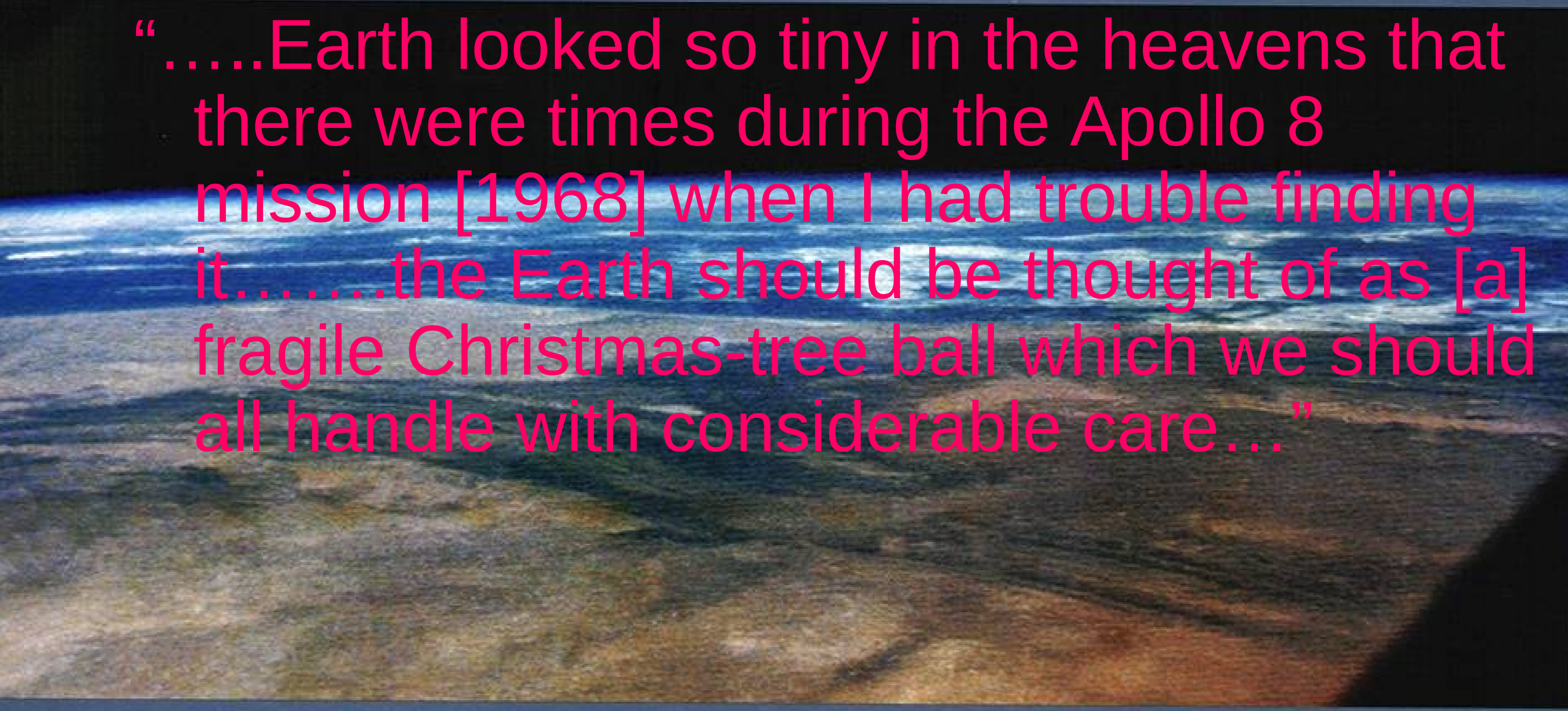
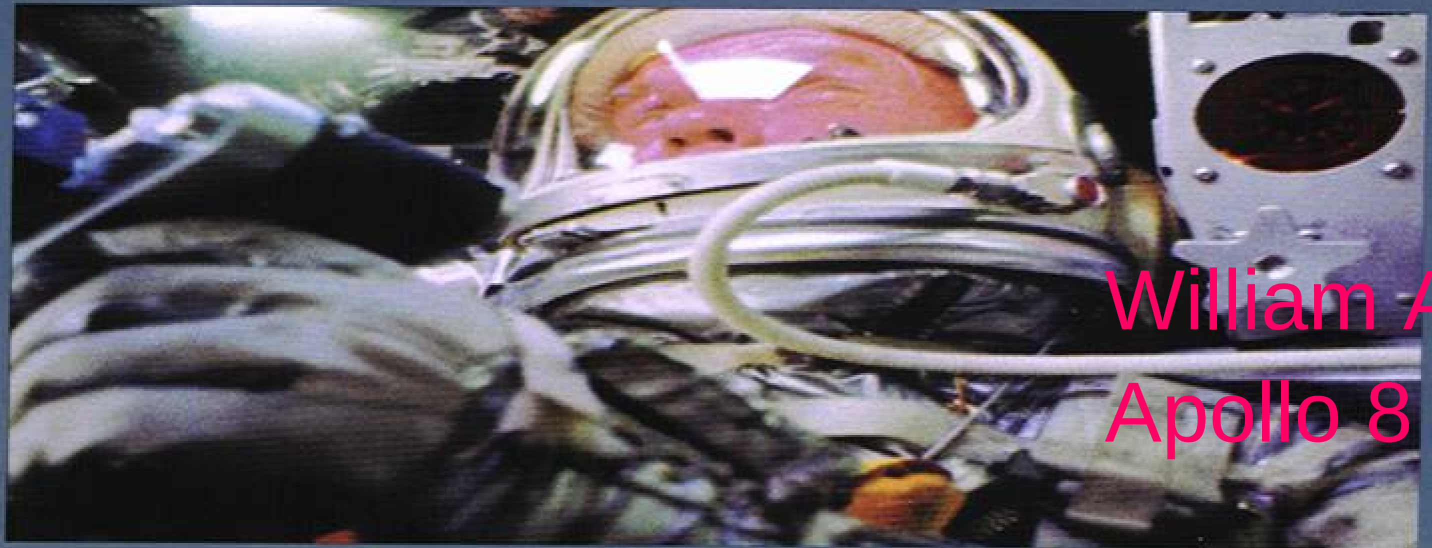
Remote Sensing & GIS

Dr Doreen Boyd

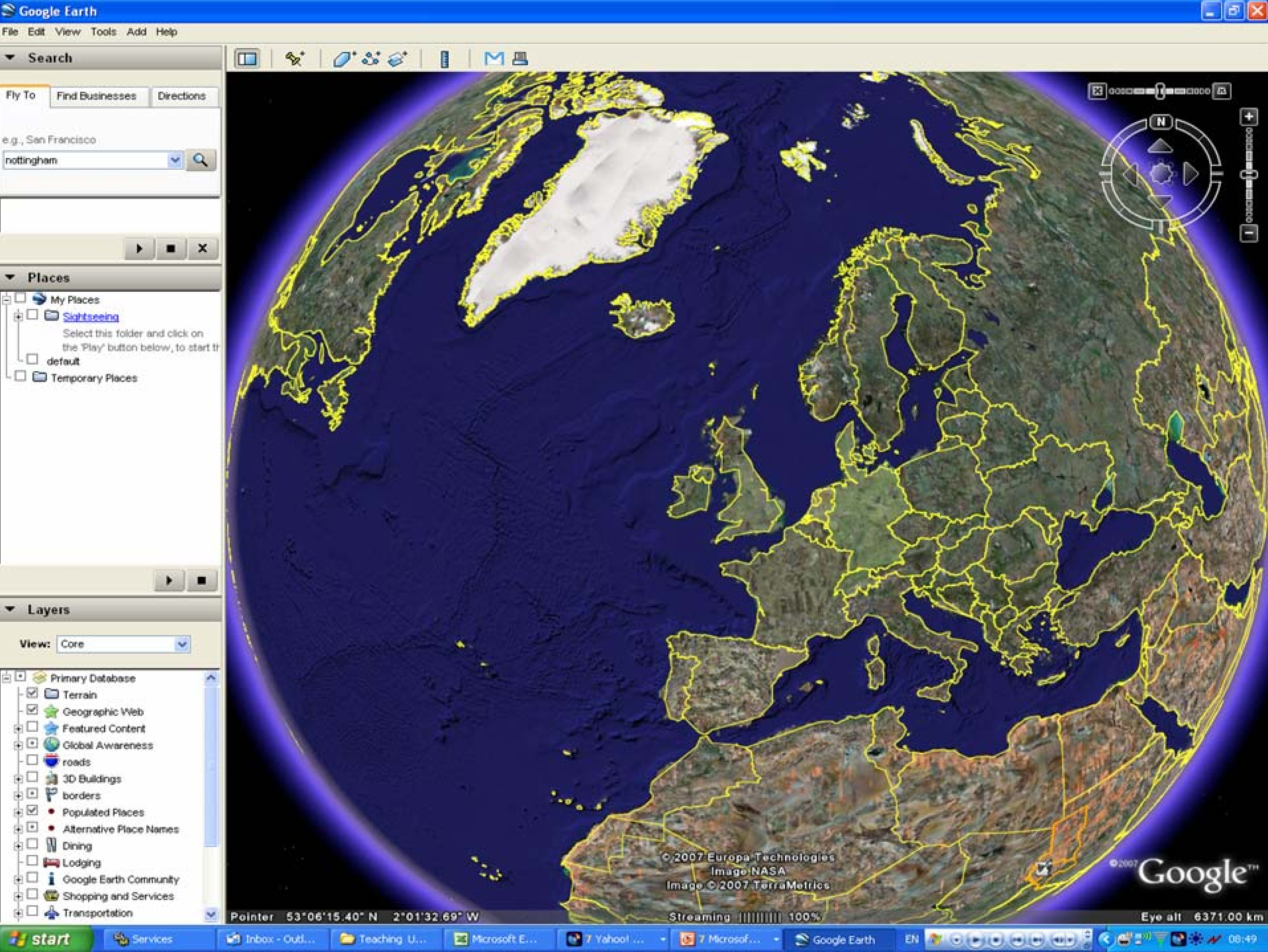
School of Geography
Associate Professor



"…..Earth looked so tiny in the heavens that there were times during the Apollo 8 mission [1968] when I had trouble finding it…….the Earth should be thought of as [a] fragile Christmas-tree ball which we should all handle with considerable care…"

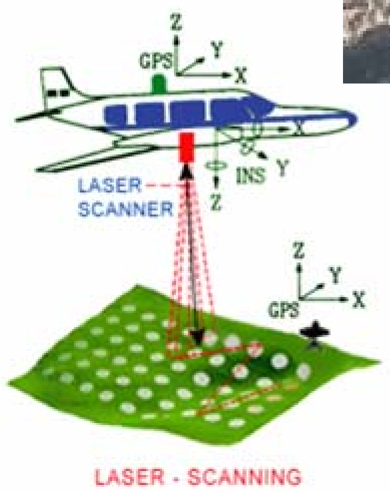


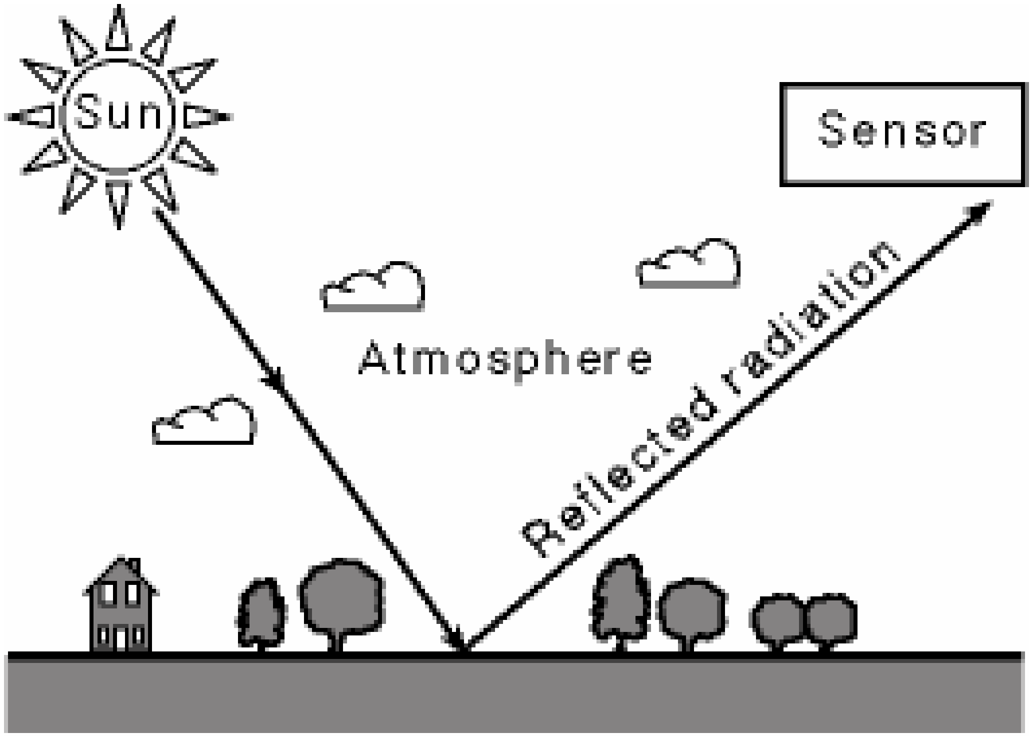
William A. Anders,
Apollo 8 Astronaut

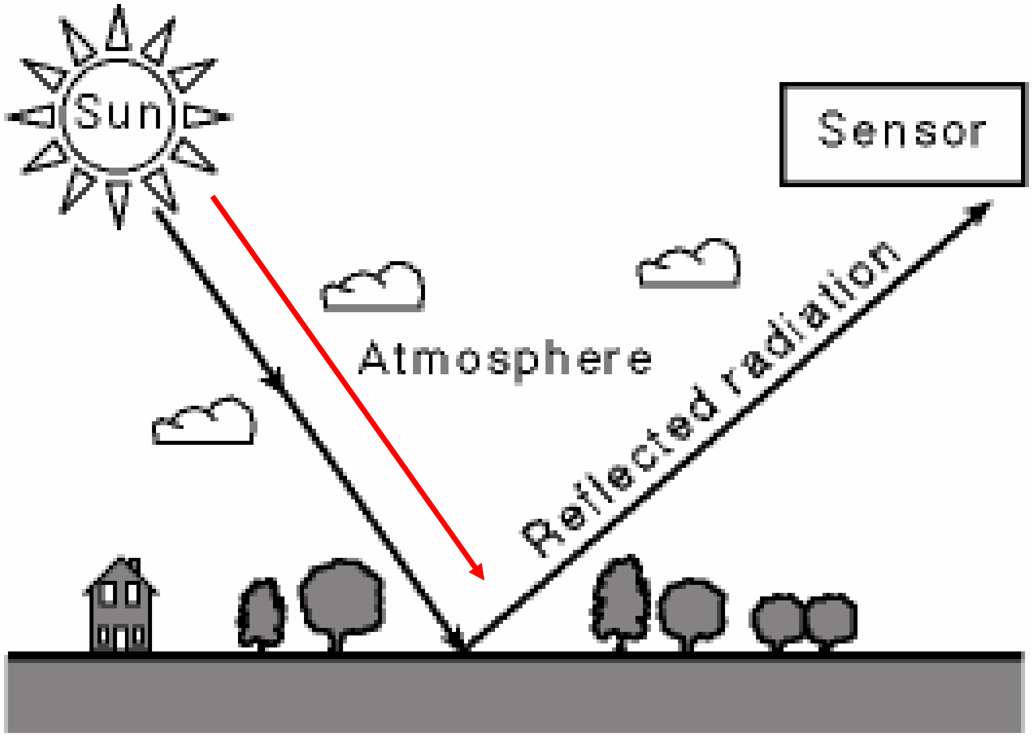

Google Earth
File Edit View Tools Add Help
Search
Fly To
Find Businesses
Directions
e.g., San Francisco
nottingham
Places
My Places
Sightseeing
Select this folder and click on
the 'Play' button below, to start th
default
Temporary Places
Layers
View: Core
Primary Database
Terrain
Geographic Web
Featured Content
Global Awareness
roads
3D Buildings
borders
Populated Places
Alternative Place Names
Dining
Lodging
Google Earth Community
Shopping and Services
Transportation
© 2007 Europa Technologies
Image NASA
Image © 2007 TerraMetrics
Google
Pointer 53°06'15.40" N 2°01'32.69" W
Streaming 100%
Eye alt 6371.00 km
start
Services
Inbox - Outl...
Teaching U...
Microsoft E...
7 Yahoo! ...
7 Microsof...
Google Earth
EN
08:49

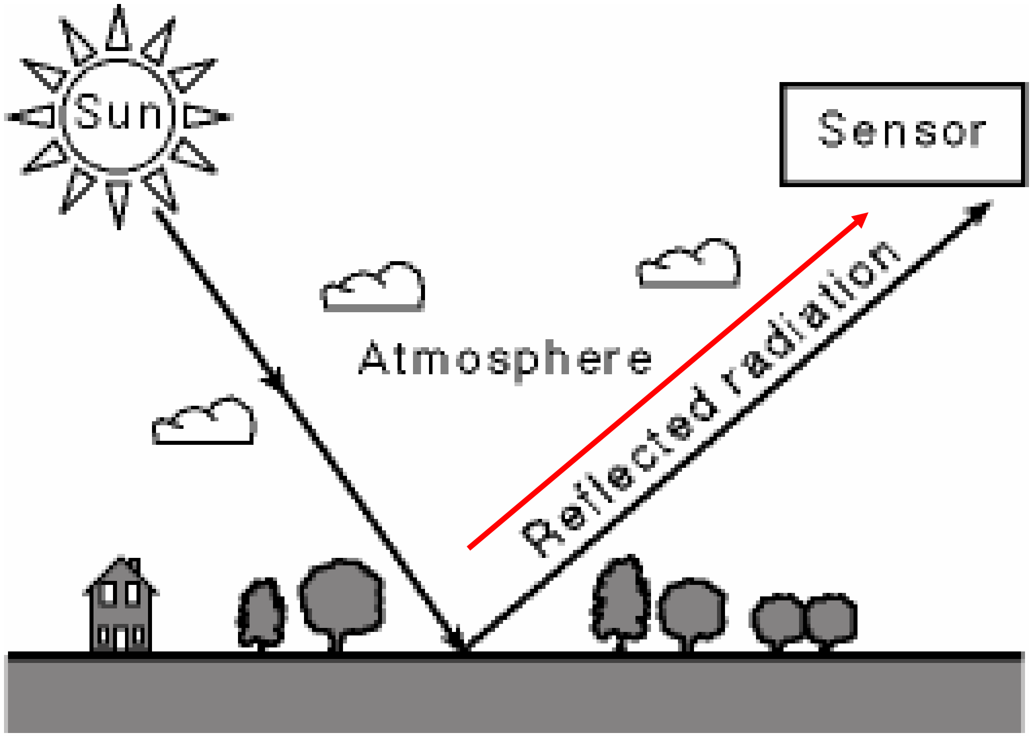
Remote Sensing for Earth Observation

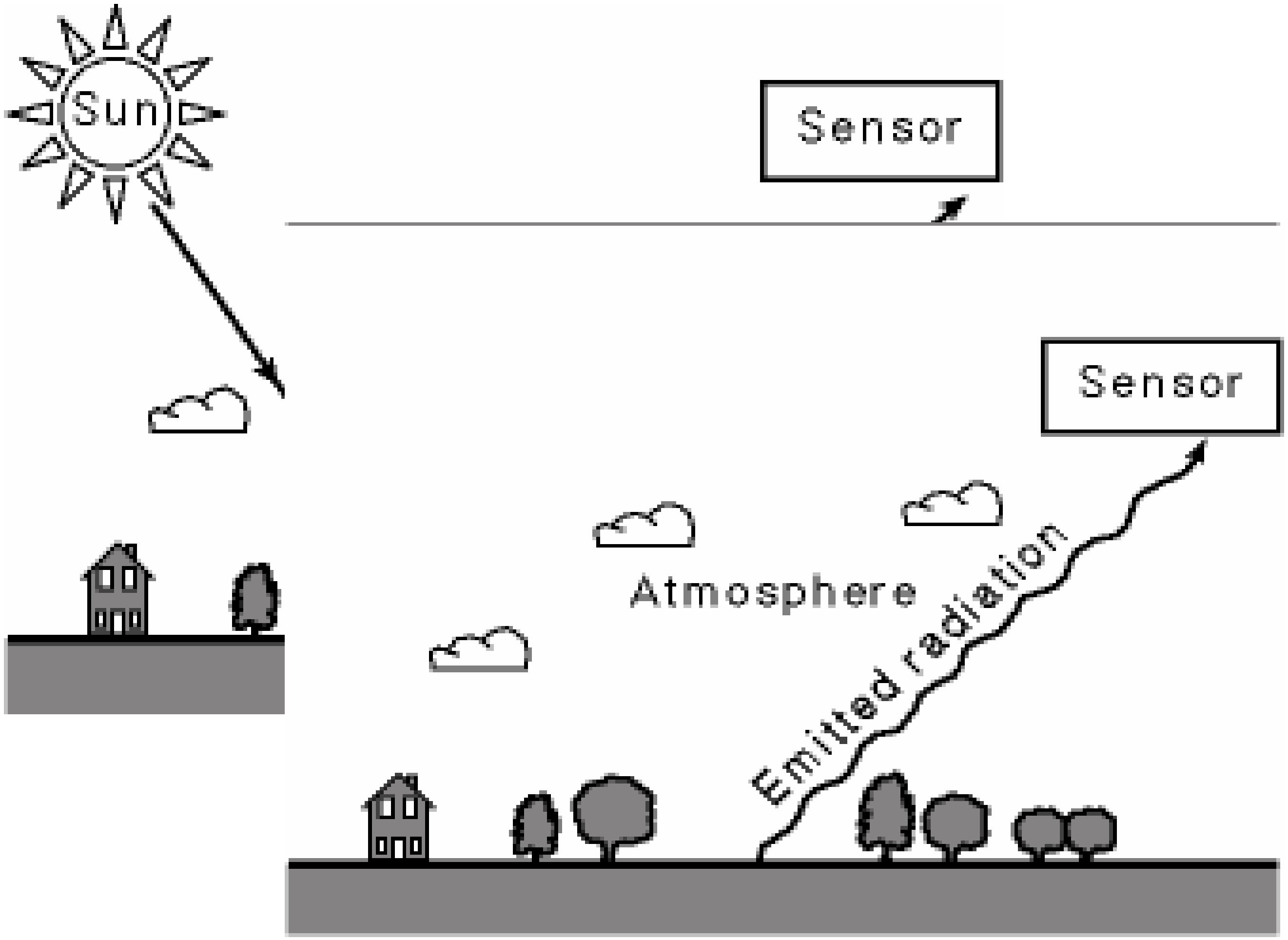
- The acquisition of information about the environment without contact with it.
- Uses passive or active electromagnetic radiation

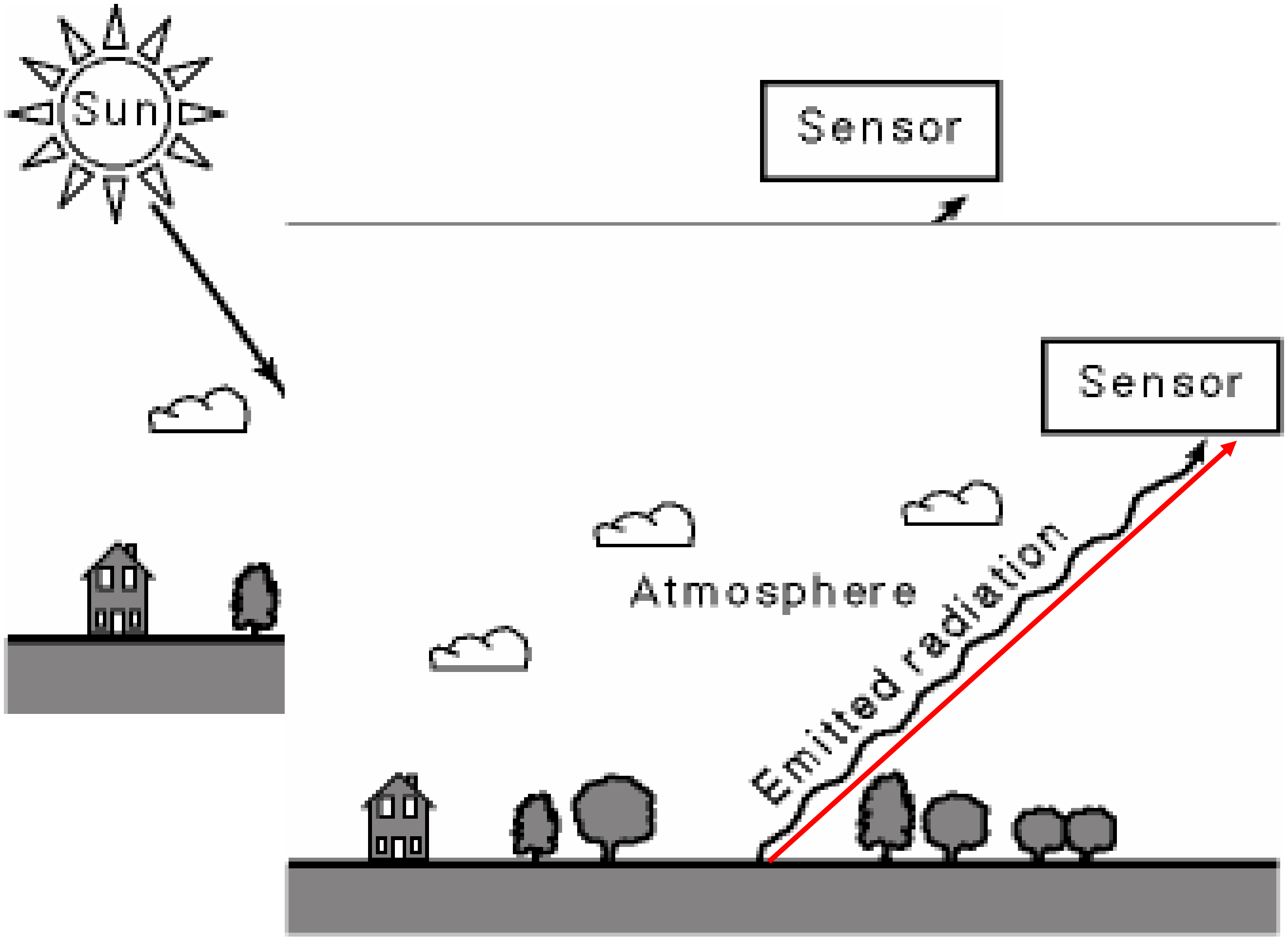


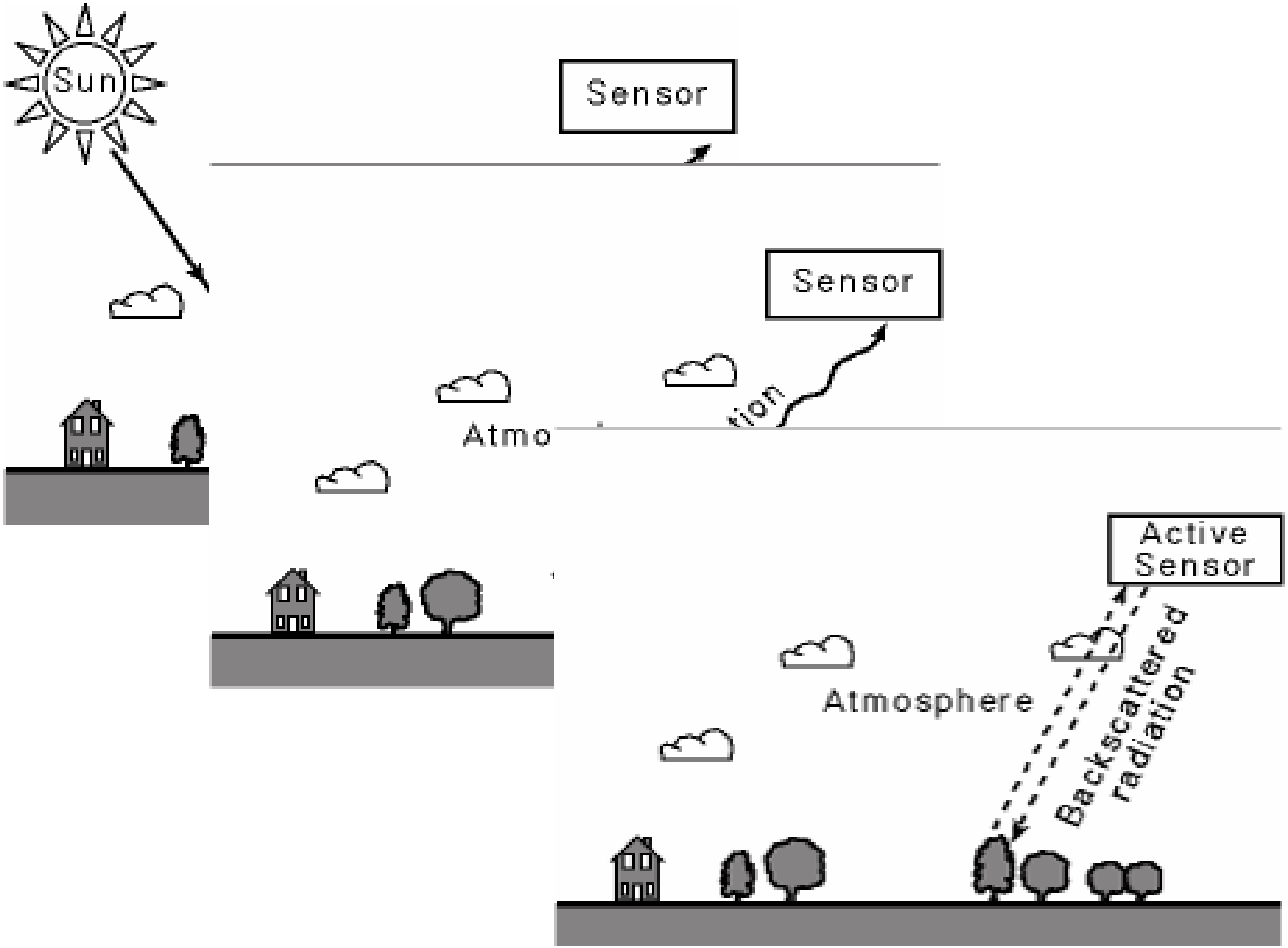

Sun
Sensor
Atmosphere
Reflected radiation

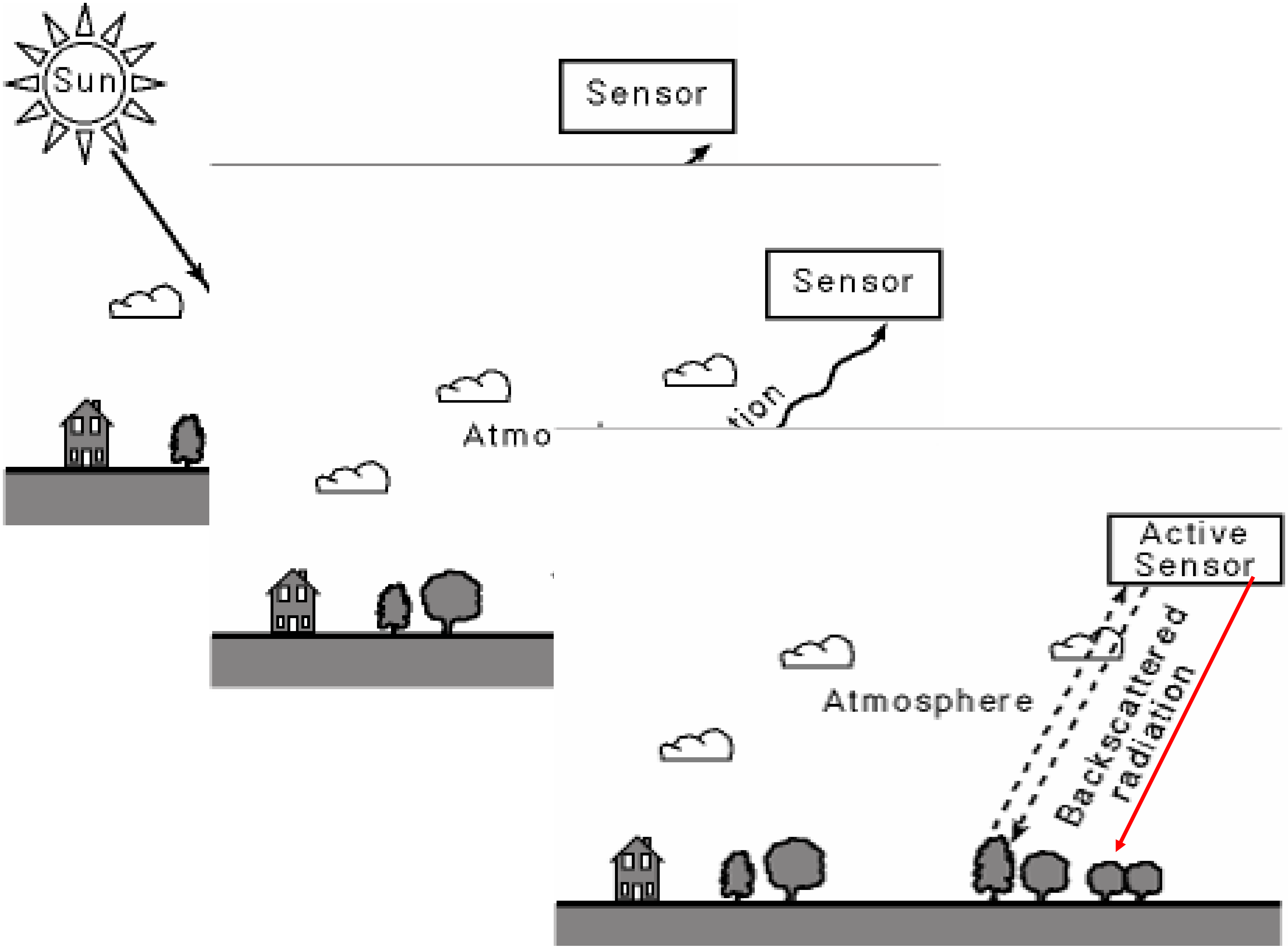

Sun
Sensor
Atmosphere
Reflected radiation


Sun
Sensor
Atmosphere
Reflected radiation

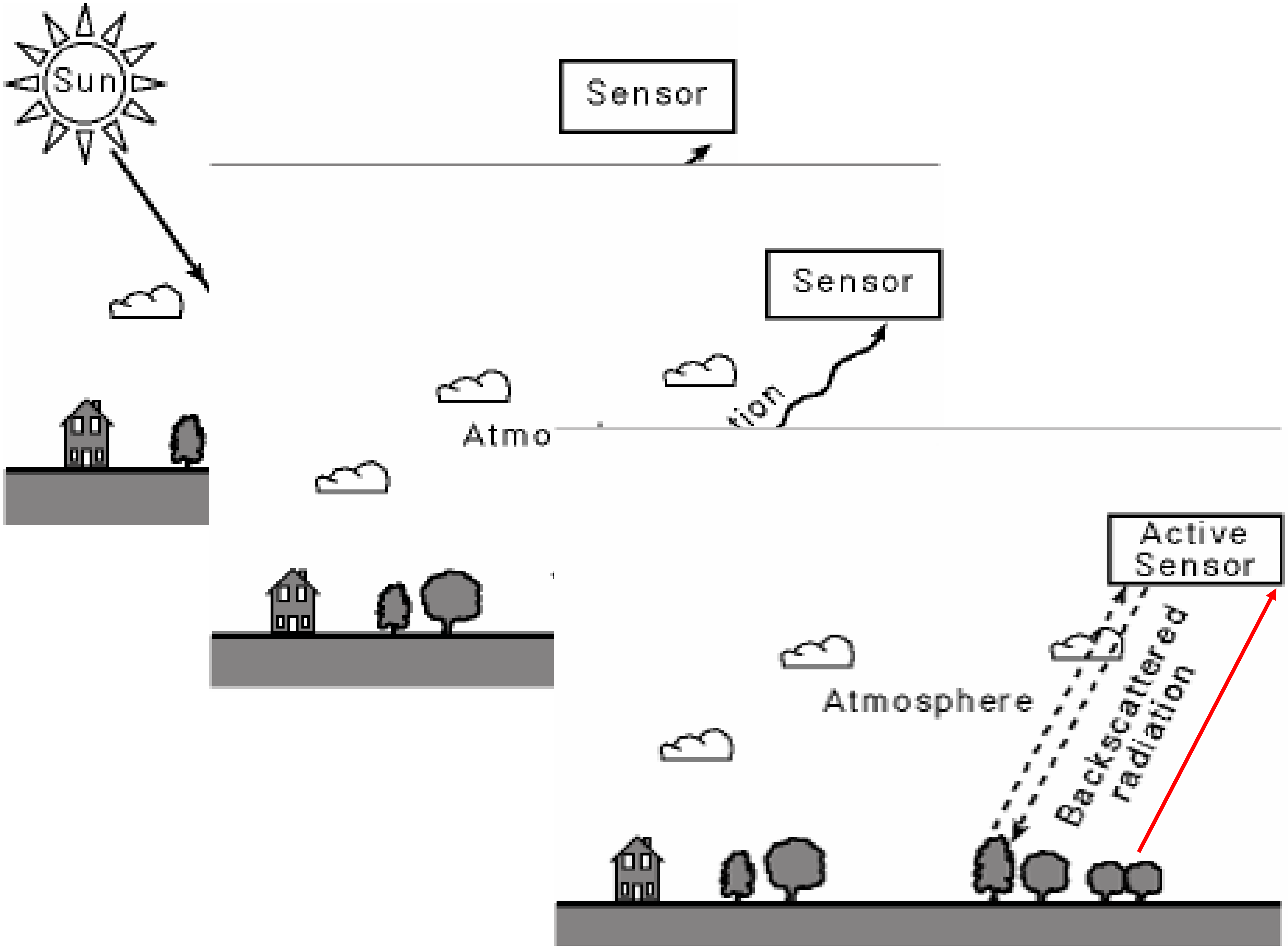

Sun
Sensor
Sensor
Atmosphere
Emitted radiation


Sun
Sensor
Sensor
Atmosphere
Emitted radiation


Sun
Sensor
Sensor
Atmo
Active Sensor
Atmosphere
Backscattered radiation



Sun
Sensor
Sensor
Atmo
tion
Active Sensor
Atmosphere
Backscattered radiation


Sun
Sensor
Sensor
Atmo
tion
Active
Sensor
Atmosphere
Backscattered
radiation

Consider the four main components:

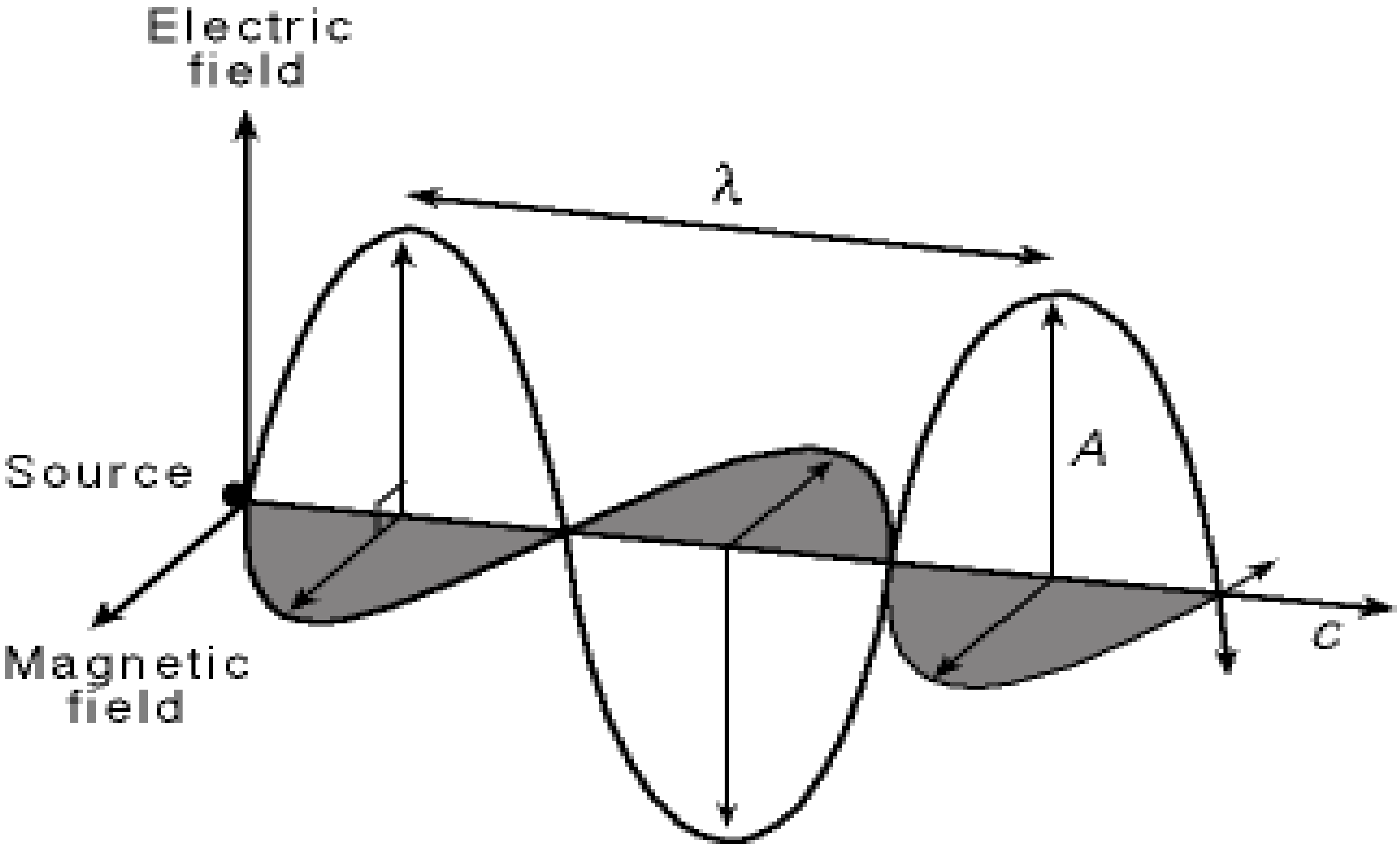
Electromagnetic radiation – the medium by which remote sensing operates

Target – what we are observing

Sensor – measures radiation from the target

Atmosphere – need to consider its influences

Electromagnetic Radiation



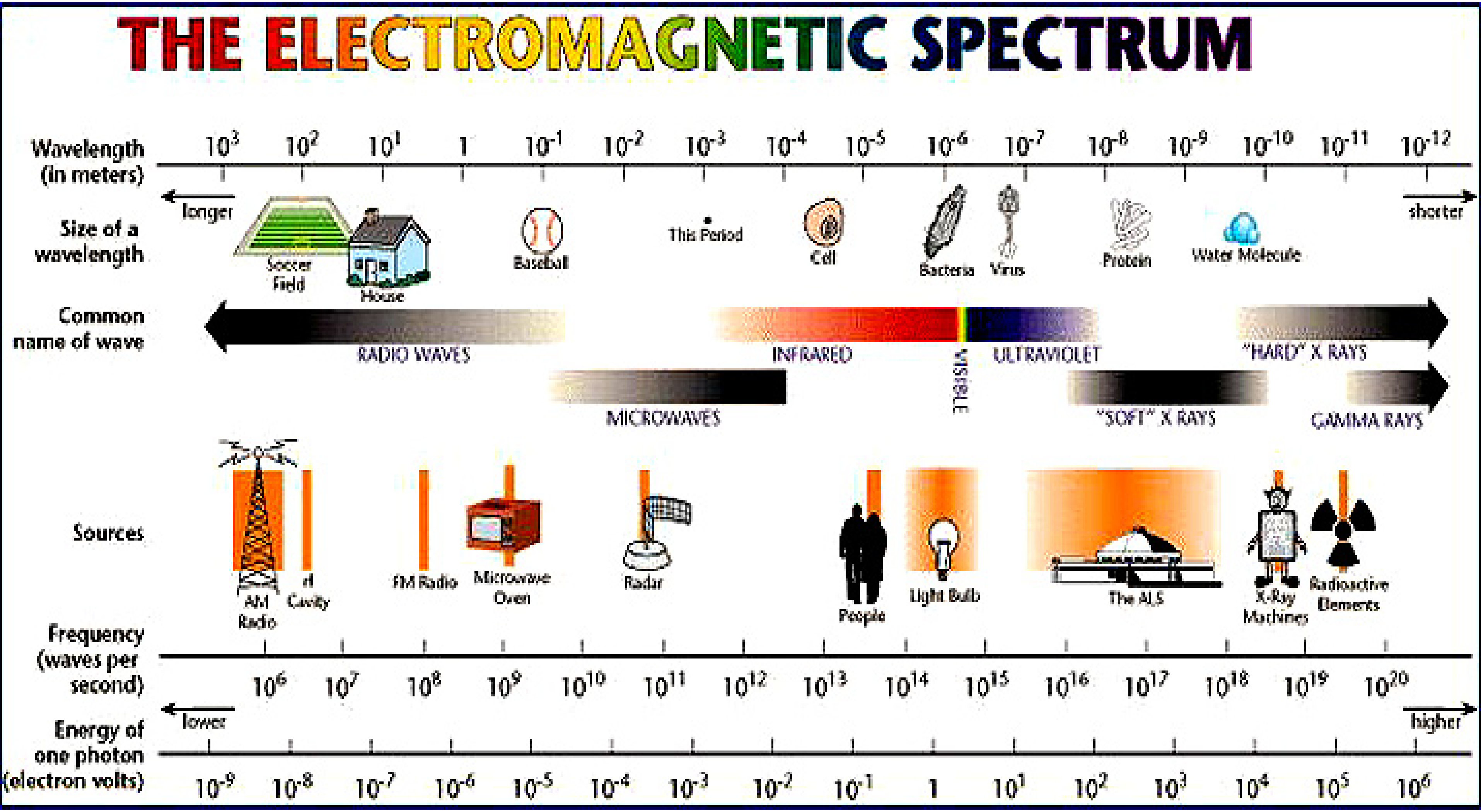
Electromagnetic Radiation: Basic Wave Theory

- The waves can be characterised through a number of variables:

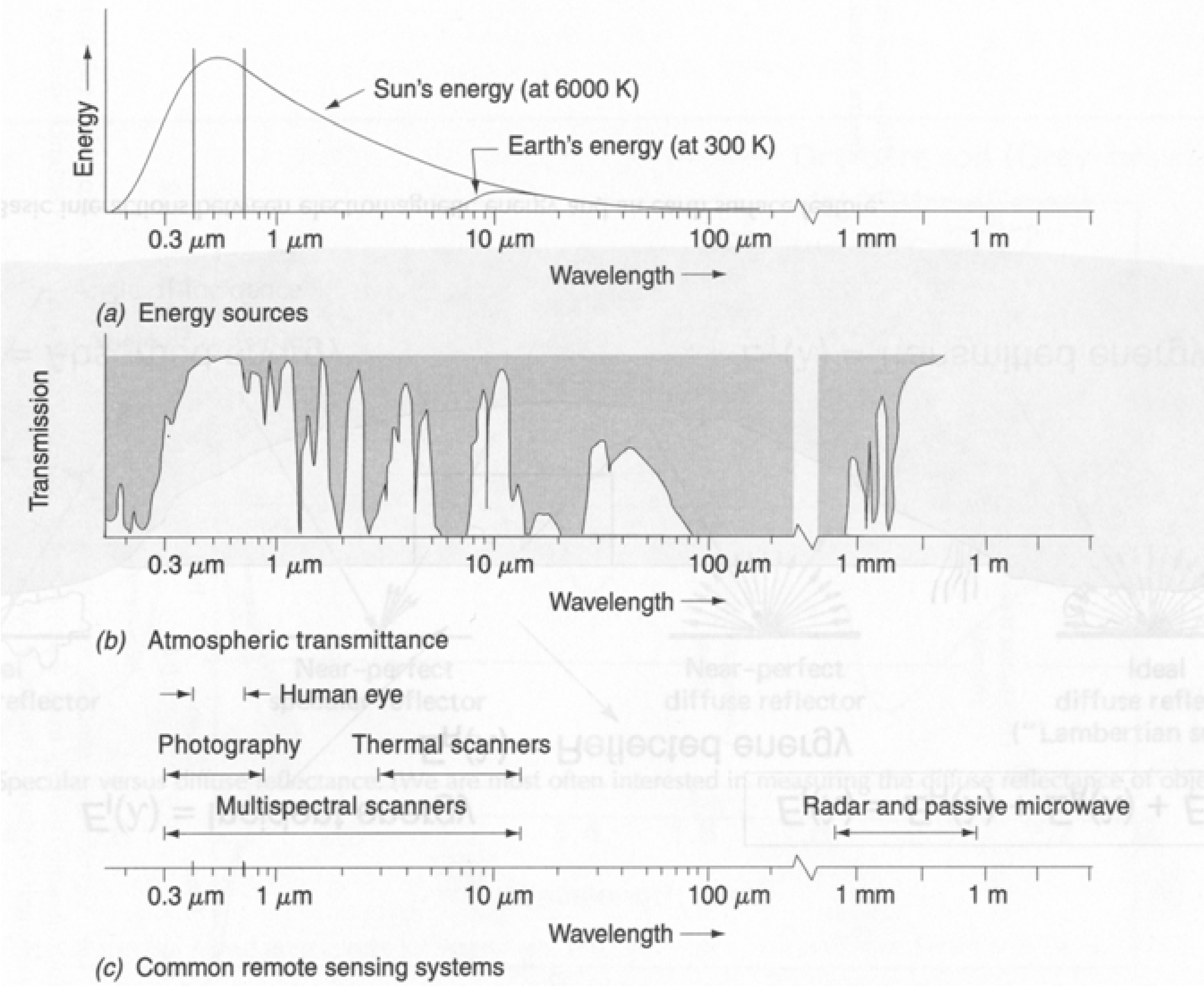
- The three variables of wavelength, frequency and speed are related to each other by the general equation:

$$c = v\lambda \qquad (1)$$

- since c is regarded as a constant (3×10^8 $msec^{-1}$), frequency and wavelength for any given wave are related inversely, and either can be used to categorise any wave.


THE ELECTROMAGNETIC SPECTRUM
Wavelength (in meters)
10^3 10^2 10^1 1 10^-1 10^-2 10^-3 10^-4 10^-5 10^-6 10^-7 10^-8 10^-9 10^-10 10^-11 10^-12
longer
shorter
Size of a wavelength
Soccer Field
House
Baseball
This Period
Cell
Bacteria
Virus
Protein
Water Molecule
Common name of wave
RADIO WAVES
INFRARED
VISIBLE
ULTRAVIOLET
"HARD" X RAYS
MICROWAVES
"SOFT" X RAYS
GAMMA RAYS
Sources
AM Radio
rf Cavity
FM Radio
Microwave Oven
Radar
People
Light Bulb
The ALS
X-Ray Machines
Radioactive Elements
Frequency (waves per second)
10^6 10^7 10^8 10^9 10^10 10^11 10^12 10^13 10^14 10^15 10^16 10^17 10^18 10^19 10^20
lower
higher
Energy of one photon (electron volts)
10^-9 10^-8 10^-7 10^-6 10^-5 10^-4 10^-3 10^-2 10^-1 1 10^1 10^2 10^3 10^4 10^5 10^6

Transmission of EMR through Atmosphere: the windows



Main Regions of the Electromagnetic Spectrum used in Remote Sensing

The University of Nottingham

Region Name	Wavelength Range	Details
Visible	0.4 - 0.75µm	Narrow but well used region since the short wavelengths are of high frequency and high energy. Comprises the three additive primaries; blue (0.4 - 0.5 µm), green (0.5 - 0.6µm) and red (0.6 - 0.7 µm).
Near Infrared (NIR)	0.75 - 1.5µm	Start of the region beyond the red wavelengths. Like visible region, frequently used in remote sensing.
Mid Infrared	1.5 - 5.0µm	Comprises two main portions; shortwave infrared (SWIR; 1.5 - 3.0 µm) and middle infrared (MIR; 3.0 -5.0 µm). MIR radiation measured by sensors can comprise a mixed signal of reflected solar radiation and radiation emitted from the Earth's surface.
Thermal Infrared (TIR)	5.0 - 15.0µm	Comprises of long wavelengths of lower frequency and thus lower energy. Much of the thermal infrared signal is comprised of emitted radiation from the Earth's surface.
Microwave	1mm - 1m	Longest wavelengths used in remote sensing. Passive remote sensing difficult as wavelengths have low energy so some sensors that record microwave radiation in this region generate radiation artificially and measure radiation backscattered from the Earth.

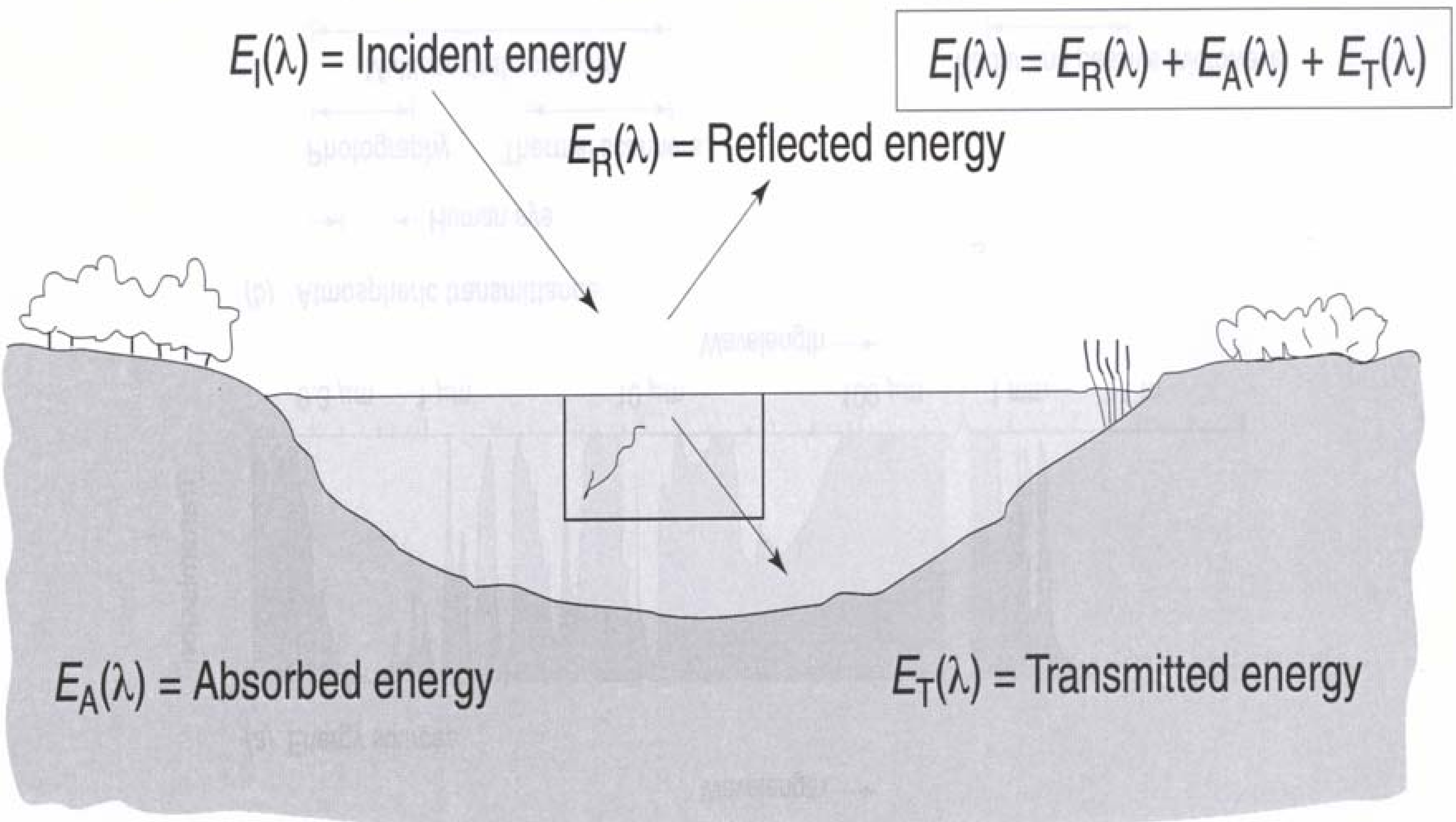
Sources of EMR:

- *Natural*: all objects with a temperature above absolute zero

(-273 ºC, 0K) emit EMR continuously

  - Sun
  - Earth's surface
  - Atmosphere
- *Artificial*:
  - Radar (radio detection and ranging) (operates at microwave wavelengths).
  - Lidar (light detection and ranging) has grown in popularity recently (uses laser).

The target



$E_I(\lambda)$ = Incident energy
$E_I(\lambda) = E_R(\lambda) + E_A(\lambda) + E_T(\lambda)$
$E_R(\lambda)$ = Reflected energy
$E_A(\lambda)$ = Absorbed energy
$E_T(\lambda)$ = Transmitted energy

Environmental Properties

The University of Nottingham

	Electromagnetic Spectrum (wavebands)				
Environmental Component	Visible (0.4-0.7 μm)	Near infrared (0.7-1.5 μm)	Middle infrared (1.5-5.0 μm)	Thermal infrared (5.0-15.0 μm)	Microwave (3-300 cm)
Rock and Soil	• Iron Bearing minerals • Texture/structure • Soil moisture • Organic matter	• Iron bearing minerals • Texture/structure • Soil moisture • Organic matter	• Texture/structure • Soil moisture • Organic matter • *Carbonates* • *Sulphates*	• Temperature	• Surface soil moisture • Texture/structure
Vegetation	• Chlorophyl	• Physiological structure • *Protein* • *Lignin* • *Oil*	• Water content • *Nitrogen* • *Lignin* • *Sugar* • *Cellulose*	• Temperature	• Canopy structure and roughness
Snow and Ice	• Snow depth • *Snow grain size*	• Snow water • *Snow grain size*	• Water/ice differentitaion • Cloud/ice differentiation	• Temperature	• Snow depth
Water	• Organic matter • Suspended sediments • Chlorophyll			• Surface temperature	• Surface roughness
Atmosphere	• Aerosol properties • Cloud thickness • Aerosol optical thickness	• Water vapour • Cloud top height • Aerosol optical thickness • Precipitable water	• Cloud particle radius • Aerosol optical thickness	• Cloud temperatures	

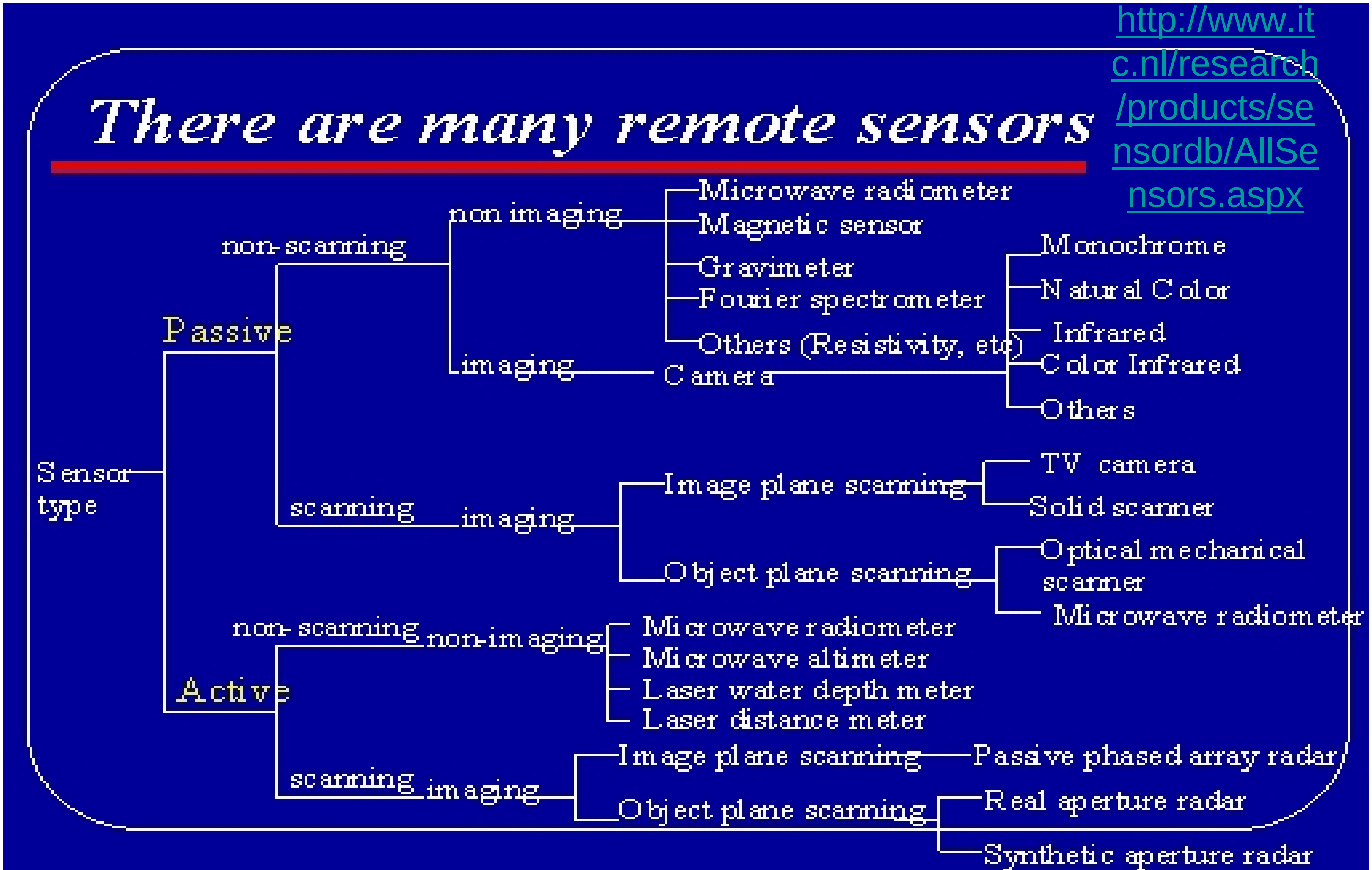
The sensor

The remotely sensed radiation (R) received by a sensor is a function (f) of the location (x), time (t), wavelength (λ) and viewing geometry (θ) of a given area of interest:

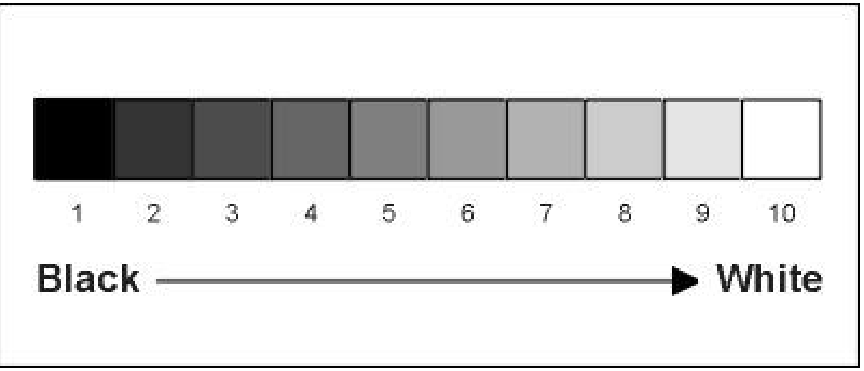
$$R = f(x, t, \lambda, \theta)$$

The sensor

http://www.itc.nl/research/products/sensordb/AllSensors.aspx



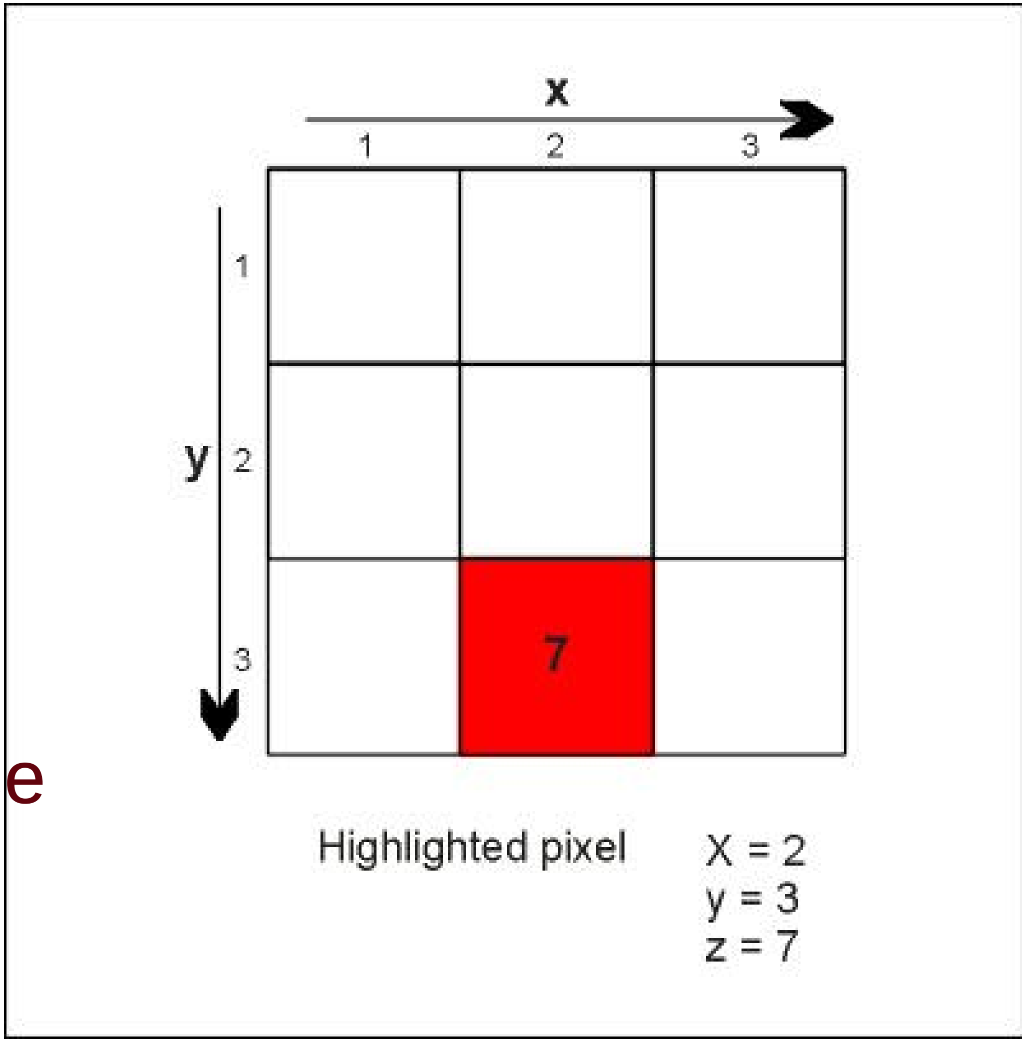
Commonly the sensor records the radiation from a target in raster format to produce an image



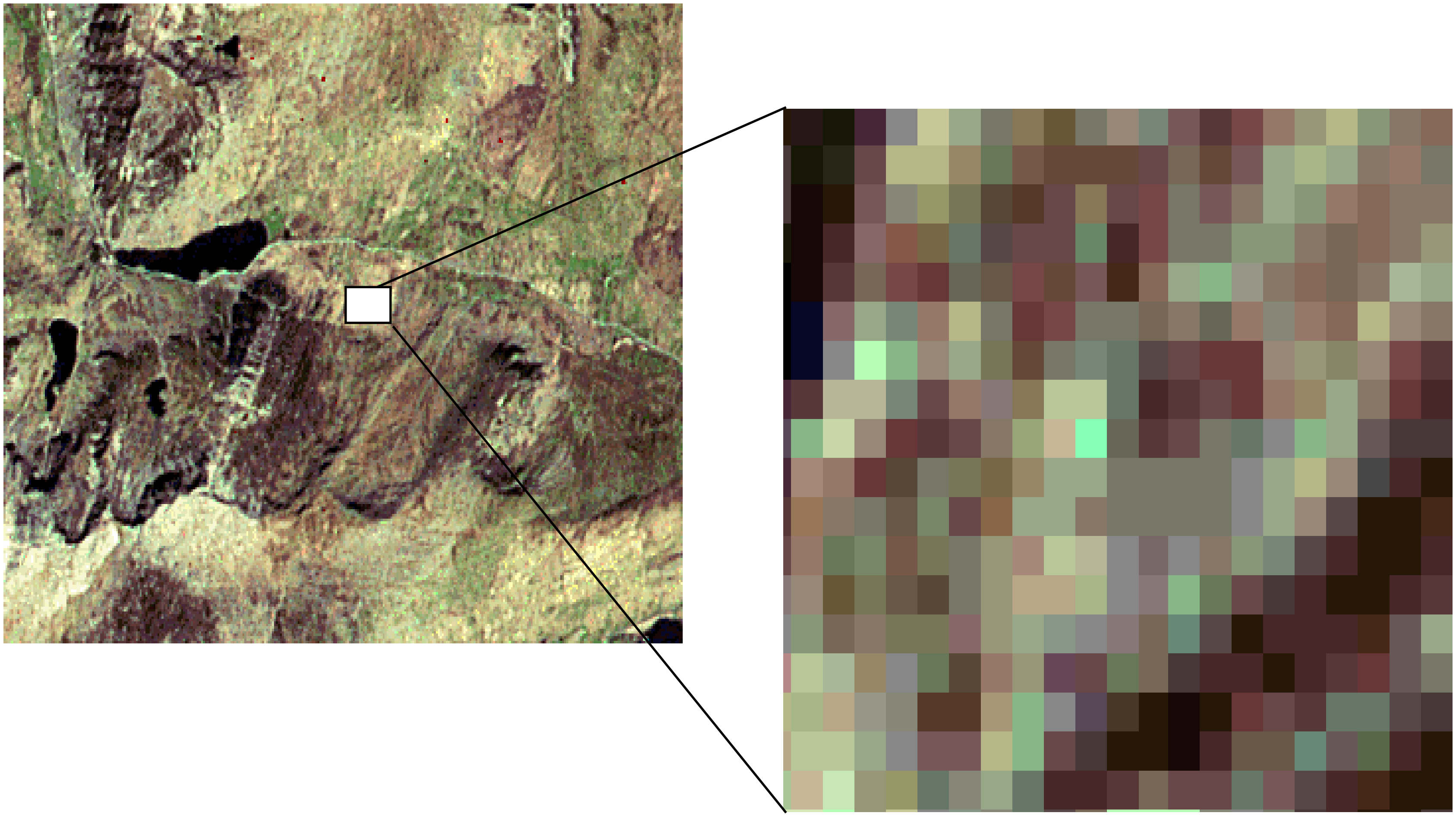
Each pixel in the image layer displays the Digital Number

high DN = high radiance

low DN = low radiance



Resolving the pixel



Sensor characteristics

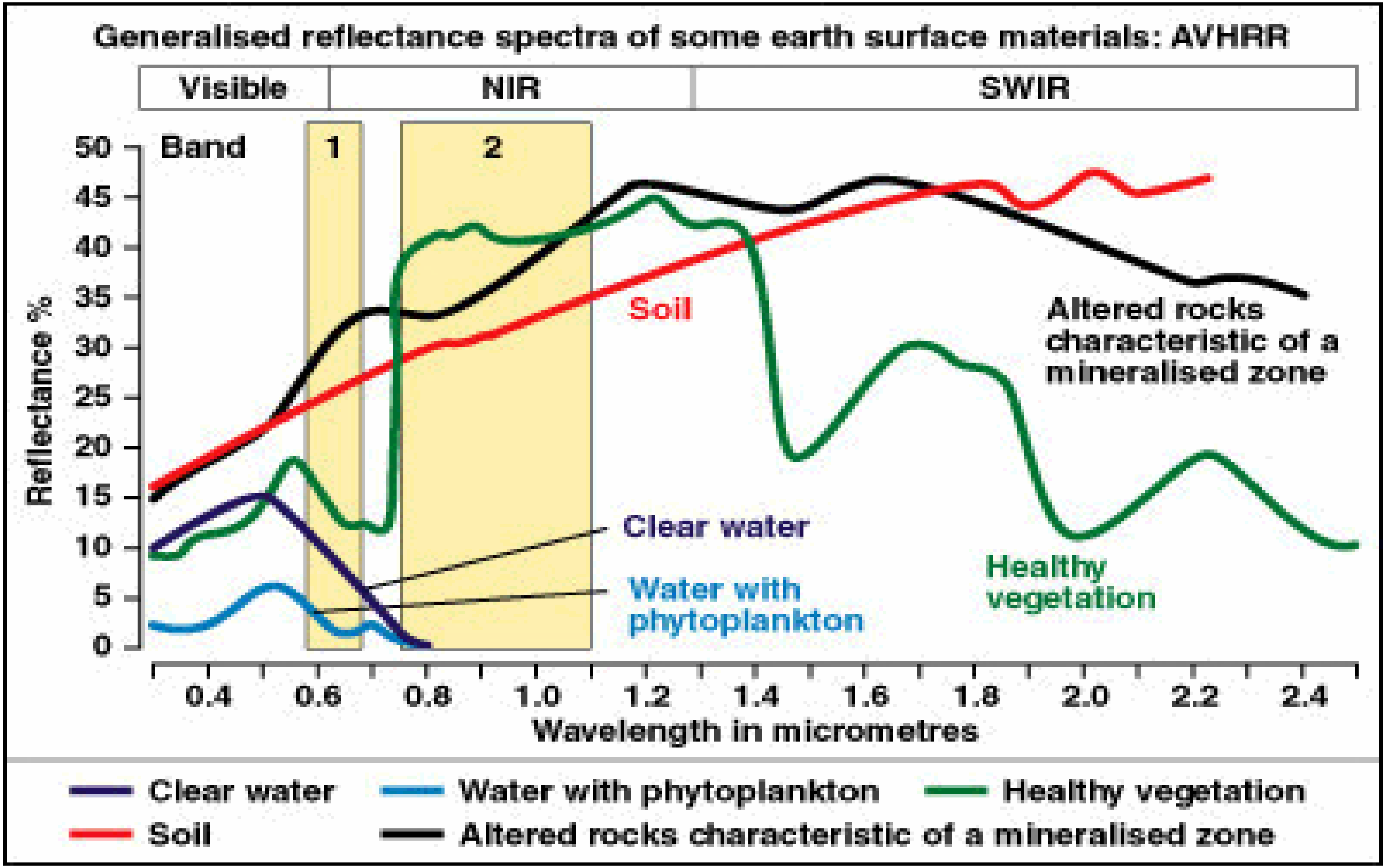
Spectral resolution

Radiometric resolution

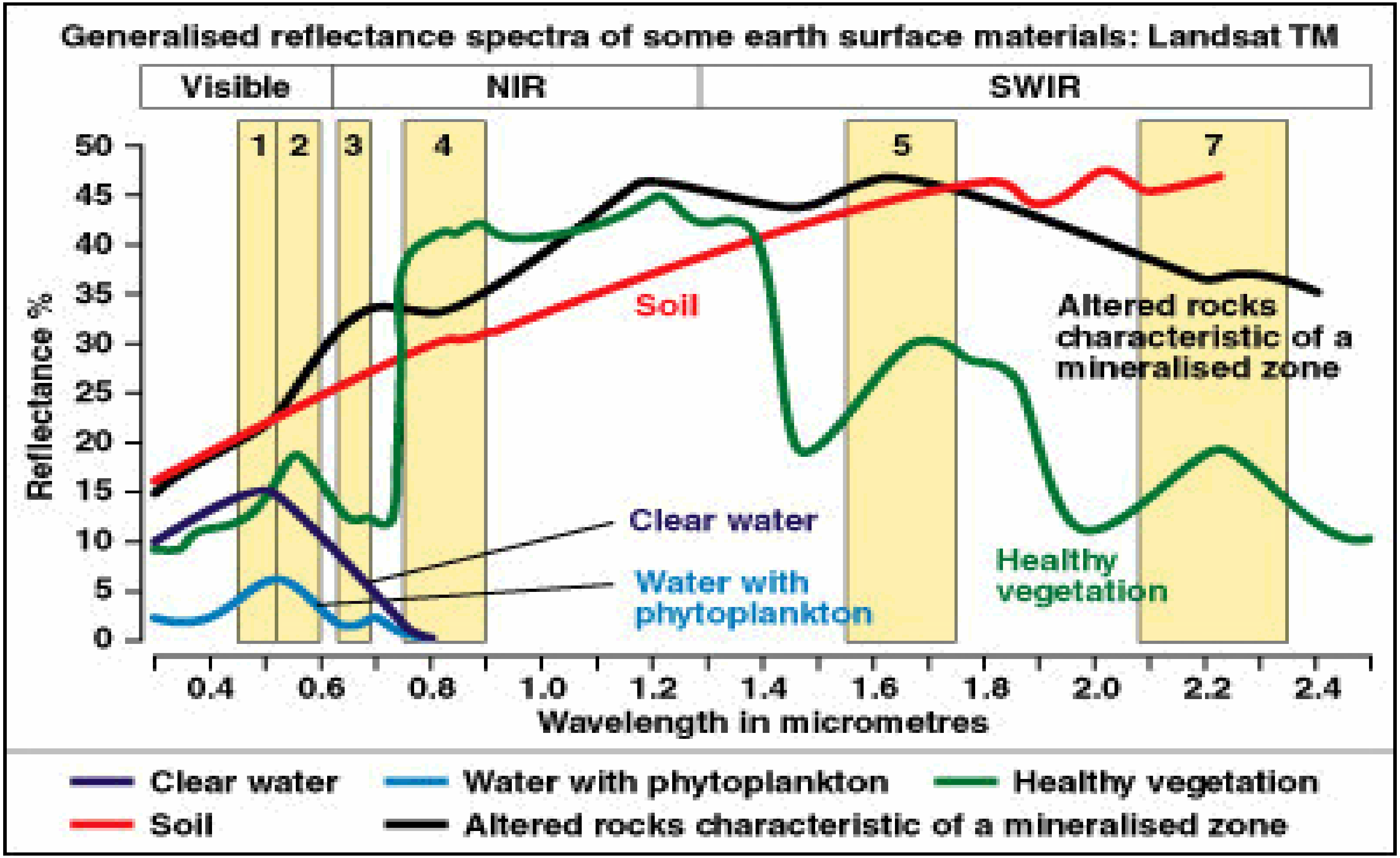
Spatial resolution

Temporal resolution

Spectral resolution



Spectral resolution



Spectral resolution

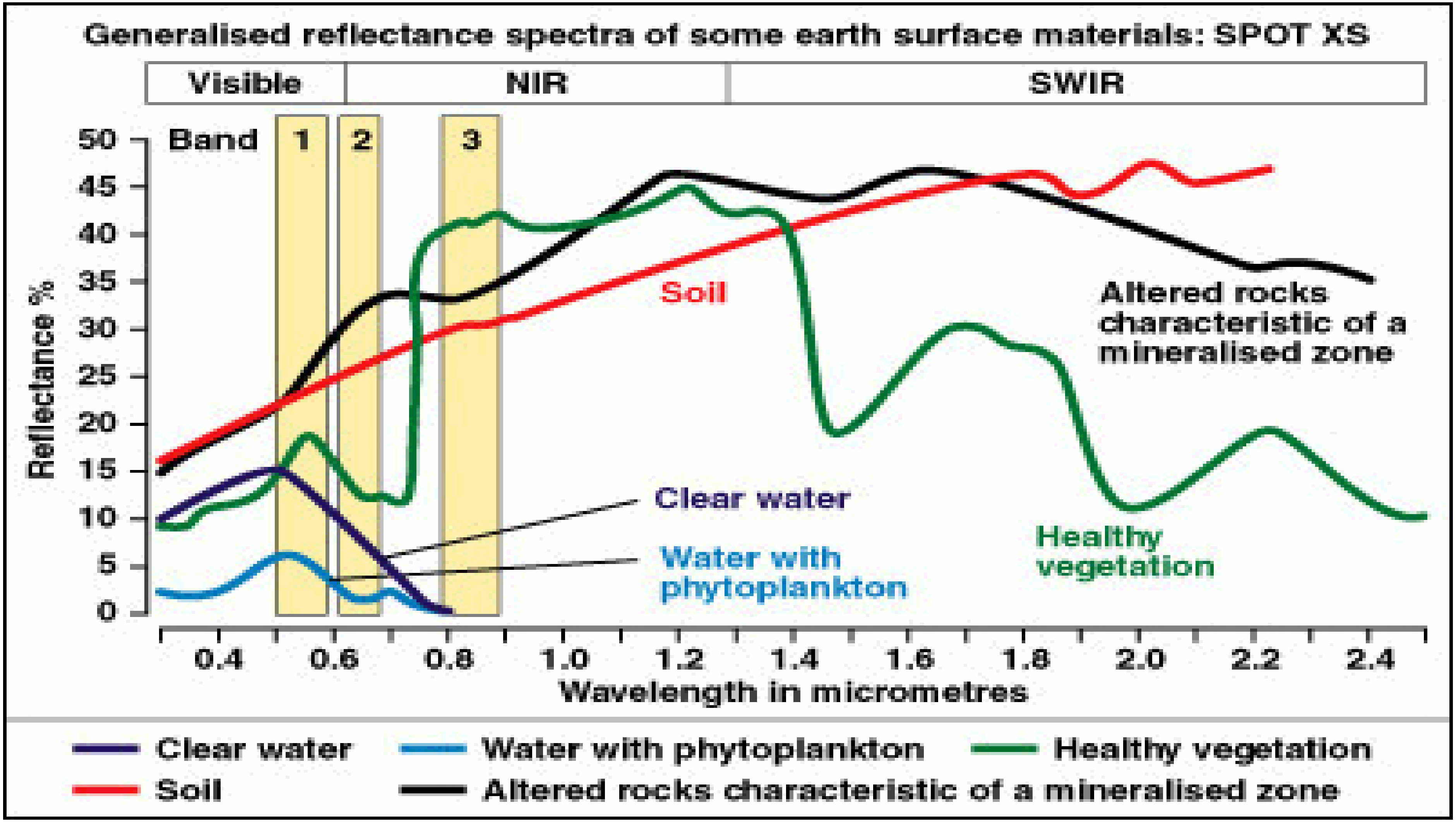


Image is acquired in each waveband - shows spectral radiance

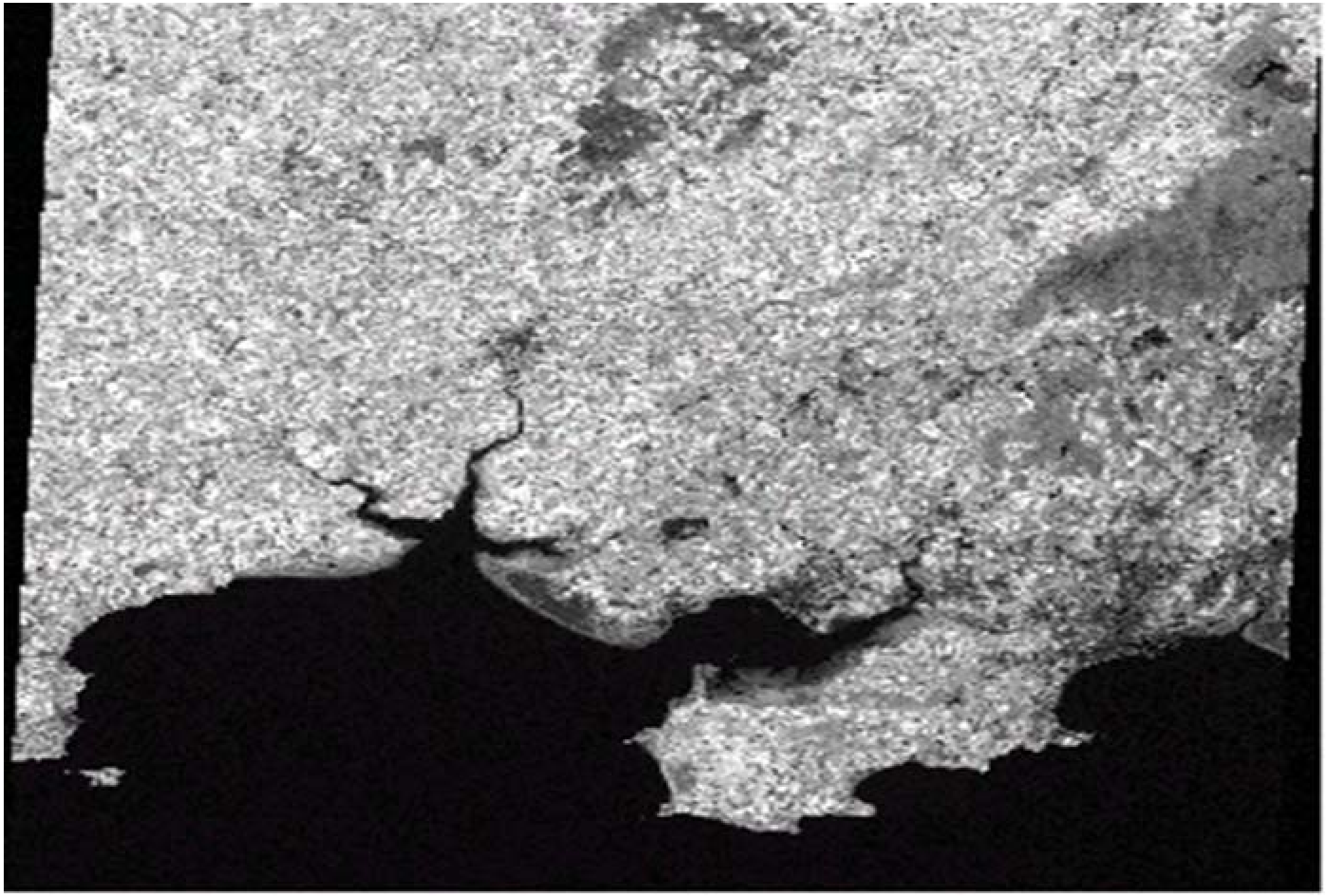


Image is acquired in each waveband - shows spectral radiance

Image is acquired in each waveband - shows spectral radiance

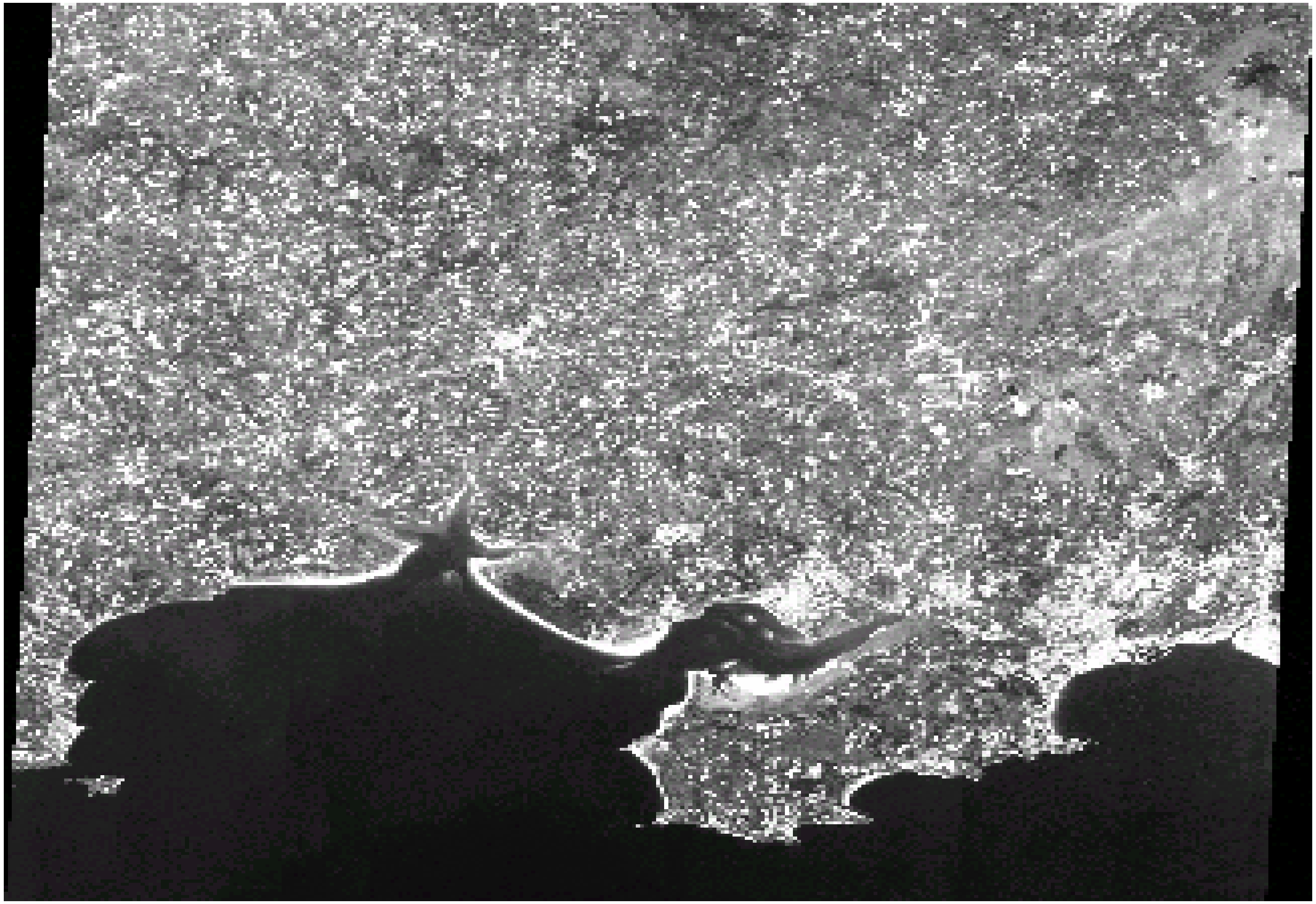
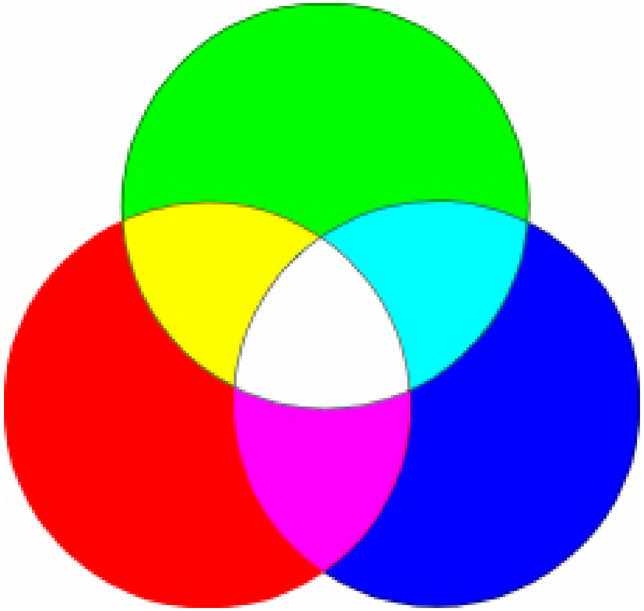


Image display uses colour additive principle



Spatial resolution

- Determined by IFOV and height of platform carrying sensor: controls swath width and pixel size

Platforms available to carry sensors:

satellites
helicopters
planes
booms/tripods
by hand (terrestrial)

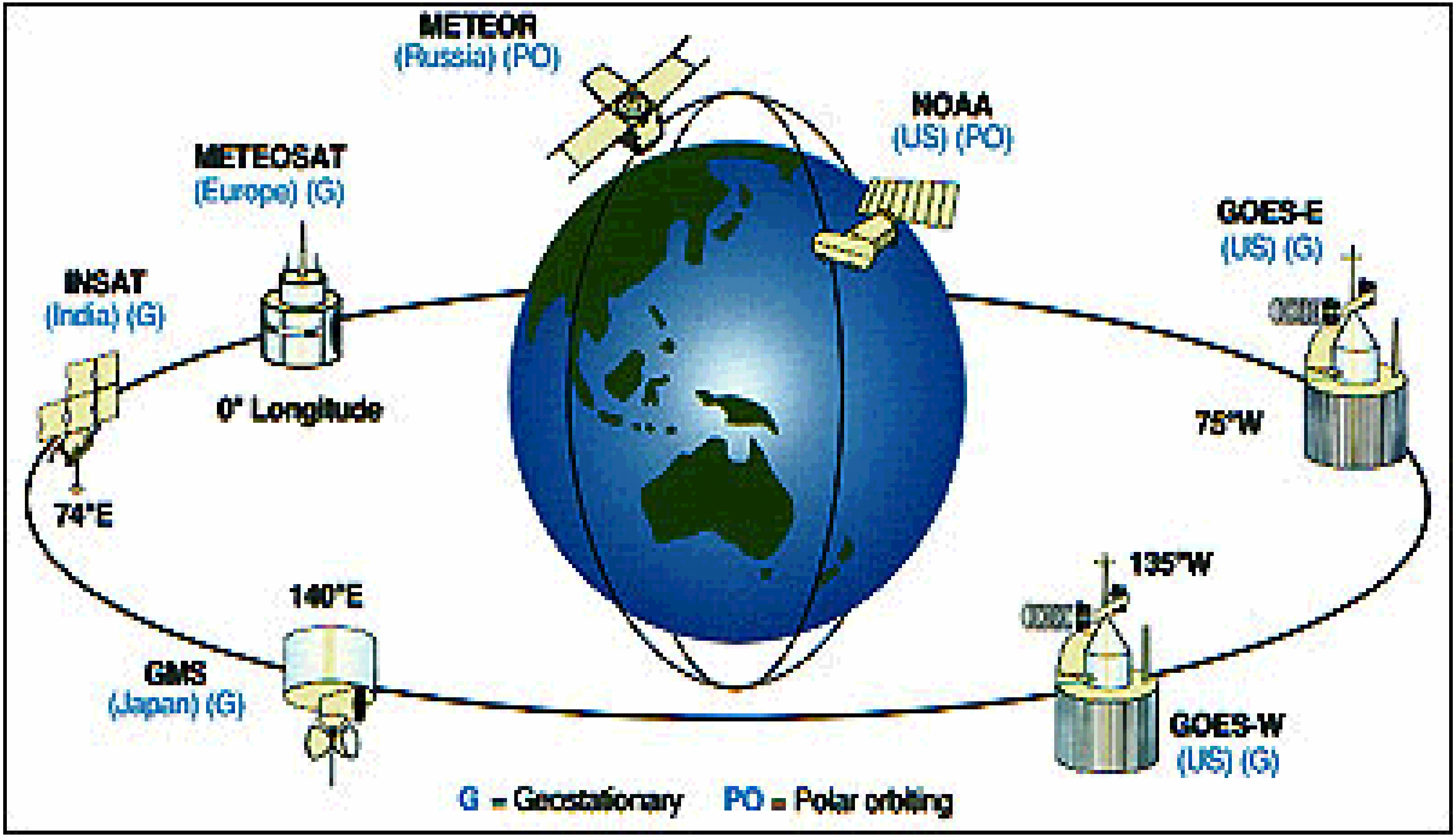
Ikonos (1m)

Thematic Mapper (30m)

AVHRR (1.1km)

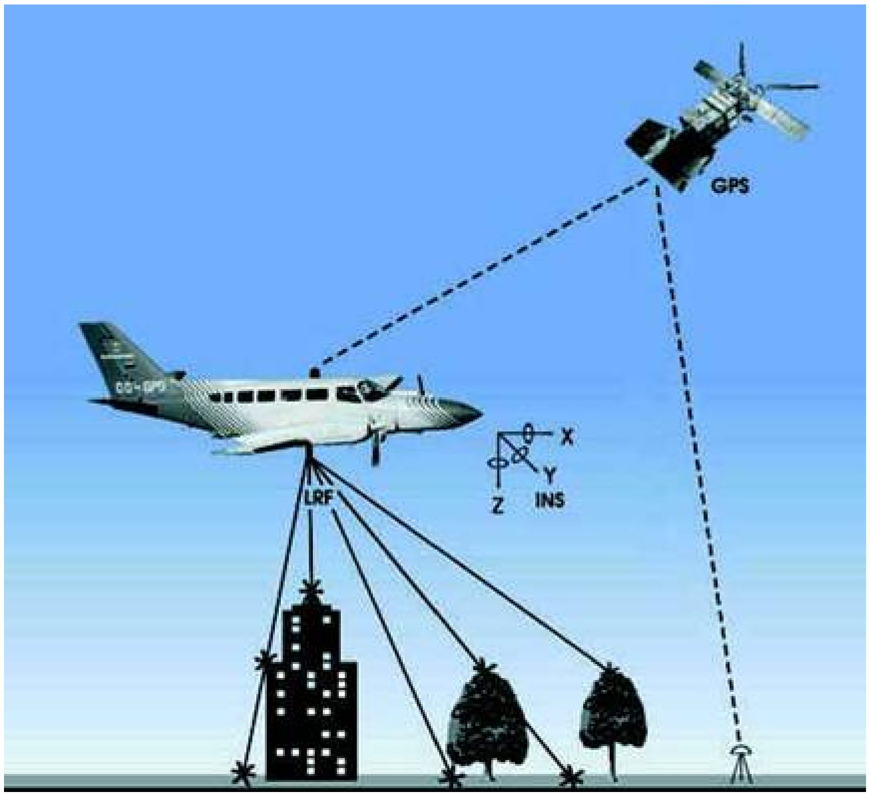
Meteosat (4km)

Temporal resolution

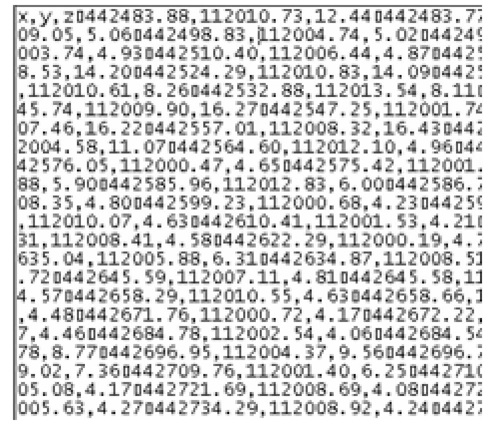


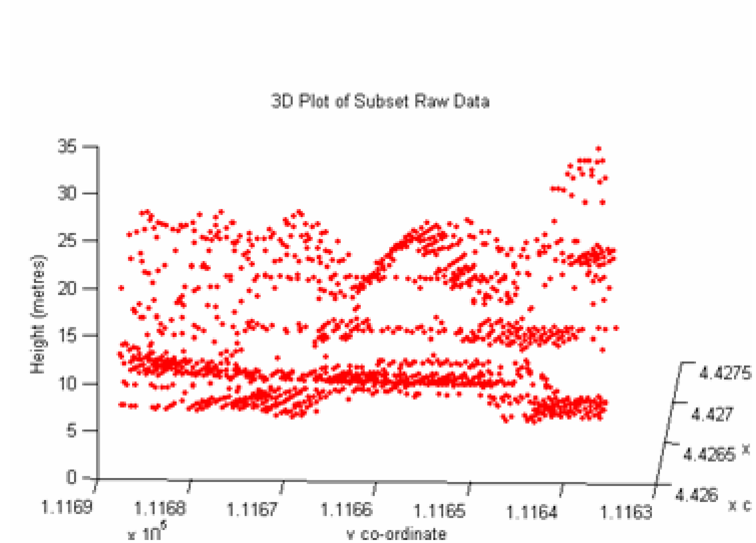

Aqua
TOPE
Terra
Aura

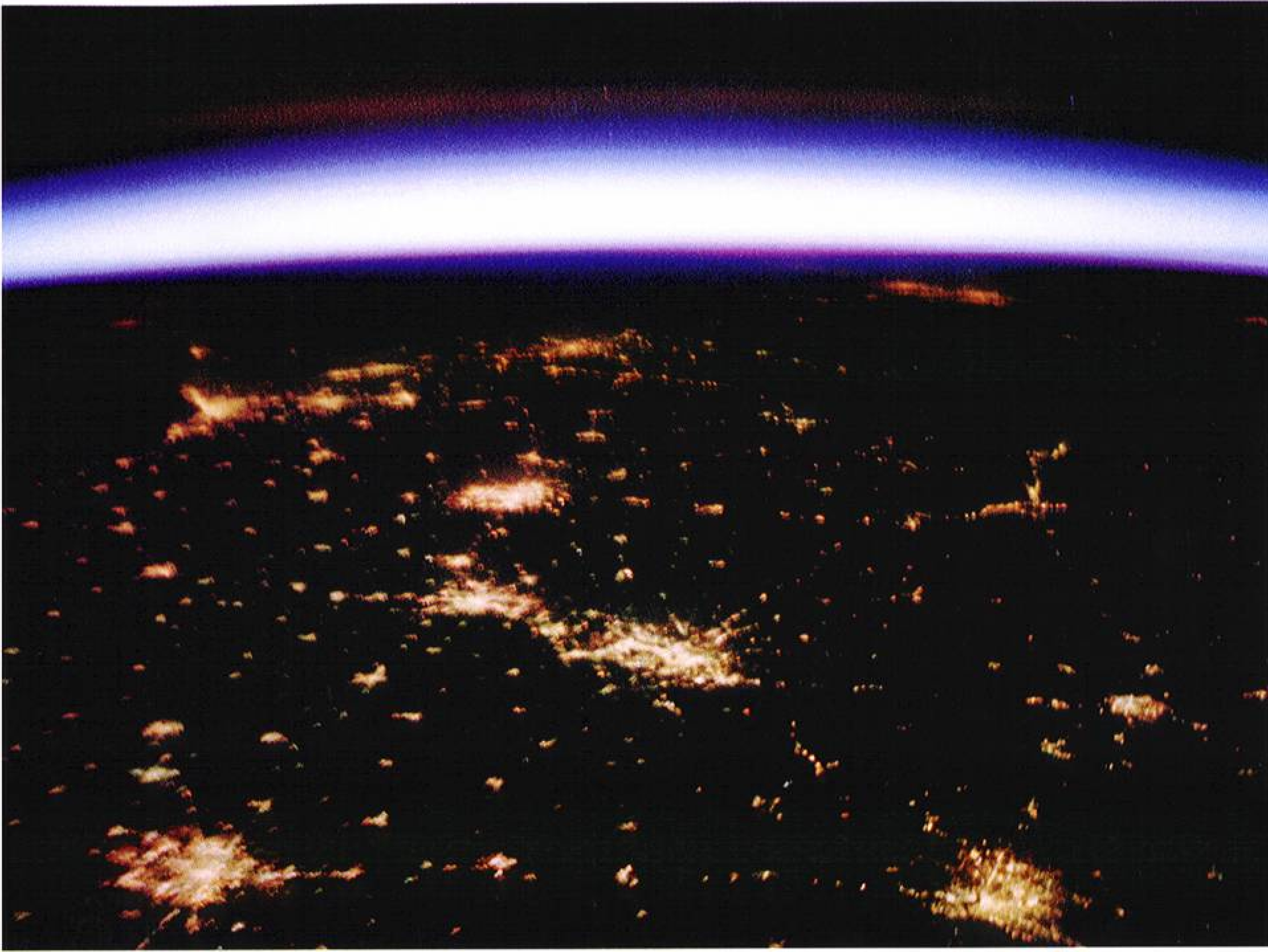
Laser scanning



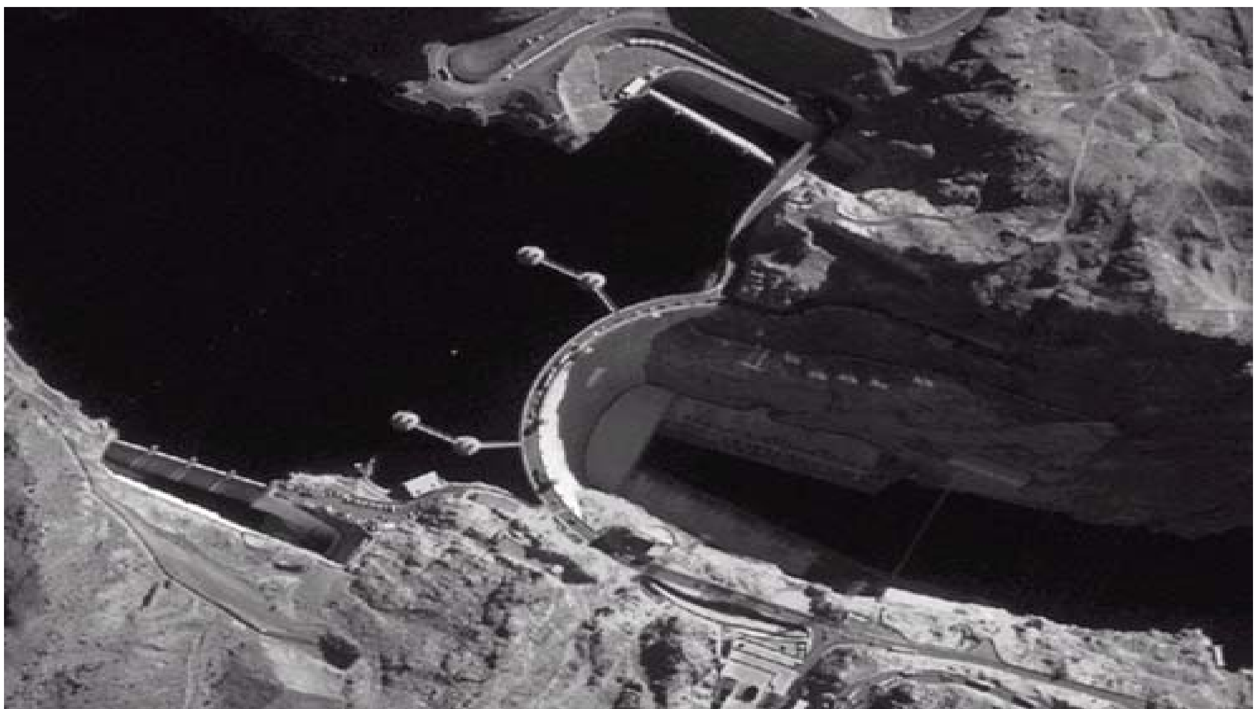
http://www.eurosense.com/UK/serv_laser_uk.htm#Technical Considerations


x,y,z□442483.88,112010.73,12.44□442483.7
09.05,5.06□442498.83,112004.74,5.02□44249
003.74,4.93□442510.40,112006.44,4.87□4425
8.53,14.20□442524.29,112010.83,14.09□4425
,112010.61,8.26□442532.88,112013.54,8.11
45.74,112009.90,16.27□442547.25,112001.7
07.46,16.22□442557.01,112008.32,16.43□442
2004.58,11.07□442564.60,112012.10,4.96□44
42576.05,112000.47,4.65□442575.42,112001.
88,5.90□442585.96,112012.83,6.00□442586.
08.35,4.80□442599.23,112000.68,4.23□44259
,112010.07,4.63□442610.41,112001.53,4.21
31,112008.41,4.58□442622.29,112000.19,4.
635.04,112005.88,6.31□442634.87,112008.5
.72□442645.59,112007.11,4.81□442645.58,1
4.57□442658.29,112010.55,4.63□442658.66,
,4.48□442671.76,112000.72,4.17□442672.22,
7,4.46□442684.78,112002.54,4.06□442684.5
78,8.77□442696.95,112004.37,9.56□442696.
9.02,7.36□442709.76,112001.40,6.25□44271
05.08,4.17□442721.69,112008.69,4.08□44272
005.63,4.27□442734.29,112008.92,4.24□4442





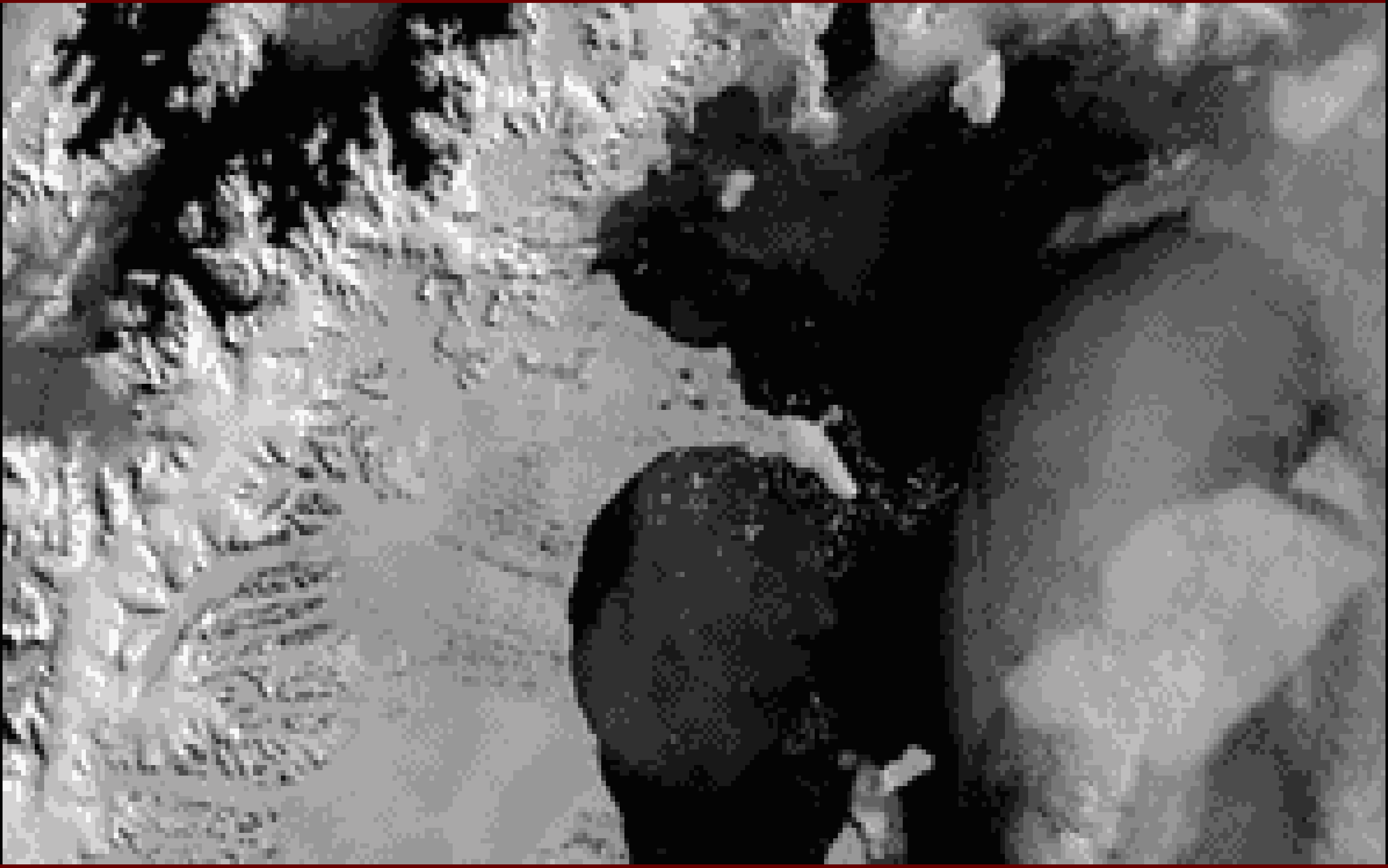
Ikonos images



Inference of socioeconomic characteristics from RS

- Studies have documented how quality-of-living indicators, such as house value, median family income, education can be inferred by extracting the following attributes from imagery:
- Building size (sq. ft), plot size (acerage), pool (sq. ft), placement of house on lot (distance from street), houses with driveway (%), health of landscaping, street width (ft), houses with garage.
- The relationship between indicators and imagery-derived indicators will vary by region or neighbourhoods.

LARSEN B ICE SHELF (JAN 31 2002)



Animating ...

1/3

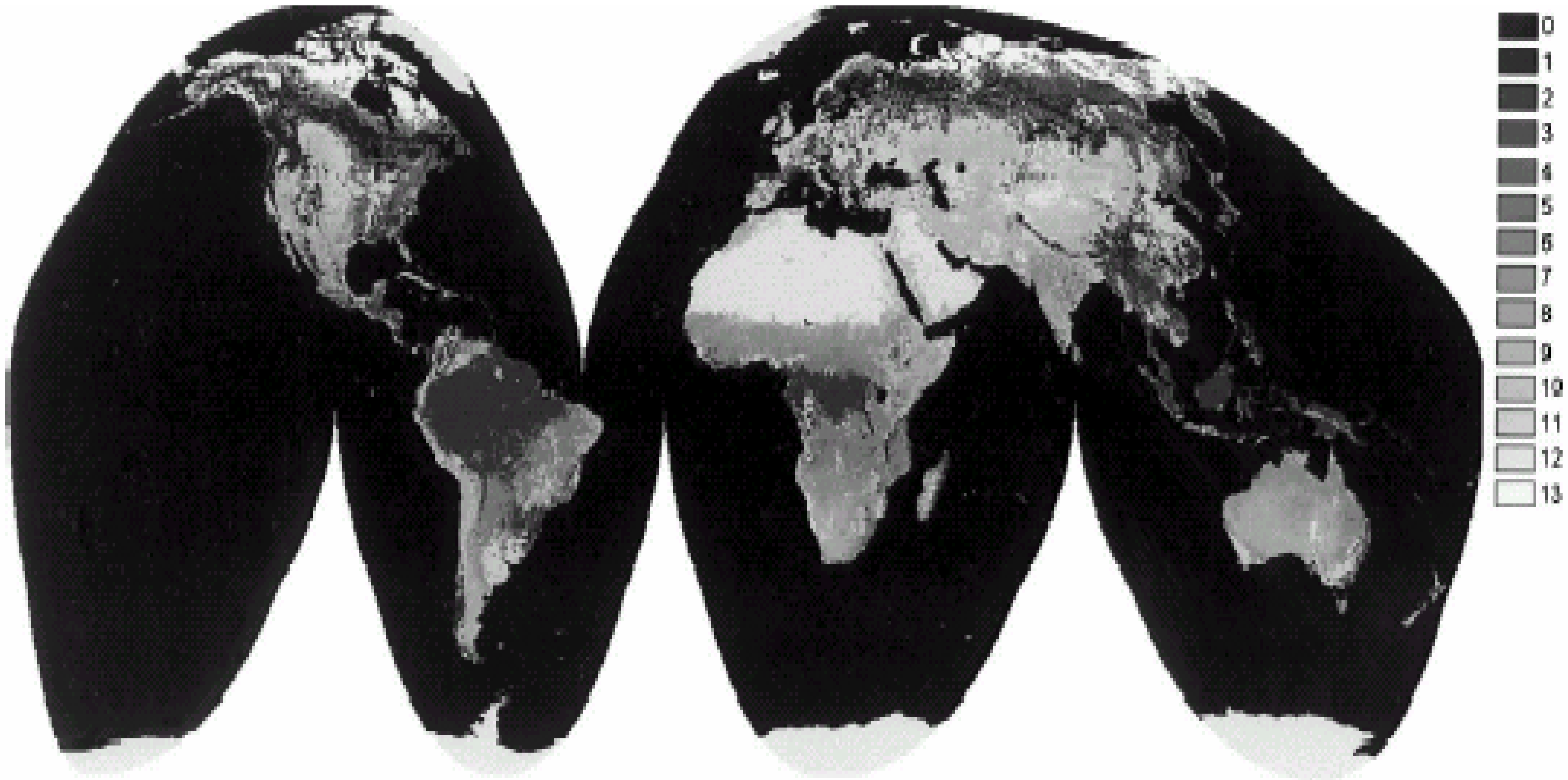
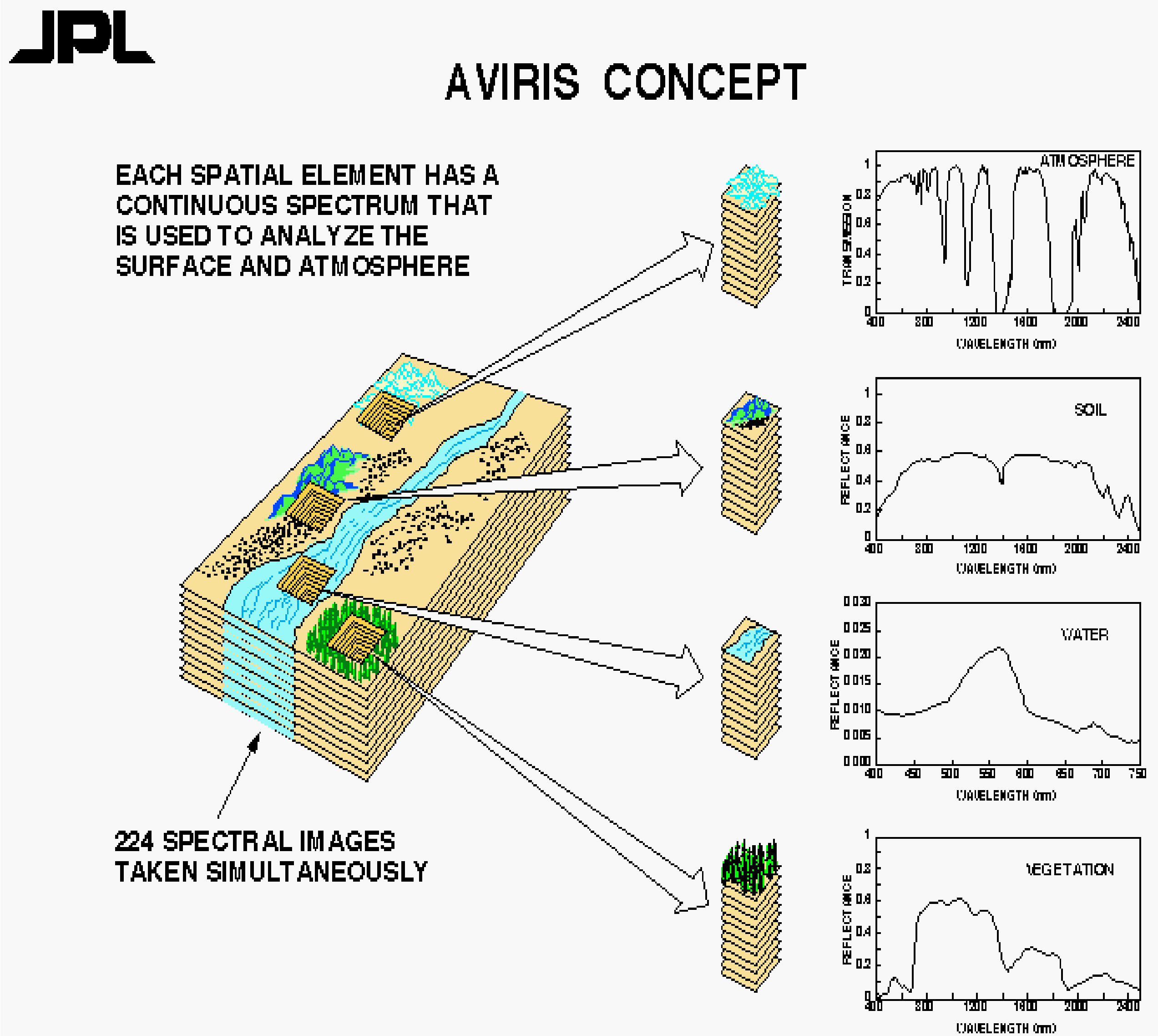


Figure 4.1 An example of a global land cover map. The map shown is that derived by DeFries *et al.* (1998) from NOAA AVHRR data. Although full appreciation requires colour, the map indicates the nature of land cover maps typically derived from satellite remote sensor data. The 13 land cover types shown are Evergreen needleleaf forests (1); Evergreen broadleaf forests (2); Deciduous needleleaf forests (3); Deciduous broadleaf forests (4); Mixed forests (5); Woodlands (6); Wooded

Exploiting advances in sensing technology

- EO-1 Hyperion
- Proba CHRIS
- Envisat MERIS
- ADEOS-II GLI



Remote sensing radionuclide contaminated forests in Belarus

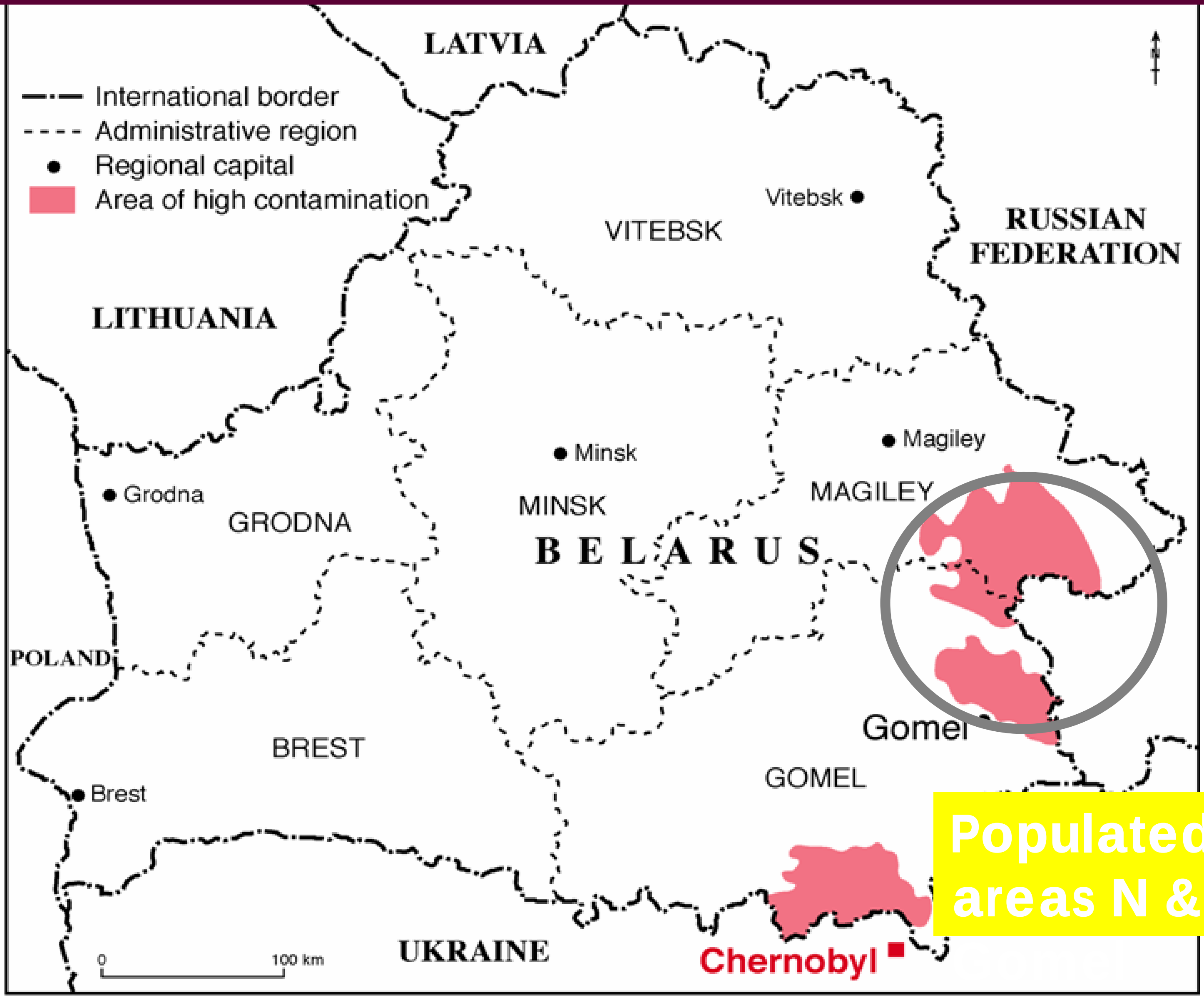
The Chernobyl disaster

- Explosion in reactor 4, April 1986
- 85Pbq Cs-137 released into environment
- Belarus received 80% of contamination
- Cs-137 predominant radionuclide

still remaining today (half life 30.5 years)

Main Regions of High Levels of Radioactive Fallout (>555kBq/m² Cesium-137 in 2001)

Main Regions of High Levels of Radioactive Fallout ($>555 kBq/m^2$ Cesium-137 in 2001)



Populated areas N & NE of

Civinka, Vetka District (relocated 1991)


"My home..
1940 - 1991"

Agricultural land, forest, enterprises and resources removed from service as a consequence of Chernobyl

- 264 000 ha agricultural land
- 200 000 ha forest
- 54 agricultural & forest enterprises
- 9 service enterprises
- 22 raw material deposits

Source: UNDP/UNICEF (2002)

Investigate remote sensing of radionuclide contaminated forest

- Information on radionuclide concentration will afford the division of the forests into categories related to their ecological and economic capabilities.
- Make decisions about future forestry practices and land-use in order to promote a sustainable economy in Belarus

Pinus sylvestris (12-25 years)

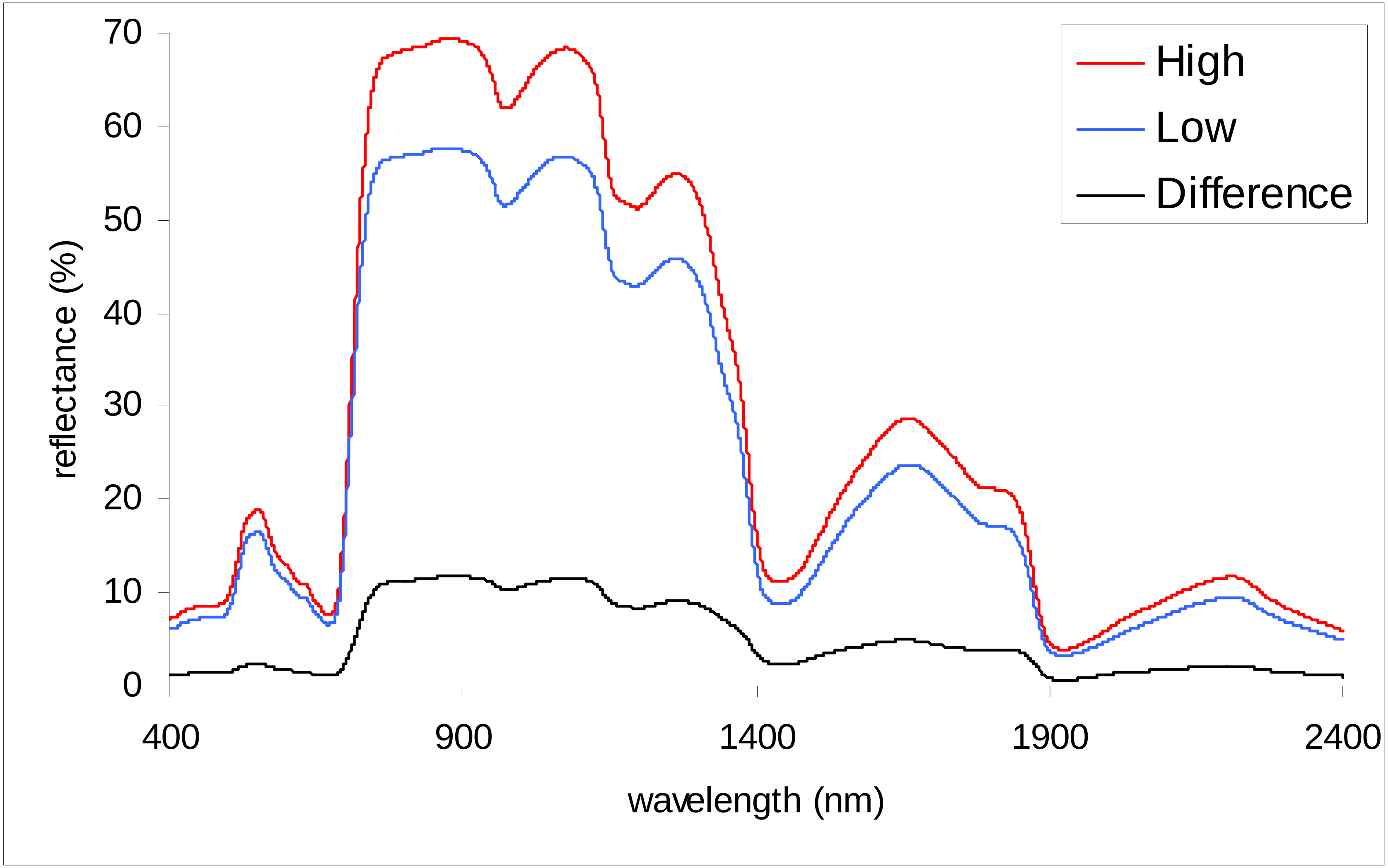
0.06 ± 0.01 uSv/hr

1.59 ± 0.72 uSv/hr

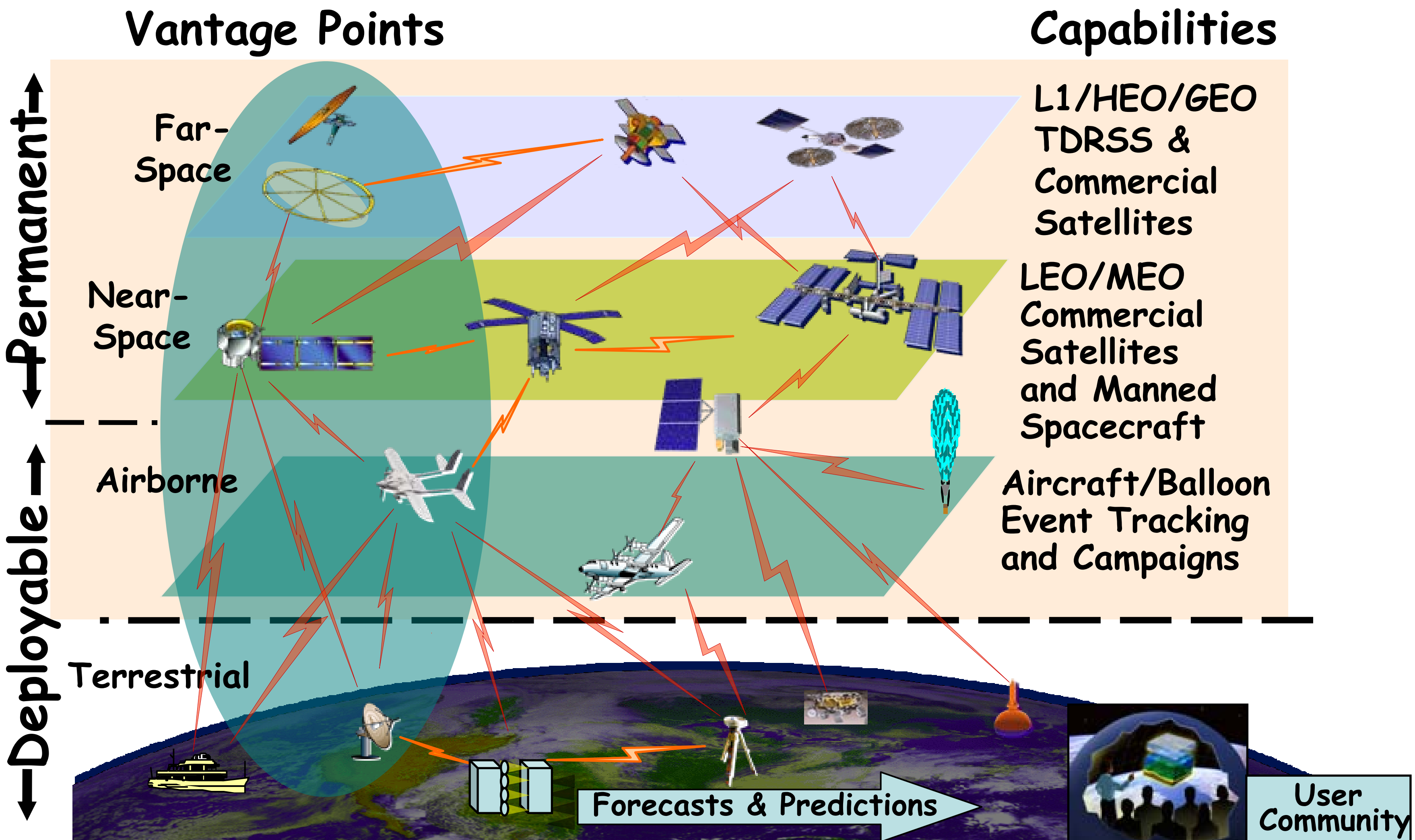
Pinus sylvestris (>70 years)

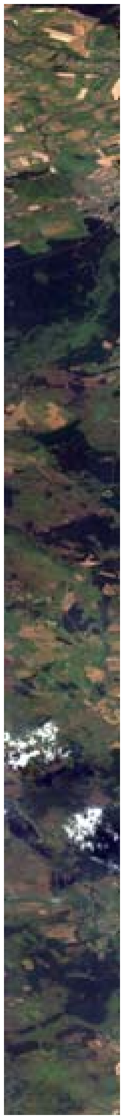
0.15 ± 0.06 uSv/hr

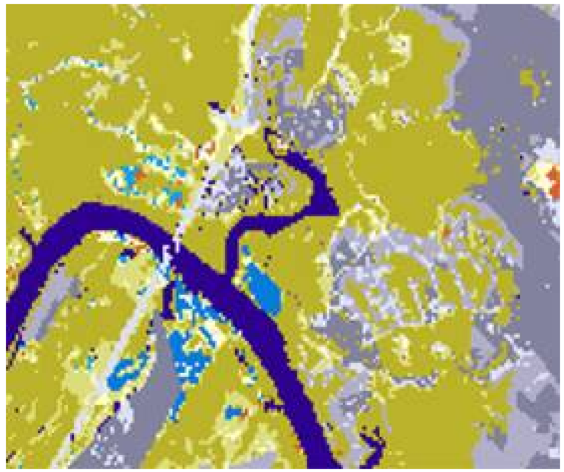
1.67 ± 0.59 uSv/hr

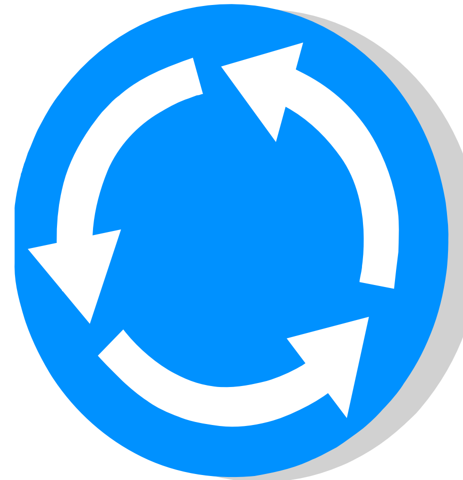

reflectance (%)
wavelength (nm)
0
10
20
30
40
50
60
70
400
900
1400
1900
2400
High
Low
Difference

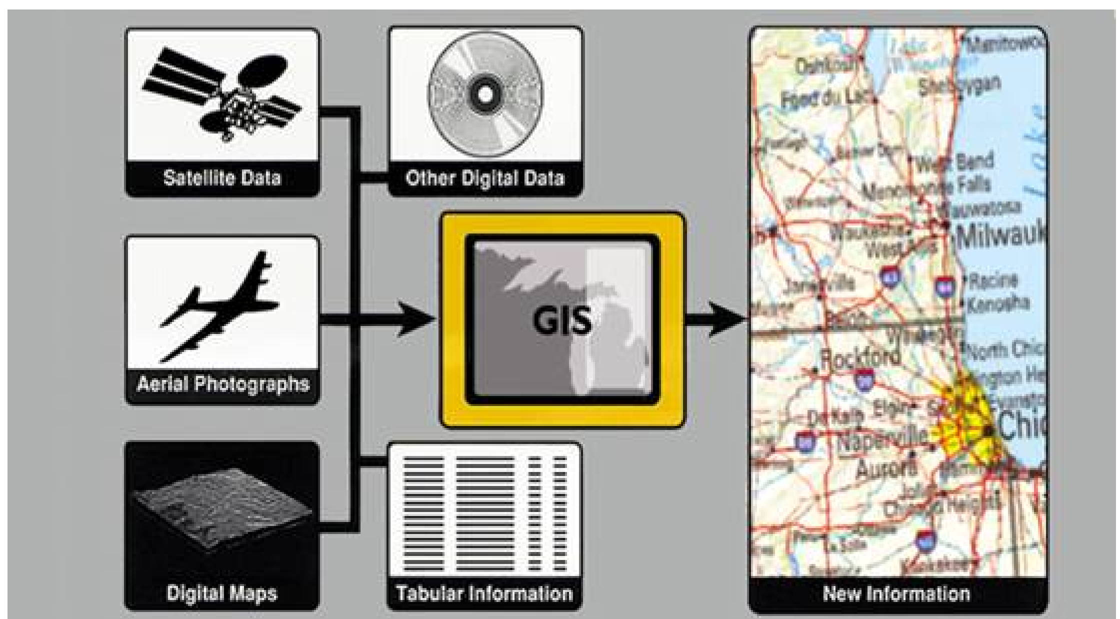
Coordinating Earth Observing Systems










Satellite Data
Other Digital Data
Aerial Photographs
GIS
Digital Maps
Tabular Information
New Information

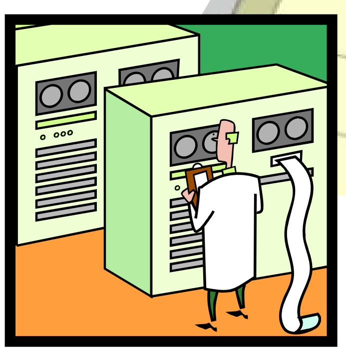
Spatial data

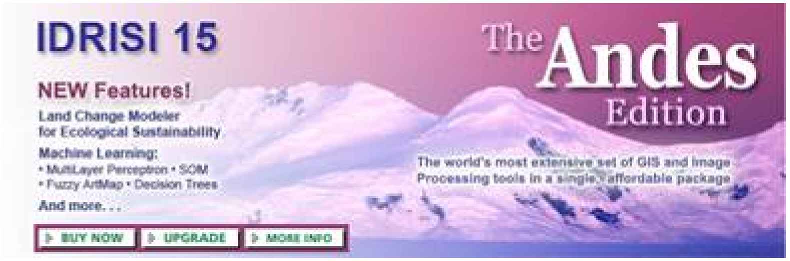
http://www.kingston.ac.uk/centreforgis/resources.htm

GIS

An objective !

Hardware and software tools





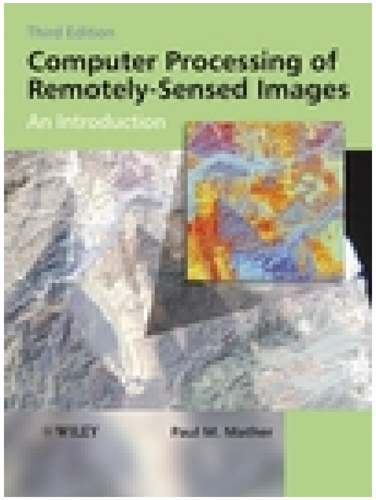
ER Mapper
ER Viewer

ArcGIS ESRI

ORACLE

MapInfo

Laser-Scan



cadcorp

INTERGRAPH

GeoMedia
GeoMedia
Professional

Autodesk

http://homepage.ntlworld.com/paul.mather/ComputerProcessing3/index.html

Acknowledgments

- Many of the diagrams have been redrawn from Boyd, D.S. (2004) Physical basis of remote sensing. In P.M. Atkinson (ed.) Encyclopaedia of Life Support Systems. UNESCO, New York.
- NERC EPFS/FSF for loan of spectroradiometer to conduct fieldwork in Belarus and colleagues at Universities of Kingston, Northumbria and Salford.