Multispectral Scanners in the Optical and Thermal IR

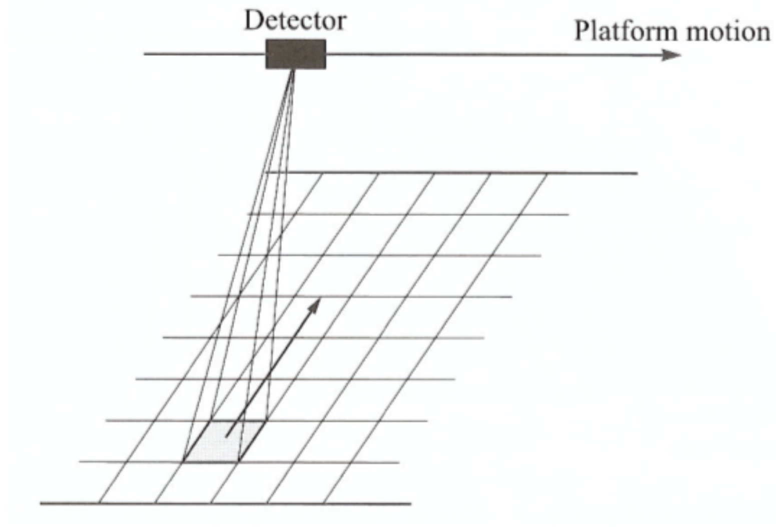
Multispectral Scanners

- We usually refer to electro-optical systems and the sensor is thus composed of one or more elements sensible to EM radiation
- Usually, the radiation coming from different land regions and in different sub-bands is measured by means of one or more sensors combined with optical and mechanical devices such as movable mirrors, prisms and/or filters that allow to scan the different land regions and split the different components to be measured by different sensors.

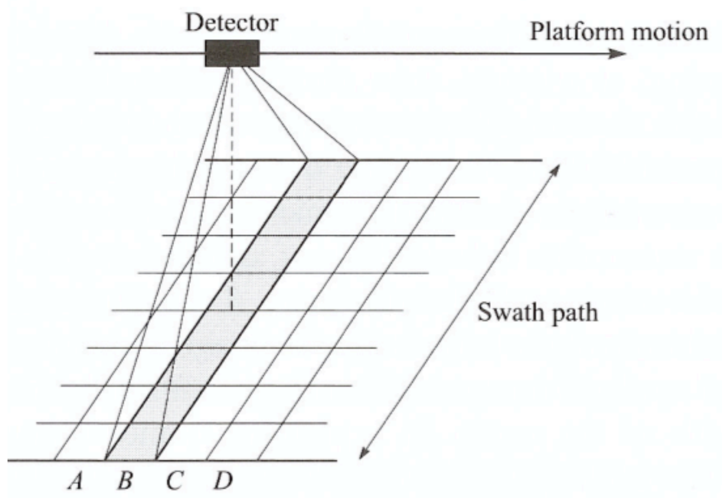
Electro-optical sensors

- Pros
  - Less problems in co-registering the sub-bands
  - Larger usable band, for example they can be used in the thermal infrared
  - It is easier to give a precise measure of the quantity of energy received by each sensor in each time interval
  - They do not need developing processes nor material transport of physical supports

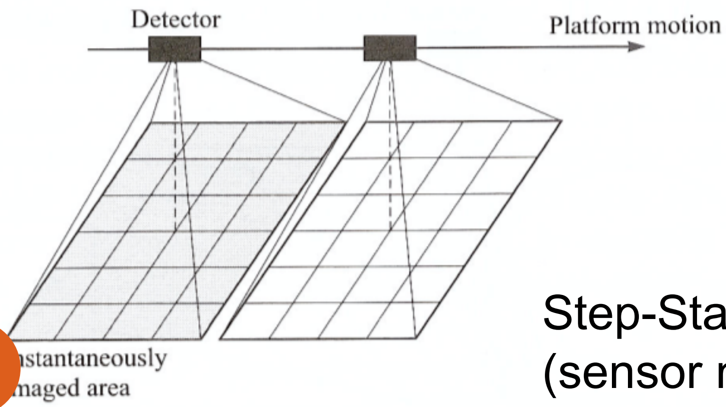
Overview of scanning systems



Whisk-Broom imaging



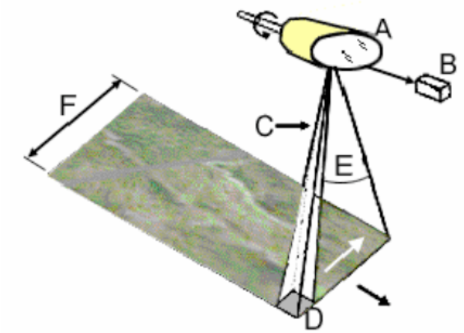
Push-Broom imaging
(array of sensors)



Step-Stare
(sensor matrices)

Across-track scanning (Whisk-Broom)

- Data are acquired by one single sensor for each band.
- By means of mechanical rotation of a mirror, the ground pixels are sequentially acquired in the direction transversal to the motion direction



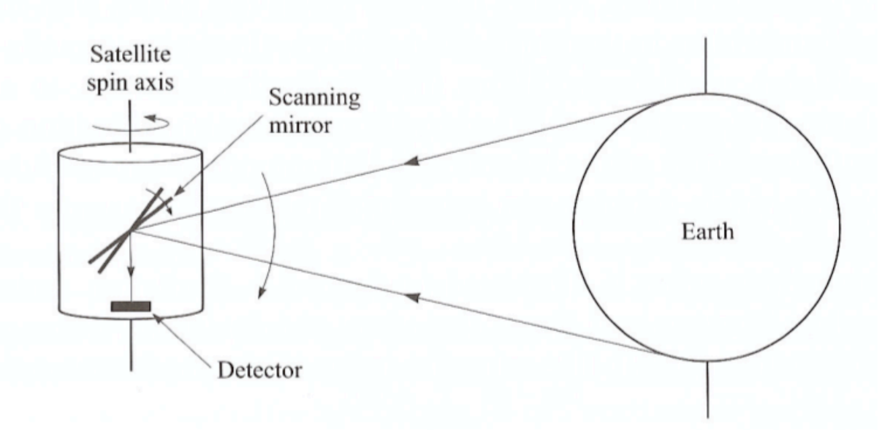
- A system of lenses and filters is responsible for the splitting of different bands to be acquired by different sensors

Across-track scanning (Whisk-Broom)

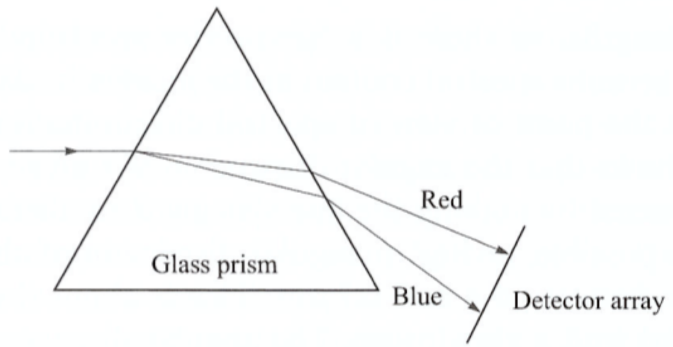
- Pros:
  - Smaller number of required sensors: this implies a higher homogeneity of measurements, less calibration problems
- Cons:
  - The needed mechanical scanning system can make the system less reliable and induce vibrations
  - Less time available for each single pixel acquisition and, hence, less radiometric resolution.

Across-track scanning (Whisk-Broom)

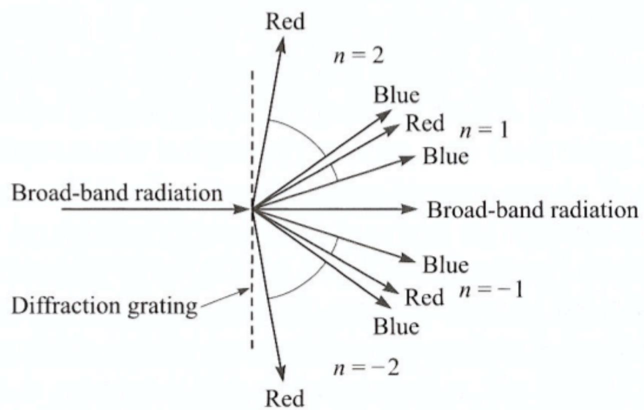
- Mirror



- Components for sub-band splitting



Prism (using refraction)

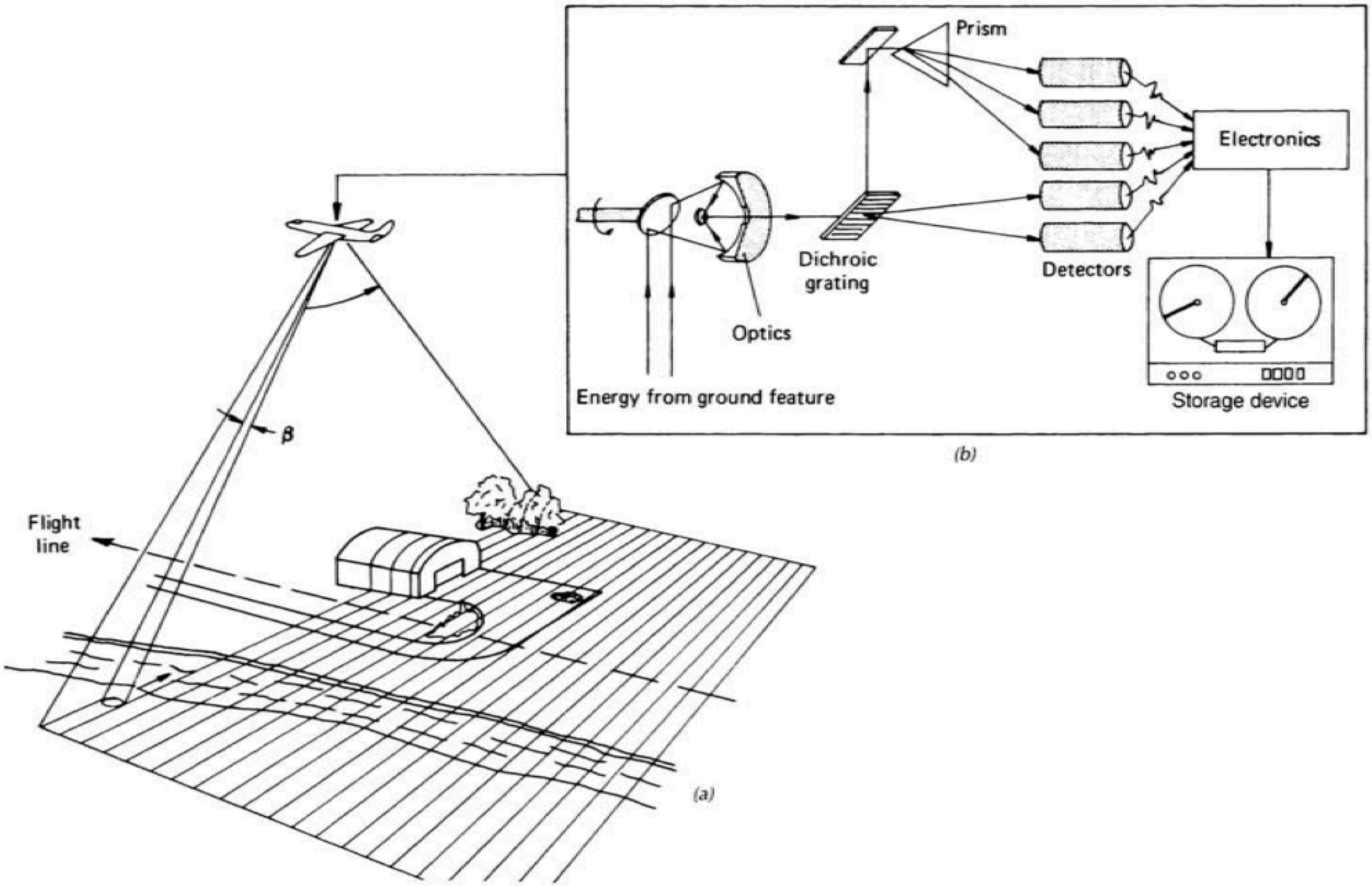


Grid (using diffraction)

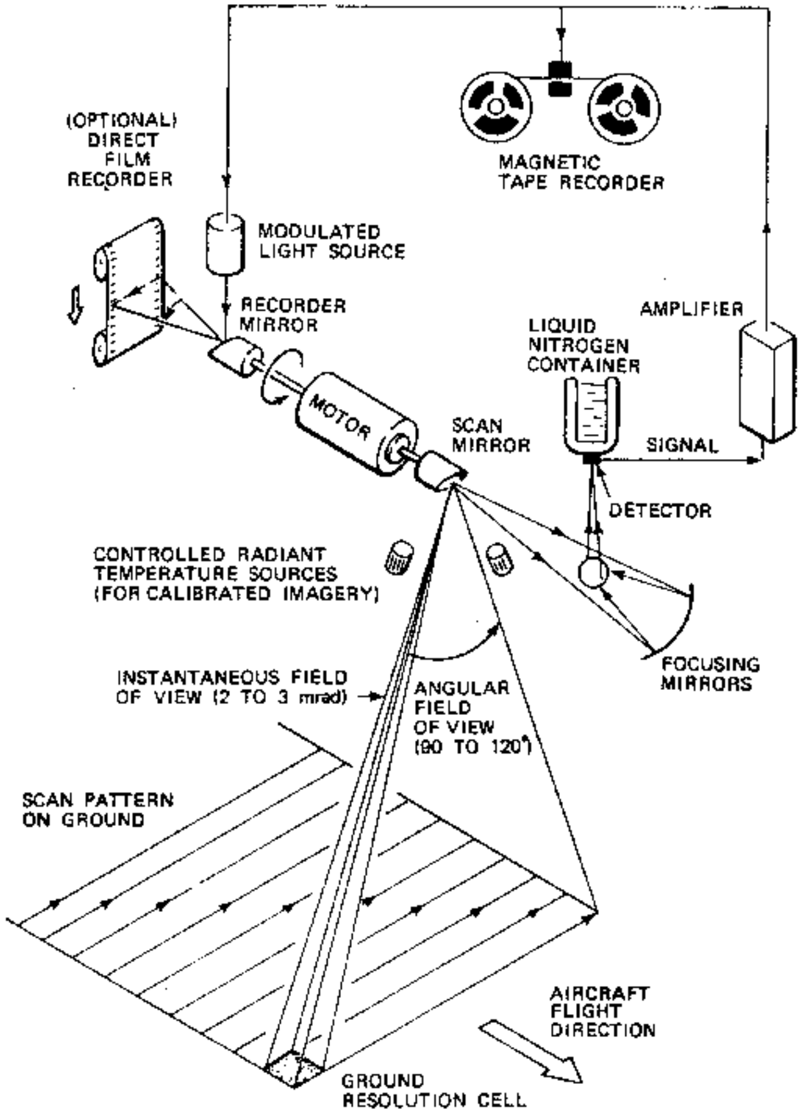
Across-track scanning (Whisk-Broom)

- Thermal/Non-Thermal components
  - Some devices acquire both in the optical and thermal bands
  - These two portions of the spectrum are first separated by means of a dichroic grating which
    - Sends the optical portion to an additional prism (or diffraction grating) for further splitting the sub-bands
    - Disperses the thermal components toward different sensors
  - The thermal component must be measured by sensors whose temperature is kept low and under precise control to avoid noise

Across-track scanning (Whisk-Broom)

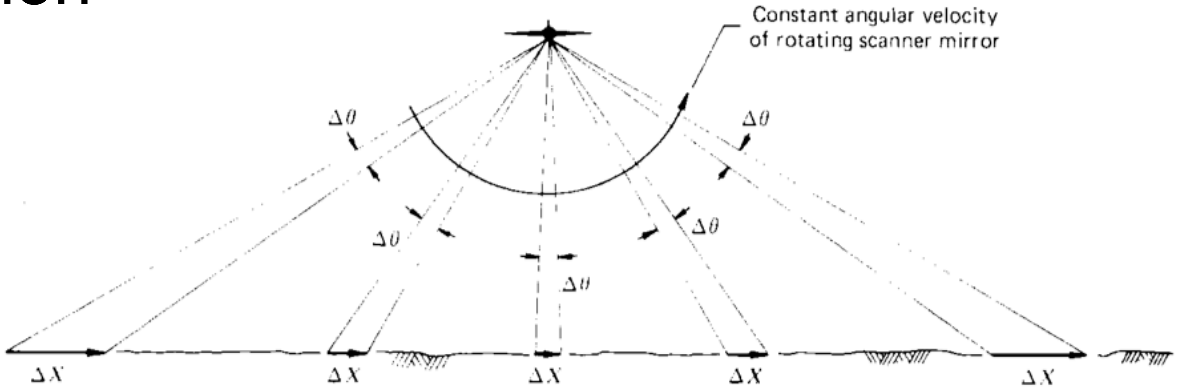


Across-track scanning (Whisk-Broom)

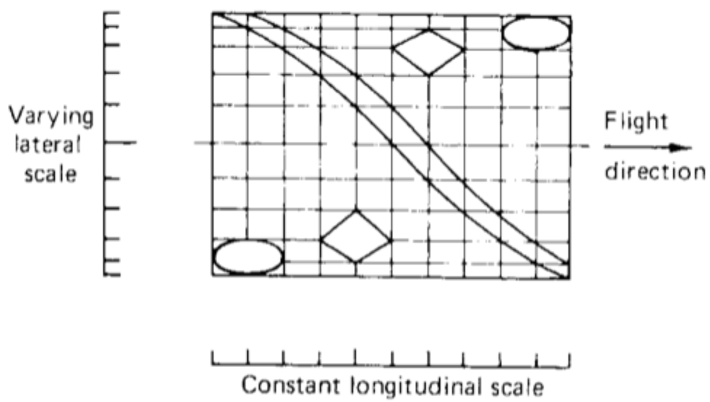


Across-track scanning (Whisk-Broom)

- Distortion

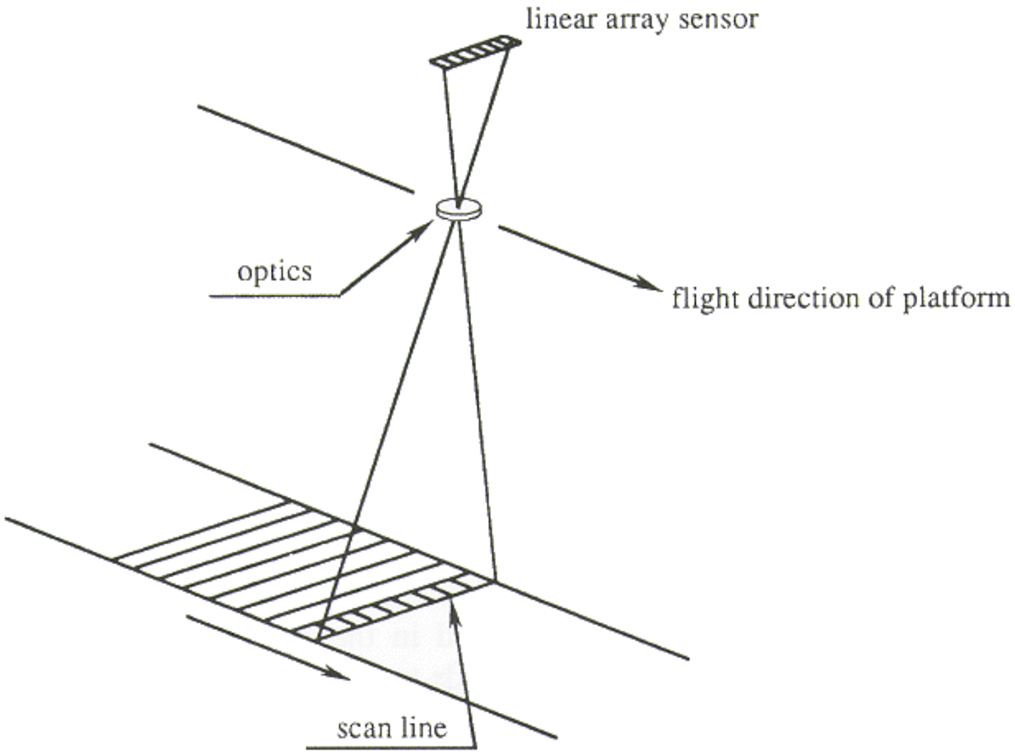


- If the mirror has a constant angular velocity, the image exhibit a *tangential-scale distortion*, which must be corrected



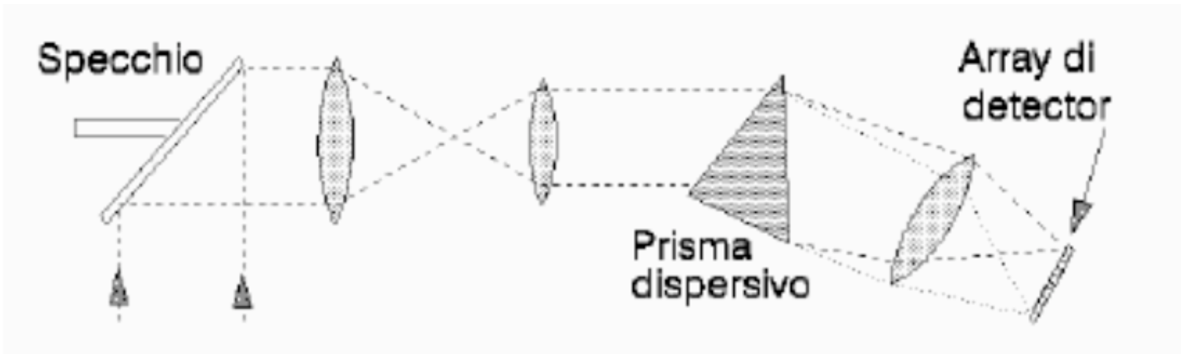
Along-track scanning (pushbroom)

- There is again a system for splitting different sub-bands on different sensors, but in this case for each sub-band an entire row of pixels is acquired by an array of sensors without the need of a moving mechanical apparatus



Along-track scanning (pushbroom)

- Example of composition

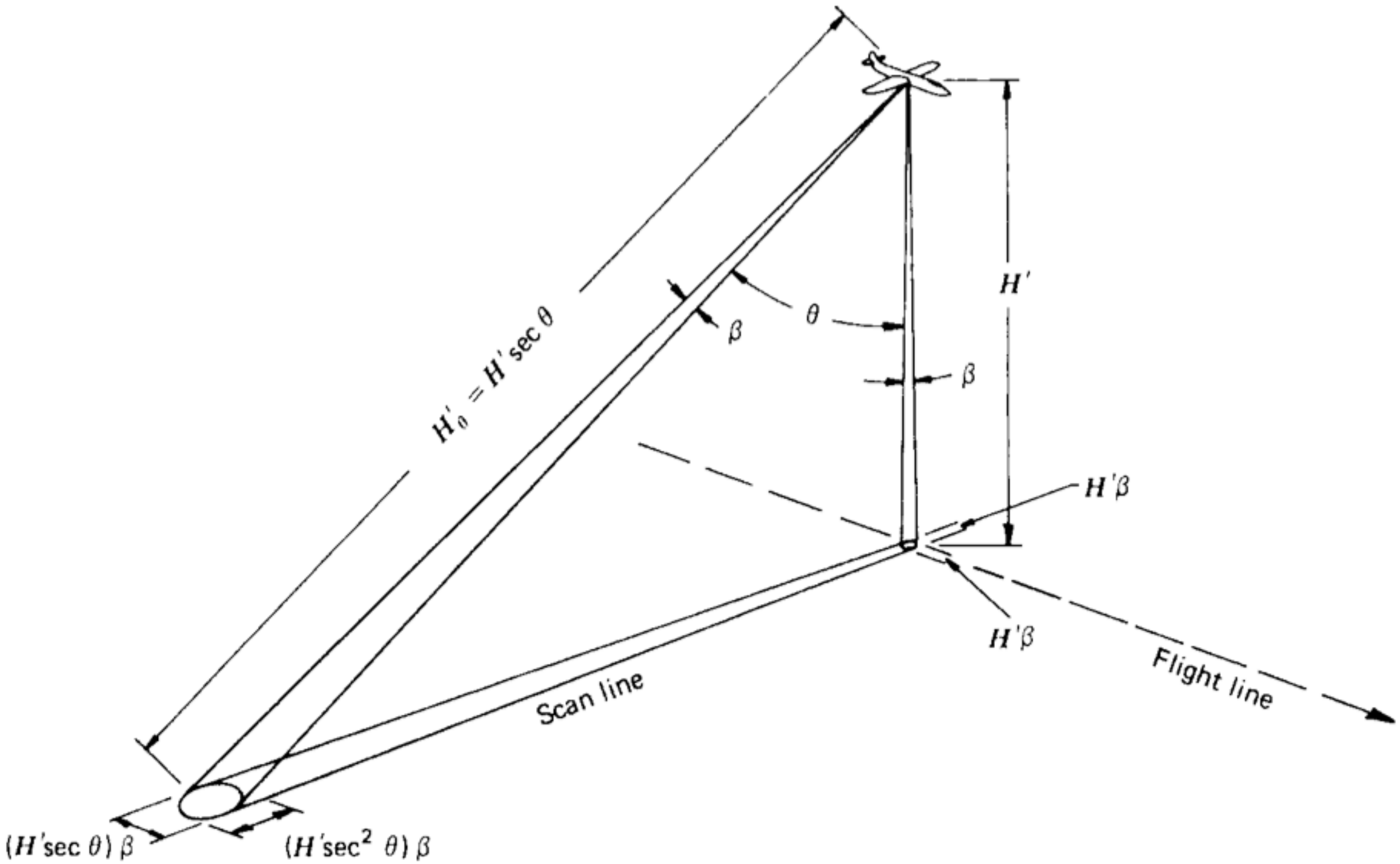


Along-track scanning (pushbroom)

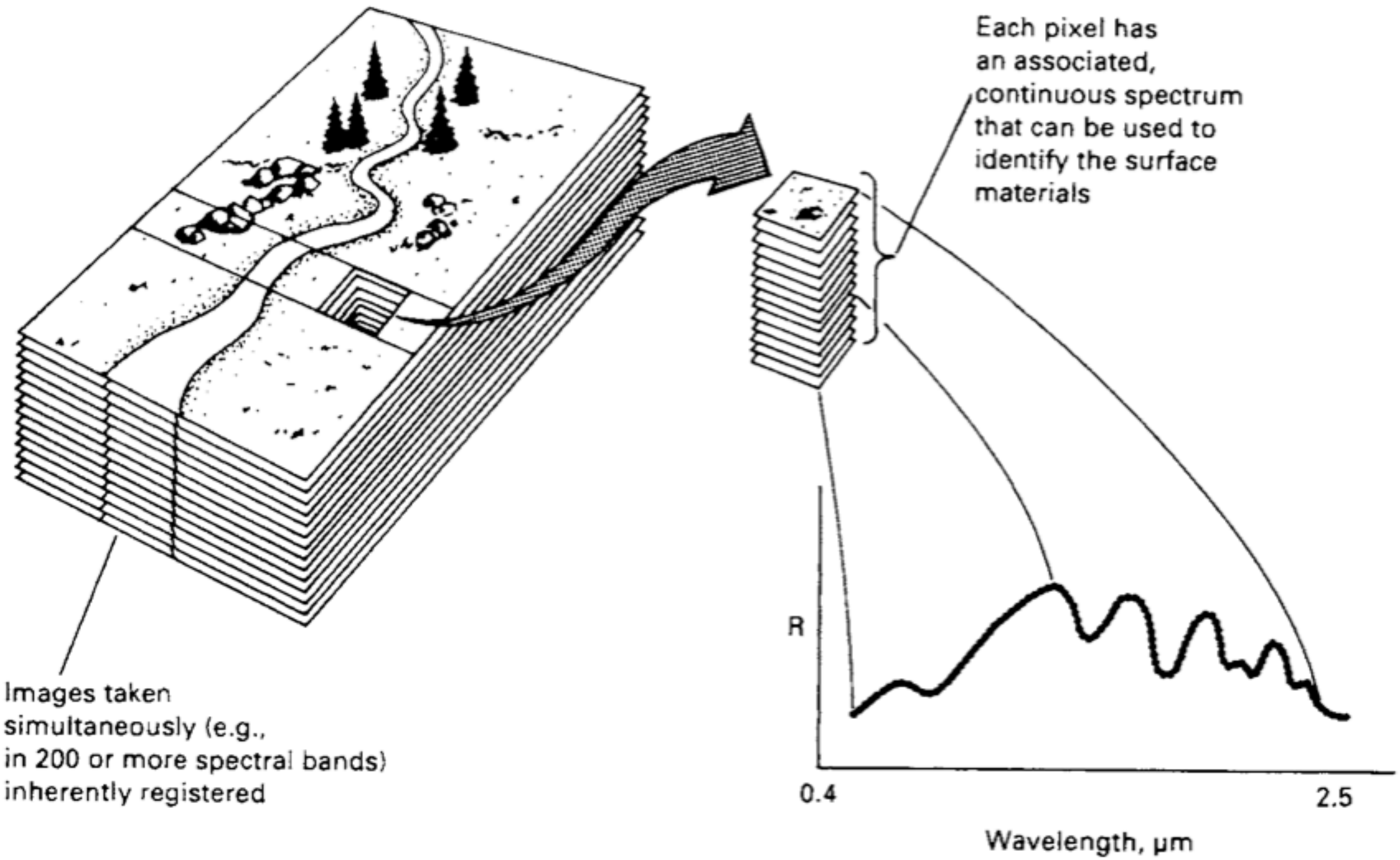
- Pros:
  - No need for mechanical movable parts, makes the system more reliable
  - Higher exposition time for each pixel, allows for larger radiometric resolution
- Cons:
  - It is difficult to calibrate all sensors
  - Originally they could not be used in the thermal infrared, (but this is changing in recent times.. see LDCM!)
  - Technological problems limit the swath of such systems

Ground Resolution

- At low altitudes, the ground resolution is not constant across the track (negligible for satellites)

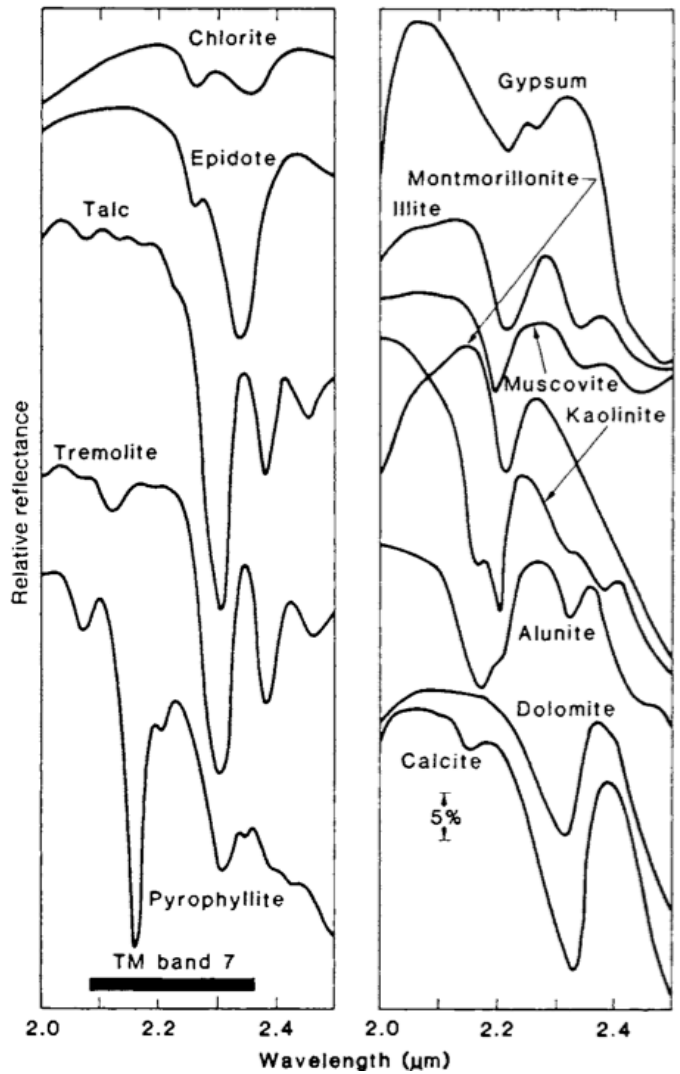


Hyperspectral Scanners



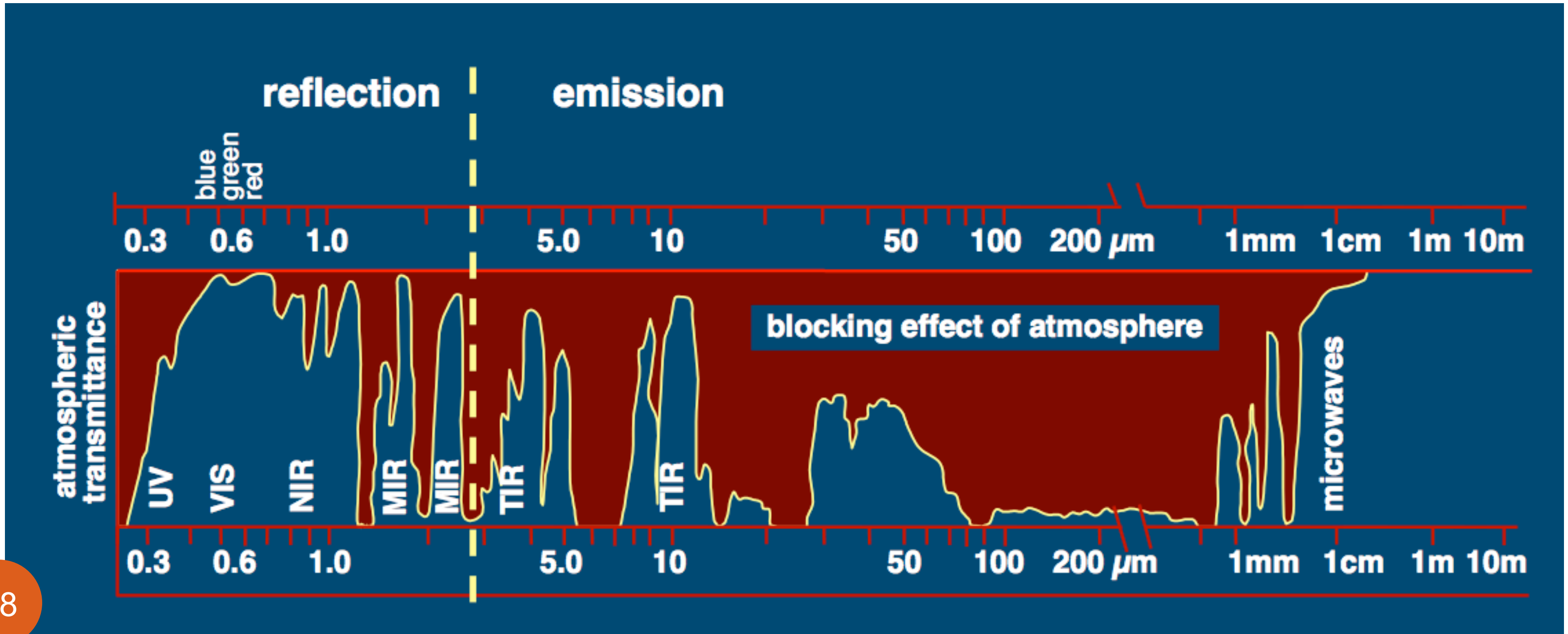
Hyperspectral Scanners

- Such a detailed spectral resolution allows one to study the composition of soil, rocks etc to a very specific level
- Different materials that could not be distinguished with few bands can instead be distinguished with such a detailed acquisition



Thermal Scanners

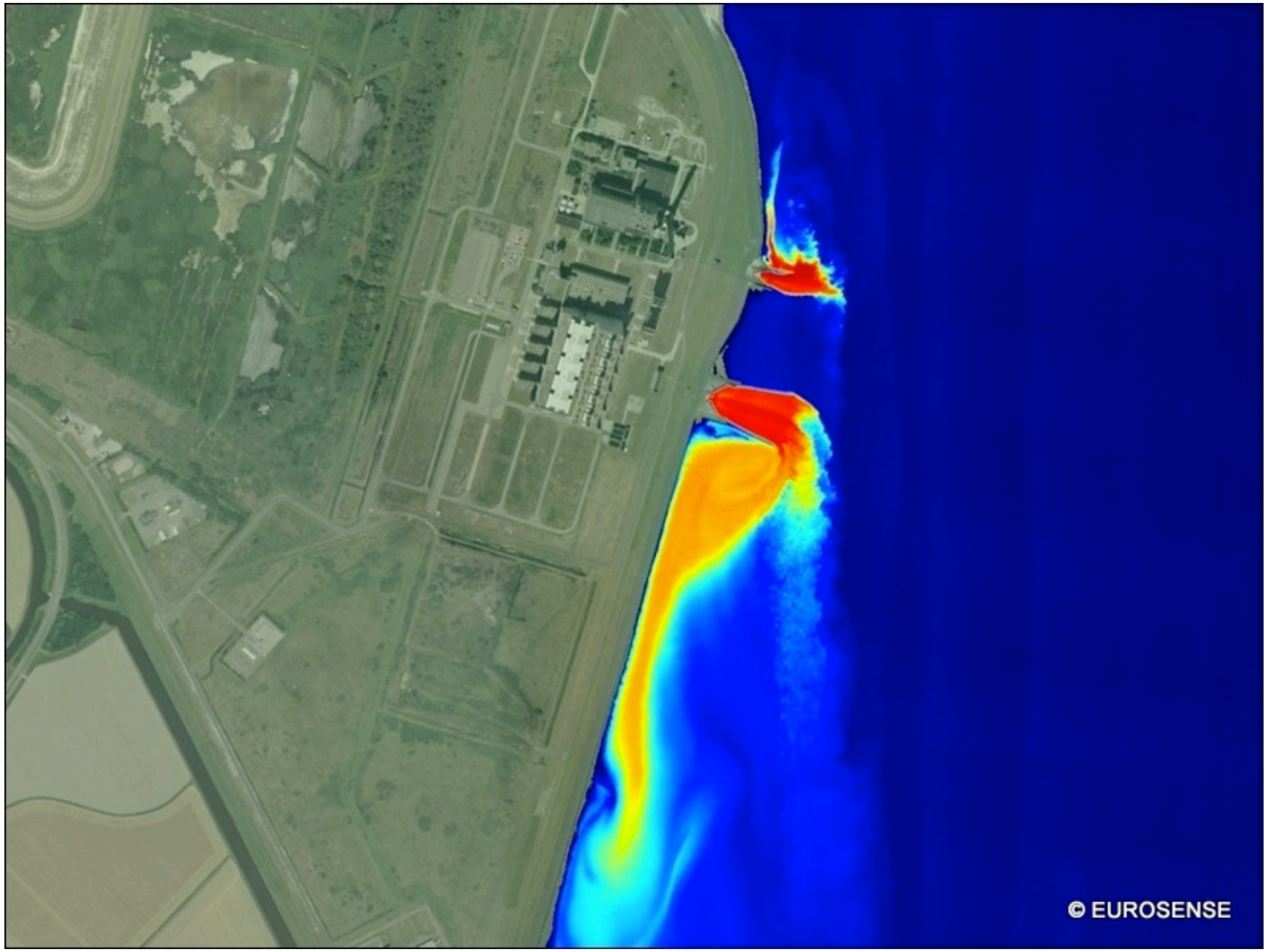
- Thermal scanners acquire in the thermal infrared region
- They catch the emitted radiation rather than the reflected radiation



Thermal Scanners

- As already said, one of the pros of using electro-optical sensors is the possibility of acquiring in the thermal infra-red
- Due to the atmospheric absorption, there are two main windows that can be used with thermal scanners, that is 3-5μm and 8-14μm
- Due to the low energy of photons at these wavelengths, the IFOV cannot be too small, and the resolution is thus smaller than in the visible band
- Usually, across-track scanning devices are used
- The images produced, called *thermograms*, associate lighter gray tones to hotter regions, with a resolution usually of the order of 0,1^{o}C
- False colors are also often used to render this information (red for hot, blue for cold)
- Thermograms show in the correct way the differences in temperatures between different regions, but a complex calibration stage is required to obtain absolute values

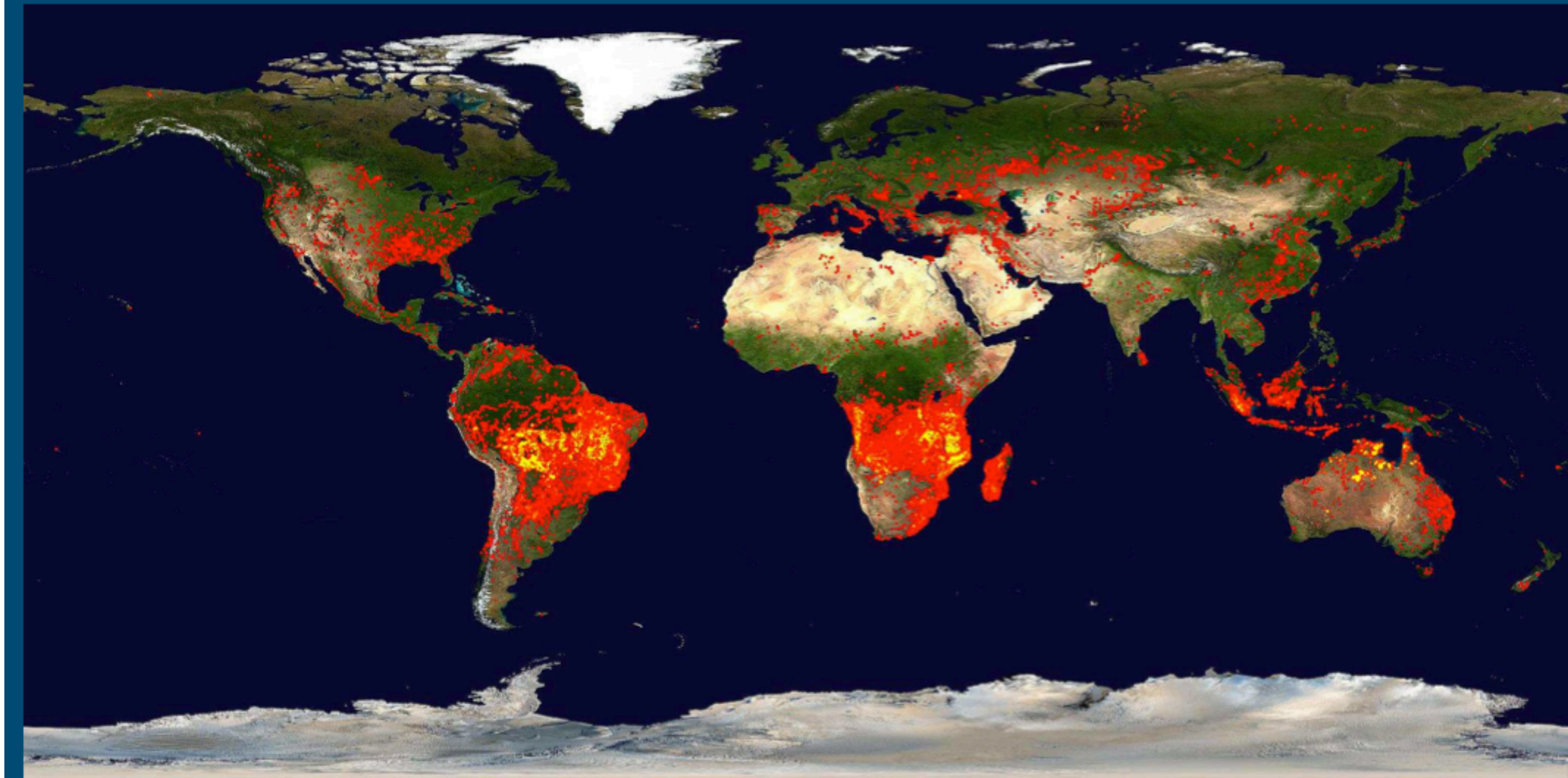
Thermograms (example)



Thermograms (example)

Applications

- Detection of Fire



Global fire map
18/9/2007 – 27/9/2007

Image: MODIS rapid response system
http://rapidfire.sci.gsfc.nasa.gov