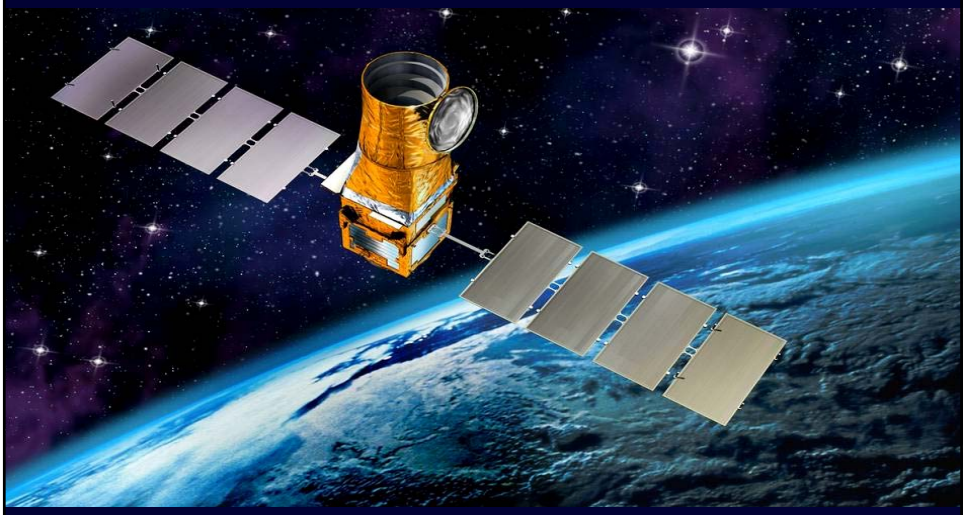
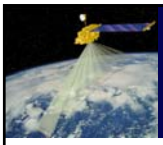
Remote Sensing



Tamas Utasi , Noemie Perona

Readings in VGIS



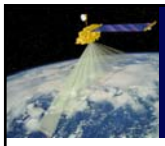
Outline

1 - Introduction

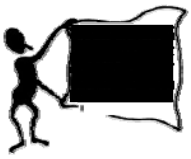
2 - Sensor

3 - Image Analysis

4 - Applications



Outline



1 - Introduction

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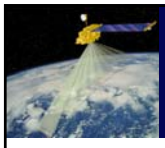


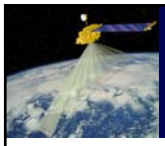
What is Remote Sensing?

« The science used to determine physical and biological characteristics of objects by measures made remotely, without contact with these. »
Interministerial committee of the aerospace remote sensing terminology, on 1988.

Can be used :
- To the surface of the Earth towards the atmosphere or towards the space
- To the space towards the Earth

But for this lecture → the techniques of the aerospace remote sensing

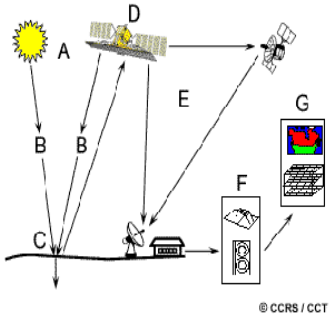
Aims : to study the Earth, the oceans and the atmosphere from planes, from balloons or from satellites, by using the properties of the electromagnetic radiation



What is Remote Sensing?

« The science 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. »
Canadian centre of remote sensing

- **Introduction**
- Sensors
- Image analysis
- Applications



(A) Energy Source or Illumination

(B) Radiation and the Atmosphere

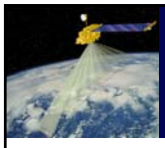
(C) Interaction with the Target

(D) Recording of Energy by the Sensor

(E) Transmission, Reception, and Processing

(F) Interpretation and Analysis

(G) Application



Why is it an interessing topic?

Use of this science needs :

- Understanding the physical events

- Knowledge in sensor

- Image processing

→ Used for many applications

- **Introduction**
- Sensors
- Image analysis
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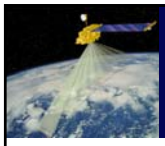

Constitution of Electromagnetic Radiation

- **Introduction**
- Sensors
- Image analysis
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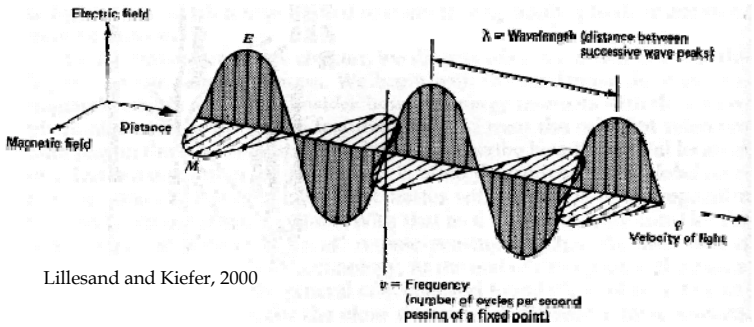
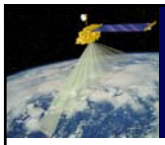


Lillesand and Kiefer, 2000

The wavelength = the length of one wave cycle, which can be measured as the distance between successive wave crests.

Frequency = refers to the number of cycles of a wave passing a fixed point per unit of time.



Interaction with the atmosphere

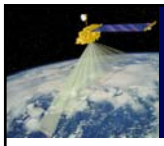
- **Introduction**
- Sensors
- Image analysis
- Applications

Particles and gases in the atmosphere can affect the incoming light and radiation.
These effects are caused by the mechanisms of **scattering** and a**bsorption**.

Absorption → electromagnetic energy is transformed in another kind of energy

Scattering → particles the atmosphere interact with and cause the electromagnetic radiation to be redirected

How much scattering takes place depends on several factors including :
- the wavelength of the radiation
- the abundance of particles or gases
- the distance the radiation travels through the atmosphere



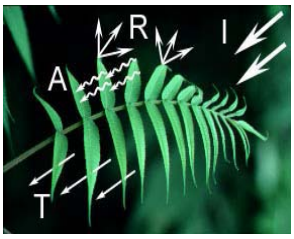
Radiation - Target interaction (1/2)

- **Introduction**
- Sensors
- Image analysis
- Applications

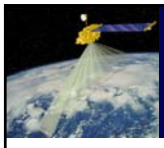
Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface.

There are three forms of interaction :

- absorption (A)
- transmission (T)
- reflection (R)



The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

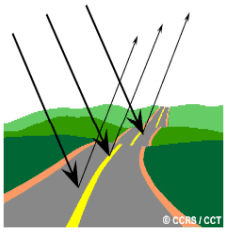


Radiation - Target interaction (2/2)

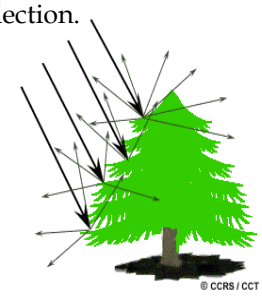
- **Introduction**
- Sensors
- Image analysis
- Applications

In remote sensing, most interesting : to measure the radiation reflected from targets.

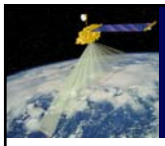
Two types of reflection :
specular reflection and diffuse reflection.



Specular reflexion



Diffuse reflexion



Outline

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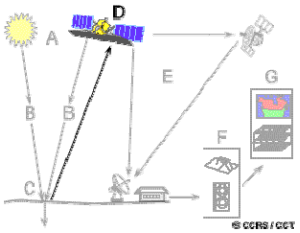
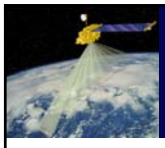
2 - Sensor



3 - Image Analysis

4 - Applications

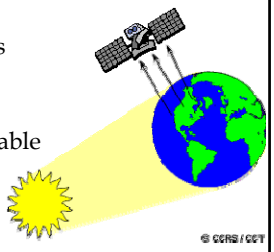


Passive vs. Active Sensing (1/2)

- Introduction
- **Sensors**
- Image analysis
- Applications

The sun's energy is :

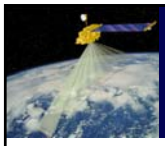
1 - **reflected**, or absorbed, for visible wavelengths
2 - **reemitted**, for thermal infrared wavelengths



Passive sensors : measure energy naturally available → used to detect energy when the naturally occurring energy is available.

For all reflected energy : during the time when the sun is illuminating the Earth. No reflected energy available from the sun at night.

Energy that is naturally emitted : (such as thermal infrared) detected day or night, as long as the amount of energy is large enough to be recorded.



Passive vs. Active Sensing (2/2)

- Introduction
- **Sensors**
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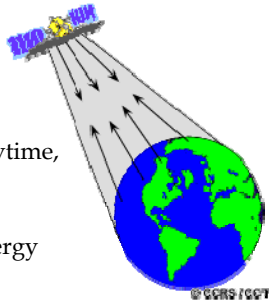
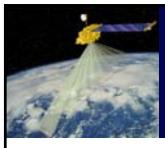
Active sensors : provide their own energy source for illumination.

The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.



Advantage : ability to obtain measurements anytime, regardless of the time of day or season.

Drawback : require a fairly large amount of energy to adequately illuminate targets.



Sensors Utilisation

- Introduction
- **Sensors**
- Image analysis
- Applications

Ground based sensors :

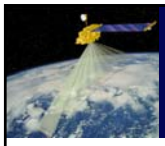
- to record detailed information and to compare with information collected from aircraft or satellite sensors
- to better characterize the target of these other sensors
- to better understand the information in the imagery

Sensor on aircraft :

- to have very detailed images
-to facilitate the collection of data, exctaly in the place and at the time wanted

Sensors on satellites :

to have, thanks to their orbits, repetitive coverage on a continuing basis.

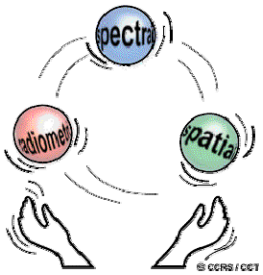


Sensors features

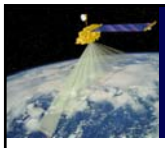
- Introduction
- **Sensors**
- Image analysis
- Applications

Performance of the sensors is connected to several parameters :

- the spatial resolution
- the spectral resolution
- the radiometric resolution
- the temporal resolution



There are trade-offs between spatial, spectral,and radiometric resolution which must be taken into consideration when engineers design a sensor.

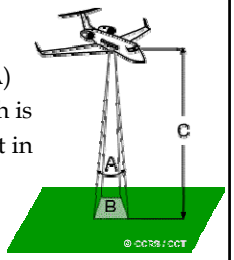


Spatial Resolution

- Introduction
- **Sensors**
- Image analysis
- Applications

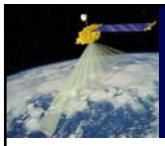
The detail discernible in an image is dependent on the **spatial resolution.**

Spatial resolution of passive sensors depends on their **Instantaneous Field of View (IFOV)**.



The IFOV = angular cone of visibility of the sensor (A)
It determines the area on the Earth's surface (B) which is "seen" from a given altitude at one particular moment in time.

The size of the area viewed = IFOV * (C)
Where (C) = the distance from the ground to the sensor
This area on the ground is called the **resolution cell** and determines a sensor's maximum spatial resolution

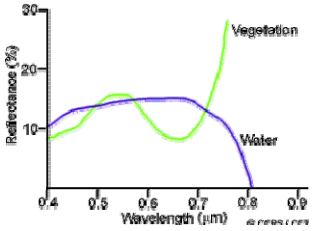


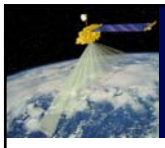
Spectral Resolution (1/2)

The ability of a sensing system to resolve or differentiate electromagnetic radiations of different frequencies

Spectral response and **spectral emissivity curves :** characterize the reflectance and/or emittance of a target over a variety of wavelengths

- Introduction
- **Sensors**
- Image analysis
- Applications





Spectral Resolution (2/2)

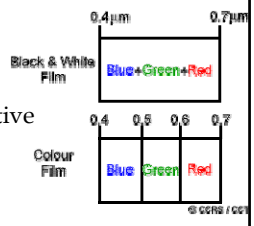
Example 1 :

- Water / Vegetation (Visible light/ Infrared)
- Different kinds of rock → needs finer wavelength ranges
  → needs higher spectral résolution

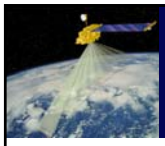
- Introduction
- **Sensors**
- Image analysis
- Applications

Example 2 :

- <u>Black and white film</u> : all the visible portion
  → Coarse spectral resolution
- <u>Colour film</u> :visible portion & individually sensitive to energy at the blue, green, and red wavelengths
  → Higher resolution



High spectral resolution facilitates fine discrimination between different targets



Radiometric Resolution

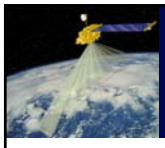
- Introduction
- **Sensors**
- Image analysis
- Applications

The radiometric characteristics describe the actual information content in an image.

The radiometric resolution → ability to discriminate very slight differences in energy.
Fine radiometric resolution of a sensor → very sensitive to detecting small differences in reflected or emitted energy.

The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded

Thus, if a sensor used 8 bits to record the data, there would be 2^8=256 digital values available, ranging from 0 to 255

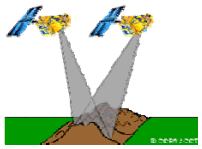


Temporal Resolution

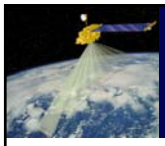
Elapsed time between two images acquired on the same geographical zone

- Introduction
- **Sensors**
- Image analysis
- Applications

The actual temporal resolution of a sensor depends on a variety of factors like:
- the satellite/sensor capabilities
- the swath overlap
- the latitude



By imaging on a continuing basis at different times → to monitor the changes that take place on the Earth's surface
Examples :
-naturally occurring (changes in natural vegetation cover, flooding…)
- induced by humans (urban development or deforestation)



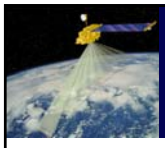
Geometric distortion

- Introduction
- **Sensors**
- Image analysis
- Applications

Problem : geometric distortion
Cause : representation of the three-dimensional surface of the Earth as a two-dimensional image.

The geometric distortions depends on the manner in which the data are acquired.

Factors :
- the perspective of the sensor optics,
- the motion of the scanning system,
- the motion and (in)stability of the platform,
- the platform altitude, attitude, and velocity,
- the terrain relief, and
- the curvature and rotation of the Earth.



Geometric distortion

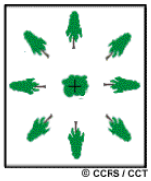
- Introduction
- **Sensors**
- Image analysis
- Applications

In vertical aerial photographs → due to **relief displacement**.

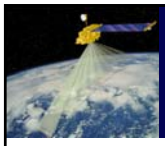
Objects directly below the centre of the camera lens →only their tops visible

All other objects → their tops and sides are visible → give the impression that these objects lean away from the centre of the photo

If the objects are tall or are far away from the centre of the photo →larger distortion and positional error



These problems vary with each specific situation
They are inherent in remote sensing imagery.
They must be taken into account in each instance before attempting to make measurements or extract further information.



Data reception, Transimssion and Processing (1/3)

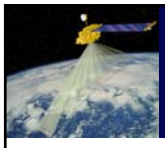
- Introduction
- **Sensors**
- Image analysis
- Applications

Data acquired from satellite platforms need to be electronically transmitted to Earth

Three possibilities :
- Data can be directly transmitted to Earth if a Ground Receiving Station (GRS) is in the line of sight of the satellite

- If this is not the case →data can be recorded on board the satellite for transmission to a GRS at a later time.

-Data can also be relayed to the GRS through the Tracking and Data Relay Satellite System (TDRSS)
TDRSS = consists of a series of communications satellites in geosynchronous orbit.
The data are transmitted from one satelliteto another until they reach the appropriate GRS.



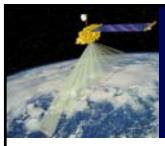
Data reception, Transimssion and Processing (2/3)

- Introduction
- **Sensors**
- Image analysis
- Applications

The data are received at the GRS in a raw digital format.
→ be processed to correct systematic, geometric, atmospheric distortions
→ be translated into a standardized format
→ are written to some form of storage medium such as tape, disk or CD

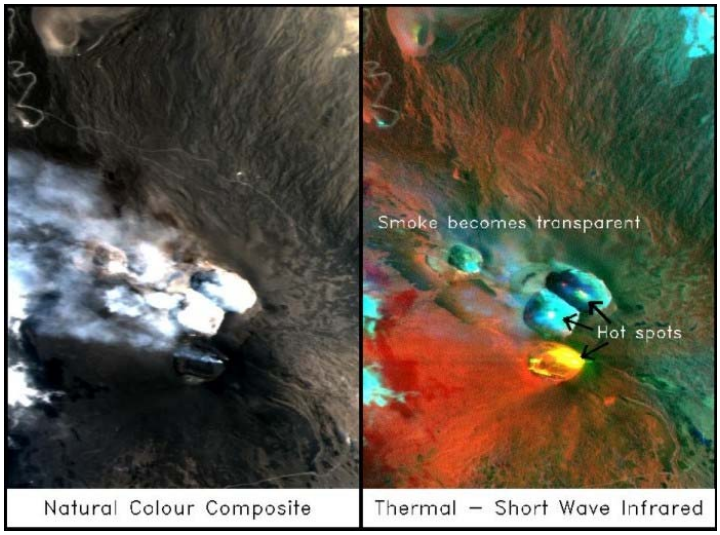
For many sensors → possibilities to provide customers with quick-turnaround imagery.
Use of real-time processing systems =to produce low resolution imagery within hours of data acquisition and to transmit digitally to end users

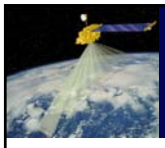
Example of application :
- imagery to ships sailing in the Arctic
- thermal infrared imagery



Data reception, Transimssion and Processing (3/3)

- Introduction
- **Sensors**
- Image analysis
- Applications





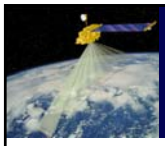
Outline

1 - Introduction

2 - Sensor

3 - Image Analysis

4 - Applications



Context

« Interpretation and analysis of remote sensing imagery involves the identification and/or measurement of various targets in an image in order to extract useful information about them »
Canadian centre of remote sensing

- Introduction
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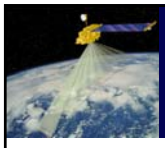
- Applications

Digital processing → to enhance data as a prelude to visual interpretation.

Digital processing and analysis use :
→ to automatically identify targets
→ to extract information completely without manual intervention by a human interpreter.

However, it is not a complete replacement for manual interpretation. Often, it is done to supplement and assist the human analyst.



Elements of Visual Interpretation

Recognizing targets is the key to interpretation and information extraction.

Observing the differences between targets and their backgrounds = comparing different targets based on the visual elements of :

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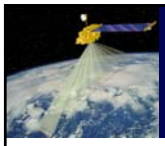
- tone
- shape
- size
- pattern
- texture
- shadow
- association



Elements of Visual Interpretation

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Tone : refers to the relative brightness or colour of objects. Fundamental element

Shape : refers to the general form, structure, or outline

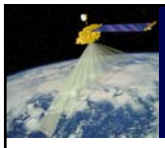
Size : of objects in an image is a function of scale

Pattern : refers to the spatial arrangement of visibly discernible objects

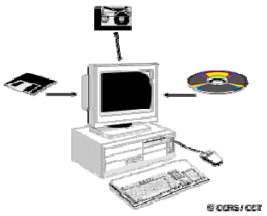
Texture refers to the arrangement and frequency of tonal variation in particular areas

Shadow : provides an idea of the profile and relative height

Association : relationship between other recognizable objects or features in proximity to the target of interest. To provide information to facilitate identification



Digital Image Processing



- Introduction
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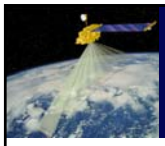
Most remote sensing data are recorded in digital format

All image interpretation and analysis involves some element of digital processing

Most of the common image processing functions available in image analysis systems can be categorized into the following four categories:

- Preprocessing
- Image Enhancement
- Image Transformation
- Image registration
- Image Classification and Analysis



Pre-processing (1/3)

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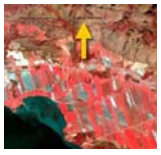
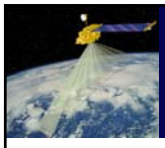
To correct the radiometric and geometric distortions of data

Radiometric distortions :

- Illumination : modeling the geometric relationship and distance between Earth, sensor and sun
- Atmospheric condition : modeling
- Noise : - striping (different detectors) → relative correction among sensors
  - dropped lines (missing data) → to put the line above or below, or average





Pre-processing (2/3)

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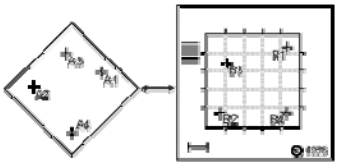
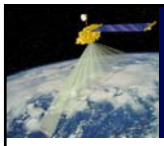
Geometric distortions :
- perspective of the sensor optics
- motion of the scanning system and of the platform
- platform altitude and terrain relief
- curvature and rotation of the Earth



- Systematic, predictable
- Unsystematic, random

Geometric registration process : i**mage-to-map registration**

- To identify the coordinates (row, column) of discernible points :
  ground control points , in the distorted image
- To match to their true positions (latitude, longitude)
- To find the transformation equations



Pre-processing (3/3)

Other procedure : **resampling**

→ to determine the digital values to place in the new pixel locations

- Introduction
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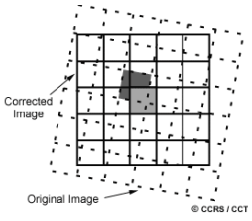
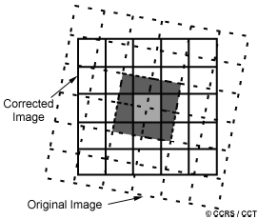
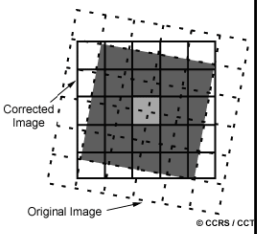
Nearest neighbour



Bilinear interpolation



Cubic convolution



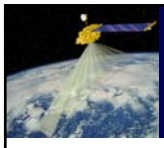


Image Enhancement (1/5)

Enhancements : to make it easier for visual interpretation and understanding of imagery

In raw imagery → the useful data often only a small portion of the available range of digital values → commonly 8 bits or 256 levels

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Contrast enhancement :
→ to change the original values
→ more of the available range is used
→To increase the contrast between targets and their backgrounds

Note : manipulating the range of digital values → its histogram

Many different techniques :
- Use of linear contrast strech
- Use of histogram-equalized strech
- Use of spatial filtering

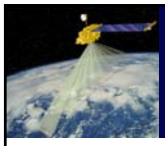

Image Enhancement (2/5)

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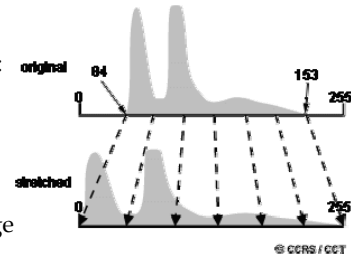
Linear contrast strech :
To identify lower and upper bounds from the histogram → to apply a transformation to stretch this range to fill the full range

This enhances the contrast in the image :
→ light toned areas appearing lighter
→dark areas appearing darker



A uniform distribution of the input range of values across the full range :
→ not always be an appropriate enhancement, particularly if the input range is not uniformly distributed

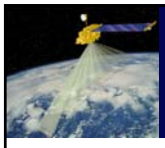


Image Enhancement (3/5)

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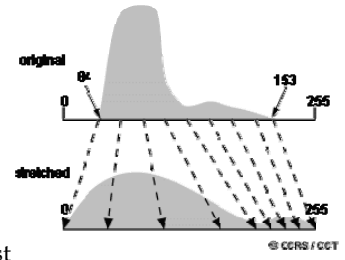
Histogramm equalized strech :
More displayed values to the frequently occurring portions of the histogram

The detail in these areas → better enhanced relative to those areas of the original histogram where values occur less frequently.



Example : wish = to enhance the contrast in only a specific portion of the histogram :
→ The detail in this part would be greatly enhanced
→ The detail in the other areas would be lost

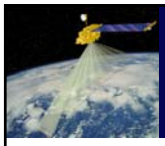


Image Enhancement (4/5)

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Spatial filtering : to enhance the appearance of an image
→to highlight or to suppress specific features based on their **spatial frequency**.
Spatial frequency → image texture.
→ the frequency of the variations in tone

"**Rough**" textured areas of an image = where the changes in tone are abrupt over a small area → high spatial frequencies

"**Smooth**" areas with little variation in tone over several pixels → have low spatial frequencies

Filtering procedure → moving a 'window' of a few pixels in dimension (e.g. 3x3, 5x5) over each pixel in the image

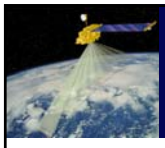
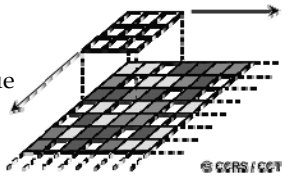


Image Enhancement (5/5)

Method:
- Applying a mathematical calculation
- Replacing the central pixel with the new value
- Repeating the calculation
→ a "new" image has been generated.



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Low-pass filter = to emphasize larger, homogeneous areas of similar tone
to reduce the smaller detail
to smooth the appearance

High-pass filters = to sharpen the appearance of fine detail

Directional, or edge detection filters = to highlight linear features
to enhance features which are oriented in specificdirections

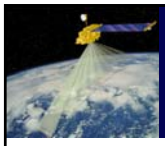

Image Transformations

- Introduction
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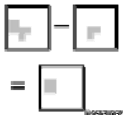
Basic image transformations → simple arithmetic operations

Image subtraction →often to identify occurred changes between images collected on different dates.



Spectral ratioing → to highlight subtle variations in the spectral responses of various surface covers

Results : enhancement variation
variations in scene illumination are reduced

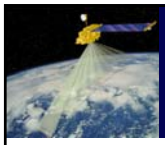


Image Registration

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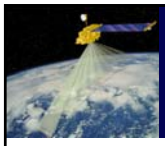

Image Classification and Analysis (1/2)

- Introduction
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Aim : to assign all pixels in the image to particular classes or themes

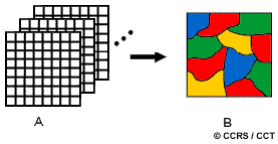
2 classes :

- information classes : categories of interest (water, forest)
- spectral classes : group of uniform pixels (brightness)

Objective : to match the spectral classes to the information classes

2 classification procedures :

- Supervised classification
- Unsupervised classification



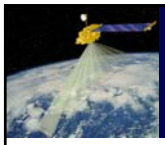


Image Classification and Analysis (2/2)

- Introduction
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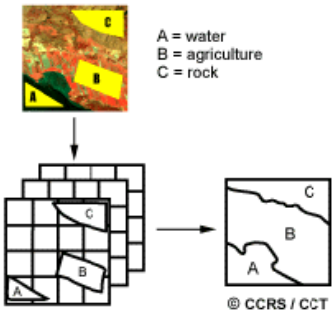
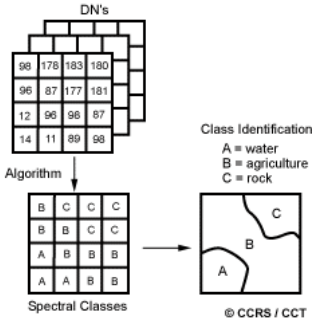
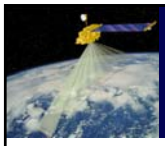
Supervised classification :



Unsupervised classification :





Data intergration and Analysis

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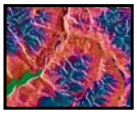
Data integration = the combining of data from multiple sources

Aim = to extract better information

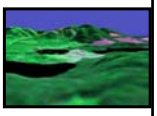
Data =

- multitemporal : image substraction

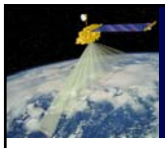
-multiresolution : to sharpen the spatial detail
to enhance some features



- multisensor : complementary information
(spectral information & structure)



- multi-data type in nature : three-dimensional perspective views



Outline

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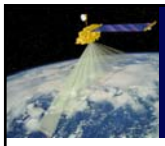

Application field

- Introduction
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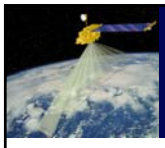
- **Applications**

Geosciences	Geology, pedology, geomorphology
Marine environment and littoral	Quality of the water , oceanic circulation, marine vegetation
Atmosphere and climate	Meteorology, energetic and hydric balance
Global change	Desertification, climatic variation, constitution of the atmosphere
Environmental calamity	Forest fire, flooding, drought, oil slick
Hydrology	Cycle of water, water on the surface of the ground and in the ground



Application field

- Introduction
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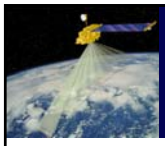
- **Applications**

Glaciology	Track of glacier
Biosphere	Vegetation cartography
Developped space	Forestry, growth of cities, agricultural statistics
Archeology	Archeological cartography
Humanitarian	Alerte for famine, refugee
Health	Forcasting of epidemic disease, link with global change



Ozone Hole

- Introduction
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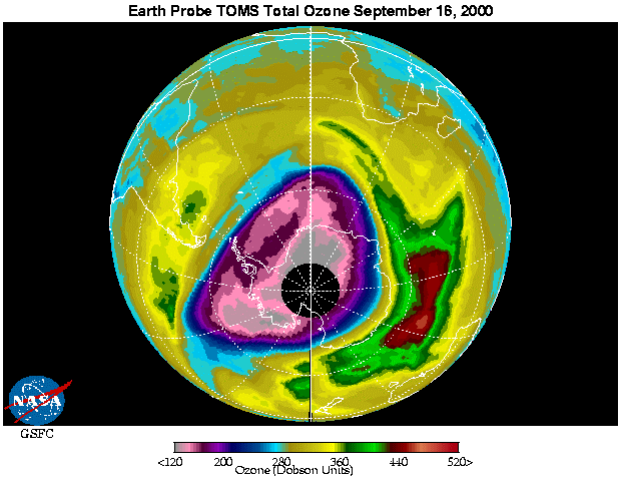
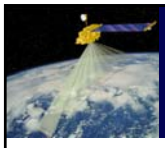
- **Applications**



Thickness of the "ozone layer" on Antarctica, on September 16th, 2000.



Oceanic turbidity

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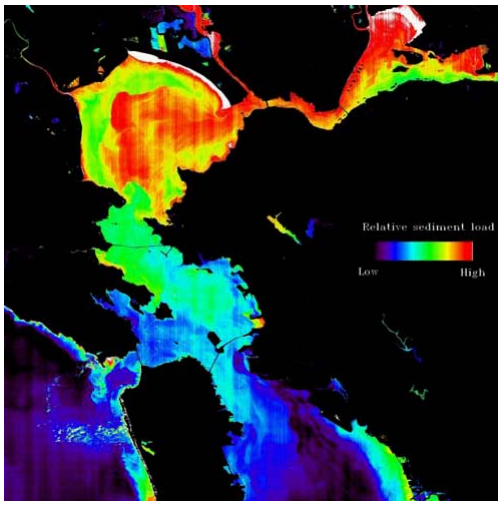
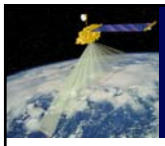
- **Applications**





Vegetation

- Introduction
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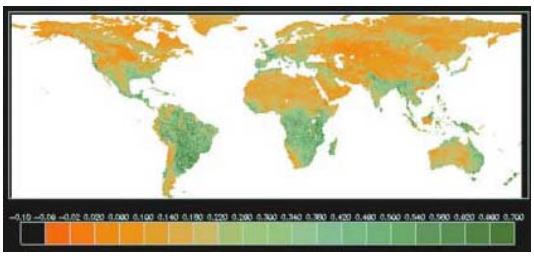
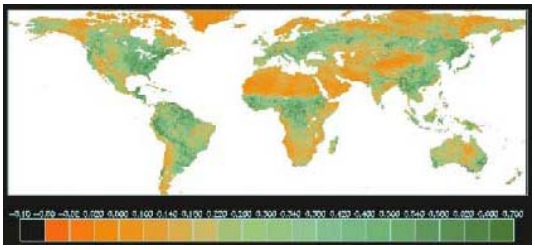
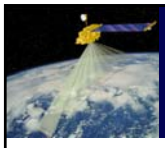
- **Applications**



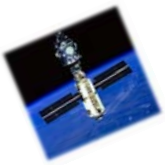
Global Vegetation Index (GVI) : 8th March 1998



Global Vegetation Index (GVI) : 13rd September 1998



Website :
http://rst.gsfc.nasa.gov/Front/tofc.html
http://www.ccrs.nrcan.gc.ca/resource/tutor/fundam/pdf/fundamentals_e.pdf
http://www.ccrs.nrcan.gc.ca/resource/tutor/digitech/index_e.php
http://unesdoc.unesco.org/images/0015/001563/156300e.pdf
Book :
Remote sensing digital image analysis : JA Richards



Questions ?