Earth Observation Laboratory
PhD Program in GeoInformation
DISP - Tor Vergata University

Remote sensing in the optical domain

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What is exactly the remote sensing? (I)

The experts say…

“Remote sensing is the science (and to some extent, art) of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information.”

http://ccrs.nrcan.gc.ca

“All the techniques used to detect and study the properties of objects, both man-made and natural, starting from their physical properties of emitting and reflecting energy.

CNES optical course “Télédétection et Traitement des images”

What is exactly the remote sensing? (II)

The not experts say "Remote Sensing is…"

• Advanced colouring-in.
• Seeing what can't be seen, then convincing someone that you're right.
• Being as far away from your object of study as possible and getting the computer to handle the numbers.
• Legitimized voyeurism

Extracted from M.Disney, UCL, http://www.geog.ucl.ac.uk/about-the-department/people/academics/mat-disney/

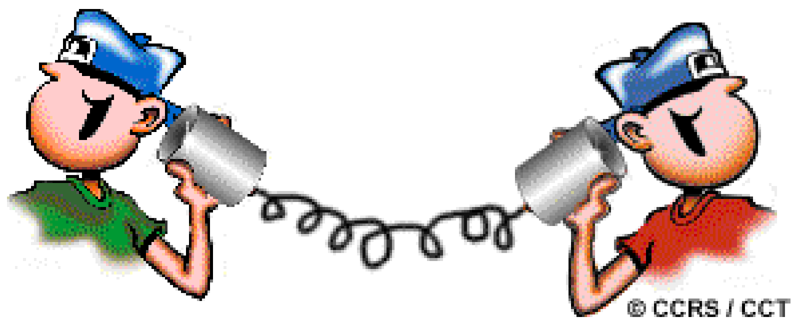
What is exactly the remote sensing? (III)

The Remote Sensing is very close to us…

Of our five senses (sight, hearing, taste, smell, touch), three may be considered forms of "remote sensing", where the source of information is at some distance.

The remote sensing is typically associated to the electromagnetic radiation, but it does not preclude the use of others form of energy. The sound could be the first alternative.

Ours telephone conversation could be considered a form of remote sensing

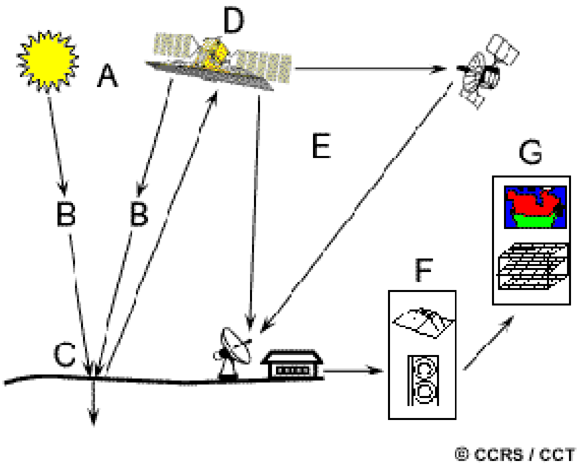


Why optical?

The RS is classified into three types with respect to wavelength region:

- Ultraviolet and Visible RS (atmosphere)
- Visible and Reflective Infrared RS (lands and sea)
- Thermal Infrared RS
- Microwave RS

The optical sensors capture the radiances coming from the system Earth-Atmosphere illuminated by the sun, on the spectral regions of Visible, Infrared and Thermal Infrared (emission)



- Generally passive
- Some example of active sensors: LIDAR
- Spacecraft and airborne
- Measures of reflecteted and emitted energy

First examples (I)

First aerial photo credited to Frenchman Felix Tournachon in Bievre Valley, 1858.

Boston from balloon (oldest preserved aerial photo), 1860, by James Wallace Black.

Extracted from M.Disney, UCL, http://www.geog.ucl.ac.uk/about-the-department/people/academics/mat-disney/

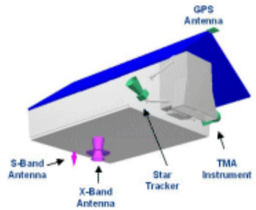
First examples (II)

Panorama of San Francisco 1906
9 large kites have been used to carry the camera

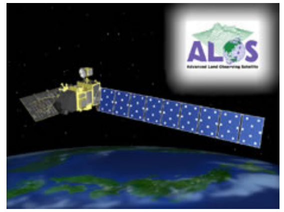
Extracted from M.Disney, UCL, http://www.geog.ucl.ac.uk/about-the-department/people/academics/mat-disney/

The incredible development

… SENTINEL 2, Venμs (superspectral)



2006 ALOS AVNIR-2 (4 spectra bands, spatial resolution of 10m)



2003 MERIS (15 spectral bands, spatial resolution of 150m)

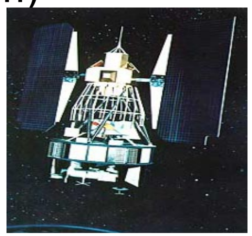
2001 CHRIS Proba (62 spectral bands, spatial resolution of 30 m)
(18 spectral bands, spatial resolution of 18 m)
(multi-angle capabilities)

2000 Hyperion (220 spectral bands, spatial resolution of 30 m)

1999 ASTER (14 spectral bands, spatial resolution of 15, 30 and 90m)
MISR (4 spectral bands, multi-angle capabilities)
Landsat 7 (7 spectral bands+pan, spatial resolution of 30m)

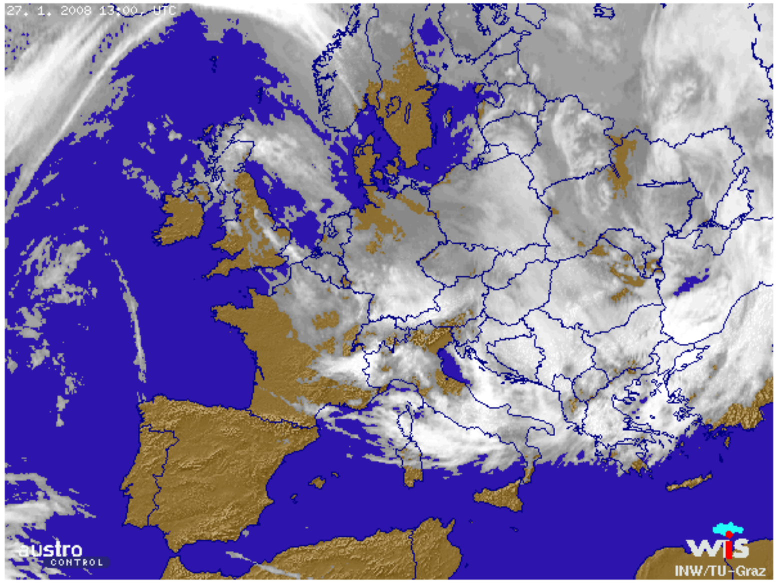
…

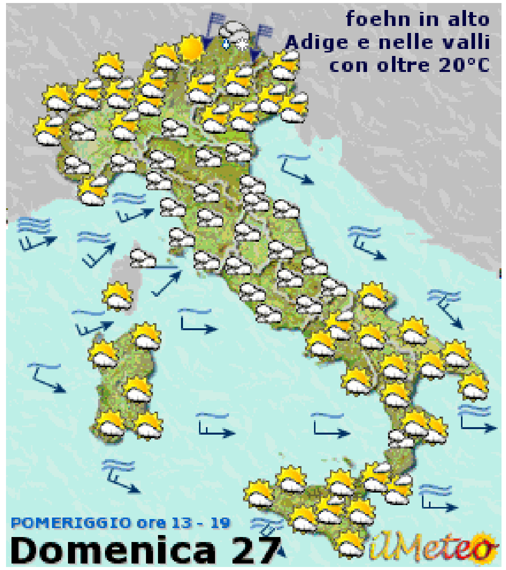
1972 Landsat 1 (5 spectral bands, spatial resolution of 80m)



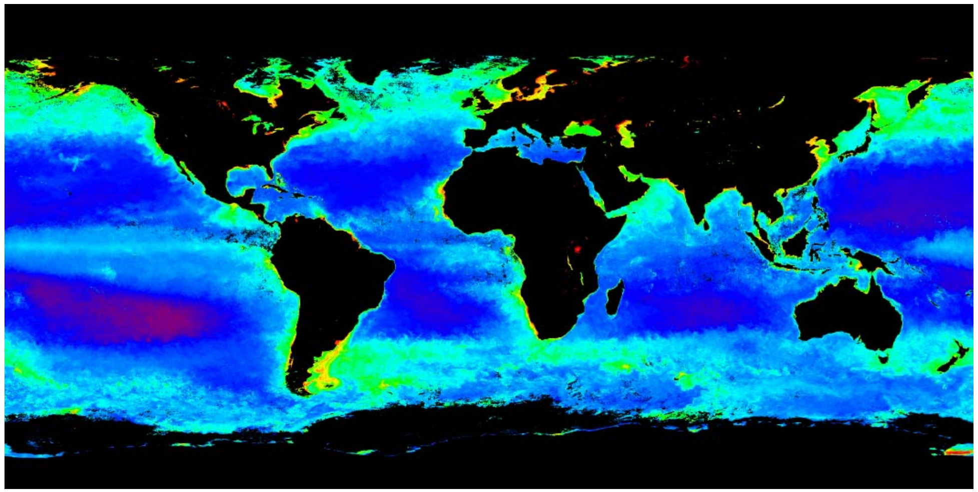
Applications of optical remote sensing

Meteorology





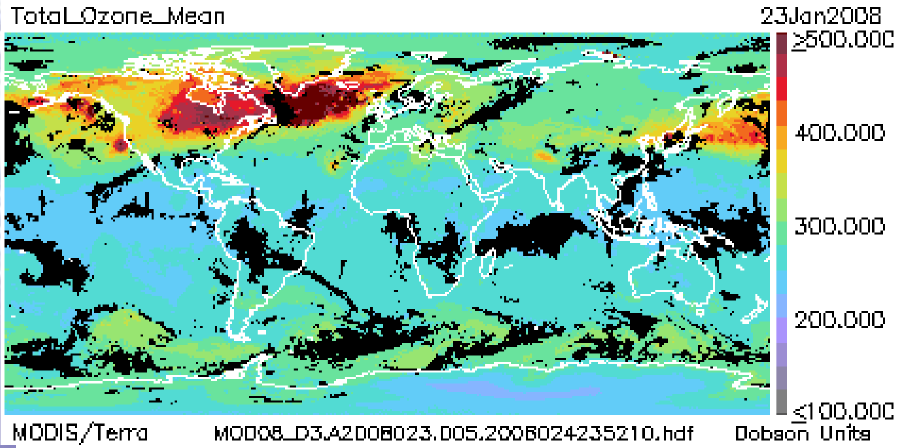
Oceanography



http://oceancolor.gsfc.nasa.gov/

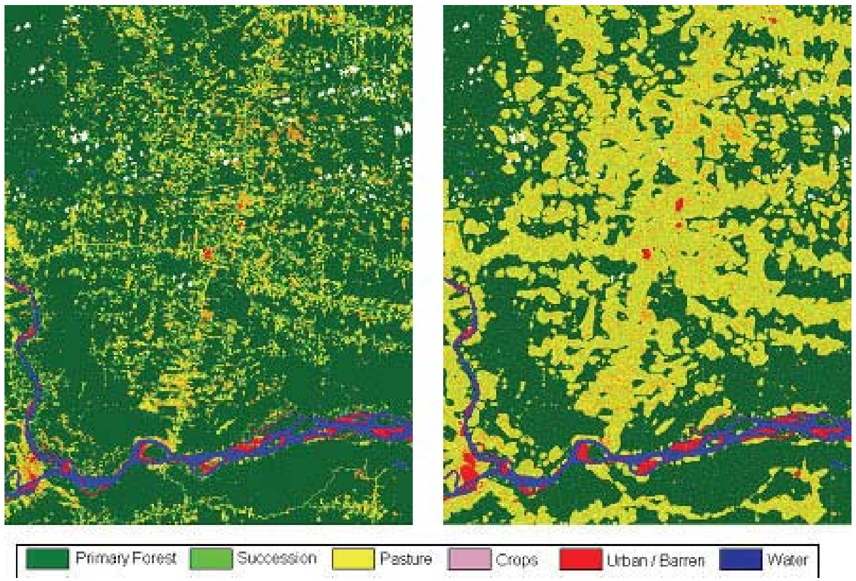
http://www.meteosatonline.it www.ilmeteo.it

Applications of optical remote sensing



Atmospheric composition

Global vegetation monitoring

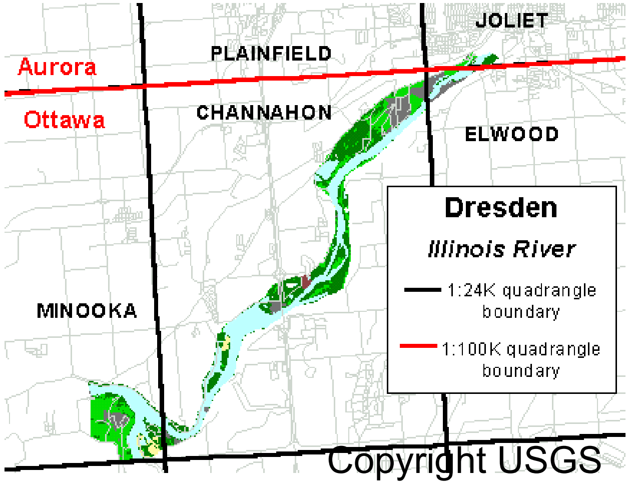


High resolution land cover and land changes maps

http://modis.gsfc.nasa.gov/

http://lcluc.umd.edu

Applications of optical remote sensing



Cartography and Hydrology

Disaster monitoring,
Hazard mitigation

Very high resolution mapping, infrastructures and urban monitoring
Strategic planning

AND…

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Cronache

LA COMMISSIONE TRIBUTARIA: LEGITTIMO L'USO DELLE FOTO SATELLITARI

A caccia di evasori con Google Earth

Scovati a Pisa sei proprietari di rimessaggi di barche e yacht che denunciavano solo 3mila euro annui

Headline News!

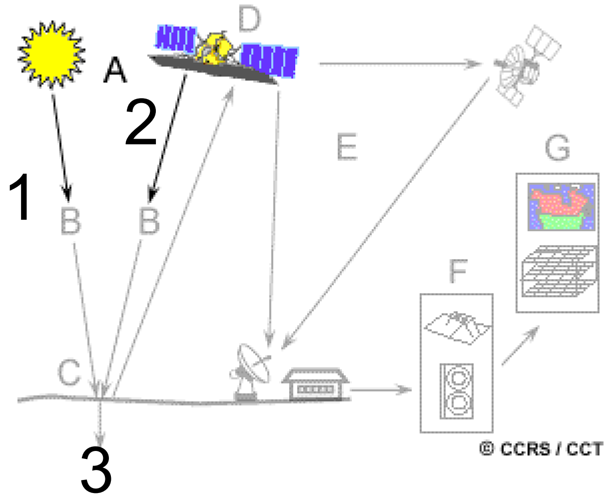
…«Con GoogleEarth c'è la possibilità di avere anche un database storico delle fotografie satellitare – spiegano all'agenzia delle entrate pisana – e dunque è stato possibile mettere a confronto il numero di imbarcazioni presenti nei rimessaggi in date diverse. Poi, sono stati fatti accertamenti sul numero di fatture emerse» …

…

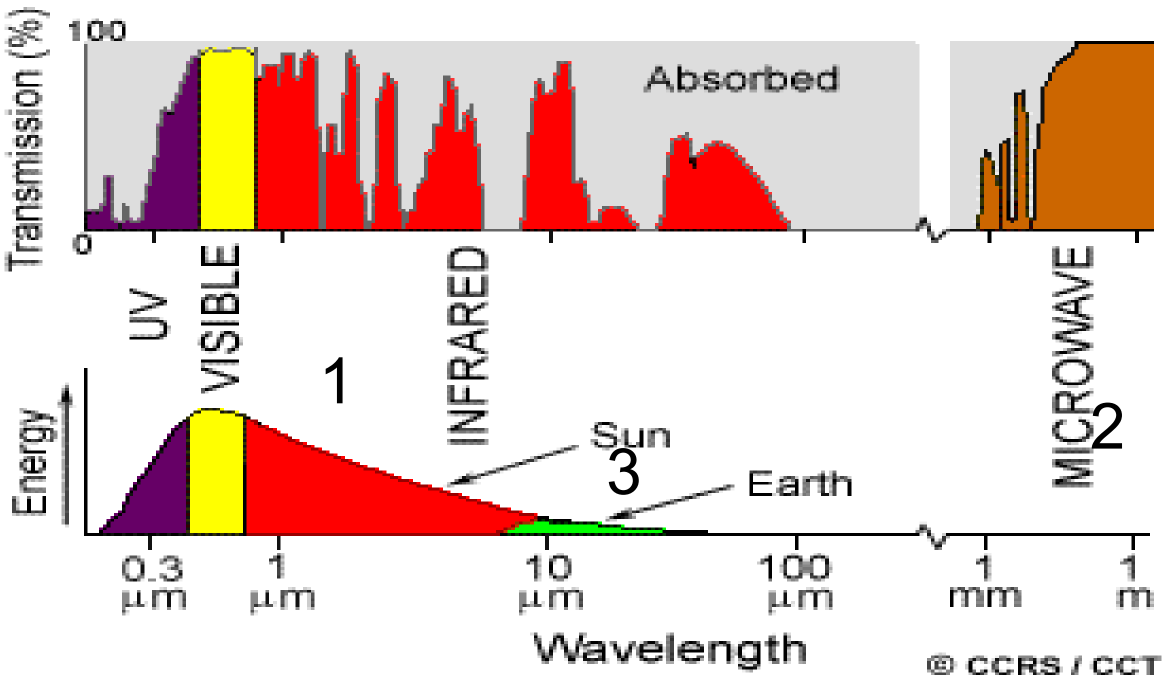
…non solo alle imbarcazioni, ma agli stabilimenti balneari della costa per controllare, per esempio, quanti sono gli ombrelloni utilizzati in estate e da qui cercare di capire il reale giro di affari del gestore a volte, dicono i maligni, un po' apatico con il fisco…

M.Gasperetti Corriere.it

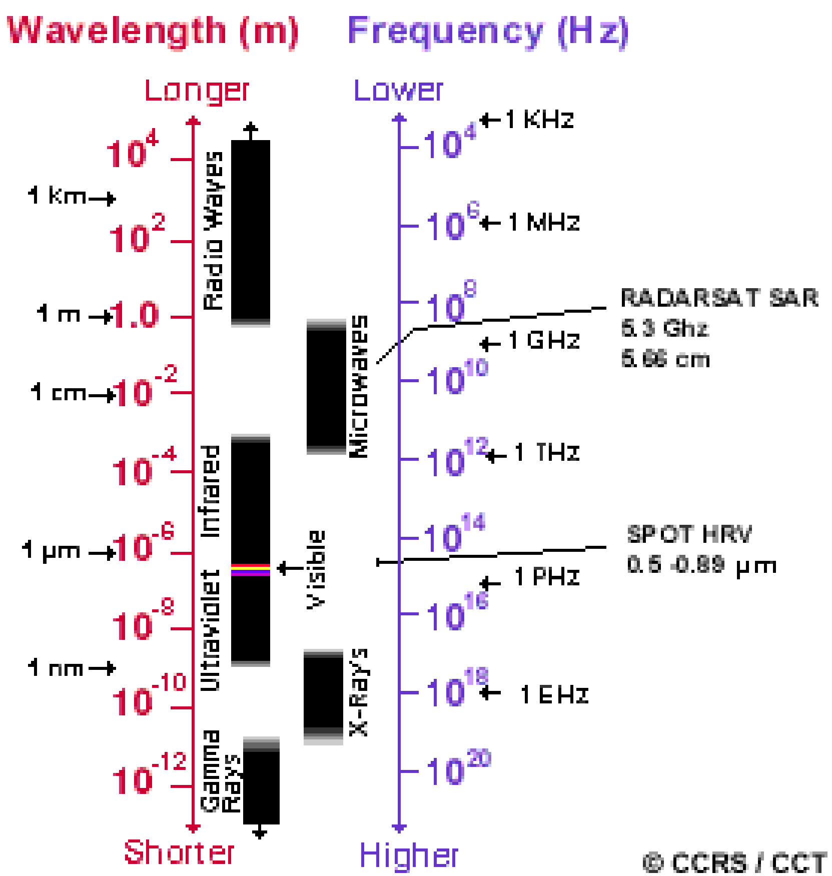
The target illumination: solar irradiance

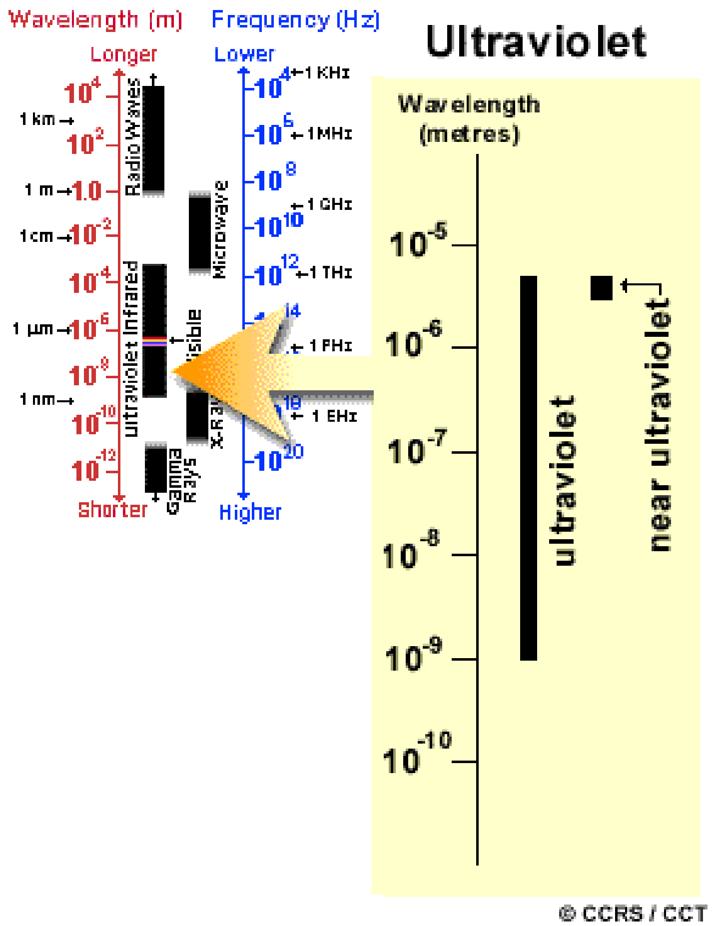


1. External illumination
2. The observer illuminates the target
3. No illumination, the target emits energy

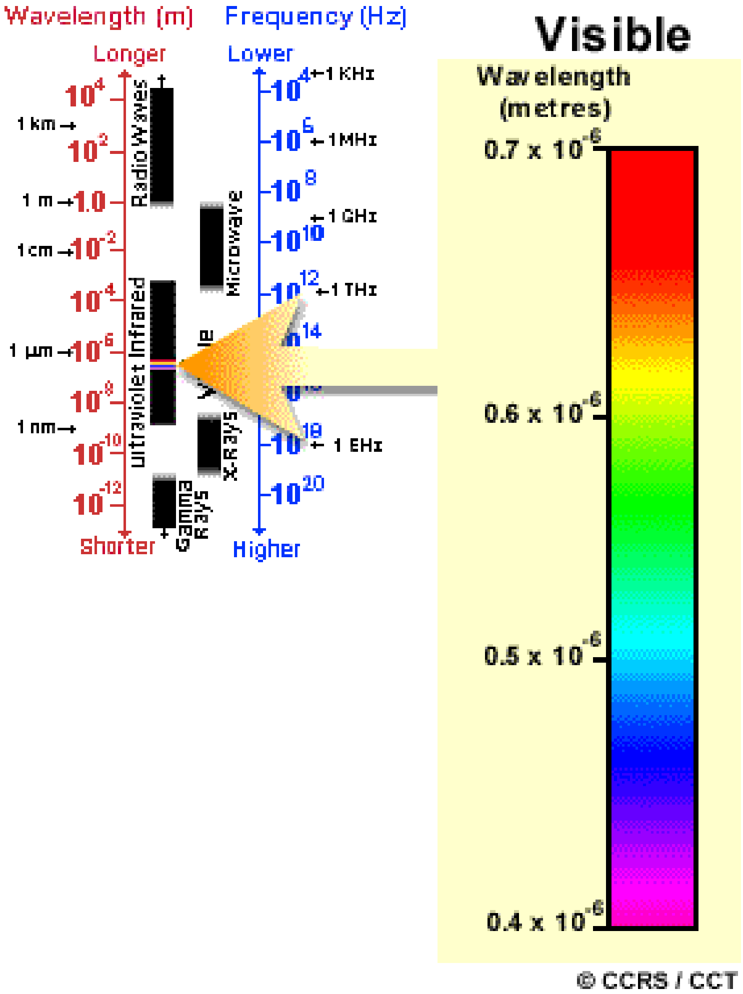


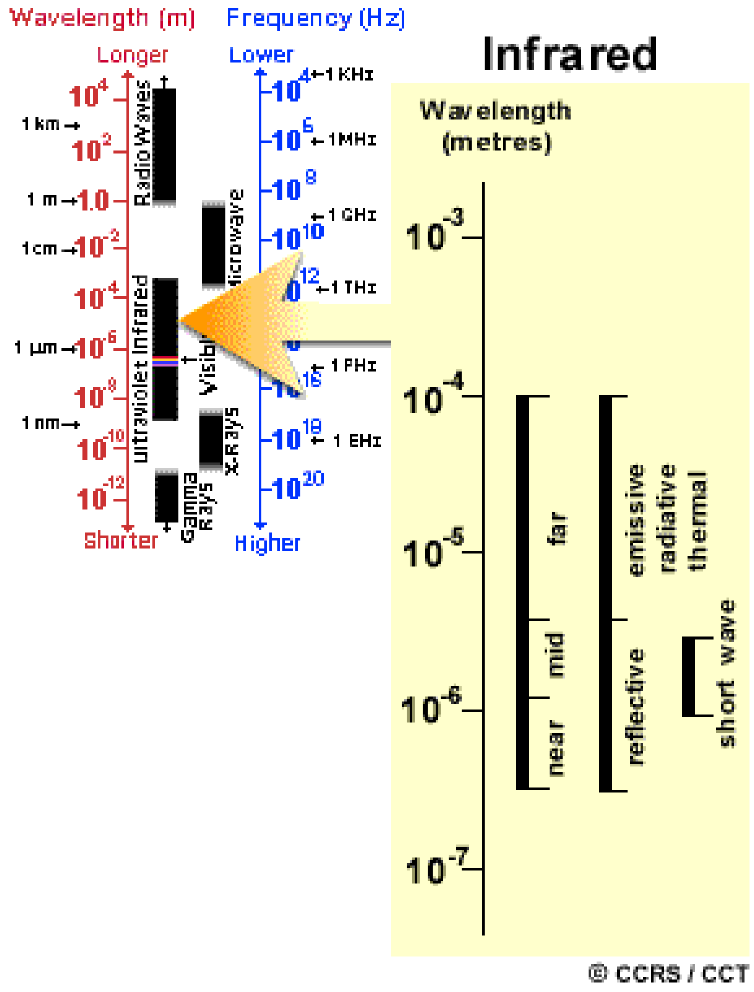
The electromagnetic spectrum





The electromagnetic spectrum





The system Earth-Atmosphere

The irradiance reaches the targets…

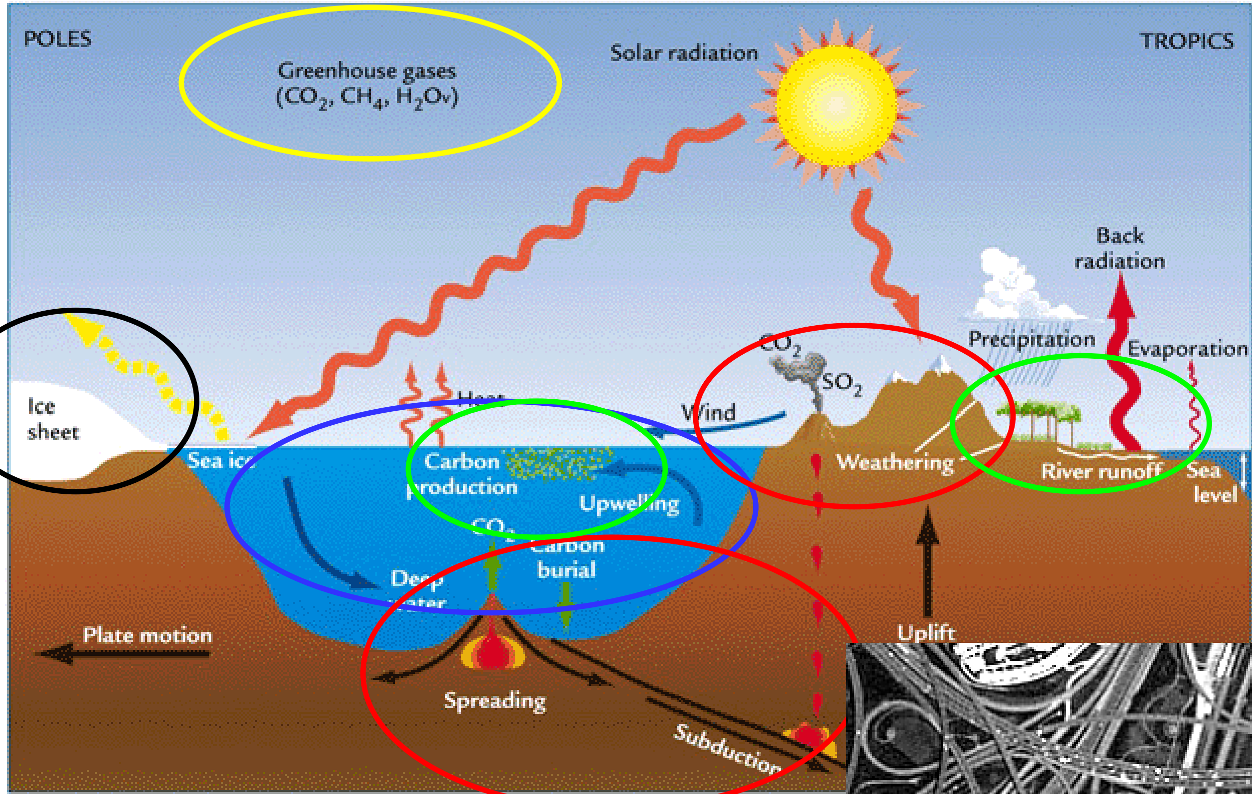
Hydrosphere

Atmosphere

Cryosphere

Geosphere

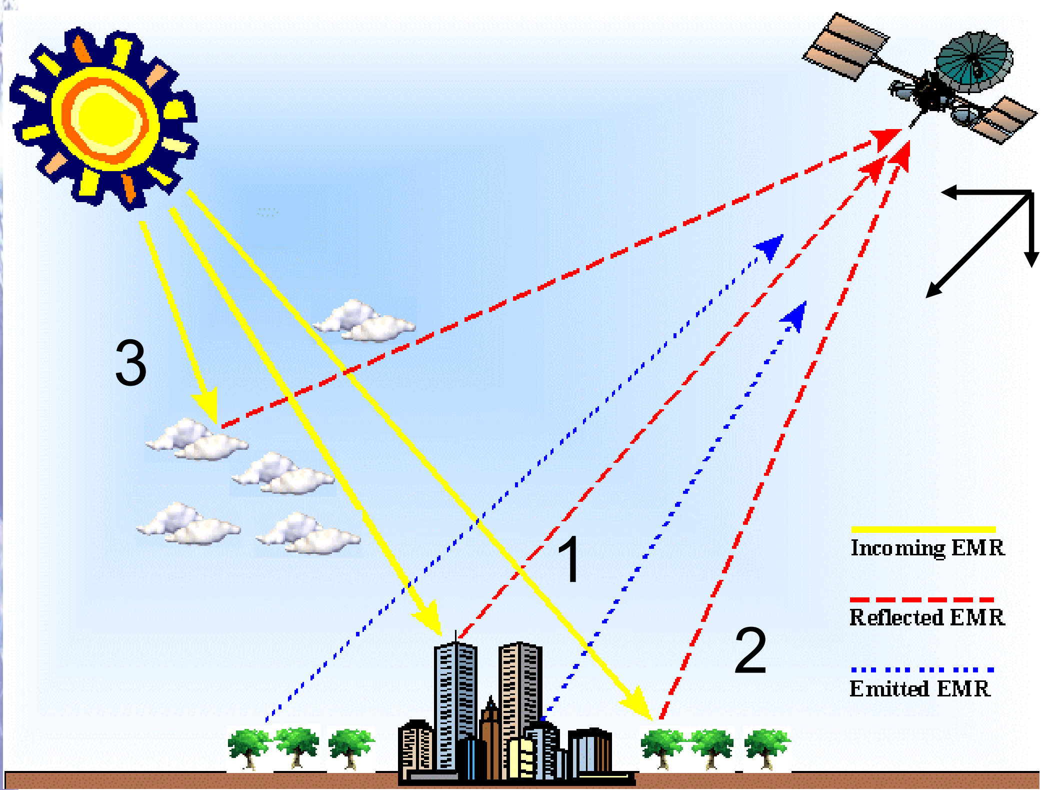
Biosphere



Artificial structures
and
Man interactions

From SpotImage

The signal measured by the sensor (i)



The optical sensors capture the radiance reflected or emitted, along the observation direction:

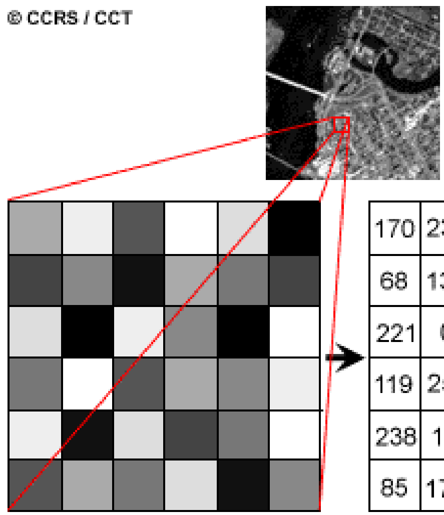
1. Radiance from the target(s)
2. Radiance from adjacent targets or areas
3. Radiance scattered by the atmosphere toward the sensor

The atmosphere attenuates the signal which is captured by the instrument

The signal measured by the sensor (ii)

Condition of illumination

- Sun condition (season, day, year,…)
- Latitude and longitude of the target



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Atmospheric properties

- Aerosols scattering and absorption
- Gases concentration, temperature, pression
- Water content

Target properties

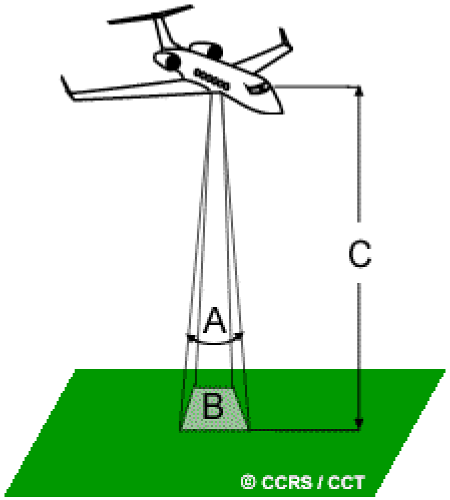
- Physical properties (for reflection and emission), material composition
- Shape, structure, geometry
- Temporal changes

Sensor, spacecraft and processing

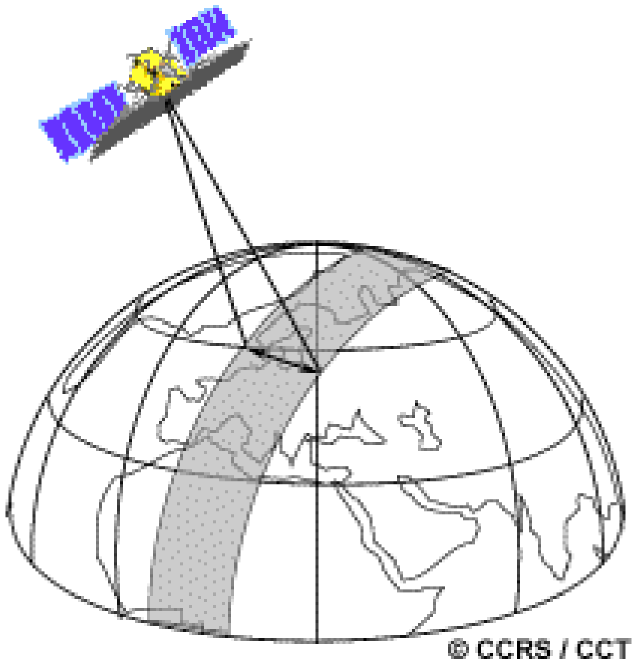
- **Spatial resolution, spectral resolution, radiometric resolution**
- Electro-Optical properties (transducers, telescope)
- Altitude, geometry of observation
- Processing, compression, filtering, deconvolution, sampling

Rendering of spatial details (i)

The detail discernible in an image is dependent on the **spatial resolution** of the sensor and it refers to the size of the smallest possible feature that can be detected.



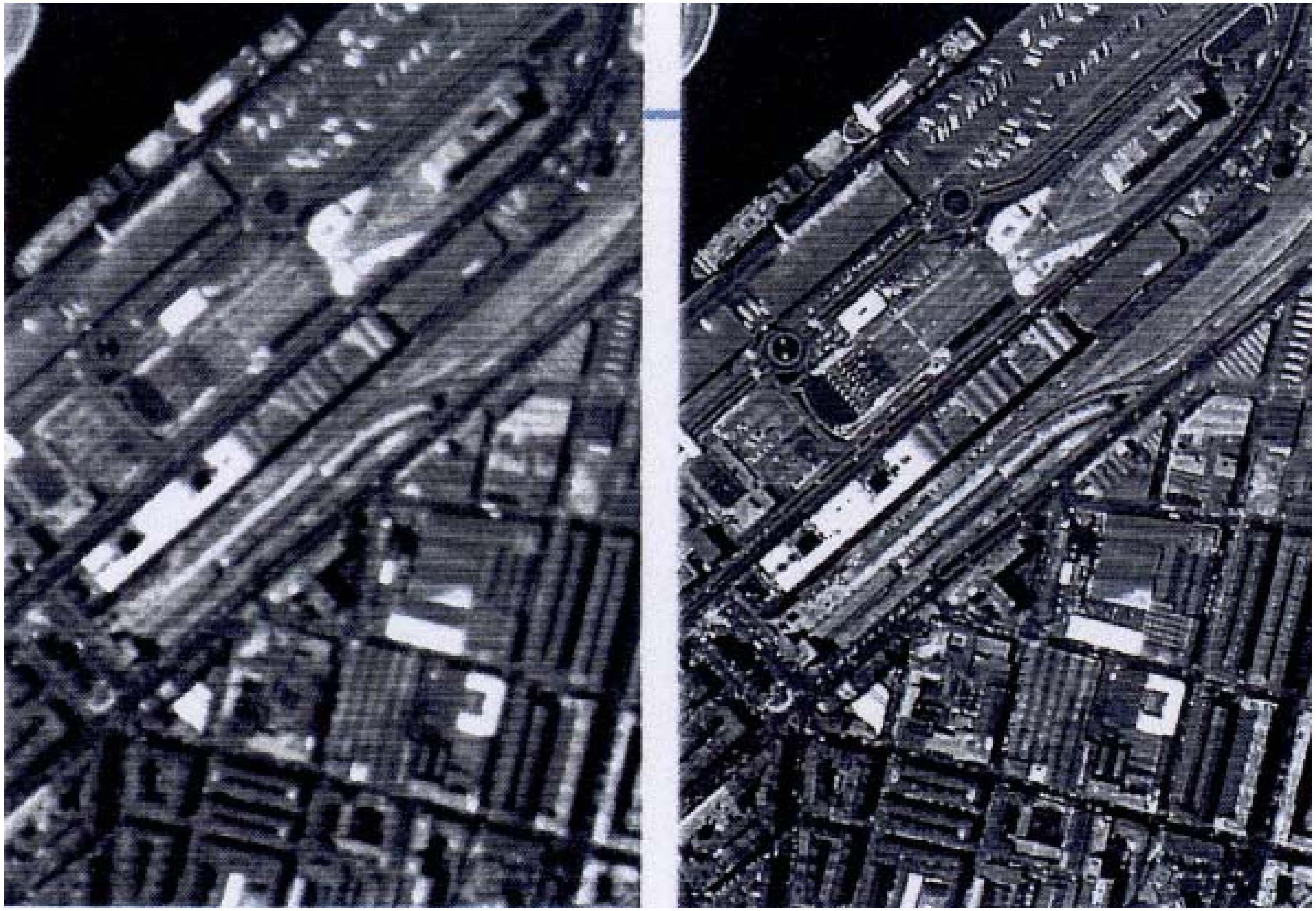
A Ifov
B resolution cell
C Altitude



As a satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface. The area imaged on the surface, is referred to as the **swath**.

Rendering of spatial details (ii)

Poor rendering | Good rendering

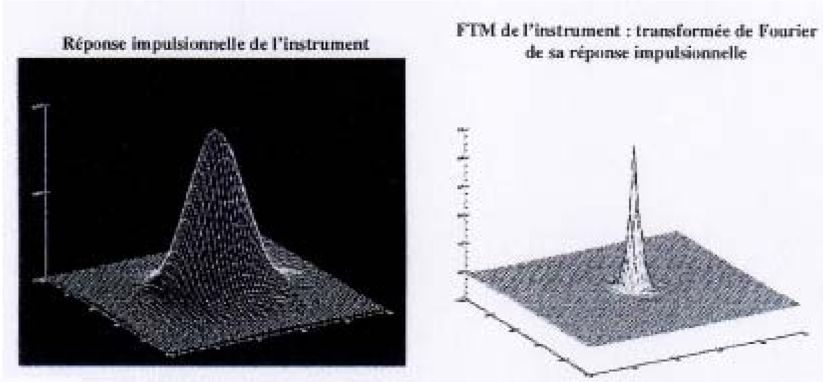


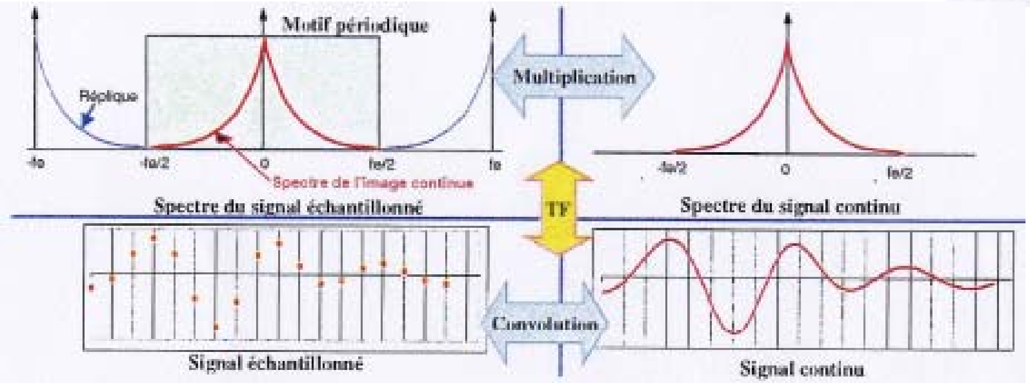
CNES optical course “Télédétection et Traitement des images”

Rendering of spatial details (iii)

Several parameters impact the spatial rendering

Good MTF (Modulation Transfer Function)
3 components: telescope, detectors and rows





Signal Sampling
And reconstruction

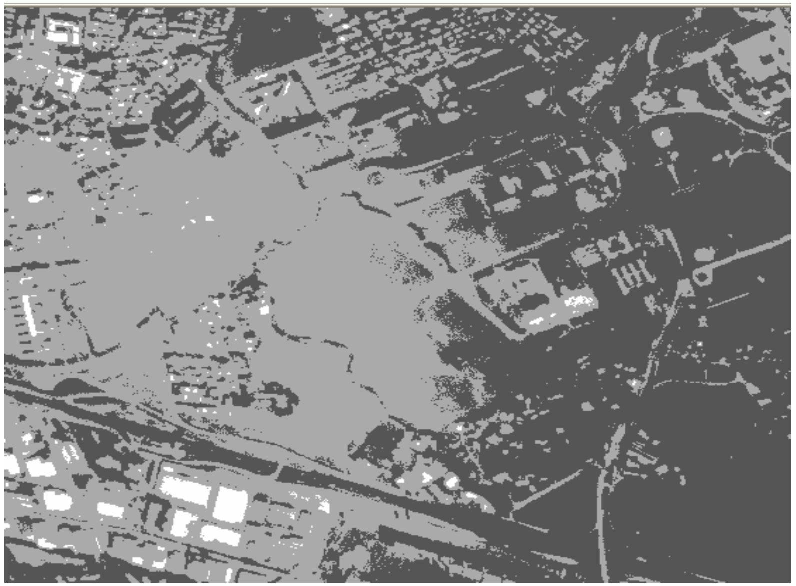
Compression + Decompression

Deconvolution +Denoising

Radiometric Resolution

The **radiometric resolution** of an imaging system describes its ability to discriminate very slight differences in energy

Tor Vergata Campus 8 bit



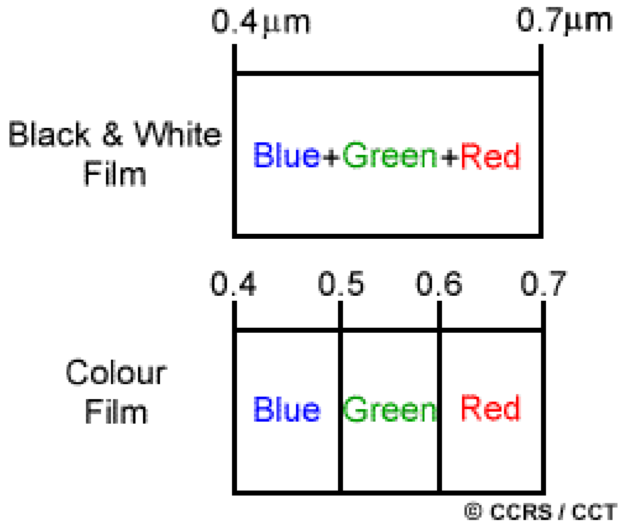
Tor Vergata Campus 2 bit

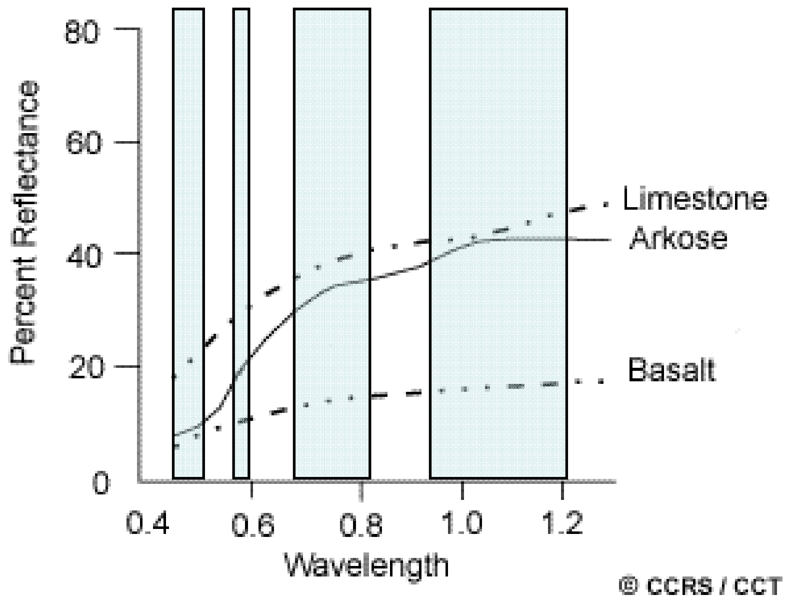
8 bit → From 0 to 255 values of radiances

2 bit → From 0 to 3 values of radiances

Spectral Resolution (i)

Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.



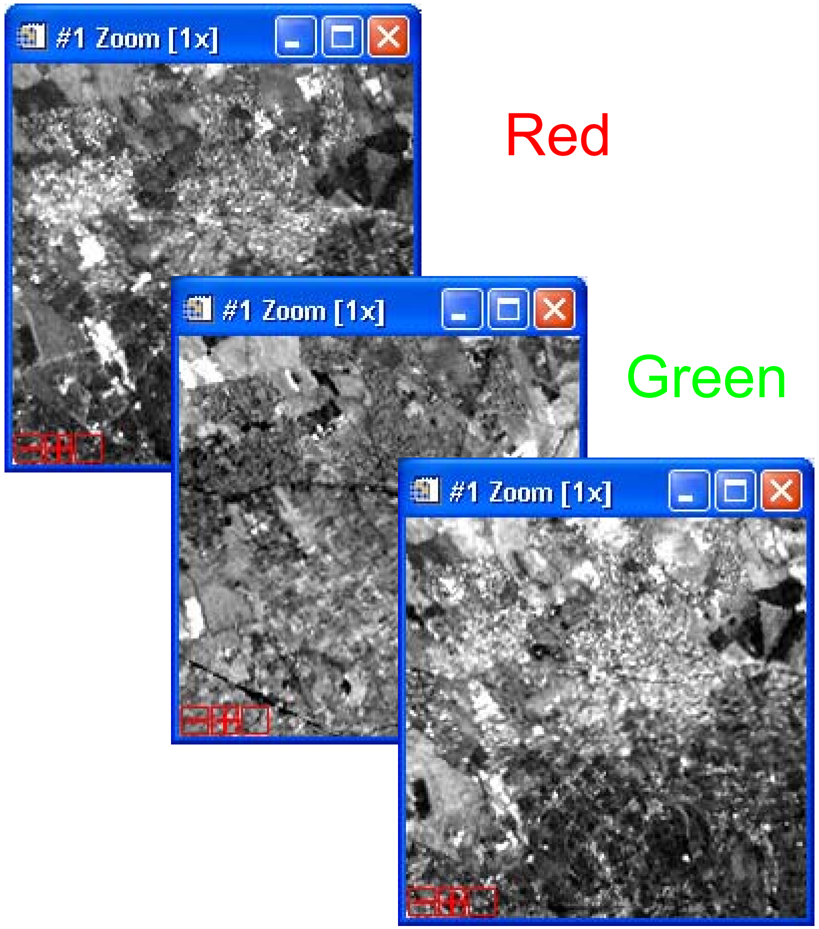


Panchromatic Image: single wide band, very high resolution for details rendering

Multi-Spectral Image: several bands, lower resolution, reflective properties at different λ

Spectral Resolution (ii)

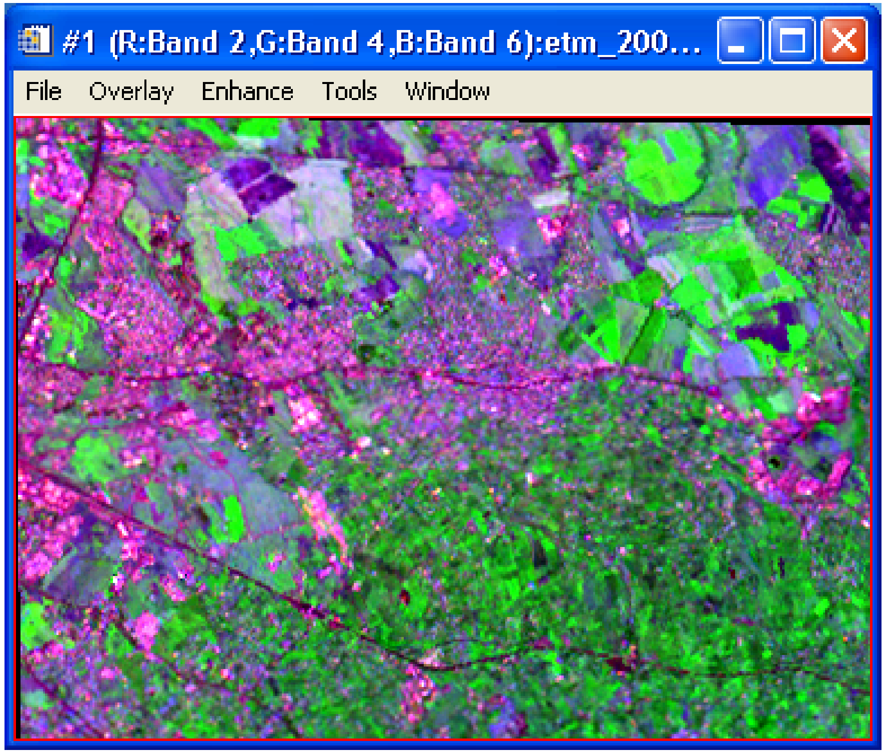
The spectral bands can be composed in RGB products in order to visualize particular spectral properties



Red

Green

Blue



Pan Vs Multi

Spot 5 over Tor Vergata

Pan Image

Multi-S Image

The evolution of optical sensors

Very high resolution
PAN and Multi

Optical
Cameras

High/Medium resolution
multi-spectral

Low resolution
multi-spectral
wide swath

High/Medium resolution
Hyper-spectral

Very high resolution sensors

- Very high resolution (around 1 m Pan and 4 m Multi)
- Excellent discrimination of details and spatial features
- Very high resolution multi-spectral bands to produce basic RGB composition
- High accuracy for the geo-location
- Satellite and aerial

Disadvantages

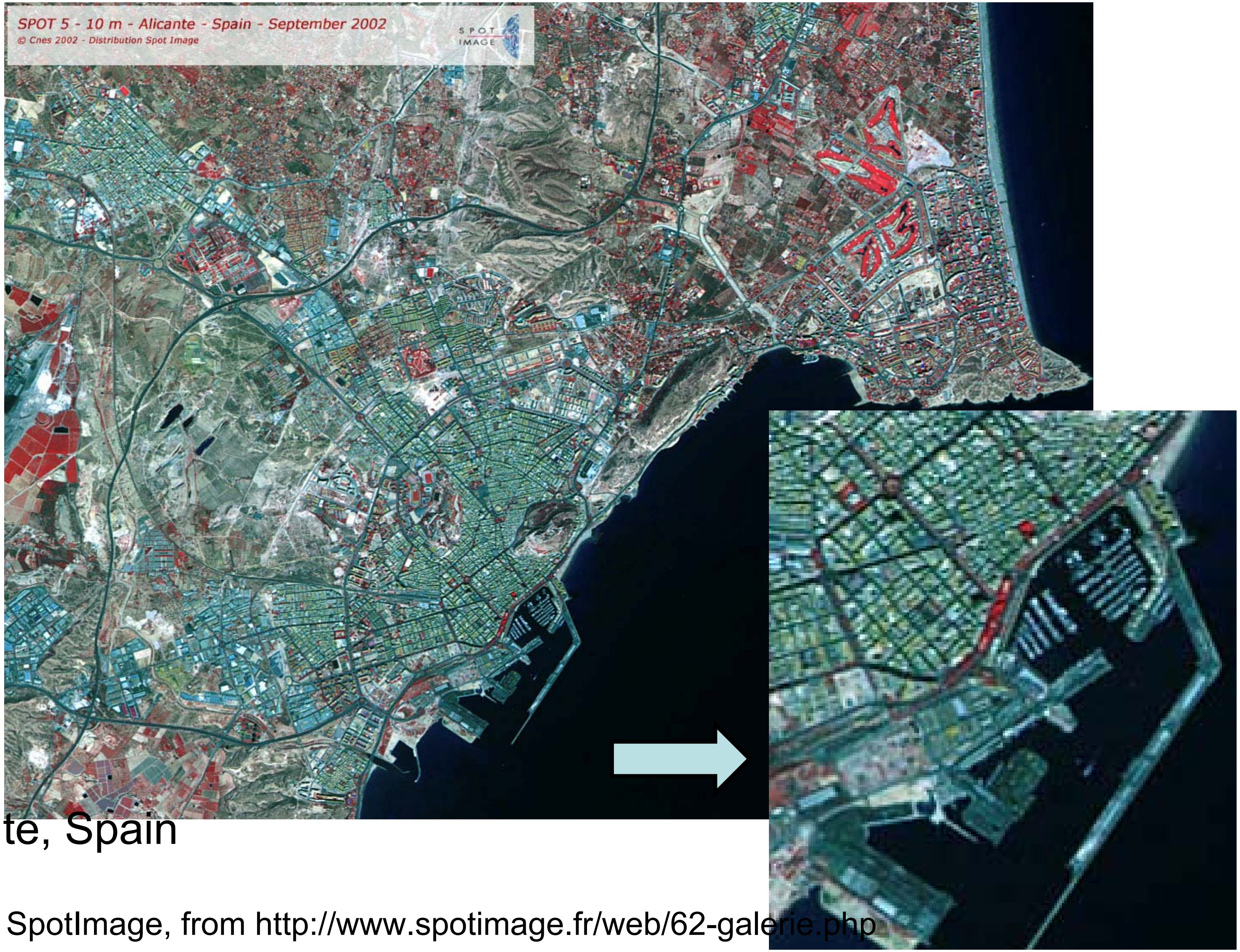
- Very expensive, mainly for commercial and military use
- Limited spectral analysis
- Limited acquisition swath, not global coverage
- Huge amount of data

Applications

- Cartography at very high resolution
- Localization
- Land cover and land changes

Very high resolution sensors examples

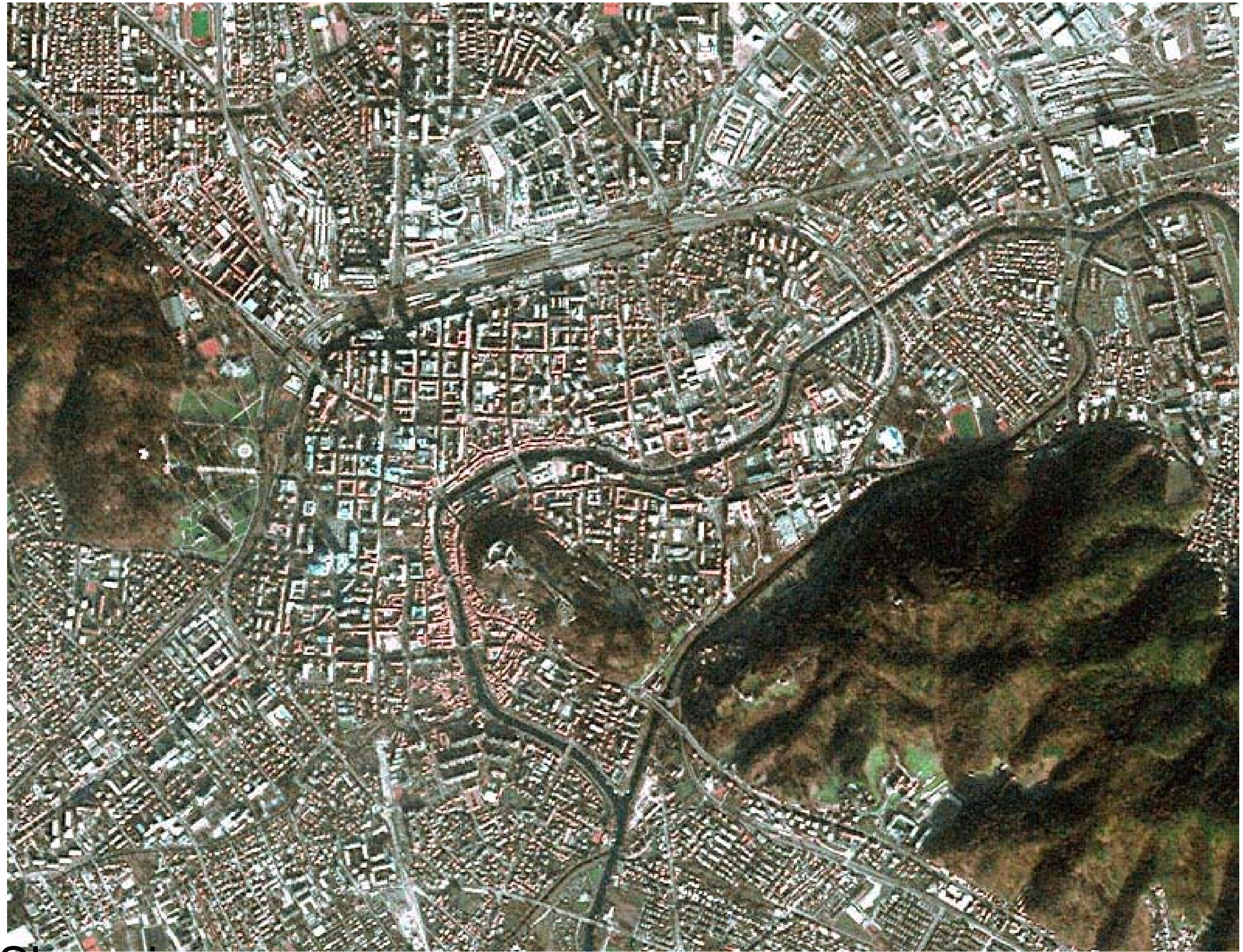
SPOT5
10m



Alicante, Spain

Very high resolution sensors examples

SPOT5
5m



Lubiana, Slovenie

Very high resolution sensors examples

SPOT5
2,5m

Dublin, Ireland

Very high resolution sensors examples

Ikonos
1m

Paris, France

Very high resolution sensors examples

1m Quickbird

… but we can have more

Around 50 cm

Rome

Padova

High and medium resolution multi-spectral

- Around 10 – 30 meters of spatial resolution
- Several spectral bands located in the Visible and Infrared range
- Possibility to combine spectral bands to highlight particular features
- Bands located in the thermal infrared with a reduced resolution
- Swath wide enough to cover large areas (180 km for Landsat)
- Increase in <u>temporal resolution</u>

Disadvantages

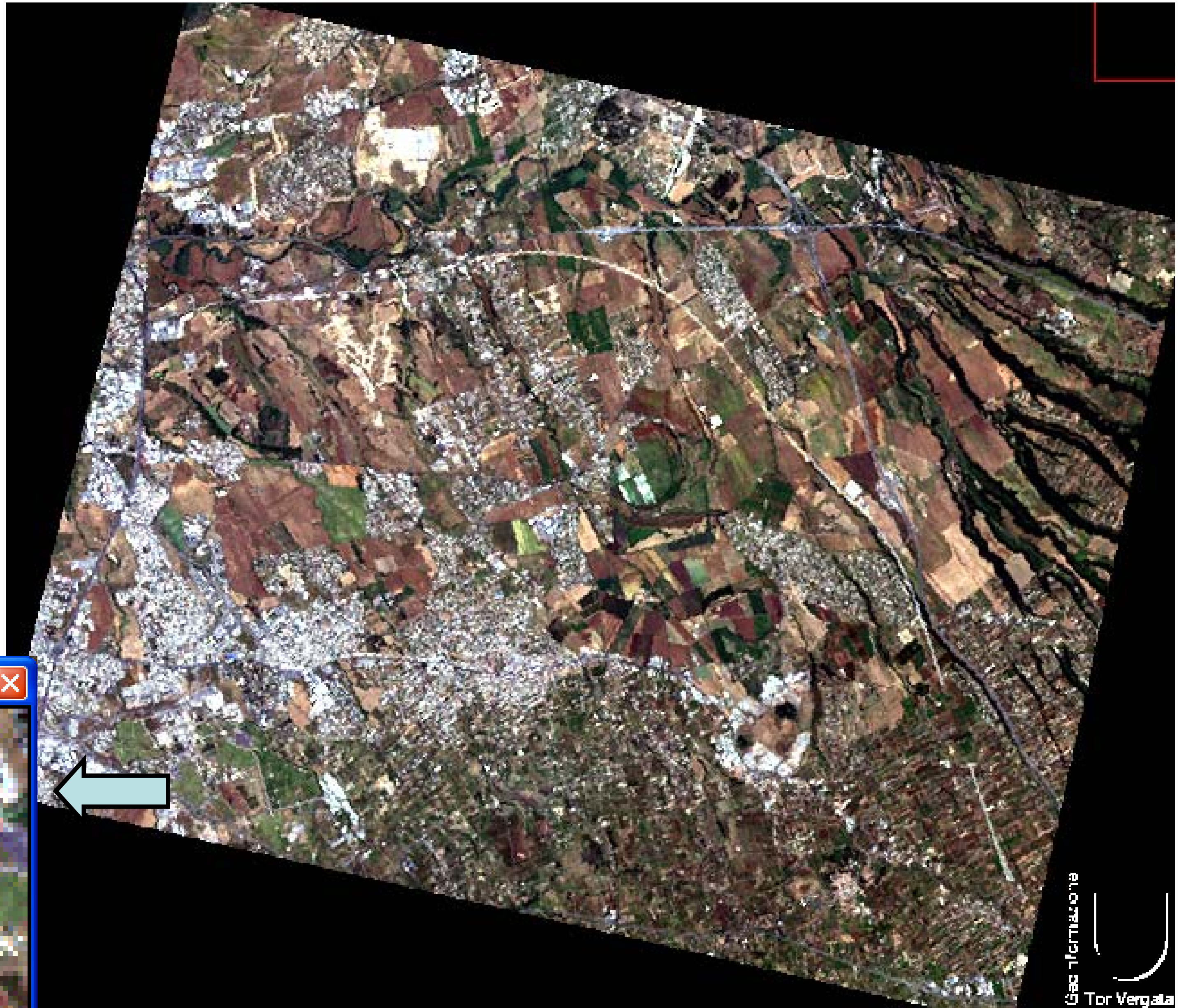
- Limited spatial analysis
- More processing are required (atmospheric correction, de-noising)

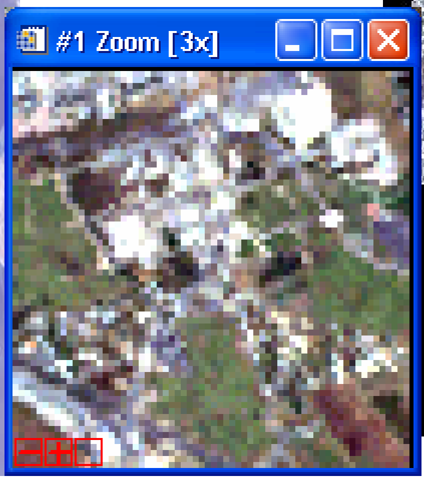
Applications

- Land Cover and Land changes at high resolution
- Vegetation index
- Monitoring of crops, forests, natural areas and coastal areas
- Monitoring of disaster effects (burned areas, deforestation,…)

High and medium resolution multispectral

Landsat
28.5 m

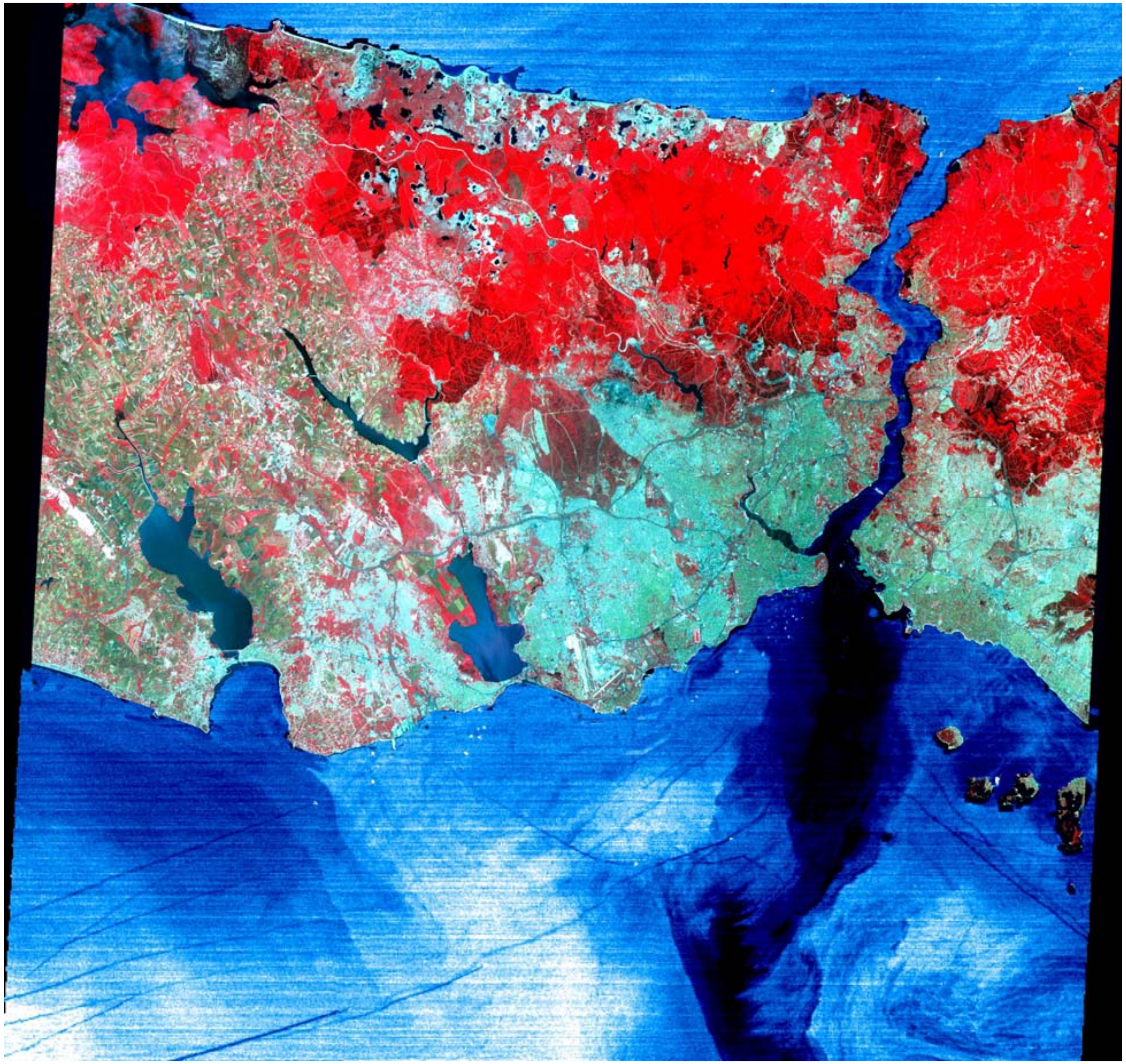




Aster ,15, 30 and 90 meters

High and medium resolution multispectral

Aster
Visible and
Infrared
composition



Istambul

Hyper-spectral sensors

- Many contiguous and narrow spectral bands (more than200 in some cases)
- 20-30 meters of resolution for satellite
- 1-2 meters for airborne

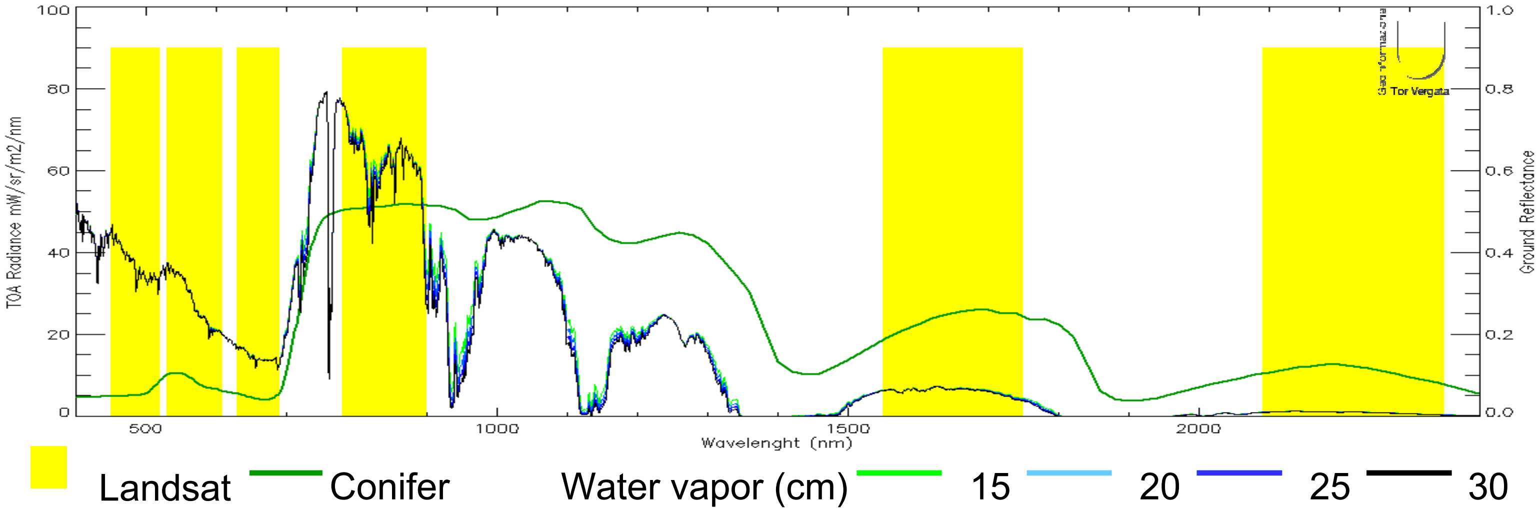
Disadvantages

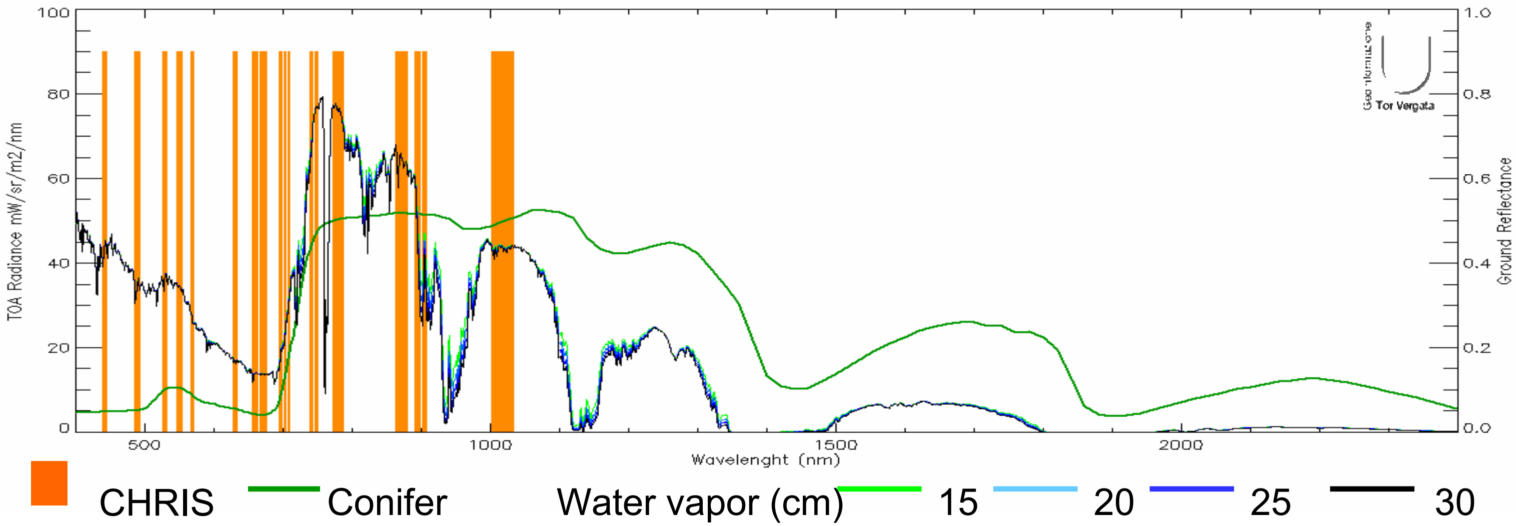
- Very expensive, especially for satellite
- The SNR could be not good in some cases
- Noise in some bands (around 400 nm)
- Difficulties in image processing and elaboration

Applications

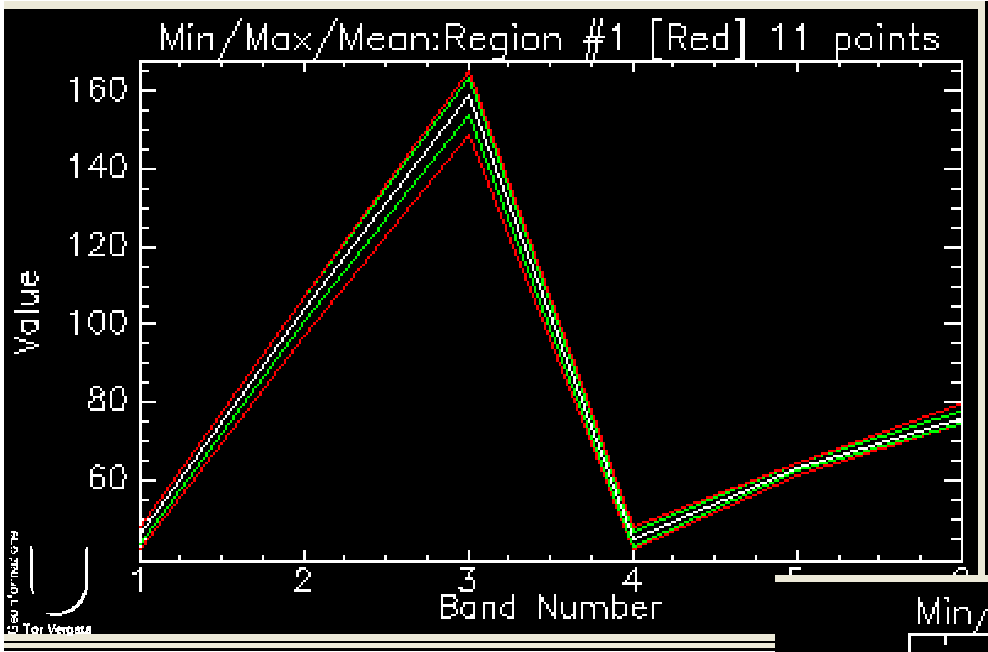
- Land Cover and Land changes at high spatial and spectral resolution
- Materials discrimination (urban and natural)
- Vegetation monitoring and differentiation

Hyper-spectral Vs Multi-spectral



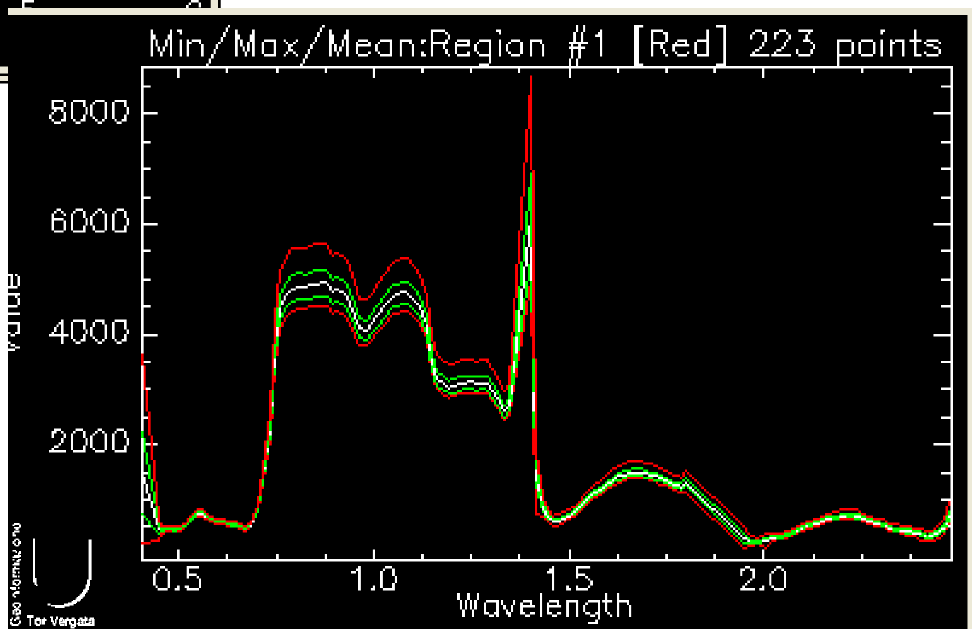


Hyper-spectral Vs Multi-spectral



Multi-spectral

Hyper-spectral



Low resolution multi-spectral

- Spatial resolution more than 100 meters
- Several bands (Visible, Infrared and Thermal)
- Very wide swath
- High temporal resolution, global coverage in few weeks

Disadvantages

- Limited spatial analysis
- Huge amount of data, difficulties for processing and managing
- Many corrections are required

Applications

- Land Cover and Land changes at global scale
- Vegetation index at global scale
- Monitoring of phenomena at global scale (desertification, huge deforestation)
- Ocean applications (ocean color, algae bloom, river sediments,…)

Low resolution multi-spectral examples

Meris
300m

California fires

Low resolution multi-spectral examples

Modis
250 m
500 m
1 km

Copyright NASA, from http://modis-land.gsfc.nasa.gov/

Next time

Basic processing

- Filtering, de-noising, de-striping
- Atmospheric correction
- Geometric correction and geo-rectification

Spectral properties

- Reflectance of surfaces
- Angular reflectance
- Temporal changes

Applications