Fundamentals in optical remote sensing

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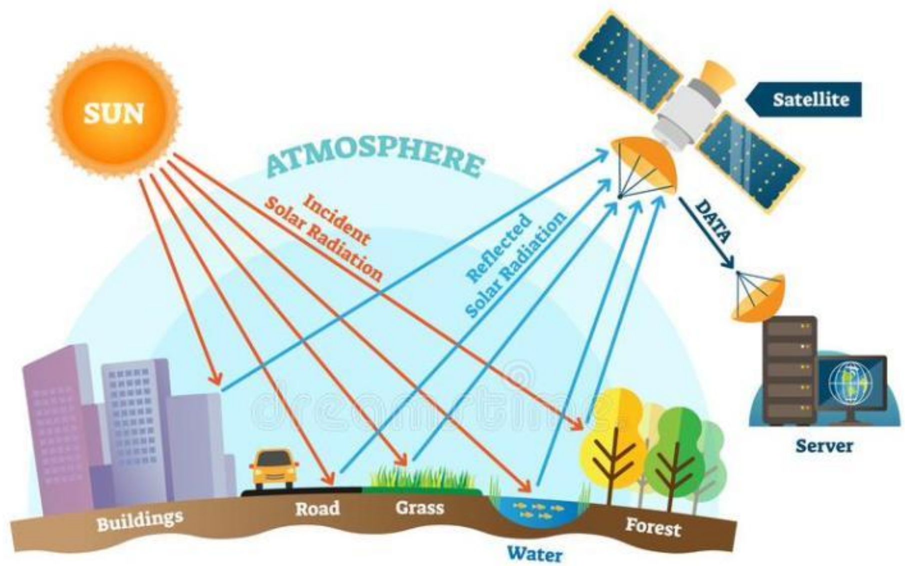
Program

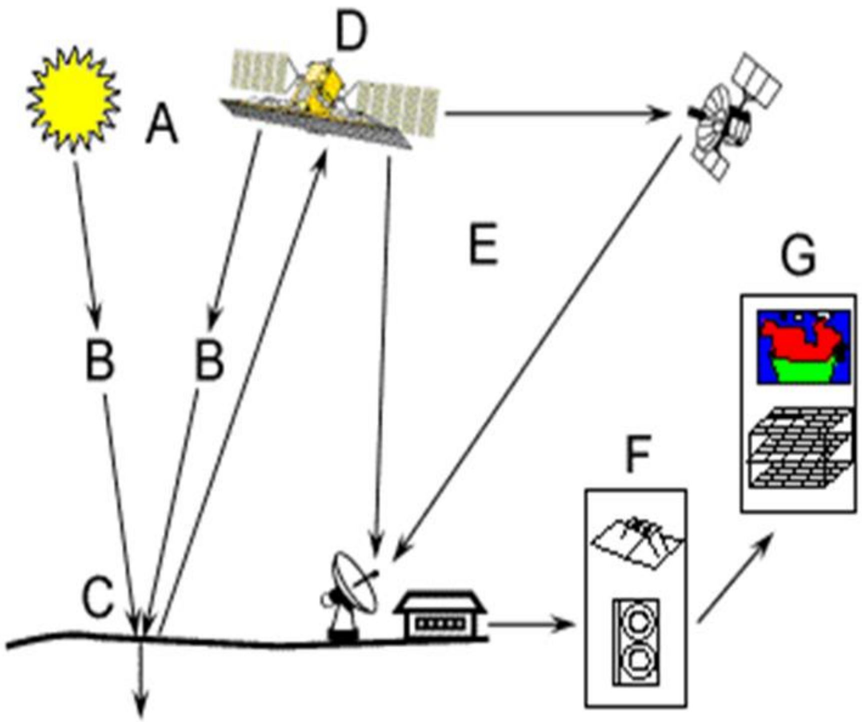
- Definition
- Physical basics
  - ✓ Electromagnetic radiation
  - ✓ interactions
  - ✓ Target behavior
- Some technical notions
- Spatial/temporal/spectral resolutions
- Satellites available (free)
- …

Remote Sensing : Definition

“Remote sensing designates the measurement or acquisition of information on an object or a phenomenon, using a measuring instrument that has no contact with the object under study. It is the remote use of any type of instrument (aircraft, spacecraft, satellite, etc.) allowing the acquisition of information on the environment. We often use instruments such as cameras, lasers, radars… ” **according to Wikipedia**



Remote sensing process



Source: Canadian Center for Remote Sensing

Natural source "Sun " or artificial "sensor "

➔ emission of electromagnetic radiation which is characterized by its wavelength

(A) Power Source / Illumination

(B) Interaction with the atmosphere

(C) Interaction with the target

(D) Energy recording by the sensor

(E) Transmission, reception and processing

(F) Interpretation and Analysis

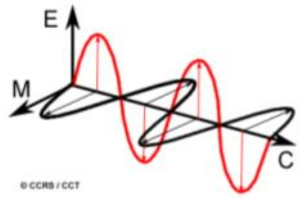
(G) Apps

Electromagnetic radiation

To **illuminate** the target, a source of energy is needed in the form of electromagnetic radiation.

Electromagnetic radiation corresponds to all the radiation emitted by a source which may be either the sun, the land or ocean surface or the atmosphere, or even the sensor itself , in the form of electromagnetic waves.

Electromagnetic radiation is composed of an electric field (E) and a magnetic field (M) oscillating at the same frequency. (E) is oriented ⊥ to the direction of radiation propagation. (M) is oriented so ⊥ at (E). (E) and (M) move at a speed which depends on the medium considered. In a vacuum, the speed of propagation (c) is equal to 3.10^{8} ms^{-1} .



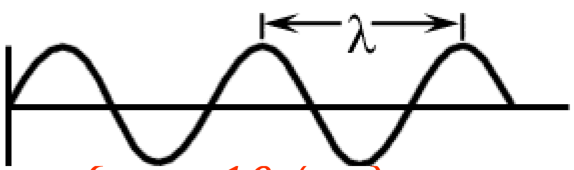
Electromagnetic radiation

radiation is defined by wavelength λ or frequency (f)

Wavelength = length of a cycle of a wave = distance between two successive crests of a wave.

Frequency = number of oscillations per unit time (in Hertz: Hz) (i.e. in oscillations per second):

$$c=\lambda .\ f$$



Units: m, cm, mm, nanometers (nm=10 $^{-9}$ m), micrometers (μm , 10 $^{-6}$ m).
MHz=10 ^{6} Hz, GHz=10 ^{9} Hz

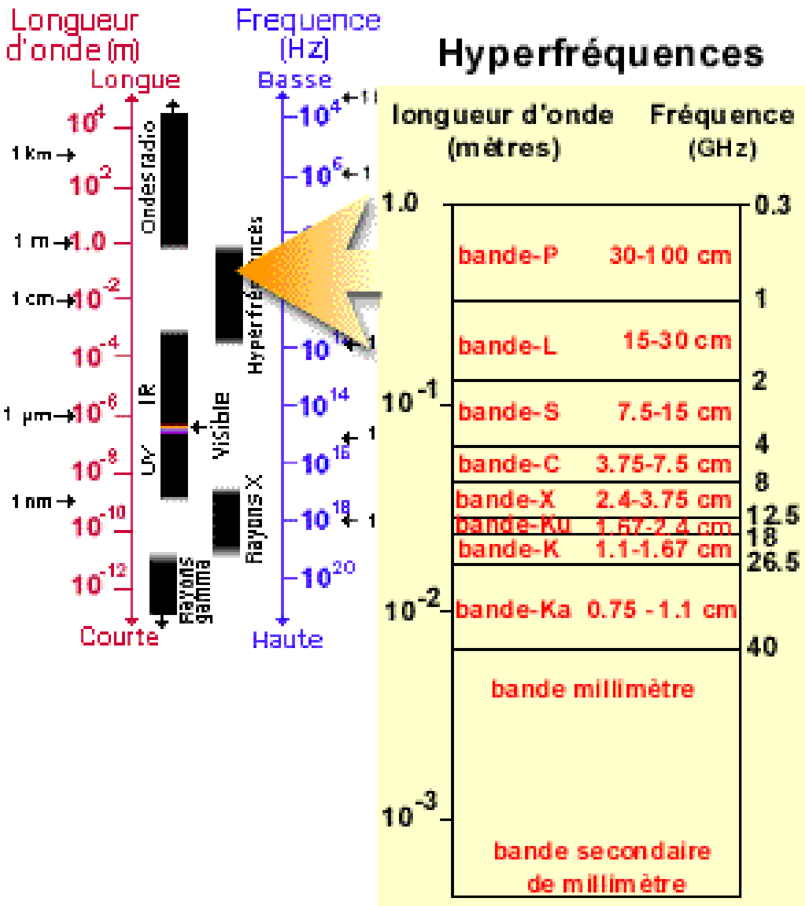
Example: f=6 GHz then λ= 3.10 ^{8} / 6.10 ^{9} = 0.05 m = 5 cm

Rayonnement électromagnétique

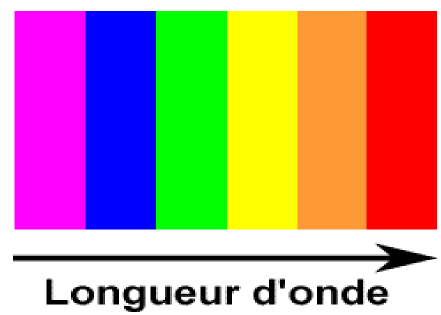
Courtes longueurs d'onde: rayons gamma et rayons X

Grandes longueurs d'onde: micro-ondes et ondes radio

Longueurs d'onde en télédétection: UV → Hyperfréquences

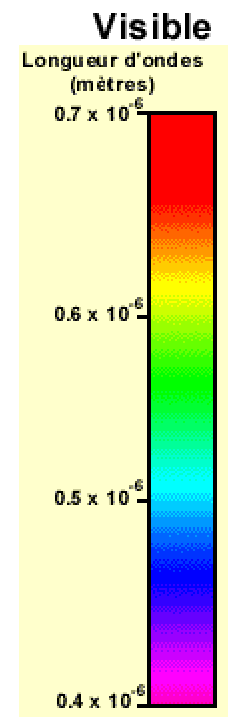


Nos yeux détectent spectre visible: 0.4 à 0.7μm



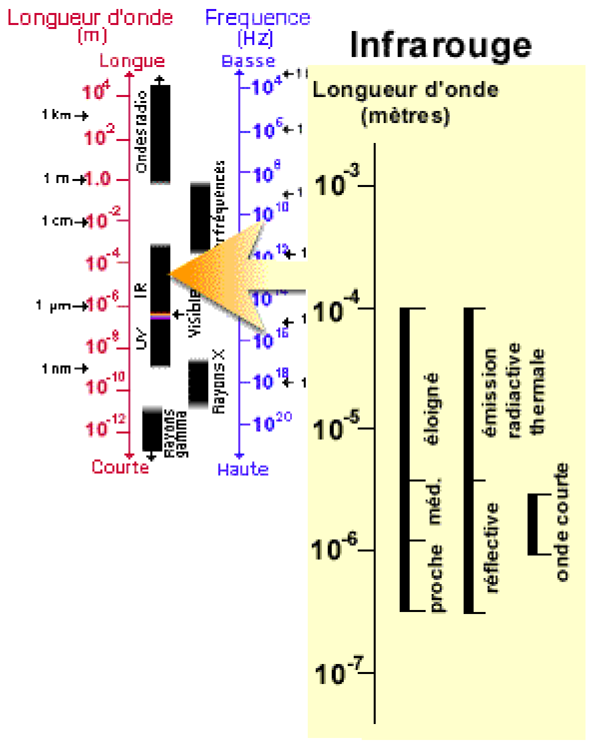
Violet: 0,400 à 0,446 μm
Bleu: 0,446 - 0,500 μm
Vert: 0,500 - 0,578 μm

Jaune: 0,578 - 0,592 μm
Orange: 0,592 - 0,620 μm
Rouge: 0,620 - 0,7 μm



Electromagnetic radiation

- Infrared (IR) extends from 0.7 to 100 µm (very wide)



- IR falls into two categories:

Reflected IR and **Emitted** or **Thermal IR**

- Reflected IR ranges from 0.7 to 3 µm

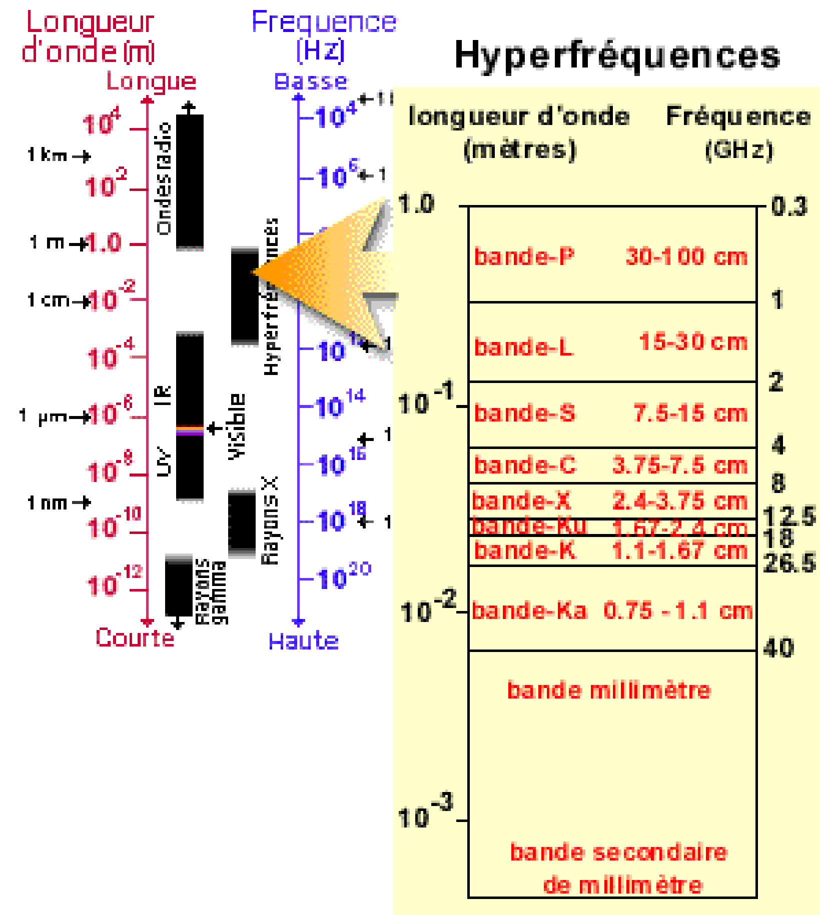
- Thermal IR (IRT) is very different from the visible spectrum and reflected infrared. This energy is essentially radiation that is emitted as heat from the Earth's surface and ranges from approximately 3 to 100µm .

Electromagnetic radiation

- Microwaves: the longest wavelengths used in remote sensing, from 1 mm to 1 m .

- Shorter wavelengths have properties similar to thermal infrared

- The longer wavelengths resemble radio waves.



Interaction with the atmosphere

- As radiation passes through the atmospheric layer, it collides with molecules and particles in the atmosphere. It can be deviated from its trajectory, it is the phenomenon of atmospheric **diffusion** , or it can be totally or partially **absorbed** .

- The absorption of the radiation which yields all or part of its energy consequently leads to an attenuation of the signal in the direction of propagation of the radiation.

Interaction with the atmosphere

- Scattering = interaction between incident radiation and particles or large gas molecules (in the atmosphere). The particles deflect the radiation from its original path.

- The level of diffusion depends on:
  - ✓ the wavelength of the radiation
  - ✓ the density and size of atmospheric particles and molecules
  - ✓ the thickness of the atmosphere that the radiation must pass through .

Interaction with the atmosphere

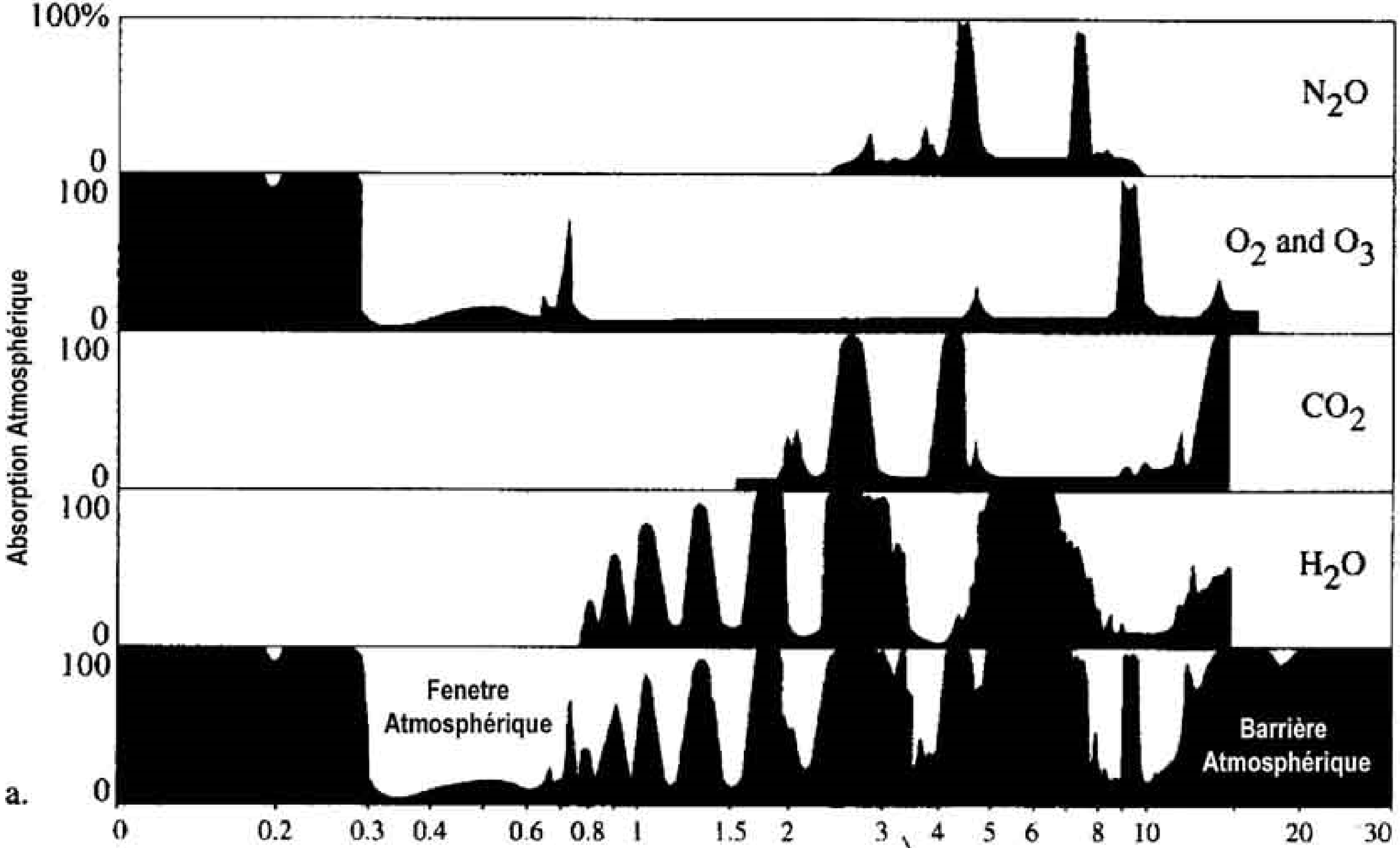
- Absorption of radiation giving up all or part of its energy leads to signal attenuation

- Absorption = large molecules in the atmosphere (ozone, carbon dioxide and water vapour) absorb energy from various λ

- Regions of the EM spectrum that are not significantly influenced by atmospheric absorption ➔ useful for remote sensing

Interaction with the atmosphere

Atmospheric windows = regions of the spectrum useful for remote sensing



N2O: Nitrogen
O3: Ozone
O2: Oxygen
H2O: water vapor

Radiation-target interaction

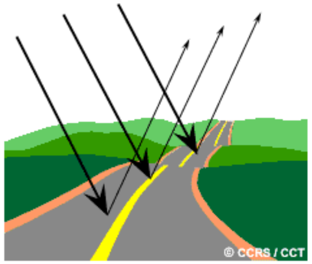
- The part of the energy that passes through the atmospheric layer reaches the earth's surface.
- The earth's surface can absorb (A) energy, transmit (T) or reflect (R) incident energy.
- The reflection depends on the land cover (building, vegetation, water, soil ...)
- The proportion of each interaction depends on λ of the energy, as well as the nature and conditions of the surface.

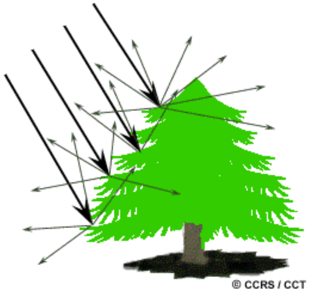
Incident energy = Reflected energy + Absorbed energy + Transmitted energy

Reflectance = % (Reflected Energy / Incident Energy) = Albedo for Earth's Surface

Radiation-target interaction

- **Reflection** is the change in direction of electromagnetic radiation when it hits a surface .





- In remote sensing, we measure the radiation reflected by a target

- There are three types of reflection:

- specular reflection
- diffuse reflection
- volume reflection

Radiation-target interaction

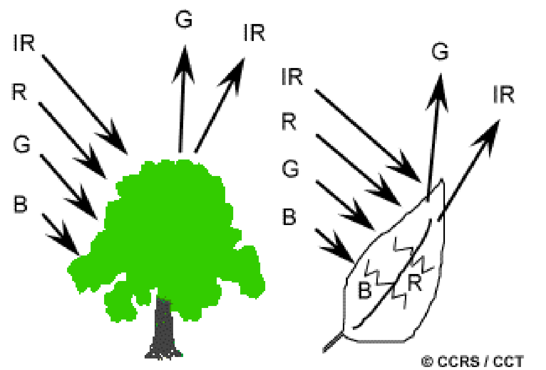
- Smooth surface produces **specular reflection ➔** all the energy is reflected in the opposite direction to the emitted radiation (mirror effect). Example : road…

- Rough surface produces **diffuse reflection ➔** scatter incident energy in many directions. Vegetated surfaces cause diffuse reflection.

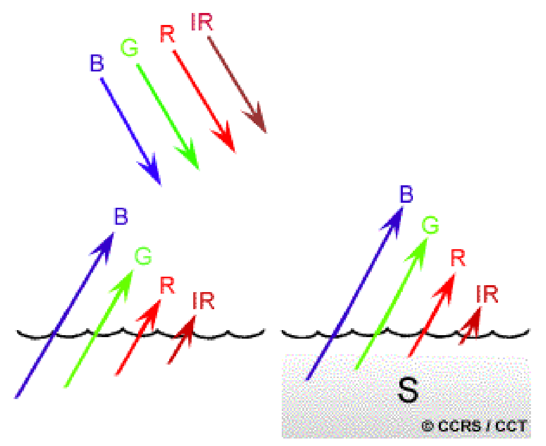
- **Volume reflection** occurs when some of the incident radiation is transmitted through a medium.

Radiation-target interaction

- **Leaves :** Chlorophyll, a molecule inside leaves, absorbs red and blue radiation, but reflects green. The leaves, which contain a maximum of chlorophyll, are therefore green. In autumn, the leaves contain less chlorophyll, absorb less red, and therefore appear red or yellow (yellow is a combination of green and red)



- **Water :** Water absorbs more large λ of visible and near-IR radiation. Thus, the water usually appears blue or blue-green.



Radiation-target interaction

- **Absorption**

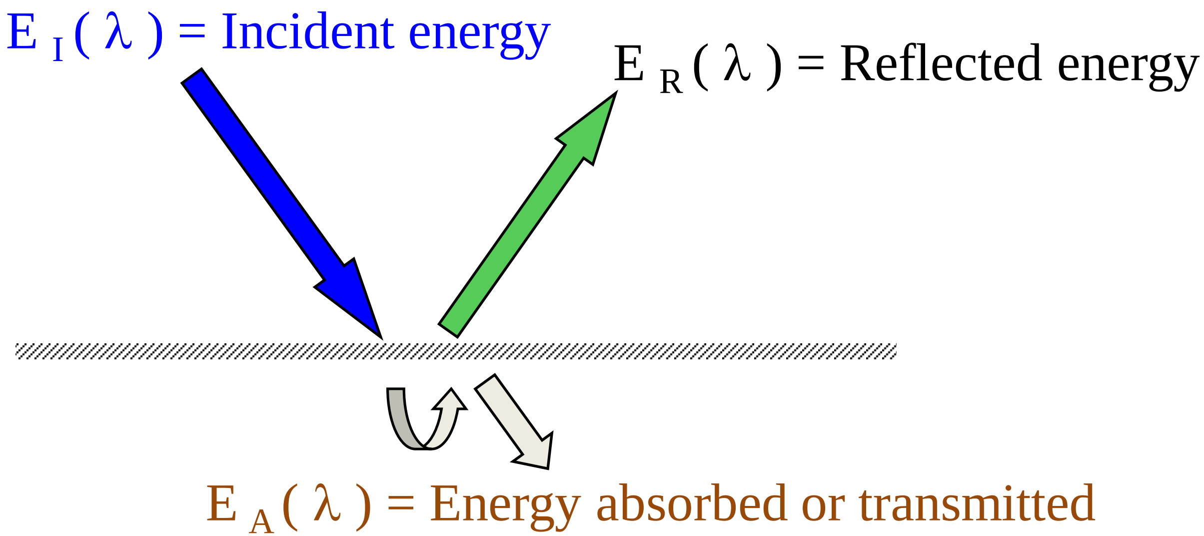
All natural bodies absorb some of the radiation that reaches them. There is production of heat and re-emission of energy at a longer wavelength.

- **Transmission**

When some of the incident radiation passes through a medium, the radiation is said to be transmitted. The transmission phenomenon concerns more or less transparent media such as water, clouds or the atmosphere, but not exclusively.

Types of remote sensing

- Interactions between radiation and target in the visible, PIR and MIR



energy = Reflected energy + Absorbed energy (*)

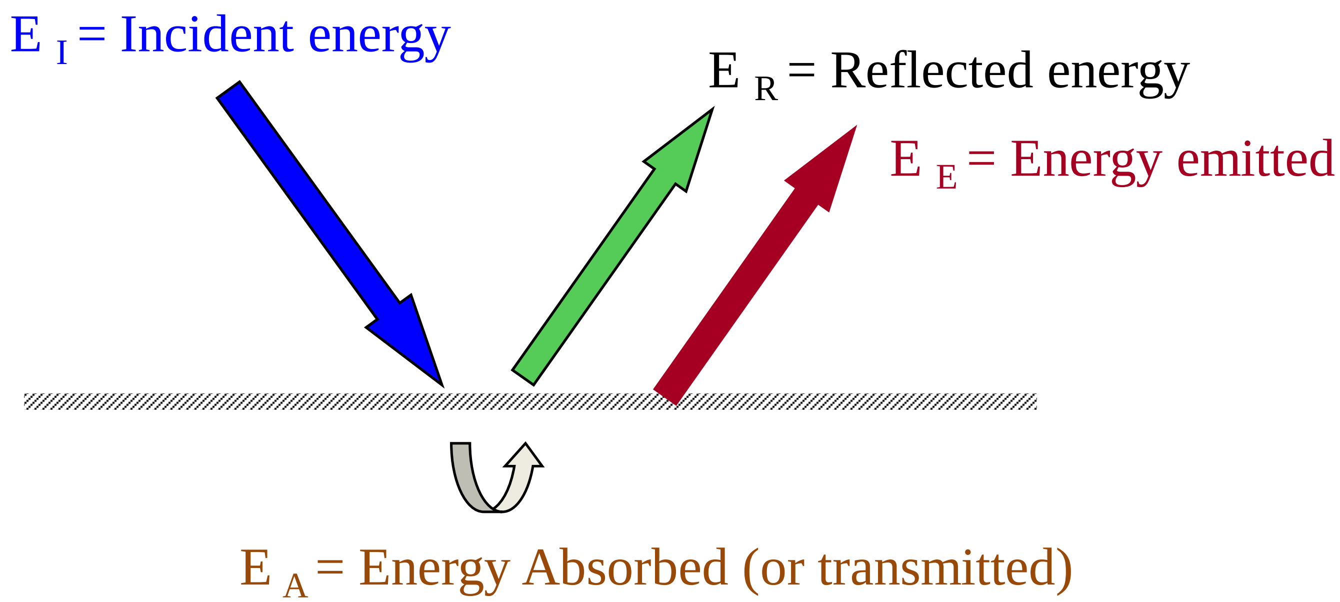
$E_I(\lambda) = E_R(\lambda) + E_A(\lambda)$

Reflectance = Reflected Energy = ρ
incident energy

(*) We assume the ground to be opaque (no transmitted energy)

Types of remote sensing

- Interactions between radiation and target in IRT

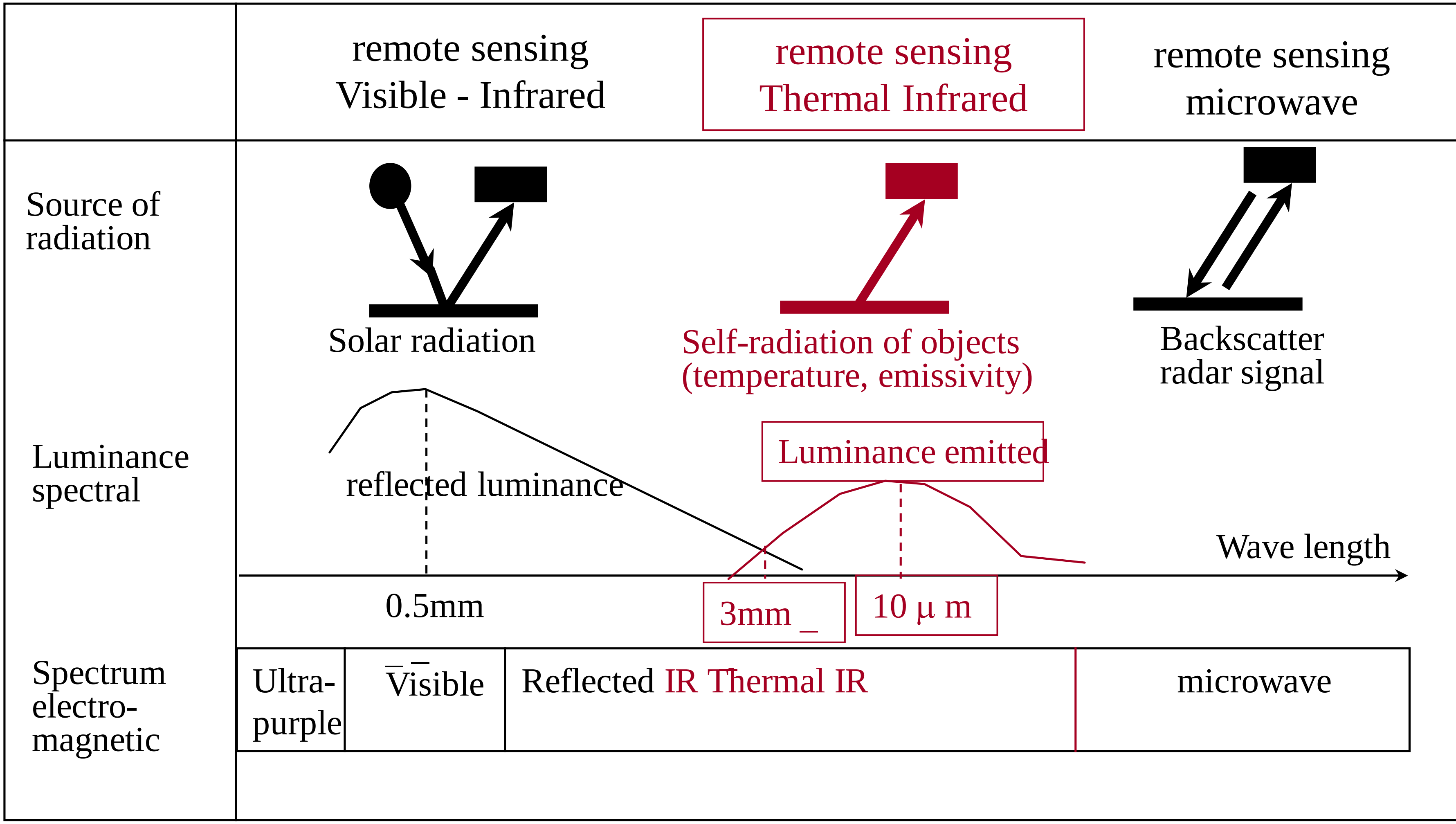


At thermal equilibrium Energy absorbed = Energy emitted

$E_A = E_E$

$$\text{Absorption} = \frac{\text{Energy absorbed}}{\text{incident energy}} = \alpha$$

Types of remote sensing



Types of remote sensing

- The Sun's energy is either reflected (visible portion) or absorbed and retransmitted (IRT) by the target.

- Passive sensor = remote sensing sensor that measures the energy available naturally

  - ✓ The passive sensor can only perceive reflected energy when the Sun illuminates the Earth

  - ✓ Energy released naturally by target (IRT) can be perceived day/night.

- Active sensor = sensor produces its own energy to illuminate target (radar/lidar).

  - ✓ sensor (day/season).
  - ✓ Example : laser/lidar and radar (Synthetic Aperture Radar "SAR")

Radiation-target interaction

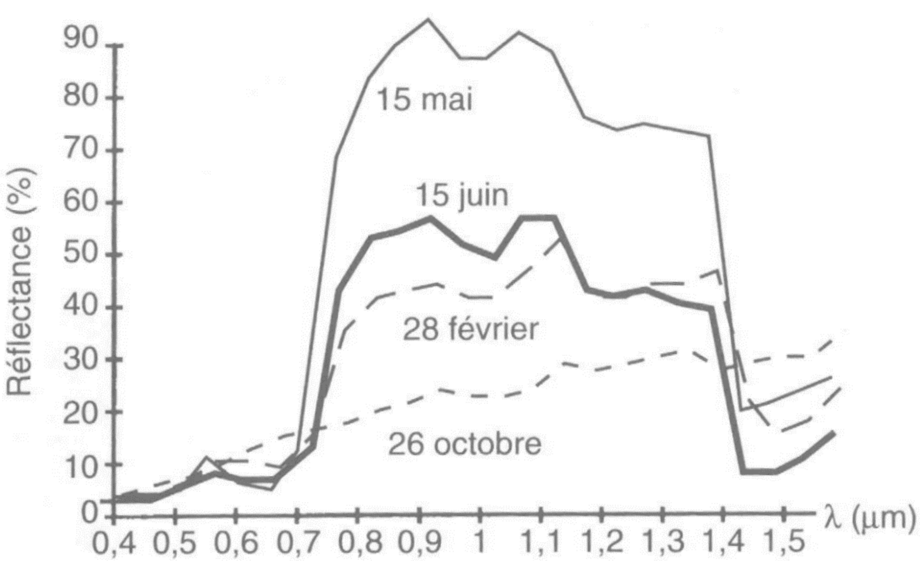
(D) Energy recording by the sensor: The reflected energy is picked up by the sensor (satellite). This captured energy will then create the satellite image

(E) Transmission, reception and processing: The satellite sends the recorded energy to a ground station in order to be processed and transformed into an image

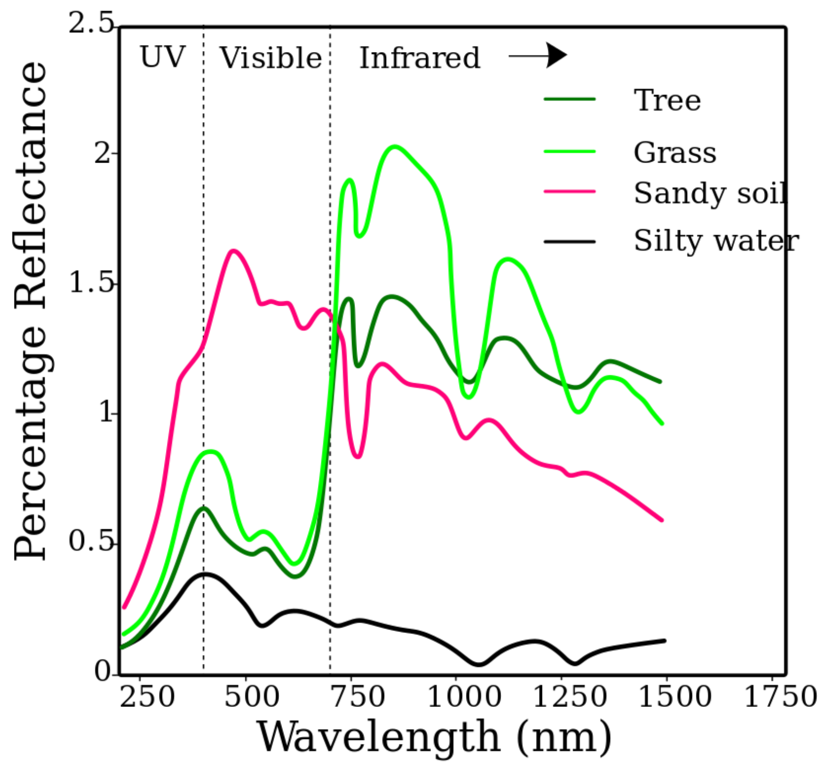
(F) and (G) Interpretation, analysis and application: The satellite image is then processed and analyzed by specialists for a specific use (land cover mapping, estimation of soil parameters, monitoring of vegetation cycles)

Interaction with the Earth's surface

- Objects can have different absorption and reflection responses in different wavelengths
- Spectral Response Can Help Us Distinguish Objects
- Each object has its own spectral curve



Winter wheat plot: reflectance measurements at different dates [Girard and Girard, 2004]



Sensors, Vectors

- Sensor = measuring instrument

- Platform or Vector = vehicle on which the sensors are embedded = ULM, aircraft, shuttle, satellite, etc.

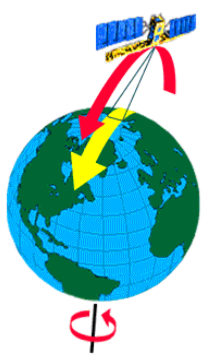
  - ✓ Helicopter / ULM = low altitude < ~1000m
  - ✓ Plane = high altitude = 5-10km
  - ✓ Space shuttle = 200- 400km
  - ✓ Earth observation satellites = ~300-700km
  - ✓ …

Caractéristiques des satellites

Orbite: Trajectoire effectuée par un satellite autour de la Terre.

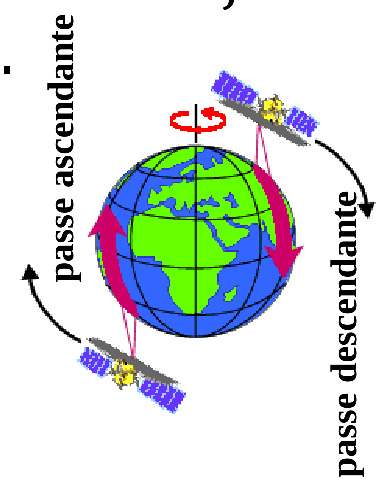
La plupart des satellites de télédétection sont sur des orbite quasi-polaires : orbites allant pratiquement du nord au sud ou vice versa. Cette configuration, combinée à la rotation de la Terre (ouest-est), fait qu'au cours d'une certaine période, les satellites ont observé la presque totalité de la surface de la Terre.

La plupart des satellites sur orbite quasi-polaires ont aussi une orbite héliosynchrone; de cette façon, ils observent toujours chaque région du globe à la même heure locale solaire.



Orbite quasi polaire

Orbite ascendante (nuit)
Orbite descendante (jour)

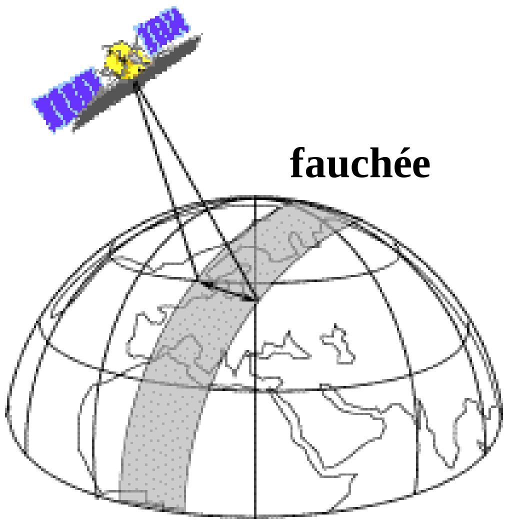


Caractéristiques des satellites

Fauchée (Swath):

Lorsqu'un satellite tourne autour de la Terre, le capteur "voit" une certaine partie de la surface de la Terre. La zone imagée est appelée Fauchée (couloir-couvert). Les Fauchées varient généralement entre des dizaines et des centaines de kilomètres de large.

Satellite	Swath (km)
Sentinel–2	290
LANDSAT-8	185
SPOT-6/7	60
MODIS	2330



Résolution spatiale

- La **résolution spatiale** correspond au plus petit objet pouvant être détecté par le capteur

➔ Résolution spatiale plus élevée = plus de détails dans l'image

- Pour pouvoir différencier un élément, l'élément doit être de dimension égale ou supérieure à la cellule de résolution. Si l'élément est plus petit, il ne sera généralement pas différencié puisque c'est **l'énergie moyenne** des éléments de la **cellule de résolution** qui sera captée. Cependant, dans certaines conditions, un élément plus petit peut être détecté si son signal domine celui des autres éléments présents dans la cellule de résolution.

Résolution spatiale

- La **résolution spatiale** correspond au plus petit objet pouvant être détecté par le capteur

- Un capteur placé sur une plate-forme éloignée de la cible pourra observer une plus grande région, mais ne sera pas en mesure de fournir beaucoup de détails.

haute résolution spatiale | **résolution spatiale moyenne** | **résolution spatiale faible**

Résolution spatiale

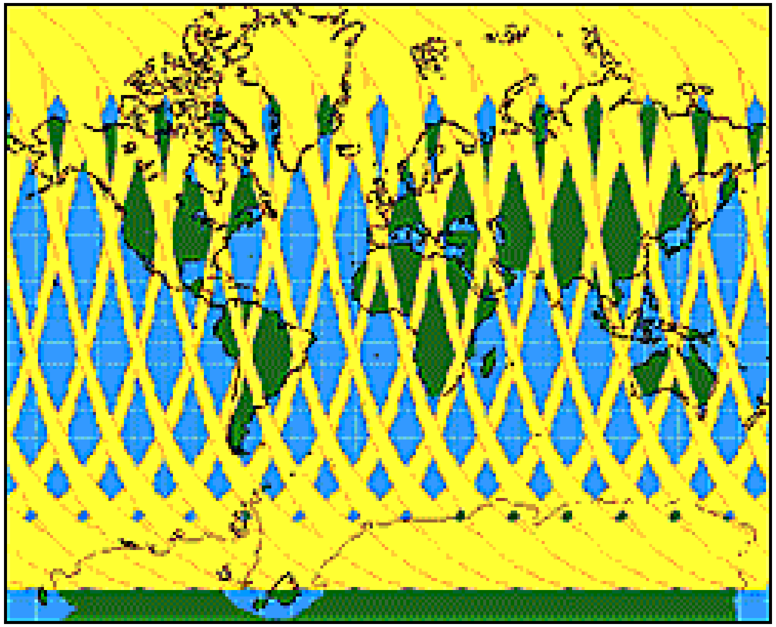
Exemples de différentes résolutions spatiales

Satellite	Résolution spatiale
Sentinel – 2	10 – 60 m selon le band
LANDSAT – 8	30-60 m
SPOT – 6/7	6 m
Pleiades 1A/B	2 m (50 cm pour l'image en Noir-Blanc)
MODIS	250, 500, 1000 m selon les bandes
WorldView-2	1,8 m
WorldView-3	0,31 m

Résolution temporelle

- Résolution temporelle : temps que prend un satellite pour effectuer un cycle orbital complet

- Certains satellites ont aussi la possibilité de pointer leurs capteurs en direction du même point pour différents passages du satellite.



Résolution spatiale dépend de la latitude

Résolution temporelle

- ➢ Comme les caractéristiques spectrales des objets peuvent changer au fil du temps ➔ besoins d'images multi-temporelles pour détecter les changements

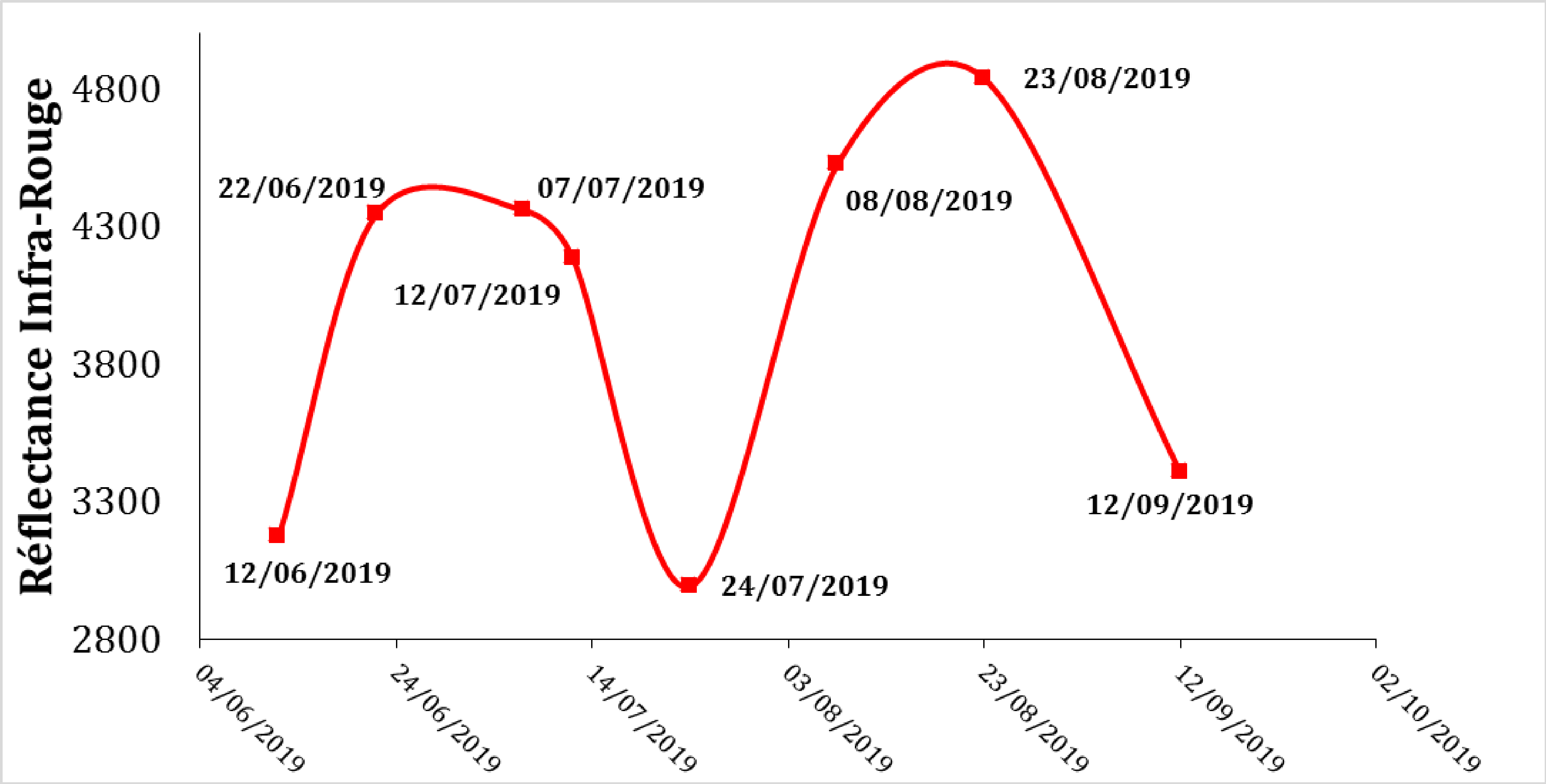
Satellite	Résolution temporelle
Sentinel – 2	5 jours avec les deux satellite S2A et S2B
LANDSAT – 8	16 jours
SPOT – 7	1 jour sur demand
Pleiades 1A/B	1 jour sur demand
MODIS	1–2 jours
WorldView-2	1,1 jours sur un résolution spatiale de 1 m
WorldView-3	4,5 jours

Résolution temporelle élevée nécessaire:

- ✓ Couverture nuageuse persistante
- ✓ Surveillance des phénomènes de courte durée (inondations …)
- ✓ …

Temporal resolution

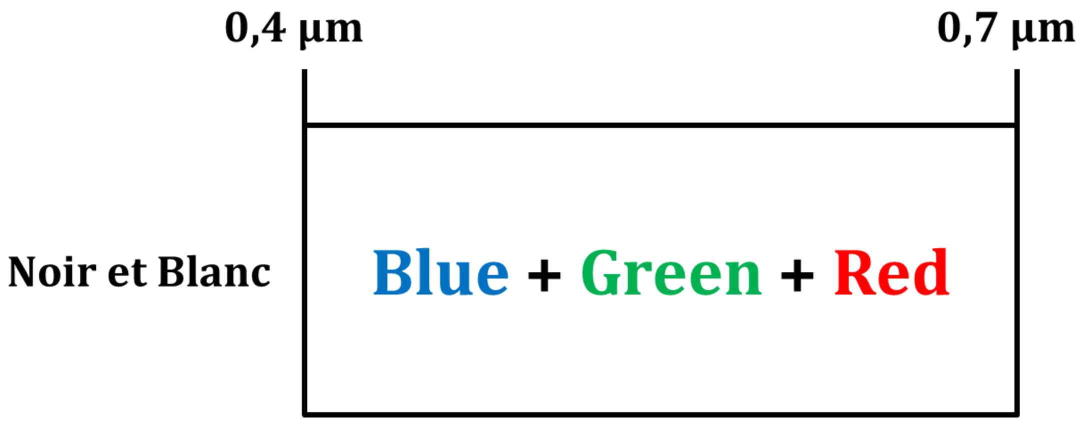
Example of multi-temporal evolution of infrared reflectance on a grassland plot between June and September 2019



Spectral resolution

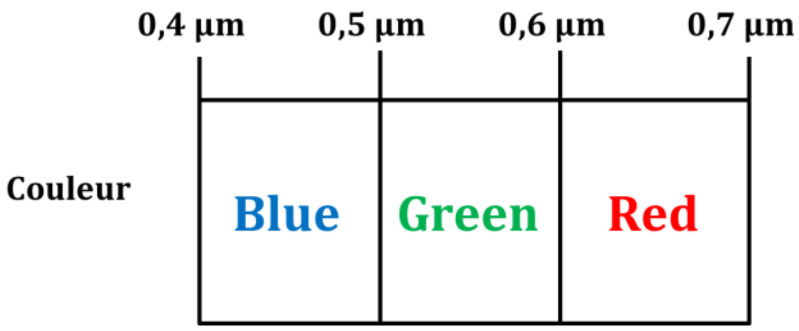
- Spectral resolution describes the sensor's ability to use small wavelength windows

- A black and white film from a camera records the λ on almost all the λ located in the visible spectrum ➔ Coarse spectral resolution because the different λ are not differentiated



Spectral resolution

- A color film has a higher spectral resolution since it can distinguish λ in blue, green and red.



- **Multi-spectral** sensors record received energy in many spectral bands

- **Hyperspectral** sensors = hundreds of very fine spectral bands in the portion of the EM wave spectrum bringing together the visible, the near IR and the mid-IR.

Spectral resolution

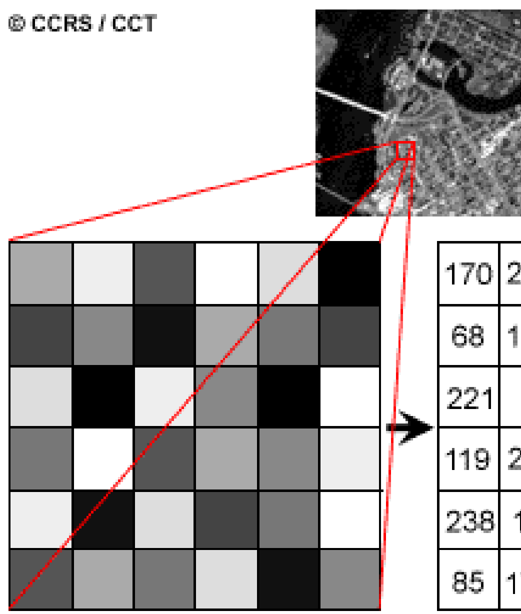
Satellite	Bandaged	Spatial resolution
Sentinel -2	Coastal Aerosol (0.443 µm)	60m
	Blue (0.490 µm)	10m
	Green (0.560 µm)	10m
	Red (0.665 µm)	10m
	Red-edge vegetation (0.705 µm)	20m
	Red-edge vegetation (0.740 µm)	20m
	Red-edge vegetation (0.738 µm)	20m
	Near Infrared (0.842 µm)	10m
	Red-edge vegetation (0.865 µm)	20m
	Water vapor (0.945 µm)	60m
	Wave Shorts (1.375 µm)	60m
	Short Wave Infrared (1.610 µm)	20m
	Infrared Wave Shorts (2,190 µm)	20m
SPOT - 6/7	Blue (0.455µm – 0.525µm)	6m _
	Green (0.530µm – 0.590µm)	6m _
	Red (0.625µm – 0.695µm)	6m _
	Close Infrared (0.760 µm – 0.890 µm)	6m

Radiometric resolution

- The radiometric resolution of a system describes its ability to discriminate very small differences in EM energy

- finer the radiometric resolution of a sensor , the more sensitive it is to detecting small differences in the received energy

- Image data is represented by numeric values



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

Radiometric resolution

The digital values of the pixels correspond to the number of bits used to encode the received energy in binary format

Example: if a sensor used "8 bits" to record data, there would be 2^{8} =256 numerical values available, ranging from 0 to 255

2 values

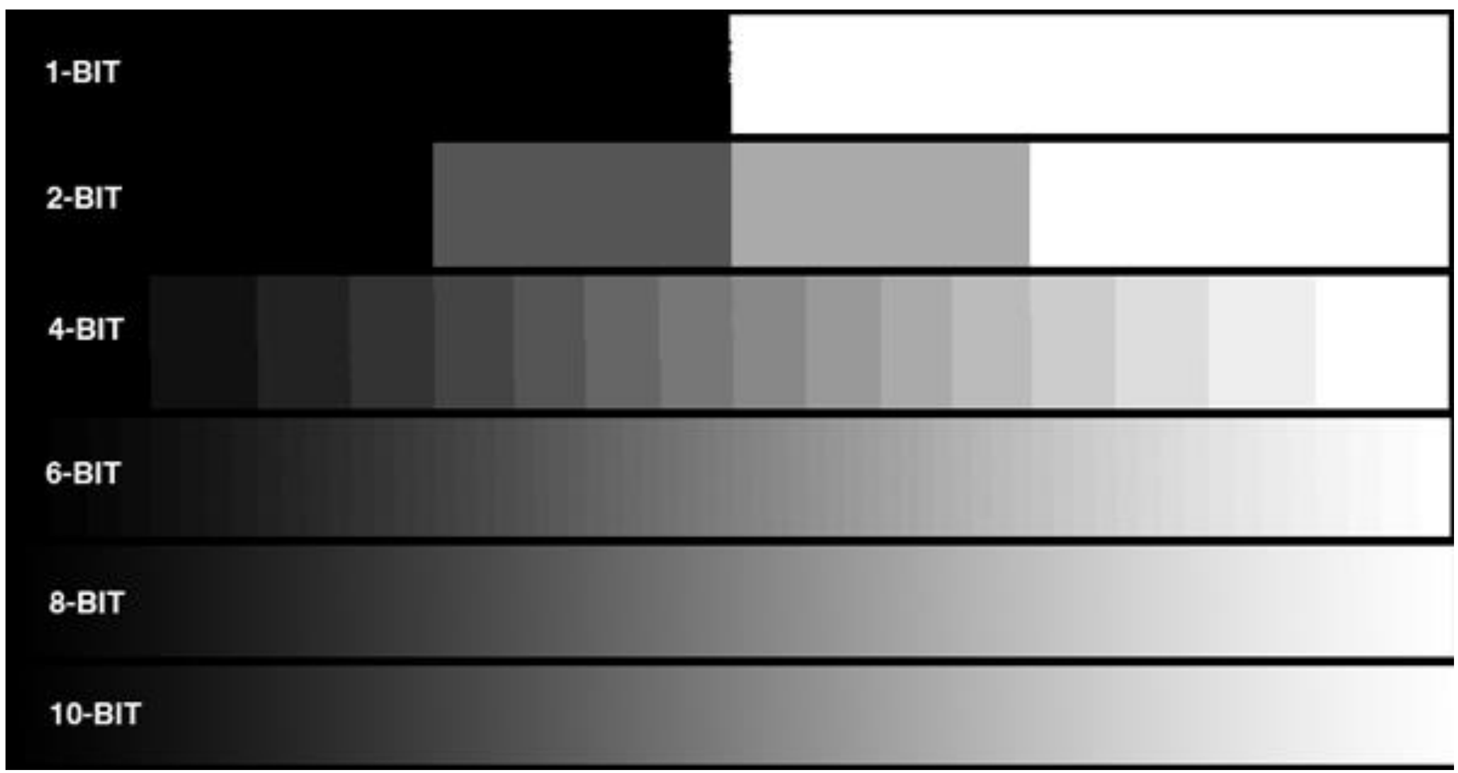
4 values

16 values

64 values

256 values

1024 values



Caractéristiques de l'image satellitaire

Une image est définie comme suit:

x Taille du pixel (m) y

Y

Nombre de lignes

5	50	88	92	95	201
22	14	80	75	95	240
39	48	41	65	77	250
74	69	35	0	2	112
45	55	32	30	26	16

Nombre de colonnes

X

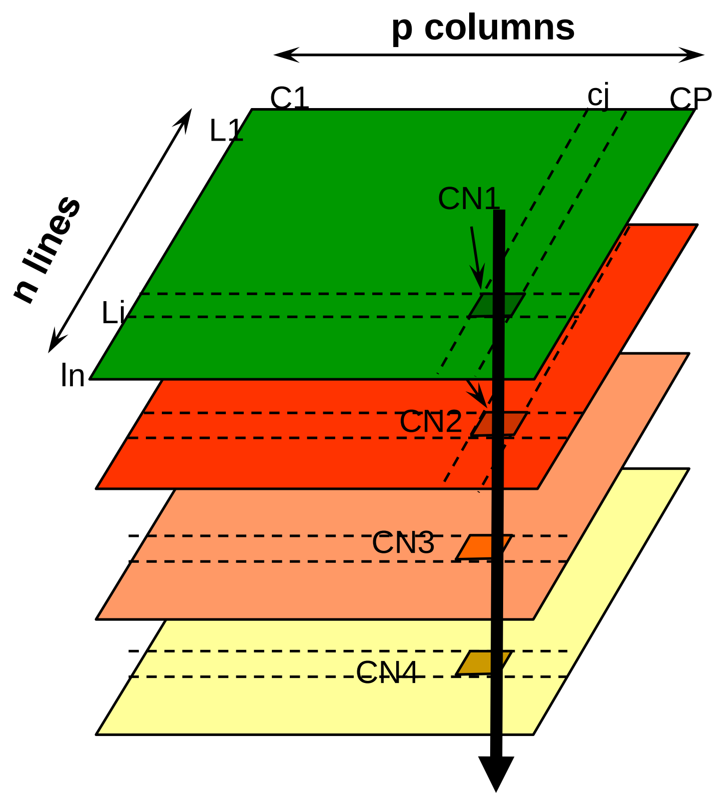
Valeur Numérique pour chaque pixel (DN)

- Une image en 16 bits nécessite deux fois plus de place disque qu'une image en 8 bits:

- Une image en 16 bits, composée de nl lignes et de nc colonnes occupe 2 x nl x nc octets

Structure of an image

- One image = n spectral bands



Example Spot-6 : 4 channels

Blue XS1

Green XS2

RedXS3

PIR XS4

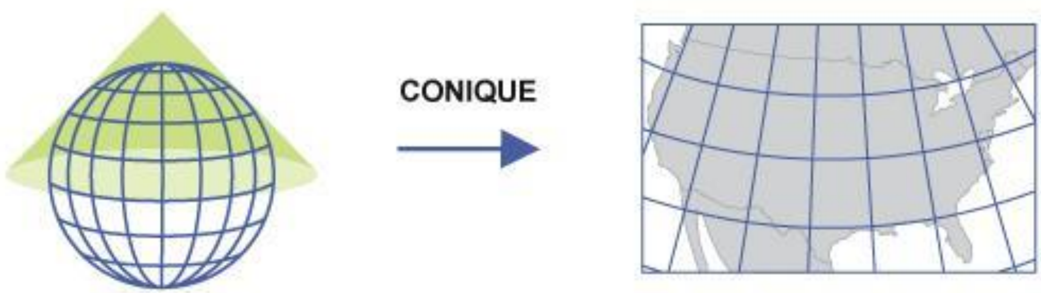
One pixel = 4 digital counts

Characteristics of the satellite image

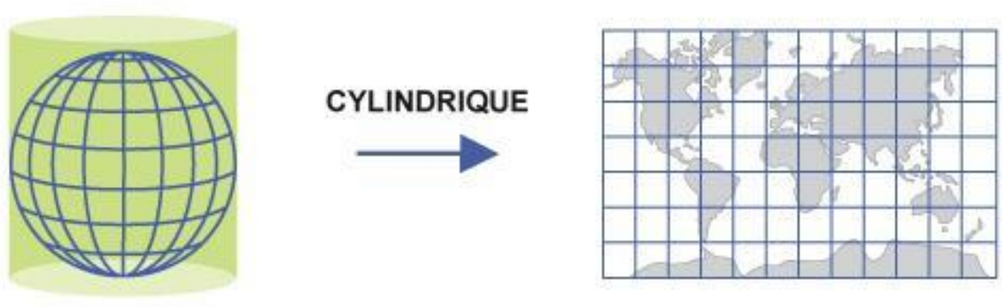
Projection system :

- All digital geographic data , including satellite or aerial imagery, must have a projection system

- The projection system helps us to define the location of each pixel of the image on the surface of the earth:



RGF93 projection system from France

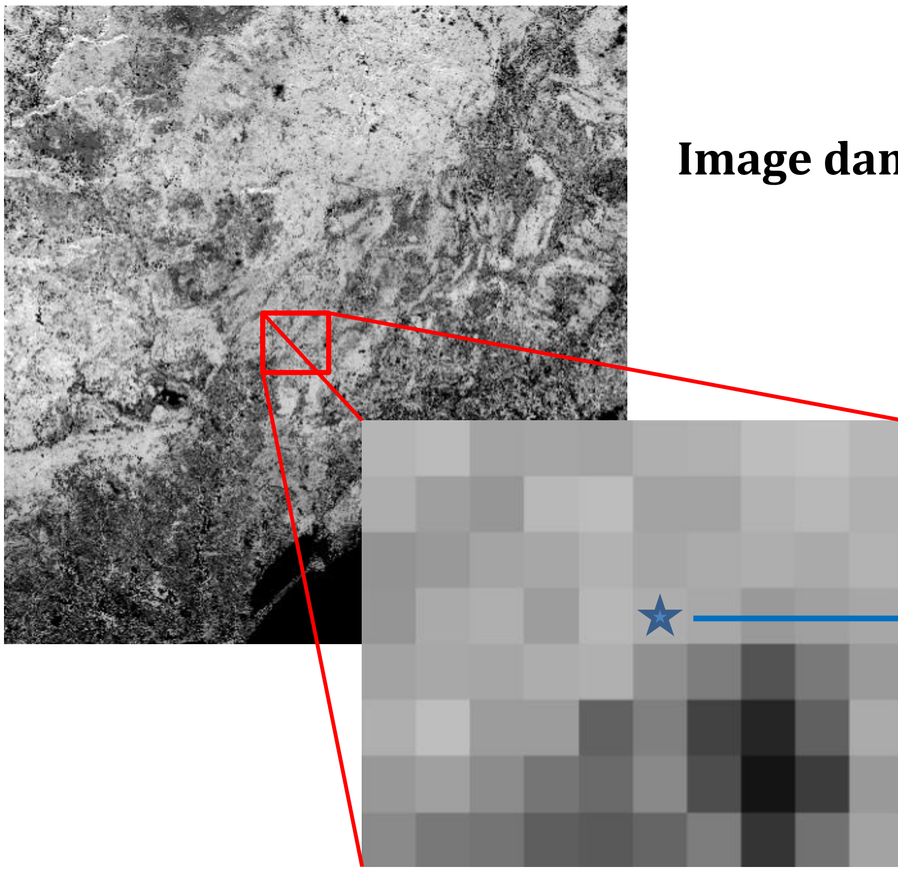


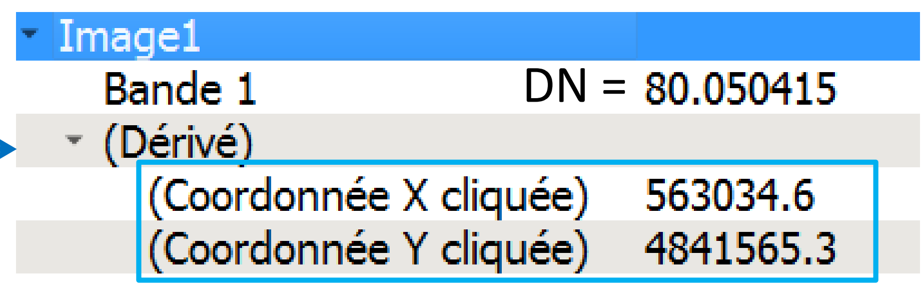
UTM projection system
(Universal Transverse Mercator)

Caractéristiques de l'image satellitaire

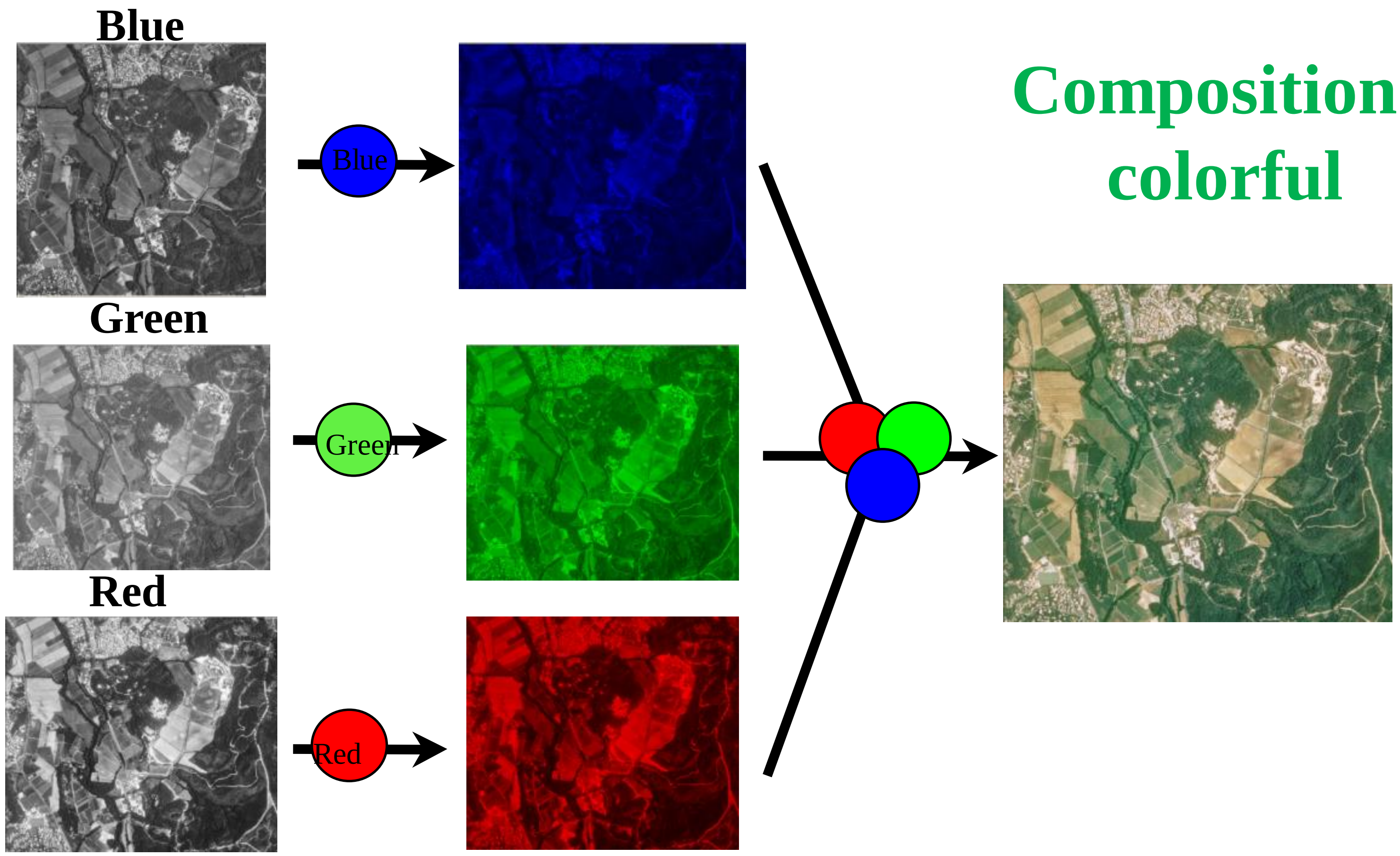
Chaque pixel est alors défini en plus du DN par les coordonnées (x,y) du centre du pixel

Image dans le système de projection UTM 31N

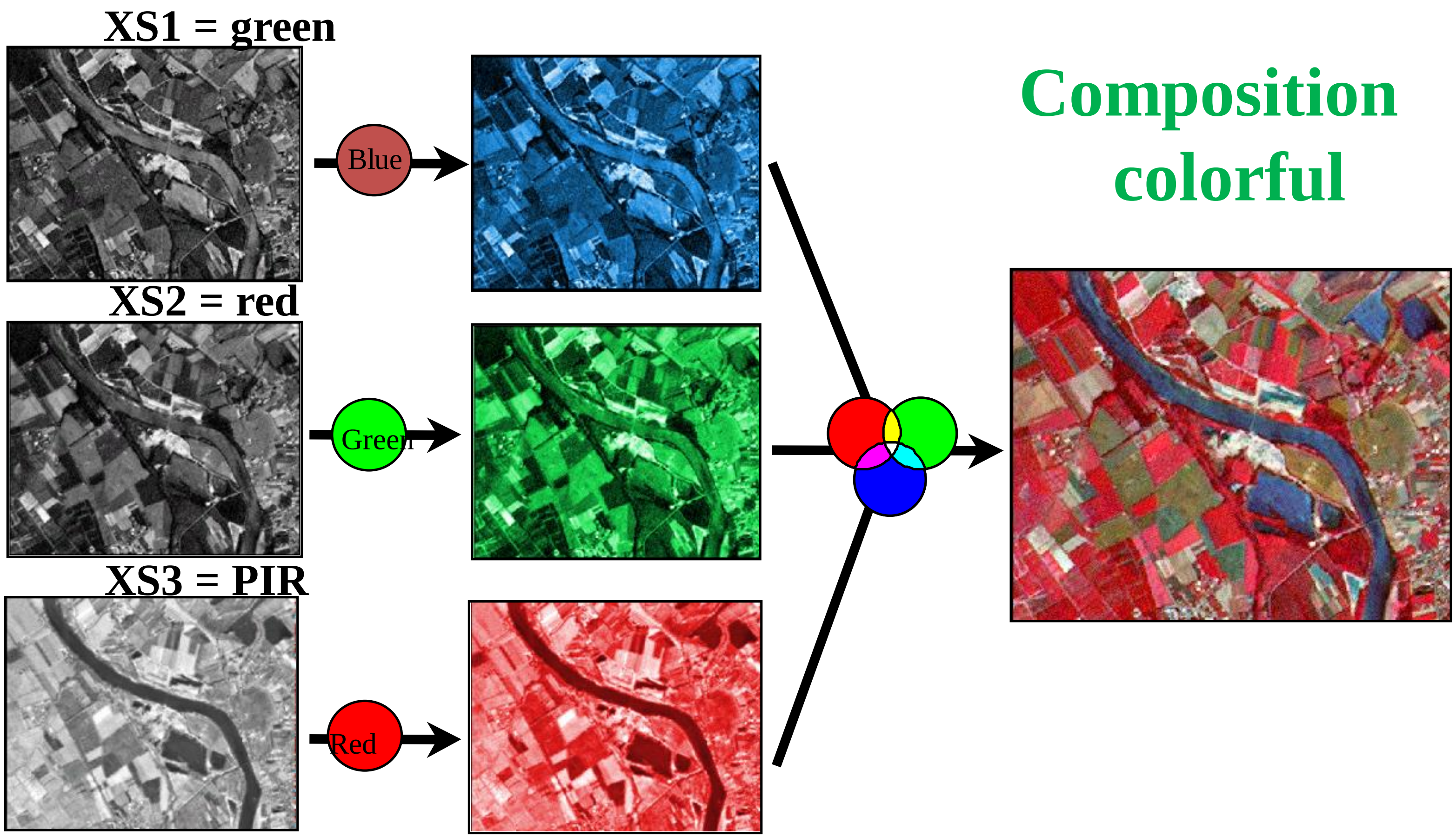




Displaying a colored composition
Image in natural colors



Displaying a colored composition
False color image



Satellite characteristics

LANDSAT 8

Le huitième satellite de la série des satellites LANDSAT américaine

- Date de lancement: 11 février 2013
- Nombre de bandes: 9
- Résolution spatiale: 15 – 30 m
- Résolution temporelle: 16 jours
- Swath: 185 km
- Accès: gratuit

Caractéristiques des données:

- Format de données: GeoTIFF
- Projection: Cartographique Transversale Universelle Mercator (UTM)
- Résolution radiométrique: 16 bits

Applications:
Agriculture, forêts, changement d'affectation des terres, changement de couverture des terres. Cartographie des variables biophysiques telles que la teneur en chlorophylle des feuilles.

LANDSAT 8

The 9 LANDSAT 8 sensor bands:

Satellite	Bandaged	bandwidth (µm)	Spatial resolution
Landsat 8	Coastal Aerosol (0.43 – 0.45 µm)	0.43 – 0.45	30m
	Blue (0.490 µm)	0.45 – 0.51	30m
	Green (0.560 µm)	0.53 – 0.59	30m
	Red (0.665 µm)	0.63 – 0.67	30m
	Near Infrared (0.842 µm)	0.85 – 0.88	30m
	Short Wave Infrared 1(1.375 µm)	1.57 – 1.65	30m
	Short Wave Infrared 2(1.375 µm)	2.11 – 2.29	30m
	Panchromatic	0.50 – 0.68	15m
	Cirrus	1.36 – 1.38	30m
	Thermal infrared 1	10.6 – 11.19	30m (100)
	Thermal Infrared 2	11.5 – 12.51	30m (100)

SENTINEL 2 (A and B)

The Sentinel-2 satellite is the first optical Earth observation satellite of the European Copernicus program .

- Launch date : June 23, 2015
- Number of bands: 13 bands
- Spatial resolution: 20 – 60 m
- Temporal resolution: 10 days (5 days in Europe with S2A and S2B)
- Access: free

Data characteristics :

- Format : GeoTIFF
- Projection: Universal Transversal Cartographic Mercator (UTM)
- Radiometric resolution: 16 bits

Applications:

Agriculture, forestry, land use change, land cover change. Mapping of biophysical variables such as leaf chlorophyll content .

SENTINEL 2 (A and B)

The 13 SENTINEL 2 8 sensor bands:

Satellite	Bandaged	Spatial resolution
Sentinels – 2	Coastal Aerosol (0.443 µm)	60m
	Blue (0.490 µm)	10m
	Green (0.560 µm)	10m
	Red (0.665 µm)	10m
	Red-edge vegetation (0.705 µm)	20m
	Red-edge vegetation (0.740 µm)	20m
	Red-edge vegetation (0.738 µm)	20m
	Near Infrared (0.842 µm)	10m
	Red-edge vegetation (0.865 µm)	20m
	Water vapor (0.945 µm)	60m
	Wave Shorts (1.375 µm)	60m
	Short Wave Infrared (1.610 µm)	20m
	Infrared Wave Shorts (2,190 µm)	20m

SPOT-6/7

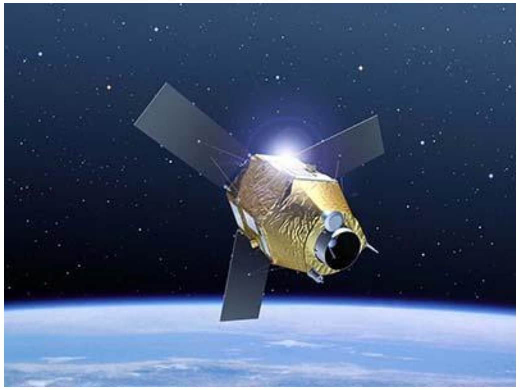
SPOT-7 satellite sensor built by AIRBUS Defense & Space

- Launch date : June 30, 2014
- Number of bands: 4 bands + panchromatic
- Spatial resolution: 1.5 – 6 m
- Temporal resolution: Regular visits everywhere
- Radiometric resolution: 12 bits
- Swath: 60km
- Access: Paying

Satellite	Bandaged	Spatial resolution
SPOT -6/7	Blue (0.455µm – 0.525µm)	6m _
	Green (0.530µm – 0.590µm)	6m _
	Red (0.625µm – 0.695µm)	6m _
	Close Infrared (0.760 µm – 0.890 µm)	6m
	Panchromatic	1.5m

Pléiades-1A et 1B

Capteur du satellite Pleiades-1A (1B) construit par AIRBUS Défense.



- Date de lancement: 16 décembre 2011
- Nombre de bandes: 4 bandes + panchromatique
- Résolution spatiale: 0.7 – 2.8 m
- Résolution temporelle: Des visites régulières partout
- Résolution radiométrique: 12 bits
- Swath: 20 km
- Accès: Payant

Satellite	Bande	Résolution spatiale
Pléaides	Bleu (0,430 µm – 0,550 µm)	2 m
	Vert (0,490 µm – 0,610 µm)	2 m
	Rouge (0,600 µm – 0,720 µm)	2 m
	Proche Infrarouge (0,750 µm – 0,950 µm)	2 m
	Panchromatique (noir er blanc)	1,5 m

Applications of remote sensing

Applications of remote sensing

Land cover mapping : optical images

- Land cover mapping is one of the most important applications of remote sensing.

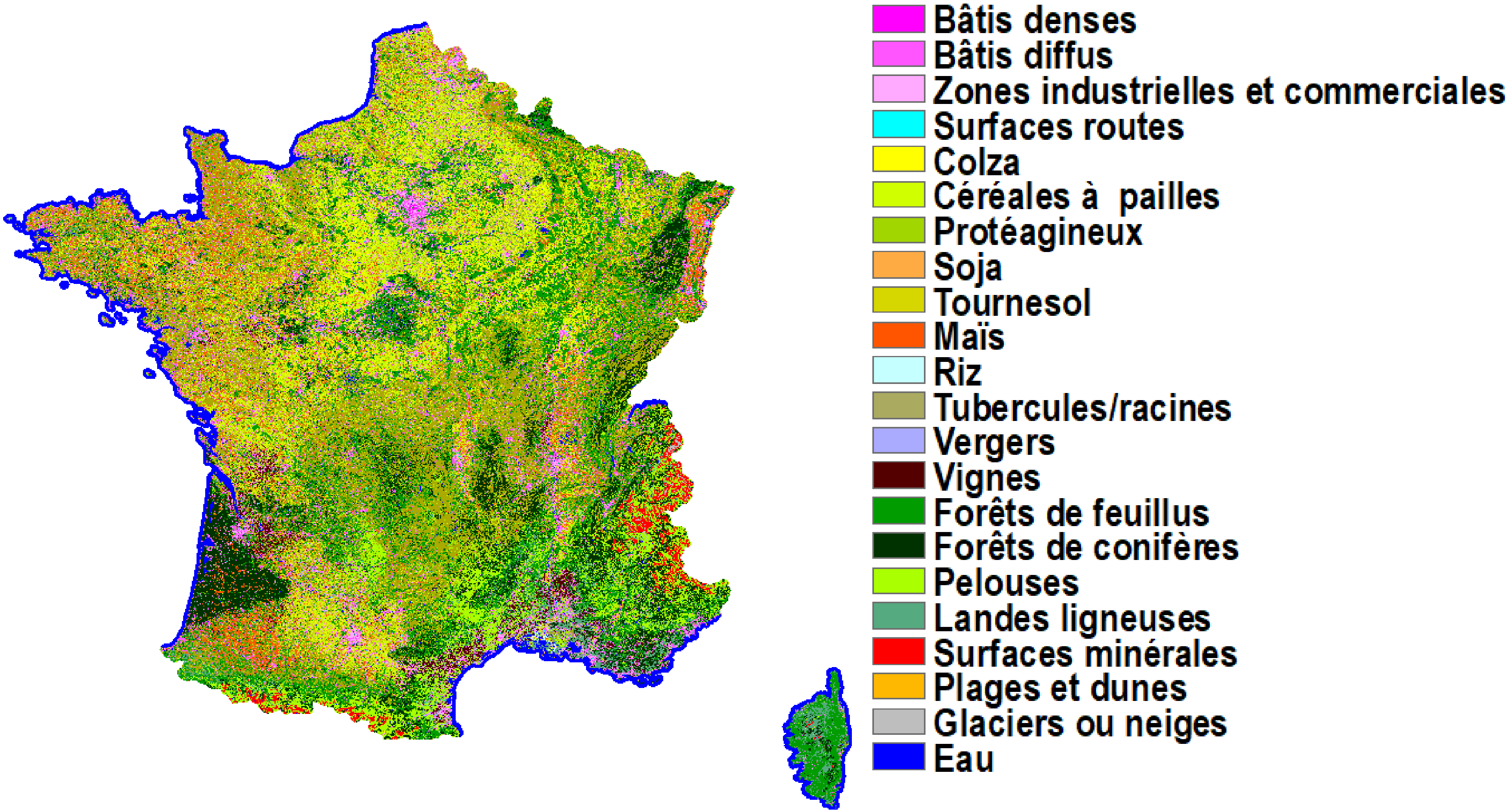
- mapping by remote sensing is mainly based on the spectral response in different wavelengths and at different dates of each object on the earth's surface Multi -temporal optical images with several spectral bands are generally used .

- For example, a land cover map is created each year in France by the Theia cluster (https://www.theia-land.fr/) using multi-temporal optical data from Sentinel-2.

- This classification is carried out thanks to the expertise of the CESBIO laboratory .

Applications of remote sensing

Land cover mapping : France



Applications of remote sensing

Moisture Mapping : Radar and Optical Images

- Important application for several applications in hydrology and agriculture

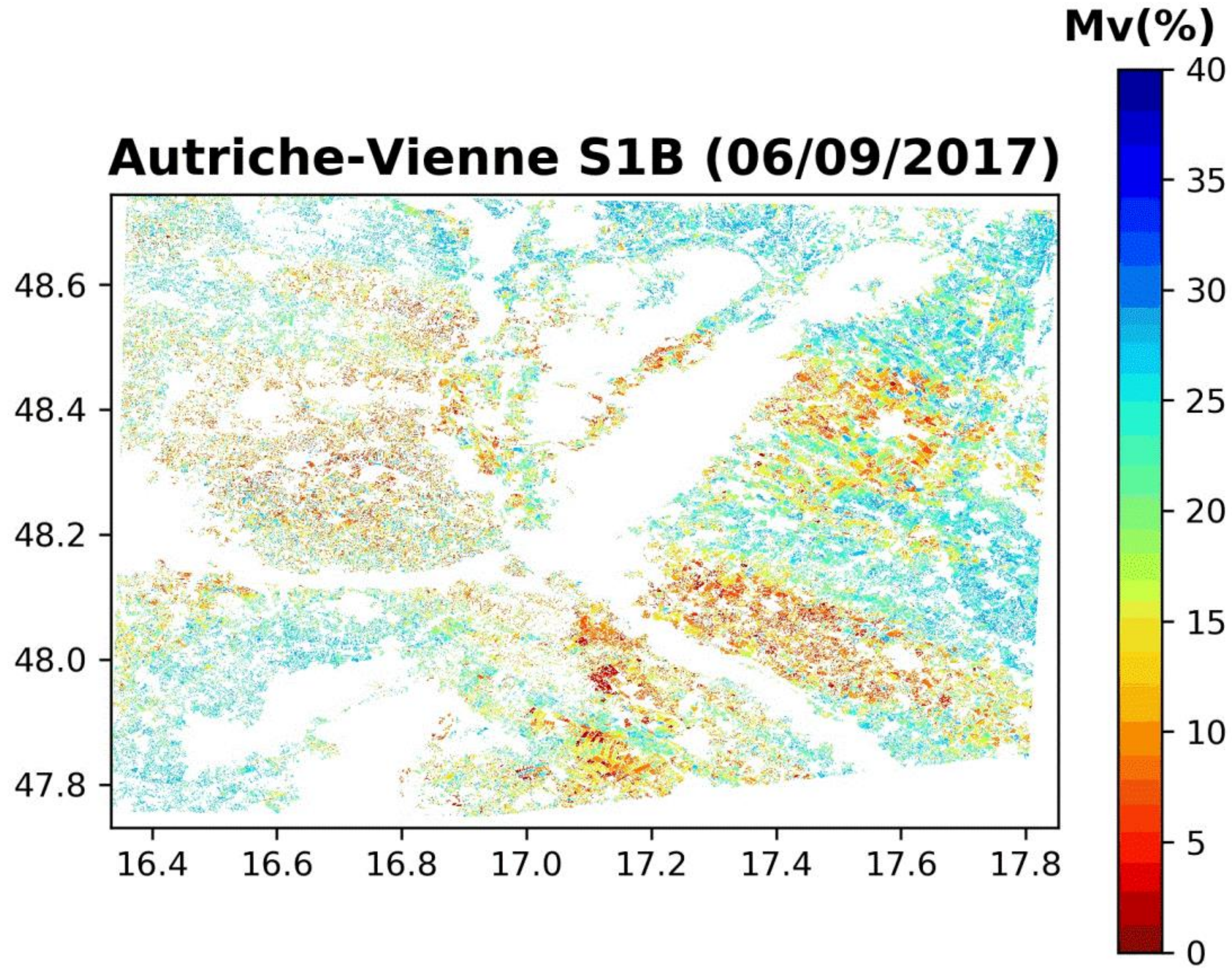
- Estimation of soil moisture at the very fine scale of the plot

- For example, the European Space Agency provides an estimate of soil moisture derived from Sentinel-1 data at a spatial resolution of 1 km

- Thanks to the expertise of UMR TETIS, the Theia cluster provides plot-scale soil moisture maps using Sentinel - 1 and Sentinel-2 data .

Applications of remote sensing

Example of soil moisture mapping at plot scale

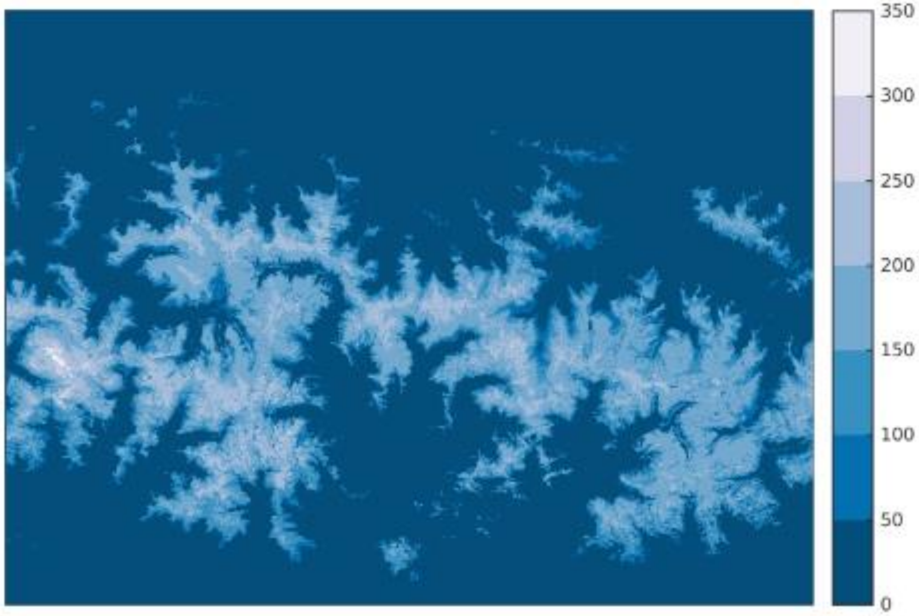


Applications of remote sensing

C artography of the snow cover:

- Snow cover is extracted using optical images

- Thanks to the expertise of CESBIO , Theia produces snow cover maps using Sentinel-2 satellite imagery at 20 m spatial resolution



Map of the snow coverage in the Pyrenees during a hydrological year (1 September 2016 to 31 August 2017) produced by synthesis of Theia snow-covered surface products.

Applications of remote sensing

Vegetation monitoring

- One of the most important applications of remote sensing is monitoring the phenological cycles of vegetation.

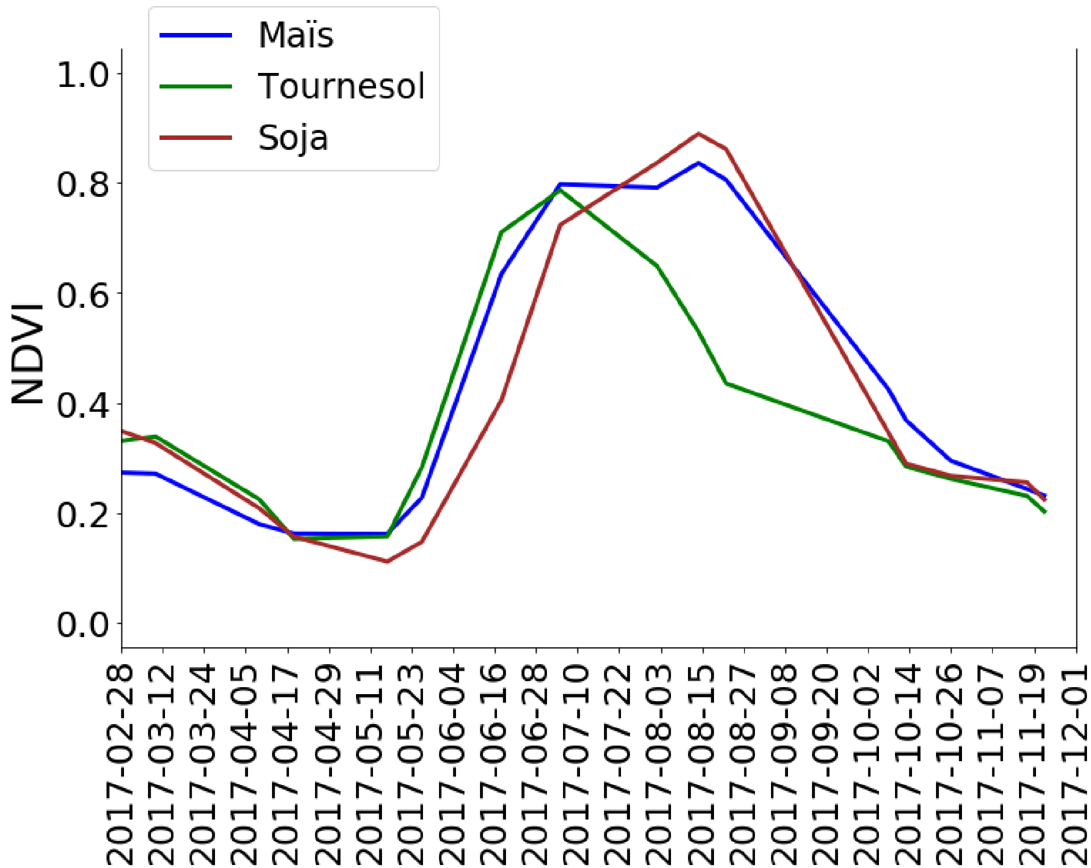
- Thanks to remote sensing, the vegetation is studied using several vegetation indices derived from the spectral bands of the optical sensors

- The **NDVI** (Normalized differential Vegetation Index) is a vegetation index calculated using optical images. It is used to study the evolution of the chlorophyll activity of the vegetation.

$$\mathbf{NDVI} = \frac{\mathbf{PIR - R}}{\mathbf{PIR + R}} \quad \mathbf{-1 < NDVI < 1}$$

Applications of remote sensing

- Each culture has its own NDVI temporal profile that represents its growth
- By using a time series of the NDVI, it is possible to distinguish different types of crops



Applications of remote sensing

- The leaf index, or leaf area index (**LAI** , in English Leaf Area Index), is a dimensionless quantity, which expresses the leaf area per unit of soil surface.

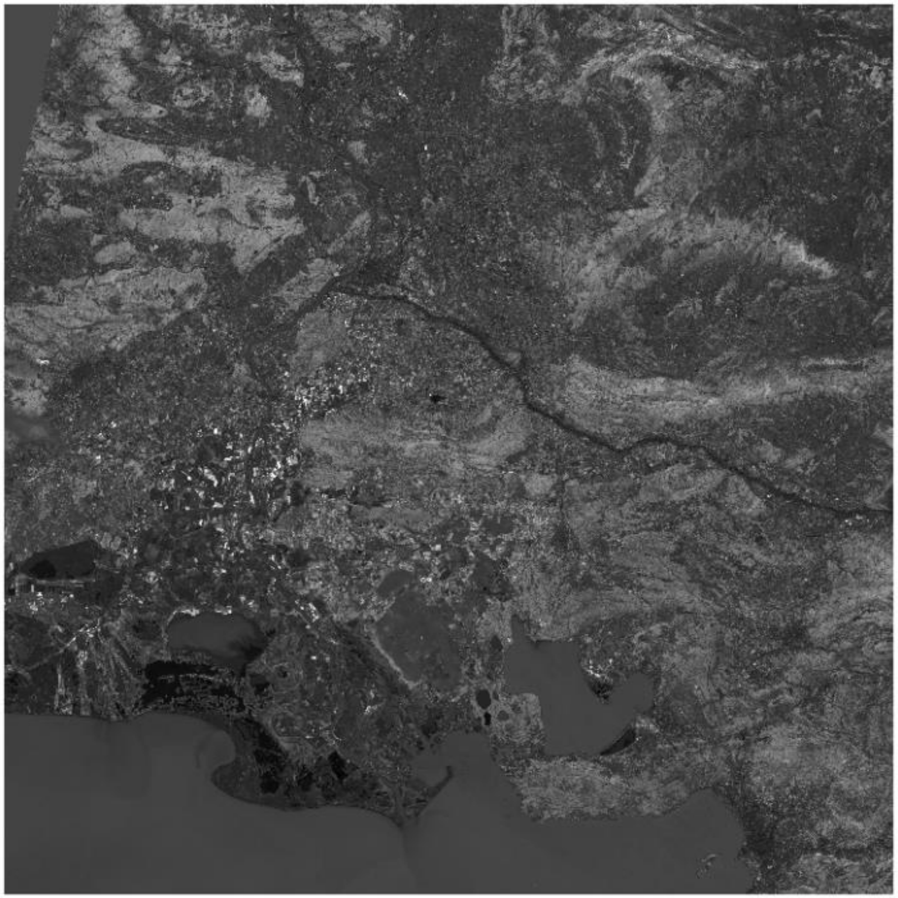
- Color index=IC= (R - G) / (R + G): characterizes the color of the floors

Applications of remote sensing

NDVI and LAI calculated from Sentinel-2 image at 10 m spatial resolution

NDVI

-1 **1**

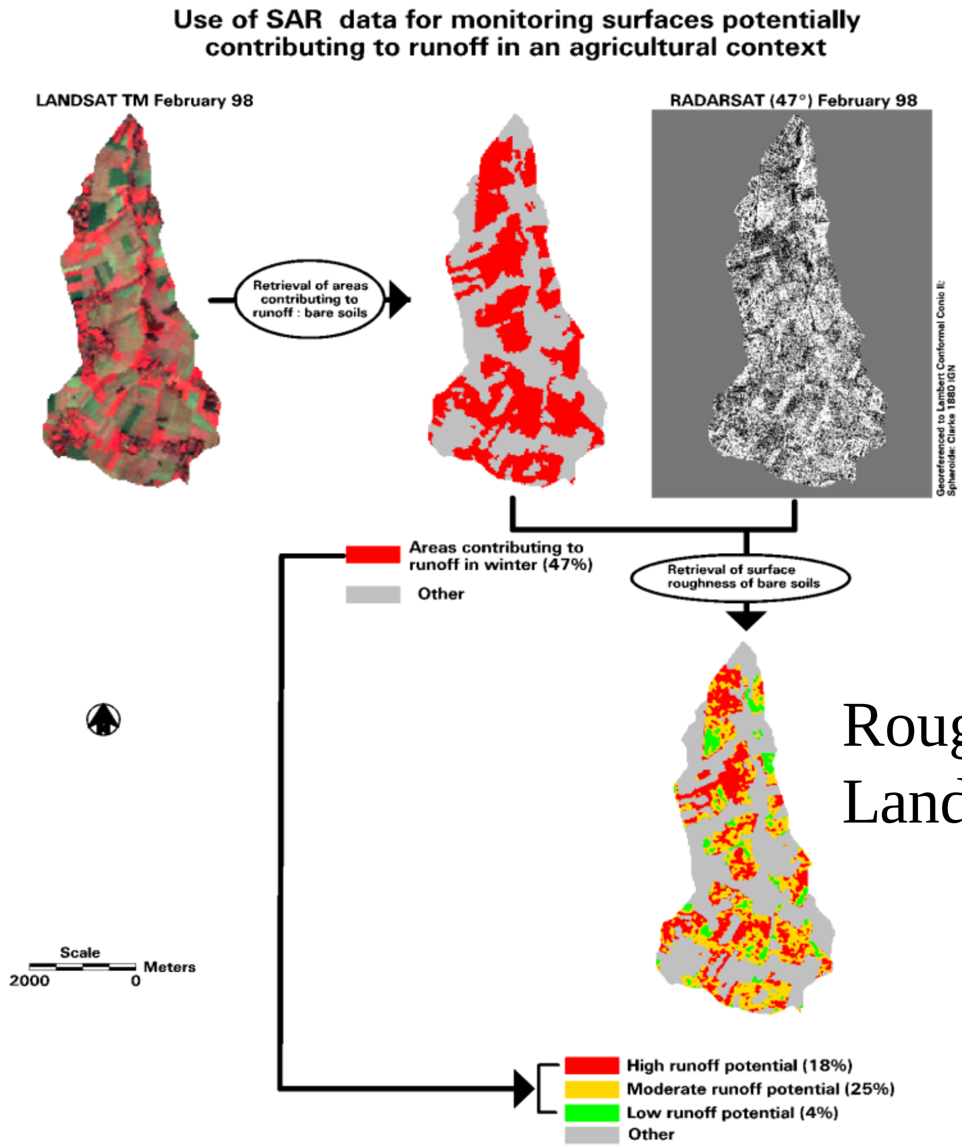


LAI

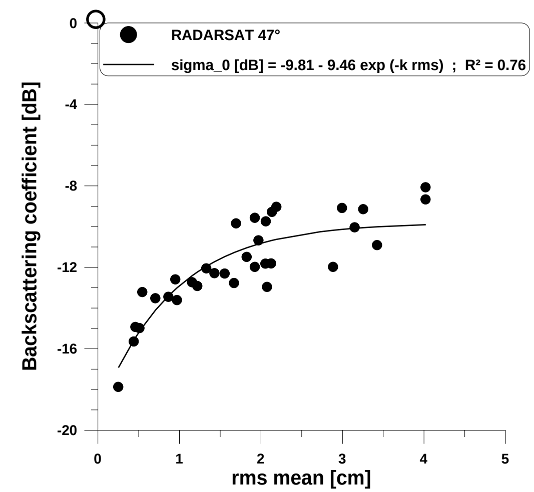
0 **5**

Applications of remote sensing

Mapping of surfaces contributing to runoff



σ RADARSAT 47°



rms

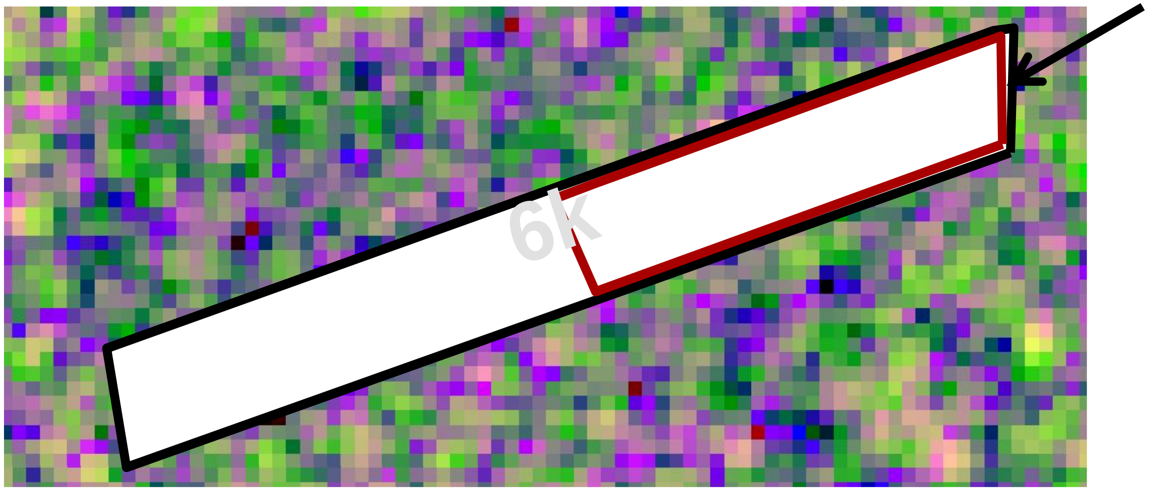
Roughness : access by radar

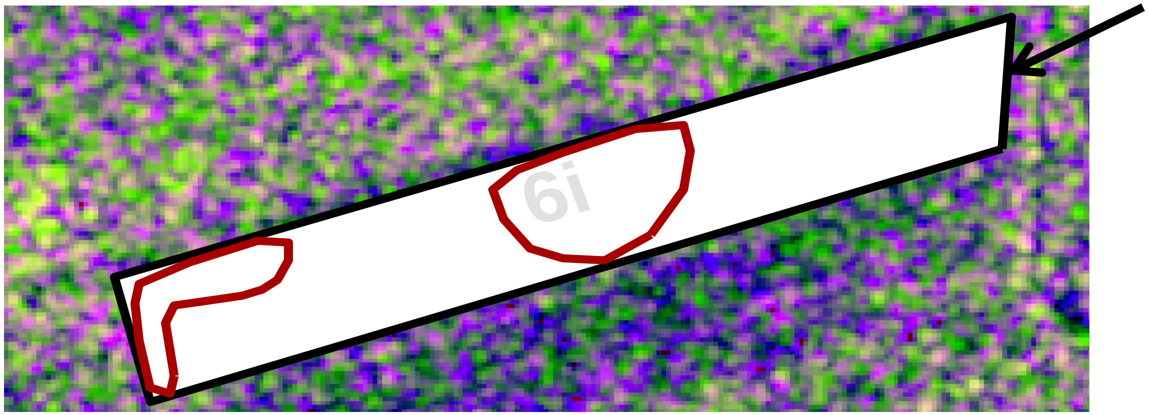
Land occupation: optical access

Applications of remote sensing

Irrigation monitoring

The Radar images are able to detect irrigation on the plots ➔ strong increase in the radar signal .





Access to data

Accès aux images

Les principaux:

Theia Land: https://www.theia-land.fr/en/products/

- Sentinel-2
- Landsat 1-7
- Spot 1-6/7
- Venus (nano-satellite)

Copernicus (ESA) https://scihub.copernicus.eu/dhus/#/home

- Sentinel-1
- Sentinel-2
- Sentinel-3

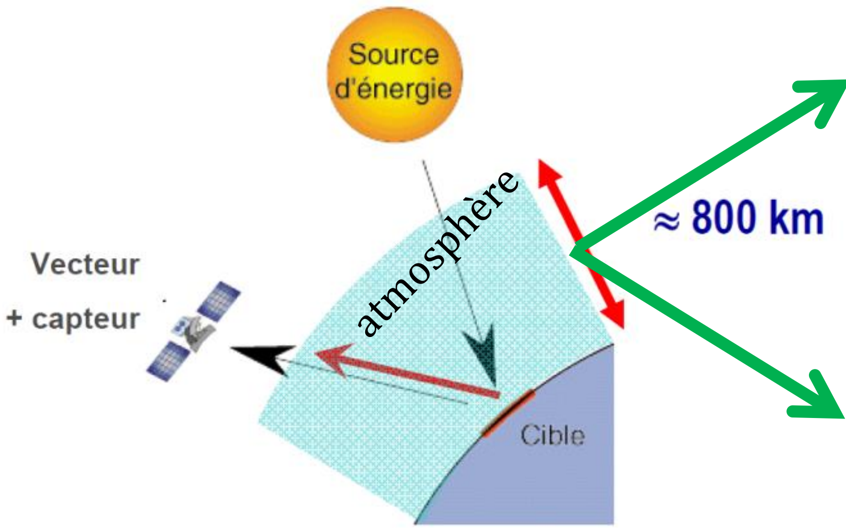
Earth Explorer (USGS): https://earthexplorer.usgs.gov/

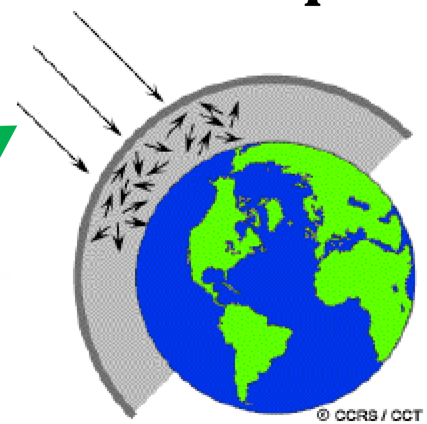
- Landsat
- MODIS (Moderate Resolution Imaging Spectroradiometer)
- SRTM (Shuttle Radar Topography Mission)

Calibration des images optiques

Corrections radiométriques

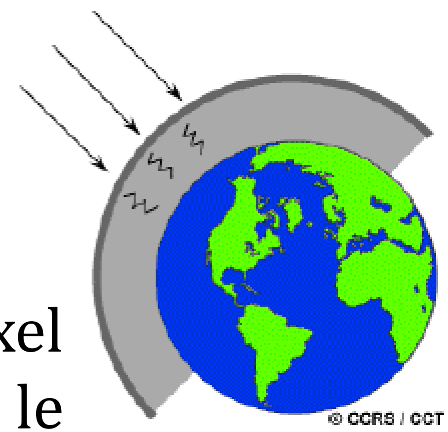
Pourquoi des corrections radiométriques?





Diffusion

- Déviation du rayonnement



Absorption

- Absorption de l'énergie par les grosses molécules de l'atmosphère (O3, H2O, CO2)

La valeur enregistrée à un pixel comprend non seulement le rayonnement réfléchi de la surface, mais également le rayonnement diffusé et émis par l'atmosphère

Corrections radiométriques

Les corrections radiométriques sont appliquées sur les images pour réaffecter à chaque pixel une valeur de réflectance. C'est une opération qui est requise avant l'extraction de l'information

LEVEL 0

données brutes de l'instrument

LEVEL 1

réflectance TOA (Top Of Atmosphere)

LEVEL 2

réflectance TOC (Top Of Canopy)

Coefficients de calibration des capteurs + paramètres d'acquisition (éclairement solaire, angles solaires, angles de visée)

Paramètres atmosphériques à la date d'acquisition

Geometric corrections

Geometric correction is required due to:

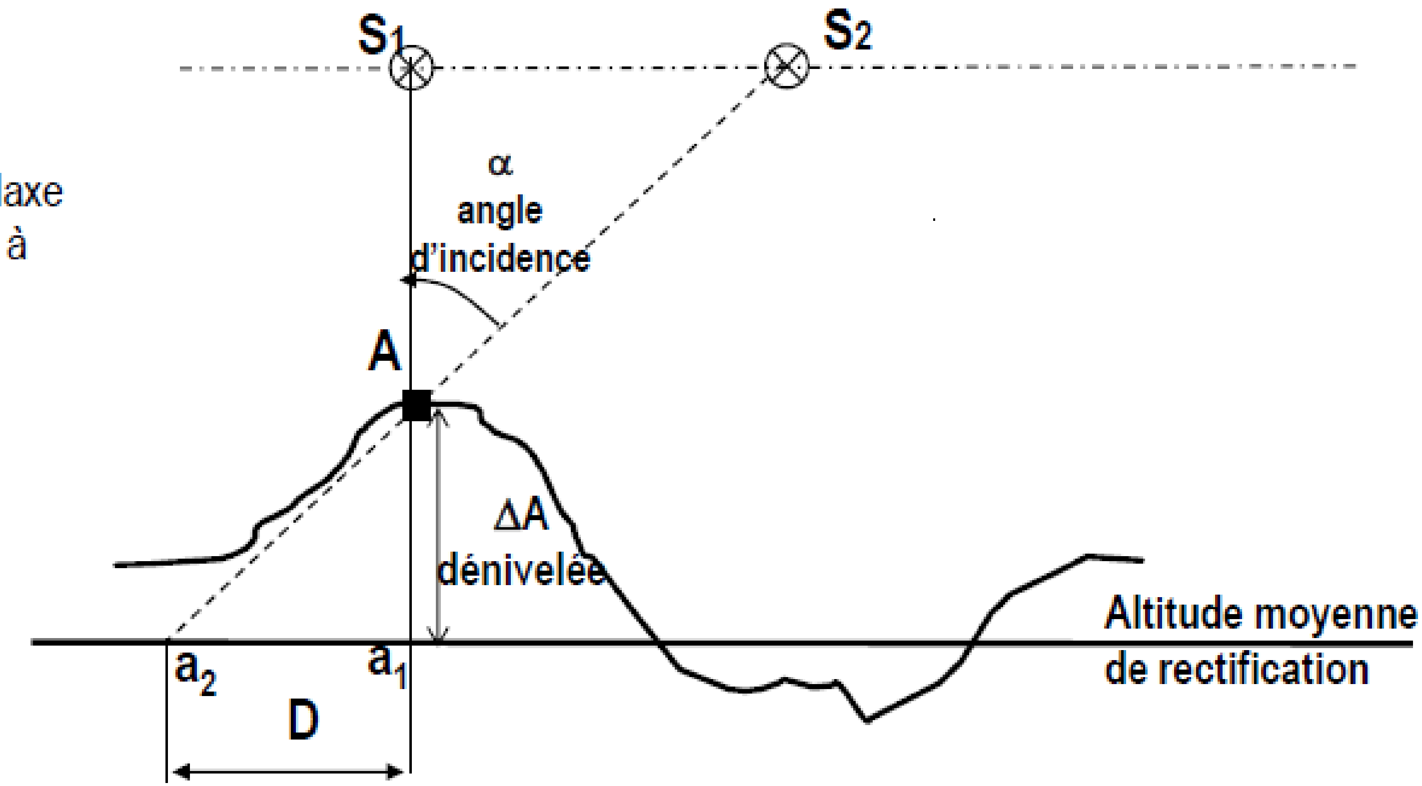
- Geometric distortions that occur due to
  - viewing angle _
  - Shooting geometry _ _

- Random distortions that occur due to relief

A digital terrain model ("z" altitude of land surface) and ground control points (GCPs) are used to correct for random distortion ➔ a **" orthorectification "**

Geometric corrections

- **Effets du relief**
  - erreurs de parallaxe dues au relief et à l'angle de visée



a1: coordonnées dans l'image en visée oblique

a2: coordonnées dans l'image en visée verticale

$$D = \Delta A \, tg(\alpha)$$

ex: pour une dénivelée de 200m et un angle d'incidence de 20°, le décalage est de 73m soit environ 7 pixels SPOT en mode multispectral

Geometric corrections

Orthorectification :

Orthorectification _ is the process of removing bump (terrain) effects from the image in an effort to create a planimetrically correct image.

In the resulting orthorectified image the features of the image are represented in their "true" positions. This allows precise direct measurement of distances, angles and areas