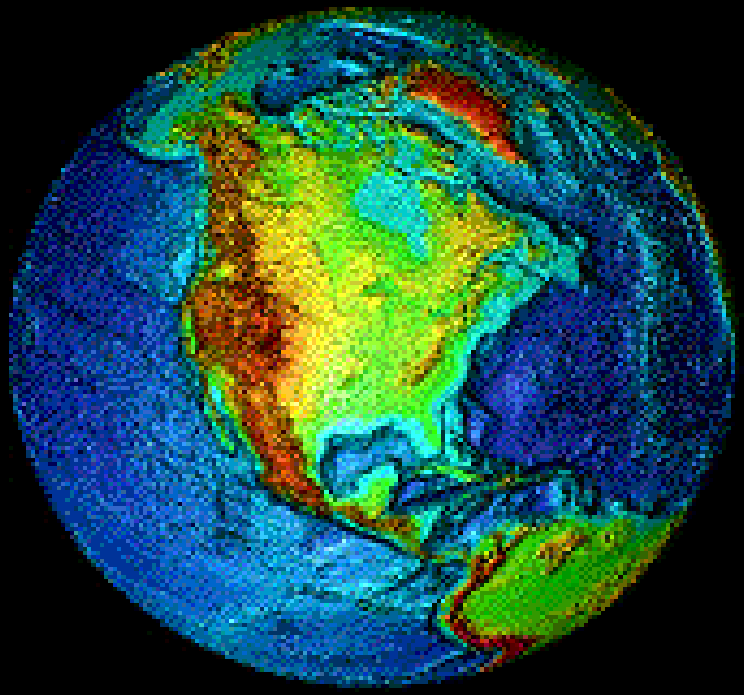

DIGITAL IMAGE PROCESSING

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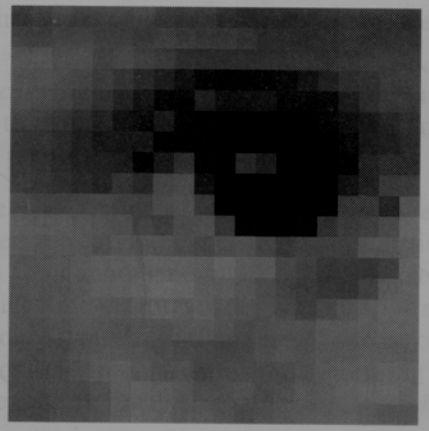
Tiruchirapalli - 620 024

INTRODUCTION TO DIP

How are images represented in the computer?



117	125	133	127	130	130	133	121	116	115	100	91	93	94	99	103	112	105	109	106
134	133	138	138	132	134	130	133	128	123	121	113	106	102	99	106	113	109	109	113
146	147	138	140	125	134	124	115	102	96	93	94	99	96	99	100	103	110	109	110
144	141	136	130	120	108	88	74	53	37	31	37	35	39	53	79	93	100	109	116
139	136	129	119	102	85	58	31	41	77	51	53	53	33	37	41	69	94	105	108
132	127	117	102	87	57	49	77	42	28	17	15	13	13	17	41	53	69	88	100
124	120	108	94	72	74	72	31	35	31	15	13	15	11	15	13	46	75	83	96
125	115	102	93	88	82	42	79	113	41	19	100	82	11	11	17	31	91	99	100
124	116	109	99	91	113	99	140	144	57	20	20	15	11	15	17	63	87	119	124
136	133	133	135	138	133	132	144	150	120	24	17	15	15	17	20	115	113	88	150
158	157	157	154	149	145	133	127	146	150	116	35	20	19	28	105	124	128	141	171
155	154	156	155	146	155	154	154	147	139	148	150	138	120	128	129	130	151	156	165
150	151	154	162	166	167	169	174	172	167	177	166	164	140	134	120	121	120	127	172
145	149	151	157	165	169	173	179	176	166	166	157	145	136	129	124	120	136	163	168
144	148	153	160	159	158	165	172	165	169	157	151	149	141	130	140	151	162	169	167
144	141	147	155	154	149	156	151	157	157	151	144	147	147	149	159	158	159	166	165
139	140	140	150	153	151	150	146	140	139	138	140	145	151	149	156	156	162	162	161
136	134	138	146	156	164	153	146	145	136	139	139	140	141	149	157	159	161	169	166
136	133	136	135	144	159	168	159	151	142	141	145	139	146	153	156	164	167	172	168
133	129	140	142	146	159	167	165	154	151	146	141	147	154	156	160	161	157	153	154

A Simple model of image formation

- The scene is illuminated by a single source.
- The scene reflects radiation towards the camera.
- The camera senses it via chemicals on film.

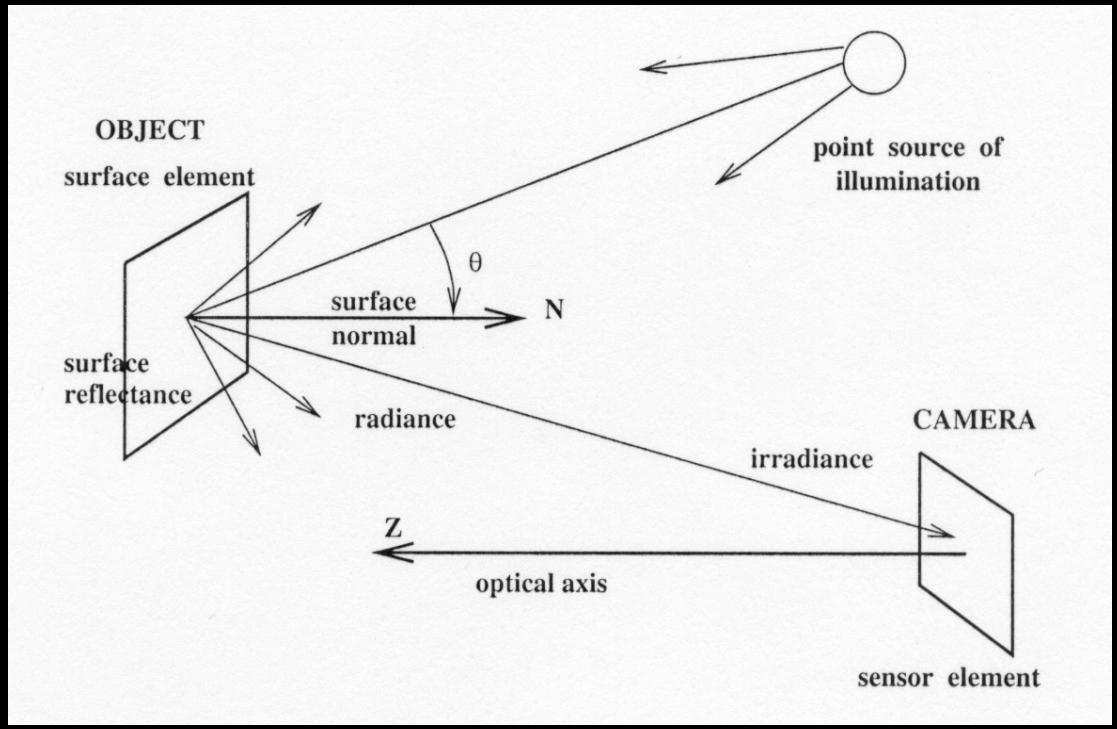


Image formation

- There are two parts to the image formation process:
  - The **geometry of image formation**, which determines where in the image plane the projection of a point in the scene will be located.
  - The **physics of light**, which determines the brightness of a point in the image plane as a function of illumination and surface properties.

REMOTE SENSING

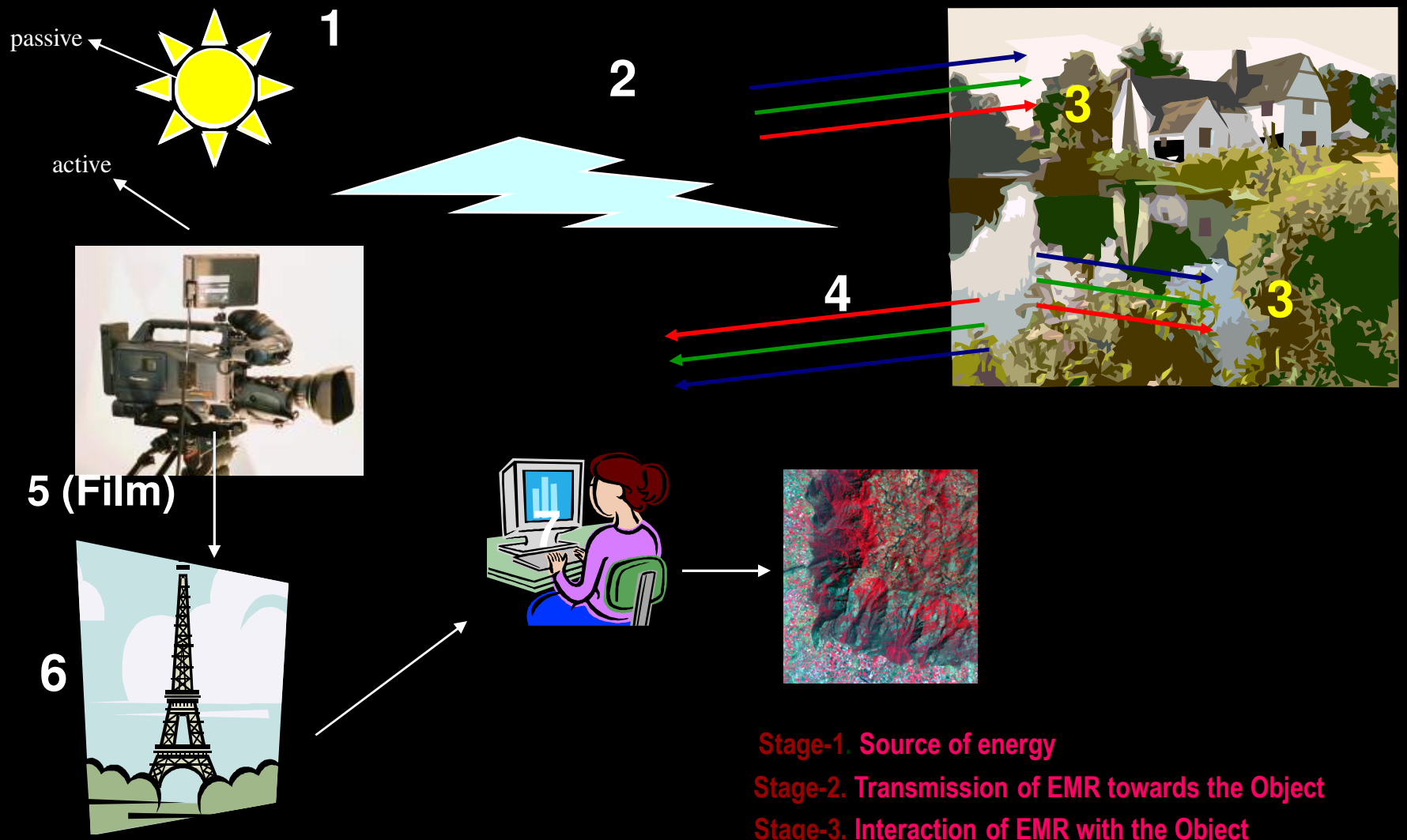
Remote Sensing is the acquisition of physical data of an object without touch or contact (Fintz and Simonett, 1976)

Remote Sensing is the acquisition of data about an object or scene by a sensor that is far from the object (Colwell, 1983)

Information about the earth's land and water areas from the images/data acquired at a distance (Campbell, 1987)

"Remote sensing is the practice of deriving information about the earth's land and water surfaces using images acquired from an overhead perspective, using electromagnetic radiation in one or more regions of the electromagnetic spectrum, reflected or emitted from the earth’s surface.” (Campbell, 1996)

Remotely Sensed Data ???



Stage-1. Source of energy

Stage-2. Transmission of EMR towards the Object

Stage-3. Interaction of EMR with the Object

Stage-4. Transmission of Interacted EMR towards the Sensor

Stage-5. Recording of the Image by the Detector

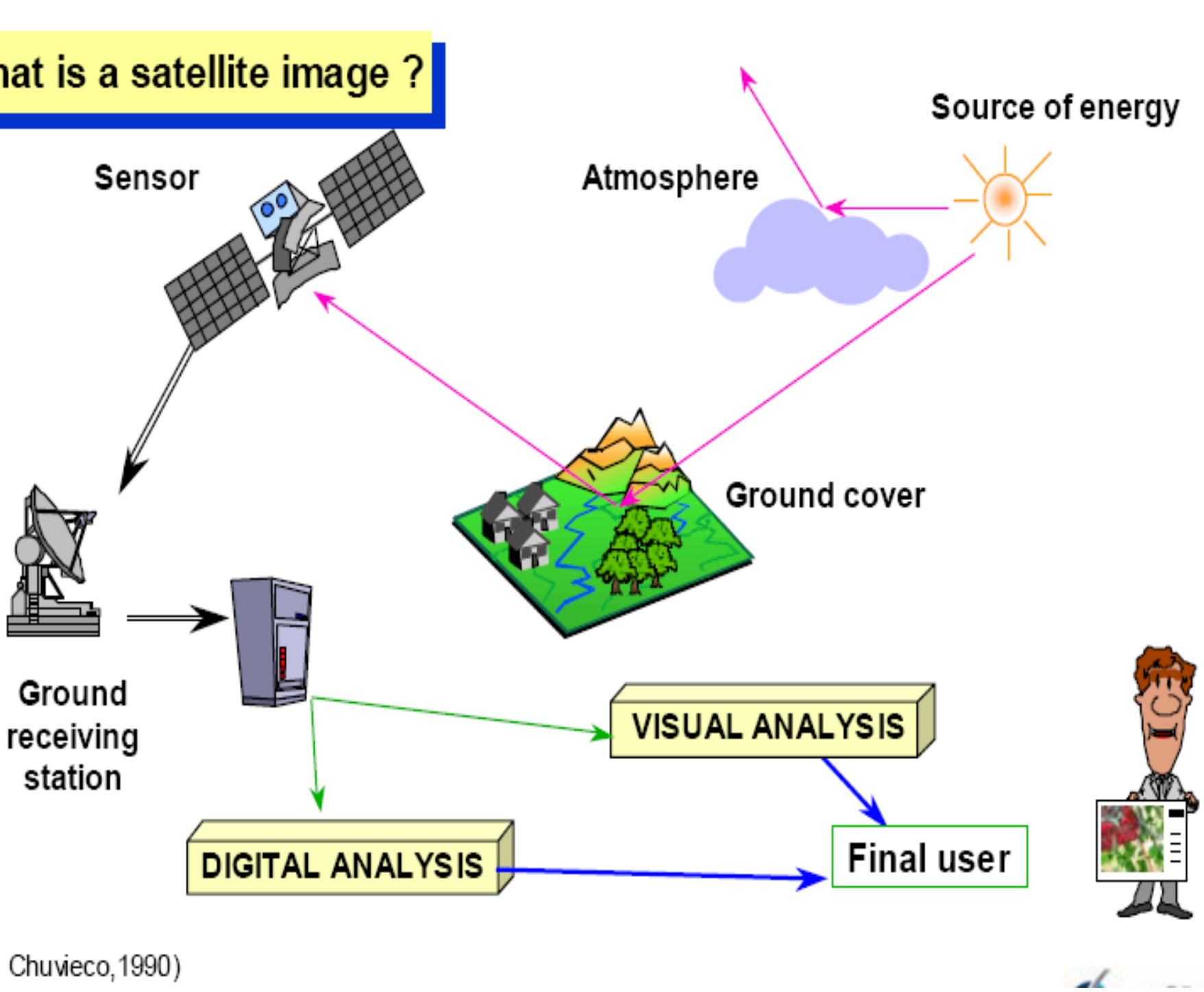
Stage-6. Relay to Ground Station

Stage-7. Analysis of the Imagery

ELEMENTS OF REMOTE SENSING

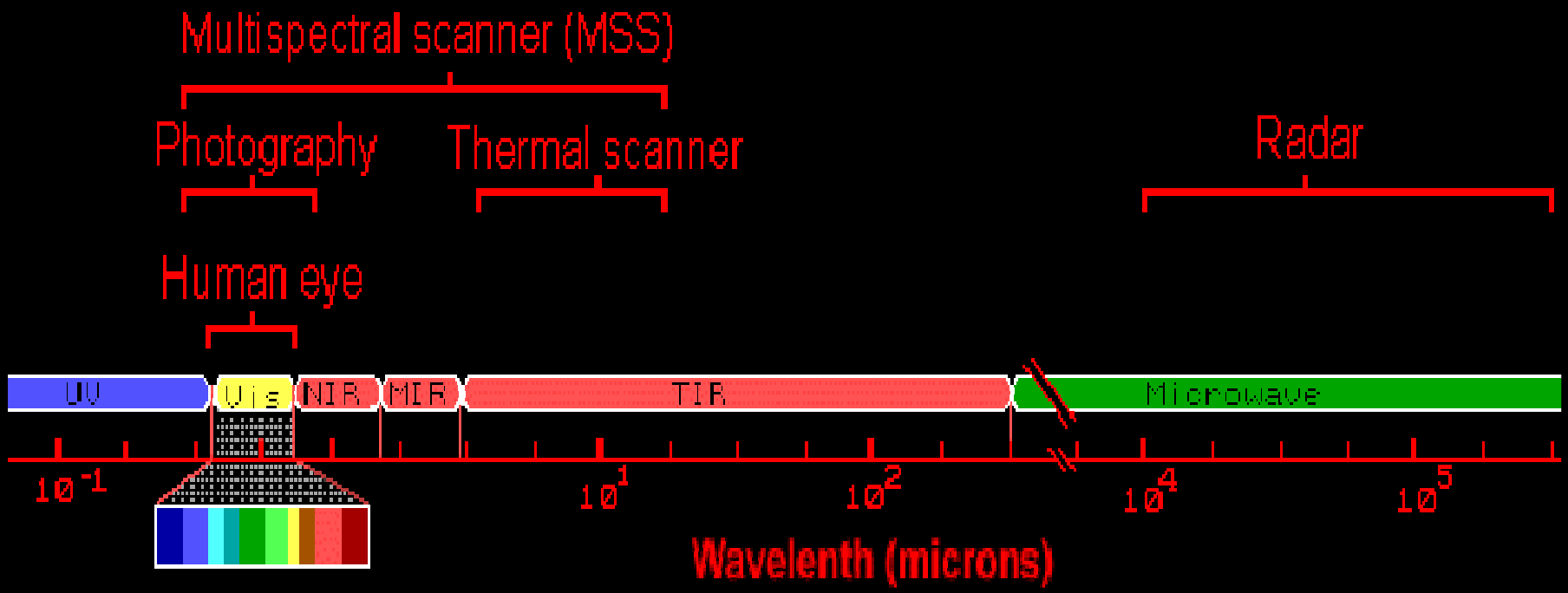
- ENERGY SOURCE
- THE ATMOSPHERE
- THE OBJECTS ON THE EARTH'S SURFACE
- PLATFORMS
- SENSOR SYSTEMS
- RECORDING SYSTEMS

What is a satellite image ?



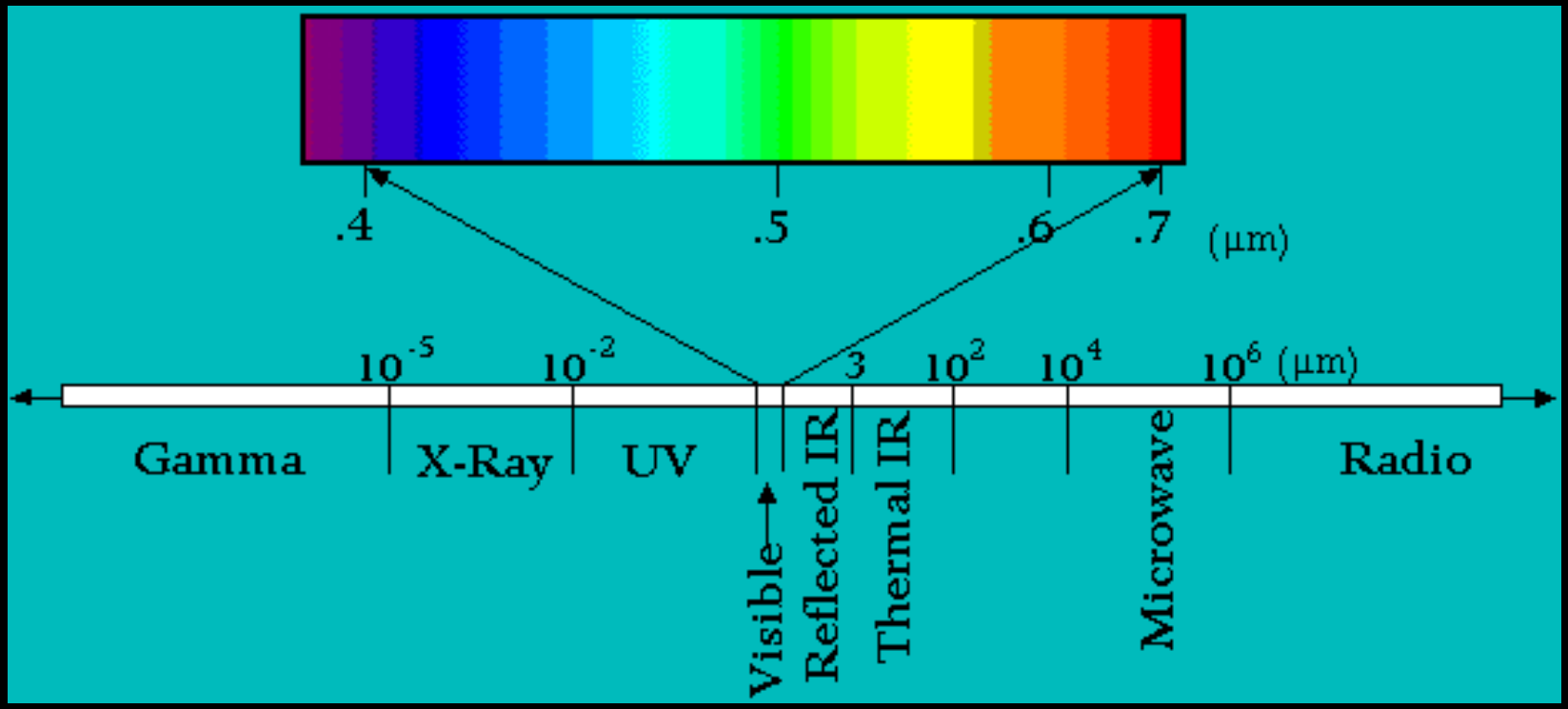
(E. Chuvieco, 1990)

REGIONS OF ELECTROMAGNETIC SPECTRUM

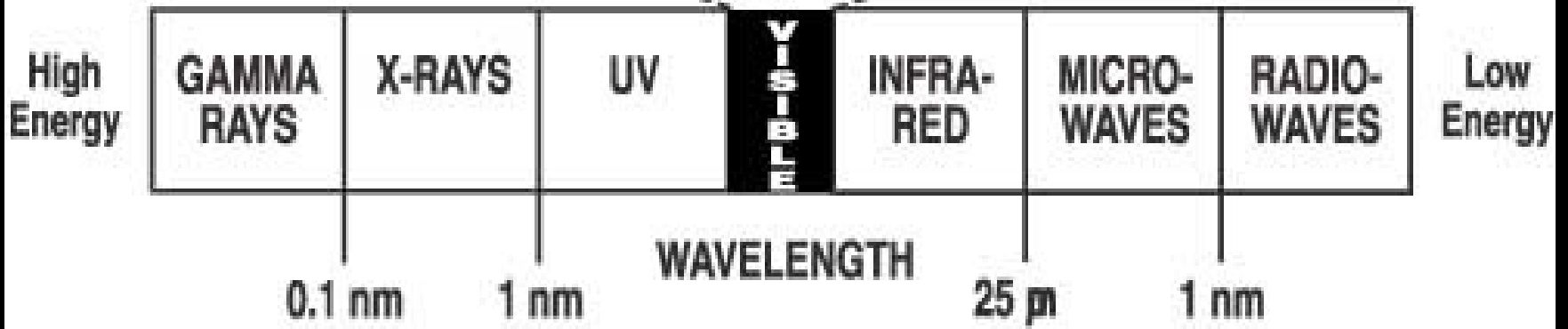


Electromagnetic Spectrum

- Remote sensing images are taken within specific spectral regions



The Electromagnetic Spectrum



1 μ = 1000 nm
1 mm = 1,000,000 nm

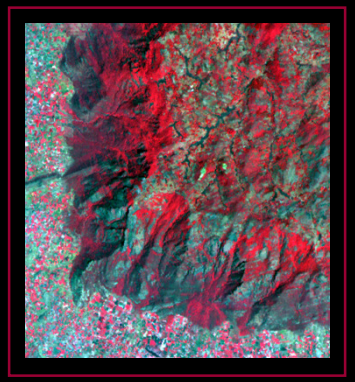
- **VISIBLE** : 0.4 - 0.8 µm
- Solar Reflection - Surface characteristics

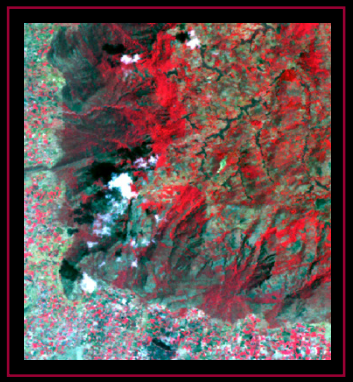
- **INFRA RED** : 0.8 - 14 µm
- 0.8 - 1.3 µm : Near Infra Red (NIR) Solar Reflection
- 1.3 - 3 µm : Moyen Infra Rouge (MIR) Réflection and Emission (little)
- 3 - 5 µm et 8 - 14 µm : Thermal Infra Red (IRT): Emission
- 5 - 8 µm : Atmospheric Absorption

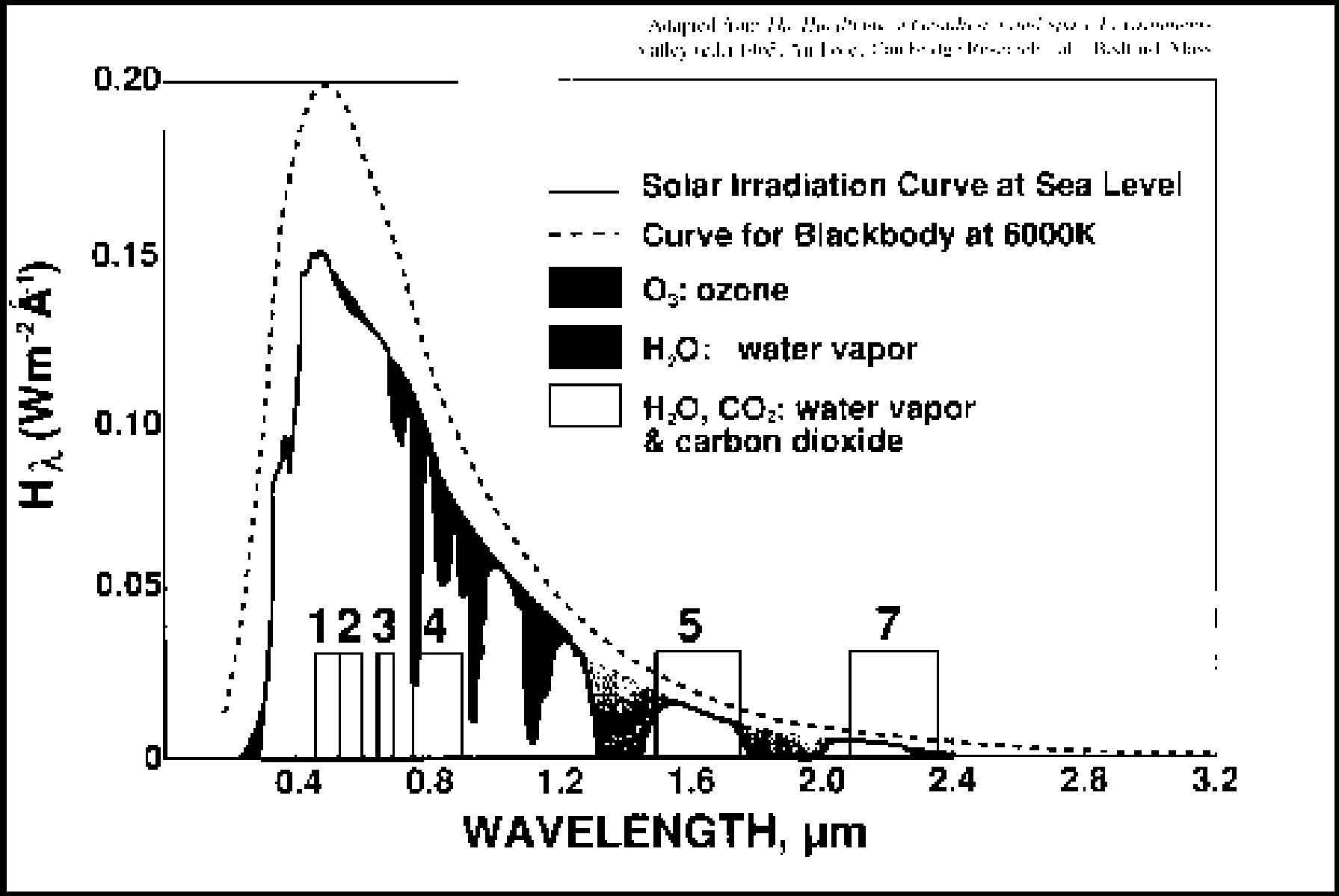
- **MICROWAVE** : 3 mm - 30 cm (100 - 1 GHz)
- Surface and Volume scattering

Atmosphere

- Via media between Landscape/ satellite, Satellite/ground station
- Any disturbing factor in this component for example clouds will negatively affect data acquisition

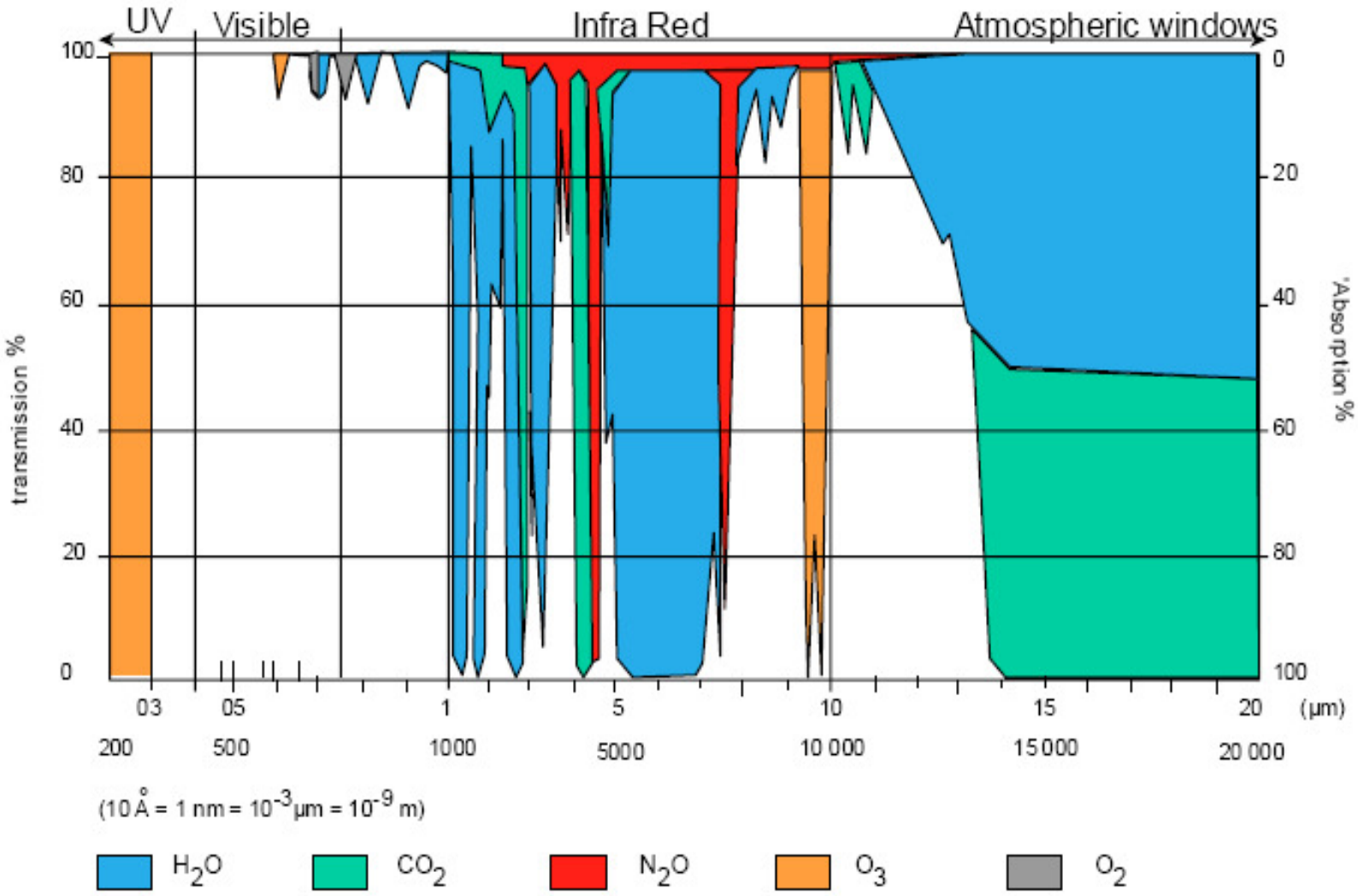


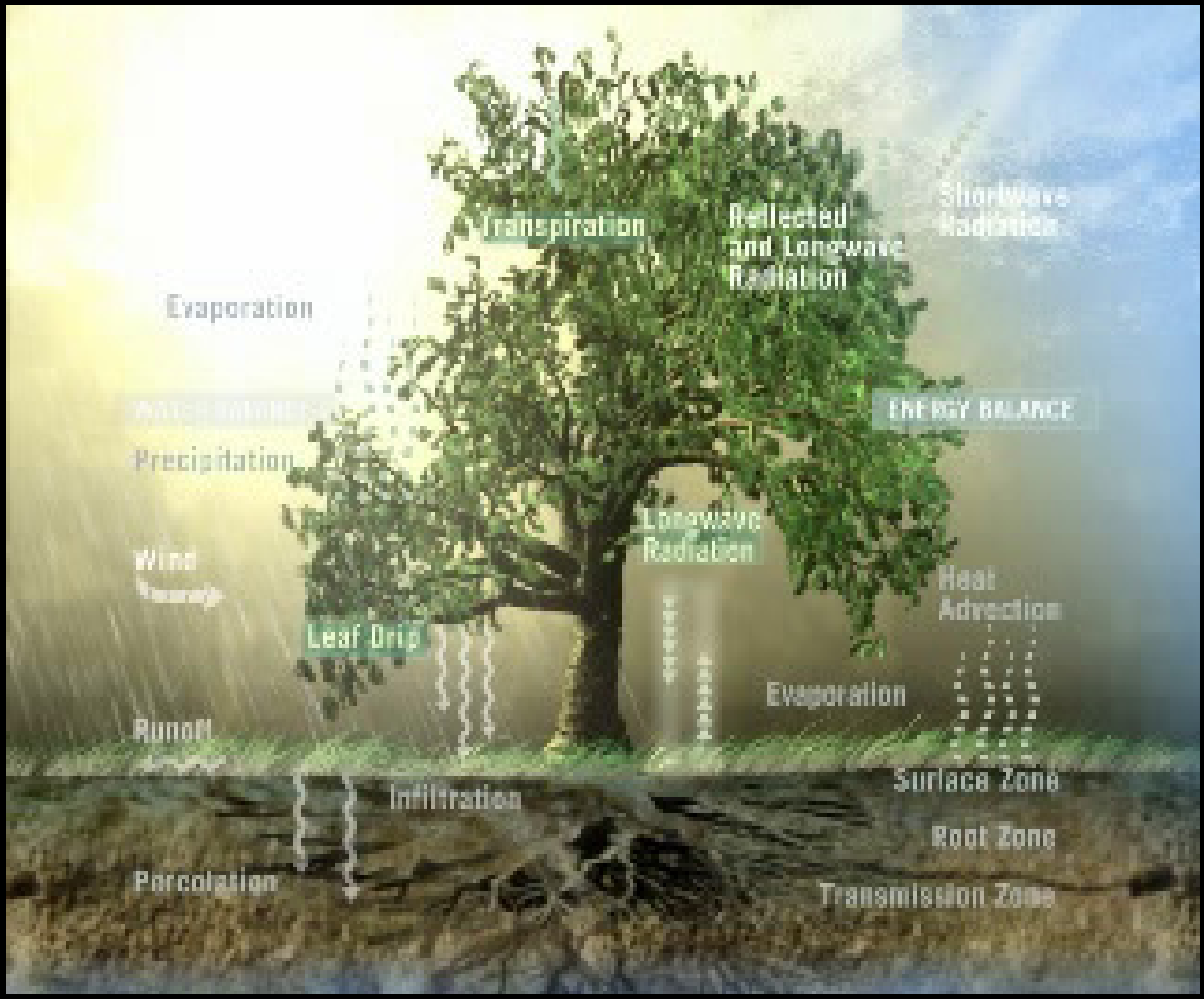




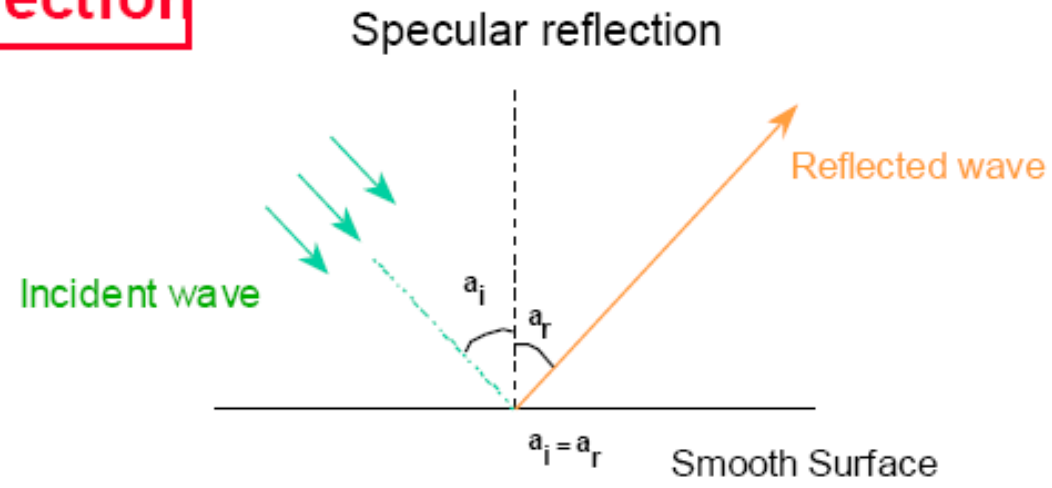
Atmospheric Absorption

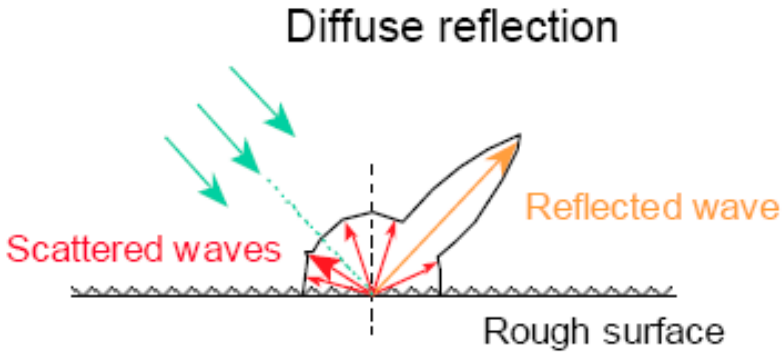
Atmospheric vertical Transmittance in the Visible and Infra-Red Spectra

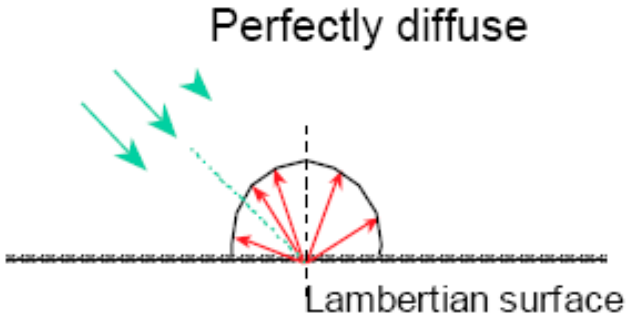



Transpiration
Reflected and Longwave Radiation
Shortwave Radiation
Evaporation
ENERGY BALANCE
Precipitation
Longwave Radiation
Wind
Heat Advection
Leaf Drip
Evaporation
Runoff
Surface Zone
Infiltration
Root Zone
Percolation
Transmission Zone

Surface reflection

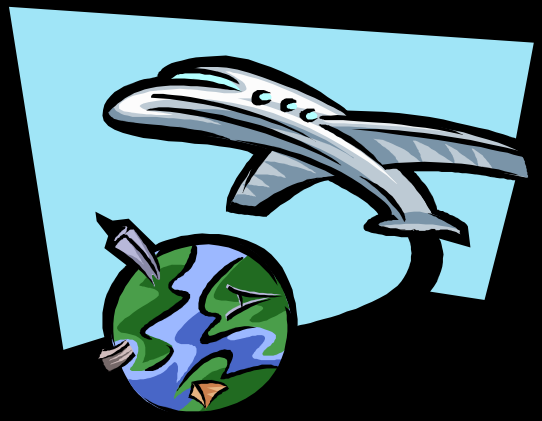






Platforms

Ground based
Air based
Space based

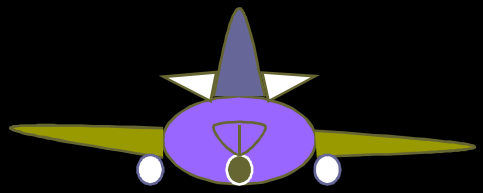


SCAFFOLDINGS, BUILDINGS
BALOON, AEROPLANE
SATELLITE

Platforms Used to Acquire Remote Sensing Data

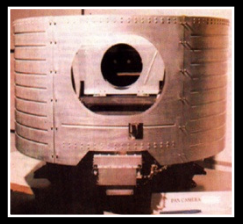
- Aircraft
  - Low, medium & high altitude
  - Higher level of spatial detail
- Satellite
  - Polar-orbiting, sun-synchronous
    - 800-900 km altitude, 90-100 minutes/orbit
  - Geo-synchronous
    - 35,900 km altitude, 24 hrs/orbit
    - stationary relative to Earth

Remote Sensing System



A device that records information on earth features

LISS III



PAN

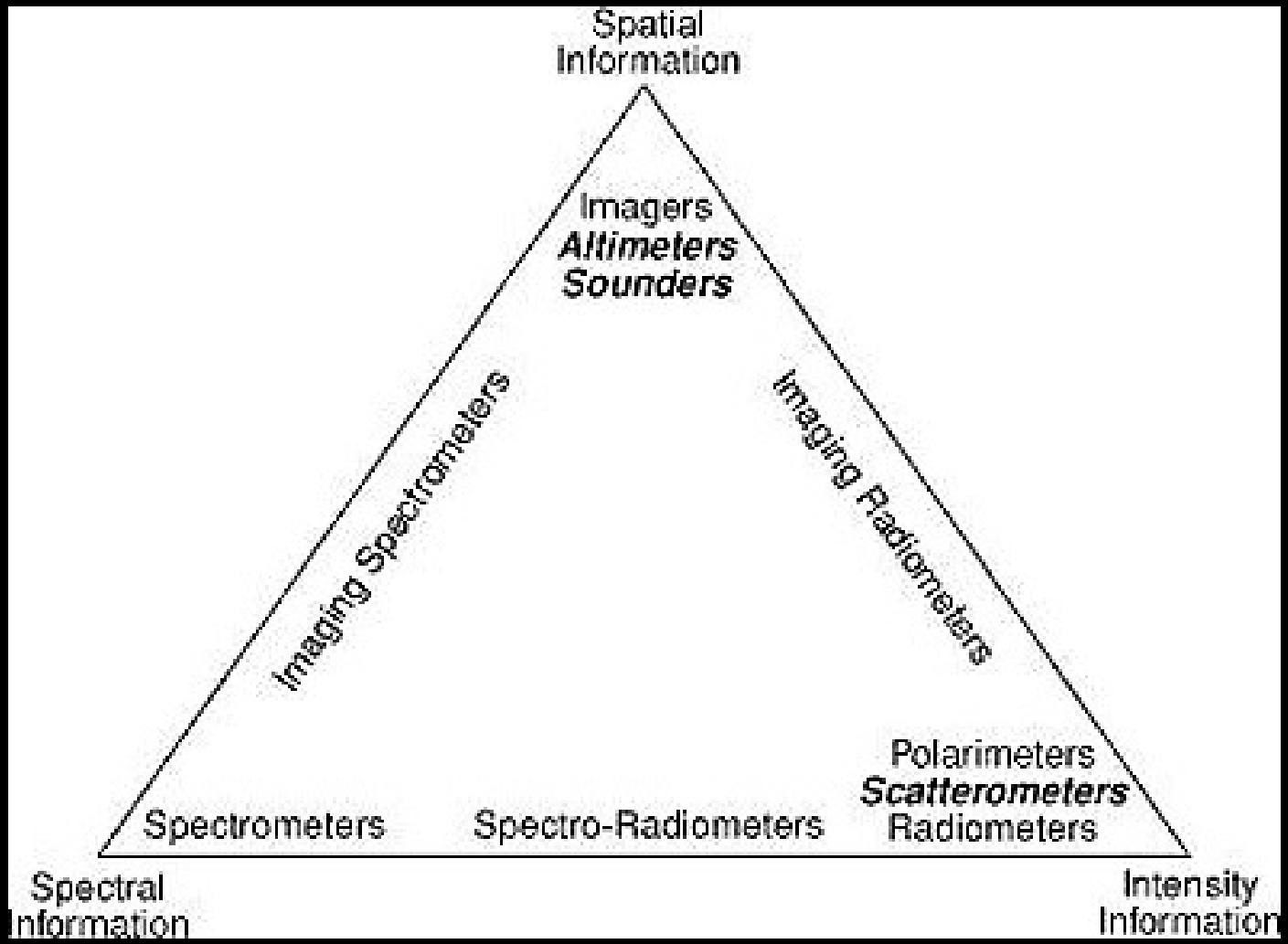
WiFS

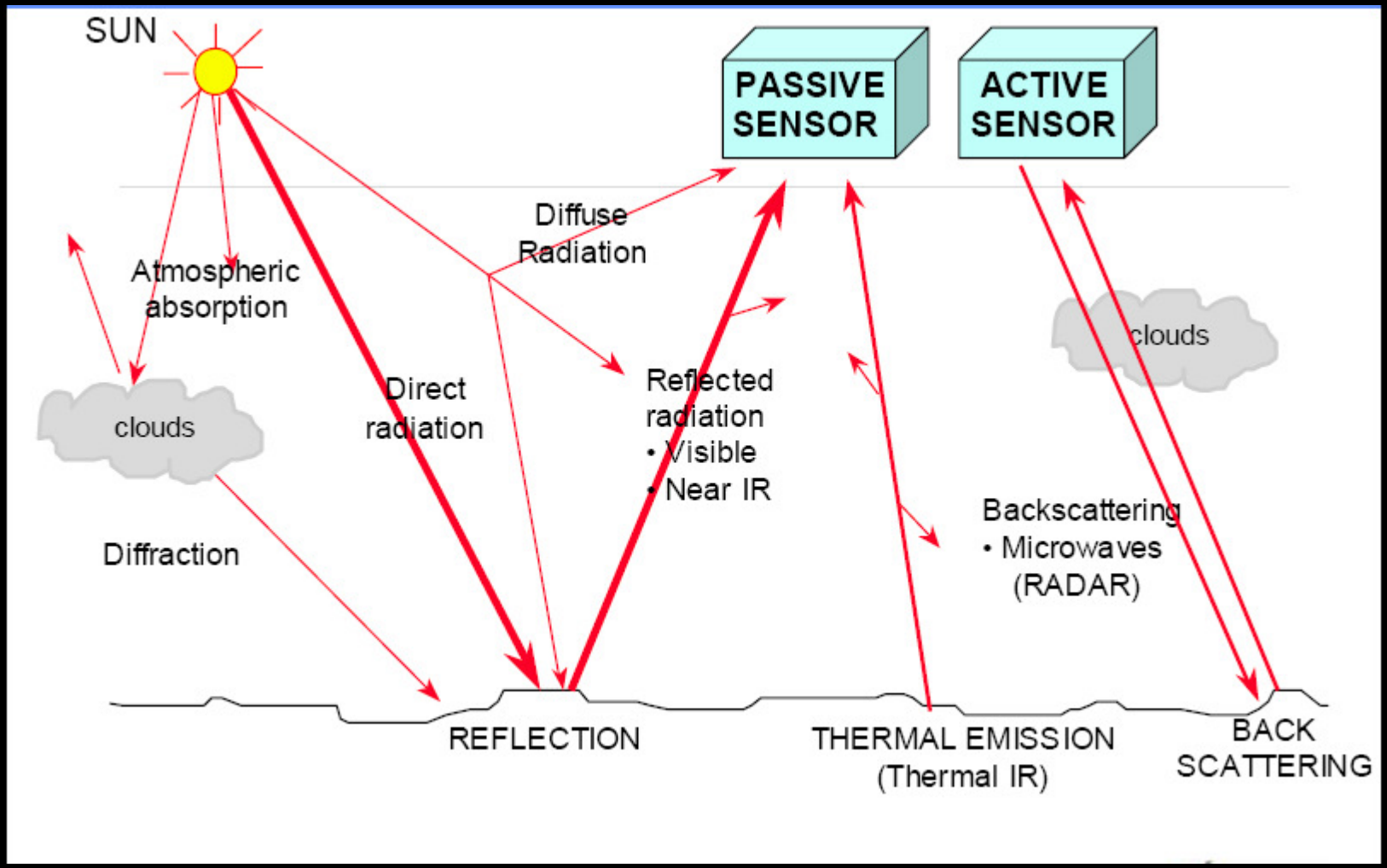
Two Types

- Aerial Photography: Similar to normal Photography – the camera is in the Flying aeroplane at a height of 1.5 km and it gives a 3D nature

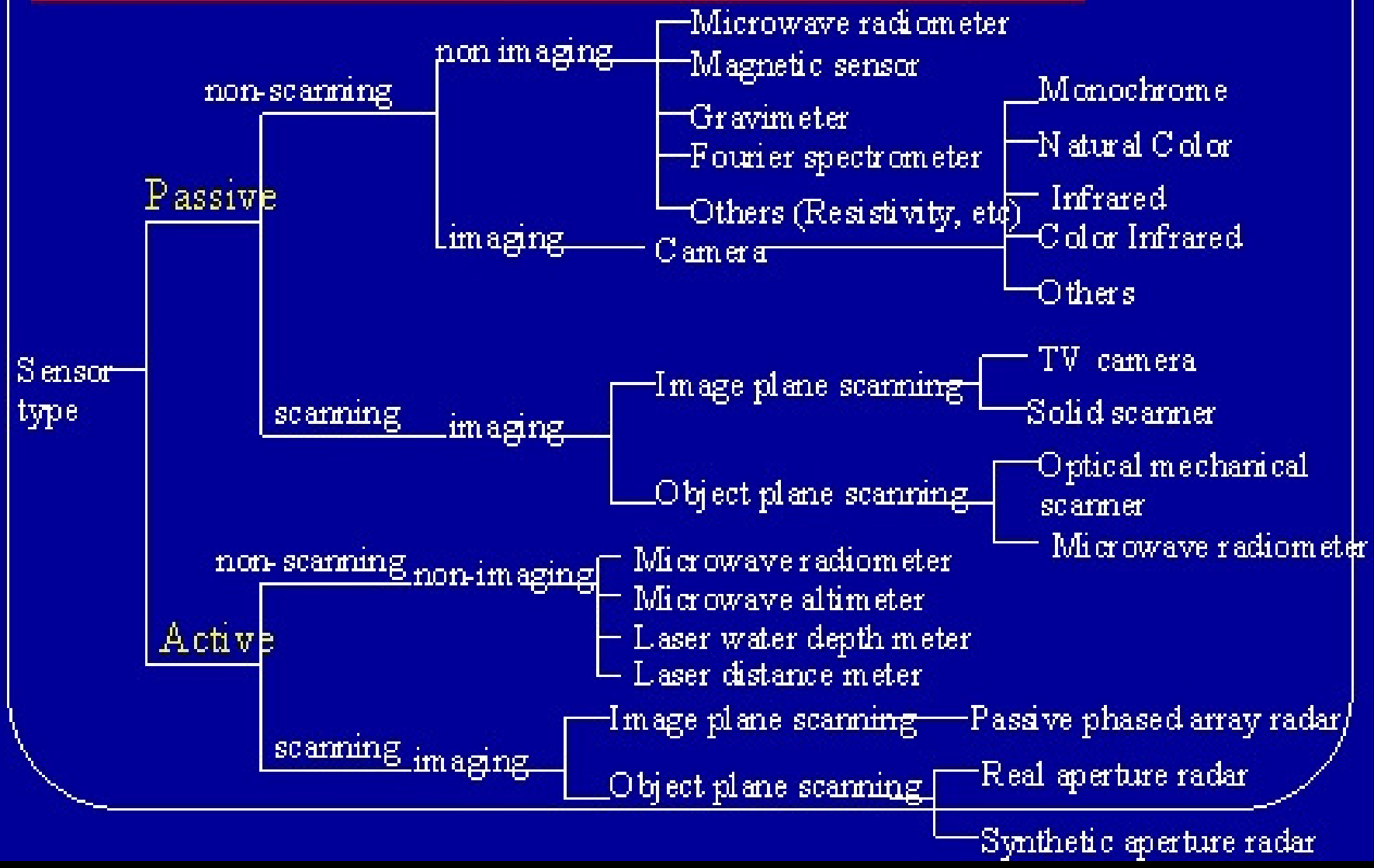
Satellite: The sensors are fixed on a satellite revolving at a height of 800 – 900 km

Several classes of sensors, determined by the principal parameter measured:
Spectral; Spatial; Intensity.




SUN
PASSIVE SENSOR
ACTIVE SENSOR
Diffuse Radiation
Atmospheric absorption
clouds
Direct radiation
Reflected radiation
• Visible
• Near IR
clouds
Backscattering
• Microwaves
(RADAR)
Diffraction
REFLECTION
THERMAL EMISSION
(Thermal IR)
BACK SCATTERING

There are many remote sensors



- Radiometer is a general term for any instrument that quantitatively measures the EM radiation in some interval of the EM spectrum.

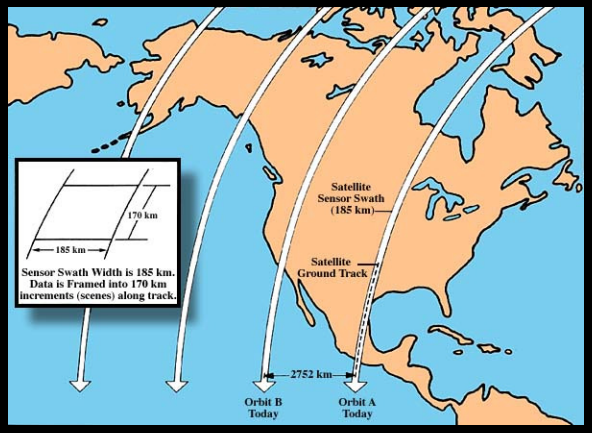
- Photometer is substituted when the radiation is light from the narrow spectral band including the visible

- Spectrometer: If the sensor includes a component, such as a prism or diffraction grating, that can break radiation extending over a part of the spectrum into discrete wavelengths and disperse (or separate) them at different angles to an array of detectors.

- Spectroradiometer : sensors that collect the dispersed radiation in bands rather than discrete wavelengths. Most air/space sensors are spectroradiometers.

Most air/space sensors are spectroradiometers

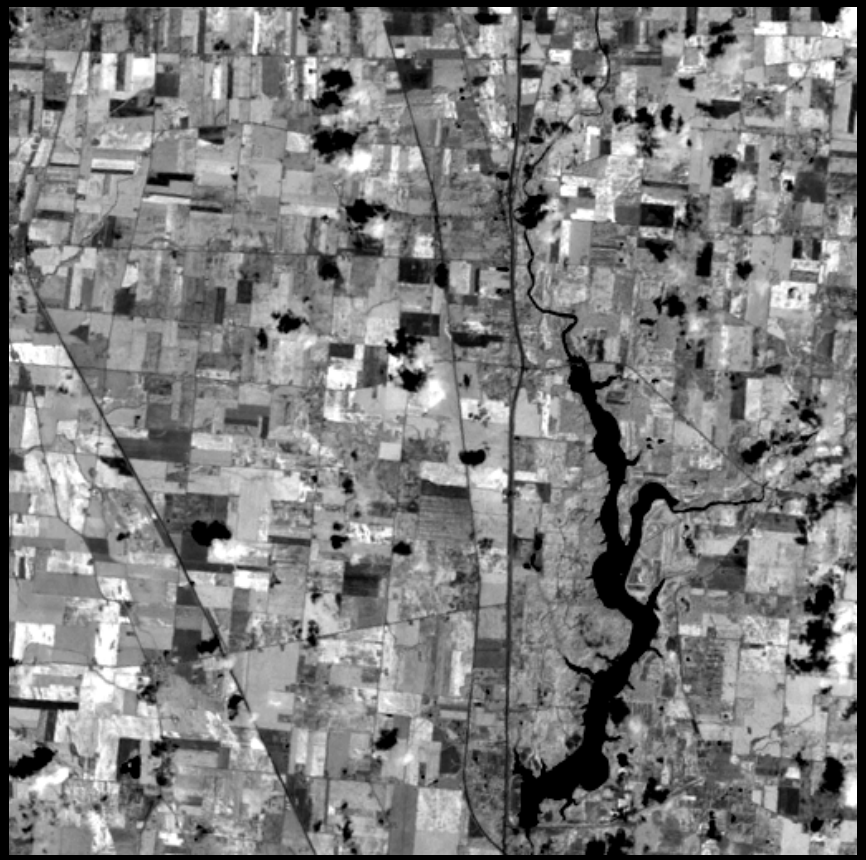
- ETM+ sensor
  - 30-m XS (for 6 bands) & 60-m thermal
  - 15-m pan band
- Image data (185 km by 185 km)
  - $475 – raw data; $600 – corrected data
  - NASA developing a global archive of ETM+



Band	*Wavelength (μm)*	*Spectral Location*	*Resolution (m)*
Pan	0.52-0.90	Pan	15
1	0.45-0.52	Blue	30
2	0.53-0.60	Green	30
3	0.63-0.69	Red	30
4	0.76-0.90	Near IR	30
5	1.55-1.75	Mid IR	30
6	10.4-12.5	Thermal IR	60
7	2.07-2.35	Mid IR	30

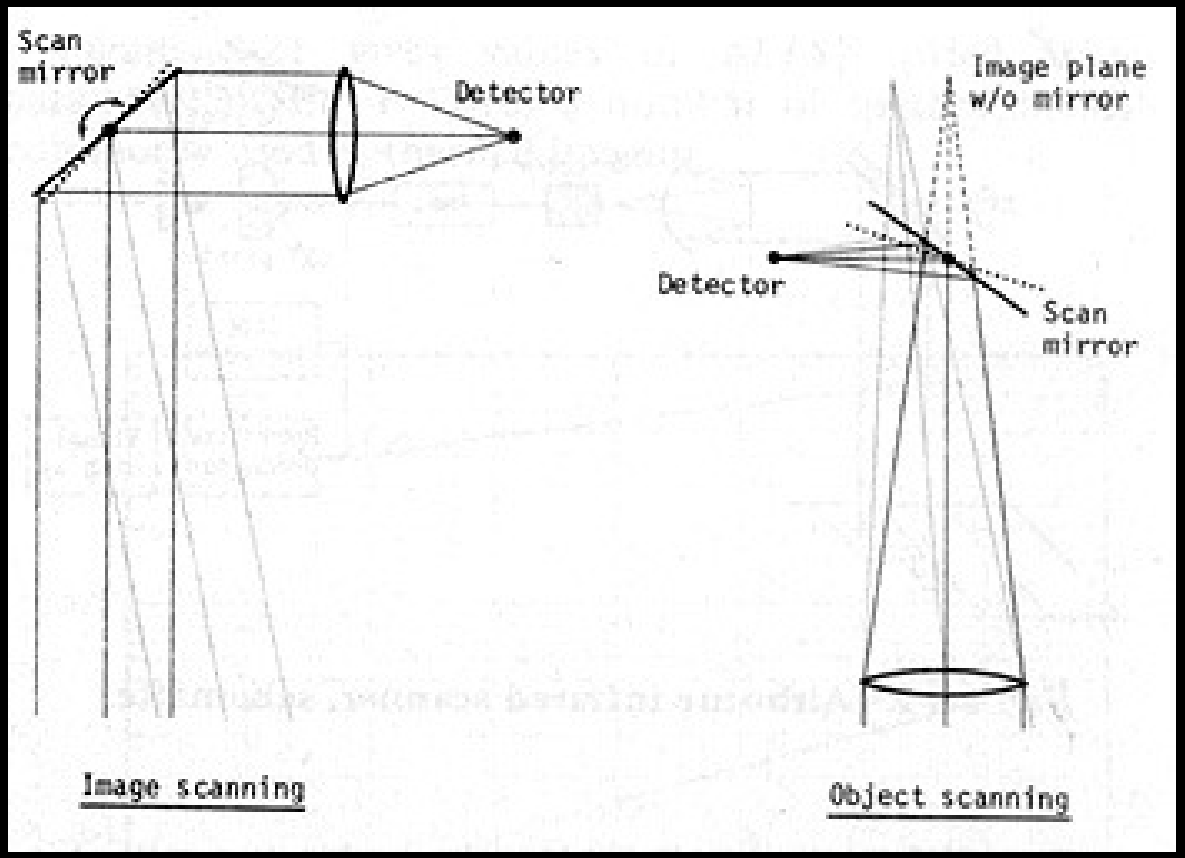
Delaware, Ohio – 26 July 2000

TM band 1
Blue – 0.45-0.52 μm

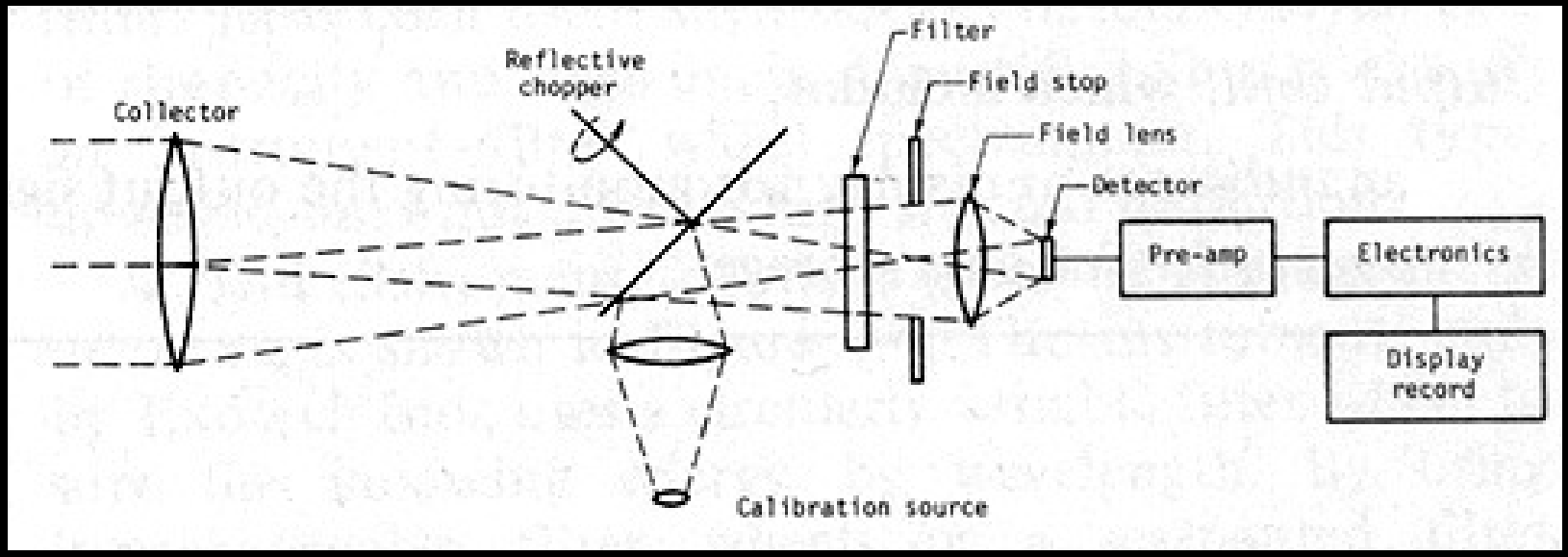


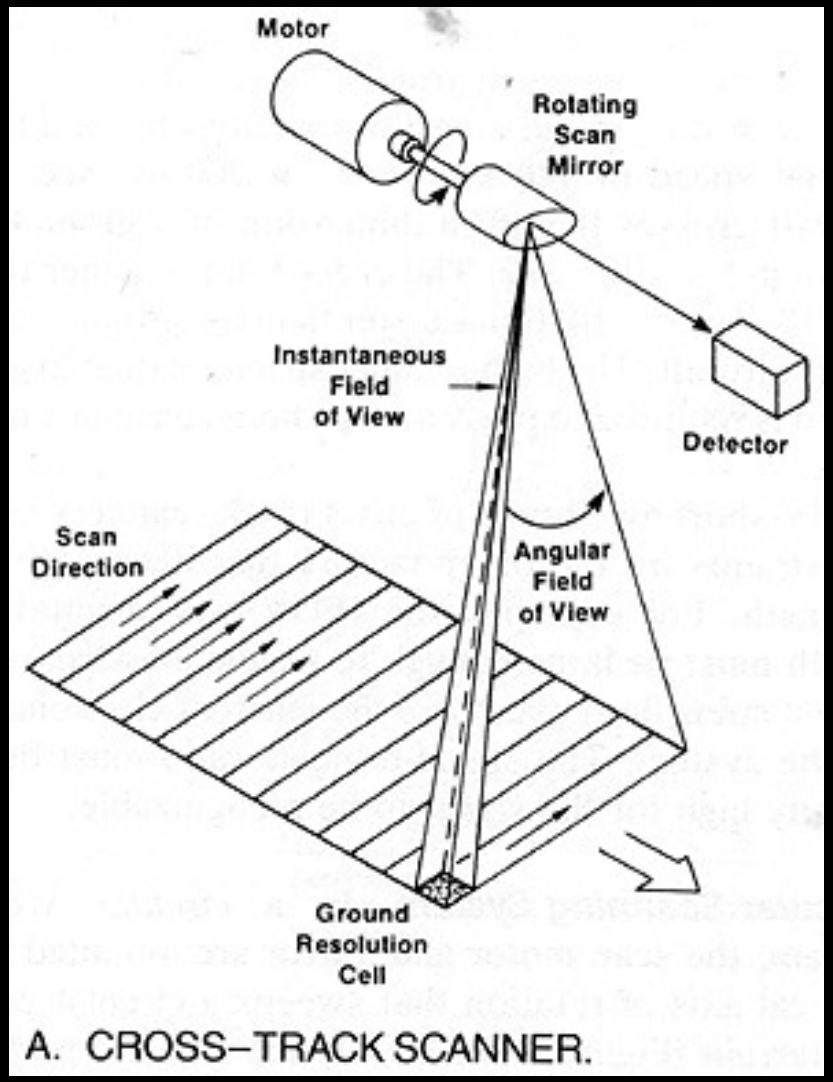
TM band 4
Near IR – 0.75-0.90 μm

Band	*Principal Applications*
1	Coastal water mapping, soil/vegetation discrimination, forest type mapping, cultural feature identification
2	Measures green reflectance peak of vegetation for vegetation discrimination & vigor assessment, cultural feature identification
3	Senses a chlorophyll absorption region aiding in plant species differentiation, cultural feature identification
4	Determine vegetation types, vigor & biomass content, delineate water bodies, soil moisture discrimination
5	Indicative of vegetation moisture content & soil moisture, differentiate snow from clouds
6	Useful for vegetation stress analysis, soil moisture discrimination, thermal mapping applications
7	Discrimination of mineral & rock types, sensitive to vegetation moisture content
Pan	Detailed mapping, useful in sharpening multispectral images

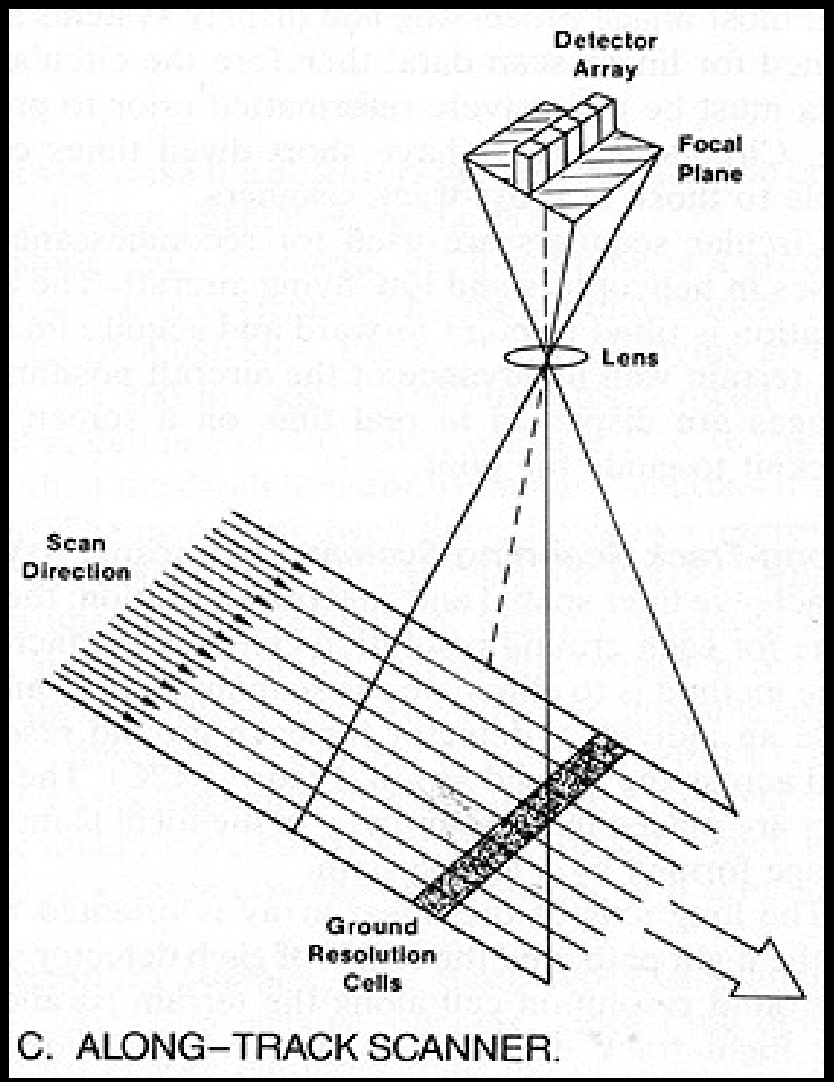

Scan
mirror
Detector
Image plane
w/o mirror
Detector
Scan
mirror
Image scanning
Object scanning

Return Beam Vidicon (TV-like) on the Landsats





A. CROSS–TRACK SCANNER.



C. ALONG–TRACK SCANNER.

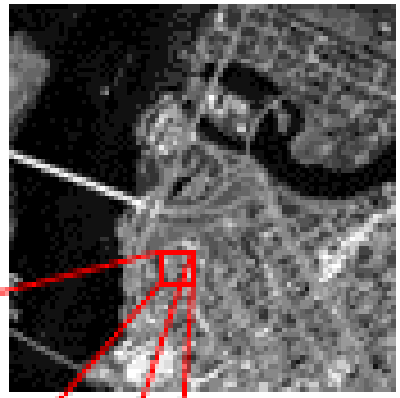
- Each line is subdivided into a sequence of individual spatial elements that represent a corresponding square, rectangular, or circular area (ground resolution cell) on the scene surface being imaged

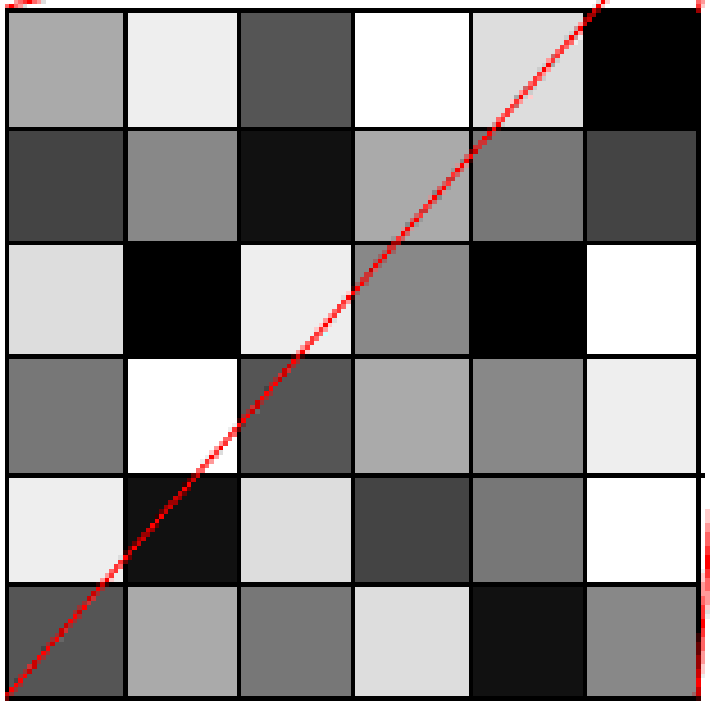
- Thus, along any line is an array of contiguous cells from each of which emanates radiation.

- The cells are sensed one after another along the line. In the sensor, each cell is associated with a **pixel** that is tied to a microelectronic detector.

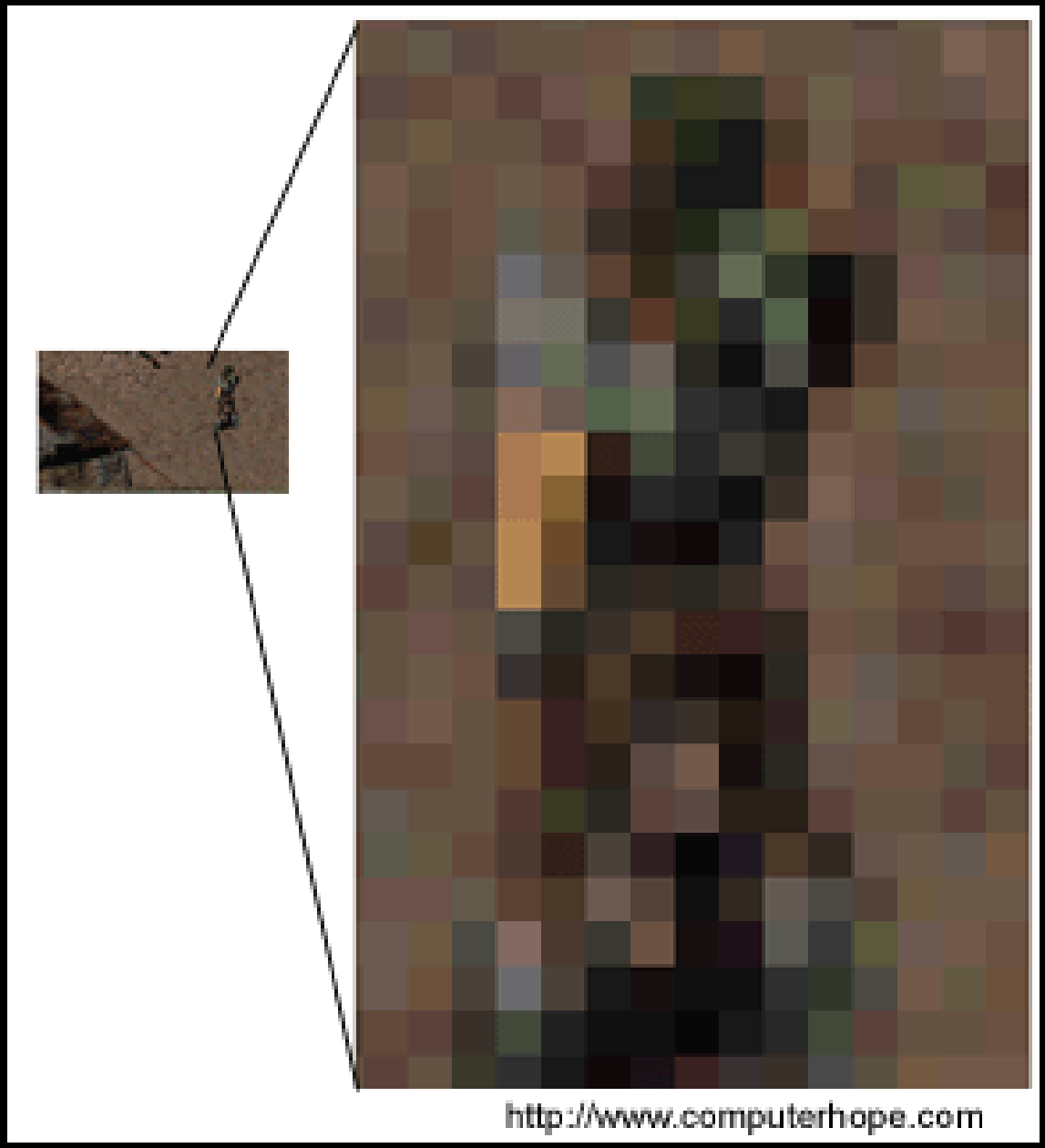
- Pixel : Picture Element, a pixel being a single point in a graphic image.

- Each pixel is characterized by some single value of radiation (e.g., reflectance) impinging on a detector that is converted by the photoelectric effect into electrons.

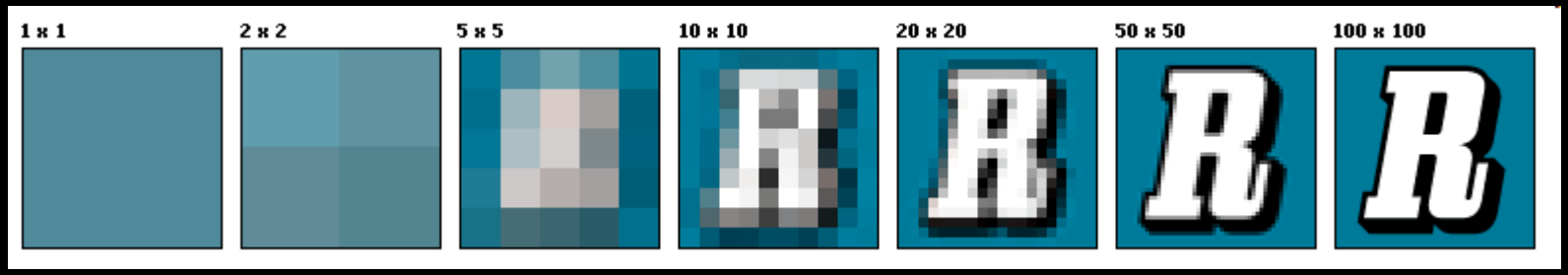




170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136


http://www.computerhope.com

- Pointillism
- French painter George Seurat in the 19th century


1 x 1
2 x 2
5 x 5
10 x 10
20 x 20
50 x 50
100 x 100

- Graphics monitors display pictures by dividing the display screen into thousands (or millions) of pixels, arranged in rows and columns.
- The number of bits used to represent each pixel determines how many colors or shades of gray can be displayed.
- 8-bit color mode, the color monitor uses 8 bits for each pixel, making it possible to display 2 to the 8th power (256) different colors or shades of gray.
- On color monitors, three dots -- a red, a blue, and a green one. Ideally, the three dots should all converge at the same point
- VGA systems display 640 by 480, or about 300,000 pixels.
- SVGA systems display 800 by 600, or 480,000 pixels.
- True Color systems use 24 bits per pixel, allowing them to display more than 16 million different colors.

- **Image resolution**

Concepts of Resolution

SPATIAL RESOLUTION

- The ground surface represented by one pixel (optical systems).
- Smallest distance between 2 differenciable objects (radar systems).

TEMPORAL RESOLUTION

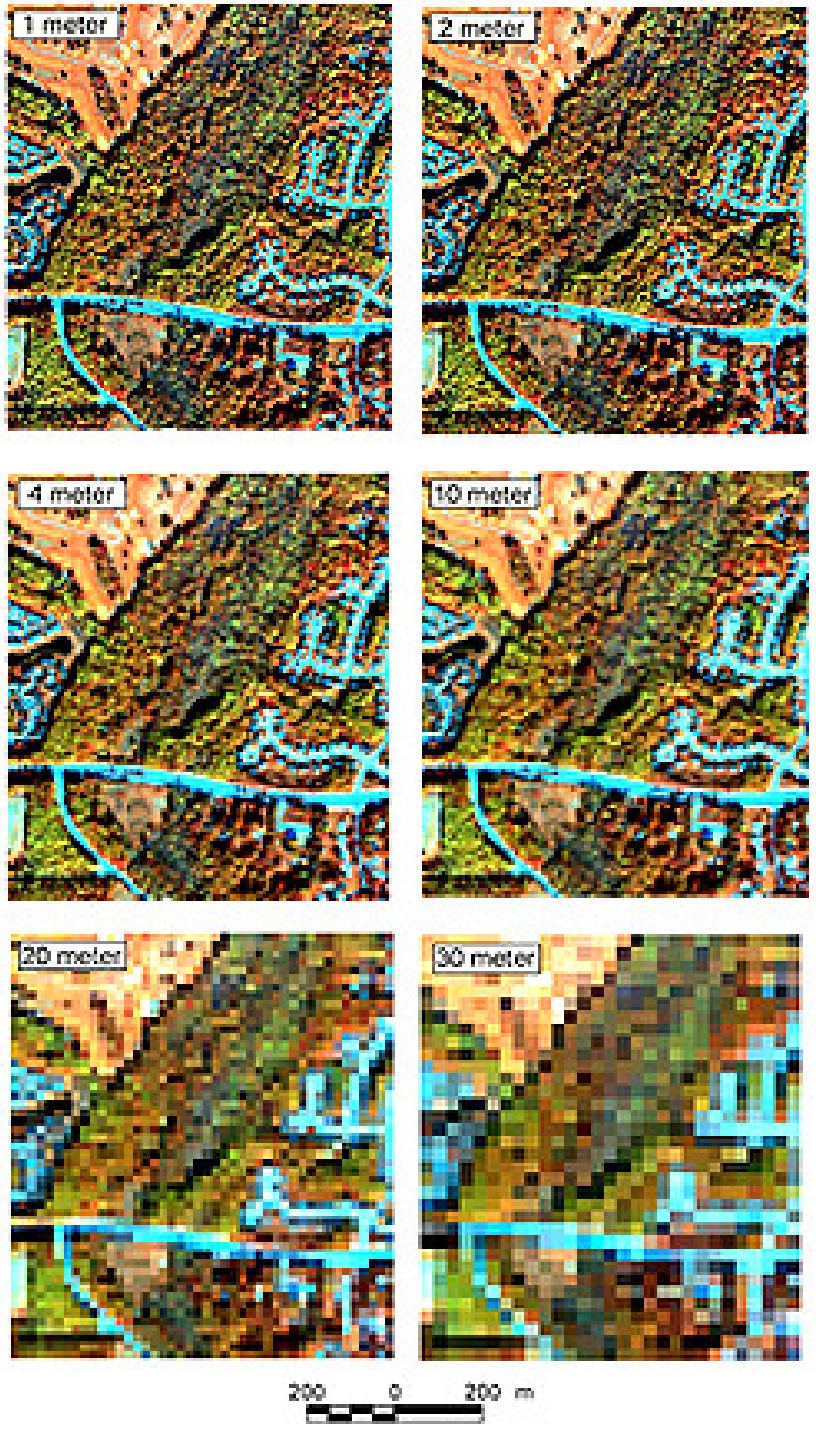
- Time lag between two possible image acquisitions on the same area.

SPECTRAL RESOLUTION

- Size and number of the bands (intervals of wavelengths) measured by a specific sensor.

RADIOMETRIC RESOLUTION

- Sensitivity of a sensor to the level of the signal received.

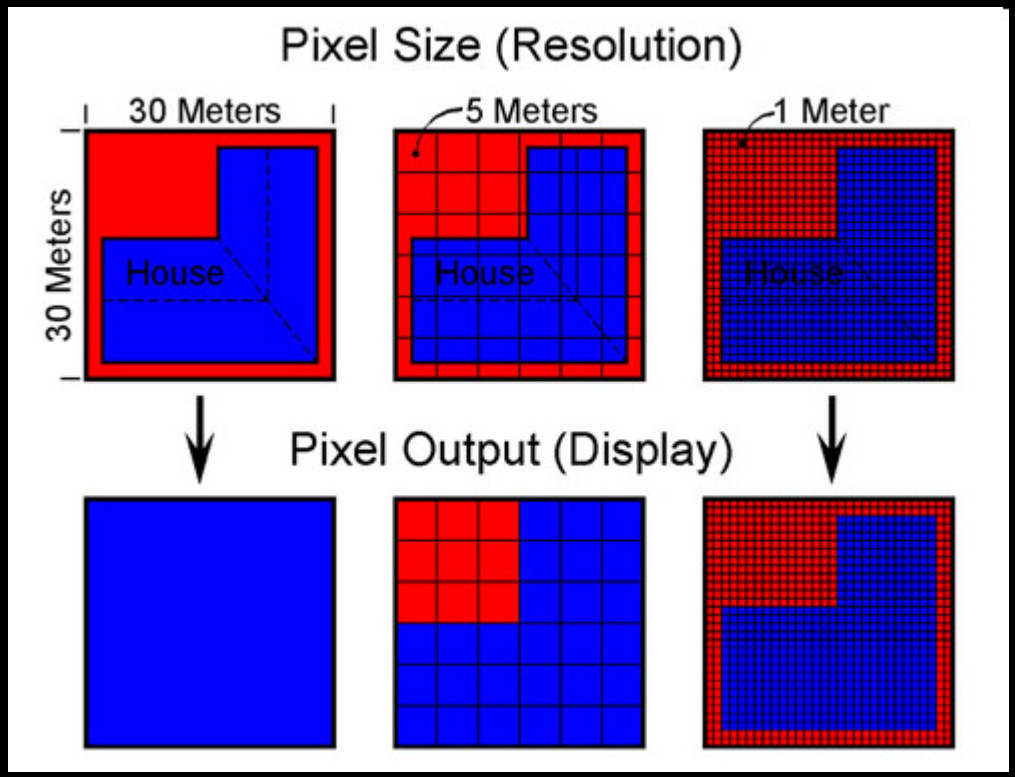

1 meter
2 meter
4 meter
10 meter
20 meter
30 meter
200 0 200 m


LANDSAT PAN 15m

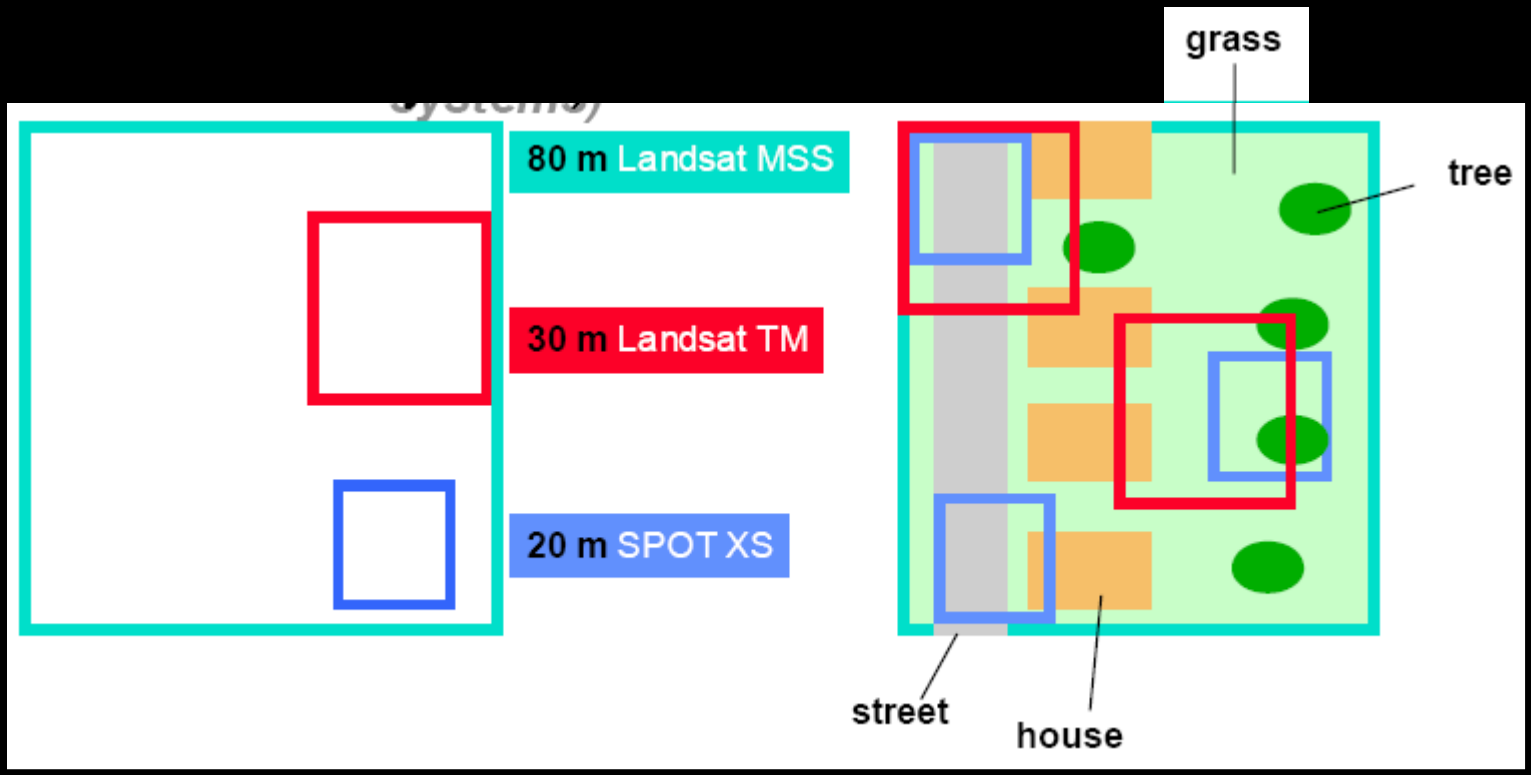

LANDSAT 30m

Spatial Resolution

- The spatial resolution specifies the pixel size of satellite images covering the earth surface.



Spatial resolution



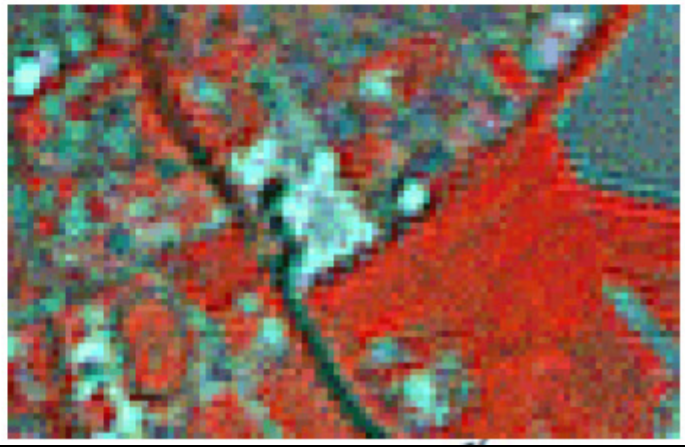
Each pixel of the image represents a sum of the values of the energy reflected by the various types of canopy cover in the concerned portion of the surface.

Spot 5 (2.5 m)

Orthophoto (0.5 m)

Spot 1..4 Panchromatique (10 m)

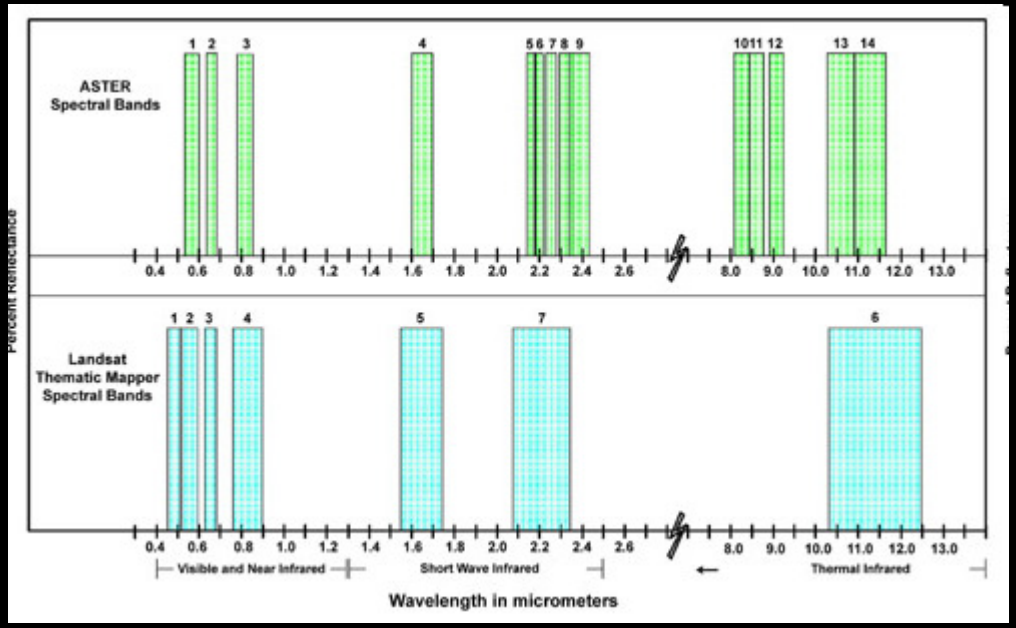
Spot 1..4 Multispectral (20 m)



Spectral resolution

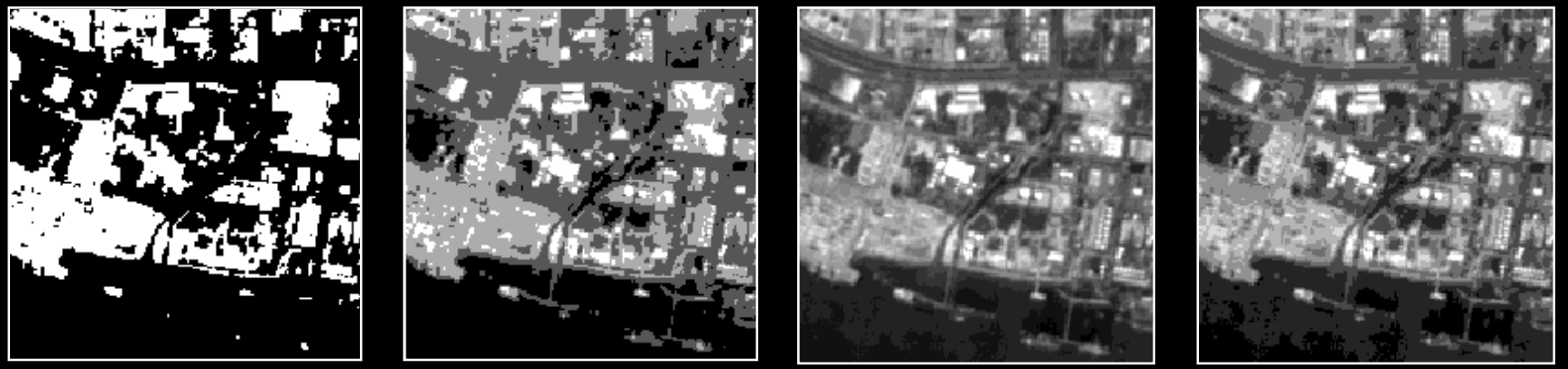
- The wavelength width of the different frequency bands recorded - usually, this is related to the number of frequency bands recorded by the platform.

- The spectral resolution achieved by a sensor depends on the number of bands, their bandwidths, and their locations within the EM spectrum



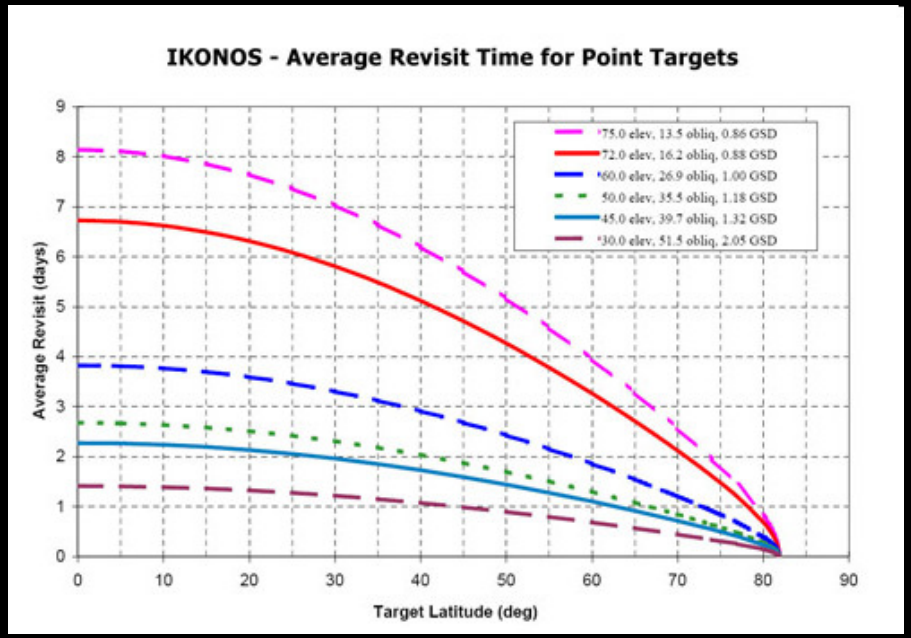
- **Radiometric resolution** : differences of intensity, and is usually expressed as a number of levels or a number of bits, for example 8 bits or 256 levels.

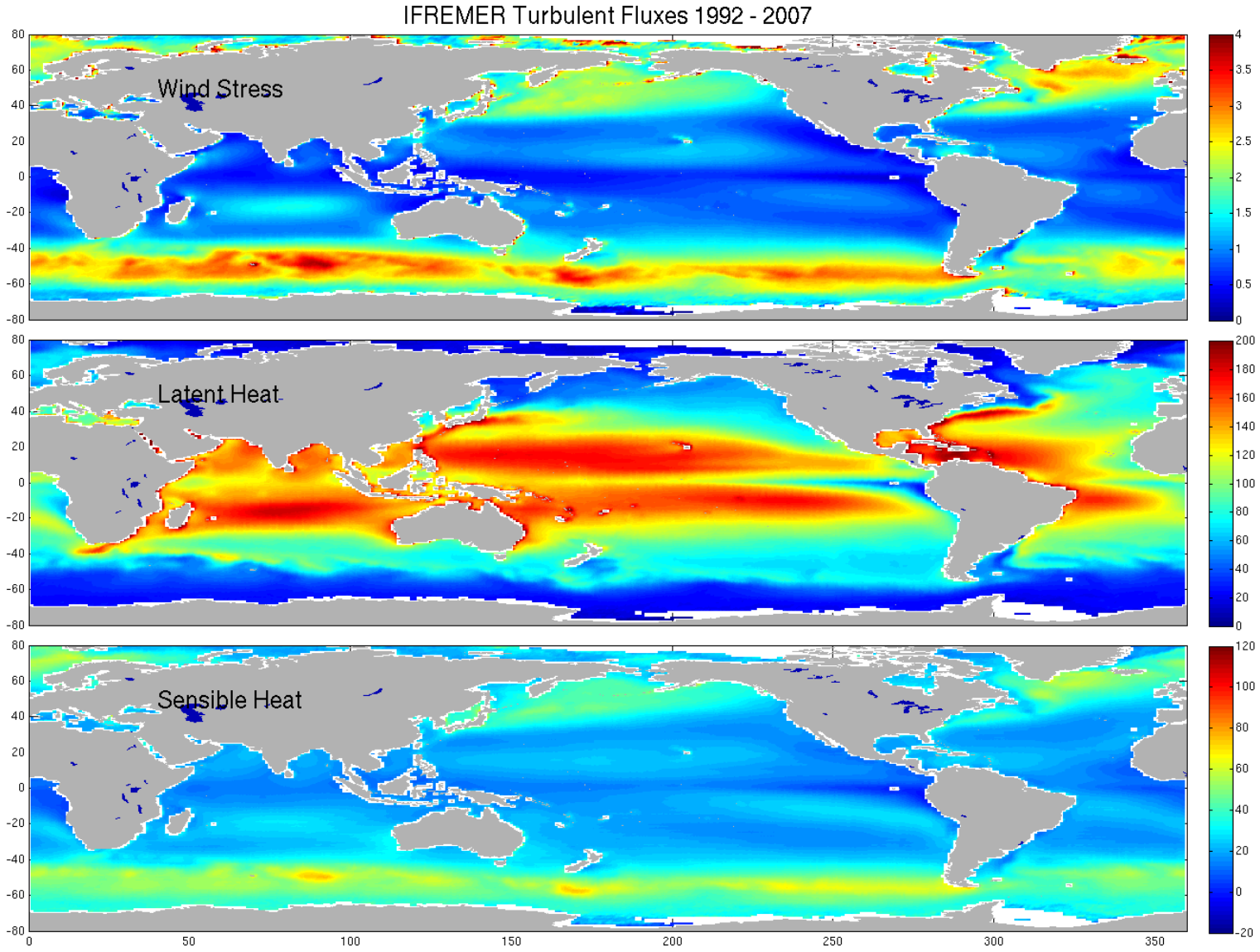
- The higher the radiometric resolution, the better minute differences of intensity or reflectivity can be represented.



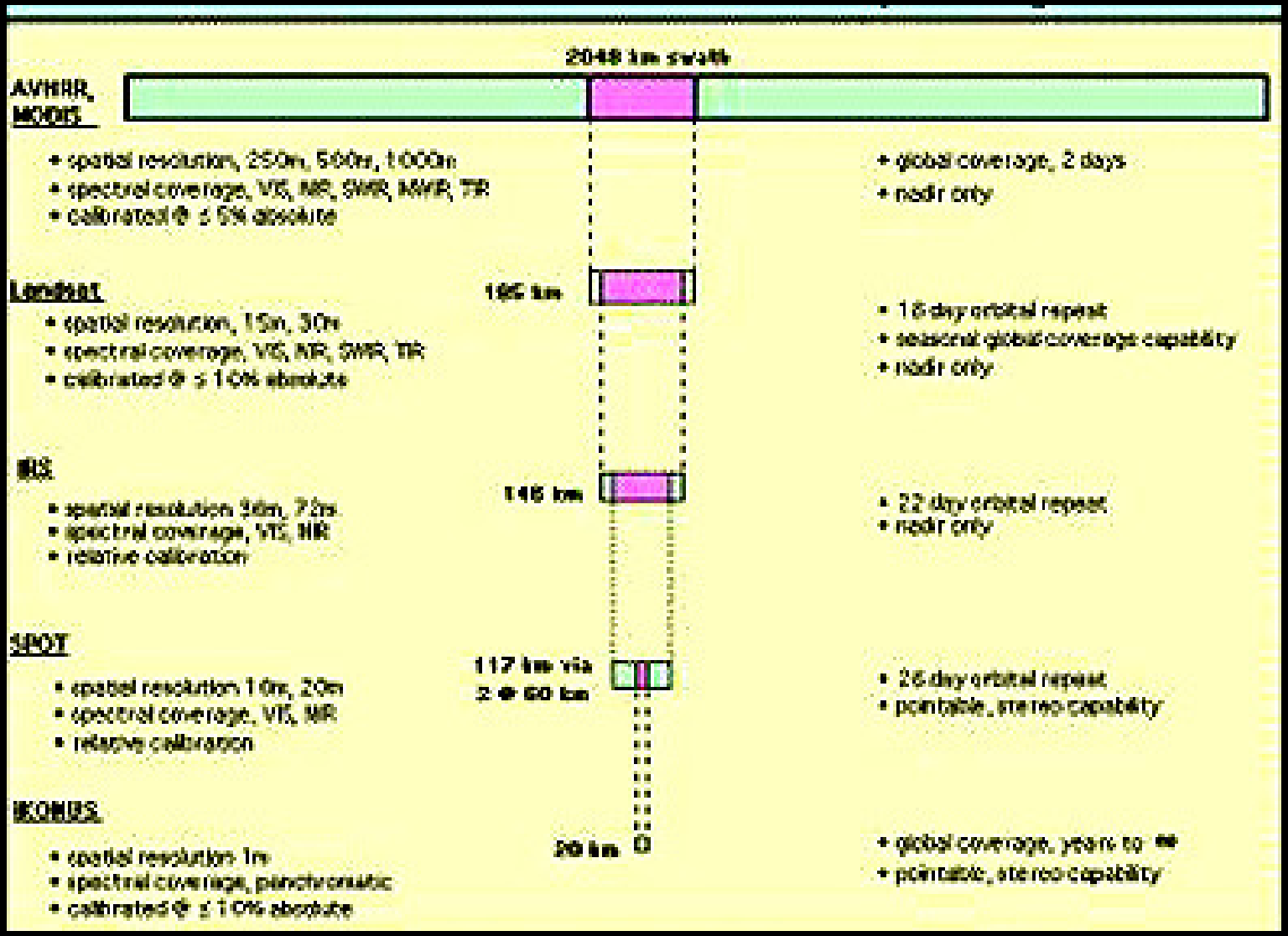
Temporal resolution

The frequency of flyovers by the satellite or plane, and is only relevant in time-series studies




IFREMER Turbulent Fluxes 1992 - 2007
Wind Stress
Latent Heat
Sensible Heat
80
60
40
20
0
-20
-40
-60
-80
0
50
100
150
200
250
300
350
4
3.5
3
2.5
2
1.5
1
0.5
0
200
180
160
140
120
100
80
60
40
20
0
120
100
80
60
40
20
0
-20

SATELLITE RESOLUTION



Parameters	EO-1		
	ALI	HYPERION	AC
Spectral Range	0.4 - 2.4 µm	0.4 - 2.4 µm	0.9 - 1.6 µm
Spatial Resolution	30 m	30 m	250 m
Swath Width	36 Km	7.6 Km	185 Km
Spectral Resolution	Variable	10 nm	6 nm
Spectral Coverage	Discrete	Continuous	Continuous
Pan Band Resolution	10 m	N/A	N/A
Total Number of Bands	10	220	256

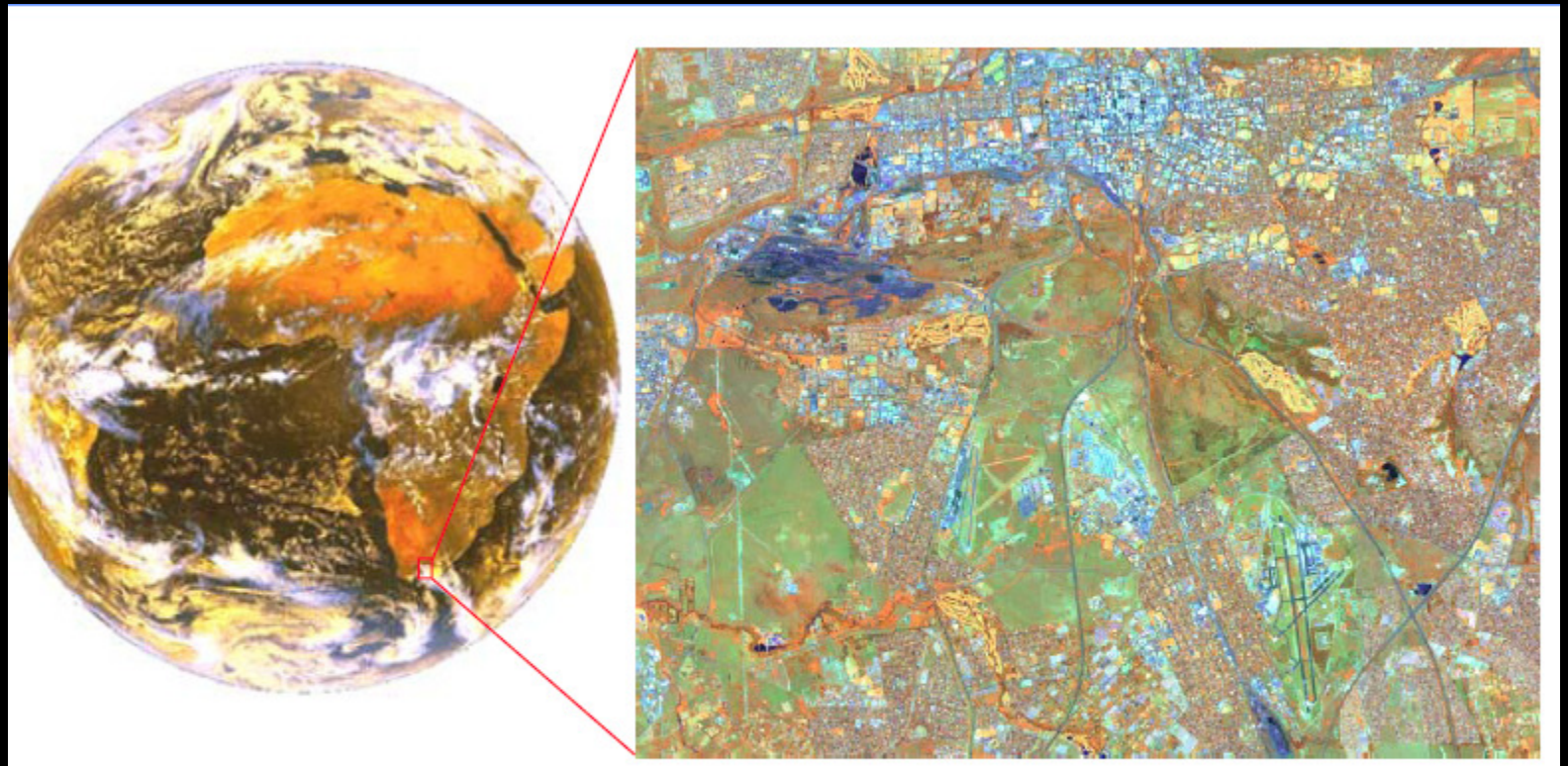
High spatial resolution: 0.6 - 4 m

» GeoEye-1
» WorldView-2
» WorldView-1
» Quick Bird
» IKONOS
» FORMOSAT-2
» ALOS
» CARTOSAT-1
» SPOT-5

Medium spatial resolution: 4 - 30 m

• ASTER
• LANDSAT 7
• CBERS-2
• IRS

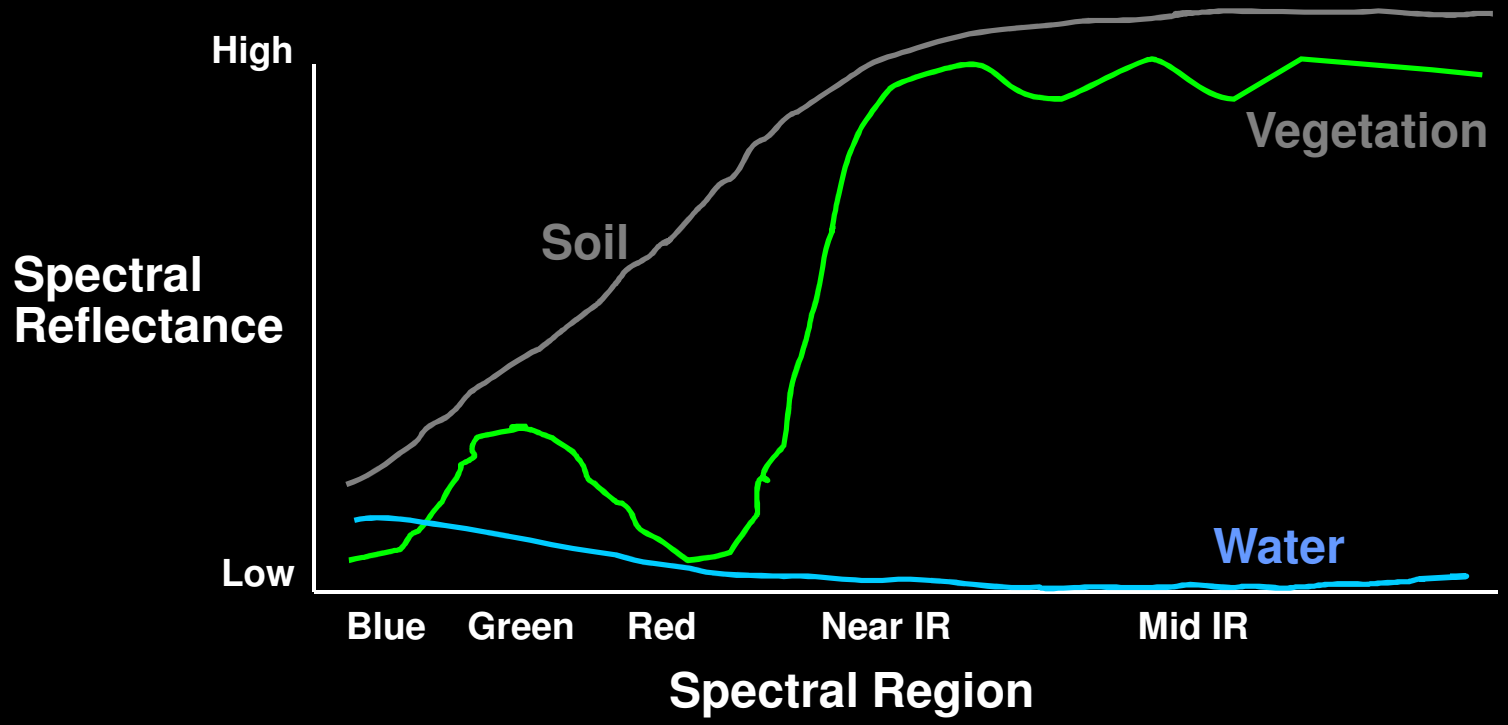
Low spatial resolution: 30 - > 1000 m
• TERRA MODIS



Low resolution : Meteosat V

High resolution : SPOT (Pretoria)

Spectral Reflectance Curve



Spectral signature of natural surfaces

The reflectance (%): The ratio of energy reflected by a surface at a given wavelength

Rocks and Soils: reflectance affected by : minerals, surface alteration, texture, structure, water content

Vegetation : related to photosynthetic activity 9plant phenology), plant morphology, leaf shape and water content

Water : low reflectance: most of the radiation is absorbed or transmitted. Reflectance is substantially modified by suspended materials (loams, algae) and depth

Roughness of surface ⇨ Increase of backscattering

Free (liquid) water
Smooth Surface ⇨ dark

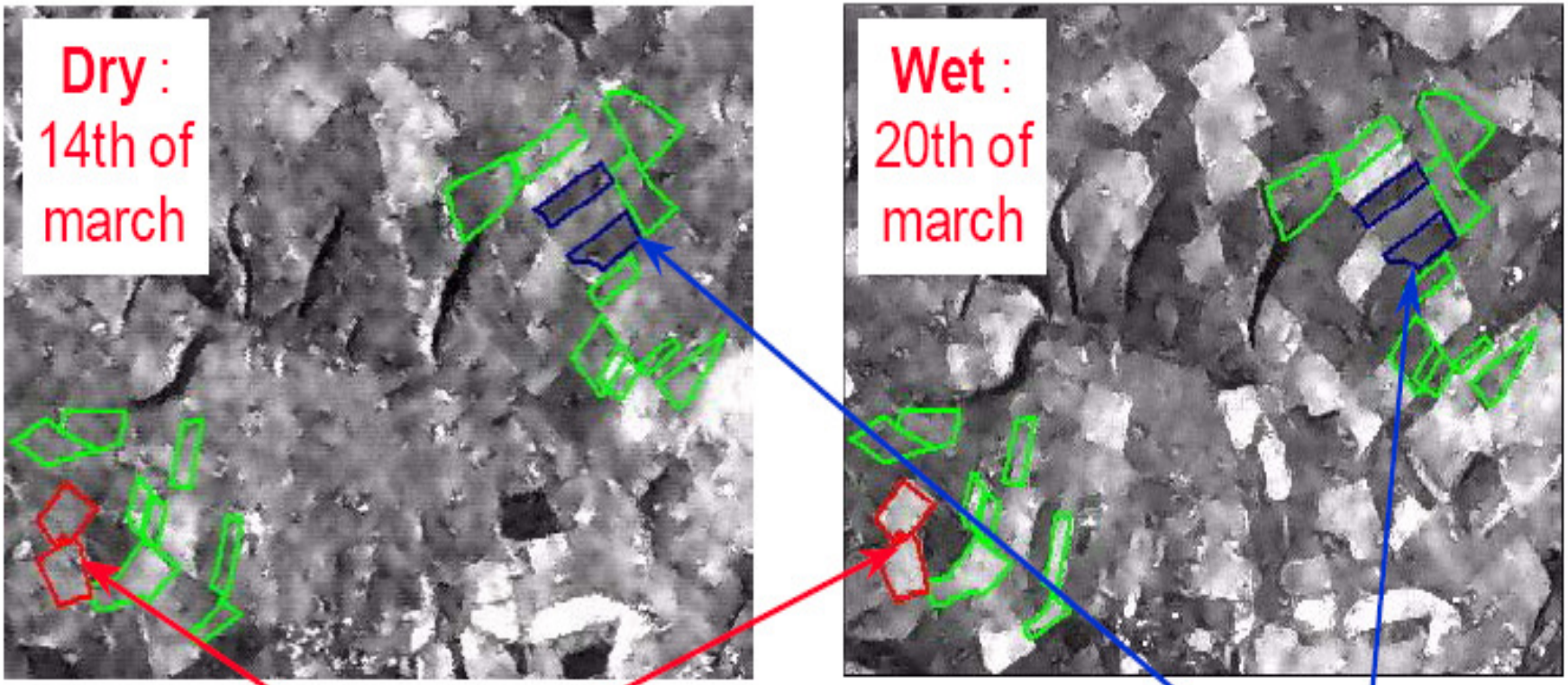
Urban Area
Rough Surface ⇨ bright

Prepared Fields
Rough Surface ⇨ bright

Crop at early stage
Smooth Surface ⇨ dark

Effect of soil roughness and moisture

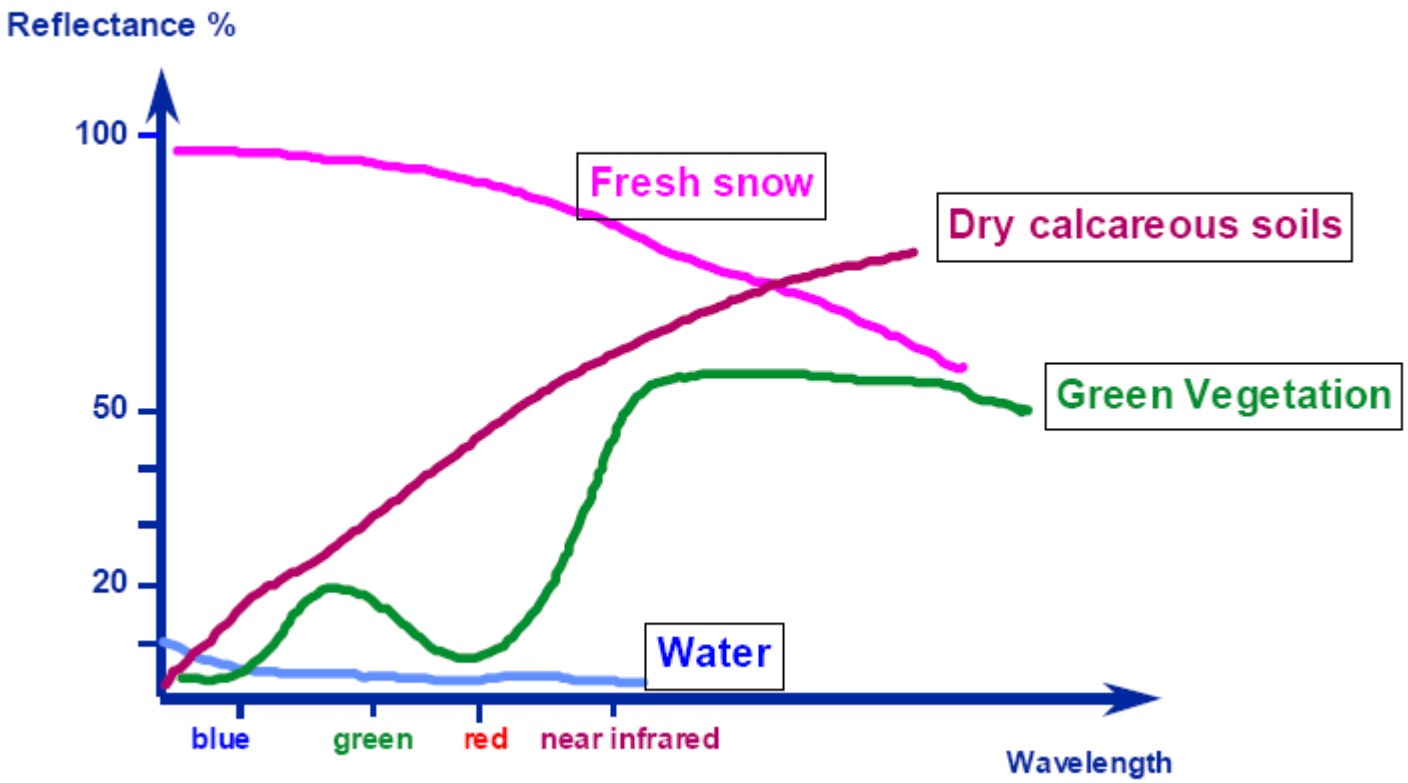
Moisture ➡ Increase in back-scatter



Fields prepared for summer crop
Rough -> High Backscatter -> Bright
Even Brighter when wet

Young winter barley (smooth)
-> Dark, a bit less when wet

TYPICAL SPECTRAL SIGNATURES OF NATURAL SURFACES



Spectral signature of vegetation

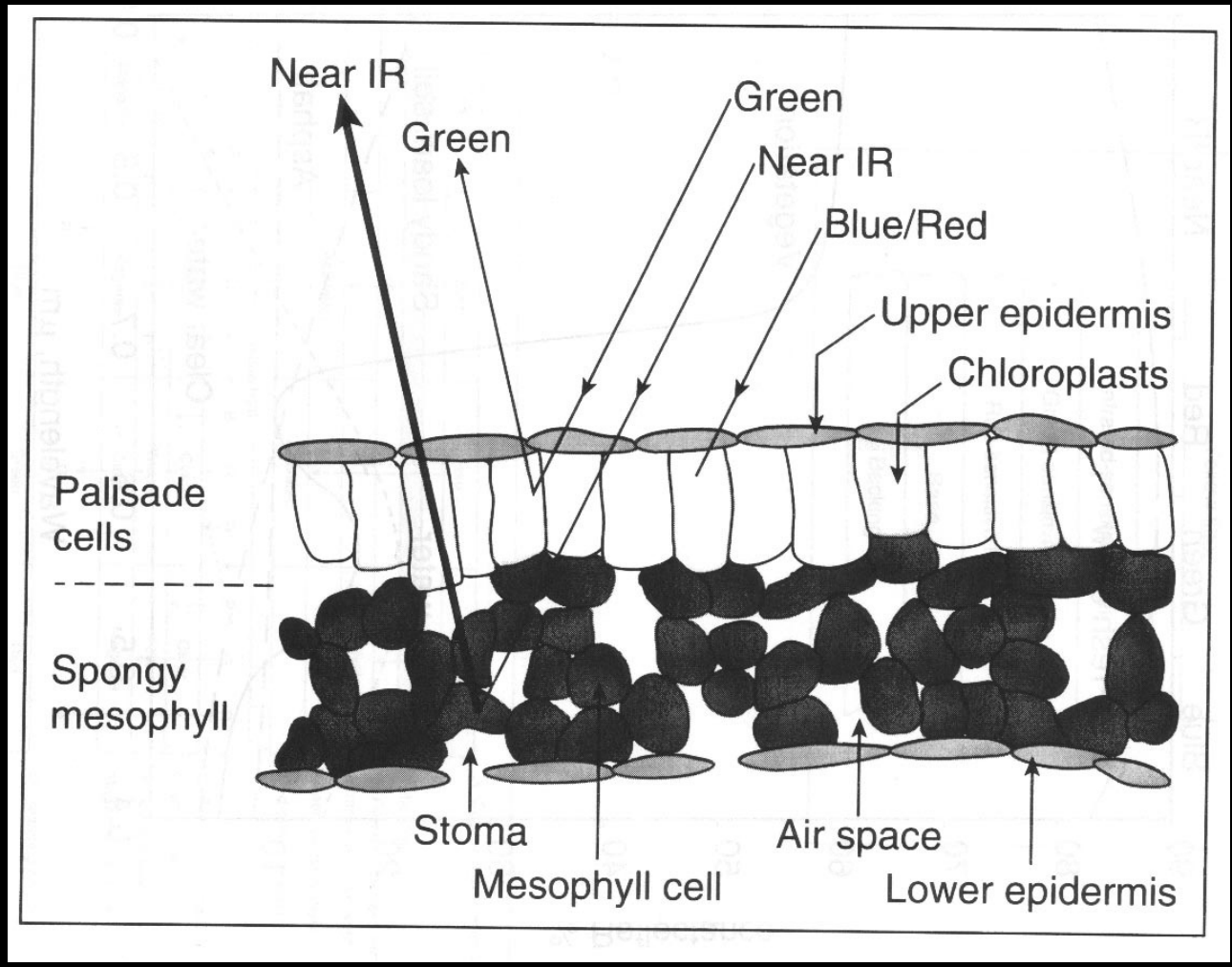
The photosynthesis process uses solar radiation as a source of energy for the fixation of atmospheric CO_2

- Solar radiation (visible) is absorbed by the leaf pigments
- Lower energy radiation (Near Infra Red) is emitted by leaf pigments

- **Chlorophyll a** (65%), **xantophyll** (29%), **carotene** (6%): 0.445µm (**blue**)
- **Chlorophyll b**: 0.645 µm (**red**)

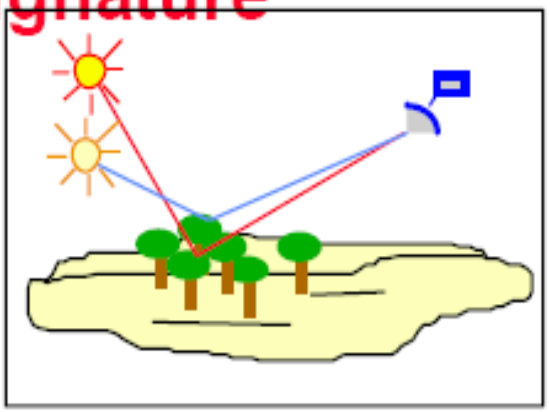
The greater the photosynthesis
*the lower the reflectance in the **visible,***
*the higher the reflectance in the **NIR**.*

Reflectance from a leaf

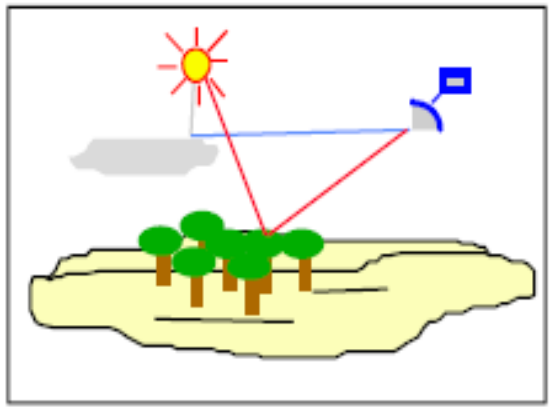


From Avery & Berlin, 1977

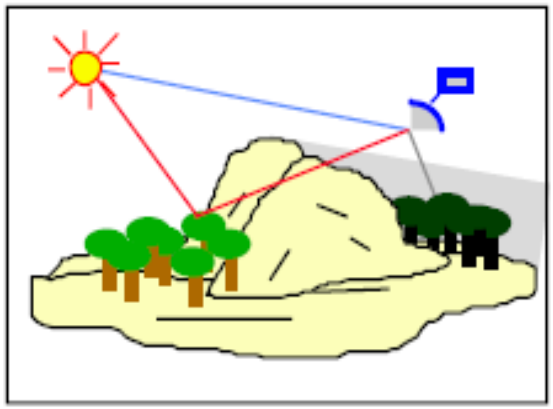
Factors influencing the spectral signature



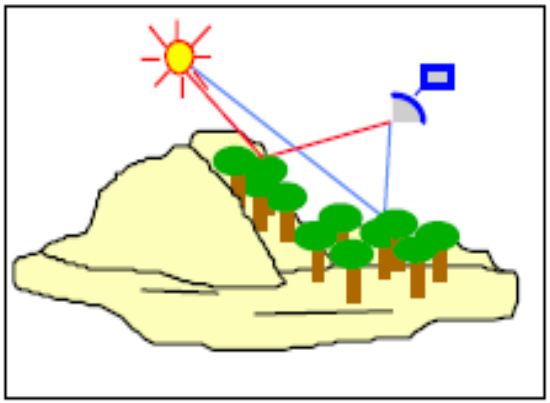
Heigth of the sun
(date, time)



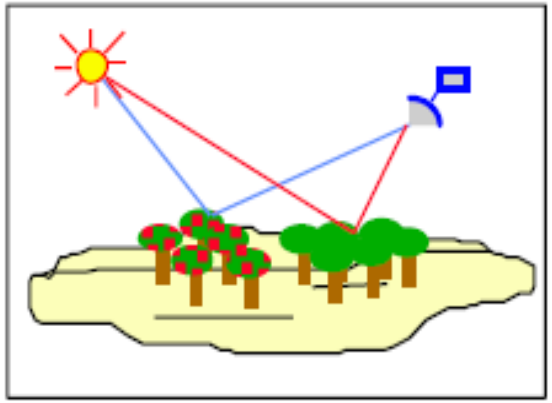
Atmospheric conditions



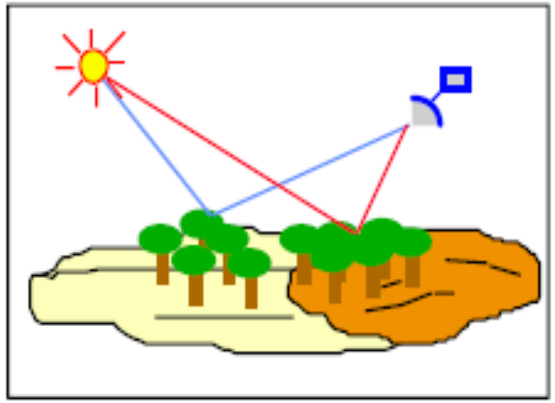
Relief (shadow)



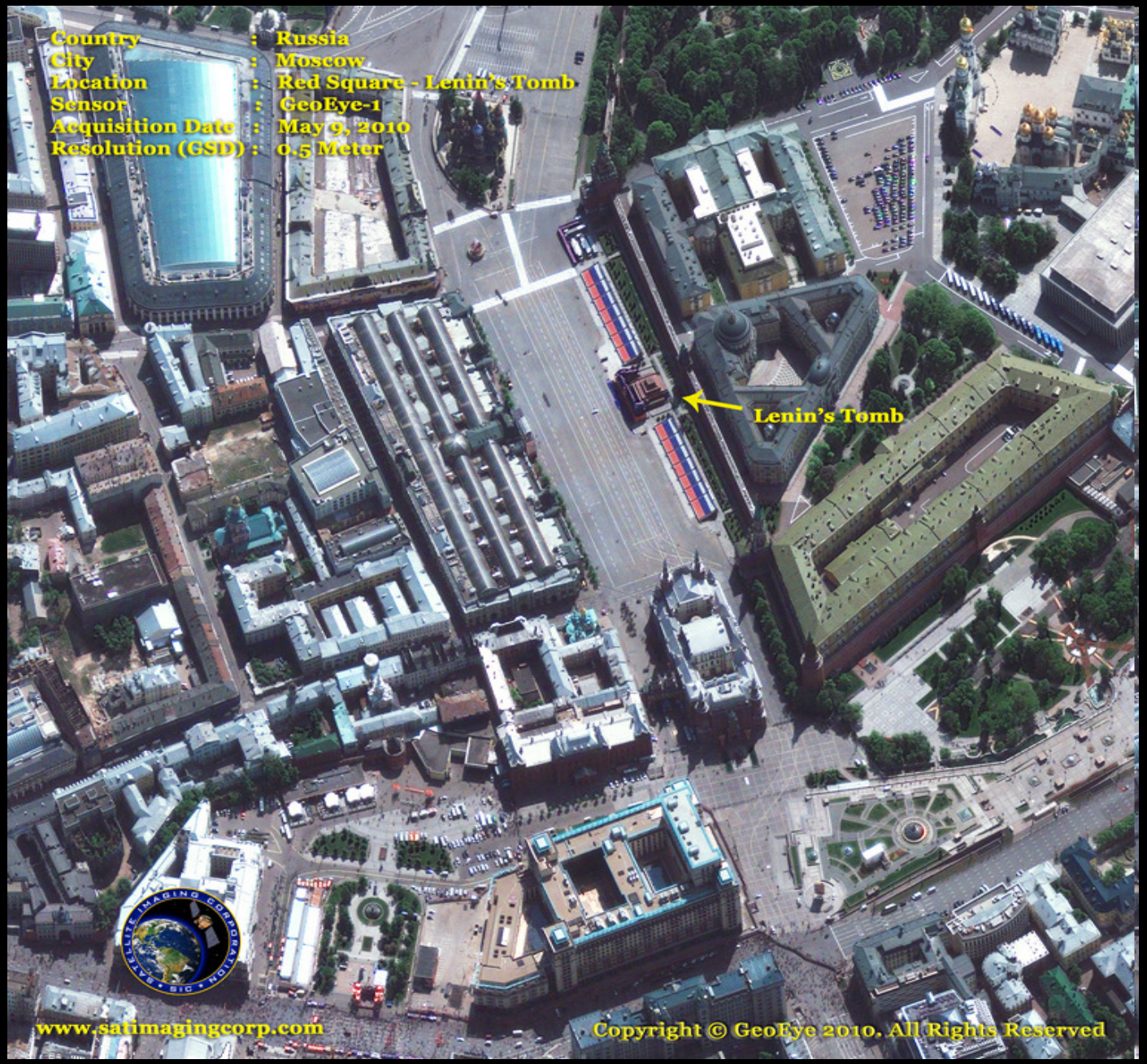
Relief (slope)



Phenology, disease



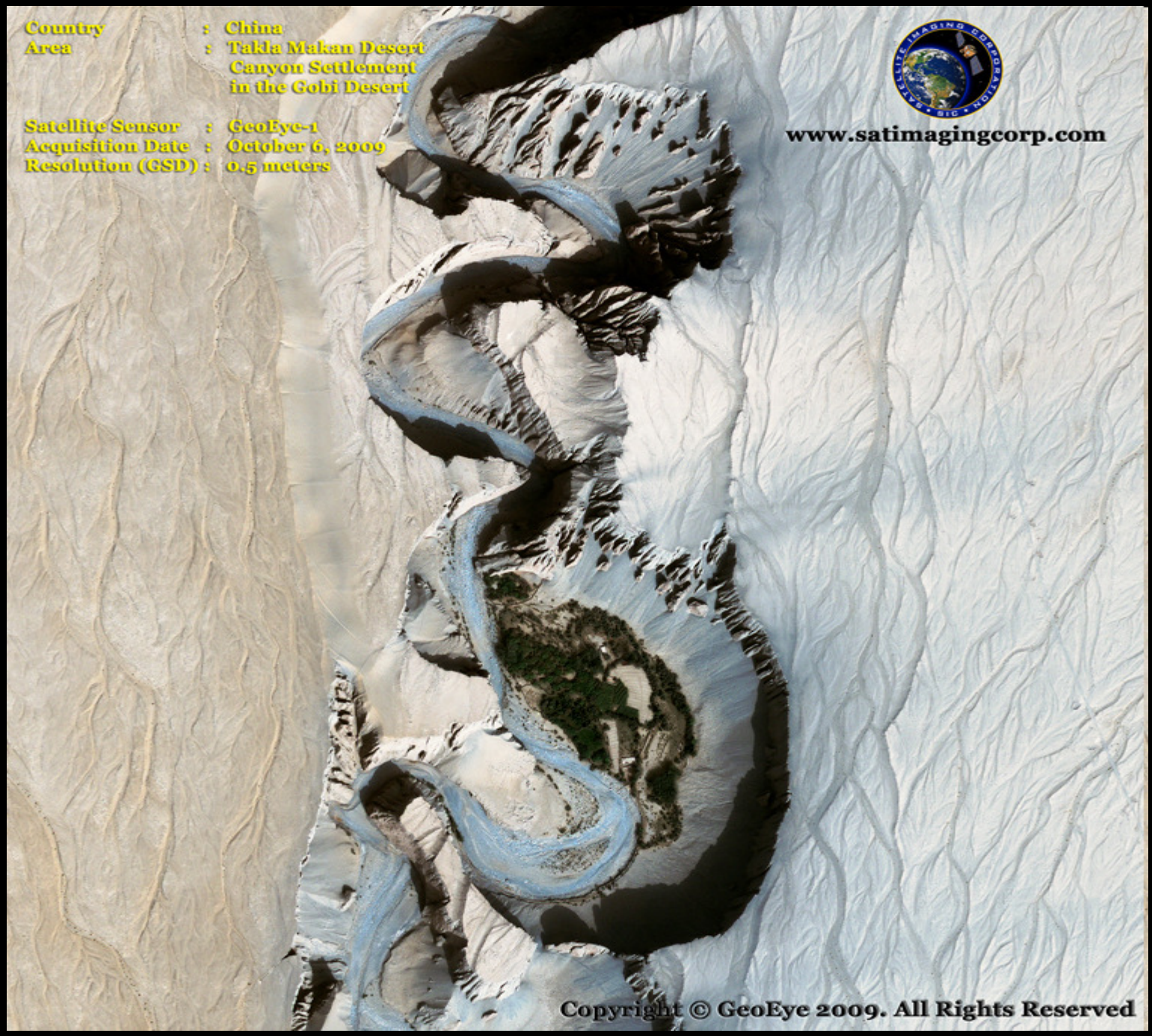
Environment


Country : Russia
City : Moscow
Location : Red Square - Lenin's Tomb
Sensor : GeoEye-1
Acquisition Date : May 9, 2010
Resolution (GSD) : 0.5 Meter
Lenin's Tomb
www.satimagingcorp.com
Copyright © GeoEye 2010. All Rights Reserved


Country : U.S.A.
State : Arizona Nevada
Location : Hoover Dam
Satellite Sensor : GeoEye-1
Acquisition Date : January 10, 2009
Resolution (GSD) : 0.5m
www.satimagingcorp.com
Copyright © 2009 - GeoEye - All rights reserved


Country : UAE
City : Dubai
Area : Burj Khalifa Building
Tallest Manmade Stucture
in the World
Sensor : GeoEye-1
Acquisition Date : February 9, 2010
Resolution (GSD) : 0.5 meters
www.satimagingcorp.com
Copyright © GeoEye 2010, All Rights Reserved


www.satimagingcorp.com
Copyright © 2007 GeoEye. All Rights Reserved.
IKONOS satellite (0.8 meter resolution)
Rapa III polynesia
April 12, 2002


Country : China
Area : Takla Makan Desert
Canyon Settlement
in the Gobi Desert
Satellite Sensor : GeoEye-1
Acquisition Date : October 6, 2009
Resolution (GSD) : 0.5 meters
www.satimagingcorp.com
Copyright © GeoEye 2009. All Rights Reserved


Country : United Arab Emirates - UAE
City : Dubai
Area : Dubai International Airport - 2009 Dubai Airshow
The Airshow is the foremost aerospace event in the Middle East.
Satellite Sensor : GeoEye-1
Acquisition Date : November 16, 2009
Resolution (GSD) : 0.5 meters
SATELLITE IMAGING CORPORATION
SIC
www.satimagingcorp.com
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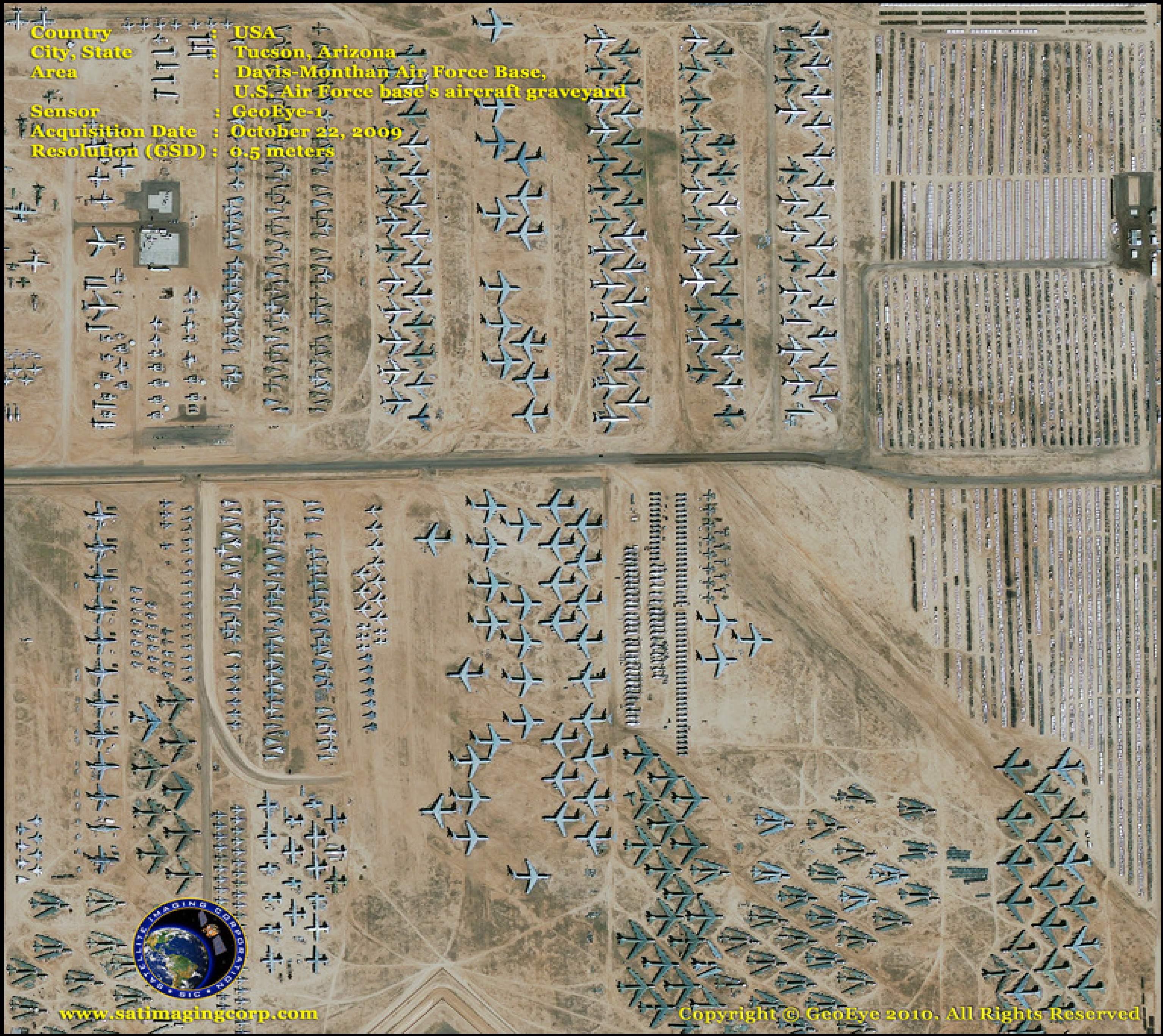
Country : USA
City, State : Tucson, Arizona
Area : Davis-Monthan Air Force Base,
U.S. Air Force base's aircraft graveyard
Sensor : GeoEye-1
Acquisition Date : October 22, 2009
Resolution (GSD) : 0.5 meters
SATELLITE IMAGING CORPORATION
SIC
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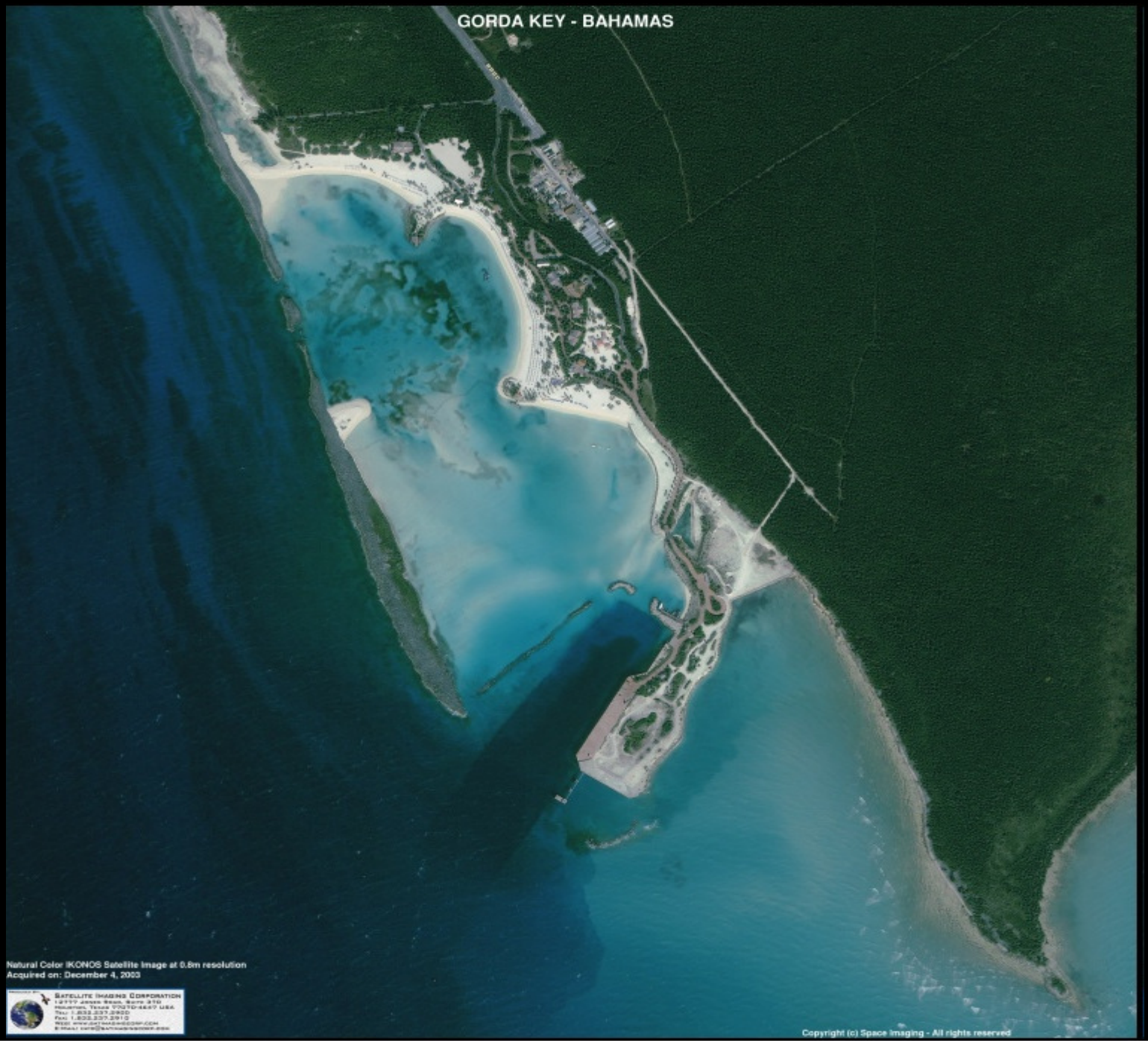
GORDA KEY - BAHAMAS
Natural Color IKONOS Satellite Image at 0.8m resolution
Acquired on: December 4, 2003
Satellite Imaging Corporation
Copyright (c) Space Imaging - All rights reserved


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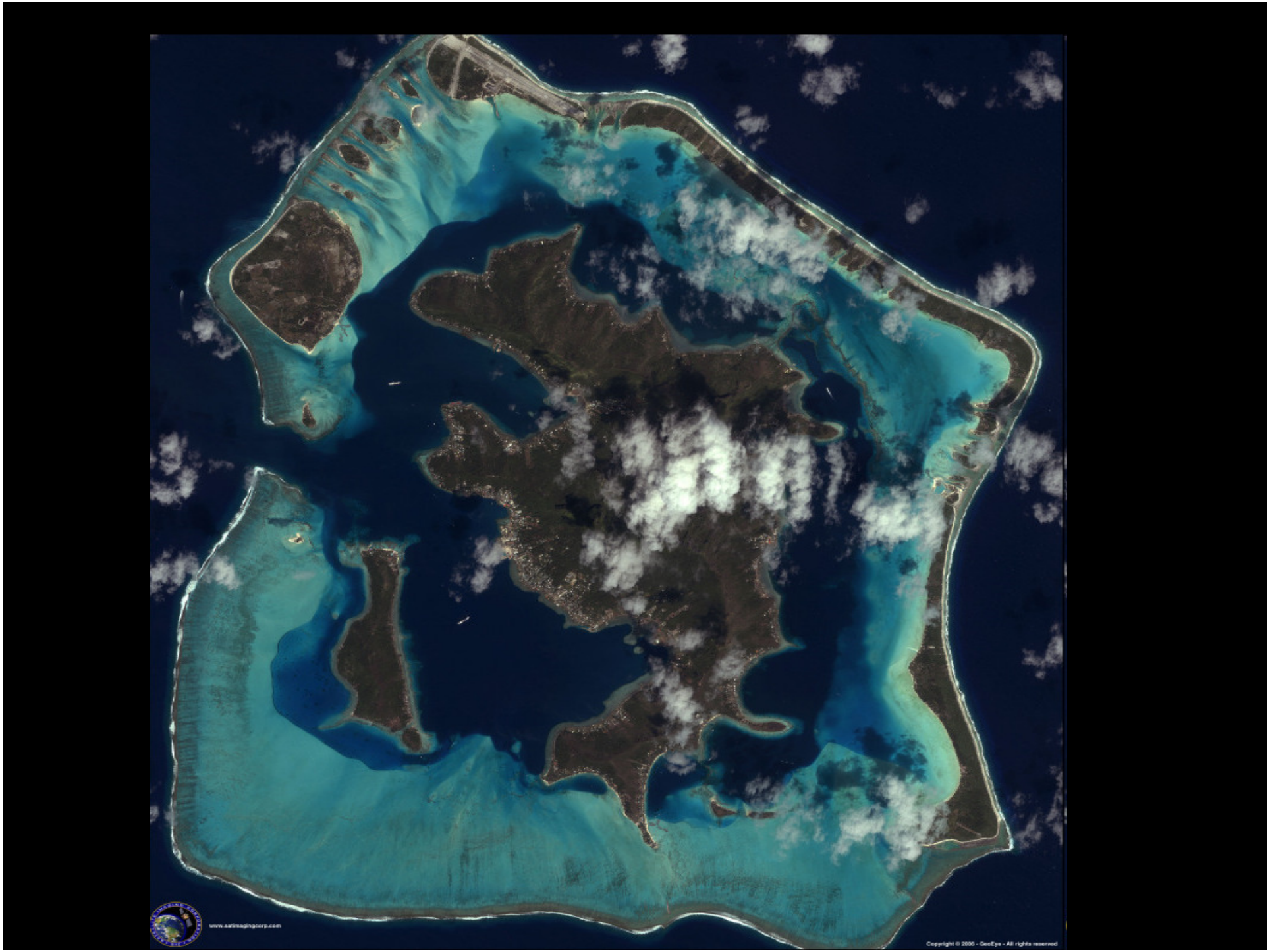
www.satimagingcorp.com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www.satimagingcorp.com

IKONOS Satellite Image of Vatican City - Rome, Italy
Acquired on: May -5, 2003

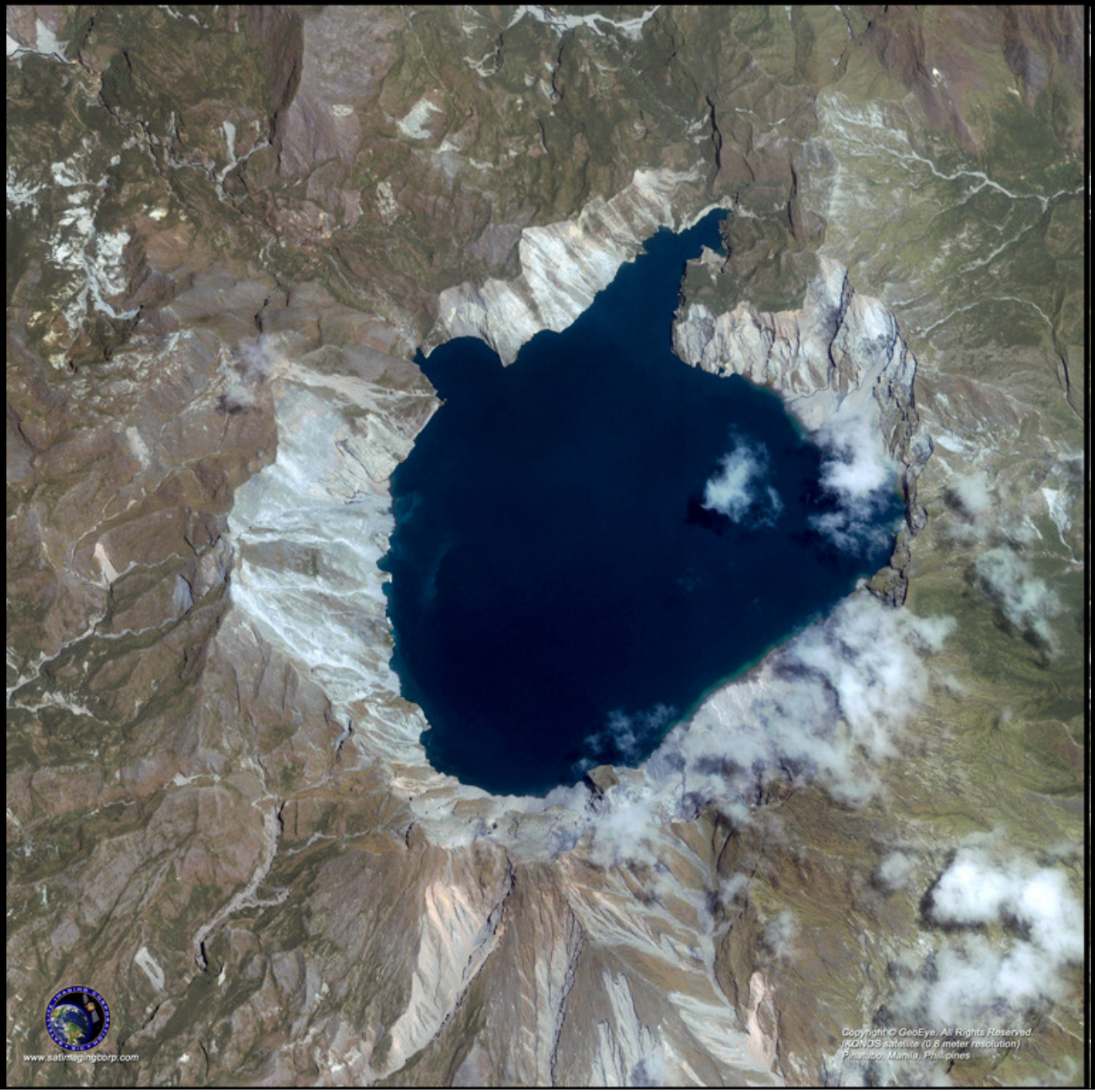

Copyright © 2007 GeoEye/EUSI. All Rights Reserved
IKONOS (0.8 meter resolution)
Barcelona, Spain
2003
www.satimagingcorp.com


NORTH KOREA - Taipo Dong Missile Complex
Missile Control Building
Missile Assembly/Checkout Building
Launch Pad
IKONOS SATELLITE IMAGE
COLLECTED: 15-JUN-2006
IKONOS Satellite Image Courtesy of GeoEye /WIA


Algiers, Algeria
IKONOS 0.8m Satellite
Acquired: 20-Aug-2004
www.satimagingcorp.com
Copyright © Space Imaging - All rights reserved

Rumalia, Iraq

Manila, Phillipines (Mt. Pinatubo)

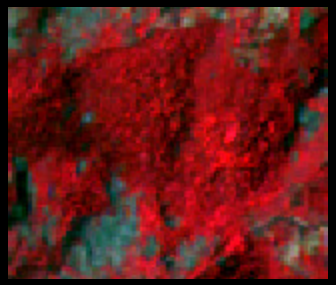



Take a break

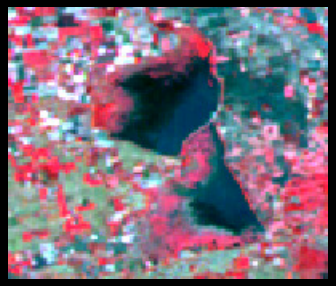
Image Interpreter

The scientist who delineates the imagery is called Image interpreter.
He gives meaning to the image based on the Tone, Texture, Size, Shape, etc.

Tone



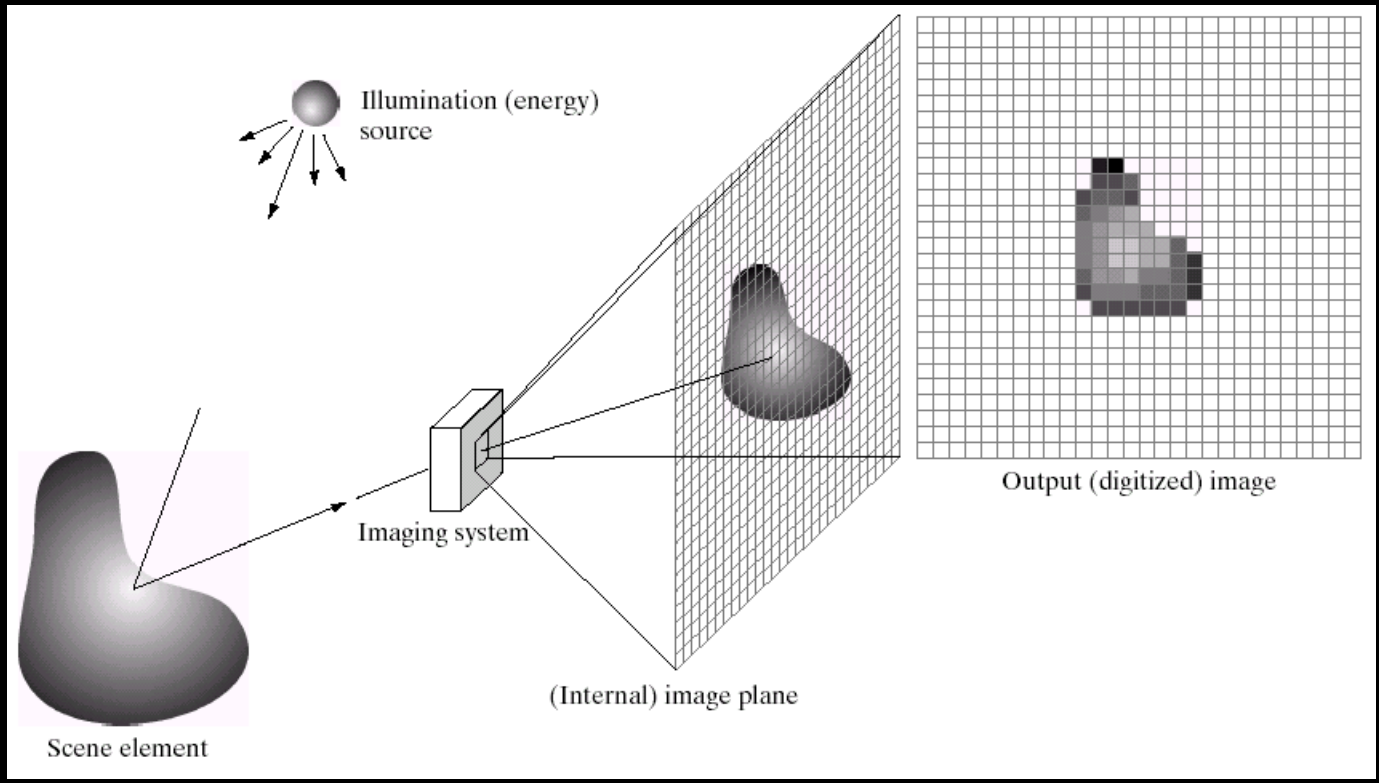
Texture



Size &
Shape

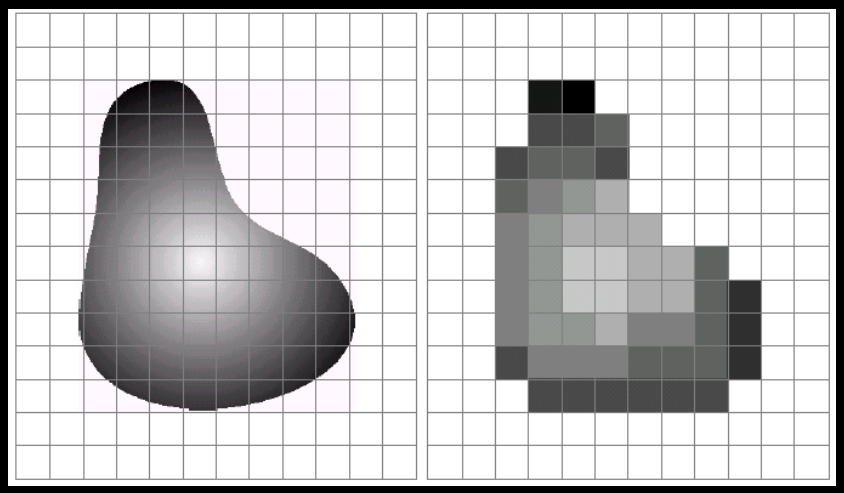
What is a Digital Image?

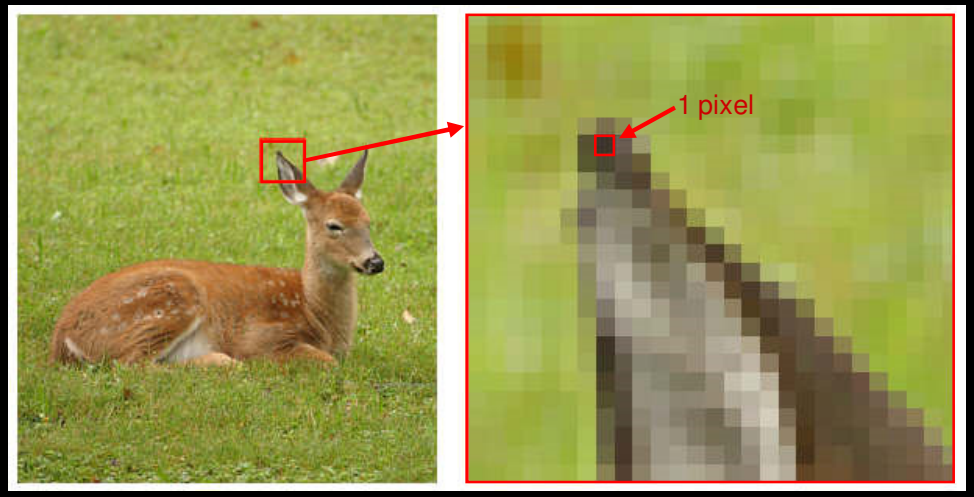
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels



What is a Digital Image? (cont…)

- Pixel values typically represent gray levels, colours, heights, opacities etc
- **Remember** *digitization* implies that a digital image is an *approximation* of a real scene





What is a Digital Image?

- Common image formats include:
  - 1 sample per point (B&W or Grayscale)
  - 3 samples per point (Red, Green, and Blue)
  - 4 samples per point (Red, Green, Blue, and “Alpha”, a.k.a. Opacity)



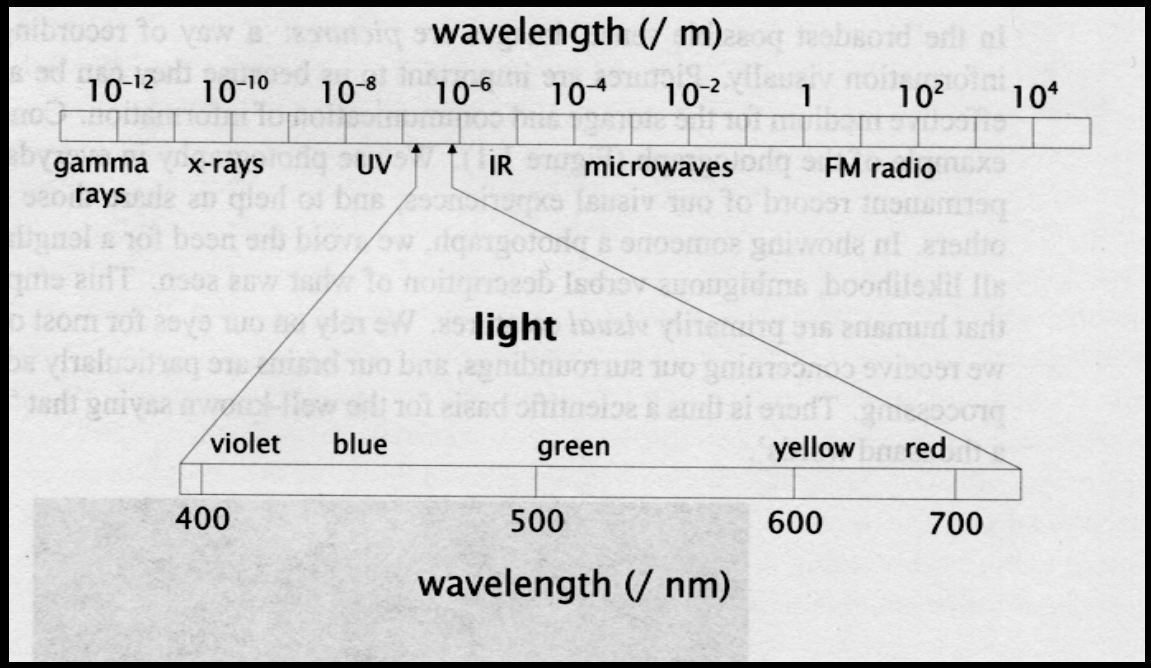
Image formation

- Optical parameters of the lens
  - lens type
  - focal length
  - field of view
- Photometric parameters
  - type, intensity, and direction of illumination
  - reflectance properties of the viewed surfaces
- Geometric parameters
  - type of projections
  - position and orientation of camera in space
  - perspective distortions introduced by the imaging process

Image distortion

What is light?

- The visible portion of the **electromagnetic** (EM) spectrum.
- It occurs between wavelengths of approximately 400 and 700 nanometers.



Short wavelengths

- Different wavelengths of radiation have different properties.
- The **x-ray** region of the spectrum, it carries sufficient energy to penetrate a significant volume or material.

Long wavelengths

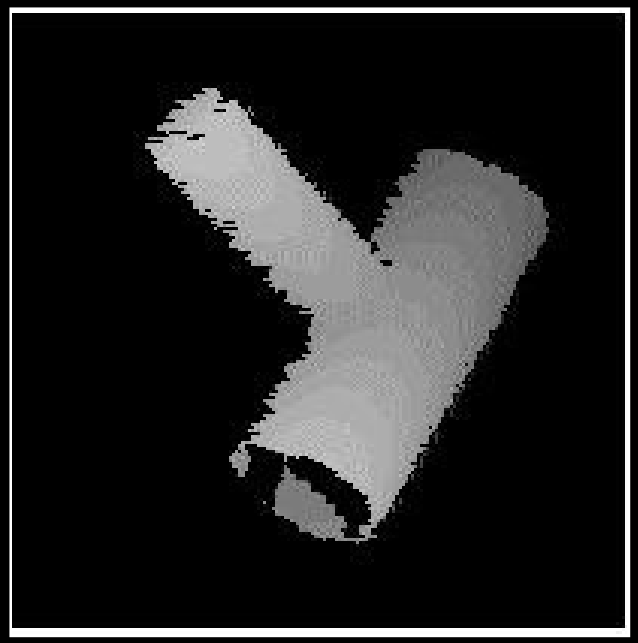
- Copious quantities of **infrared** (IR) radiation are emitted from warm objects (e.g., locate people in total darkness).

Long wavelengths

- "**Synthetic aperture radar**" (SAR) imaging techniques use an artificially generated source of microwaves to probe a scene.
- SAR is unaffected by weather conditions and clouds (e.g., has provided us images of the surface of Venus).

Range images

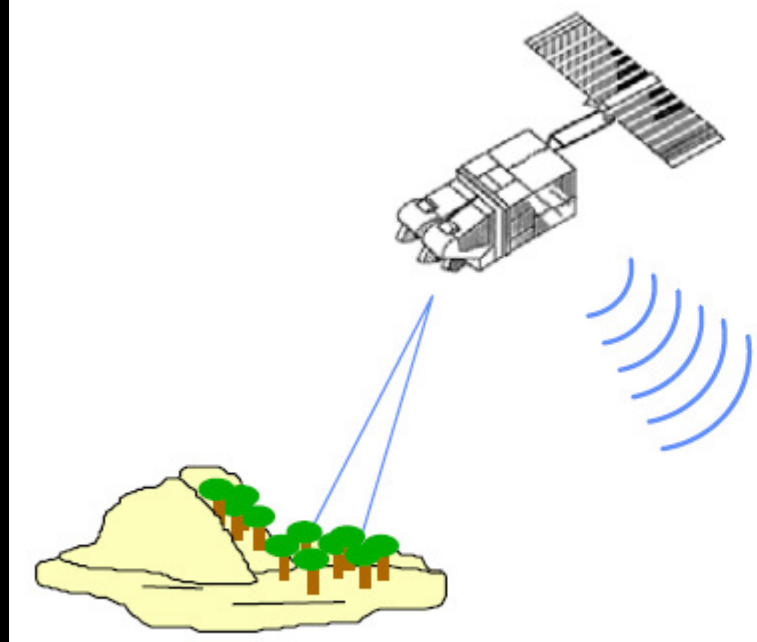
- An array of distances to the objects in the scene.
- They can be produced by sonar or by using laser rangefinders.



Sonic images

- Produced by the reflection of sound waves off an object.
- High sound frequencies are used to improve resolution.

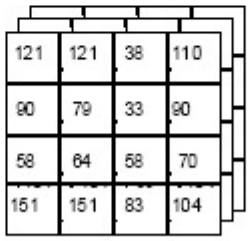
Remote sensing sensors measure the earth's surface reflection, emission or back-scattering in various wavelengths. The measurements are compiled into ***grids of mumbers****, the* ***digital images****.*

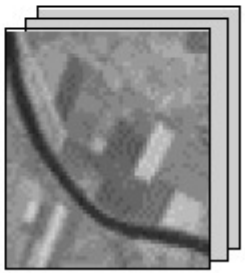


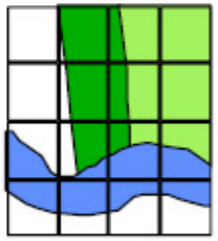
Images are matrices of individual points with digital values

→ concepts of **grid, raster**

→ concept of **PIXEL** **(Picture Element)**

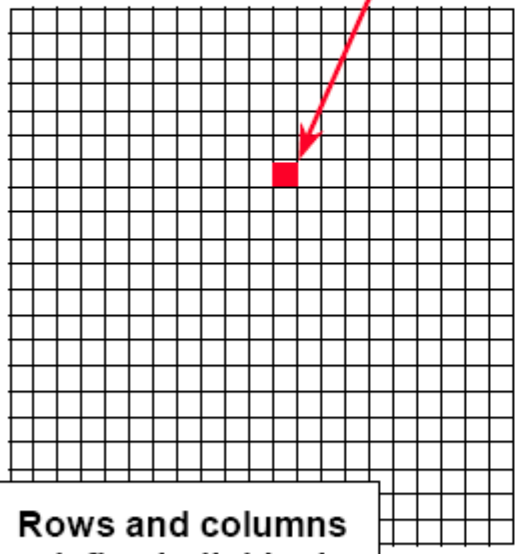






Digital image = grid system

PIXEL: • coordinates
• digital count(s)



Rows and columns define individual cells (pixels)

ROWS

COLUMNS

121	121	38	110	203
90	79	33	90	115
58	64	58	70	66
151	151	83	104	129
123	85	75	96	69

Value = Digital Count (DC)
Usually coded on 8 bits
→ $2^8 = 256$ possible values
Values range between **0** and **255**

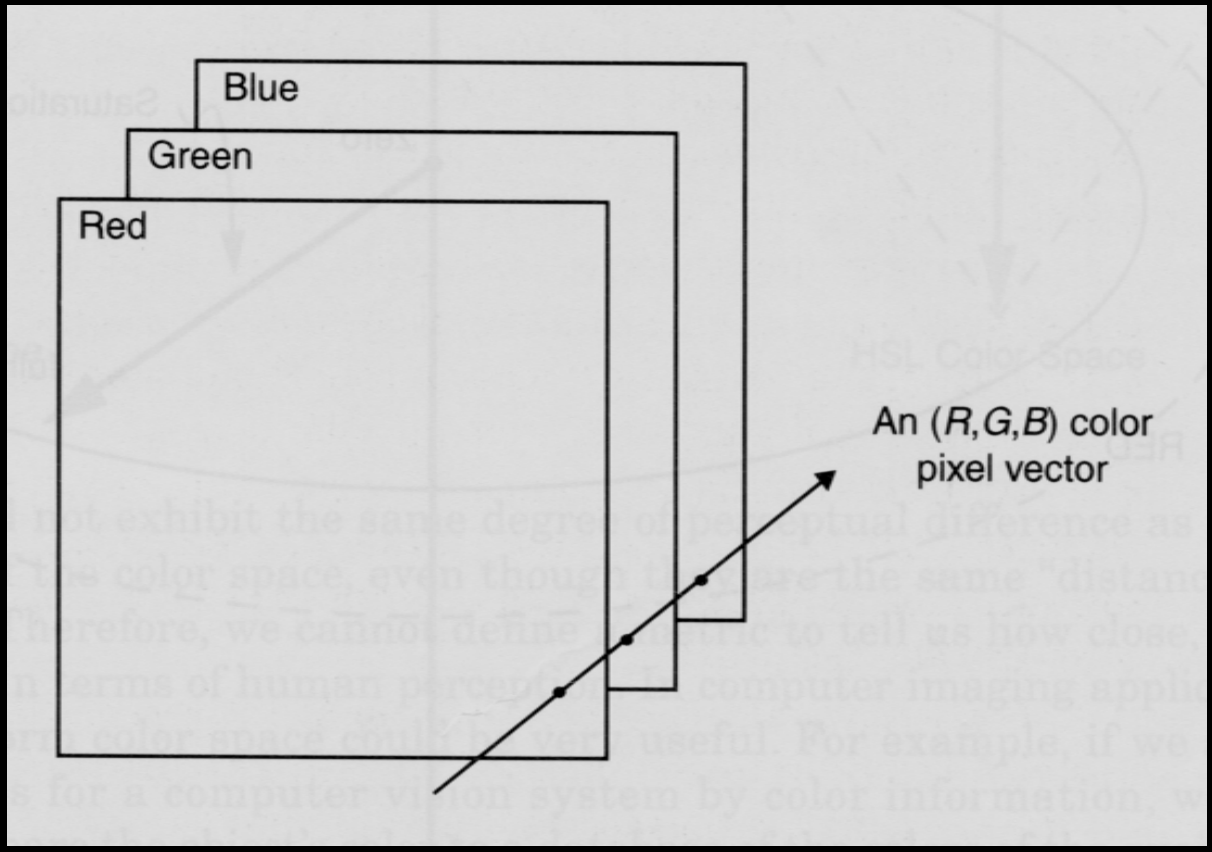
PIXEL
= Picture Element

Digital image

- An image is represented by a rectangular array of integers.
- An integer represents the brightness or darkness of the image at that point.
- N: # of rows, M: # of columns, Q: # of gray levels
  - N = 2^n , M = 2^m , Q = 2^q (q is the # of bits/pixel)
  - Storage requirements: NxMxQ (e.g., N=M=1024, q=8, 1MB)

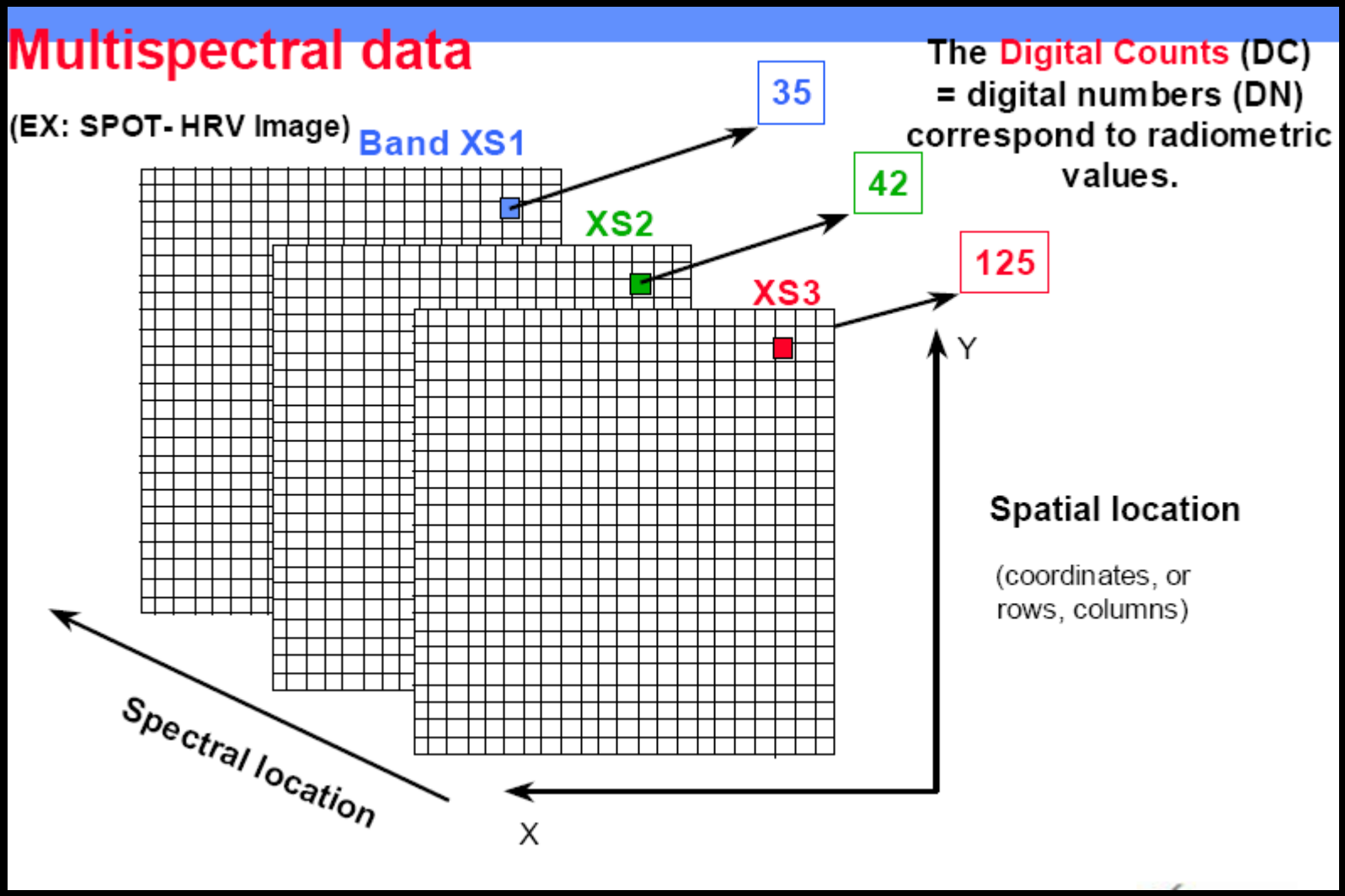
$$\begin{matrix} f(0,0) & f(0,1) & \ldots & f(0,M-1) \\ f(1,0) & f(1,1) & \ldots & f(1,M-1) \\ \ldots & \ldots & \ldots & \ldots \\ f(N-1,0) & f(N-1,1) & \ldots & f(N-1,M-1) \end{matrix}$$

Color images



Multispectral data

(EX: SPOT- HRV Image)



5 - Display and Processing

DISPLAY : ***ANY PROCESS USED TO TRANSFORM INFORMATION MEASURED BY A SENSOR INTO A DOCUMENT EASY TO READ FOR A HUMAN OBSERVER***

Association of a shade of grey or colour with each digital count using an *encoding table*, Look Up Table (LUT).

Choice of display levels. Usually less than 256.

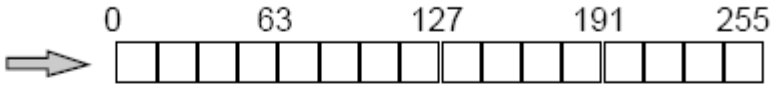
Display and processing used to enhance the image legibility only affect “colours” associated to each pixel **without modify the digital count**.

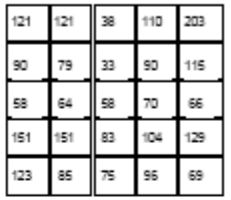
Several "representations" of the same measurement acording to the aim.

Display subjectivity and operator influence

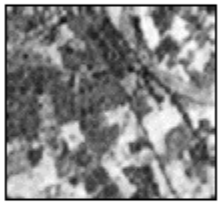
Single Band display → 3 display methods

Digital Counts measured by the sensor





Grey scale : the lowest digital count appears in black, the highest in white.

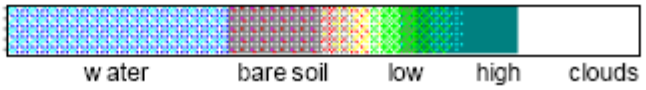


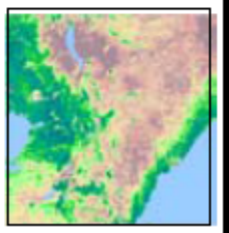
Shades of grey

Colour scale : use of the chromatic scale (from violet to red).

Look Up Table (LUT) : Digital Counts appear with discontinuous chosen colours.
Ex: Vegetation in green
Bare soil in Red/Brown

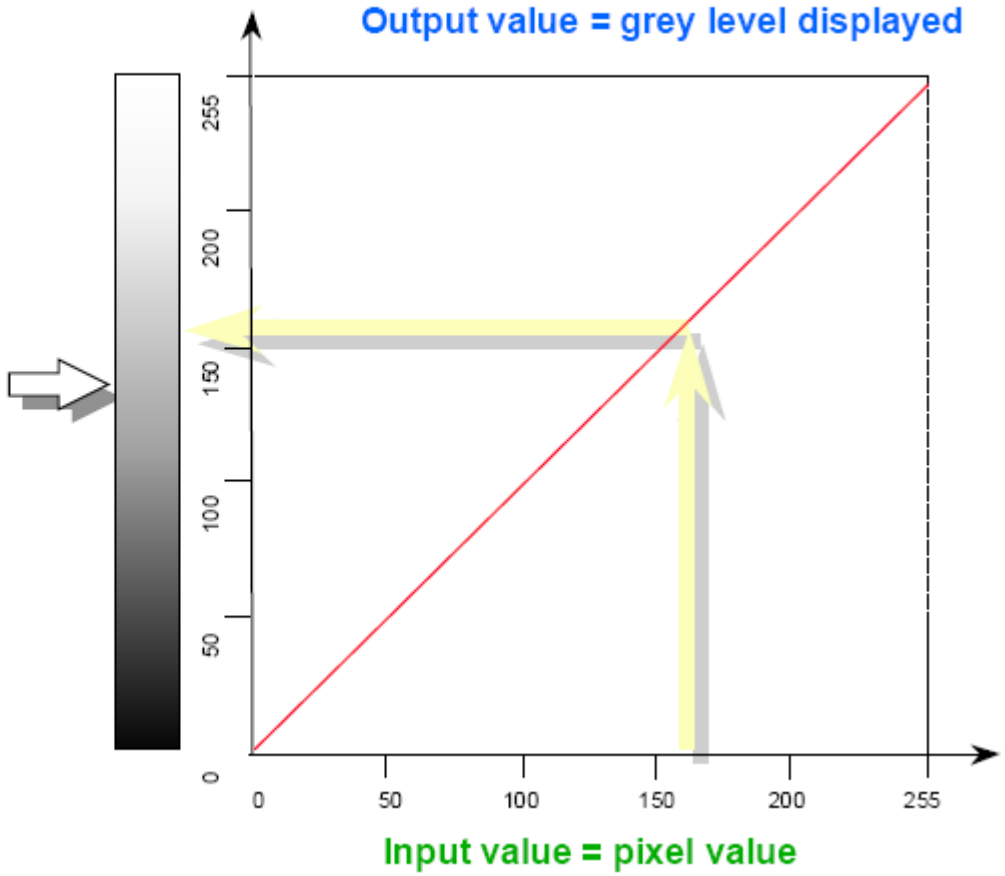
Example : VEGETATION INDEX





Encoding Table: Grey scale

Input Data	Output Data	Color or grey level
255	255	WHITE
254	254	WHITE
253	253	WHITE
206	206	VERY LIGHT GREY
205	205	VERY LIGHT GREY
204	204	VERY LIGHT GREY
154	154	LIGHT GREY
153	153	LIGHT GREY
152	152	LIGHT GREY
122	122	GREY
121	121	GREY
120	120	GREY
69	69	DARK GREY
68	68	DARK GREY
26	26	VERY DARK GREY
25	25	VERY DARK GREY
24	24	VERY DARK GREY
2	2	BLACK
1	1	BLACK
0	0	BLACK



Encoding Table: Colour scale

Input Data	Output Data	Colour or grey level
255	255	RED
254	254	RED
253	253	RED
206	206	ORANGE AND RED
205	205	ORANGE AND RED
204	204	ORANGE AND RED
154	154	ORANGE
153	153	ORANGE
152	152	ORANGE
122	122	YELLOW
121	121	YELLOW
120	120	YELLOW
69	69	GREEN
68	68	GREEN
26	26	BLUE
25	25	BLUE
24	24	BLUE
2	2	VIOLET
1	1	VIOLET
0	0	VIOLET

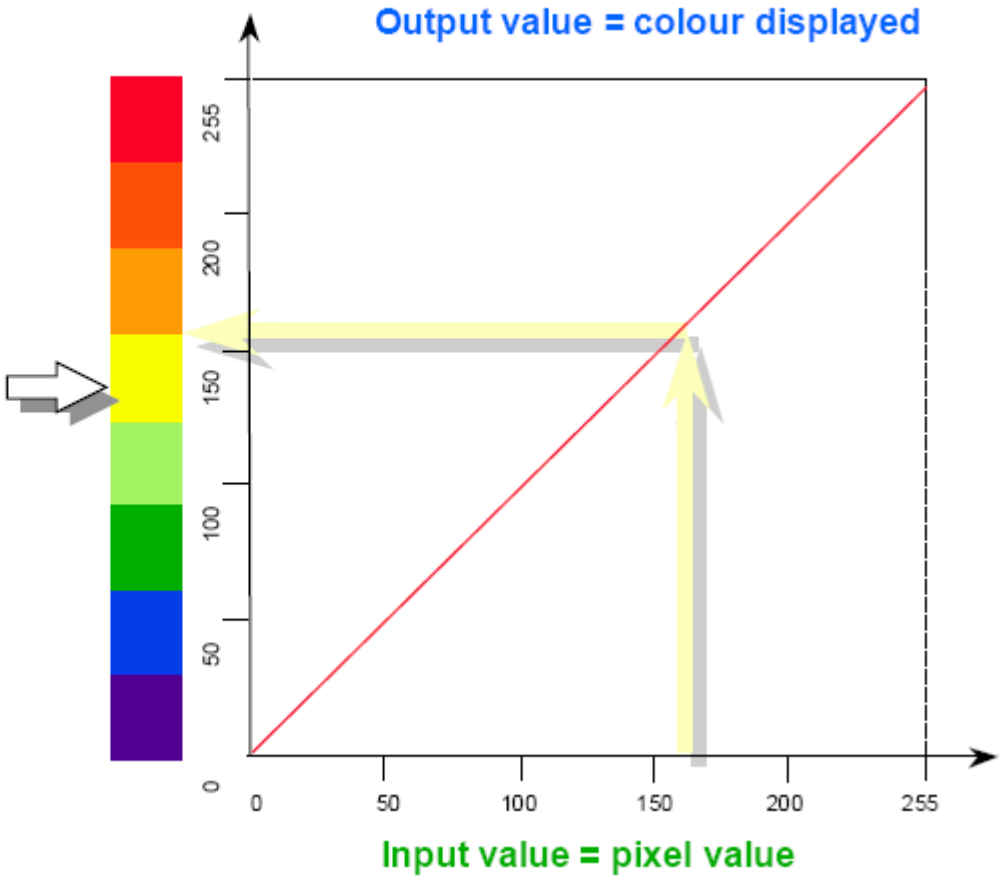


Image coordinate system

$$x = j - \frac{N-1}{2} \qquad y = -(i - \frac{M-1}{2})$$

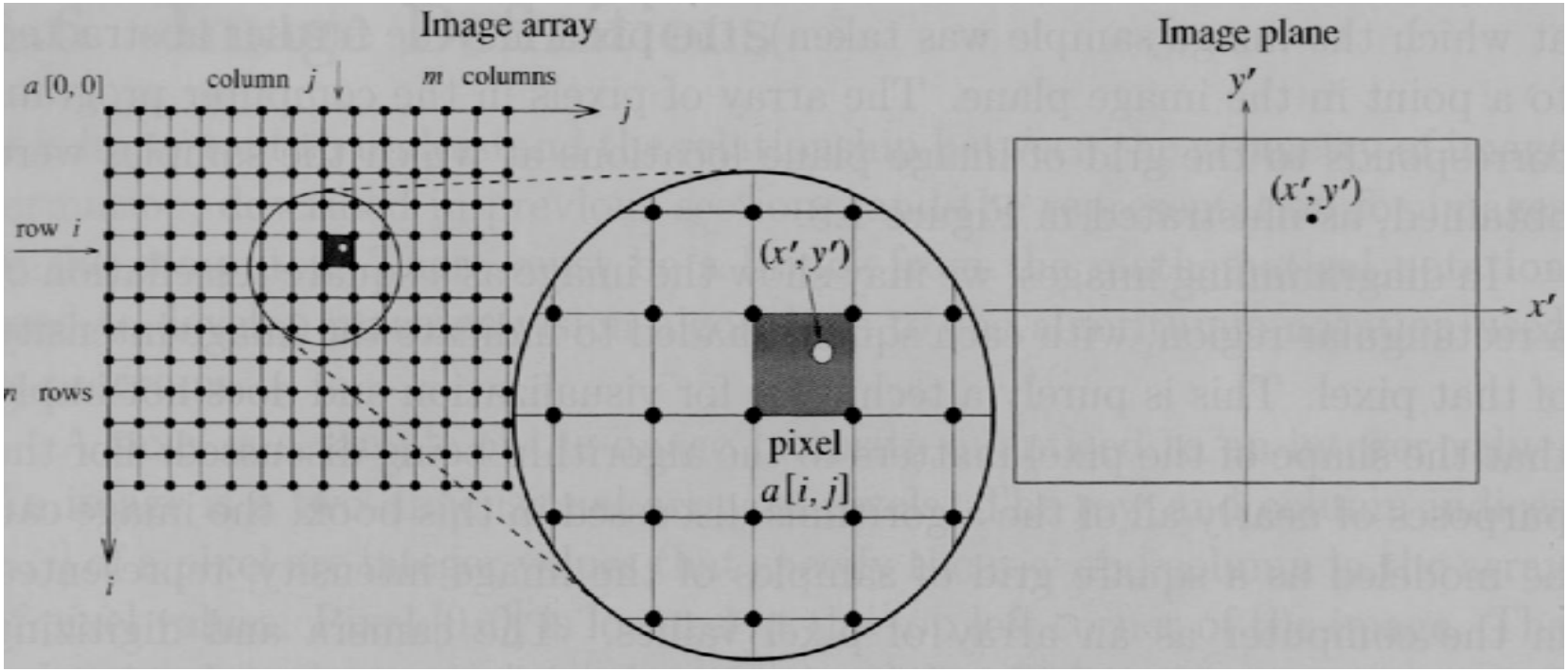
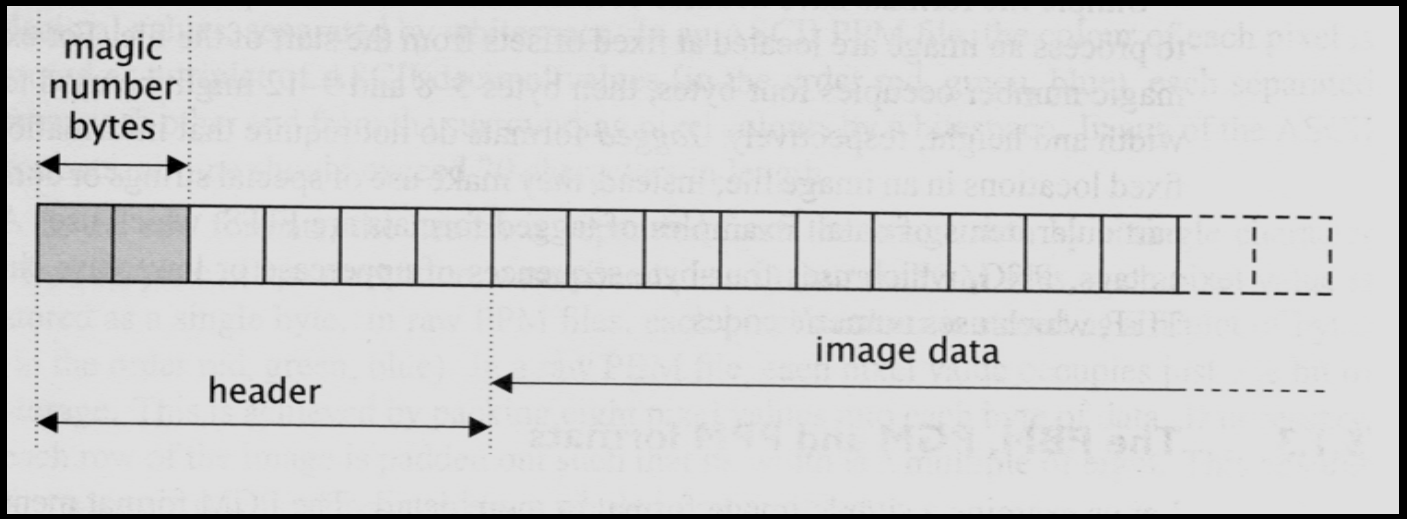


Image file formats

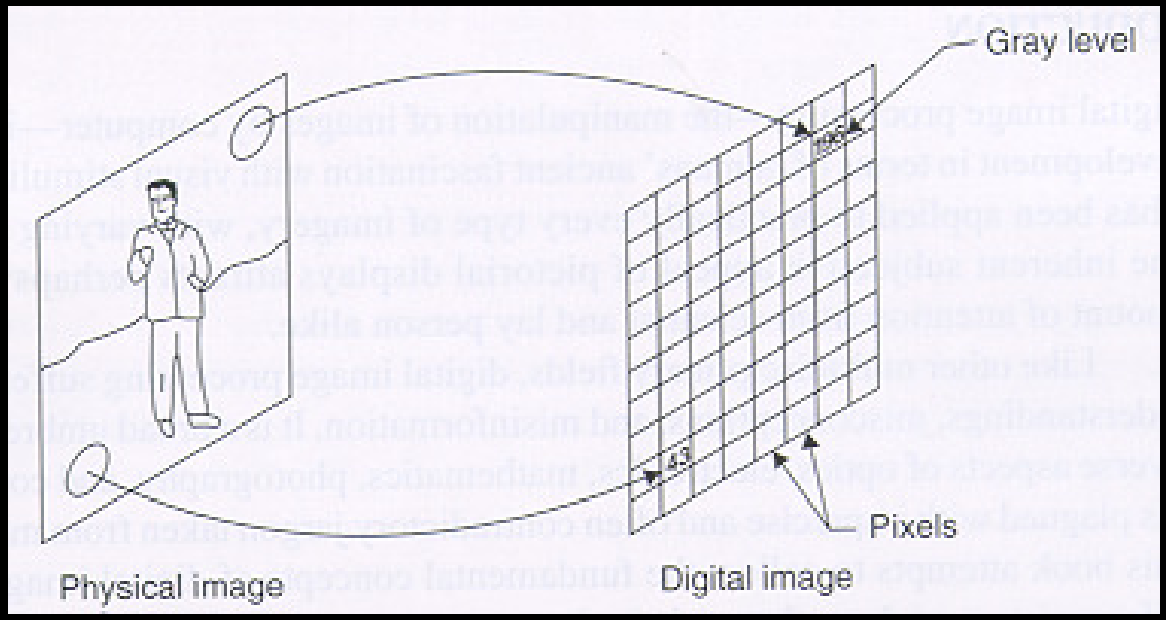
- Many image formats adhere to the simple model shown below (line by line, no breaks between lines).
- The header contains at least the width and height of the image.
- Most headers begin with a **signature** or “magic number” - a short sequence of bytes for identifying the file format.



Common image file formats

- GIF (Graphic Interchange Format) -
- PNG (Portable Network Graphics)
- JPEG (Joint Photographic Experts Group)
- TIFF (Tagged Image File Format)
- PGM (Portable Gray Map)
- FITS (Flexible Image Transport System)

Image digitization



- **Sampling** means measuring the value of an image at a finite number of points.
- **Quantization** is the representation of the measured value at the sampled point by an integer.

Image digitization (cont'd)

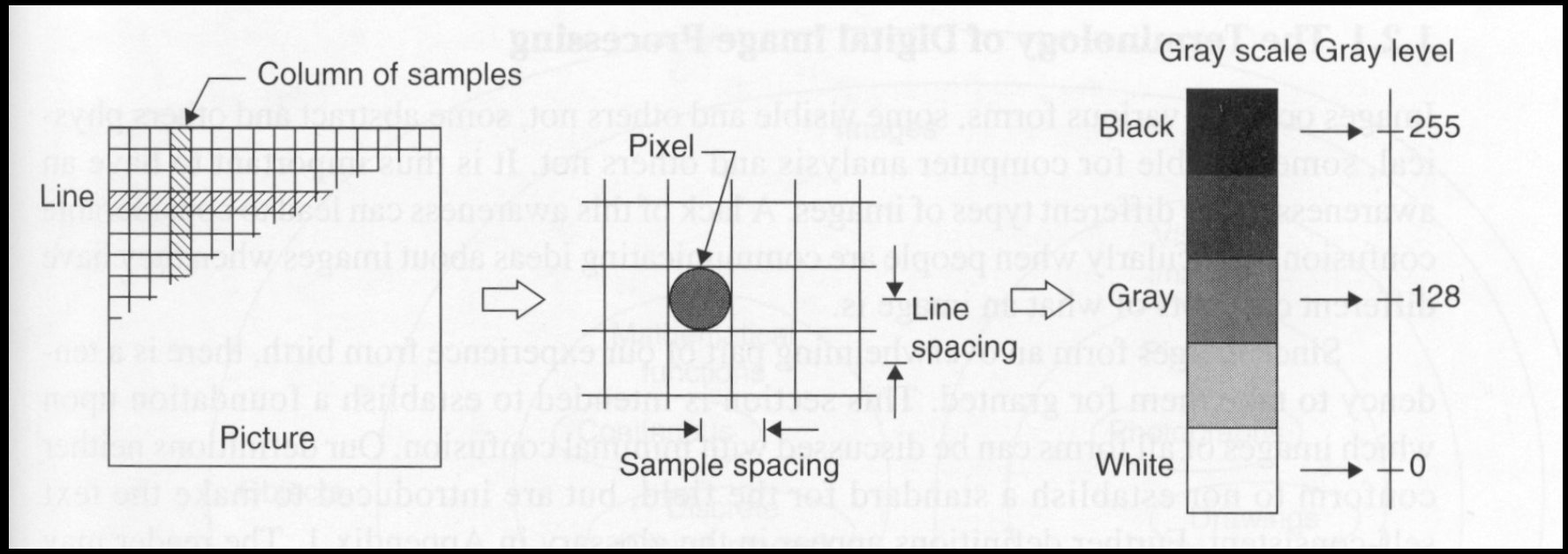


Image quantization (example)

- 256 gray levels (8bits/pixel)

32 gray levels (5 bits/pixel)

16 gray levels (4 bits/pixel)

- 8 gray levels (3 bits/pixel)

4 gray levels (2 bits/pixel)

2 gray levels (1 bit/pixel)

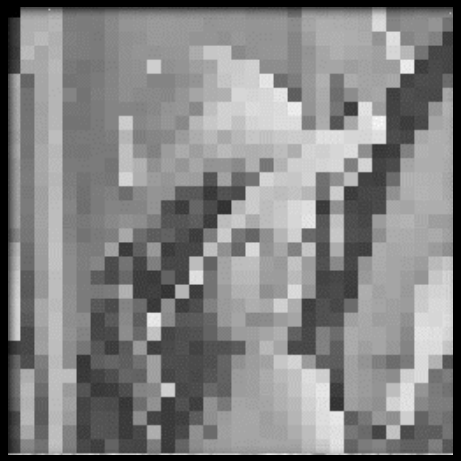
Image sampling (example)

original image

sampled by a factor of 2

sampled by a factor of 4

sampled by a factor of 8



What is Digital Image Processing?

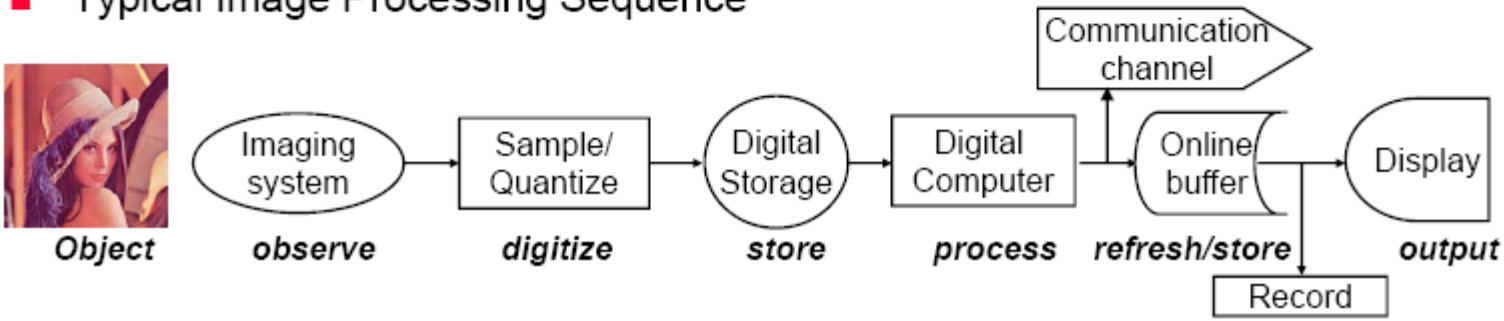
- Digital image processing focuses on two major tasks
  - Improvement of pictorial information for human interpretation
  - Processing of image data for storage, transmission and representation for autonomous machine perception

Digital Image Processing

- ***Processing of 2D (3D) picture by digital computer***

- ***Applications***
  - image display, transmission and storage
  - video compression standard like HDTV (MPEG-2), DMB (H.264/MPEG-4 AVC), IPTV codec (H.264/MPEG-4 AVC), and so on.
  - multimedia
  - medical processing (Chest X-ray; tomography, MRI, ultrasonic scanning)
  - remote sensing, deep-space-probe mission
  - radar, sonar, acoustic imaging
  - robotics, computer vision

- Typical Image Processing Sequence



Digital Image Processing

- Image Enhancement
- Image Restoration
- Image Understanding (Computer Vision)
- Image Reconstruction from Projection
- Image Coding (Image Data Compression)

What is DIP?

- The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes

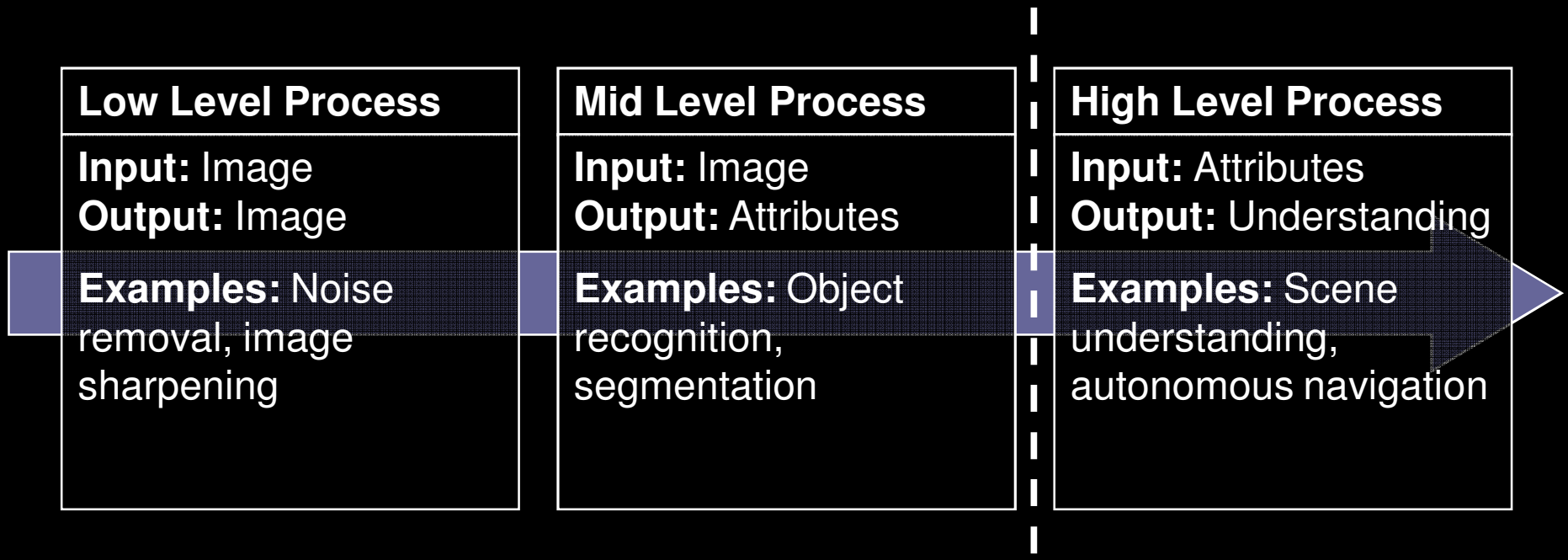


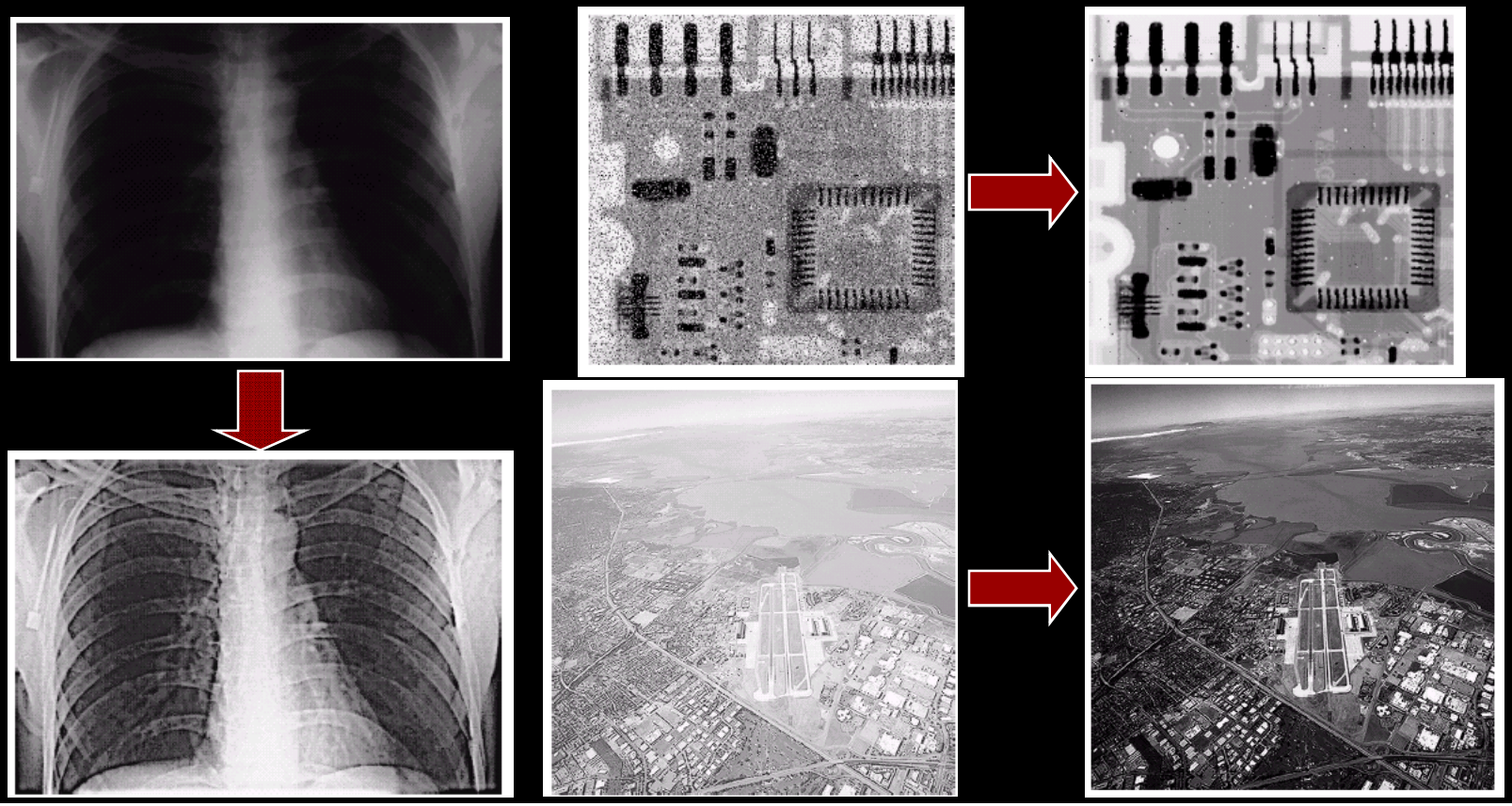
Image Enhancement

- Goal

  to accentuate certain image features for subsequent analysis or for image display

Examples: Image Enhancement

- One of the most common uses of DIP techniques: improve quality, remove noise etc



Examples: The Hubble Telescope

- Launched in 1990 the Hubble telescope can take images of very distant objects
- However, an incorrect mirror made many of Hubble's images useless
- Image processing techniques were used to fix this

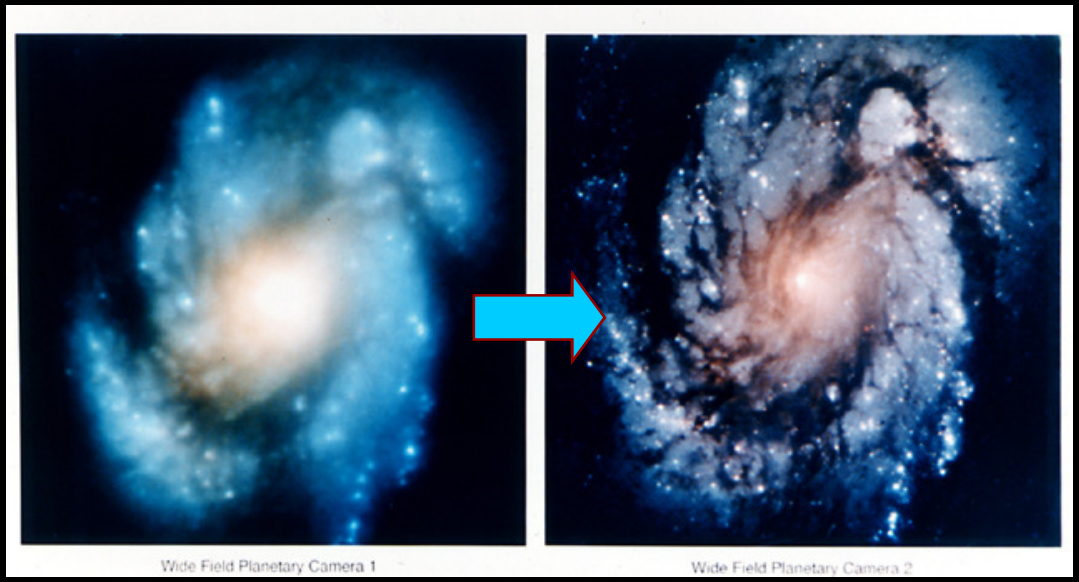


Image Restoration

- Goal

  to remove or minimize known/unknown **degradations** in image

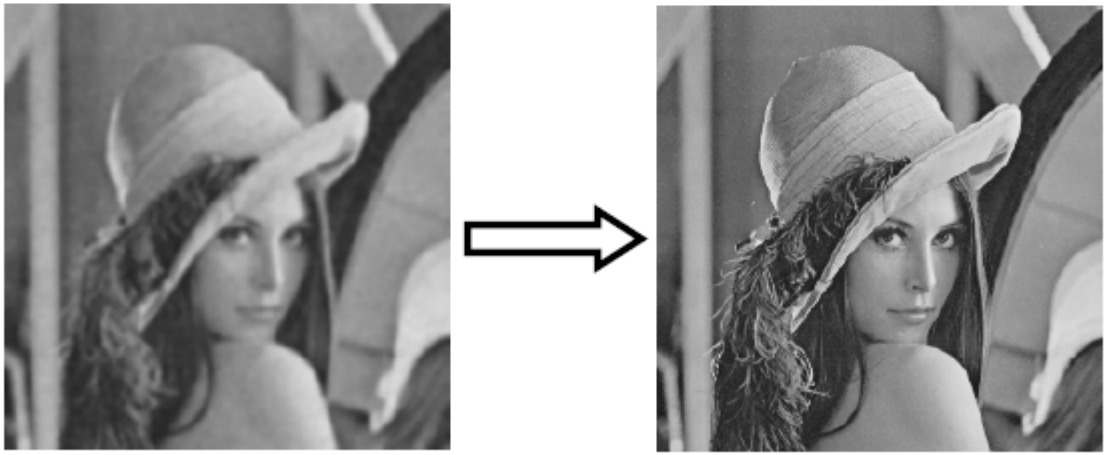
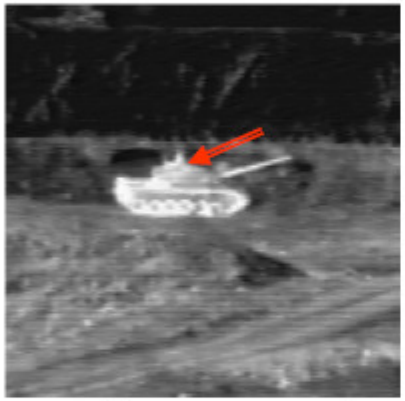
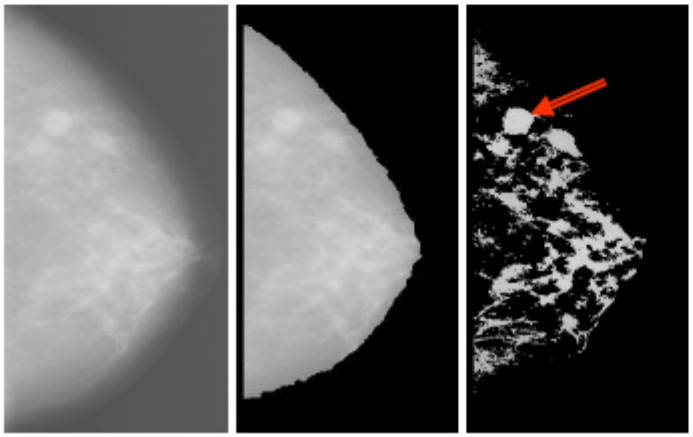


Image Understanding

- Goal

  to interpret or describe the meaning contained in the image



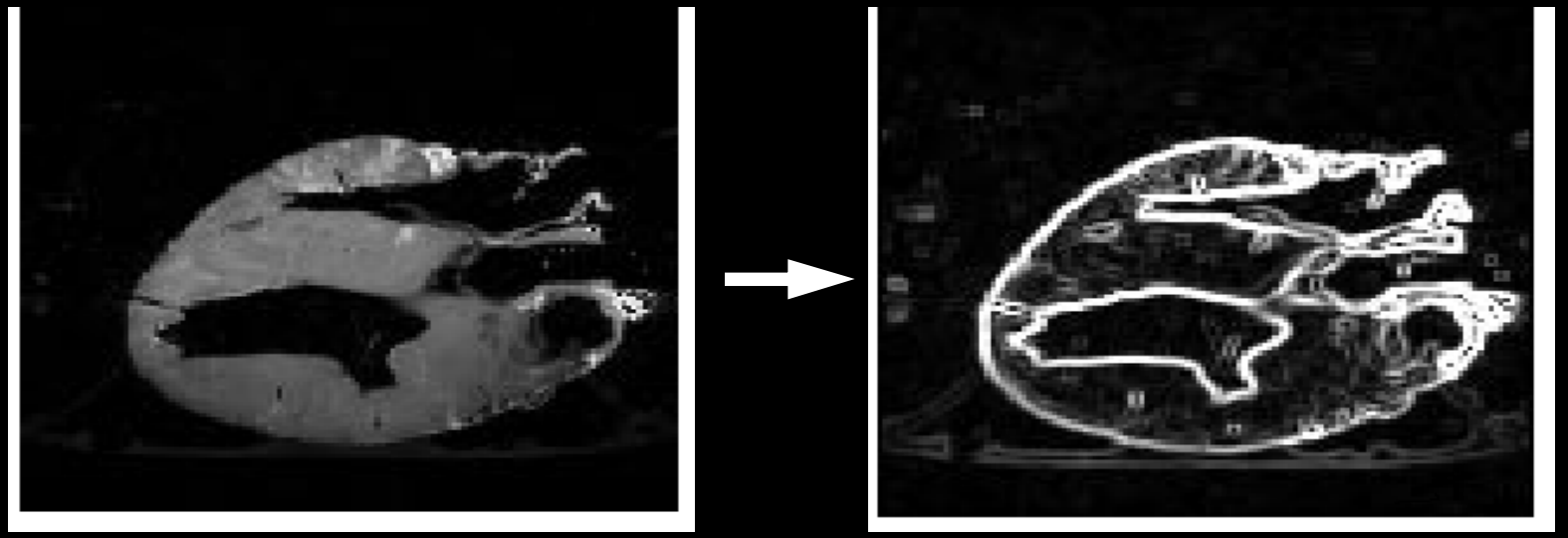


Tank

Breast Cancer

Examples: Medicine

- Take slice from MRI scan of canine heart, and find boundaries between types of tissue
  - Image with gray levels representing tissue density
  - Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart

Edge Detection Image

Image Reconstruction

- Reconstruction from projection
- Obtain cross-section image from projections
- Computerized Tomography (CT)
- Positron Emission Tomography (PET)
- Magnetic Resonance Imaging (MRI)

  In MRI, measured data is not only projection data.

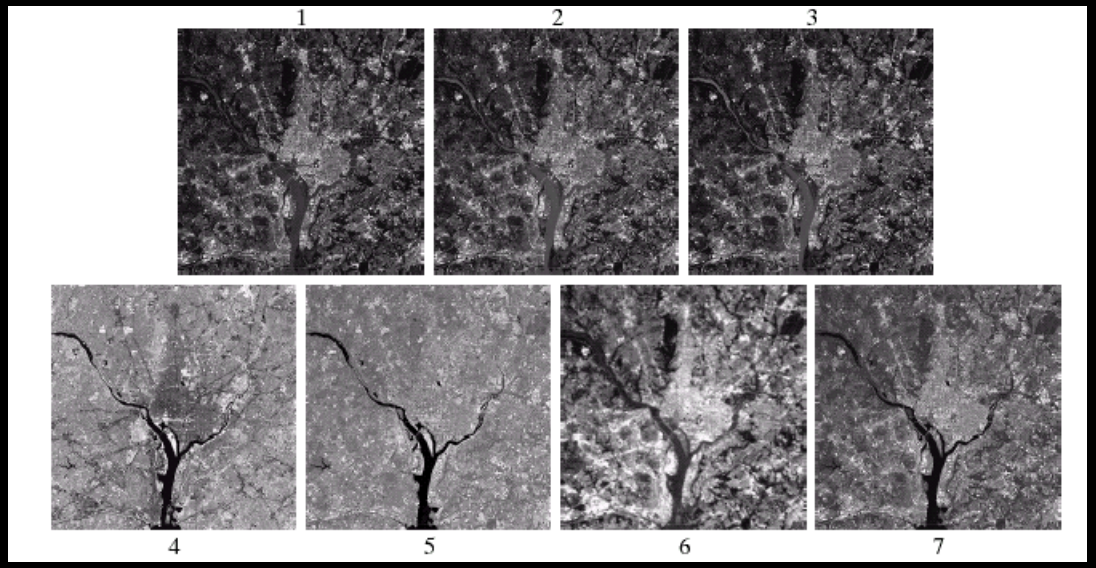
  Just Fourier transform can be used for reconstruction.

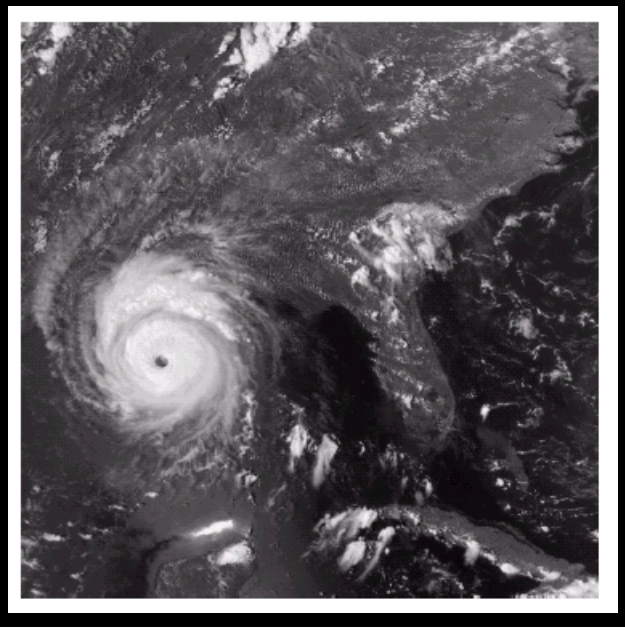
Examples: Artistic Effects

- Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

Examples: GIS

- Geographic Information Systems
  - Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification
  - Meteorology





Examples: GIS

- *Night-Time Lights of the World* data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data

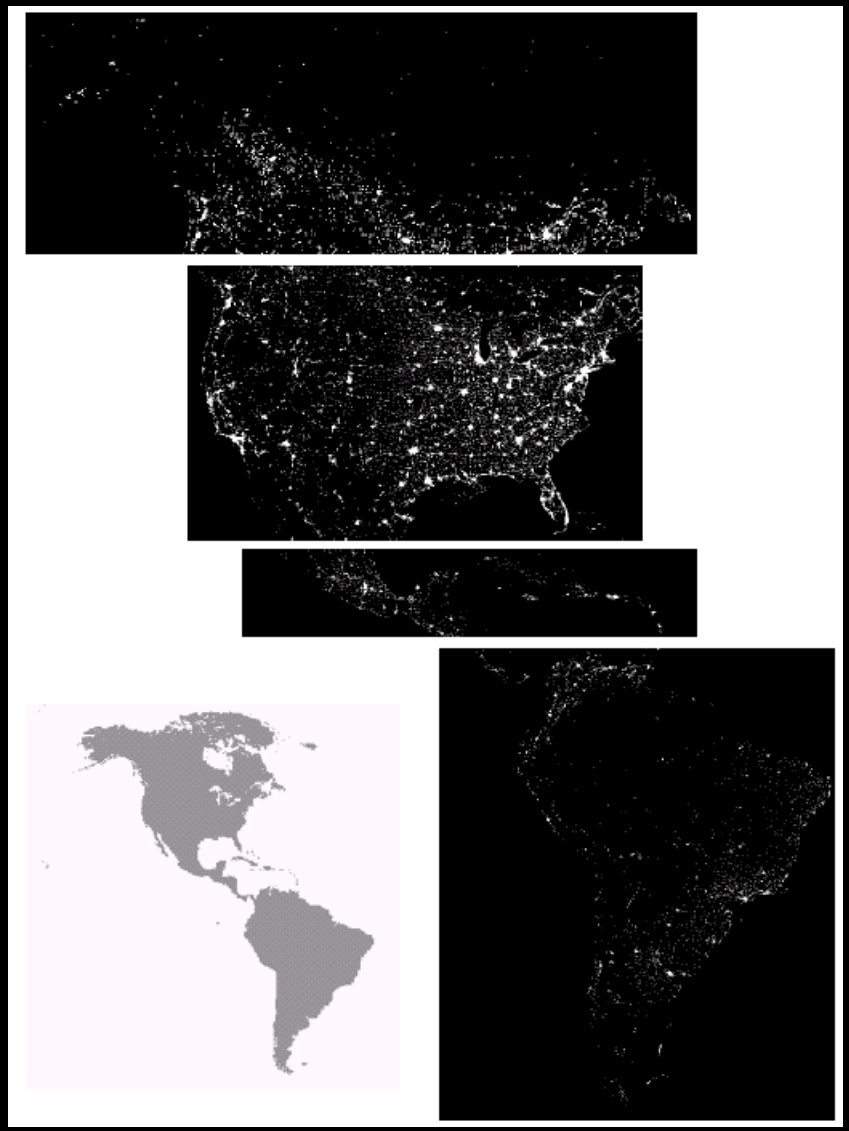
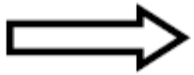


Image Data Compression

- Goal

  to reduce the amount of data required to represent images



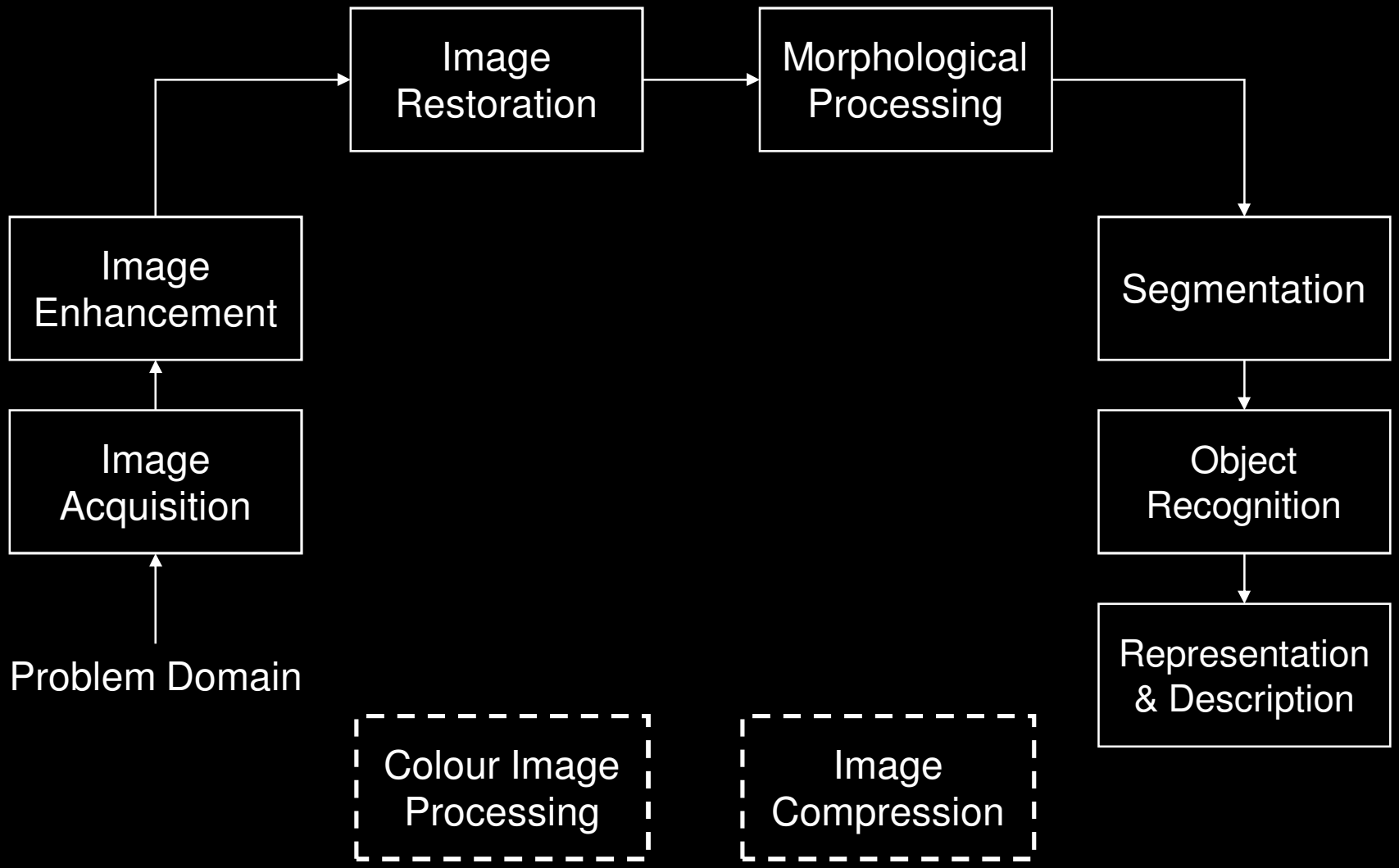
"0101001011001101010 01 . . . ."

Image Data Compression

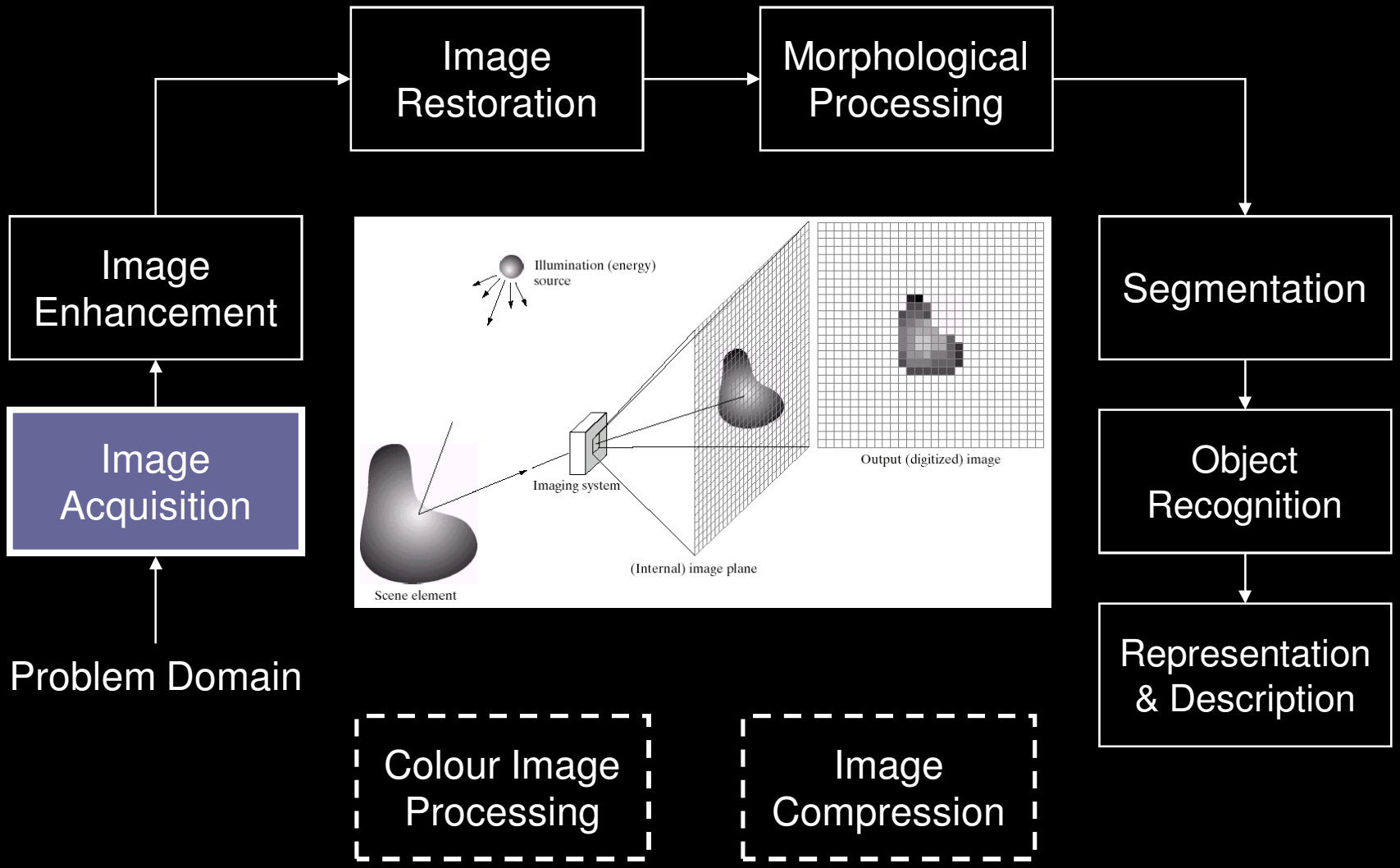
- Techniques
  - Lossless coding (Error-free coding)
  - Lossy compression
  - Image Compression Standard
    - JPEG, H.261, H.263, MPEG-1,2,4, **H.264/MPEG-4 AVC** etc

- Applications
  - Transmission
    - teleconferencing ,TV system, remote sensing via satellite
  - Storage
    - VOD (video on demand), Video CD, DVD (digital video disk), medical imaging, educational and business documents

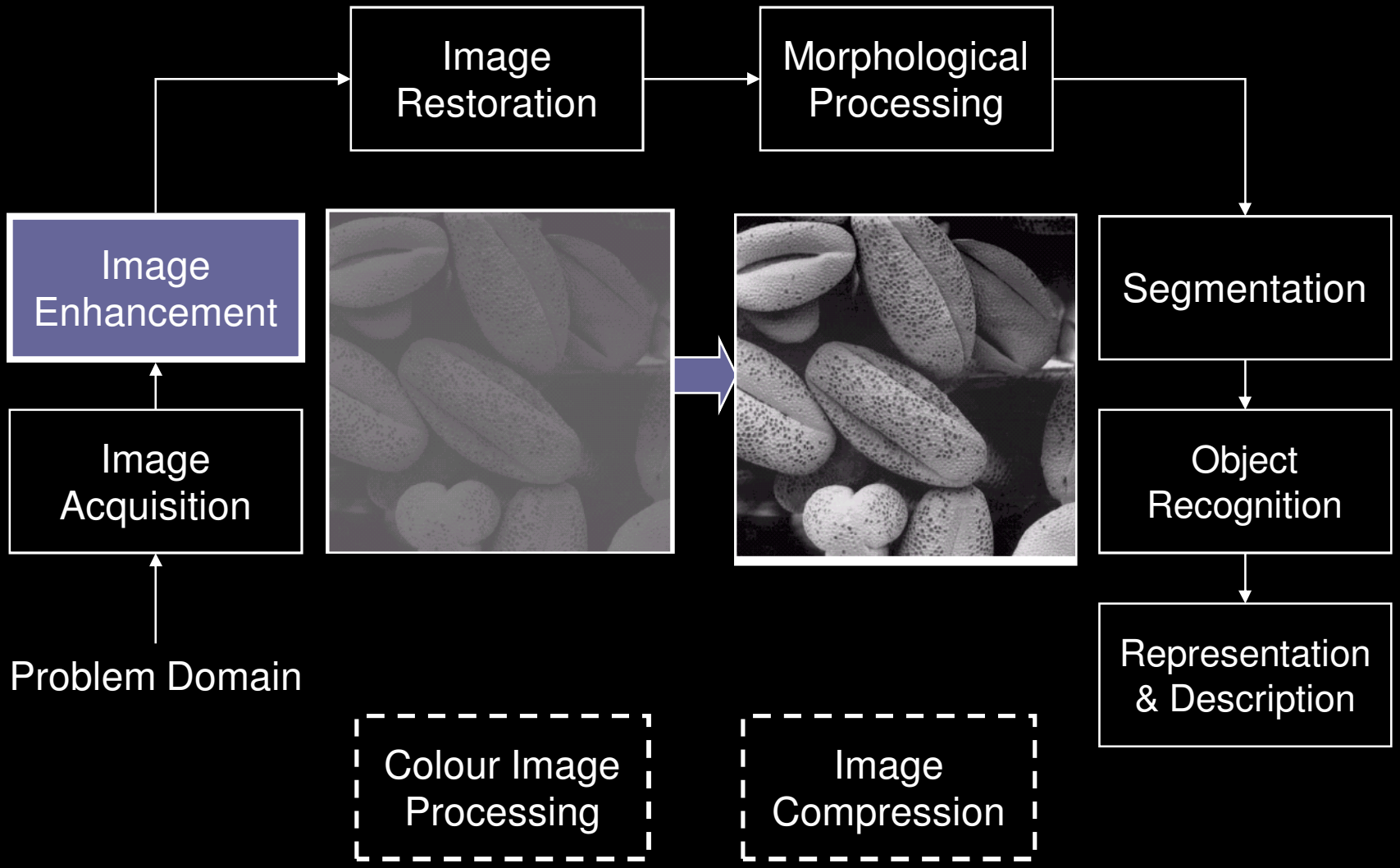
Key Stages in Digital Image Processing



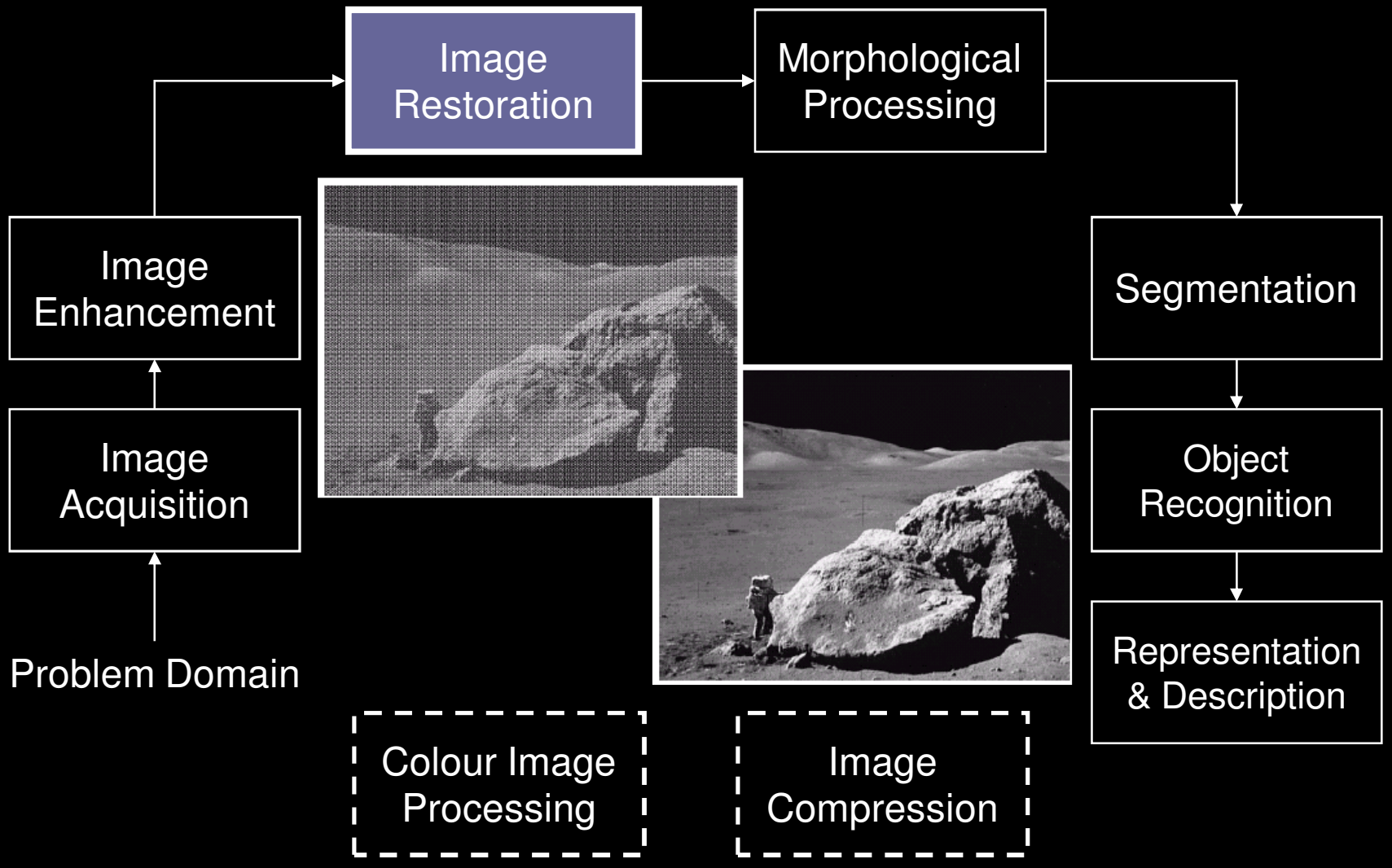
Key Stages in Digital Image Processing: Image Acquisition



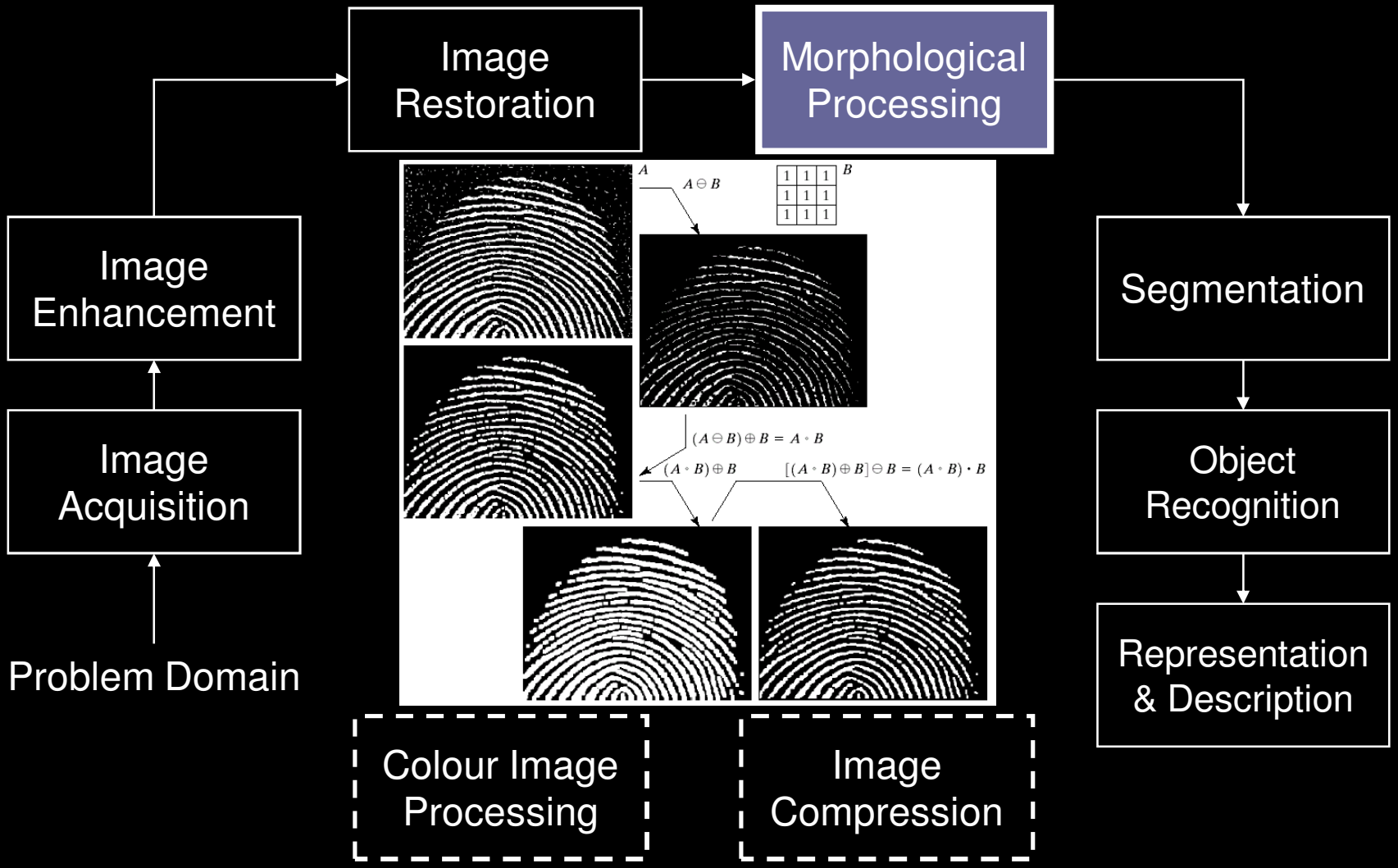
Key Stages in Digital Image Processing: Image Enhancement



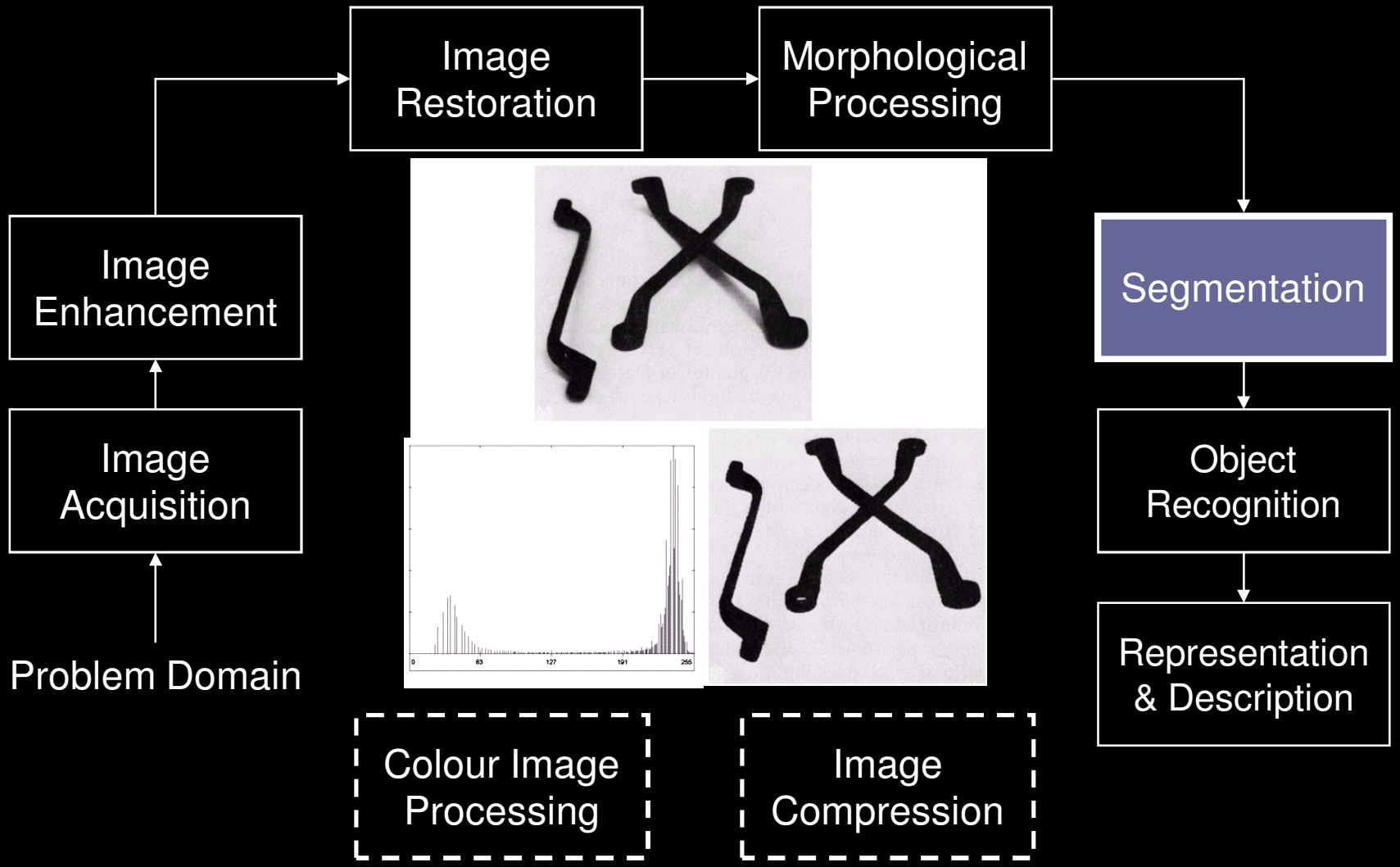
Key Stages in Digital Image Processing: Image Restoration



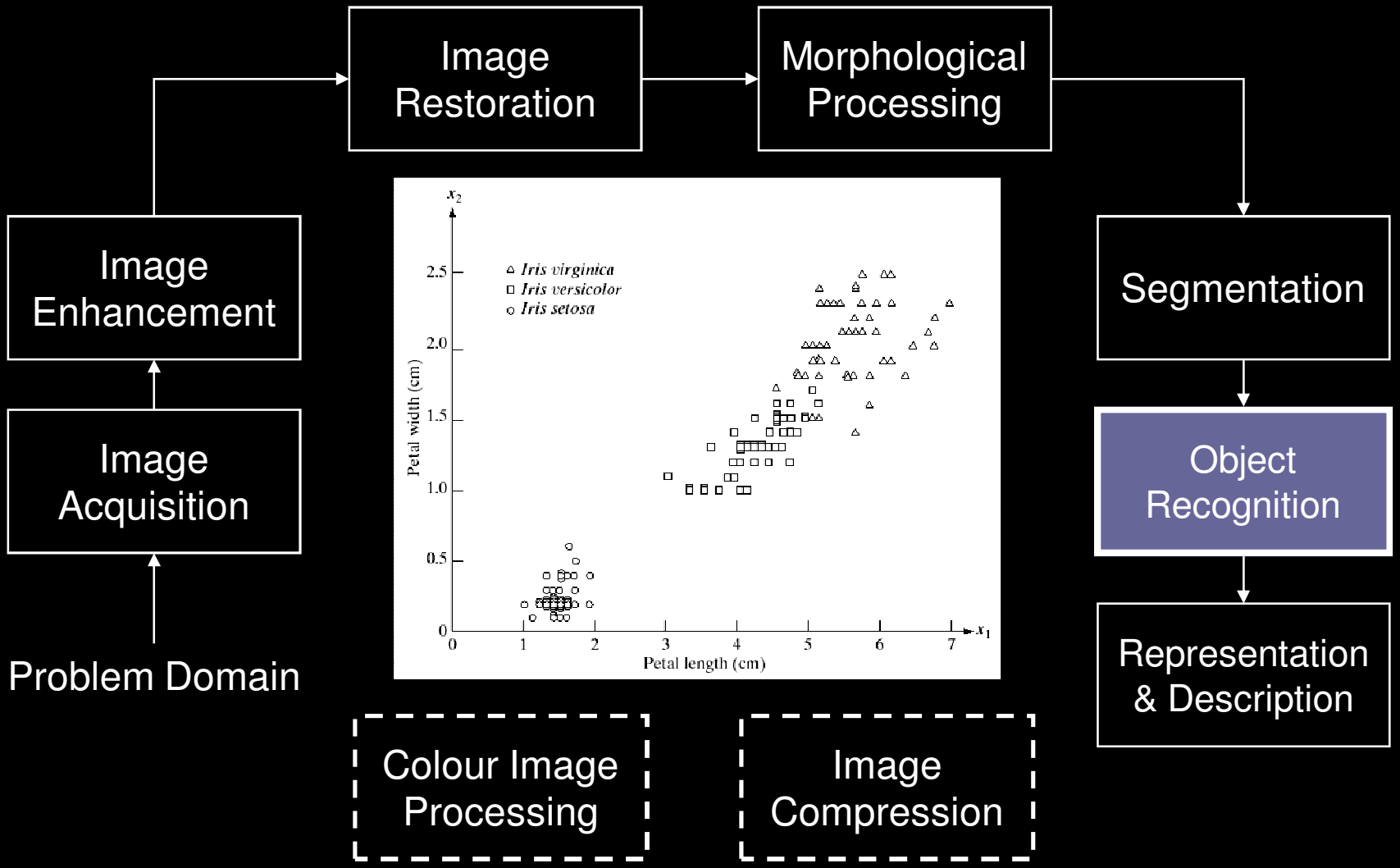
Key Stages in Digital Image Processing: Morphological Processing



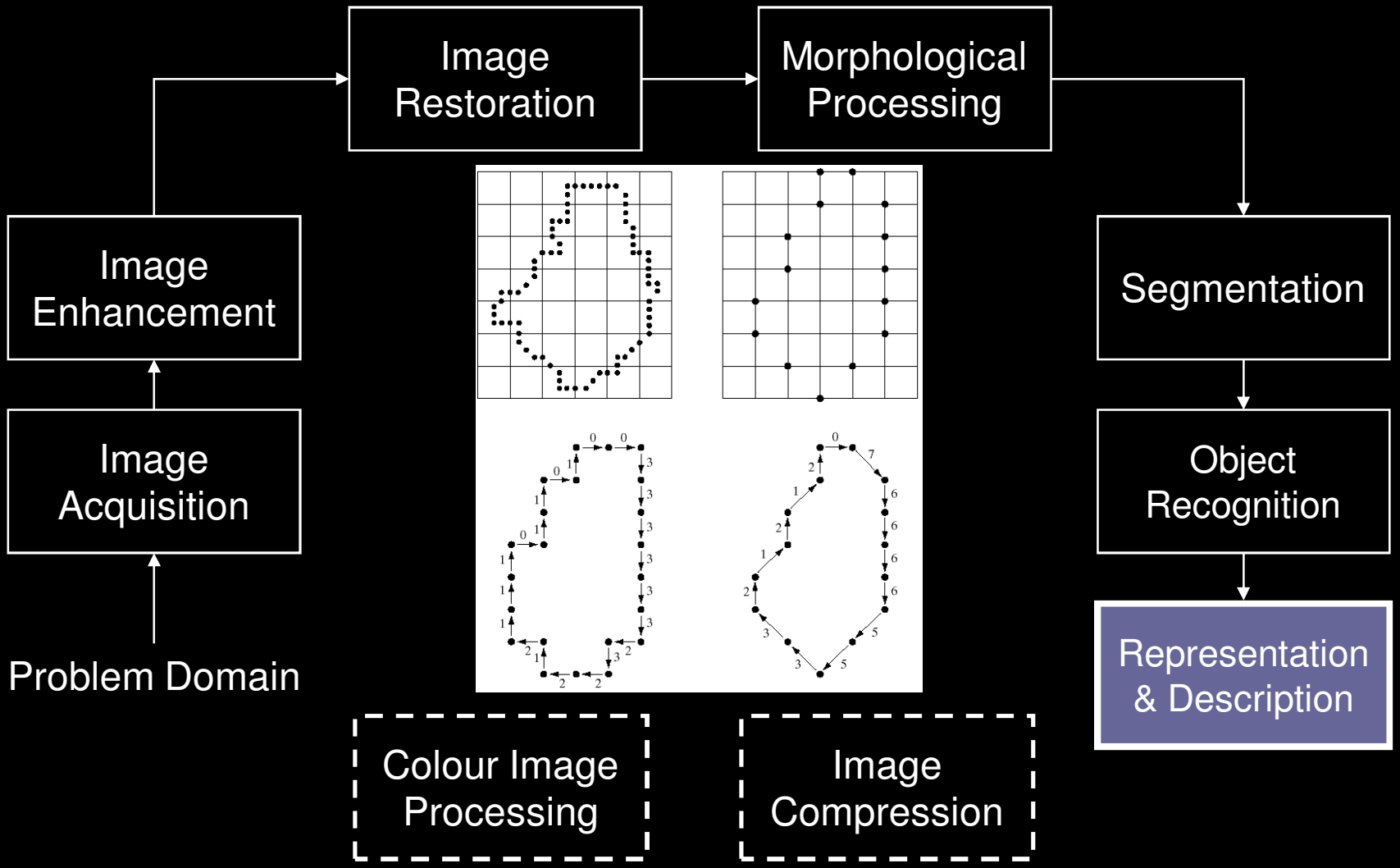
Key Stages in Digital Image Processing: Segmentation



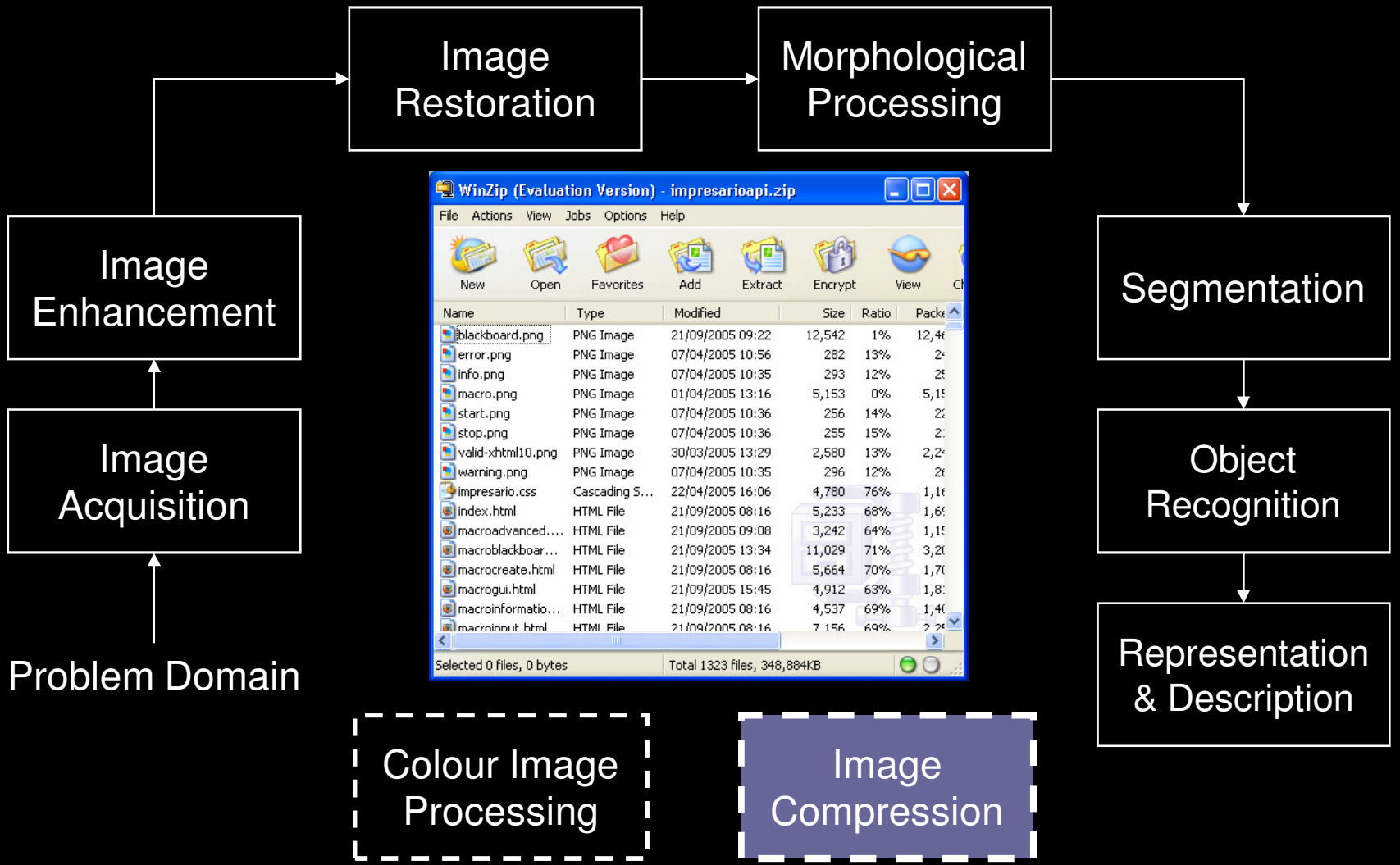
Key Stages in Digital Image Processing: Object Recognition



Key Stages in Digital Image Processing: Representation & Description



Key Stages in Digital Image Processing: Image Compression



Key Stages in Digital Image Processing: Colour Image Processing

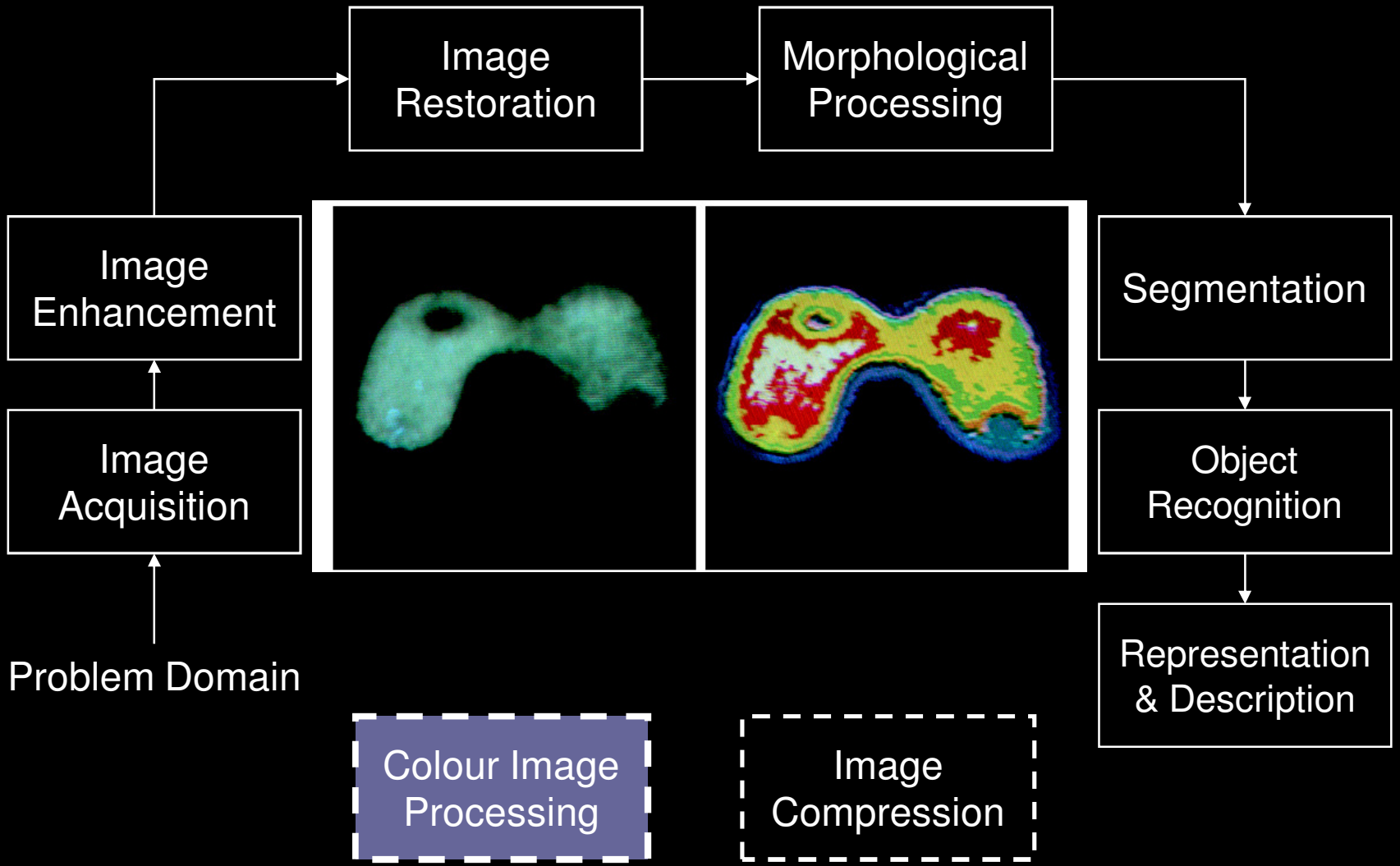
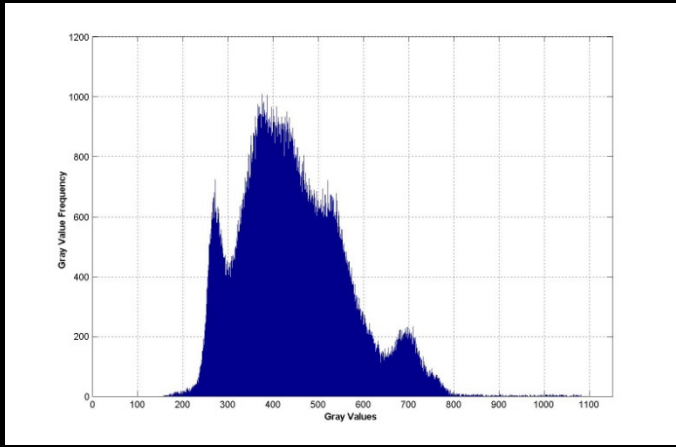
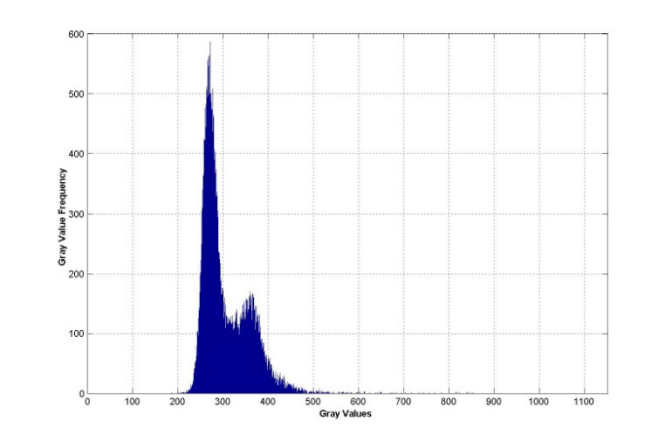


Image histogram



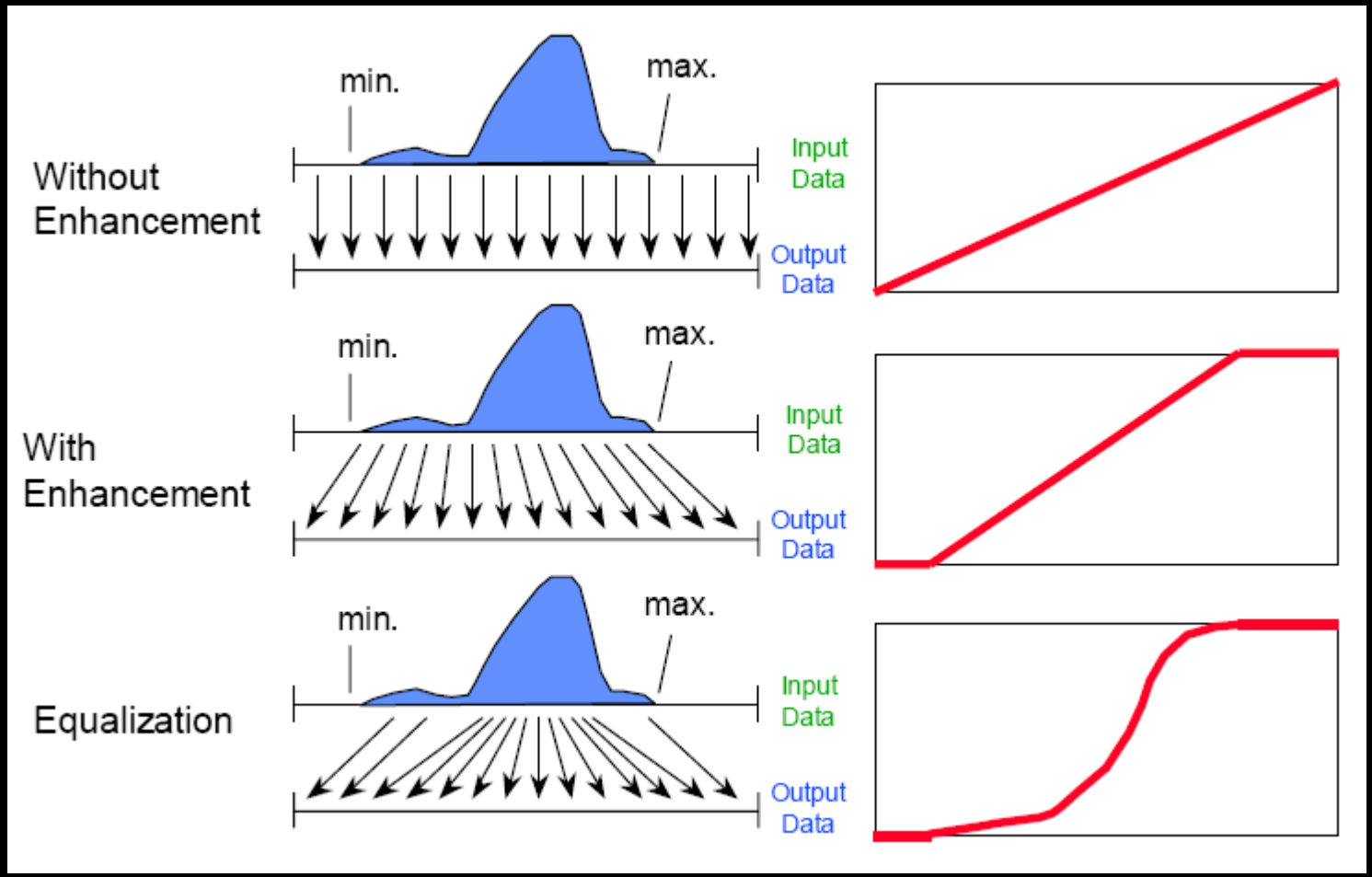
Entire image histogram



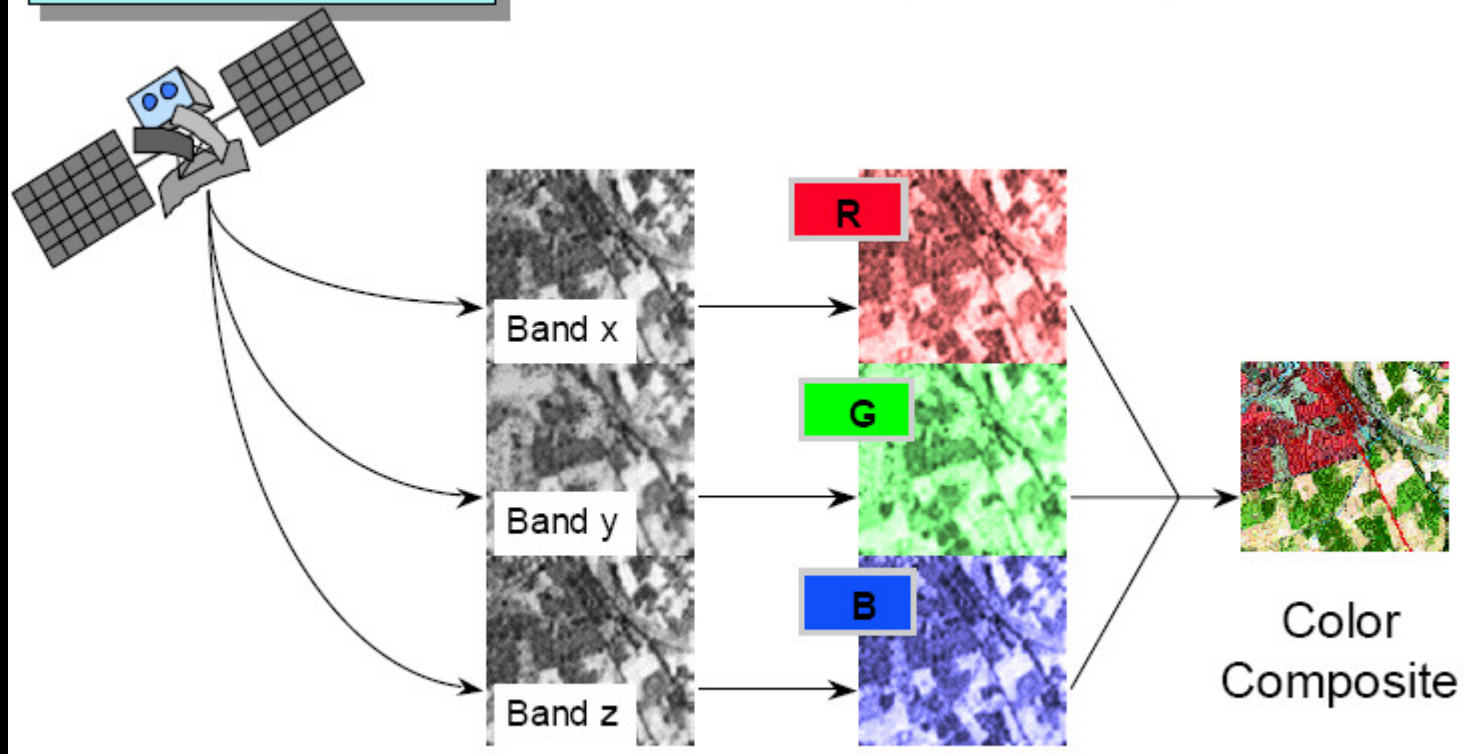
Pavement pixels only

Original image

Contrast enhancement or Contrast stretch



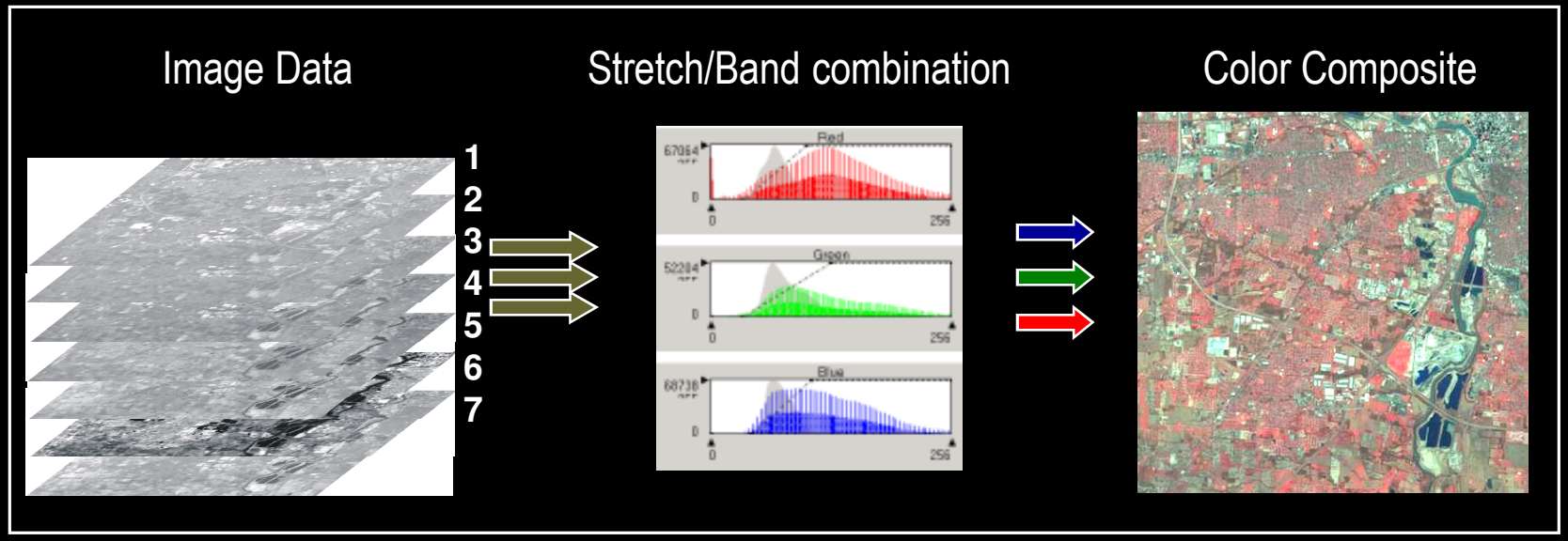
MULTI-BAND DISPLAY Color results from the ***compositing*** of 2 or 3 bands

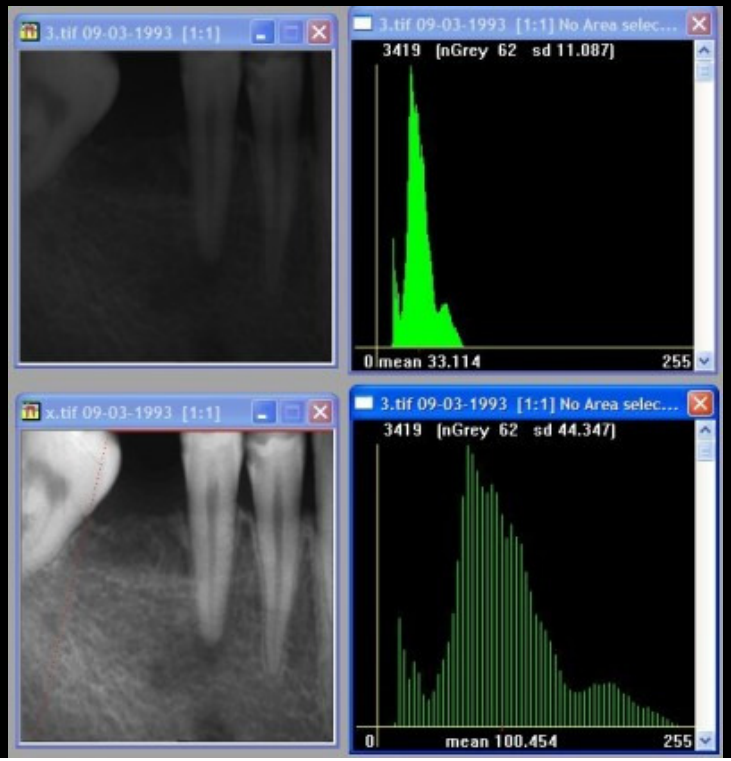


NOTE : The bands can be individually *stretched*

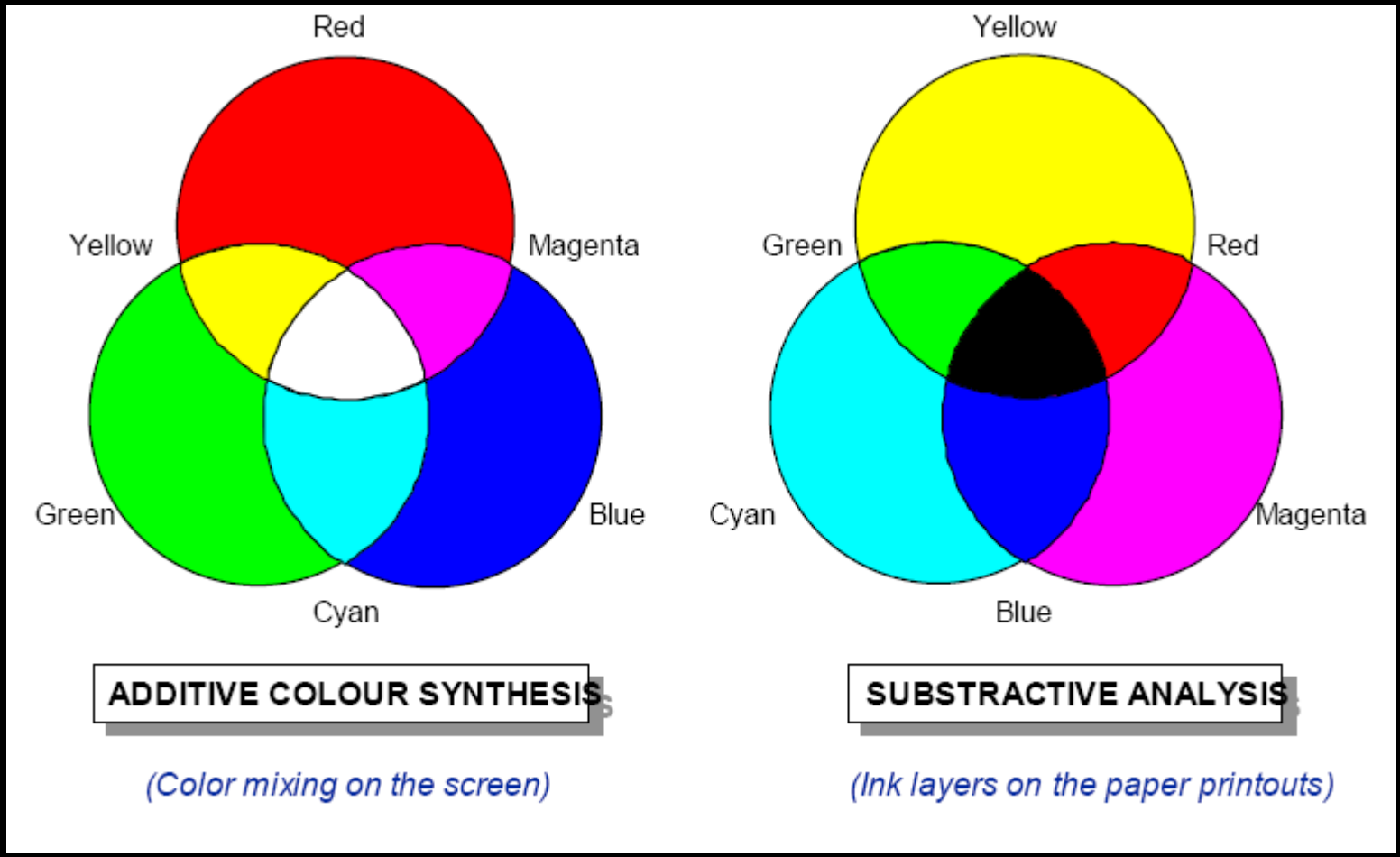
Image display

Selected bands are remapped (stretched) to fit the display device. The output image color space is called a look-up table.



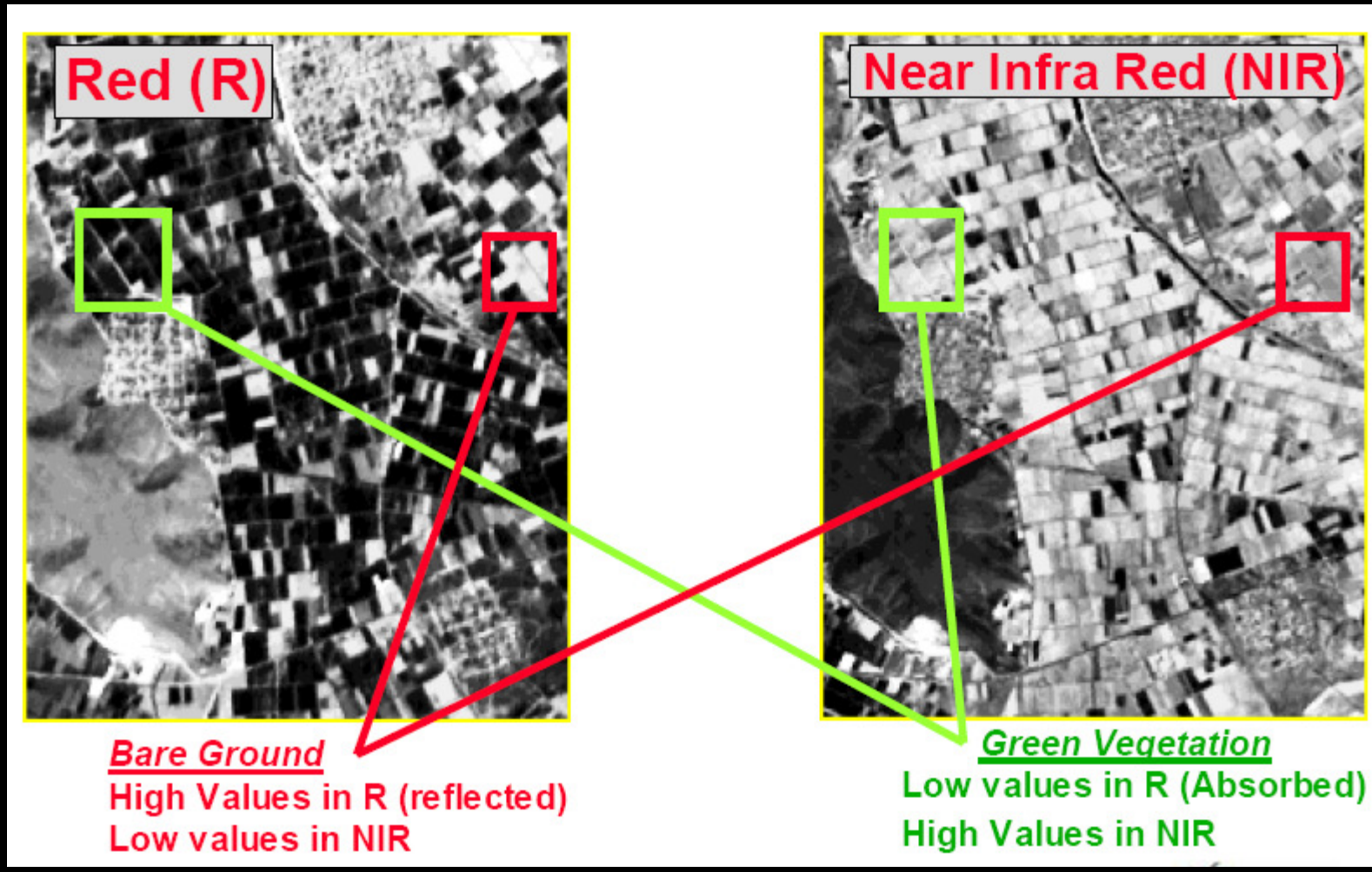

3.tif 09-03-1993 [1:1]
3.tif 09-03-1993 [1:1] No Area selec...
3419 [nGrey 62 sd 11.087]
0 mean 33.114 255
x.tif 09-03-1993 [1:1]
3.tif 09-03-1993 [1:1] No Area selec...
3419 [nGrey 62 sd 44.347]
0 mean 100.454 255

COLOUR COMPOSITES



Natural color composite
3,2,1

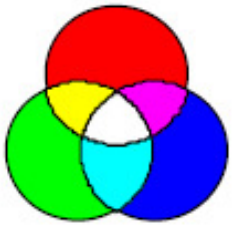
False color composite
4,3,2

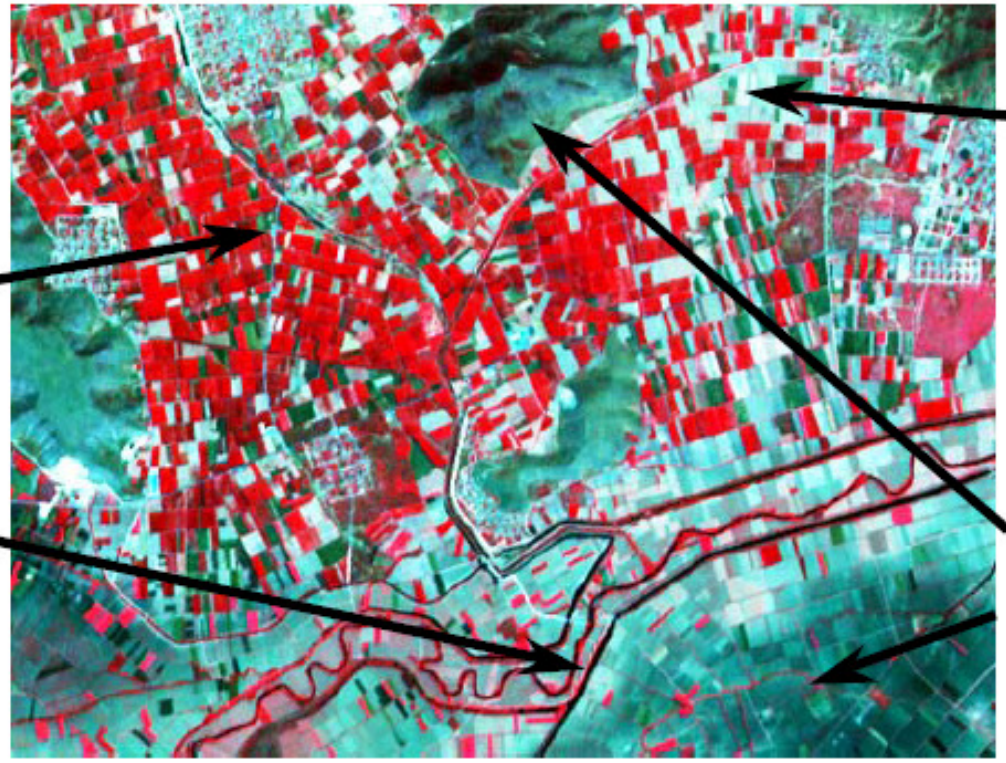

Red (R)
Near Infra Red (NIR)
Bare Ground
High Values in R (reflected)
Low values in NIR
Green Vegetation
Low values in R (Absorbed)
High Values in NIR

MULTI-BAND PRODUCTS

Standard RGB color composite

NIR band	⇨	RED
RED band	⇨	GREEN
GREEN band	⇨	BLUE





RED
Active
Vegetation

BLACK
Water

LIGHT CYAN
Bare Soil

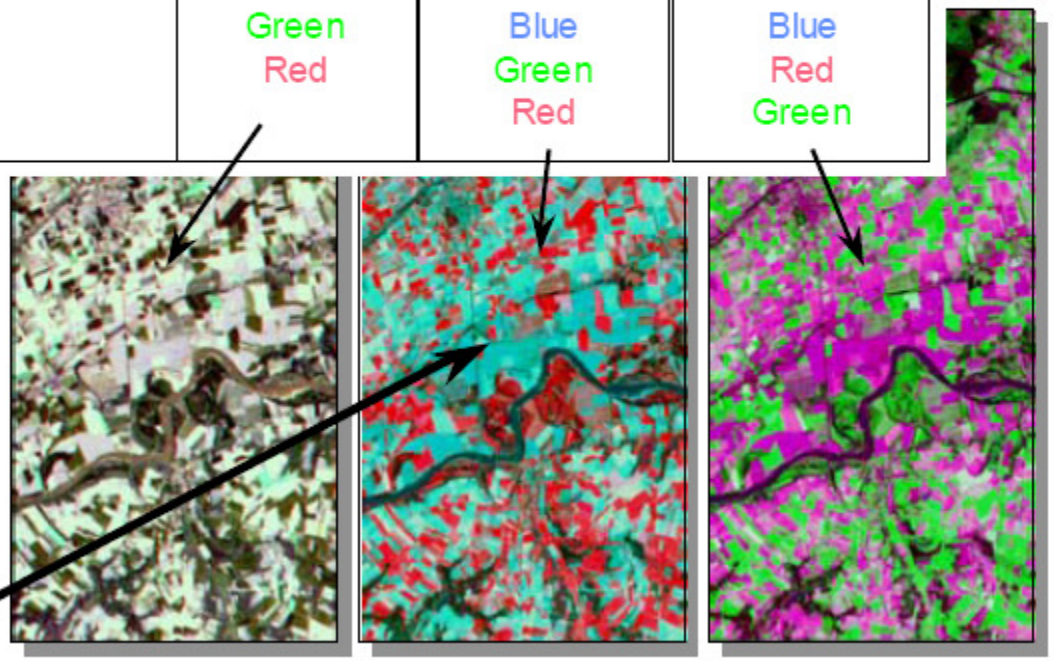
DARK CYAN
Dry Vegetation
Mature Crops

Example: **SPOT XS3, XS2, XS1**

Multi-Band products

Colour composite (additive synthesis)

Landsat TM:	True colors	Pseudo colors	pseudo colors (veget. green)
Blue band	Blue		
Green band	Green	Blue	Blue
Red band	Red	Green	Red
IR band		Red	Green



Standard Colour Composite

Multi-date radar colour composite

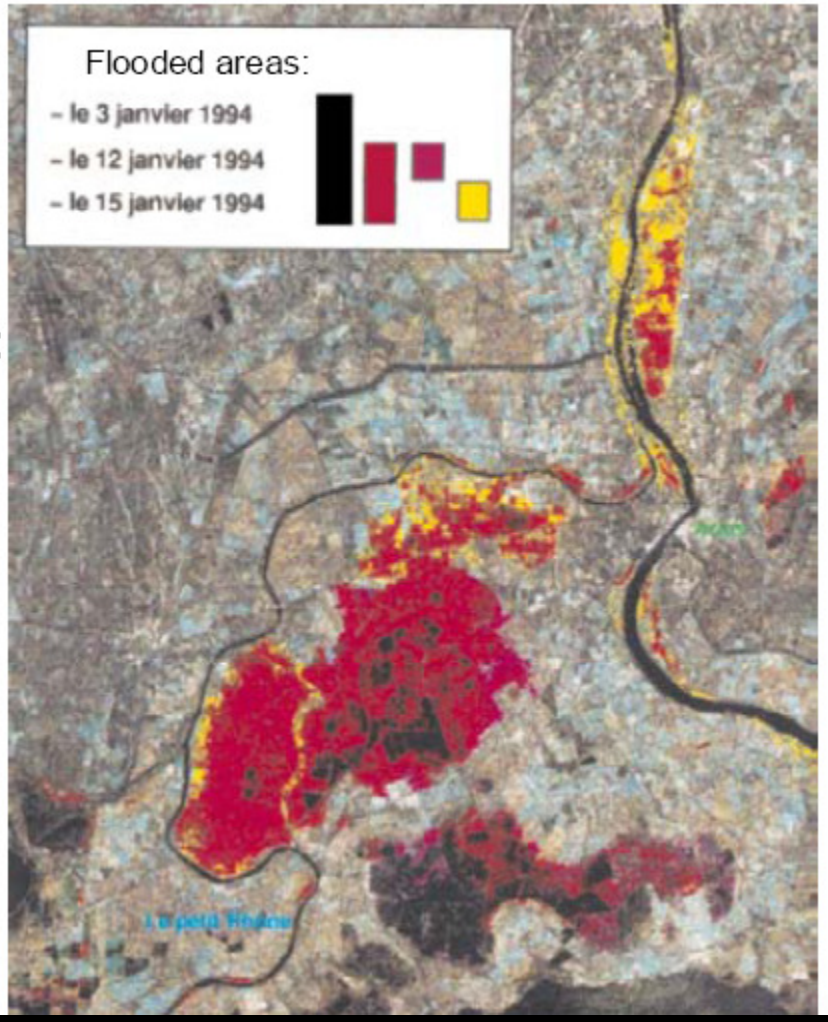
Flood management (extent) in Camargue, France

ERS images colour composite:

3 January 94 (before flooding)
12 January 94
15 January 94

Flood extent determined by colour composite interpretation

Flooded areas = dark areas due to specular reflection



Filters

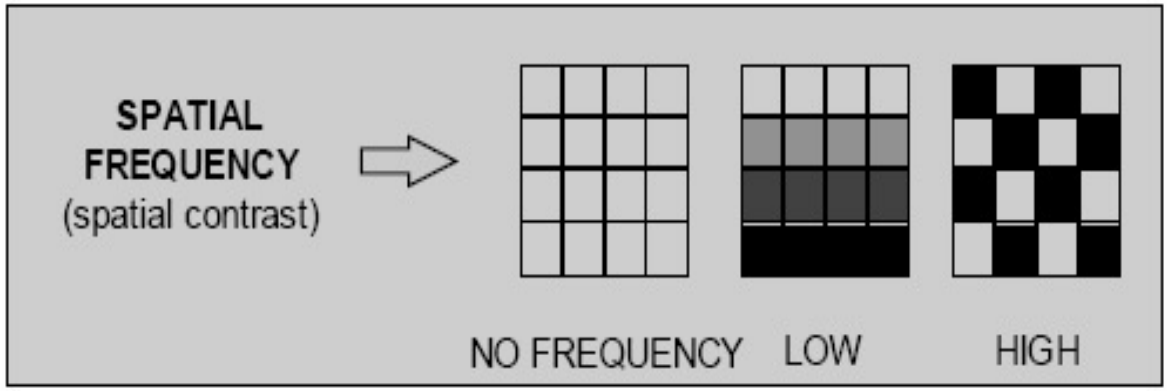
Filtering is used to improve display or remove bad values

- Filtering modifies the Digital Counts
- Filtering takes into account the environment of the pixels
- *Enhancement* changes the image tonal contrast, *filtering* changes the spatial contrast (smoothing or stretch).
- Spatial contrast is the difference between the Digital Number of a pixel and the Digital Number of its neighbours.
- Filtering provides images with modified spatial frequencies.

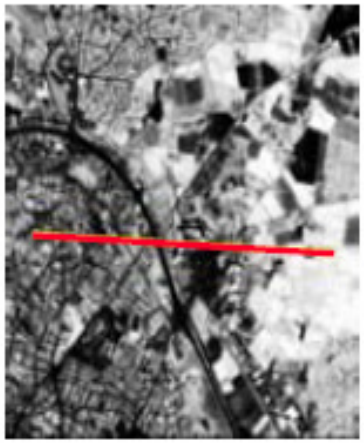
→ Noise reduction (smoothing)
→ edge detection (enhancement)

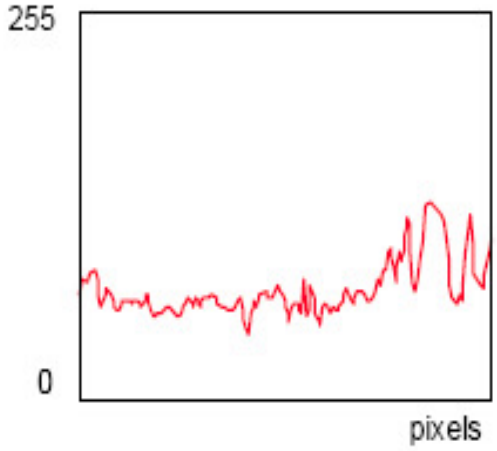
Digital Filters

SPATIAL FREQUENCY: variation of the Digital Count per space unit.



Radiometric profile: approximation of a spatial frequency spectrum



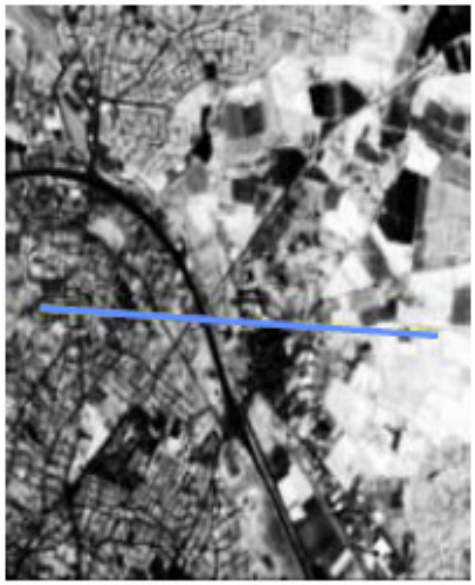


"Smooth image" : low spatial frequency

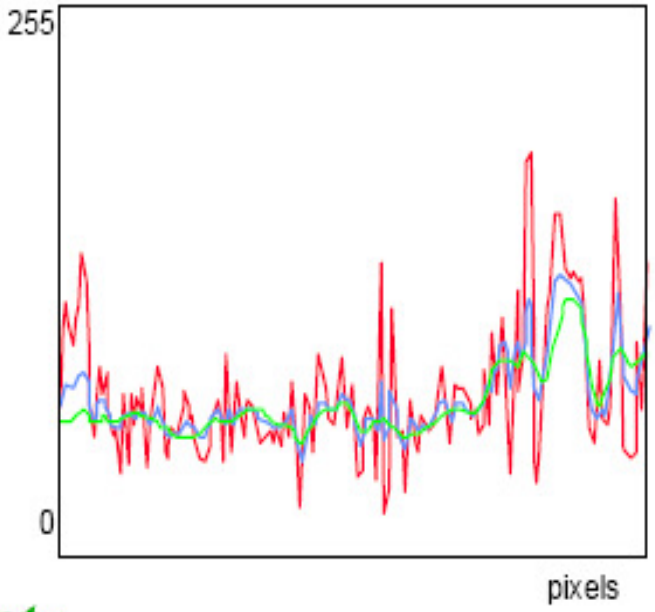
"Rough image" : high spatial frequency

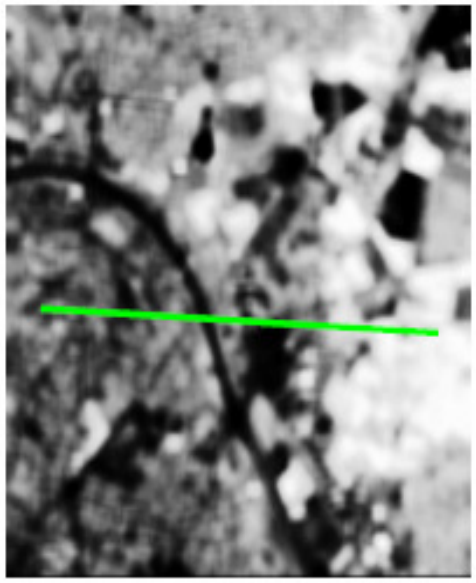
FILTERS

HIGH-PASS FILTERS:
Emphasize the detailed high frequency components of an image and de-emphasize the more general low frequency information.



LOW-PASS FILTERS:
Emphasize low frequency features (large areas changes in brightness) and deemphasize the high frequency components of an image (local detail). They are used to reduce noise and artefacts.





«Edge Enhancement»

«Smoothing»

How to extract geoinformation from satellite data ?

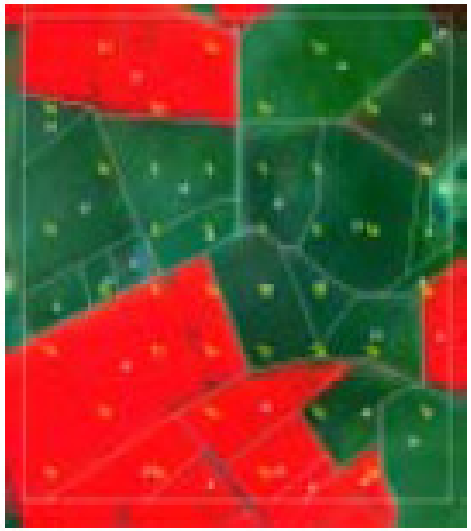
❷ **CLASSIFICATION** *(statistical approach)*

- ✓ **to classify a digital image into useful categories *(themes)*** for a given application *(land cover, etc...)*
- ✓ a pattern-based process that assigns individual pixels to categories based on spectral properties *(various algorithms available)*
- ✓ importance of " *ground truth* " and external data to properly initialize a classification and check the results (*using a GIS*)

➔ ***thematic raster layers that can be vectorized***

Classification

SPOT Image, 06/96, Montauban



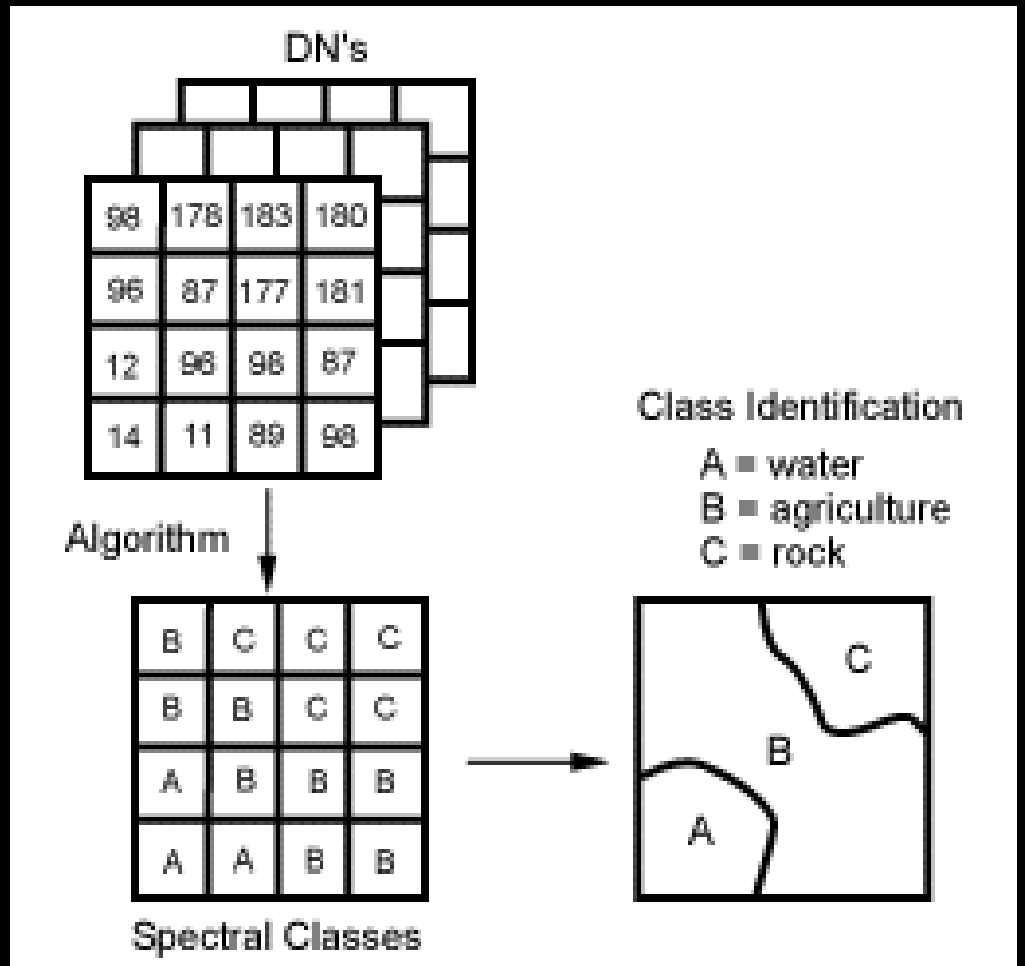
Colour composite

Classified image

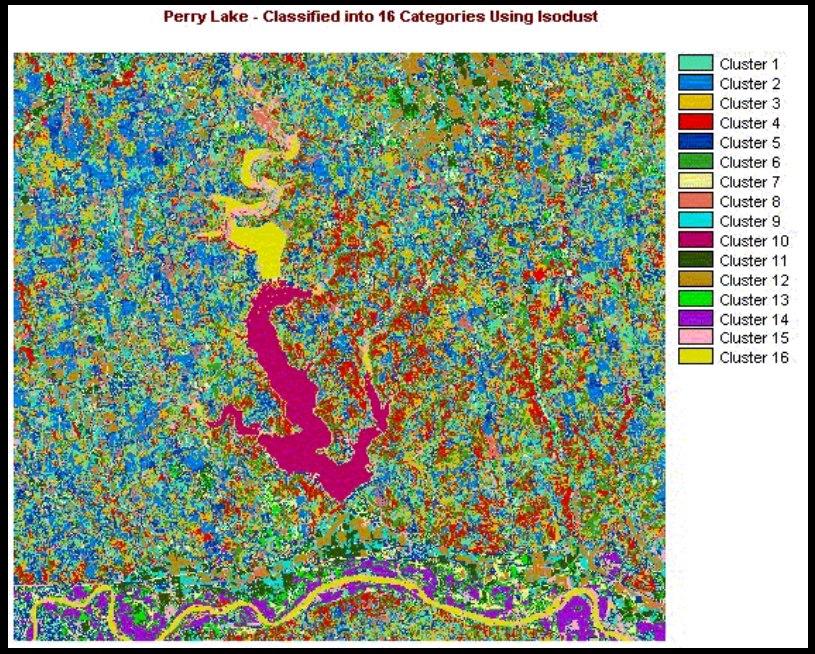
Unsupervised classification

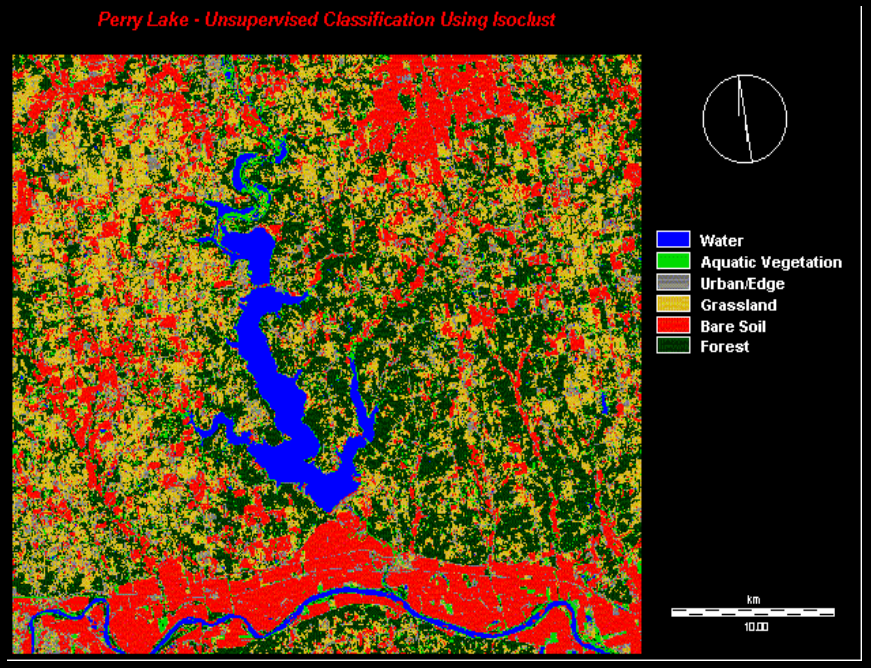
- Analyst has minimal interaction
- Computer algorithm searches for natural, inherent groupings in remote sensing images
- Clustering algorithm – ISODATA
- Analyst determines categories for these spectral groups by comparing classified image to ground reference data

Unsupervised classification



Source: Canadian Center for Remote Sensing


Perry Lake - Classified into 16 Categories Using Isodust
Cluster 1
Cluster 2
Cluster 3
Cluster 4
Cluster 5
Cluster 6
Cluster 7
Cluster 8
Cluster 9
Cluster 10
Cluster 11
Cluster 12
Cluster 13
Cluster 14
Cluster 15
Cluster 16


Perry Lake - Unsupervised Classification Using Isoclust
Water
Aquatic Vegetation
Urban/Edge
Grassland
Bare Soil
Forest
km
10.00

CHANGE DETECTION AND MONITORING

- ✓ to create data sets representing different moments in time by using mutitemporal images
- ✓ to create, from 2 or more *reference images* acquired at different times, another image that pinpoints areas of change
  - multitemporal data fusion
  - image differencing techniques

Multitemporal images

- *Toulouse airport (France) between 1984 and 1993*

How to extract geoinformation from satellite data ?

❶ **MORPHOLOGICAL APPROACH** *(continued)*

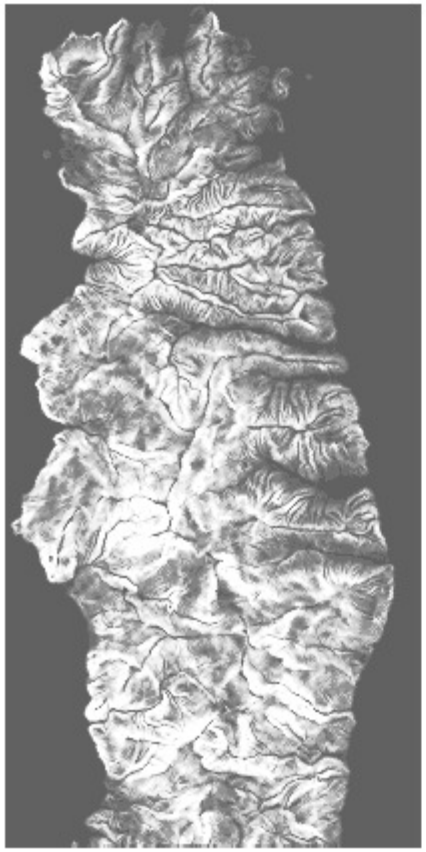
derived from photo-interpretation & photogrammetry techniques

✓ **DEM creation from image stereo pairs (SPOT)**
using automated correlation
=> analogue/digital restitution,
=> derived raster layers (slope, shadowing,…)
=> 3D views

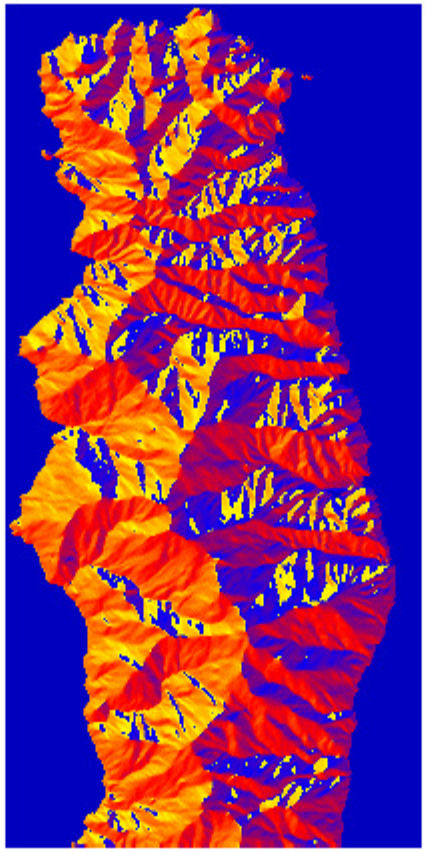
➔ ***digital file ready-to-use into a GIS*** (3D applications)

RASTER LAYERS DERIVED FROM A DEM

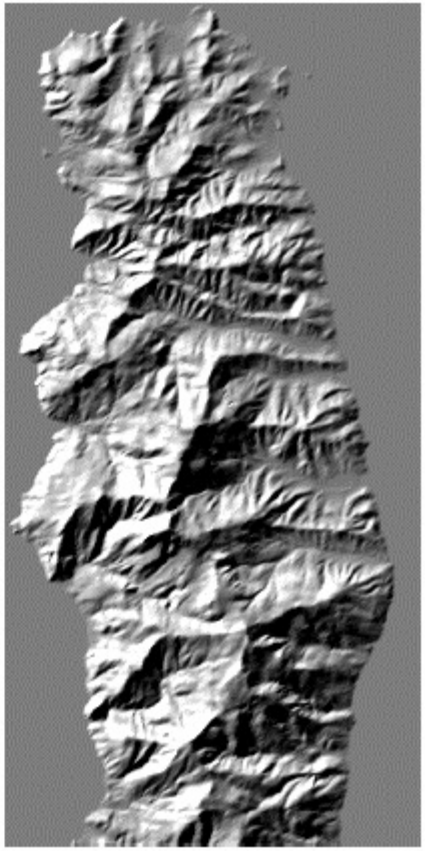
Slope



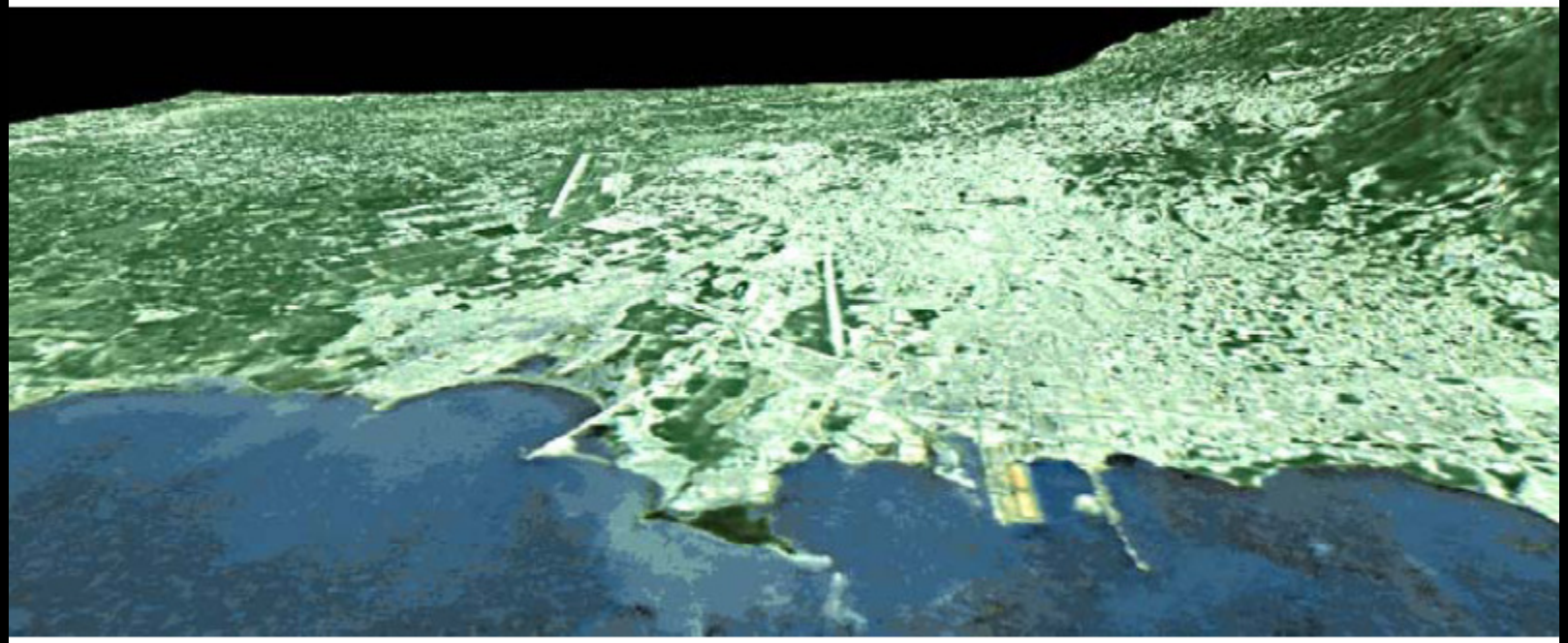
Aspect



Relief (insolation)



3D VIEW



Haïti

Satellite imagery is now recognized to be a major information source

- **Geographic**
- **Multi-thematic / multipurpose**
- **Up-to-date**
- **Reliable**
- **Cost-effective**

at various geographic levels and scales (local to global)

➢ Remotely sensed DATA data are converted into INFORMATION

⇨ Inventories
- topomaps production and updating (= GIS basemaps)
- thematic maps production and updating (= GIS layers)
- DEM and derived information (3D)

⇨ Monitoring
- change detection
- early warning
- impact studies
- modelling

➢ **Repetitivity of data acquisition** *(revisit capability of satellites)*

✓ **Up-to-date images** available for updating geo-information

✓ **Multitemporal images** available for monitoring & change detection

✓ **Acquisition programming** available to meet emergency needs *(ex: flood monitoring, impact of an earthquake...)*

⇨ off-track oblique viewing systems increase revisit capabilities *(SPOT example)*

➢ Geometric quality and " flexibility " of digital imagery

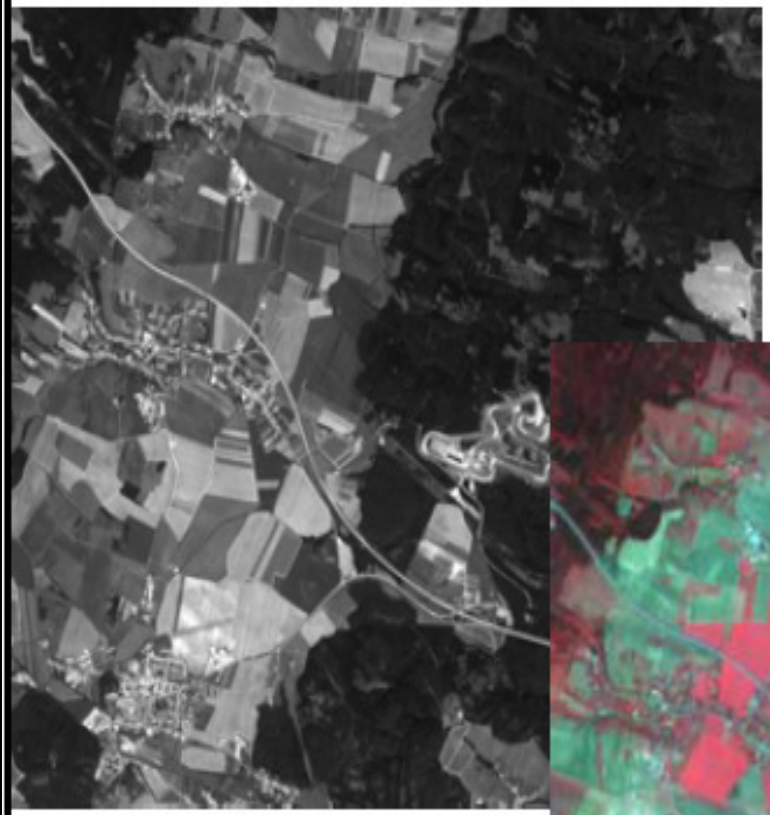
✓ Digital satellite images can be **easily georeferenced** and represented according to **various map projection systems**

⇨ easy integration into GIS data bases

✓ Existing high resolution sensors (10 to 5 m) are compatible with:

- medium scales topo-map standards (1:50 000 to 1:25 000)
- thematic studies and mapping at larger scales
- soon satellite with Very High Resolution (1 m)

KVR-1000

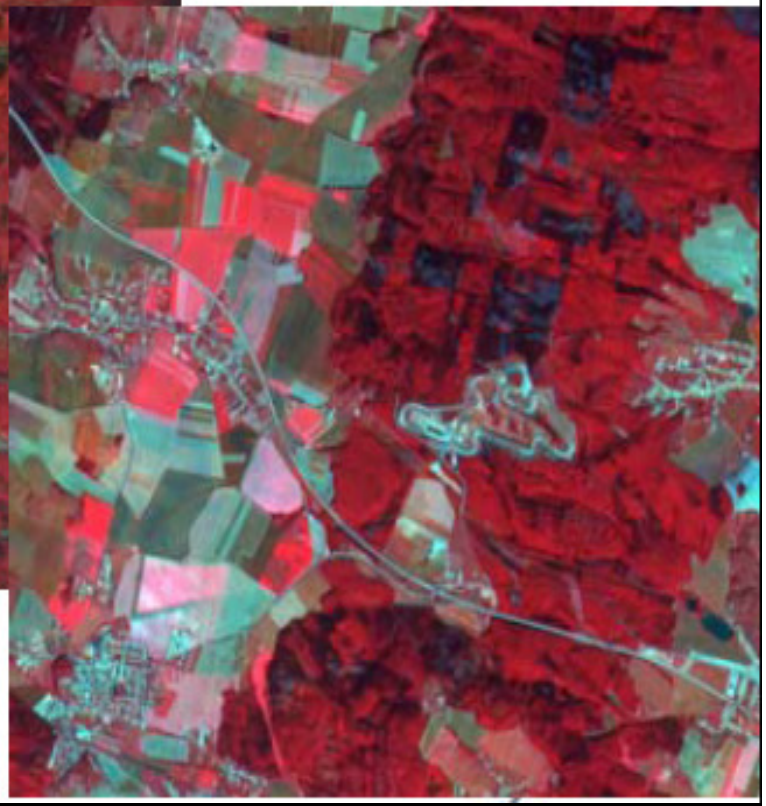


✓ Easy registration of images for data fusion & multitemporal studies *(using same type of sensor, ex: SPOT + TM or SPOT PAN + SPOT XS)*

PAN

XS

Merging P + XS



MORPHOLOGICAL APPROACH

derived from photo-interpretation & photogrammetry techniques

✓ **visual analysis using a space ortho-rectified image paper product**

➔ ***creation of paper thematic maps***

that can be digitized to create ***digital vectors layers***

✓ **computer aided photo-interpretation (CAPI) of digital space ortho-rectified images**

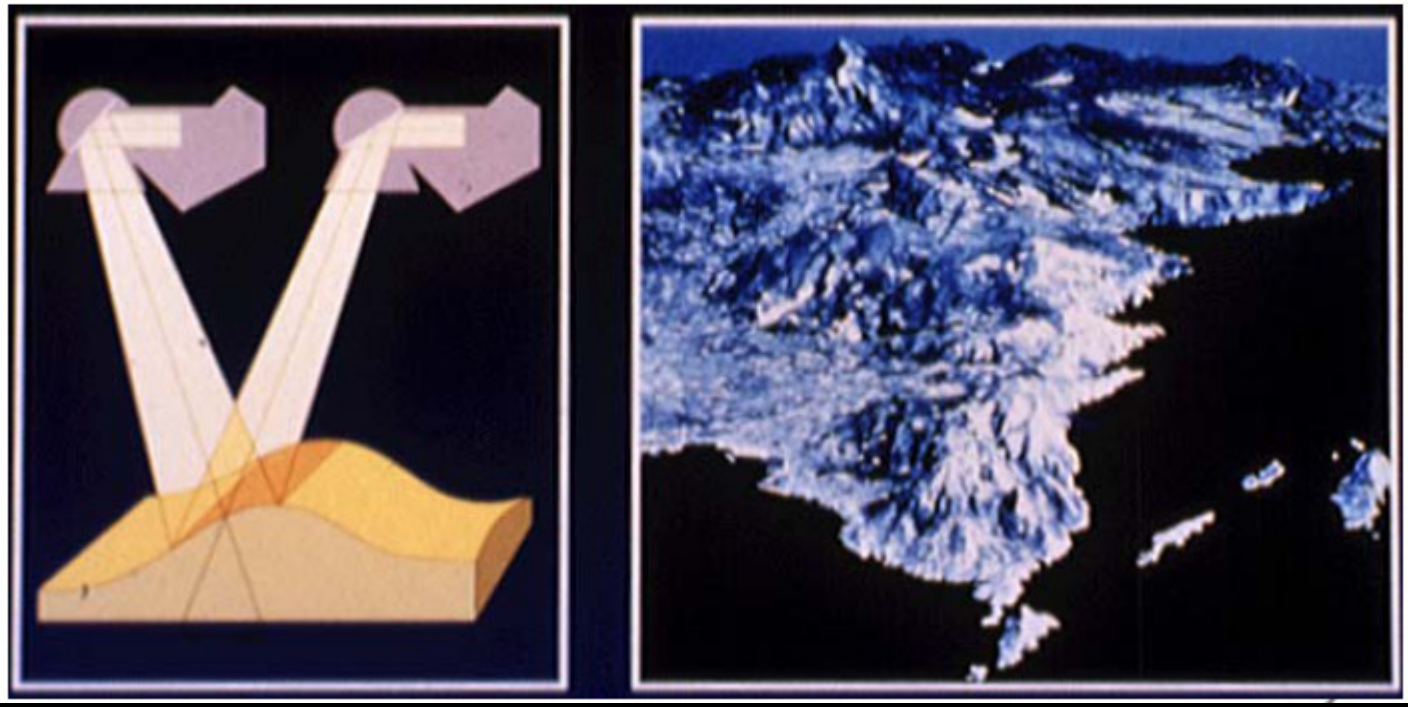
= interactive image processing techniques enabling the operator:

- to improve feature detectability/interpretability on screen
- to digitize/revise boundaries/polygons
- to extract/revise attributes

➔ ***creation/updating of digital thematic vector layers***

✓ Stereo capability (*thanks to off-track oblique viewing systems)*

⇨ Digital Elevation Modelling (DEM / DTM) and 3D applications



- **Access to bio-physical parameters**

  ex. surface temperature, vegetation index (NDVI)

  ⇨ input data for modelling *(ex: agro-meteorological models)*

- **Images available both in digital & and analog formats** *(paper products)*

  ⇨ flexibility for image analysis
  (manual and / or digital methods)
  ⇨ flexibility for GIS integration

User

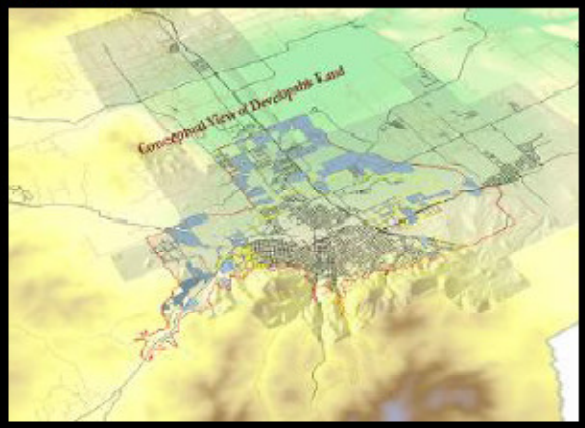
Persons or Government officials who plan
the resource management
with the help of satellite data are called user

APPLICATIONS OF REMOTE SENSING

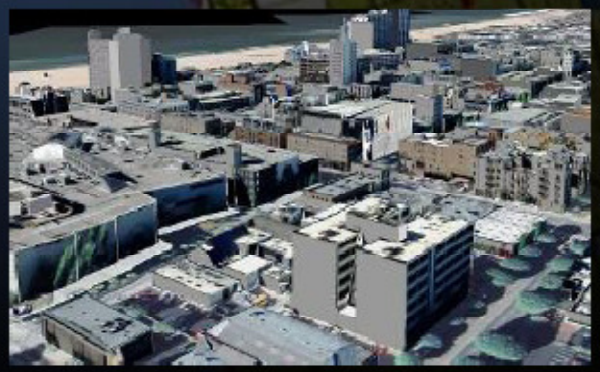
- Weather forecasting
- Communication and broadcasting
- Resources status on Global, regional and local level
- Agriculture
- Forestry and Biodiversity
- Geology, Structure and Minerals
- Landform
- Land use/Land cover
- Soil
- Water
- Disaster management
- Education
- Urban Planning
- Defence

Help us plan

Land Use Suitability
Montana



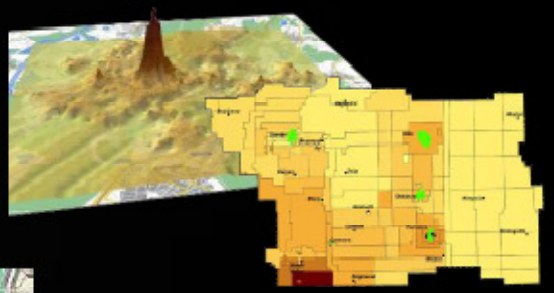
City & Urban Planning
California



Virtual City
Bangkok

Manage the land

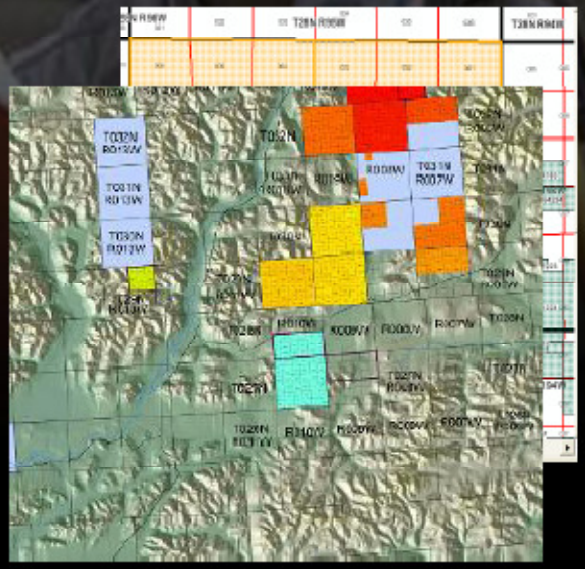
Property Evaluation
Germany



Canada

Tax Mapping
Connecticut

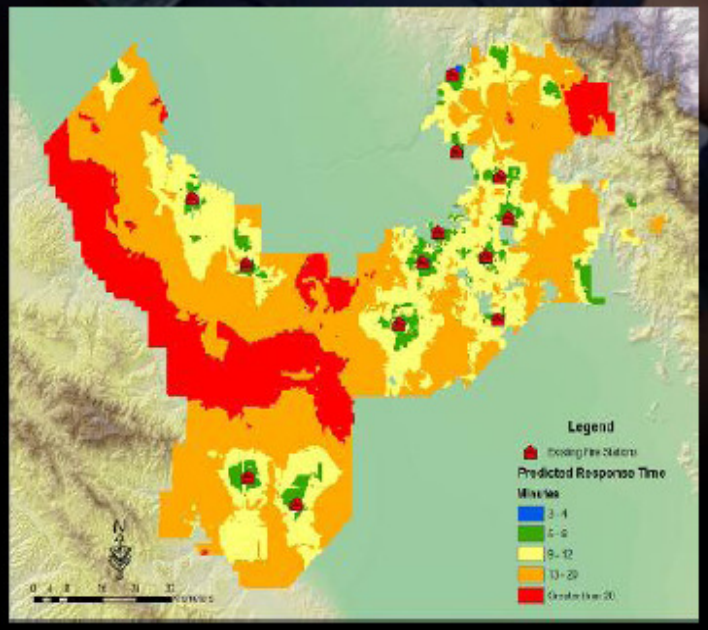
Integrated Land Management
BLM



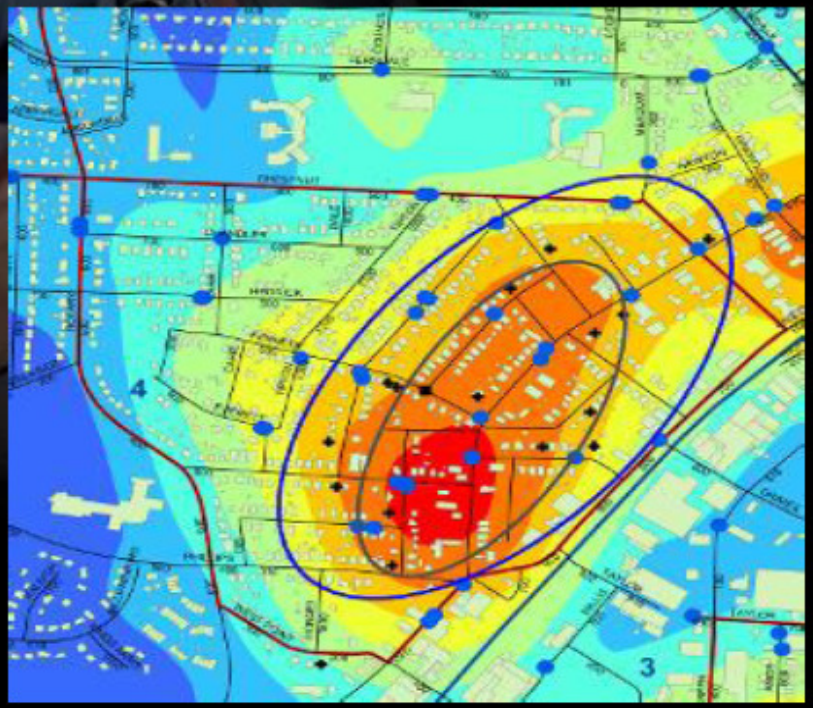
Native Land Selection
Alaska

Increase public safety & help law enforcement

Fire Response
California

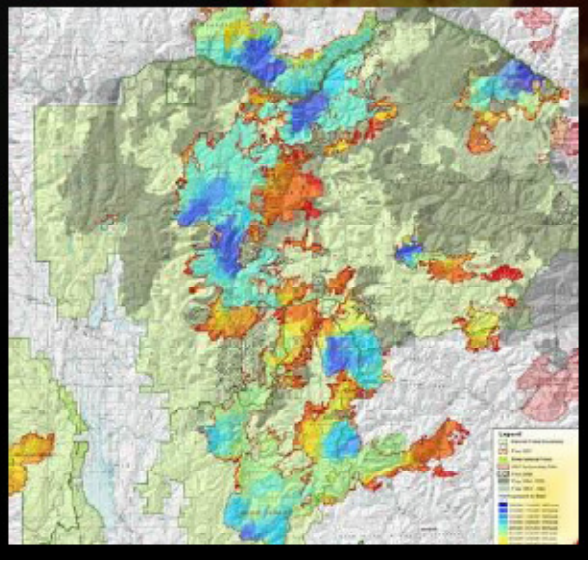


Crime Analysis
Texas

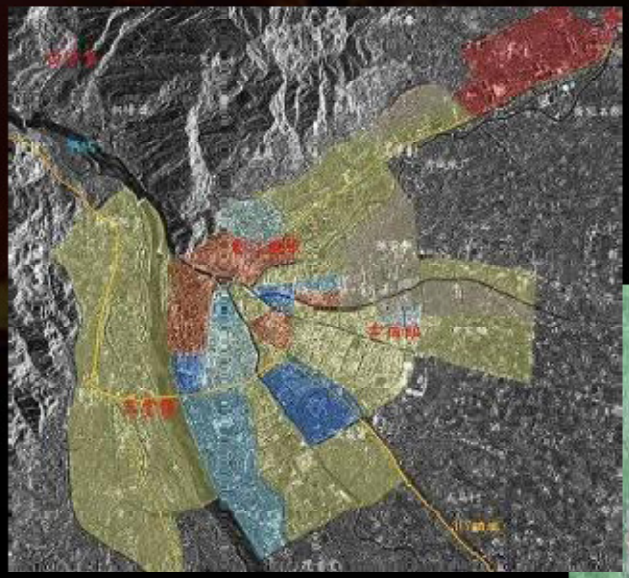


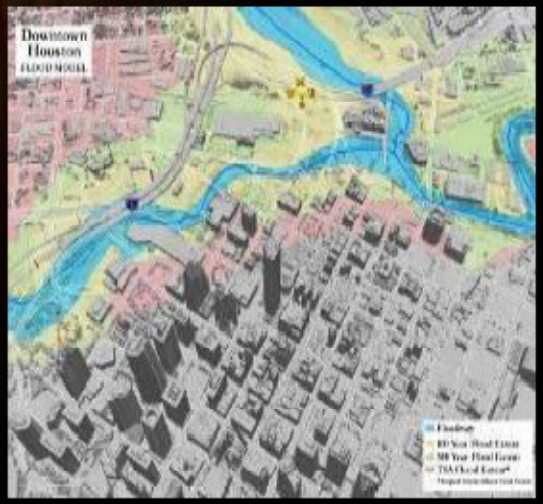
Help manage natural disasters

Wildfire
Idaho

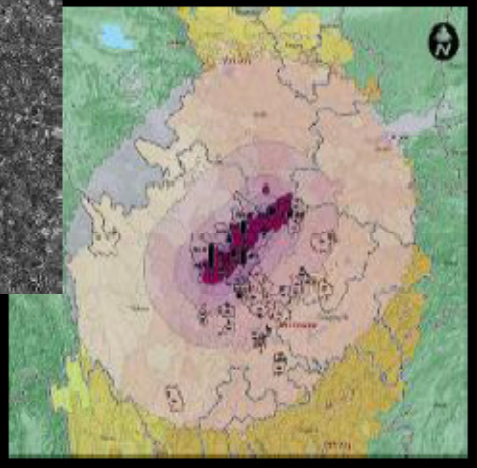


Wenchuan Earthquake
China





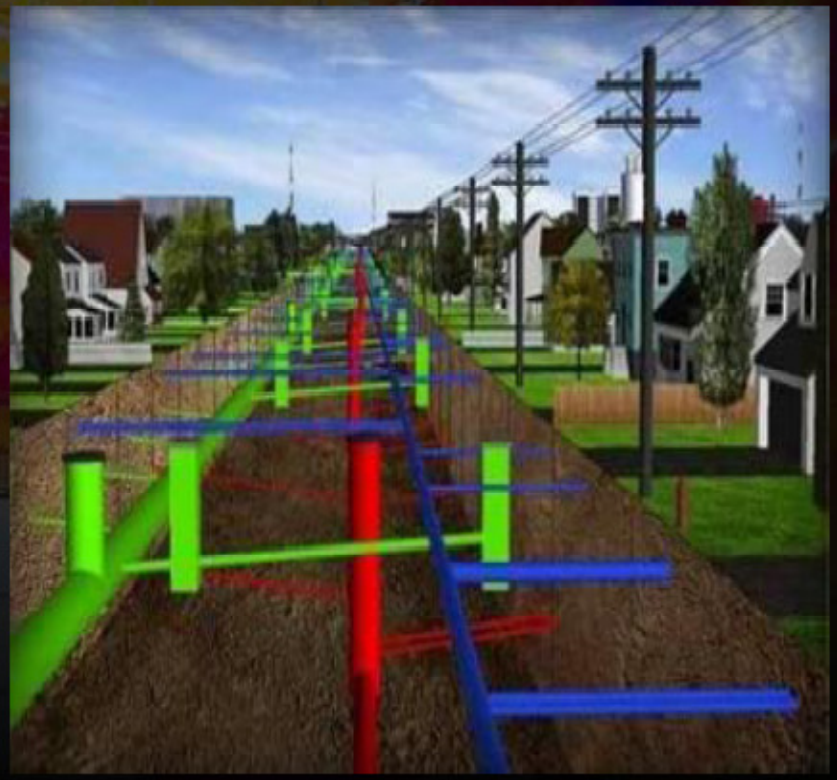
Floods Simulation
Houston



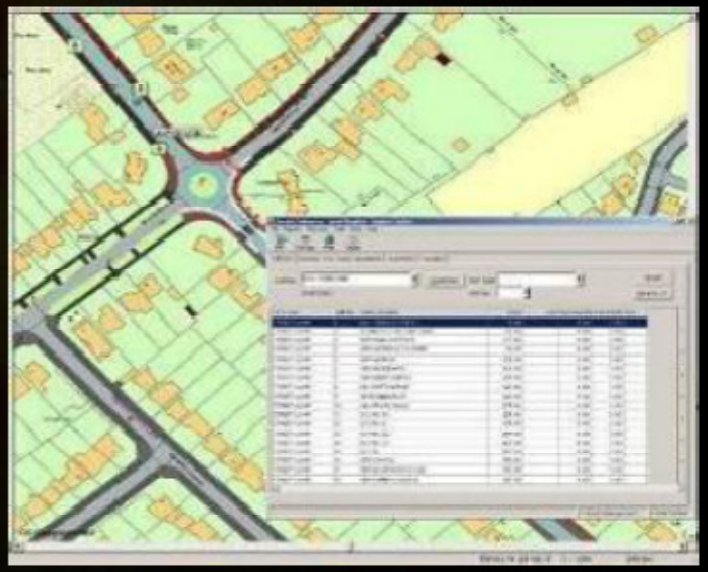
Aftershocks

Manage electricity, water, phone…

Networks
Canada



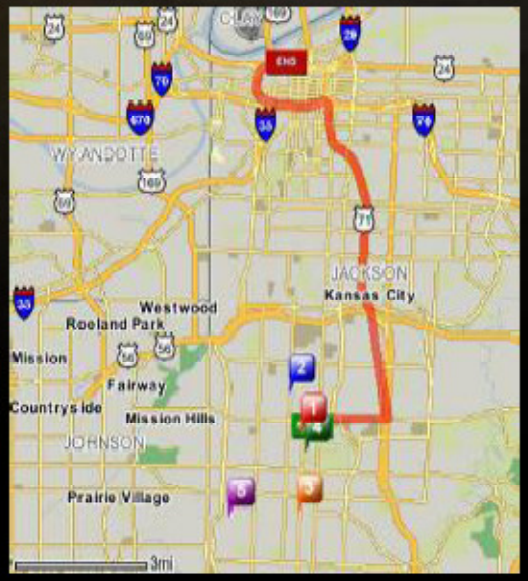
Highways
Bedfordshire, UK



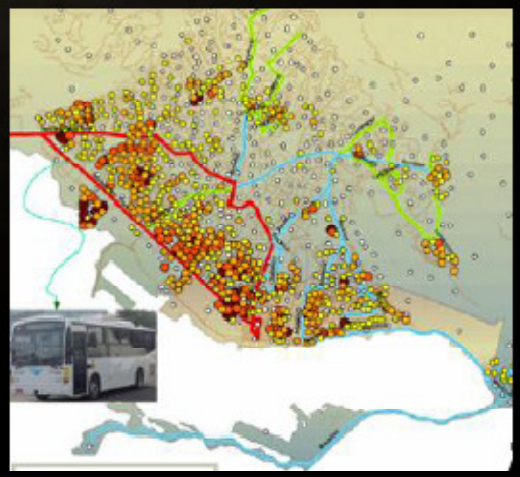
Model transportation

Real Time Traffic
Korea

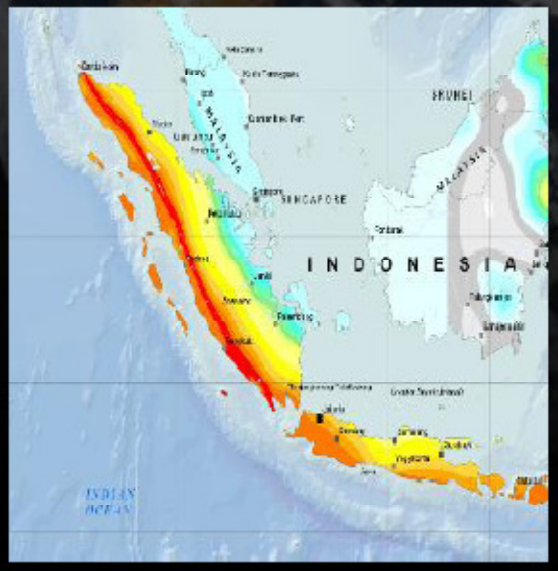
Ride Share
Kansas



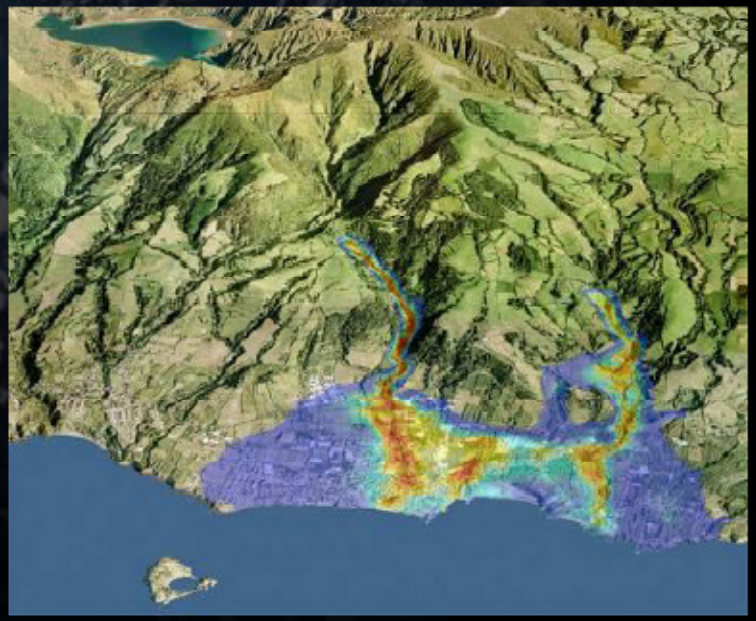
Transit Analysis
Jamaica



Earth science & water resources

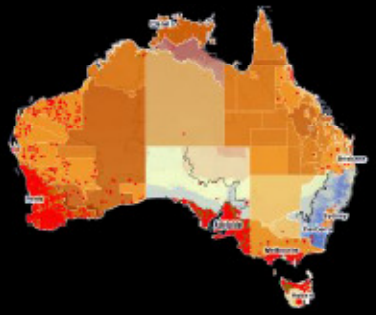


Seismic Hazards
Indonesia



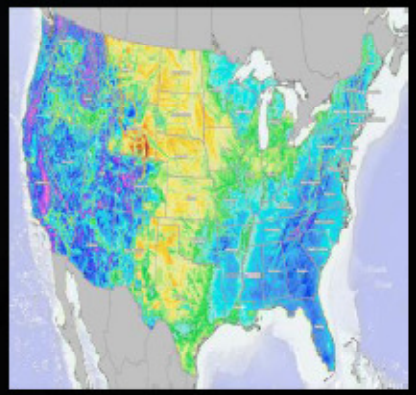
Flood Risk
Portugal

Online Soil Information
Australia

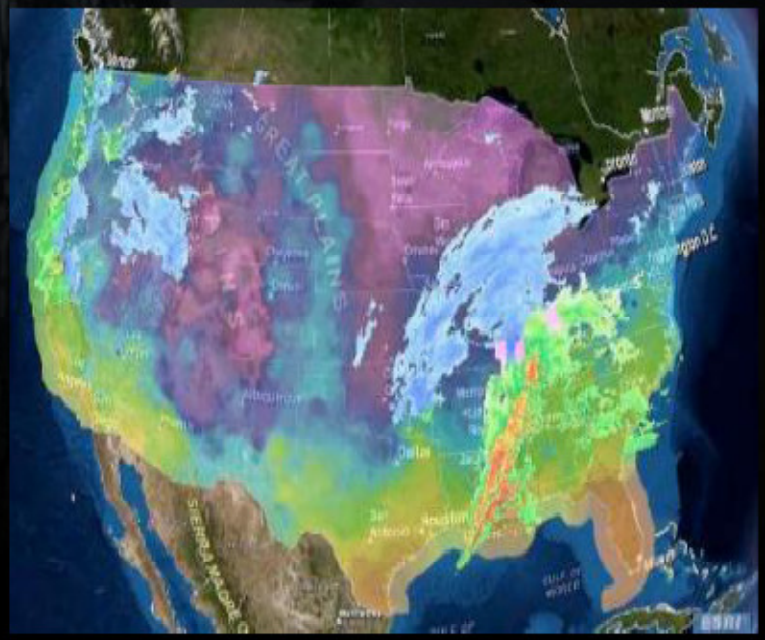


Monitor climate and energy

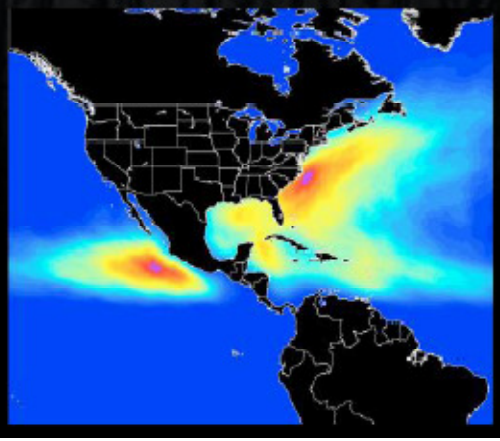
Wind Generation Potential
U.S.A.



Weather Monitoring
U.S.A.

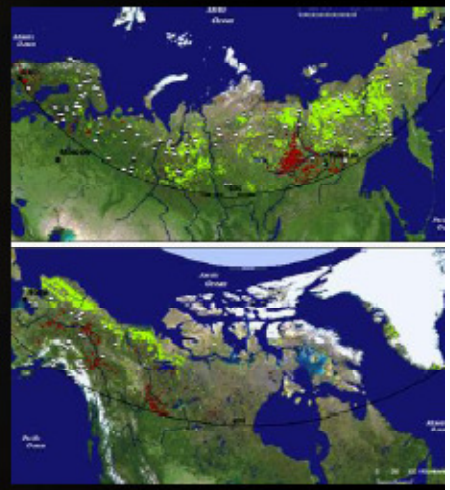


Tropical Cyclones
National Hurricane Center

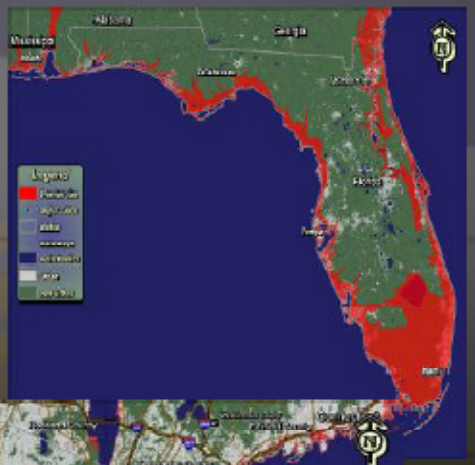


Impact of global climate change

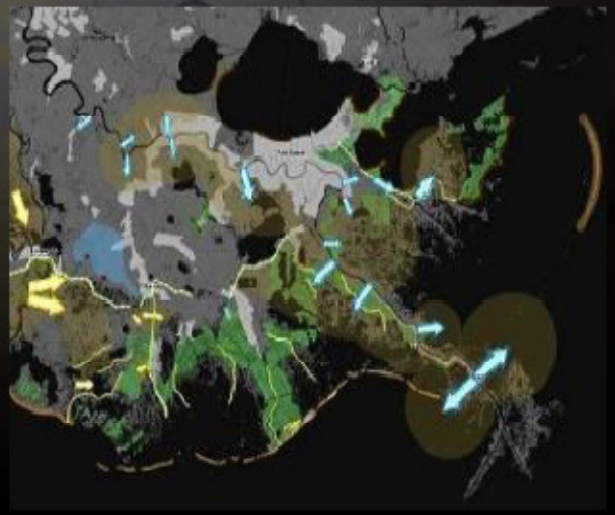
Vegetation Trends
Arctic



Sea Level Rise Modeling
Florida



New York

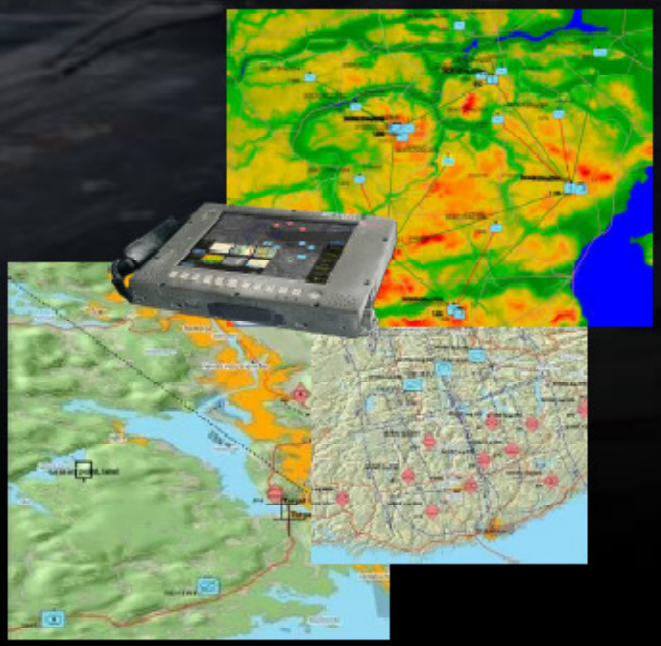


Coastal Zone Planning
Louisiana

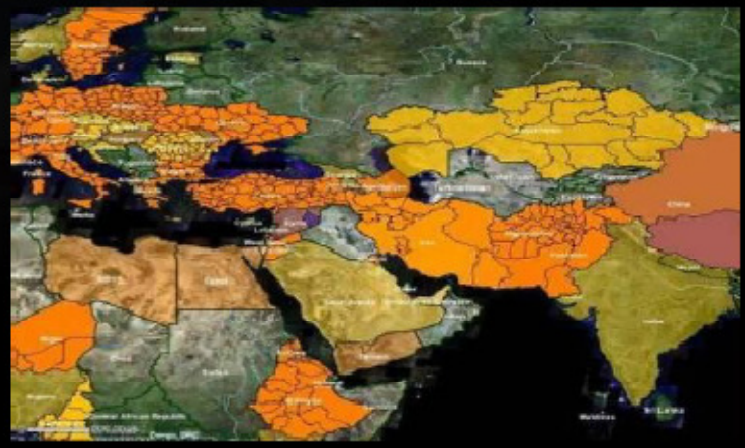
Protect our country

Geographical Security
Kingdom of Bahrain

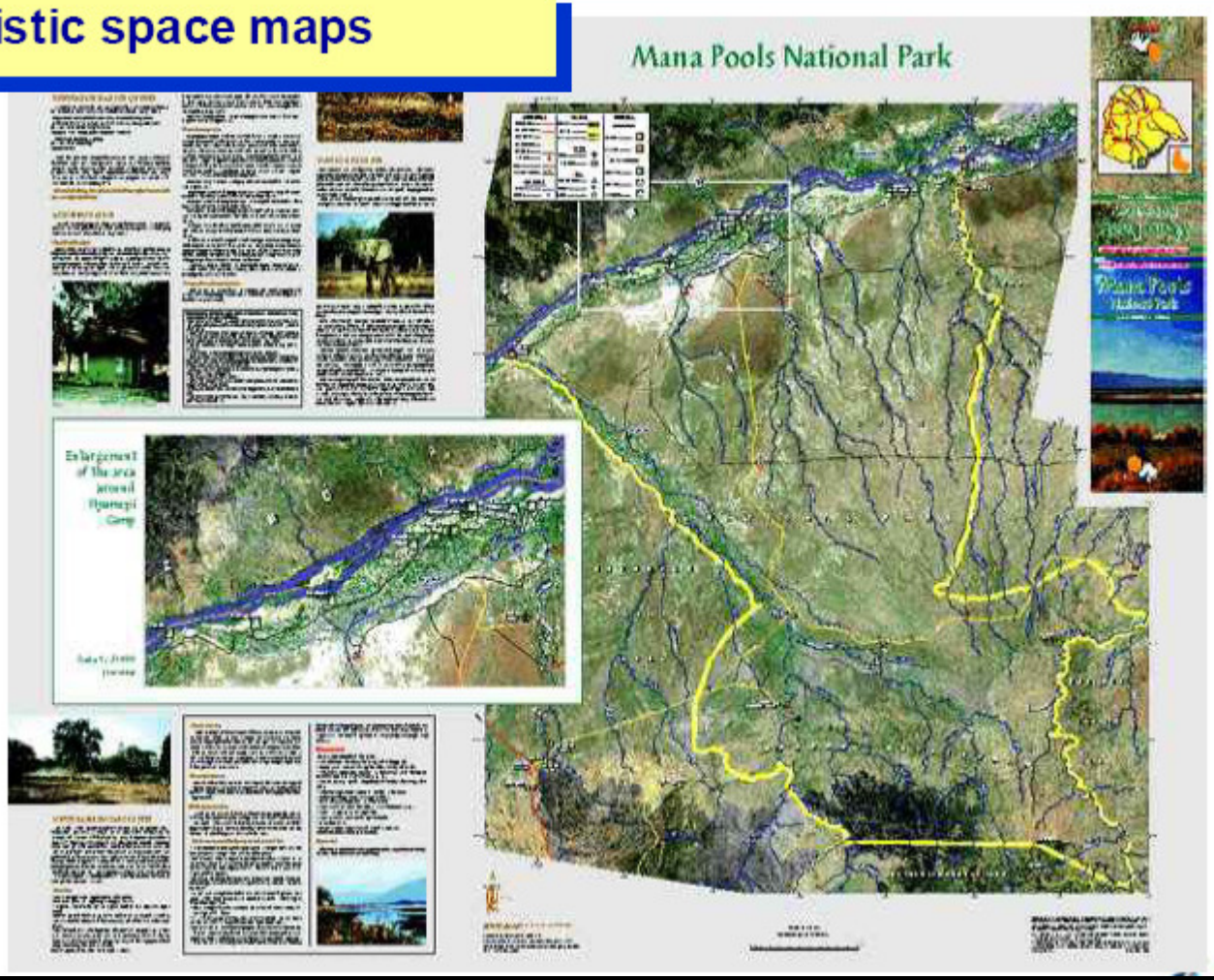
Model areas in
Europe



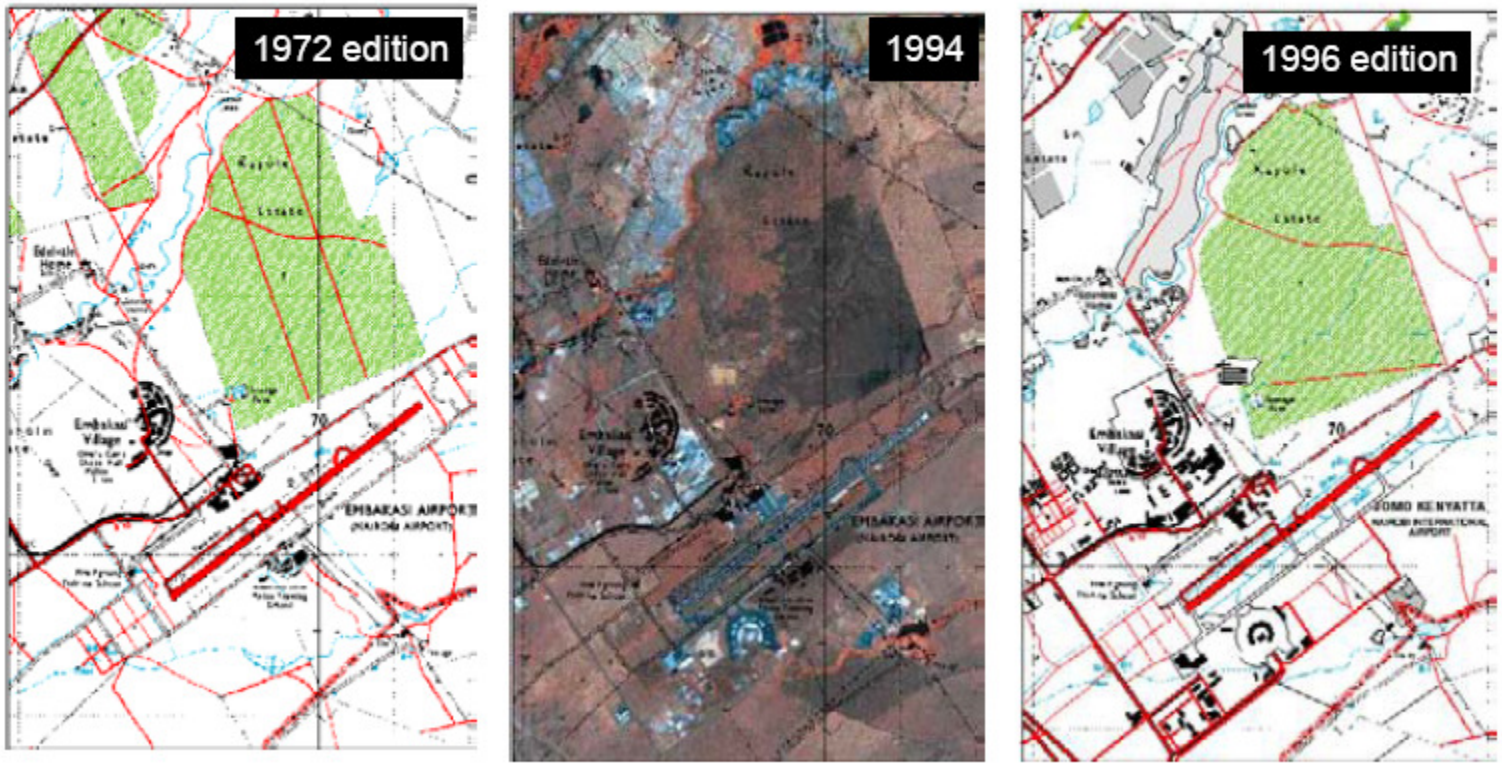
Global Surveillance



Touristic space maps

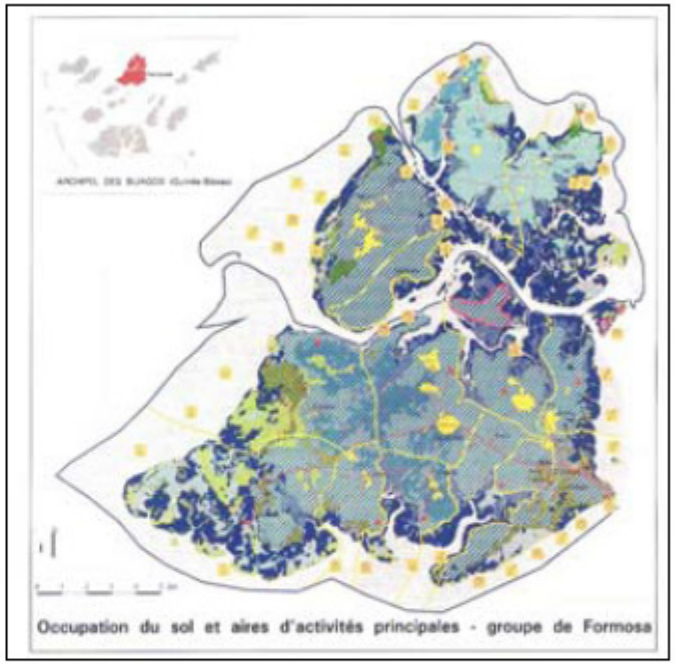


Topographic map updating



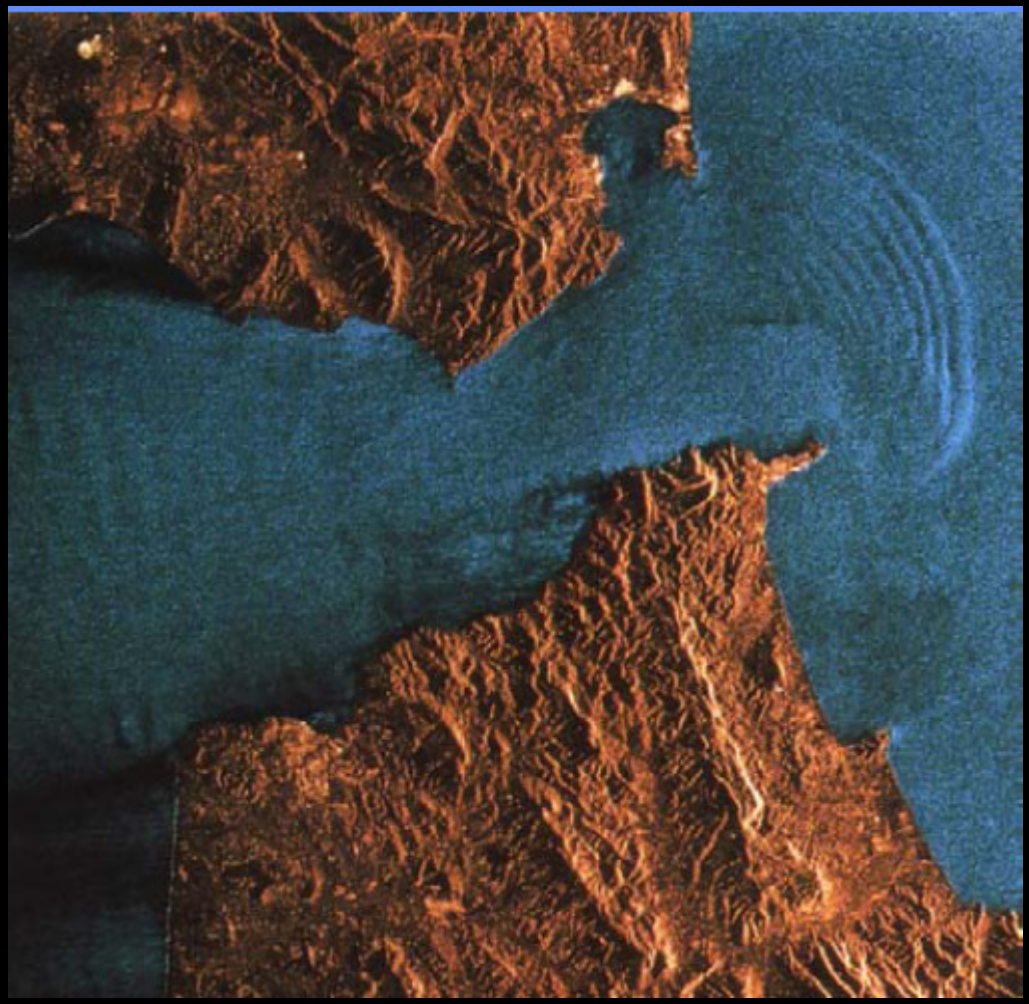
(P+XS) SPOT images, 1:50,000. Survey of Kenya / IGN International

Coastal management

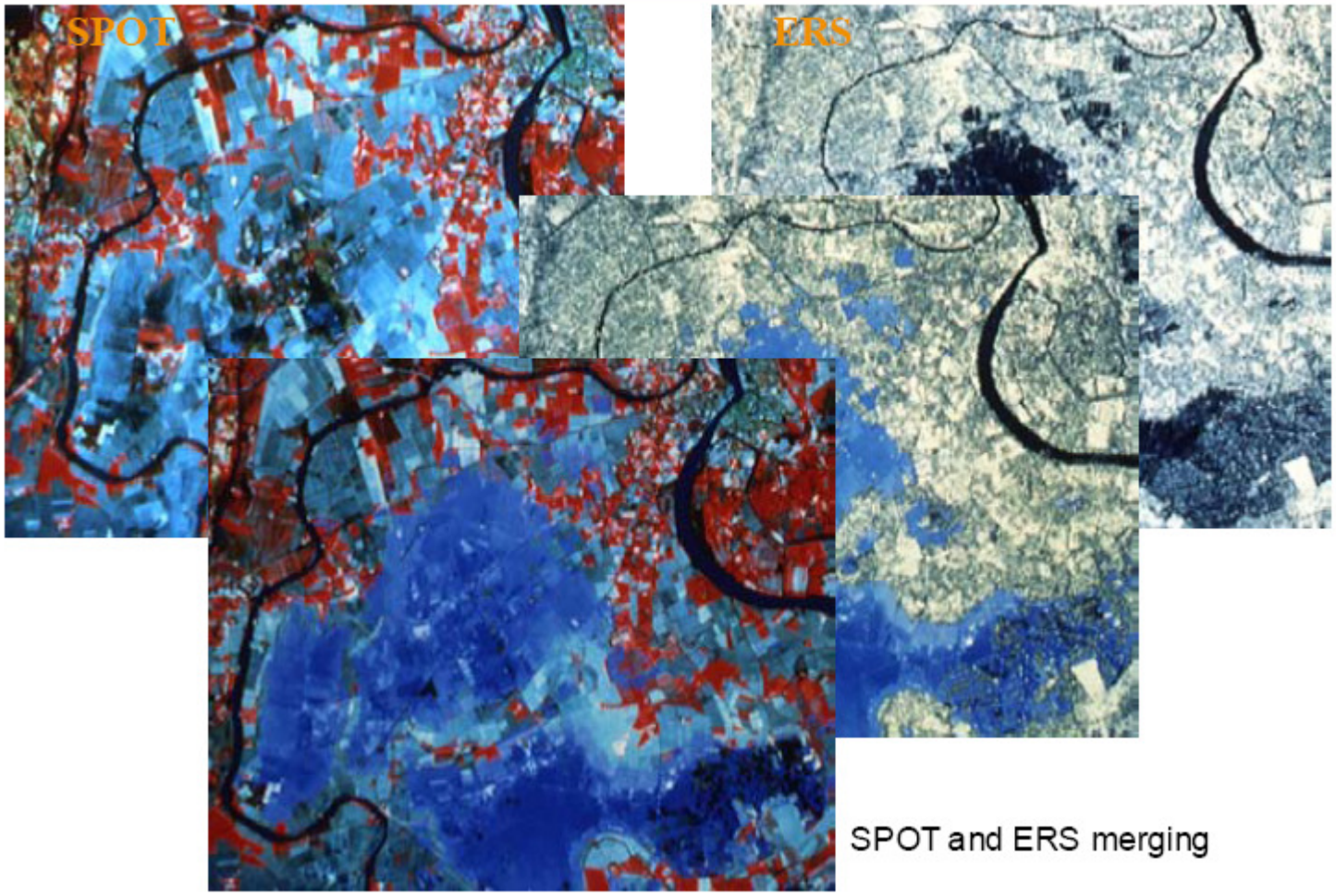


Bissau-Guinea (Bijagos Archipelago)
Digital SPOT mosaic (left)
Land use map derived from SPOT and overlayed with environment and socio-economic data (above)

Sea Surface Study

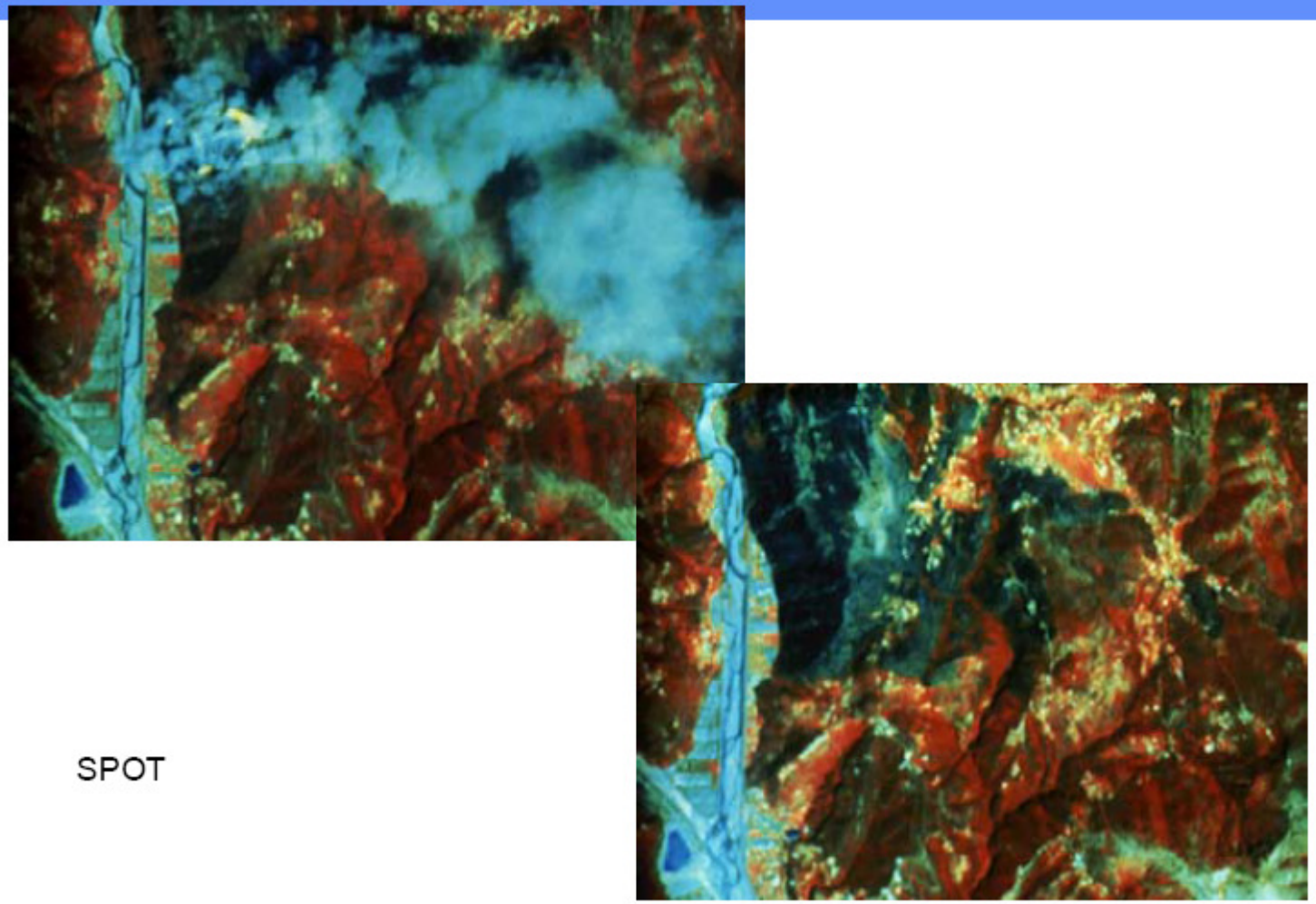


Monitoring natural disasters (floods)



SPOT and ERS merging

Environment : deforestation



SPOT

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Thank You

Questions?