Overview of EM remote sensing systems

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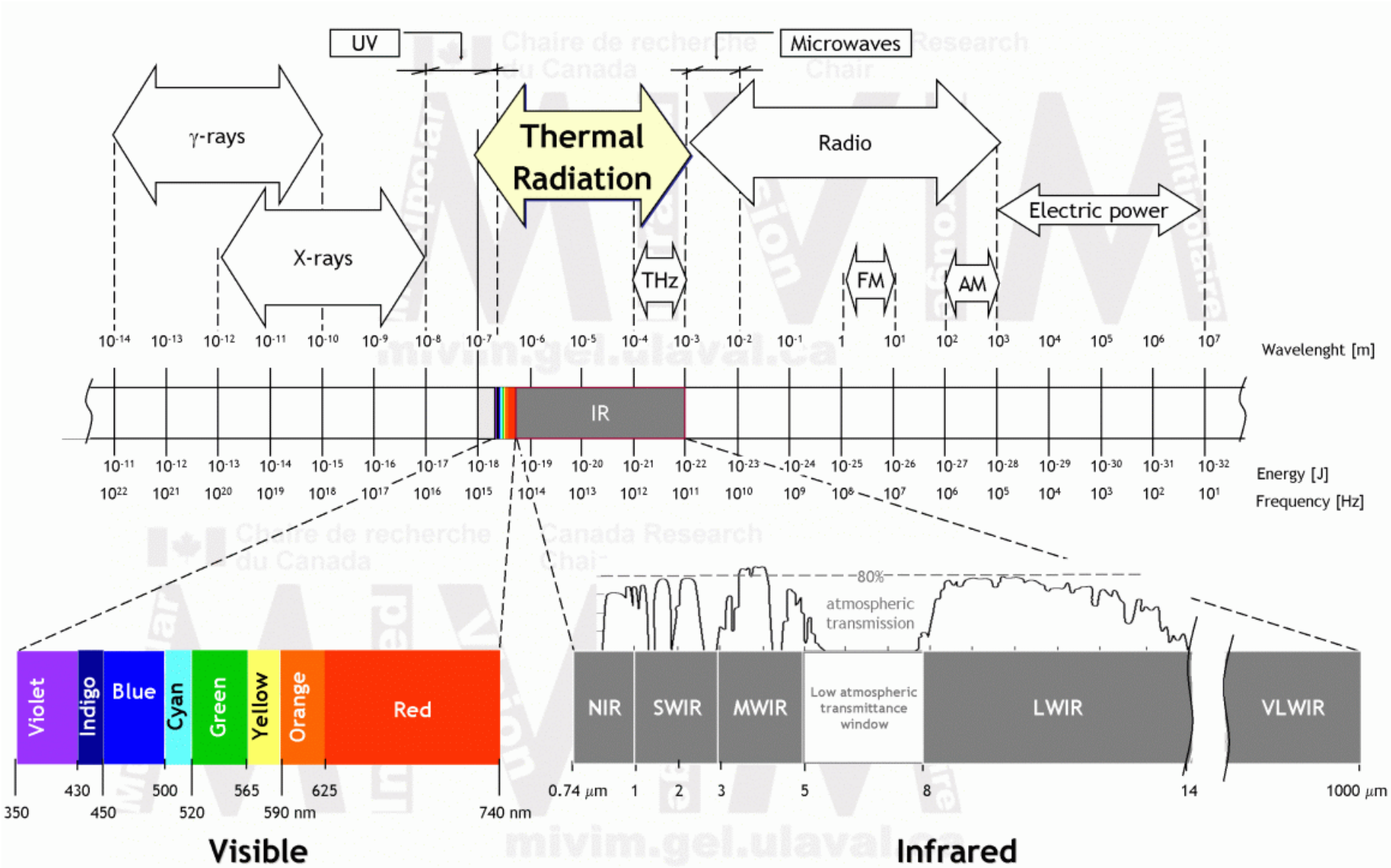
Overview of EM remote sensing

Overview

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

Electromagnetic spectrum

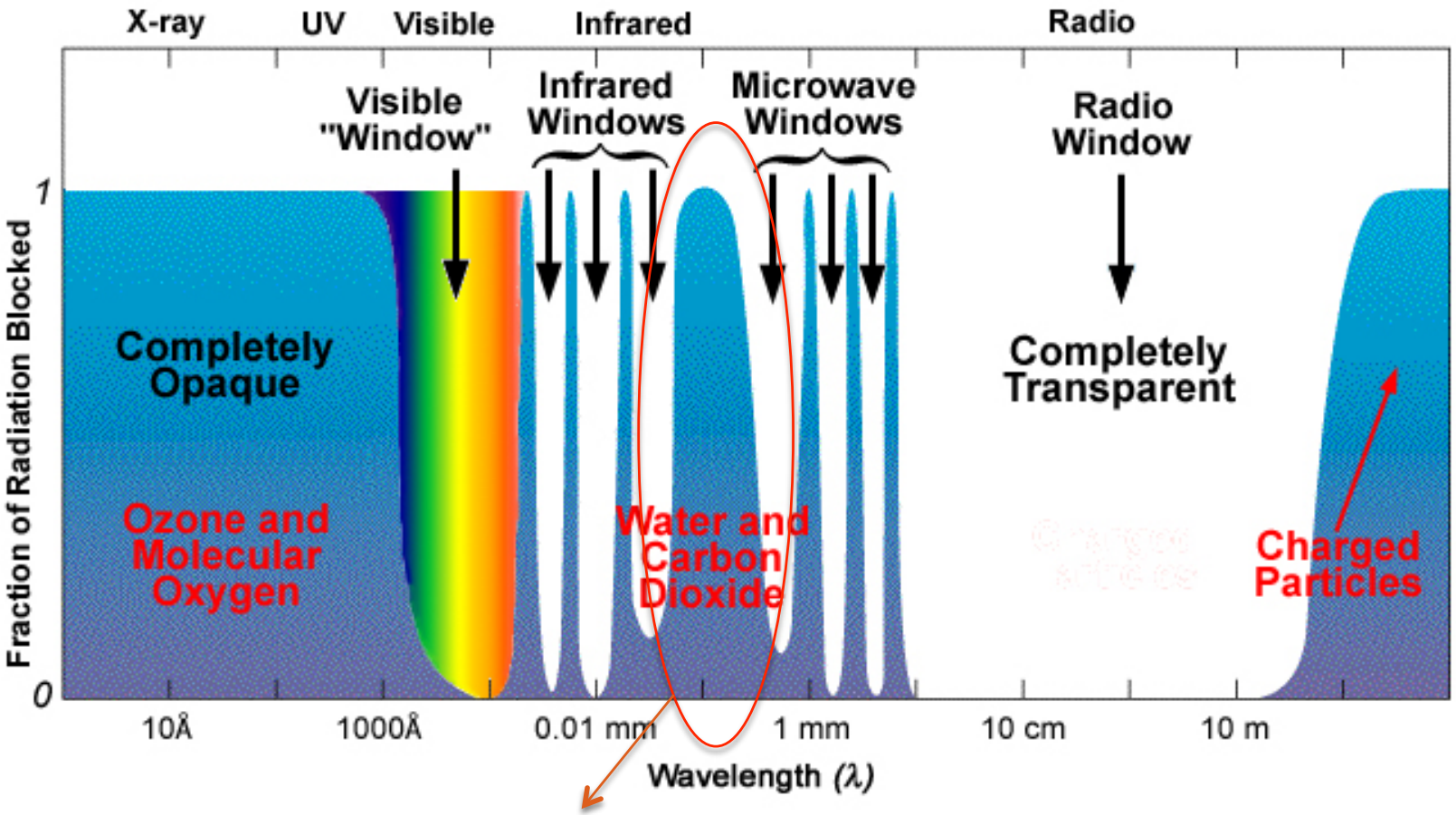


Electromagnetic spectrum

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

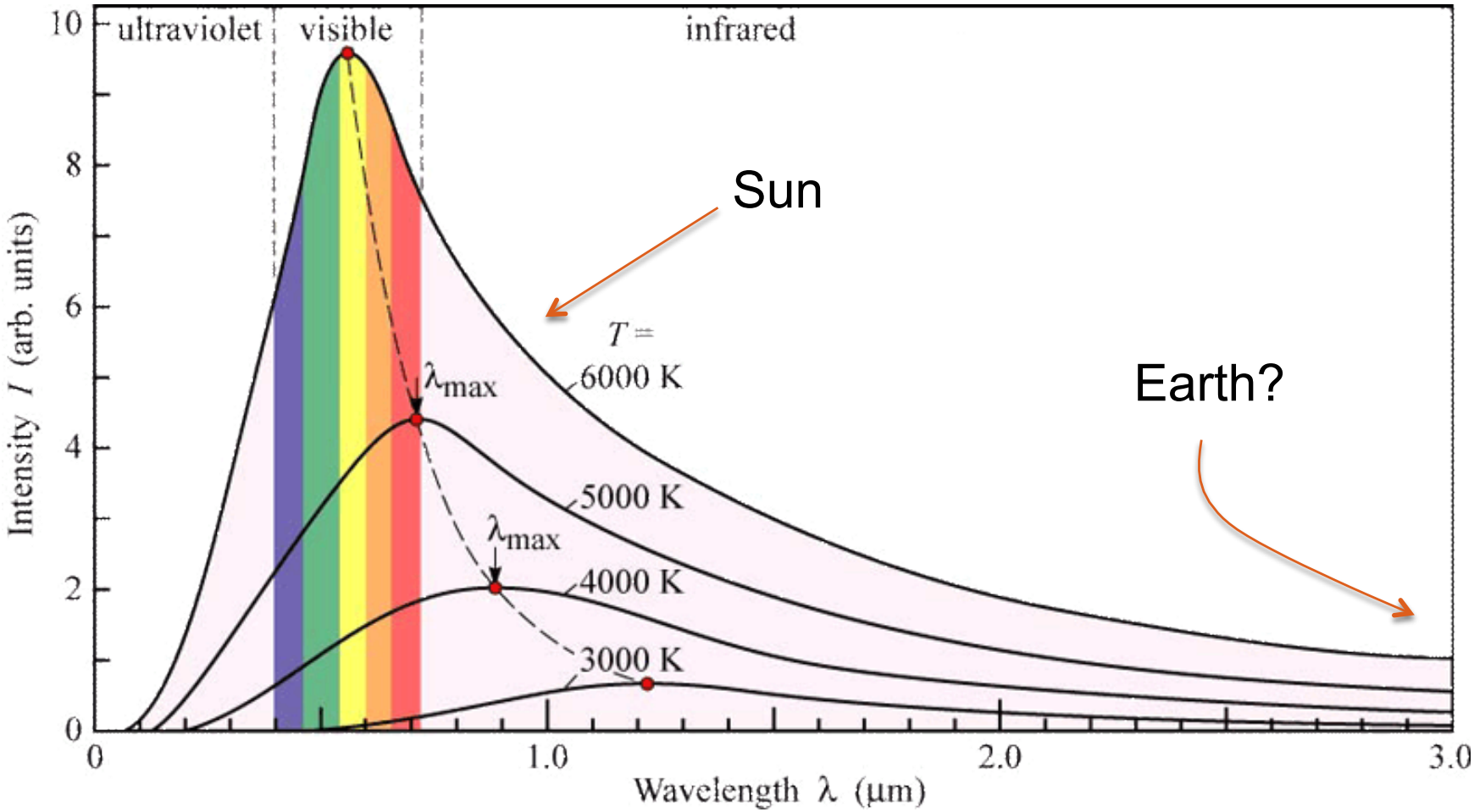
Electromagnetic spectrum and the atmosphere



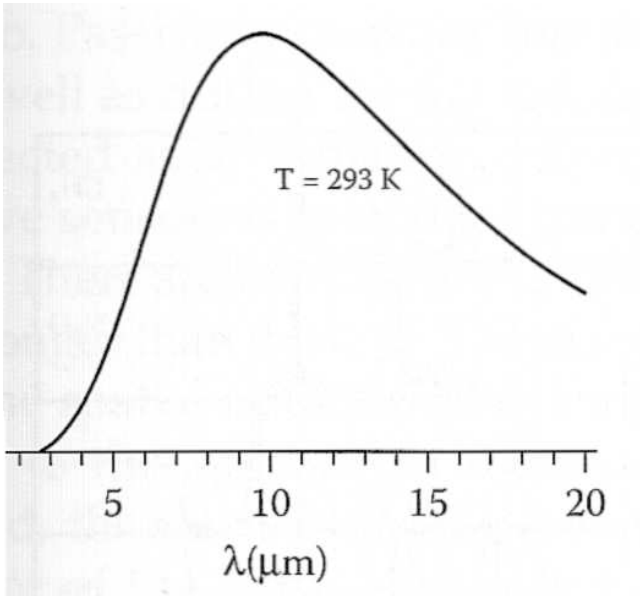
Strong absorption band, in the range 0.1 to 1 mm

This clearly separates infrared from microwaves

Black body radiation



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}

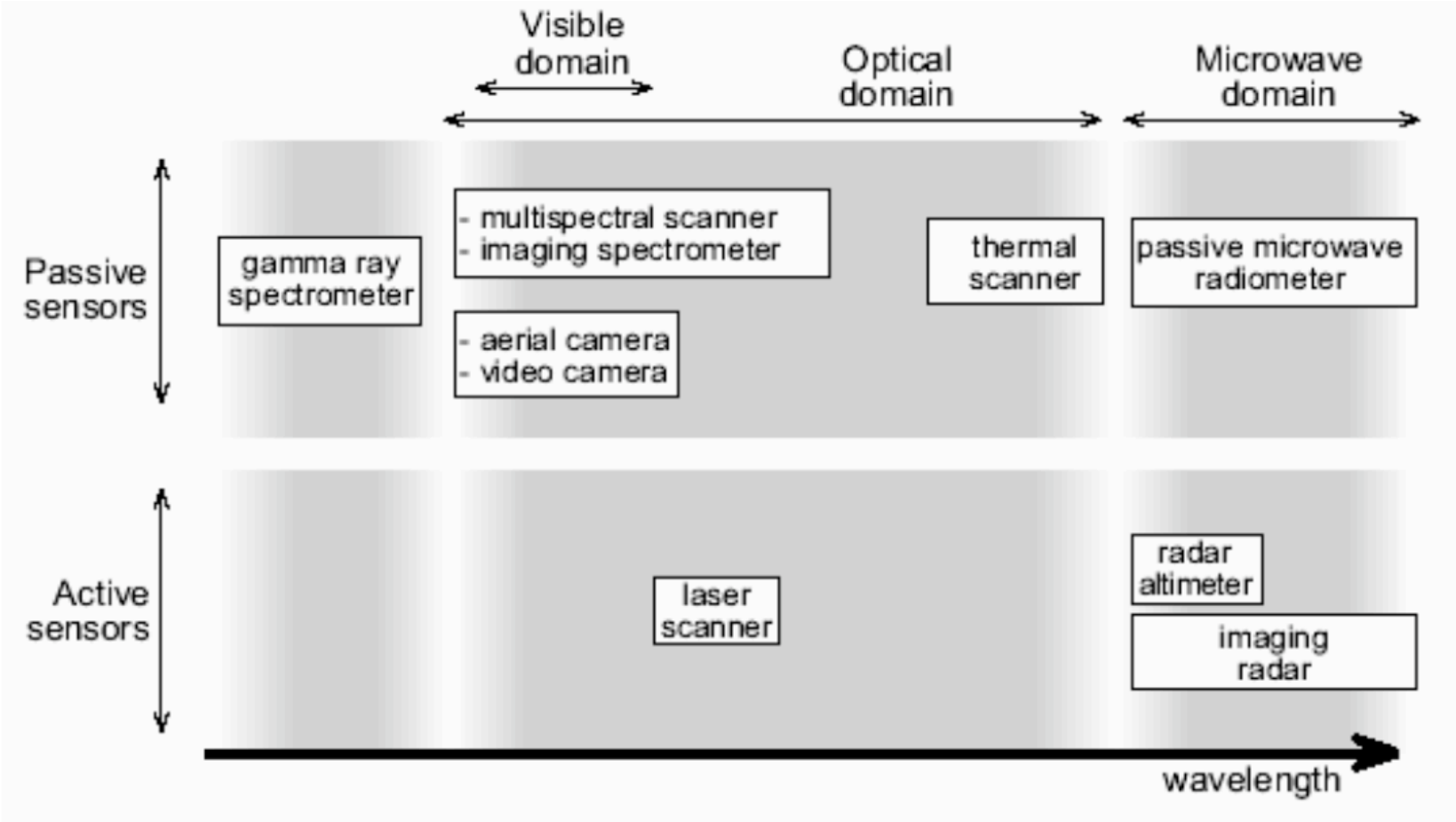
Note: Second column corresponds to $E(\lambda)$ in units of $8\pi hc$ m^{-5} for $T = 300$ K, third column corresponds to $E(\lambda)(r/R)^2$ in the same units for $T = 6000$ K.

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 depending on
  - Active/passive
  - Used band

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 and by the atmosphere imposes serious limits to the achievable distance and deepness.
  - Applications: mineral exploration ...

Passive Sensors

- Cameras

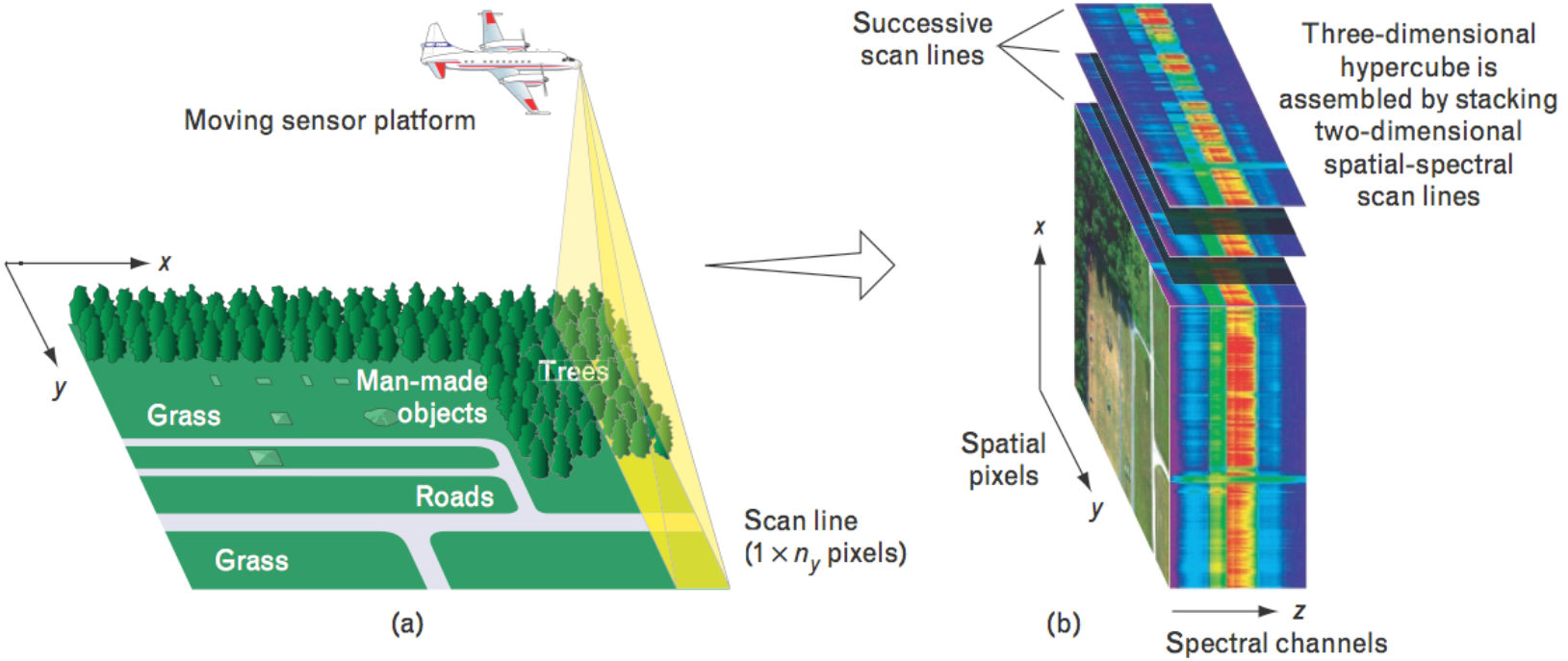
- In the past they were based on film, now digital (CCD)
- Mainly used in aerial photography,
- Sensible to wavelengths in the range $400\text{nm} \leq \lambda \leq 900\text{nm}$,
- Applications: photogrammetry, map creation, ...

Passive Sensors

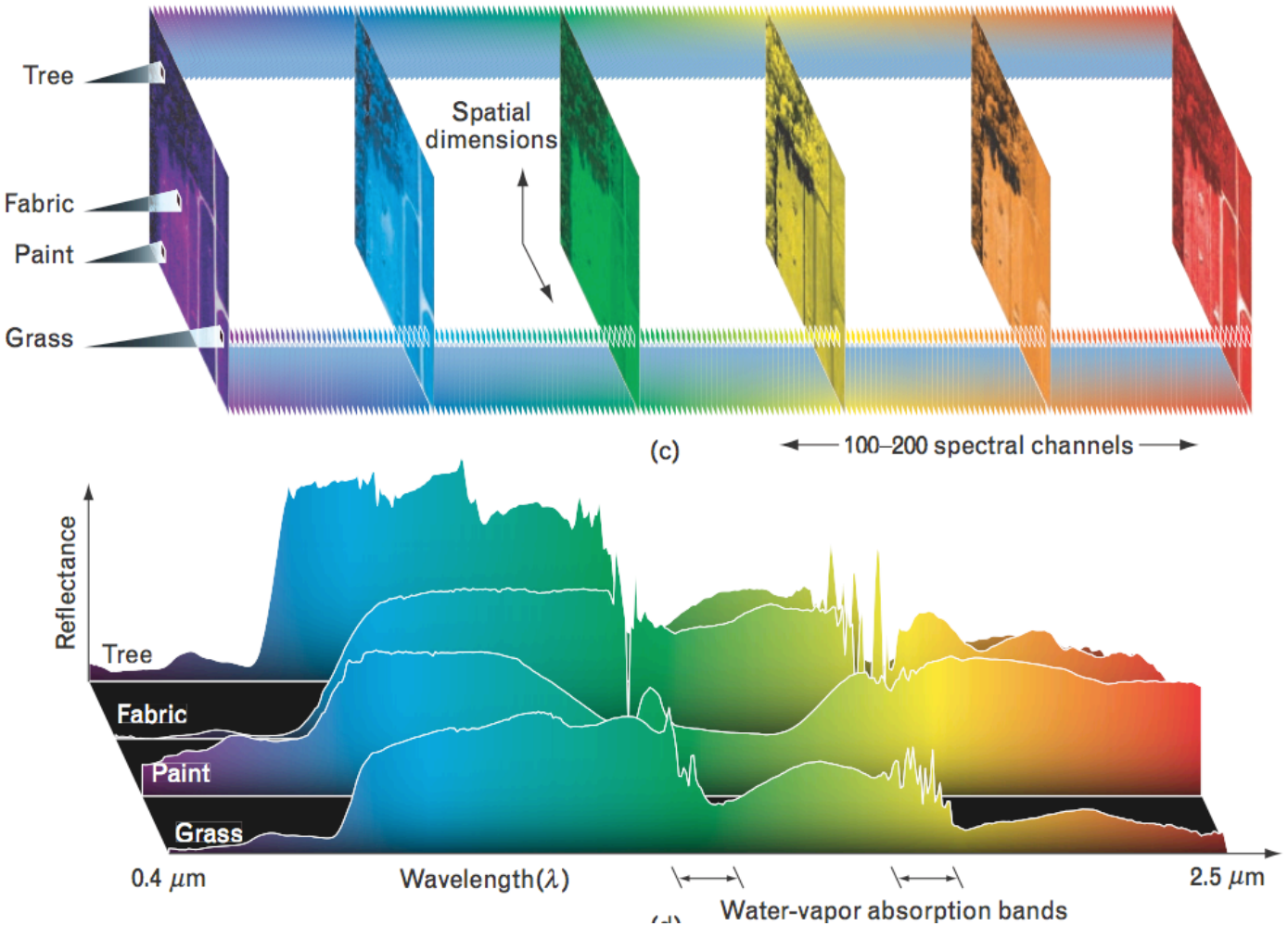
- Multispectral and Hyperspectral sensors

  - 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

Hyperspectral Imaging

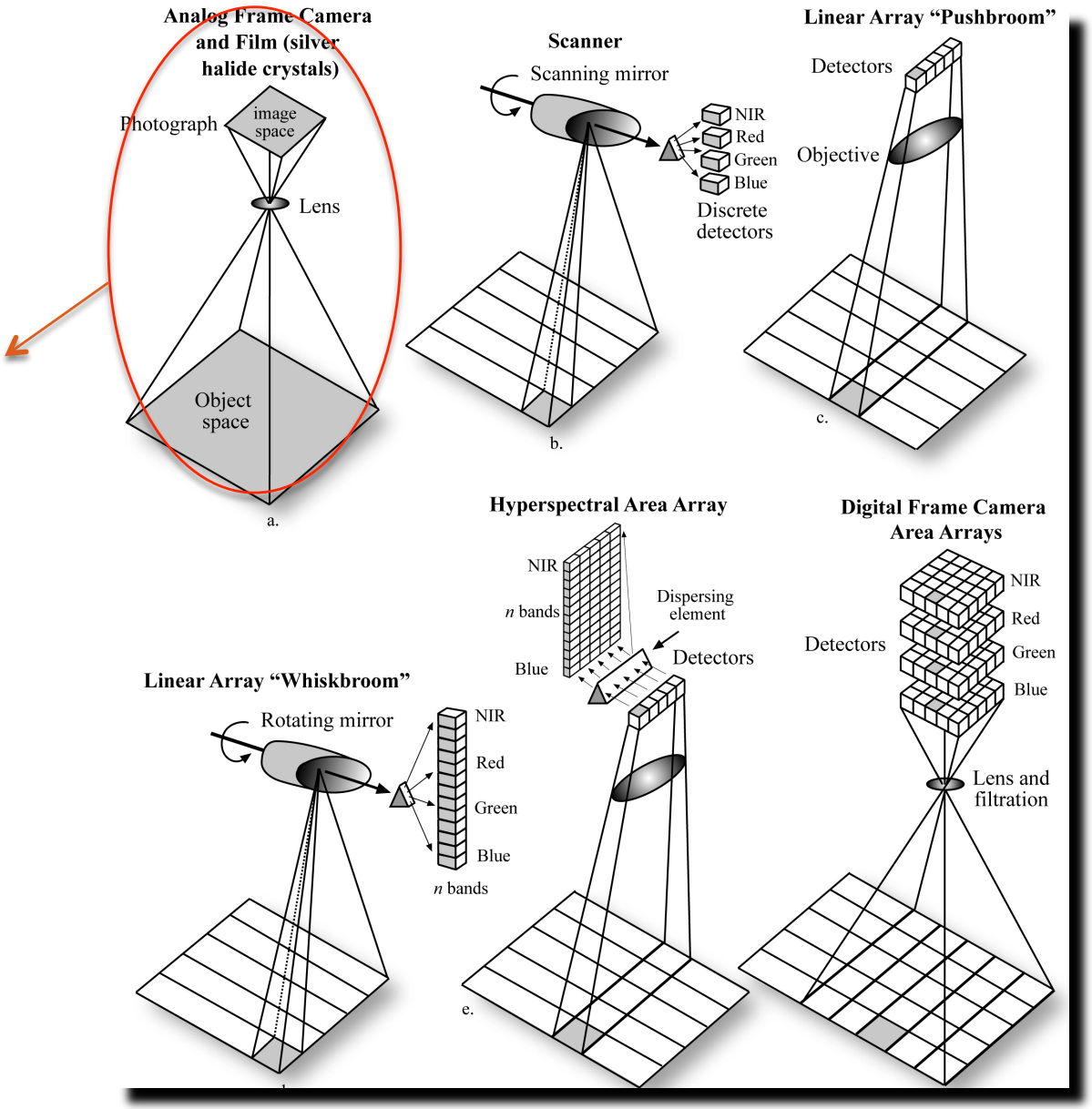


Multispectral Imaging



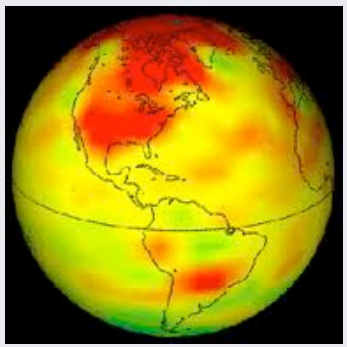
Multispectral sensors

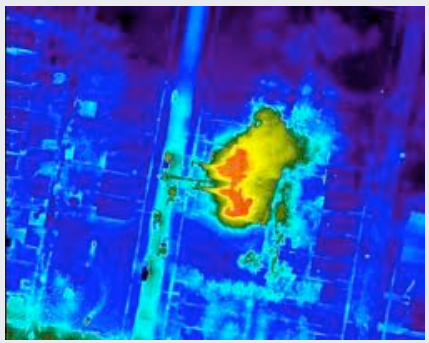
Now rarely used



Passive Sensors

- Thermographs
  - Similar to multispectral sensors but sensitive to wavelengths in the range from 10 to 14 μm, 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





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.

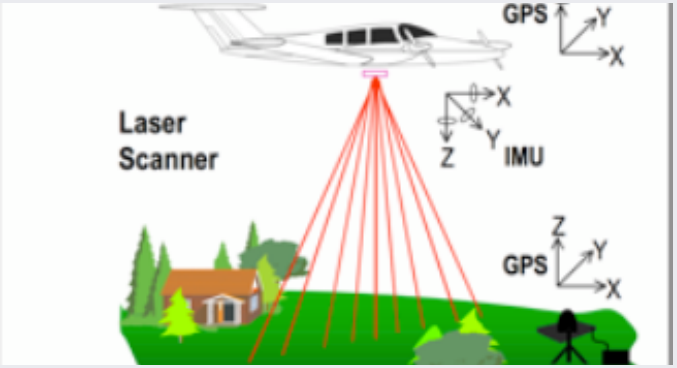
Types of sensors

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

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.

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).

Types of sensors

Active Sensors

- Imaging radar
  - They use wavelenghts 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).
  - This 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, ...)

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 termograph
- **Radiometric resolution**: the minimal variation that can be detected by the sensor.
  - Usually it is expressed in terms of Noise Equivalente Temperature Difference (NEDT) or Noise Equivalent Reflectance Difference (NEDR), 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.

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

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