetic spectrum



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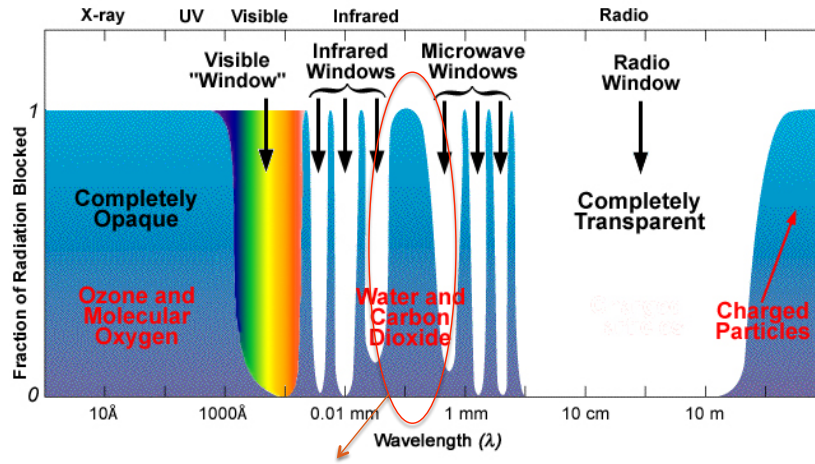
Electromagnetic spectrum

The spectrum is usually studied in different sub-bands

- Due to the different frequencies radiated by different sources
- Due to different type of interaction with matter in different wavelengths
- Due to the different behavior of the atmosphere at different frequencies
- Due to the different level of radiation of the Earth in different sub-bands

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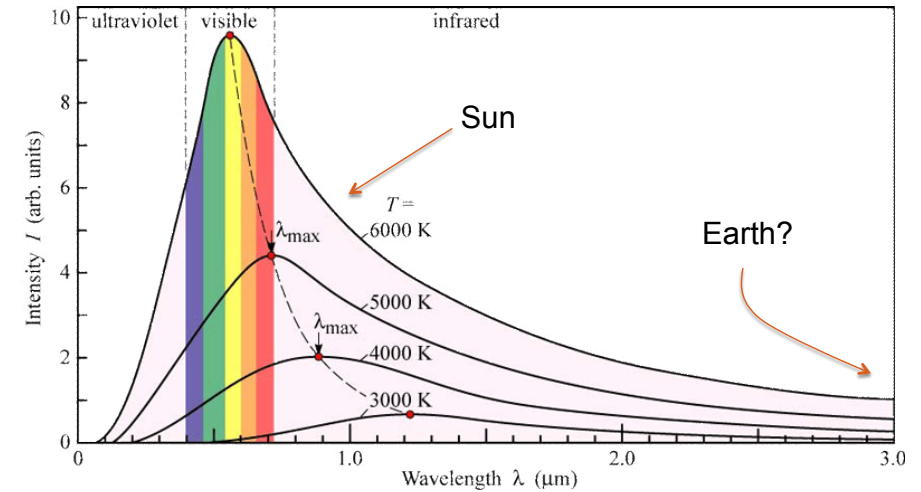
Electromagnetic spectrum and the atmosphere



Strong absorption band, in the range 0.1 to 1 mm
This clearly separates infrared from microwaves

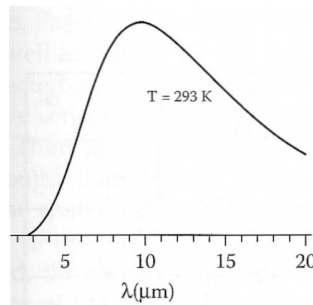
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Black body radiation



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Sun/Earth radiation



Estimates of Relative Intensities of Reflected Solar Radiation and Emitted Radiation From the Surface of the Earth

Wavelength (λ)		Emitted Intensity	Reflected Intensity
Blue	0.4 μm	7.7×10^{-20}	6.1×10^{24}
Red	0.7 μm	2.4×10^0	5.1×10^{24}
Infrared	3.5 μm	1.6×10^{21}	4.7×10^{22}
Thermal-infrared	12 μm	7.5×10^{22}	4.5×10^{20}
Microwave	3 cm	2.6×10^{10}	1.3×10^7

Note: Second column corresponds to $E(\lambda)$ in units of $8\pi hc \text{ m}^{-5}$ for $T = 300 \text{ K}$, third column corresponds to $E(\lambda)(r/R)^2$ in the same units for $T = 6000 \text{ K}$.

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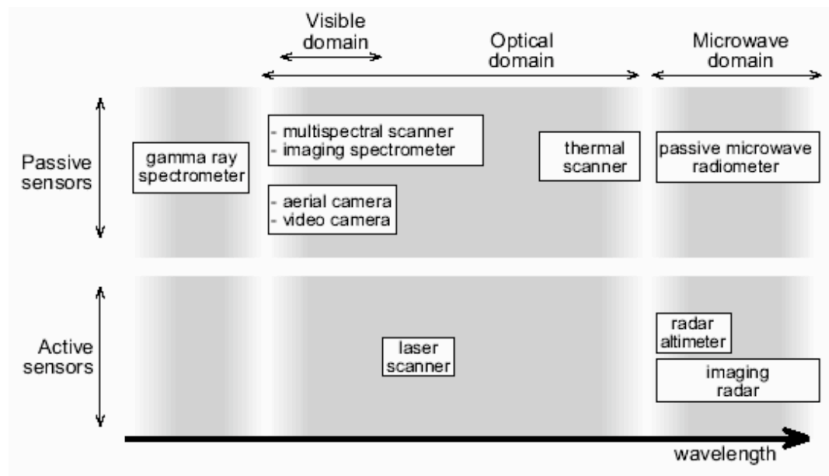
Electromagnetic Spectrum

Implications

- This clarifies why it is reasonable to split the spectrum into the following sub-bands
 - Gamma rays and X rays
 - Optical frequencies (visible and near-infrared)
 - Thermal infrared
 - Microwaves
 - Radio waves
- Sensors are thus usually classified depending on
 - Active/passive
 - Used band

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Types of sensors

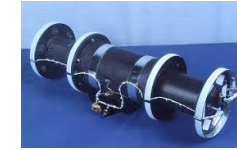


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Types of sensors

Passive Sensors

- Gamma rays spectrometers



- They measure the emission of γ rays from the Earth surface due to nuclear decay of radioactive natural materials (mainly Potassium, Uranium and Thorium)
- The strong absorption by rock and by the atmosphere imposes serious limits to the achievable distance and deepness.
- Applications: mineral exploration ...

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Types of sensors

Passive Sensors

- Cameras



- In the past they were based on film, now digital (CCD)
- Mainly used in aerial photography,
- Sensible to wavelengths in the range $400\text{nm} \leq \lambda \leq 900\text{nm}$,
- Applications: photogrammetry, map creation, ...

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Types of sensors

Passive Sensors

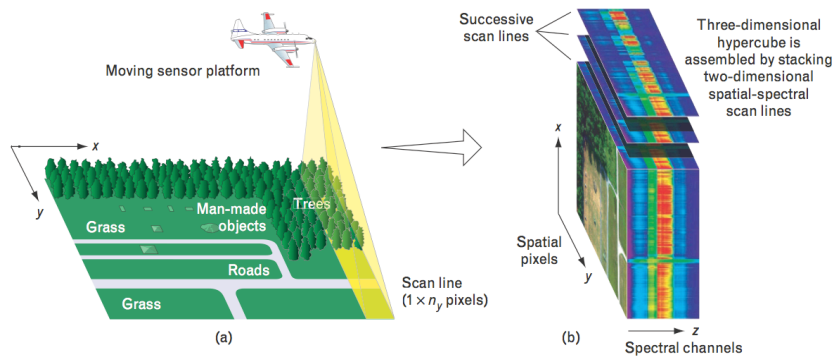
- Multispectral and Hyperspectral sensors



- They sense the EM wave coming from different points of the surface usually in the optical band (usually reflected light)
- The radiation is sensed in different sub-bands at the same time
 - Multispectral: usually some tens of bands
 - Hyperspectral: from a few hundreds to many thousands
- Applications: many, mainly in environmental monitoring

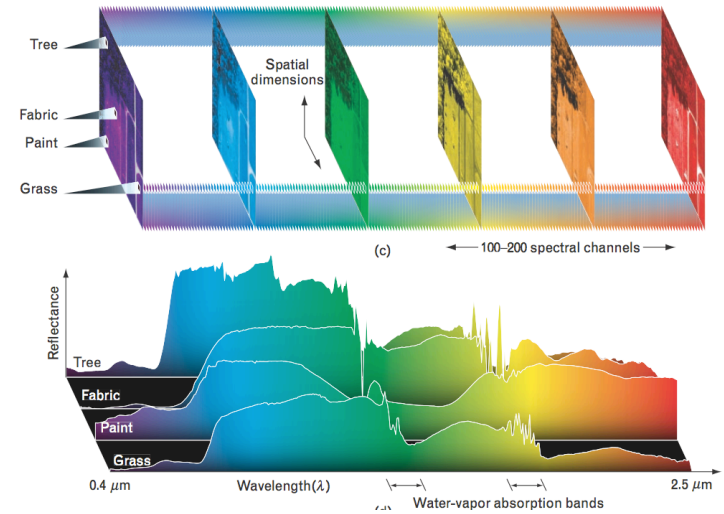
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Hyperspectral Imaging



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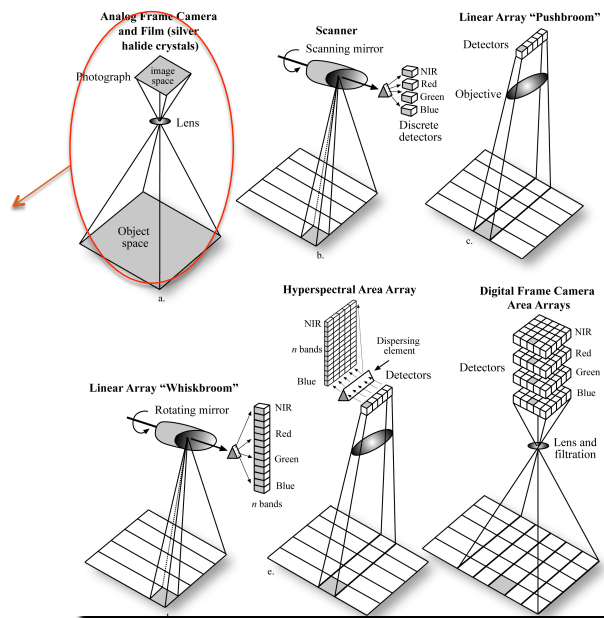
Multispectral Imaging



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Multispectral sensors

Now rarely used

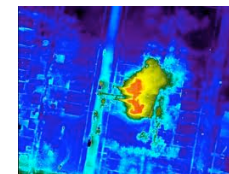
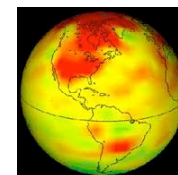


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Types of sensors

Passive Sensors

- Thermographs
 - Similar to multispectral sensors but sensitive to wavelengths in the range from 10 to $14 \mu\text{m}$, which are related to the temperature of the target object,
 - Knowing the temperature of the land surface, of the sea and of the clouds is extremely important for weather forecast and for climatic monitoring,
 - Furthermore, fires or fire outbreaks are easily spotted in the thermal IR



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Types of sensors

Passive Sensors

- Radiometer
 - The ground and near-underground soil radiate in the wavelengths between 1 cm and 1 m.
 - The emission depth, and thus the intensity, depends on the soil composition and humidity.
 - The information acquired can be used for mineral exploration, map creation, humidity maps etc.

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Types of sensors

Active Sensors

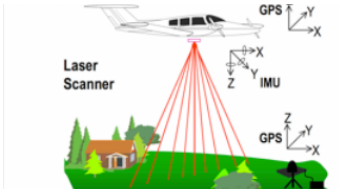
- LIDAR (Ligth Detection and Ranging)
 - Sensor that emits laser beam in the atmosphere (usually in the IR) and senses the returns
 - Two main types of LIDAR:
 - Airborne or satellite LIDAR
 - Ground based LIDAR
 - Airborne LIDAR is used to measure the elevation data (topography) or the position and shape of the objects on the ground
 - Ground based LIDAR acquires information on the atmosphere based on the intensity of the returns from different atmosphere layers

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Types of sensors

Active Sensors

- Airborne LIDAR



- The time of flight is converted in a distance and thus reveal the position of the object
- This information was initially used mainly for the generation of digital models of the land surface for the creation of topographic maps
- Now used extensively for other purposes: 3D models of buildings and cities etc.

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Types of sensors

Active Sensors

- Radar altimeter
 - Used to acquire elevation measures along a satellite track
 - They use EM waves with wavelength in the range between 1 and 6 cm, and give an elevation measurement with a precision of around 2-4 cm.
 - They are appropriate for measuring elevation variations on a large scale (nothing to do with LIDAR).

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Types of sensors

Active Sensors

- Imaging radar
 - They use wavelengths in the range between 1 cm and 1 m.
 - Different λ allow to sense different characteristics of the target (humidity, conductivity, size, roughness at different scales).
 - These wavelengths penetrate clouds and can thus be used in any weather condition.
 - The combination of different images of the same region allows one to extract also elevation information (interferometry).
 - Radar imaging has a large set of applications (classification, map creation, ground soil models, ...)

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Characteristics of acquisition systems

Radiometric characteristics

- **Range:** the interval of values of the measured radiative parameter over which the system gives accurate measurements. For example the interval of temperatures that can be measured with a thermometer
- **Radiometric resolution:** the minimal variation that can be detected by the sensor.
 - Usually it is expressed in terms of Noise Equivalent Temperature Difference (NETD) or Noise Equivalent Reflectance Difference (NERD), respectively for measures of the temperature or reflectance.
 - Quantization: the resolution is not only limited in acquisition by the sensor itself but can be due to quantization for digital communication.

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Characteristics of acquisition systems

Spatial characteristics

- Coverage: it represents the size of the studied area and/or the studied portion of the area of interest. We usually see the following terms used
 - **Swath:** the width of the strip of land covered during one pass of a satellite or airplane (from tens to thousands of Kms)
 - **Field of View (FOV):** the field of view in angular measure, from which the swath can be deduced depending on the altitude. For example, a FOV of 5,7 degrees at 1000 Kms of altitude corresponds to a swath of 100 Kms.
- Geometric resolution: the ability to distinguish details, usually measured in terms of
 - **Instantaneous Field of View (IFOV):** the minimal angle between two distinguishable elements.
 - **Ground resolution:** the size of the area projected on the ground by a solid angle of the size of the IFOV

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Characteristics of acquisition systems

Spectral characteristics

- Sub-bands: number and location of the different sub-bands that are separately sensed
- **Spectral resolution:** the width of each sub-band. Different sub-bands can have different widths but in a multispectral sensor the sub-bands have almost the same width.

Temporal characteristics

- **Temporal resolution:** the minimal interval between two observations of the same place

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