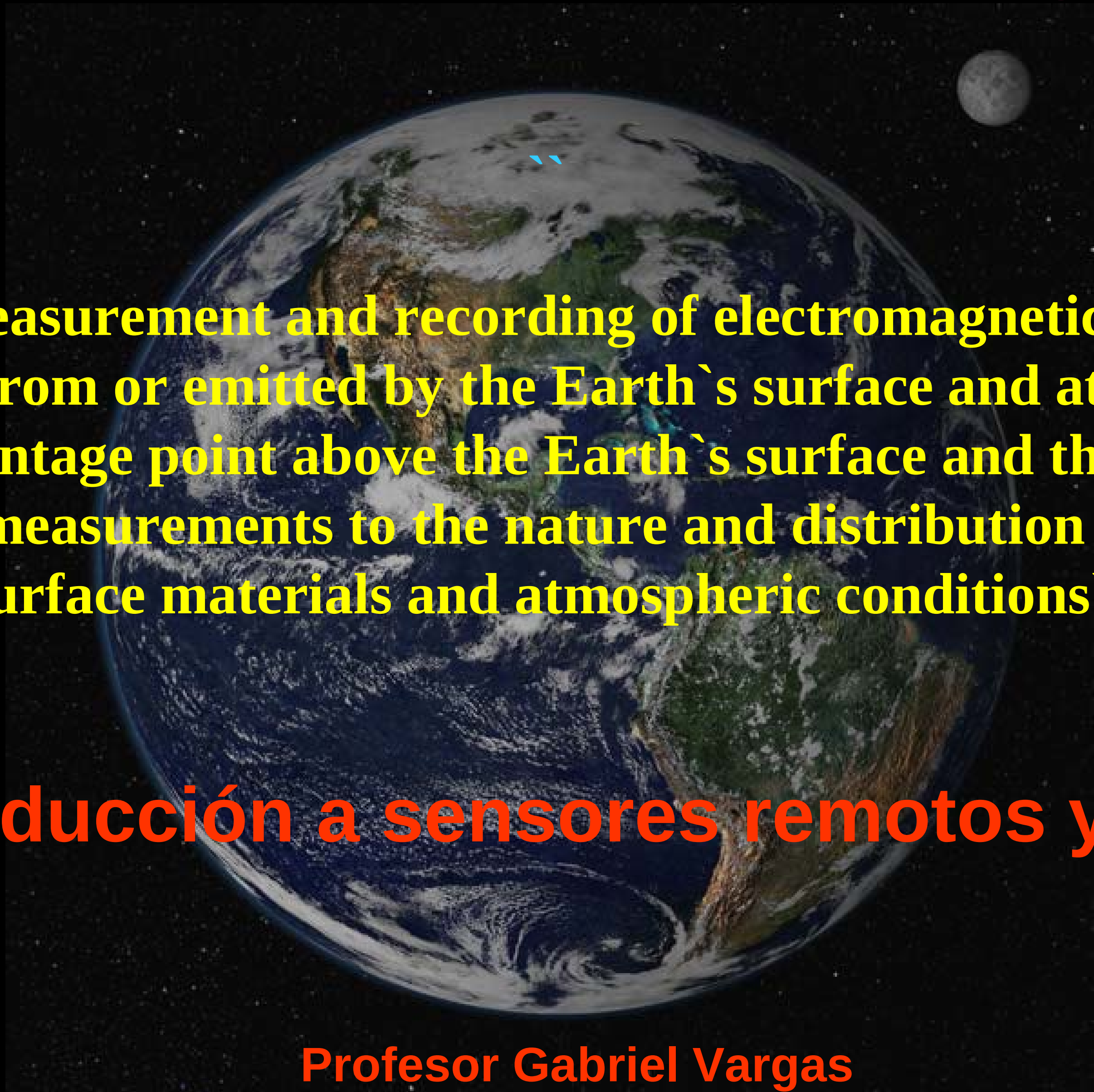
# What is remote sensing?



**``the measurement and recording of electromagnetic energy reflected from or emitted by the Earth`s surface and atmosphere from a vantage point above the Earth`s surface and the relating of such measurements to the nature and distribution of Earth surface materials and atmospheric conditions``**

## Introducción a sensores remotos y SIG

**Profesor Gabriel Vargas**

## Proceso de generación de la señal, obtención y análisis de datos de sensores remotos

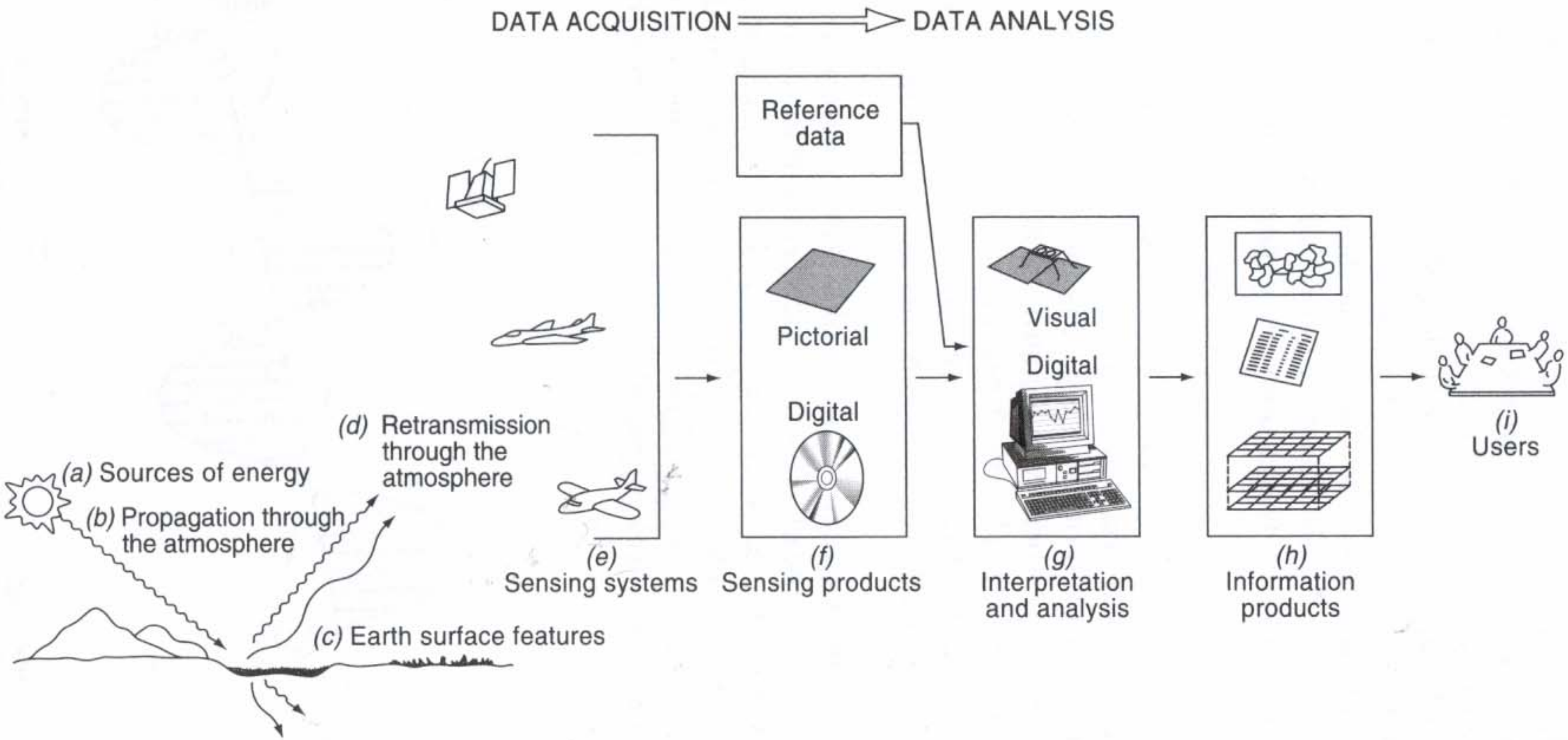



**Figure 1.1** Electromagnetic remote sensing of earth resources.

# 1. Origen de la señal, balance de energía y reflectancia

**Propagación de ondas electromagnéticas,**
***a la velocidad de la luz C, dada una frecuencia y longitud de onda***

$$c = \nu\lambda$$

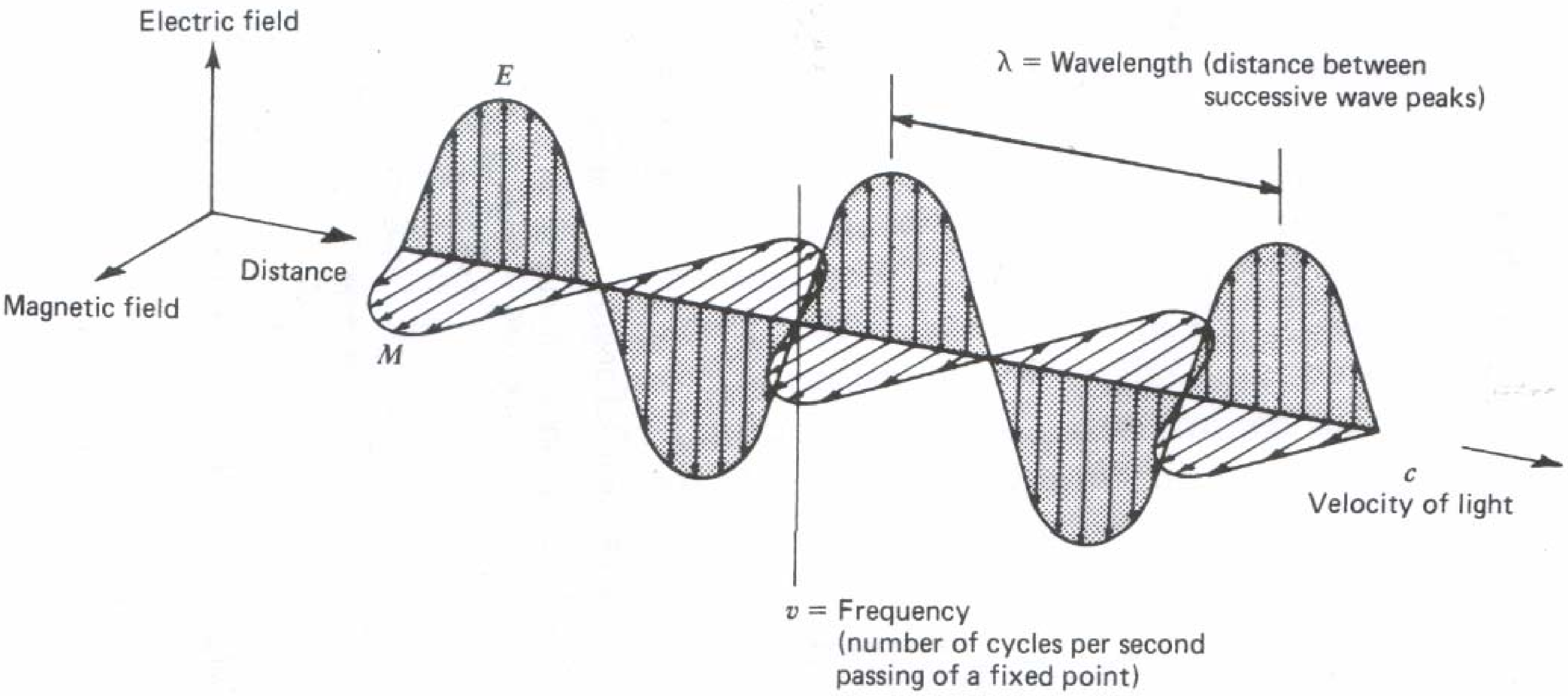



**Figure 1.2** Electromagnetic wave. Components include a sinusoidal electric wave (*E*) and a similar magnetic wave (*M*) at right angles, both being perpendicular to the direction of propagation.

# Espectro electromagnético

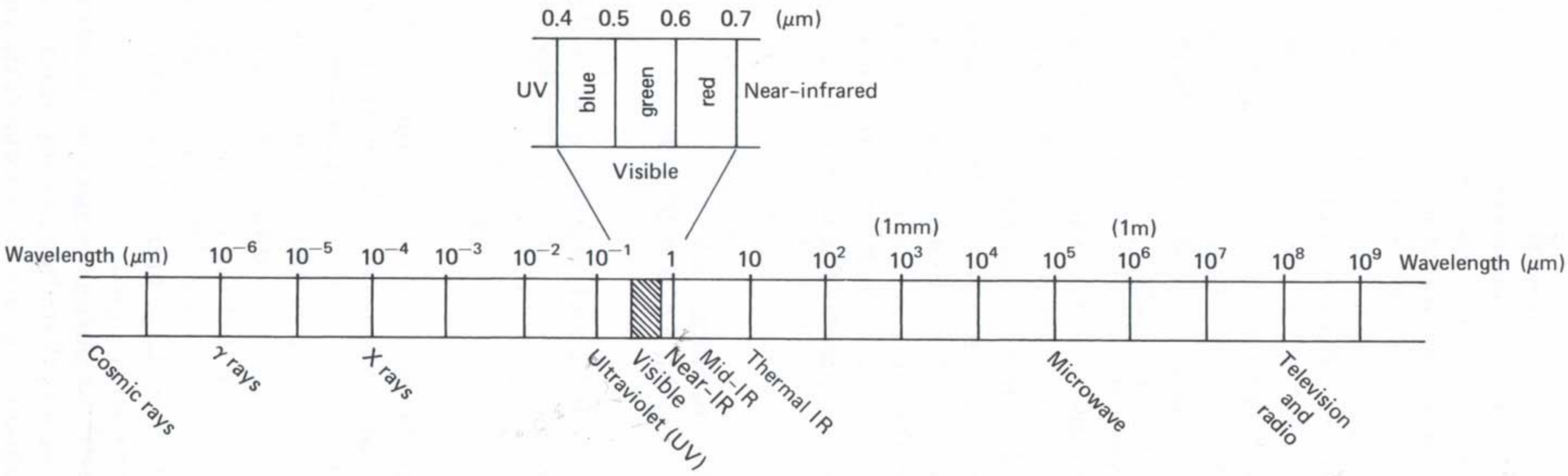



**Figure 1.3** Electromagnetic spectrum.

## Radiación de cuerpo negro:

$$M = \sigma T^4 \tag{1.4}$$

*where*

$M$ = total radiant exitance from the surface of a material, watts (W) $\text{m}^{-2}$

$\sigma$ = *Stefan–Boltzmann constant*, $5.6697 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$

$T$ = absolute temperature (K) of the emitting material

## Longitud de onda de la radiación máxima:

$$\lambda_m = \frac{A}{T} \tag{1.5}$$

*where*

$\lambda_m$ = wavelength of maximum spectral radiant exitance, $\mu$m

$A$ = 2898 $\mu$m K

$T$ = temperature, K

**Distribución espectral de la energía irradiada por un cuerpo negro a diferentes temperaturas**



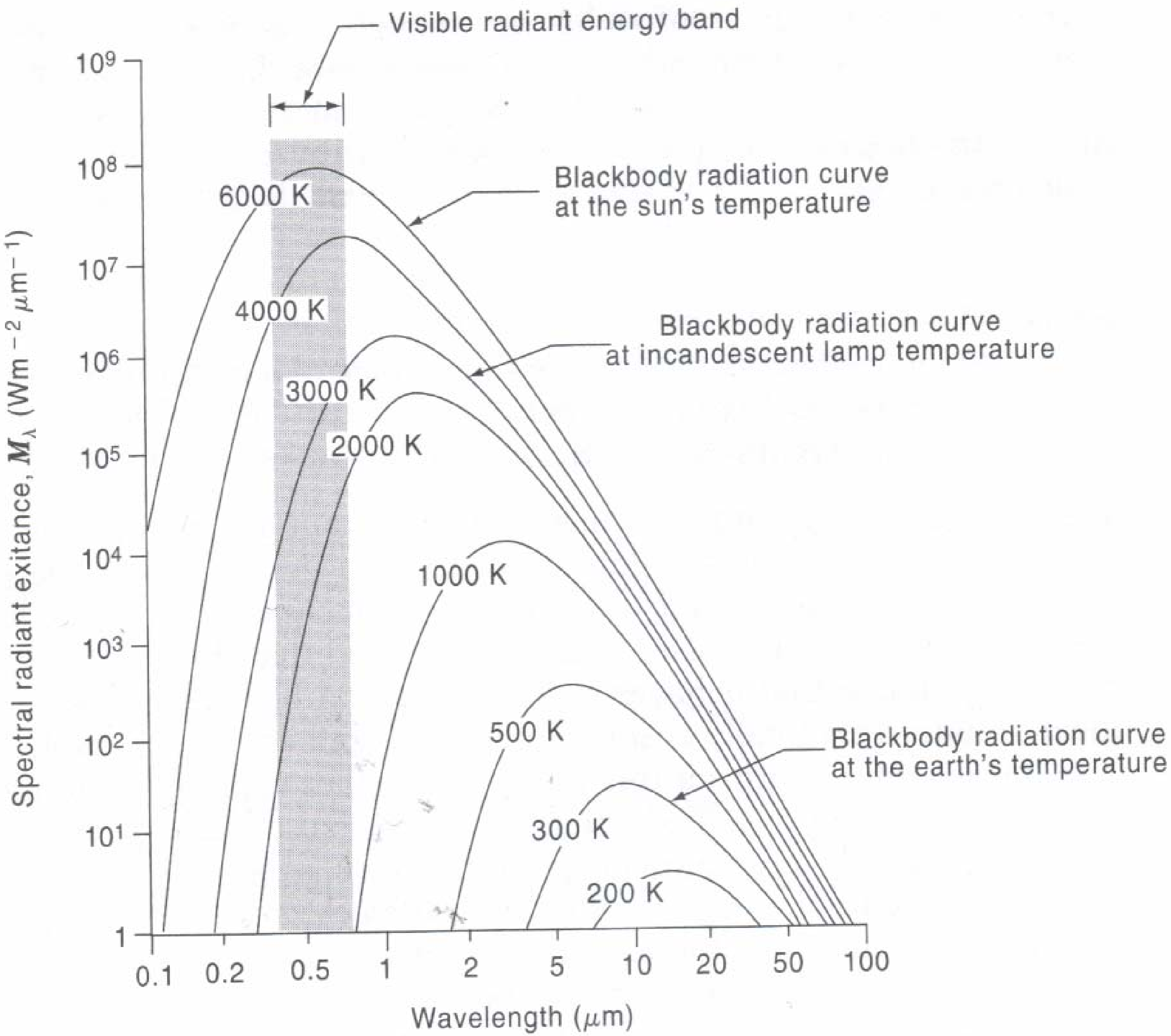



**Figure 1.4** Spectral distribution of energy radiated from blackbodies of various temperatures. (Note that spectral radiant exitance $M_\lambda$ is the energy emitted per unit wavelength interval. Total radiant exitance $M$ is given by the area under the spectral radiant exitance curves.)

## Interacción entre la radiación y la atmósfera

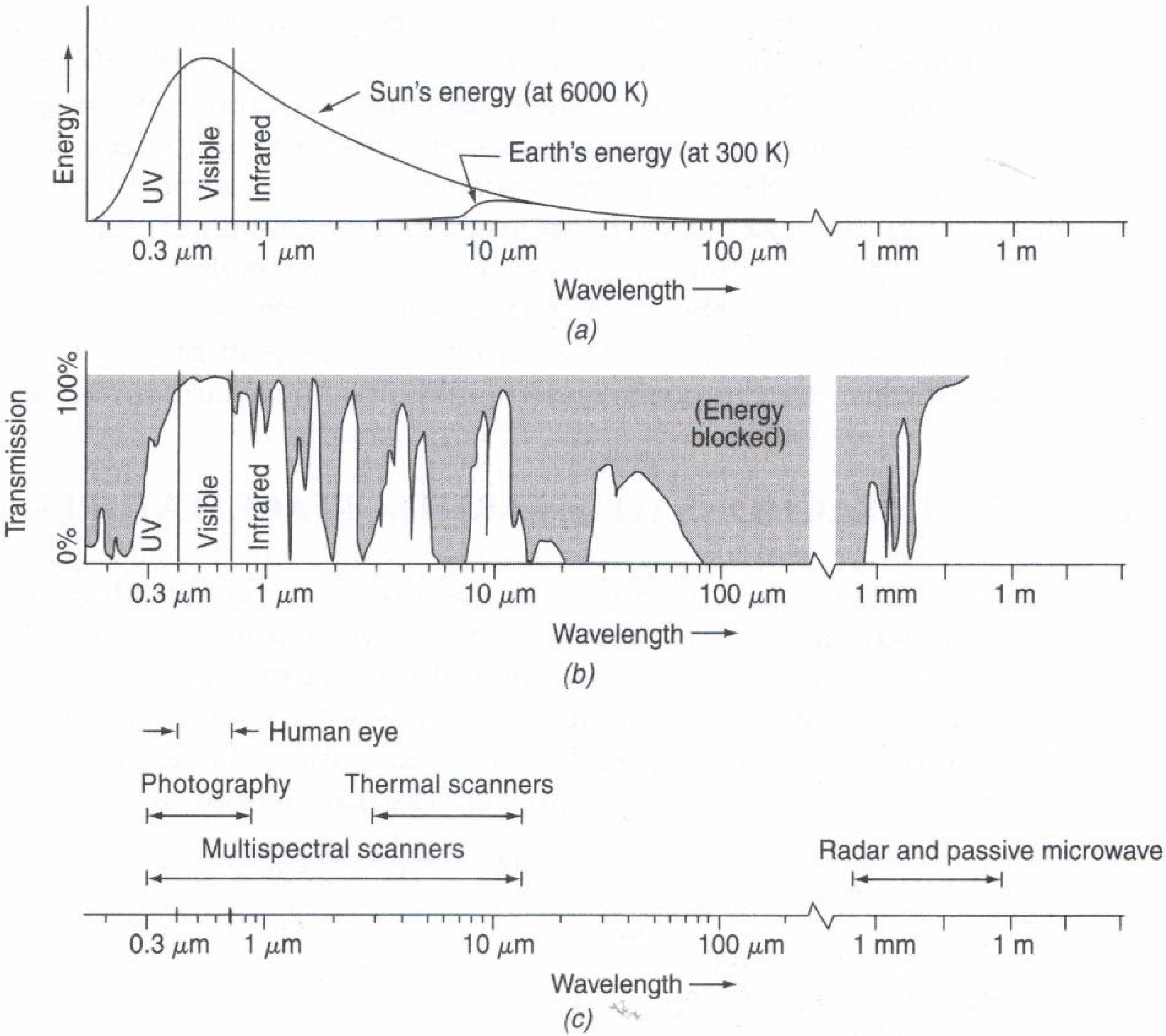



**Figure 1.5** Spectral characteristics of (*a*) energy sources, (*b*) atmospheric transmittance, and (*c*) common remote sensing systems. (Note that wavelength scale is logarithmic.)

# Balance de energía

$$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda) \quad (1.6)$$

*where*

$E_I$ = incident energy
$E_R$ = reflected energy
$E_A$ = absorbed energy
$E_T$ = transmitted energy

with all energy components being a function of wavelength $\lambda$.

Equation 1.6 is an energy balance equation expressing the interrelationship among the mechanisms of reflection, absorption, and transmission. Two

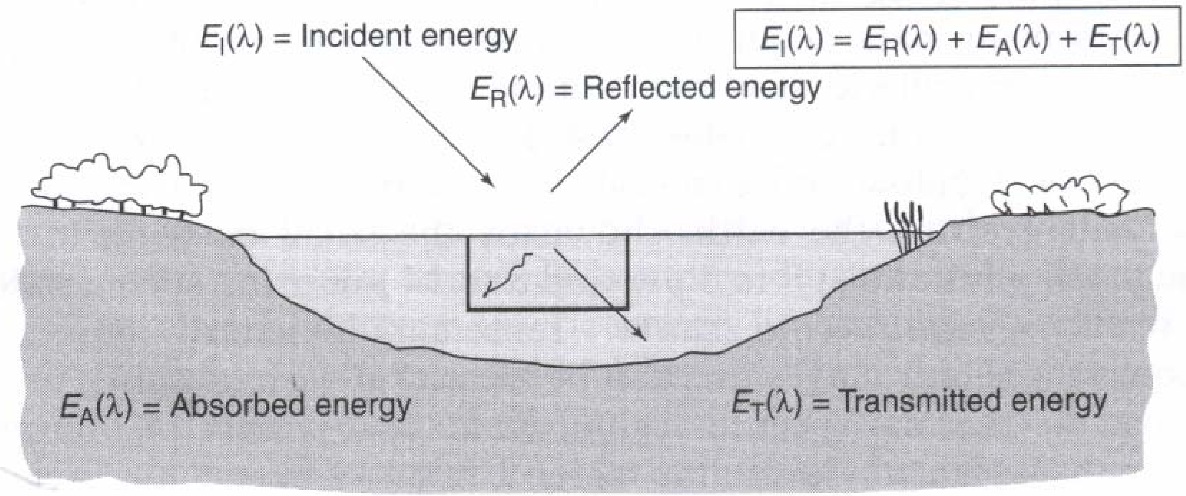



**Figure 1.6** Basic interactions between electromagnetic energy and an earth surface feature.

# Reflectancia difusa versus especular

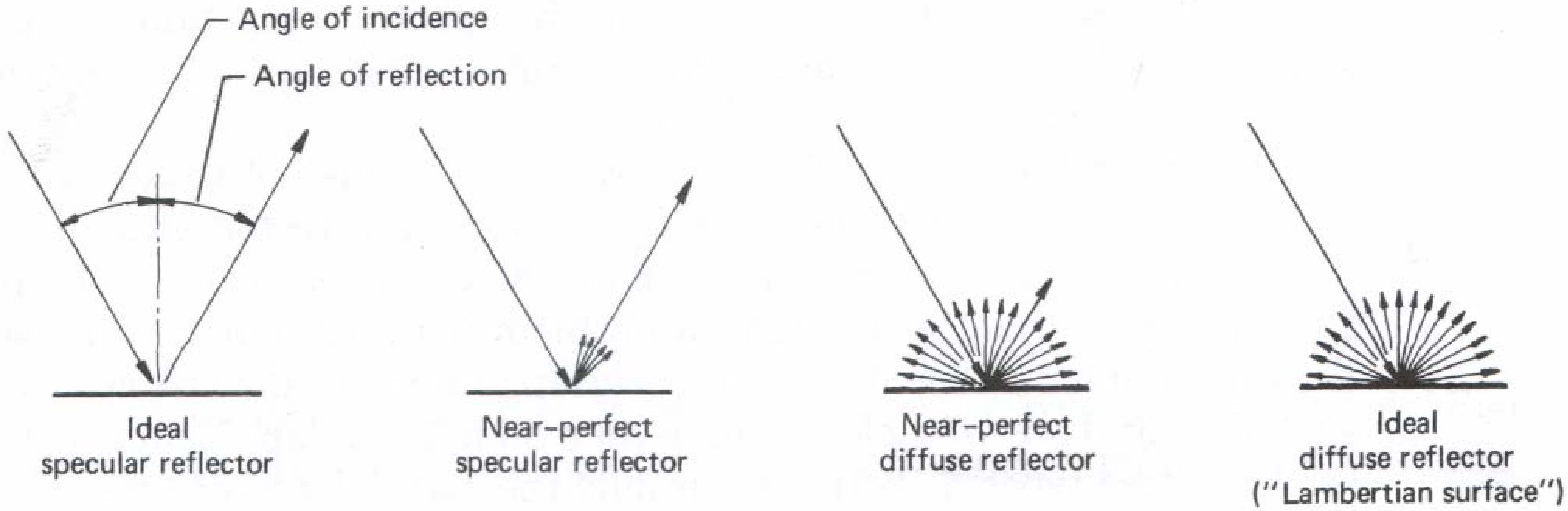



**Figure 1.7** Specular versus diffuse reflectance. (We are most often interested in measuring the diffuse reflectance of objects.)

***Balance de energía***

$$E_R(\lambda) = E_I(\lambda) - [E_A(\lambda) + E_T(\lambda)]$$

***Reflectancia espectral***

$$\rho_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)}$$

$$= \frac{\text{energy of wavelength } \lambda \text{ reflected from the object}}{\text{energy of wavelength } \lambda \text{ incident upon the object}} \times 100$$

*where* $\rho_\lambda$ is expressed as a percentage.

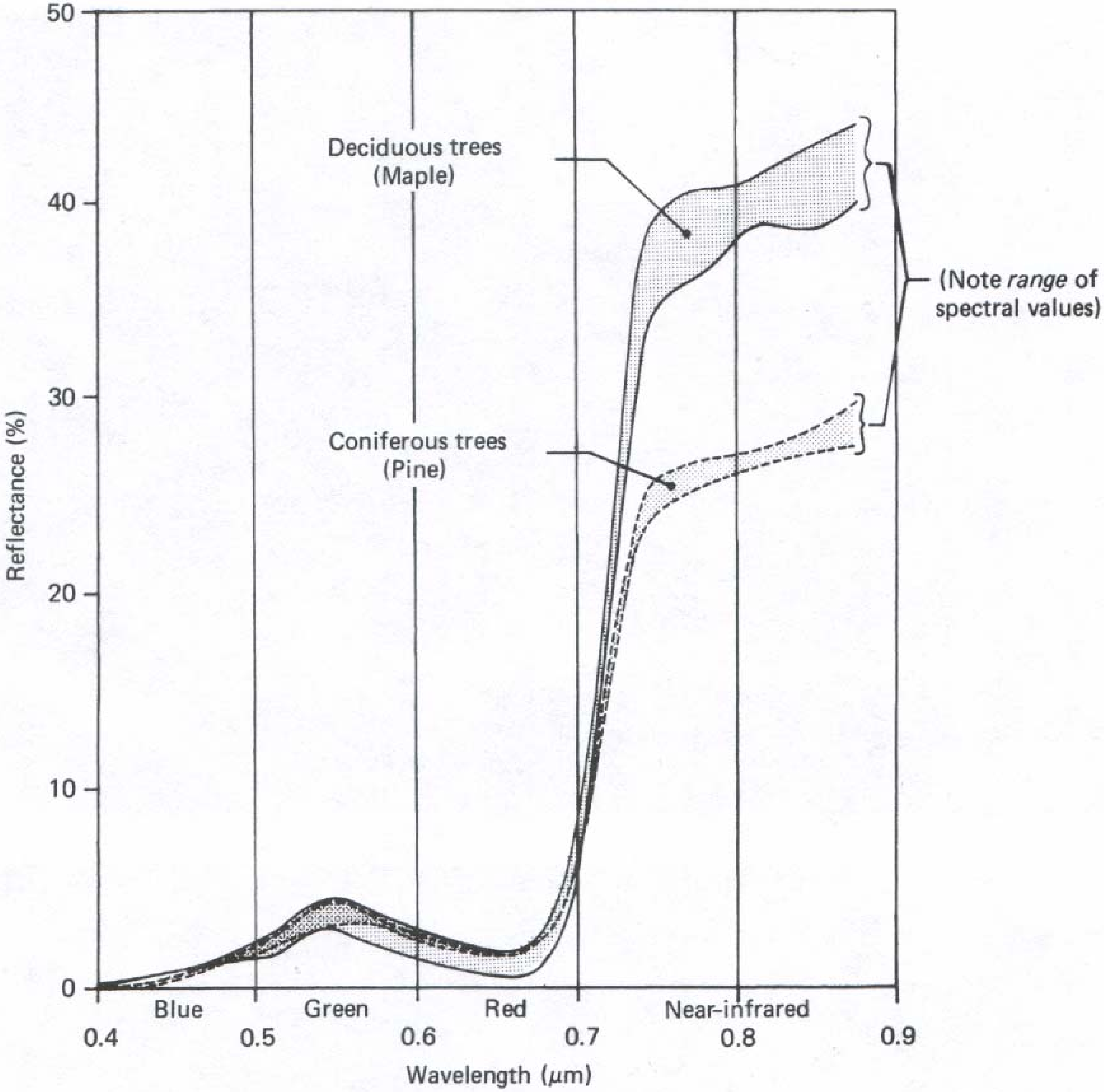



**Figure 1.8** Generalized spectral reflectance envelopes for deciduous (broad-leaved) and coniferous (needle-bearing) trees. (Each tree type has a range of spectral reflectance values at any wavelength.) (Adapted from Kalensky and Wilson, 1975.)

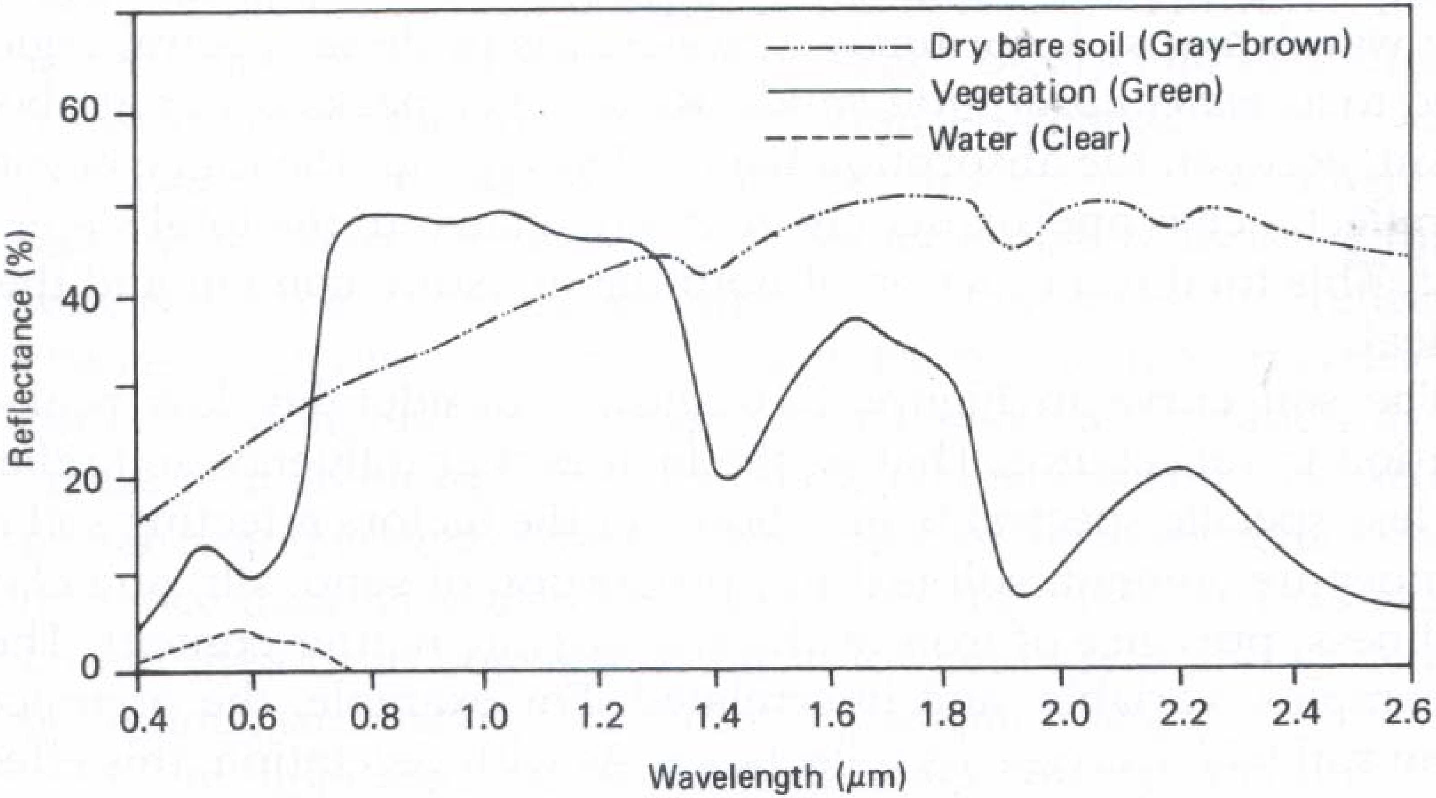



**Figure 1.10** Typical spectral reflectance curves for vegetation, soil, and water. (Adapted from Swain and Davis, 1978.)

# Aplicación a exploración de rocas y minerales

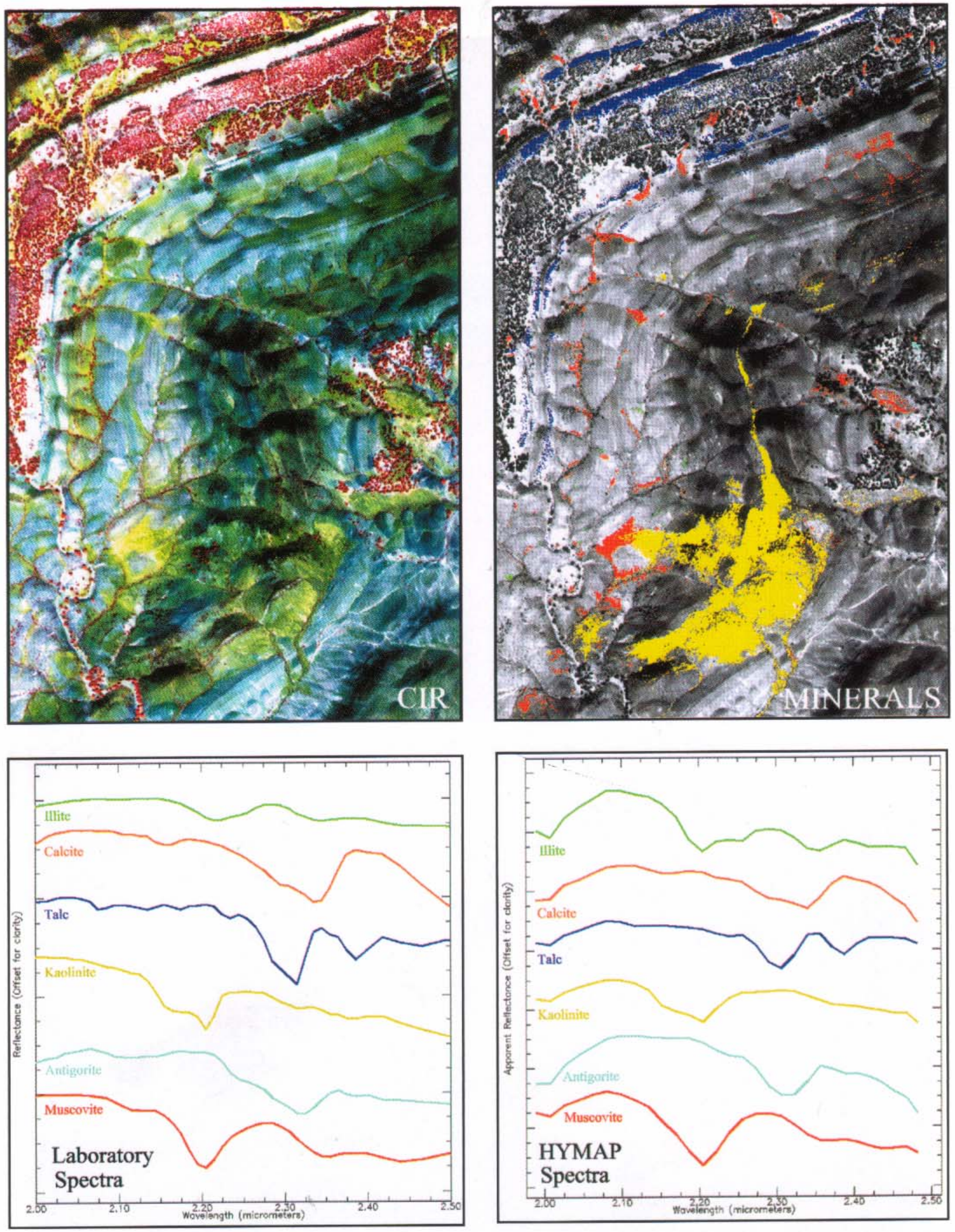



**Plate 16** HyMap hyperspectral scanner data and spectral reflectance curves: (*a*) color IR composite of three hyperspectral bands; (*b*) location of six minerals displayed on a grayscale image; (*c*) laboratory spectral reflectance curves of selected minerals; (*d*) spectral reflectance curves of selected minerals as determined from hyperspectral data. Scale 1:40,000. (Courtesy American Society for Photogrammetry and Remote Sensing, Integrated Spectronics Pty Ltd., and Analytical Imaging and Geophysics.) (For major discussion, see Section 5.14.)

## Aplicación de datos de interferometría radar

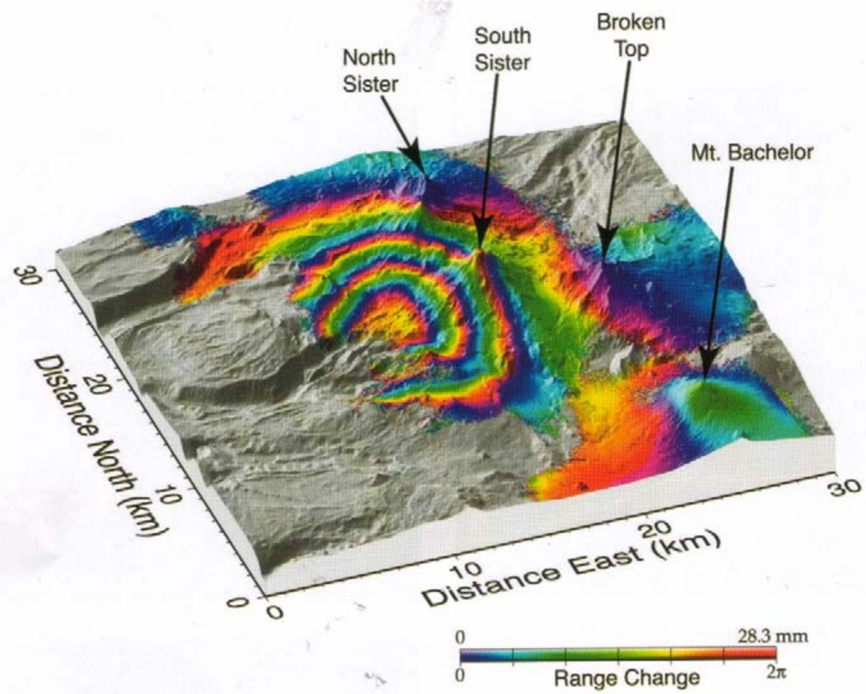



**Plate 36** Radar interferogram, South Sister volcano, central Oregon Cascade Range, showing ground uplift caused by magma accumulation at depth. (Interferogram by C. Wicks, USGS.) (For major discussion, see Section 8.9.)

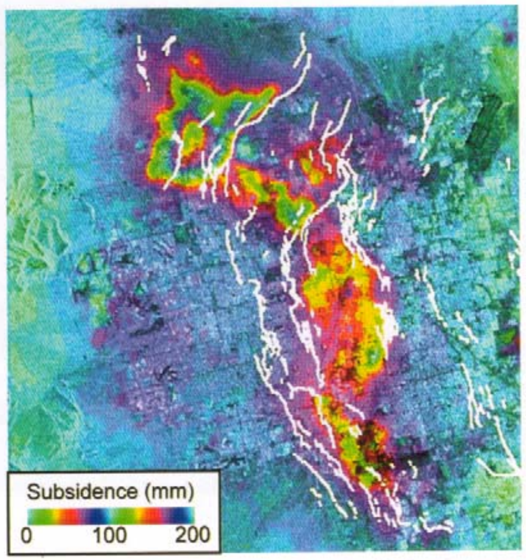



**Plate 37** Radar interferogram showing subsidence in Las Vegas, NV, 1992–1997. White lines indicate location of surface faults. Scale 1:420,000. (Courtesy Stanford University Radar Interferometry Group.) (For major discussion, see Section 8.9.)

# Correcciones atmosféricas

$$L_{tot} = \frac{\rho E T}{\pi} + L_p \qquad (1.9)$$

*where*

$L_{tot}$ = total spectral radiance measured by sensor
$\rho$ = reflectance of object
$E$ = irradiance on object, incoming energy
$T$ = transmission of atmosphere
$L_p$ = path radiance, from the atmosphere and not from the object

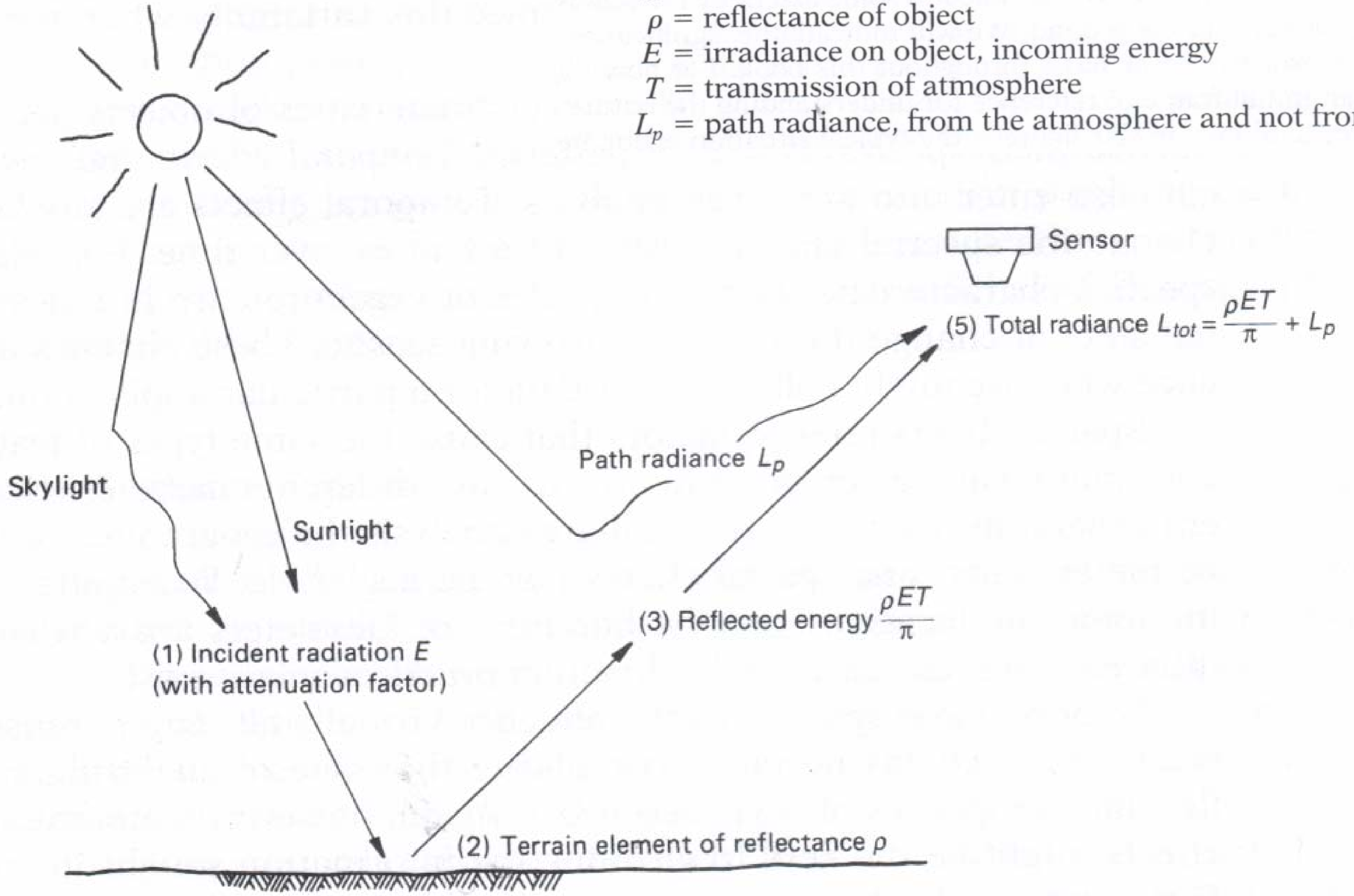



**Figure 1.11** Atmospheric effects influencing the measurement of reflected solar energy. Attenuated sunlight and skylight ($E$) is reflected from a terrain element having reflectance $\rho$. The attenuated radiance reflected from the terrain element ($\rho ET/\pi$) combines with the path radiance ($L_p$) to form the total radiance ($L_{tot}$) recorded by the sensor.

# 2. Adquisición de datos

# Data acquisition

**EMR is reflected by, or emitted from, the Earth's surface**

**Sensors mounted on satellites collect this data**

**Two main types of orbit:**

1. Low Earth orbit (near-polar orbit)

2. Geostationary (equatorial orbit)

**Choice of orbit influences spatial coverage and repeat interval**

# Low-Earth orbits

~700-800 km altitude

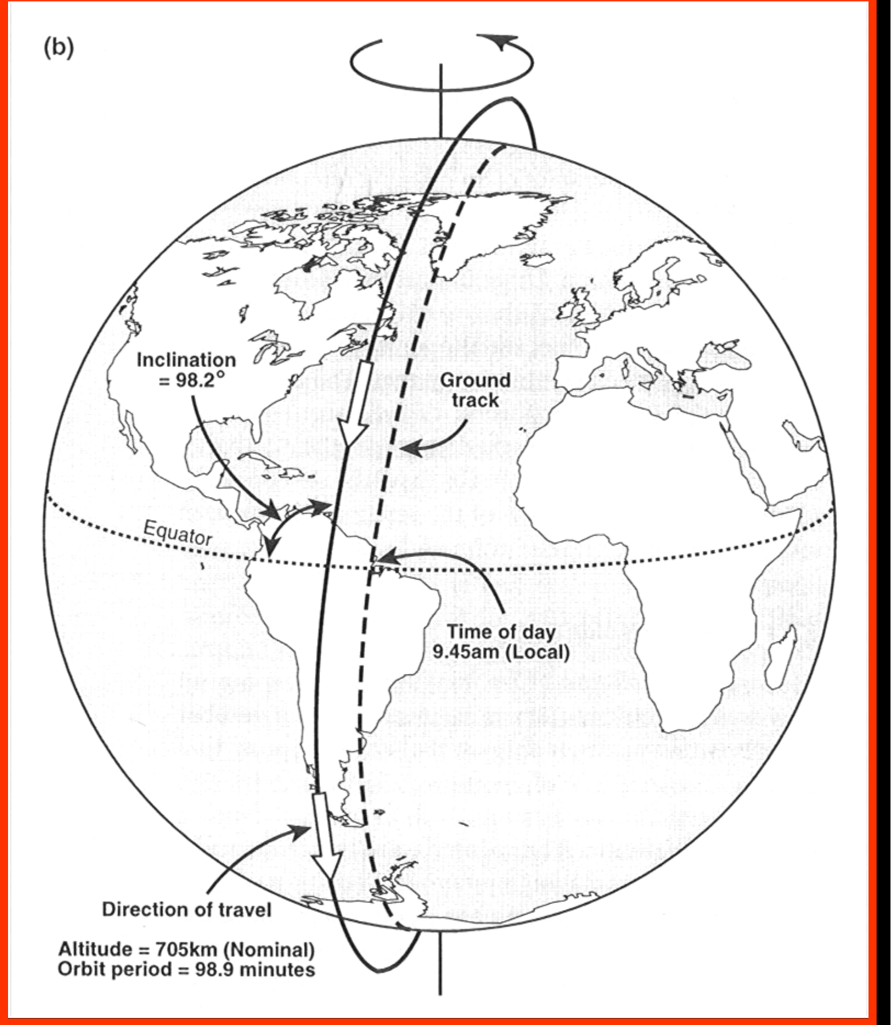
Near-polar, near-circular orbit

Satellite orbit is fixed in space and Earth rotates beneath it

By inclining the orbit at 98.7$^{o}$ the satellites are sun-synchronous (same illumination conditions)

Cross the equator (N-S) at ~10.30am local time

~90 minutes per orbit, ~15 orbits per day



# Geostationary orbits

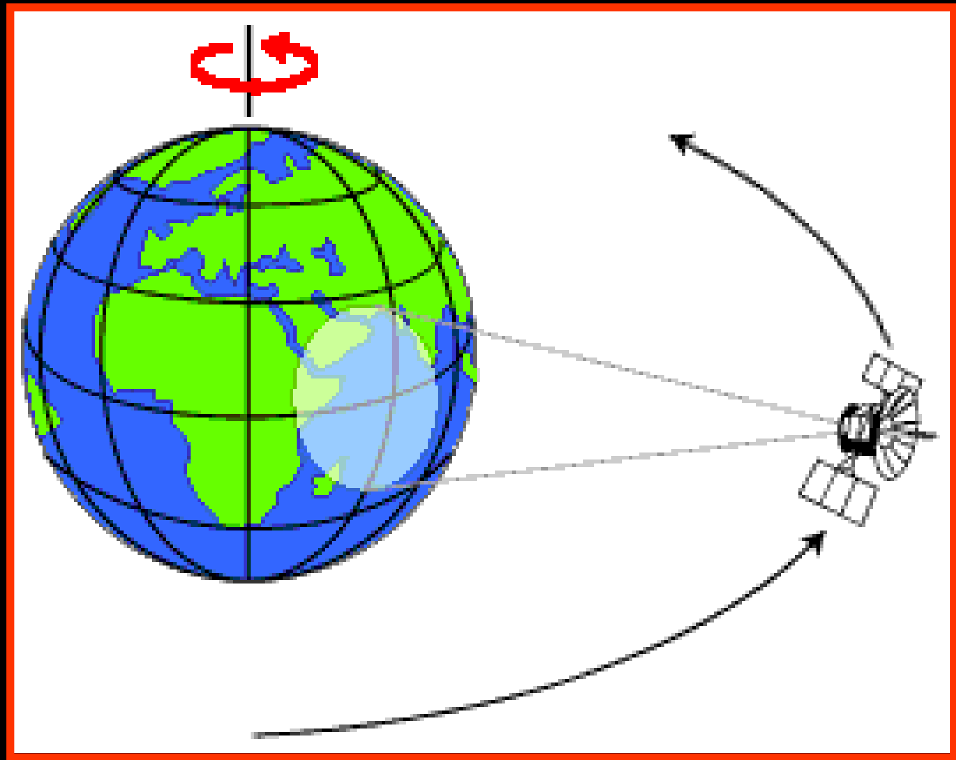
35 770 km altitude

24 hours period of orbit; thus the satellite ‘floats’ above a single point on the Equator

Global coverage with several geostationary satellites in orbits

Good for repetitive observations, poor spatial resolution

Large distortions at high latitudes



# Thematic Mapper (TM)

| Band | Spectral resolution (μm) | Application |
|---|---|---|
| 1 | 0.45-0.52 | Water penetration |
| 2 | 0.52-0.60 | Green vegetation |
| 3 | 0.63-0.69 | Chlorophyll absorption |
| 4 | 0.76-0.90 | Infrared vegetation reflectance |
| 5 | 1.55-1.75 | Moisture, cloud/snow, rocks |
| 6 | 10.40-12.50 | Temperature, soil moisture |
| 7 | 2.08-2.35 | Geology, hydrothermal alteration |

**Pixel size:** 30x30 m for bands 1-5, 7
120x120 m for band 6

**Temporal resolution:** 16 days

**Radiometric resolution:** 8-bit (0-255)

**Image size:** 185x185 km

# Image data

Our basic data set is just an array of numbers, on a CD-ROM or tape

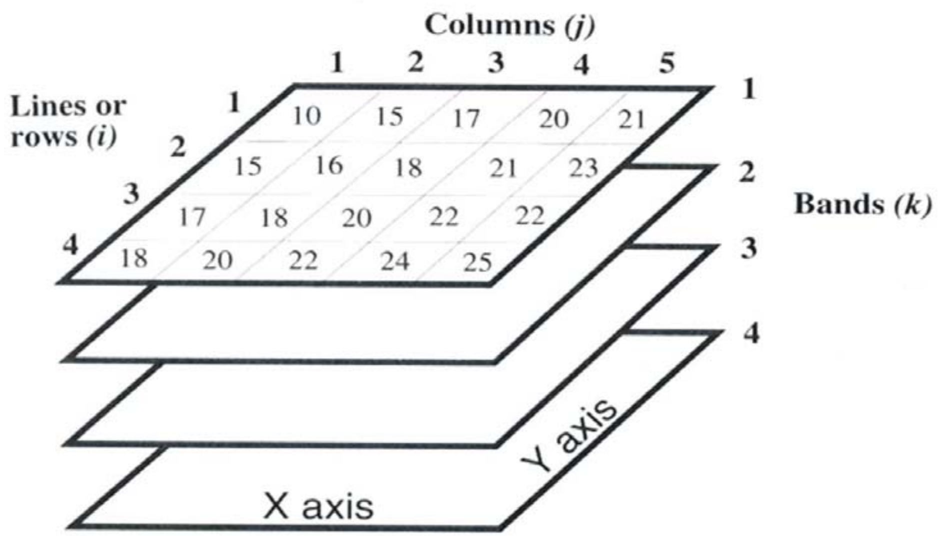
There are many ways to process this data set to highlight different information contained in the data

The PIXEL is our basic unit and corresponds to an area of the ground. The image is composed of a number of pixels with a DN representing the amount of EMR reflected and/or emitted from the corresponding area of the Earth's surface in EACH wavelength band

**Band 1**

(0,45 - 0,52 µm)

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 61 | 65 | 63 | 61 | 63 | 60 | 60 | 63 | 58 | 58 | 59 | 59 | 62 | 60 | 55 |
| 64 | 64 | 64 | 64 | 63 | 63 | 63 | 62 | 61 | 58 | 59 | 62 | 60 | 57 | 59 |
| 61 | 60 | 60 | 60 | 62 | 62 | 62 | 60 | 62 | 60 | 63 | 62 | 58 | 59 | 59 |
| 63 | 61 | 64 | 64 | 62 | 62 | 62 | 61 | 61 | 59 | 62 | 61 | 57 | 60 | 59 |
| 65 | 62 | 65 | 61 | 60 | 62 | 62 | 63 | 63 | 61 | 60 | 63 | 58 | 59 | 58 |
| 63 | 64 | 66 | 62 | 61 | 62 | 62 | 61 | 64 | 62 | 60 | 64 | 59 | 61 | 60 |
| 64 | 65 | 62 | 64 | 62 | 62 | 62 | 62 | 62 | 60 | 62 | 63 | 63 | 61 | 70 |
| 64 | 64 | 65 | 62 | 61 | 59 | 59 | 61 | 59 | 60 | 59 | 62 | 64 | 68 | 77 |
| 61 | 62 | 65 | 66 | 60 | 59 | 61 | 61 | 60 | 59 | 64 | 70 | 77 | 76 | 79 |
| 66 | 66 | 67 | 70 | 65 | 60 | 62 | 63 | 67 | 67 | 72 | 77 | 76 | 78 | 80 |
| 64 | 68 | 65 | 69 | 63 | 63 | 73 | 77 | 78 | 77 | 76 | 74 | 74 | 75 | 76 |
| 68 | 69 | 69 | 70 | 67 | 66 | 76 | 77 | 77 | 76 | 75 | 75 | 77 | 77 | 79 |
| 82 | 83 | 83 | 69 | 66 | 65 | 74 | 75 | 77 | 77 | 76 | 77 | 75 | 77 | 78 |
| 84 | 86 | 84 | 86 | 69 | 67 | 70 | 76 | 79 | 76 | 76 | 76 | 74 | 74 | 81 |
| 85 | 87 | 83 | 83 | 78 | 66 | 66 | 68 | 75 | 78 | 75 | 77 | 77 | 77 | 76 |



# Adquisición y almacenamiento de datos

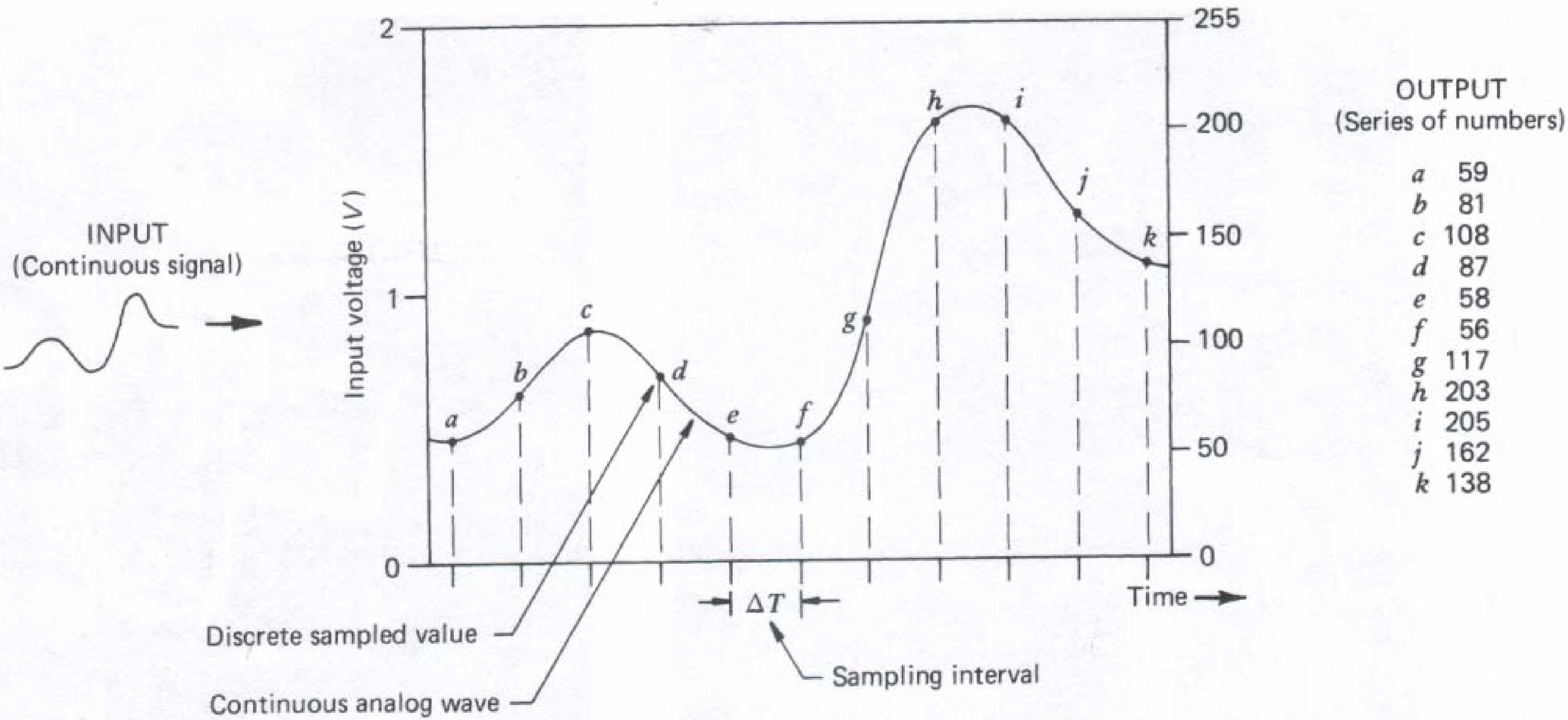
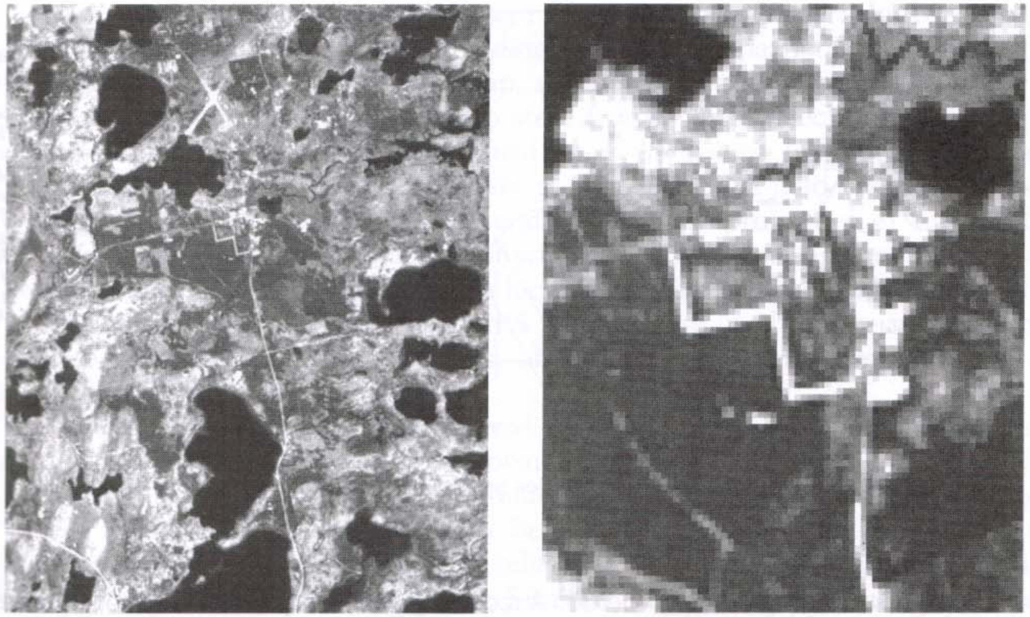
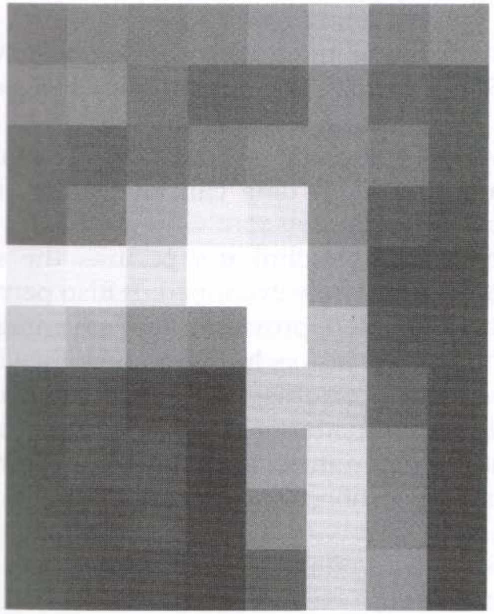



**Figure 1.13** Analog-to-digital conversion process.

# Almacenamiento de datos digitales



(a) (b)



(c)

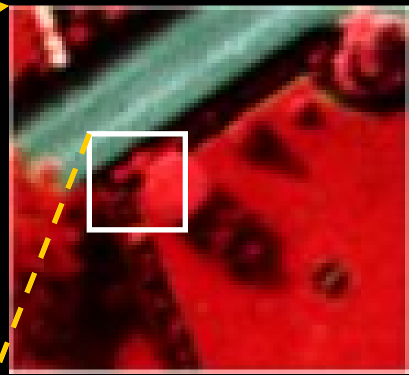
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 34 | 36 | 35 | 36 | 39 | 46 | 35 | 37 |
| 36 | 38 | 34 | 31 | 32 | 38 | 32 | 30 |
| 32 | 31 | 33 | 35 | 37 | 37 | 35 | 30 |
| 32 | 35 | 44 | 57 | 56 | 38 | 30 | 28 |
| 57 | 58 | 55 | 60 | 65 | 42 | 26 | 26 |
| 50 | 47 | 39 | 37 | 60 | 48 | 28 | 27 |
| 26 | 27 | 25 | 23 | 51 | 51 | 32 | 26 |
| 26 | 28 | 28 | 22 | 43 | 54 | 36 | 25 |
| 27 | 26 | 28 | 23 | 37 | 54 | 37 | 24 |
| 28 | 26 | 26 | 24 | 31 | 53 | 40 | 25 |

(d)

**Figure 1.12** Basic character of digital image data. (*a*) Original 500 row × 400 column digital image. Scale 1:200,000. (*b*) Enlargement showing 100 row × 80 column area of pixels near center of (*a*). Scale 1:40,000. (*c*) 10 row × 8 column enlargement. Scale 1:4000. (*d*) Digital numbers corresponding to the radiance of each pixel shown in (*c*).

Image columns

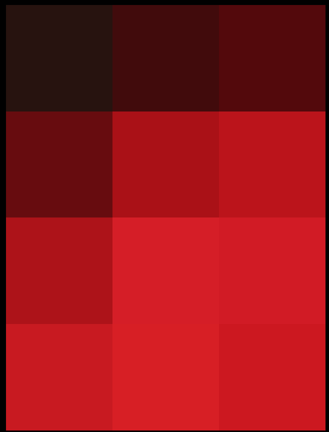
Zoom 4x



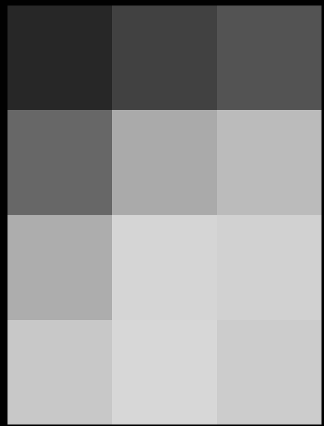
Zoom 4x again

Infrared colour aerial photo from Skåne, Sweden

NIR as Red



NIR as B/W



Intensities as decimal numbers

| | | |
|---|---|---|
| 39 | 65 | 83 |
| 103 | 170 | 187 |
| 173 | 213 | 209 |
| 200 | 215 | 204 |

Intensities as binary numbers stored in the computer

| | | |
|---|---|---|
| 00100111 | 01000001 | 01010011 |
| 01100111 | 10101010 | 10111011 |
| 10101101 | 11010101 | 11010001 |
| 11001000 | 11010111 | 11001100 |

| Digital intensity values Ranges | Data storage size per measurement: |
| --- | --- |
| 0 – 15 | 4 bit |
| 0 – 63 | 6 bit |
| **0 – 255** | **8 bit = 1 byte** |
| 0 – 1023 | 10 bit |
| 0 – 65536 | 16 bit |

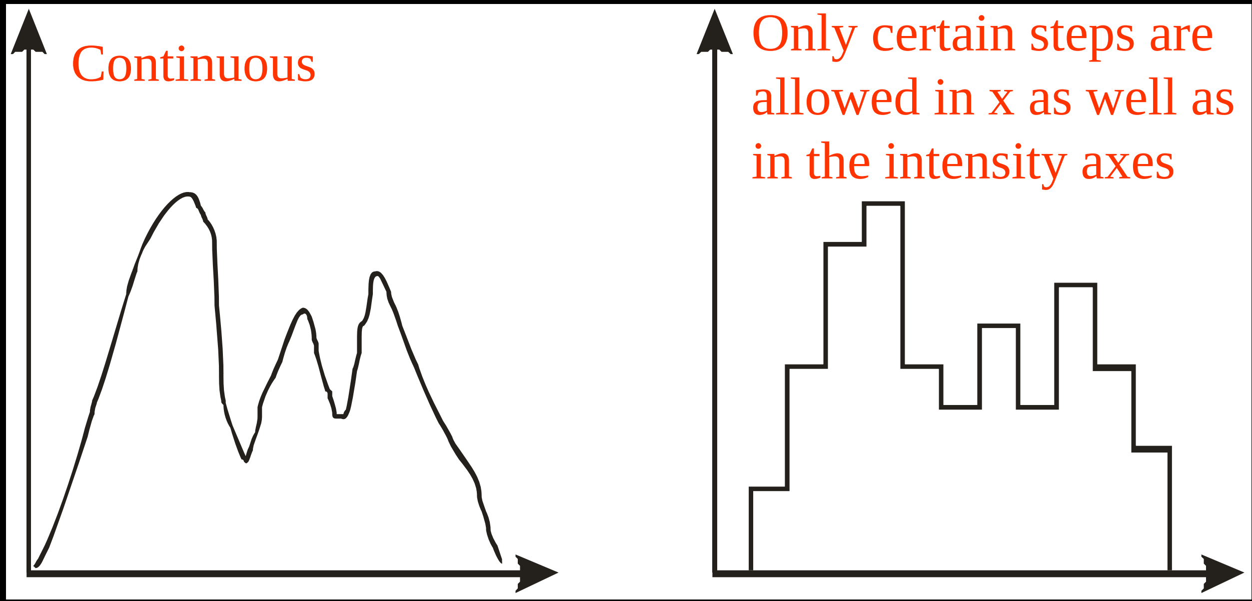
The first 16 (0-15) numbers in decimal and binary format:

| Decimal | Binary | Decimal | Binary |
| --- | --- | --- | --- |
| 0 | 0 | 8 | 1000 |
| 1 | 1 | 9 | 1001 |
| 2 | 10 | 10 | 1010 |
| 3 | 11 | 11 | 1011 |
| 4 | 100 | 12 | 1100 |
| 5 | 101 | 13 | 1101 |
| 6 | 110 | 14 | 1110 |
| 7 | 111 | 15 | 1111 |

Ikonos
Cape Town
South Africa

Intensity variations along a transect

**Intensity (millivolts)** **Intensity (DN)**

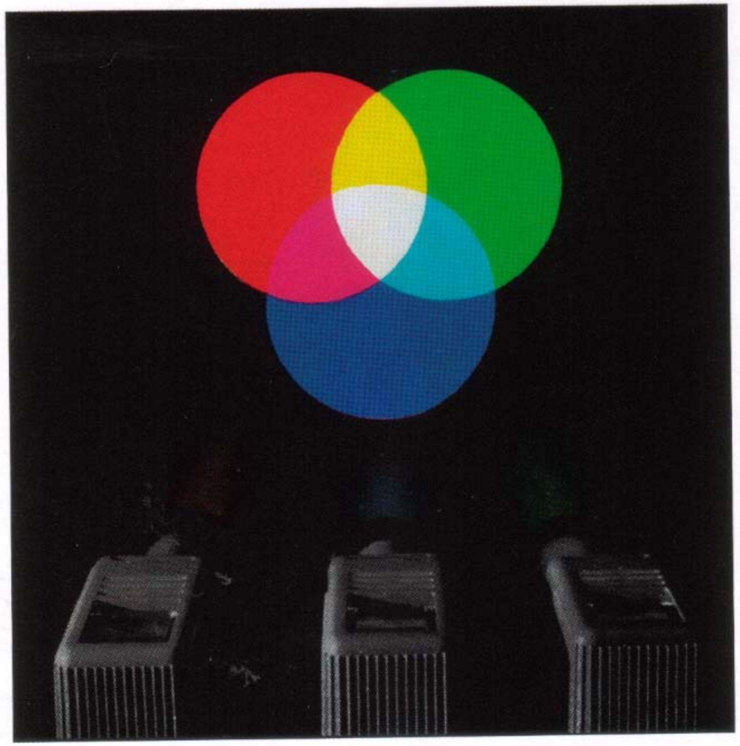



x-direction in image x-direction in image

Analogue image function Digital image function

# 3. Visualización de imágenes

## Combinación de colores: adición y sustracción


(a)

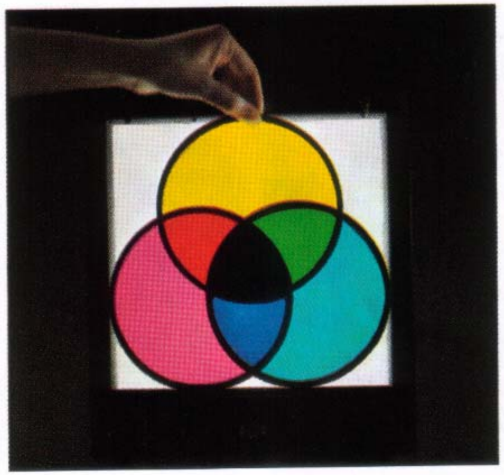
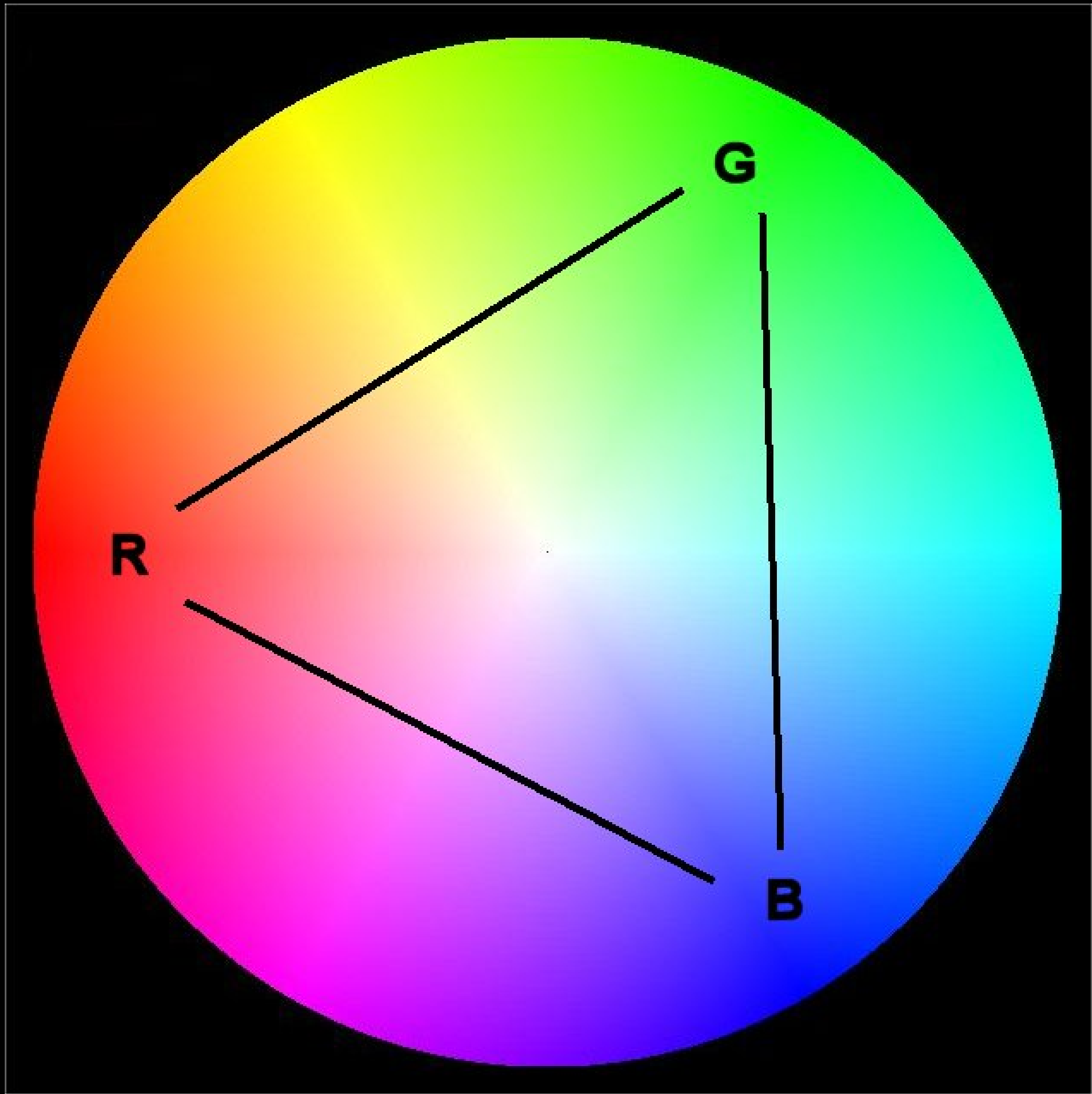
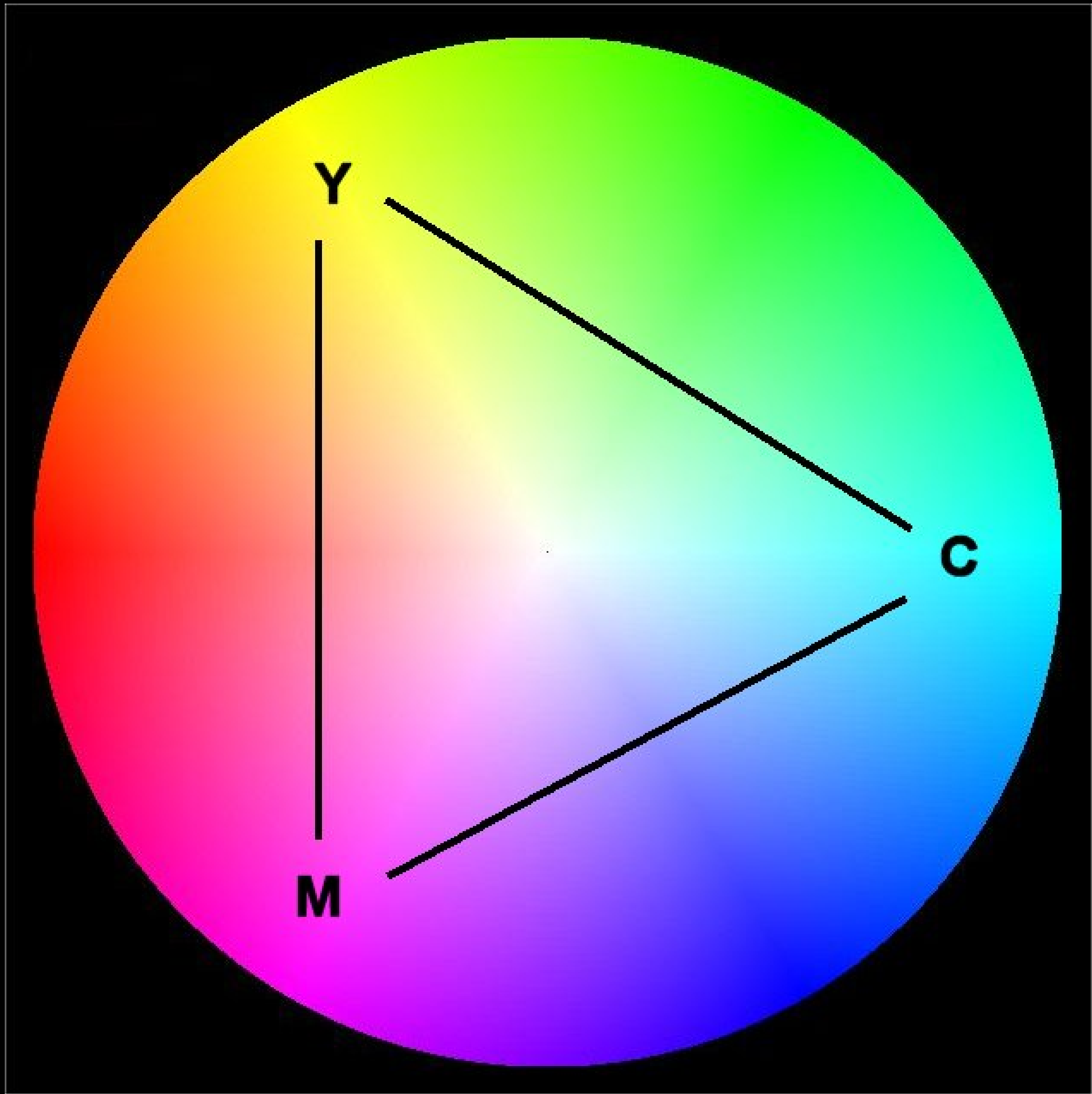
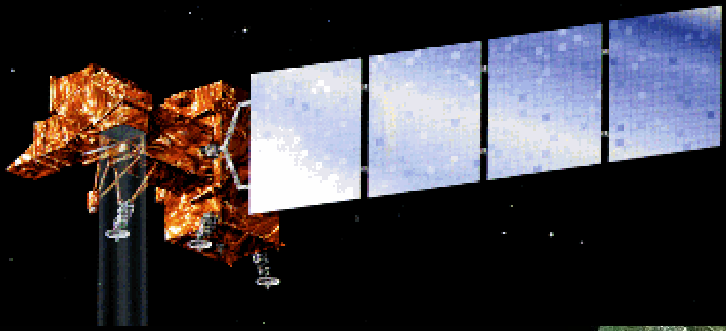

(b)

**Plate 2** Color-mixing processes. (*a*) Color *additive* process—operative when *lights* of different colors are superimposed. (*b*) Color *subtractive* process—operative when *dyes* of different colors are superimposed. (Courtesy Eastman Kodak Company.) (For major discussion, see Section 2.7.)


G
R
B

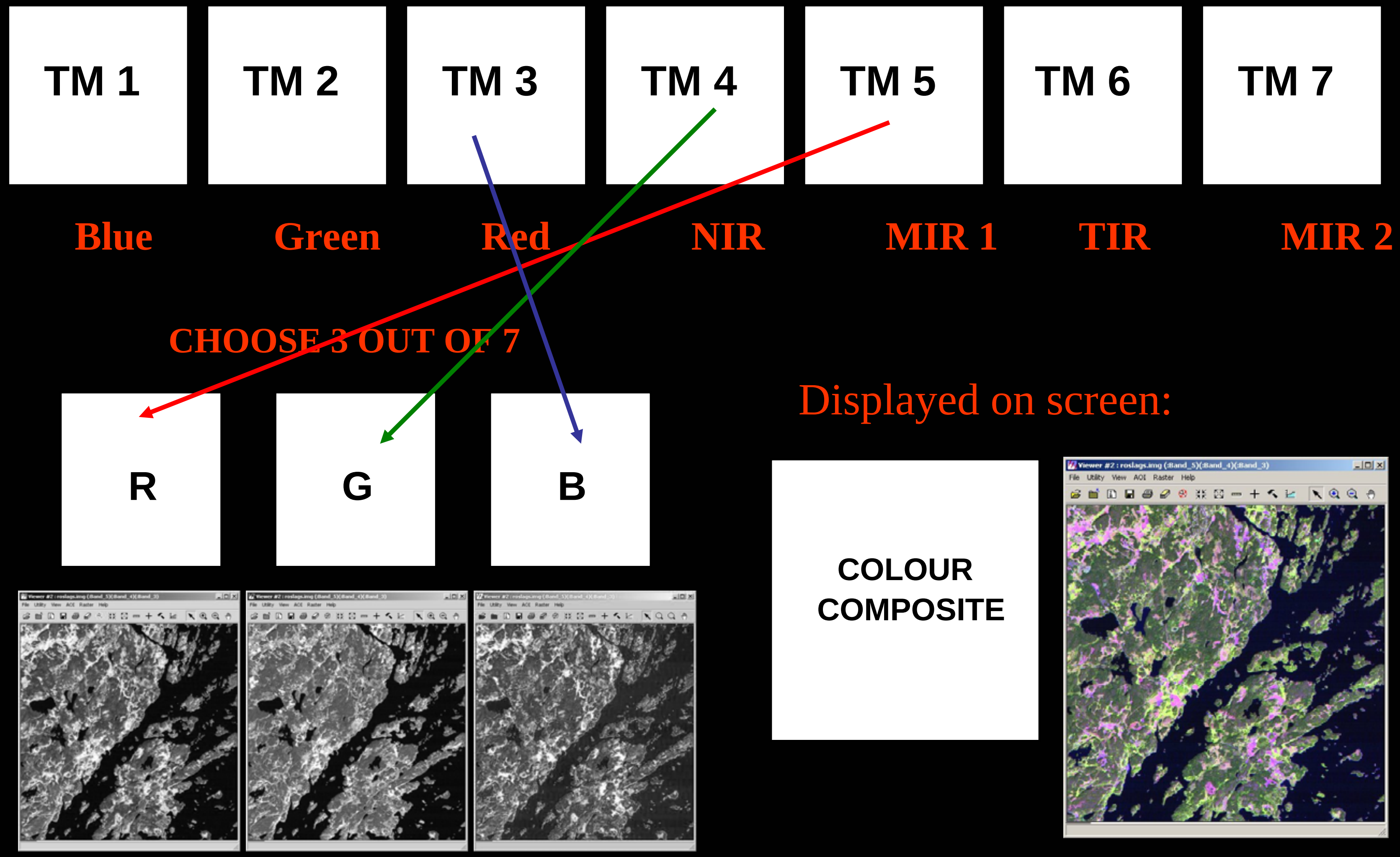

Y
C
M



# Landsat 7, ETM+ instrument

San Francisco
May 14 1999

# LANDSAT THEMATIC MAPPER (TM) IMAGE, 7 SPECTRAL BANDS



# Image analysis

**Purpose:** To extract relevant information from an image

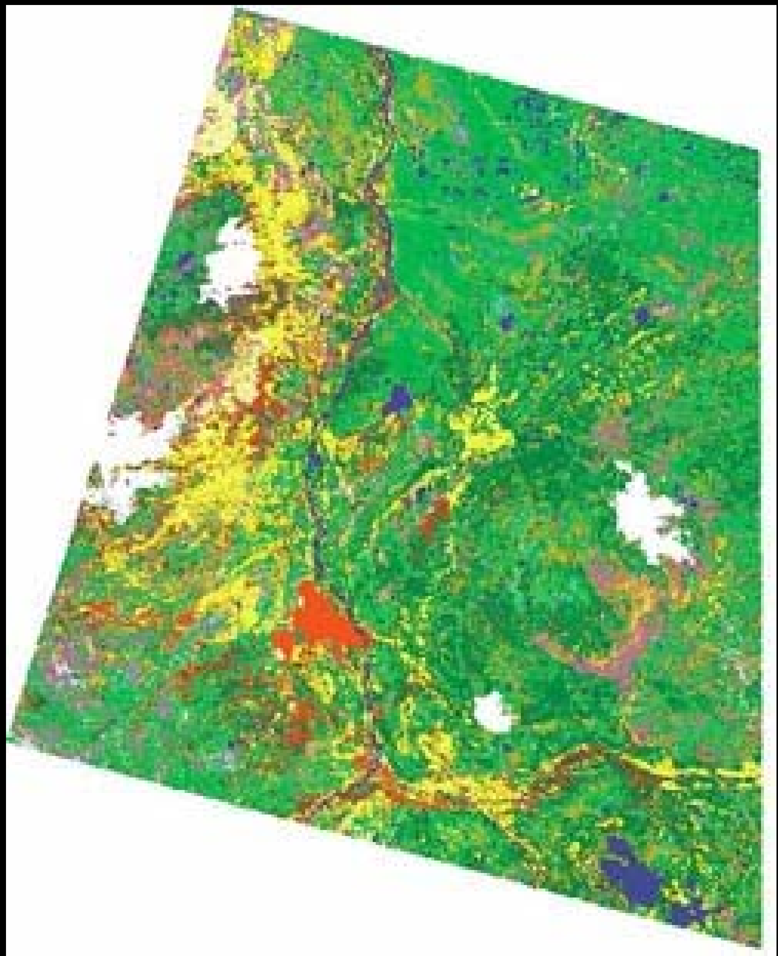
Levels of decisions in image analysis about objects:

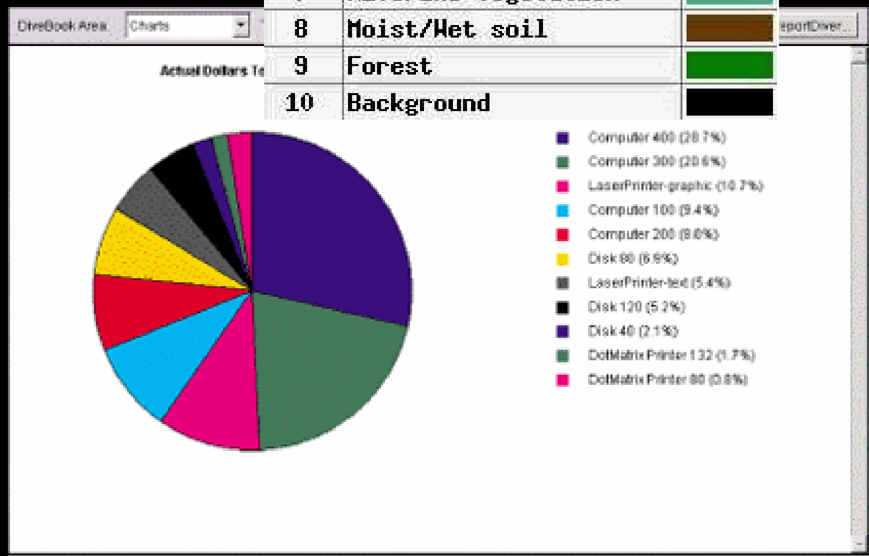
| | |
|---|---|
| Localize | Find something to be investigated. |
| Identify | You know what it is. |
| Classify | Give it a name within your classification scheme. |

# Image classification

**Results:** Maps

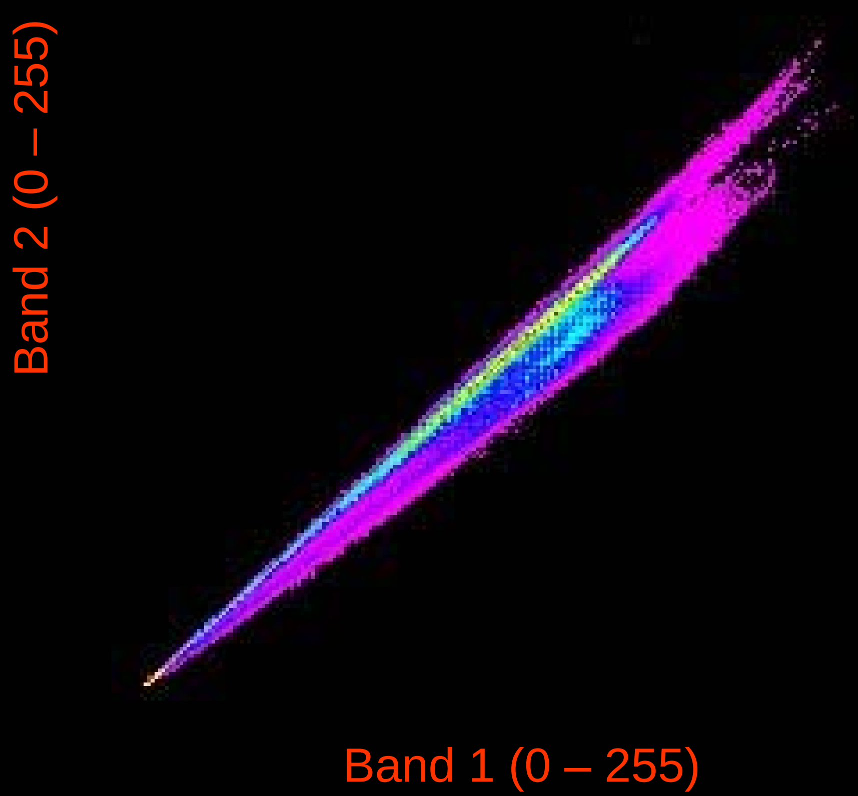
Statistics






| Value | Name | Colour |
|---|---|---|
| 1 | Water | |
| 2 | Bare soil | |
| 3 | Dense Shrubland | |
| 4 | Dense grassland | |
| 5 | Grassland | |
| 6 | Recently flooded | |
| 7 | Riverine vegetation | |
| 8 | Moist/Wet soil | |
| 9 | Forest | |
| 10 | Background | |

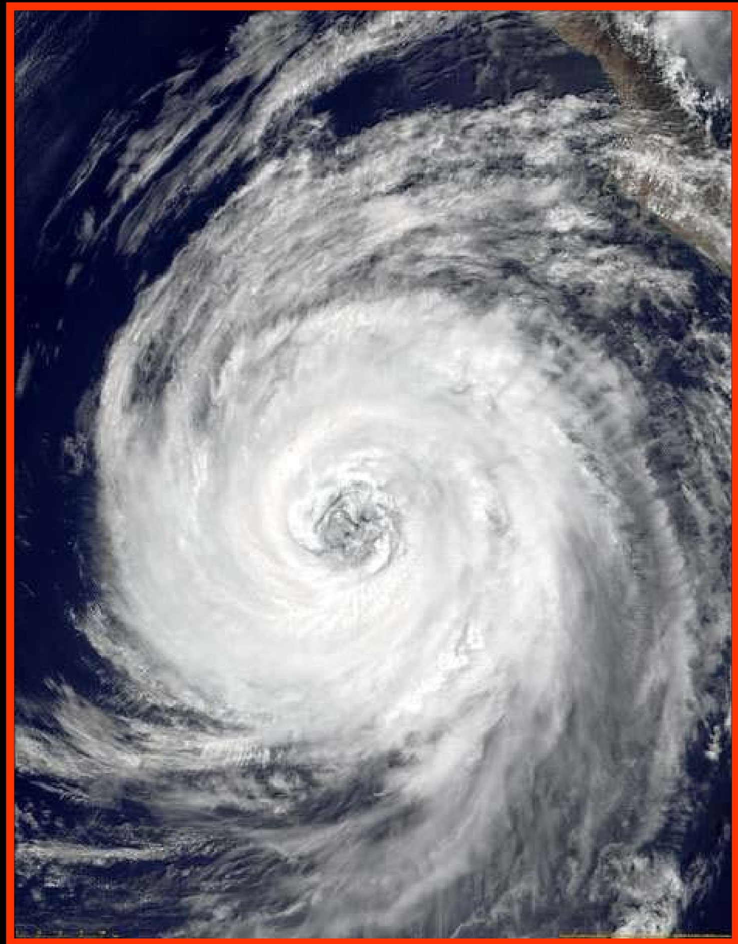
# Scatterplot band 1 vs band 2



# 4. Aplicaciones

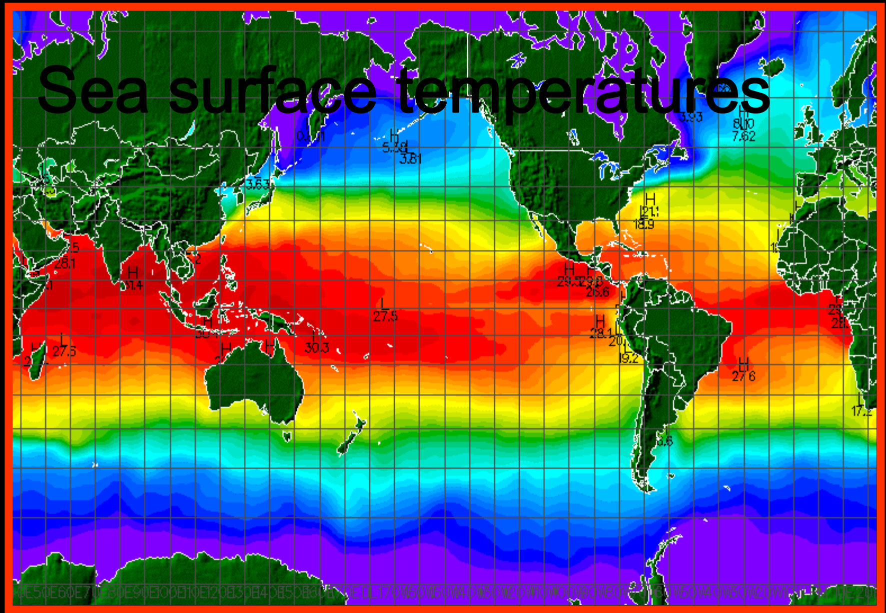
# Environmental remote sensing

**Sensors mounted on Earth-orbiting satellites or aeroplanes record spatial variations in the amount of electromagnetic radiation emitted or reflected by the Earth`s surface at several different wavelengths**

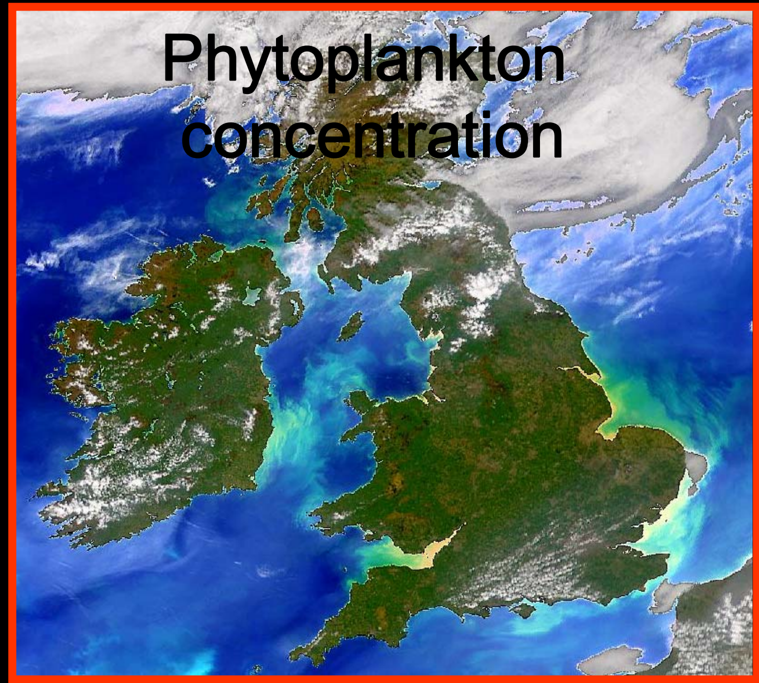


**Applications: Meteorology, oceanography, geology, agriculture, environmental protection, glaciology....**

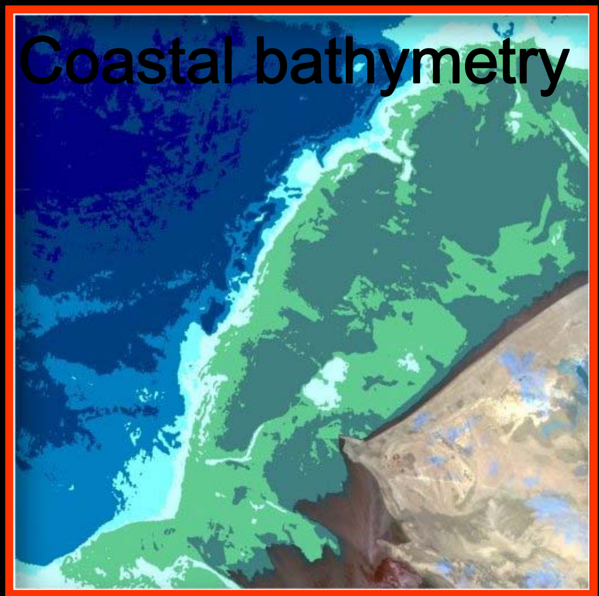
# Oceanography



Sea surface temperatures

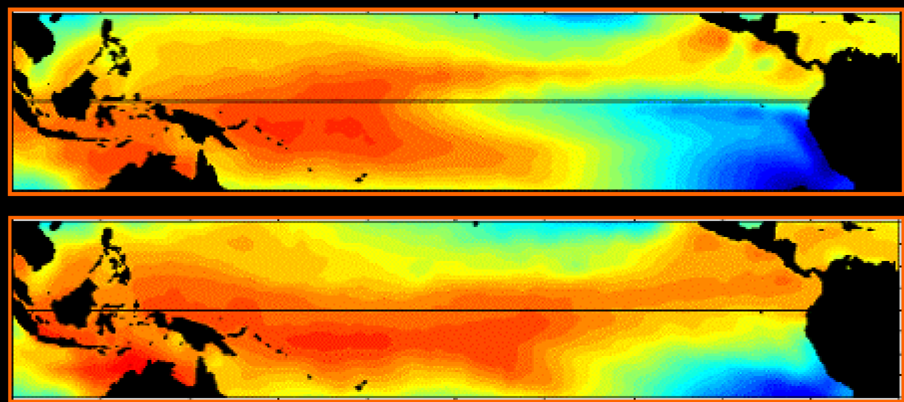


Phytoplankton concentration



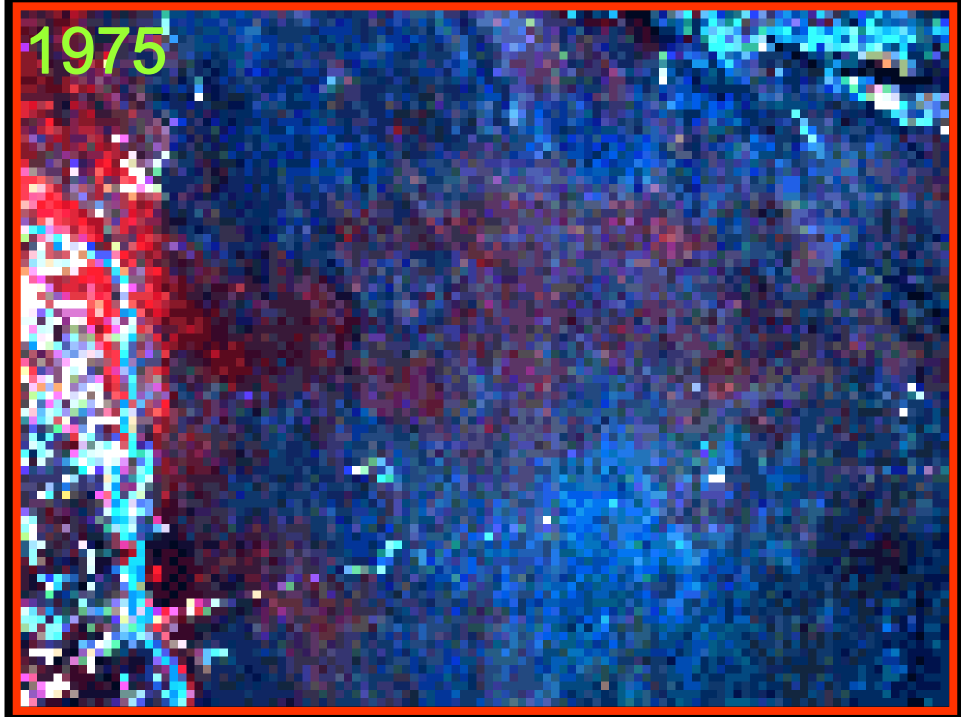
Coastal bathymetry

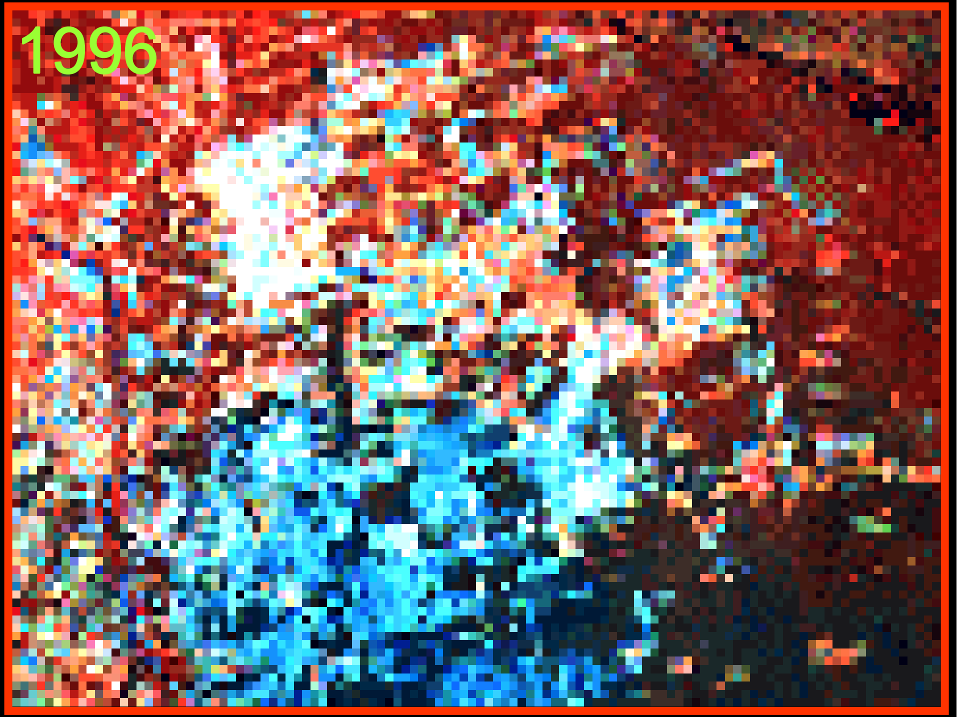
El Nino



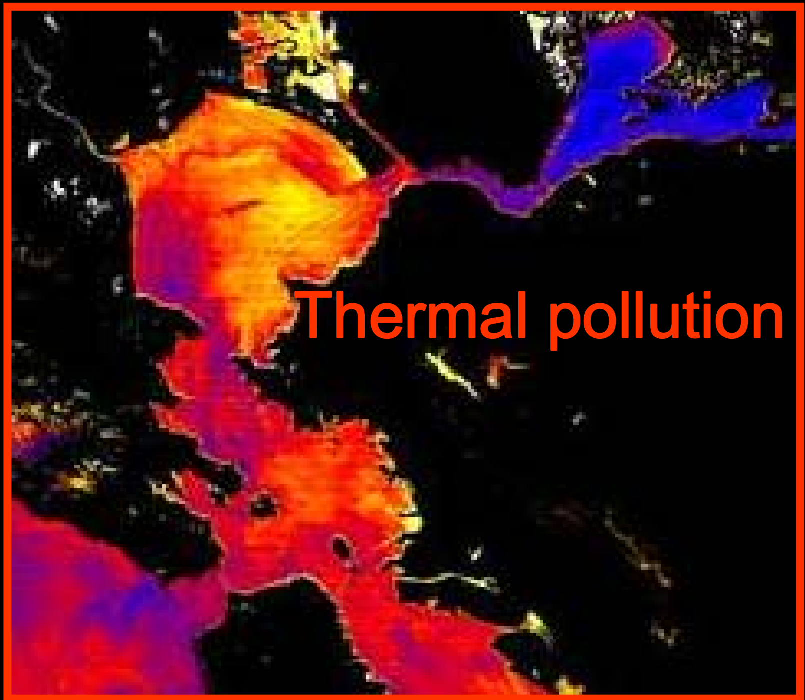
# Tropical deforestation

## Deforestation in Bolivia

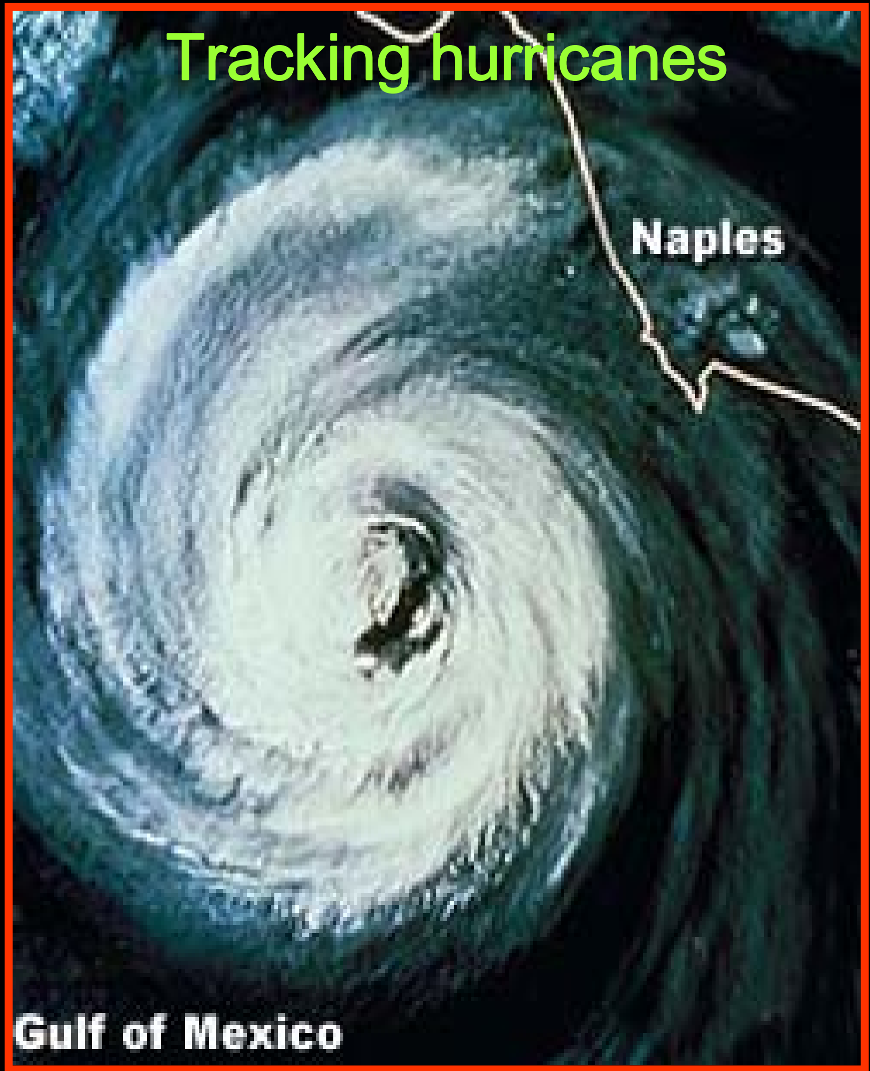


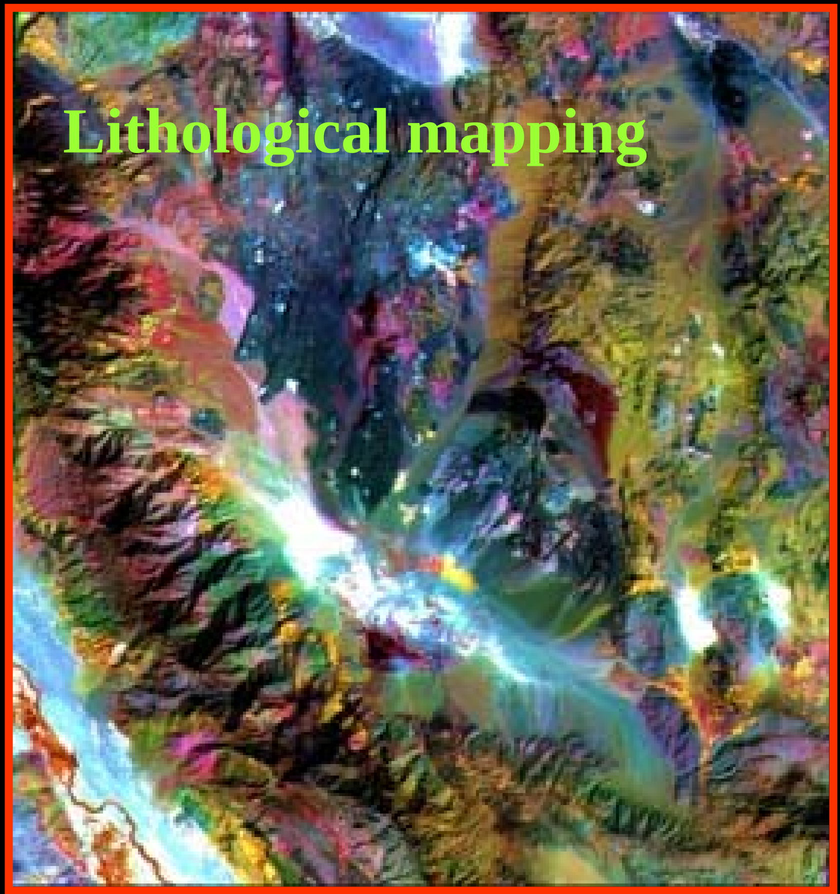
# Monitoring pollution

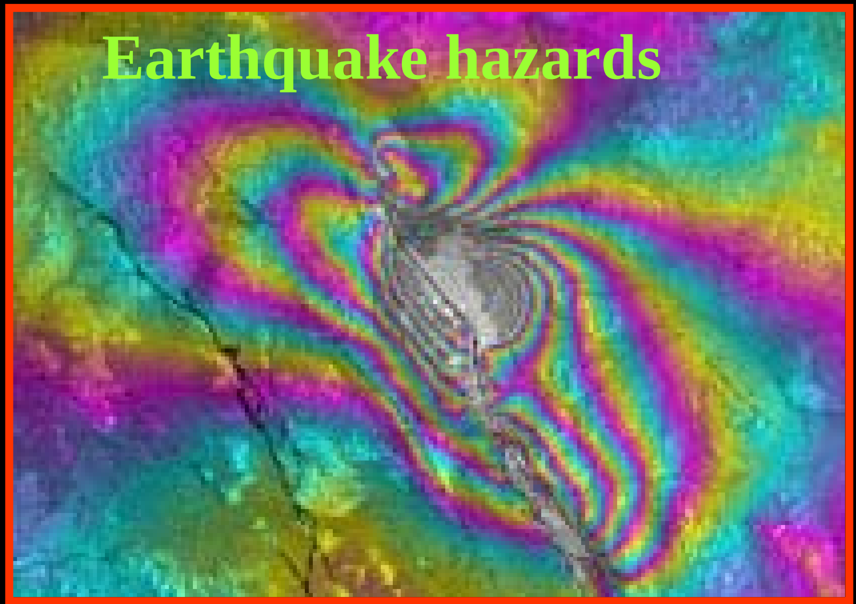




# Meteorology



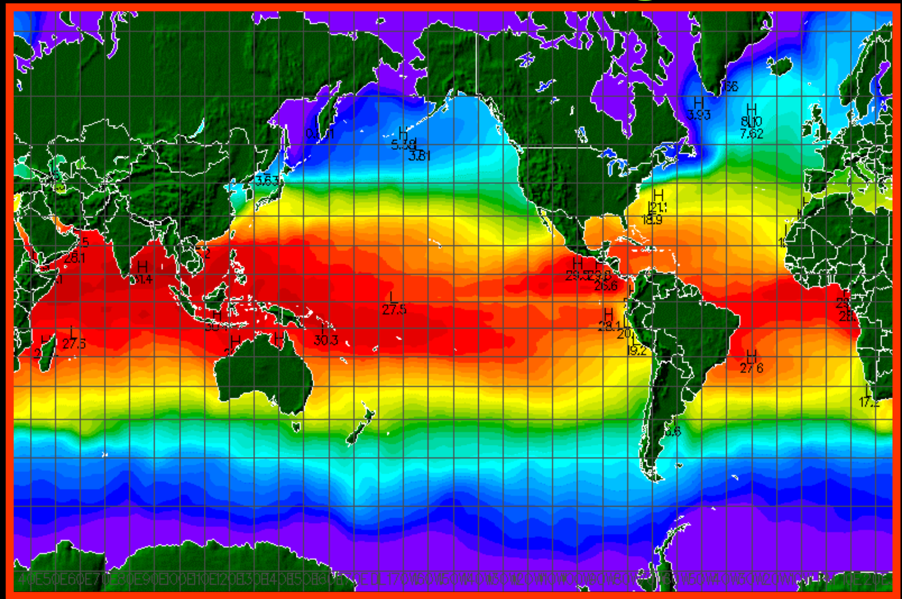

# Geology

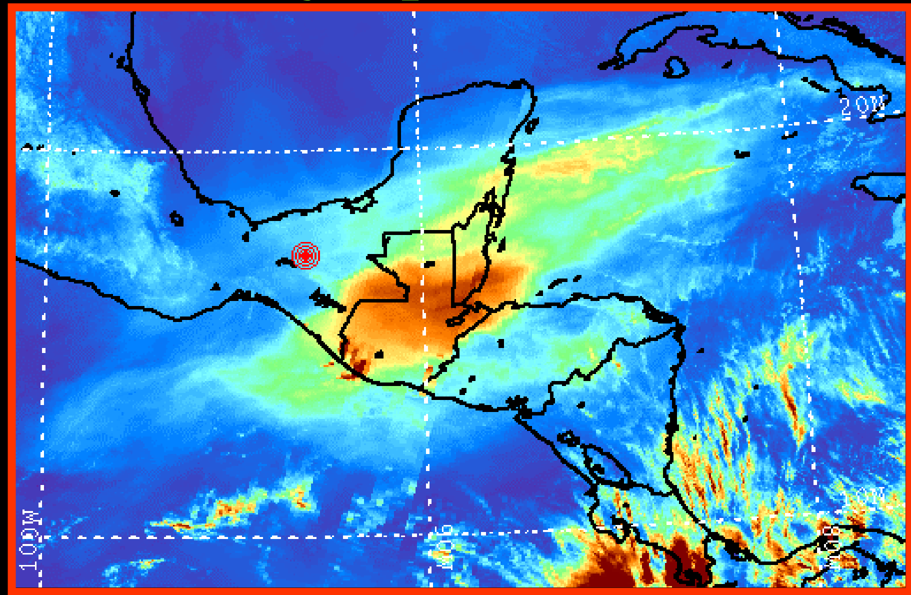



# Advantages of remote sensing

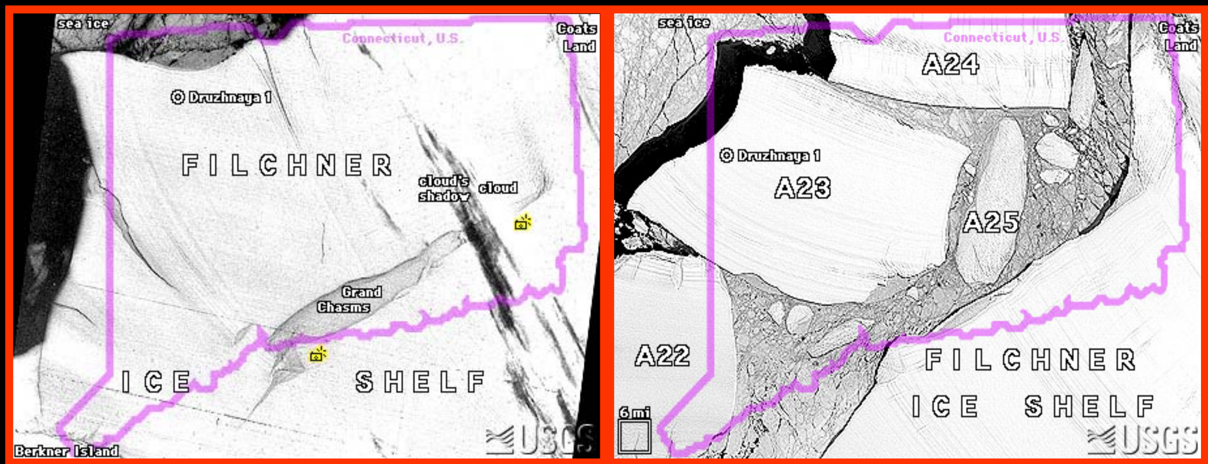
## Global coverage



## Synoptic view




## Repeatability




## ➡ Cost