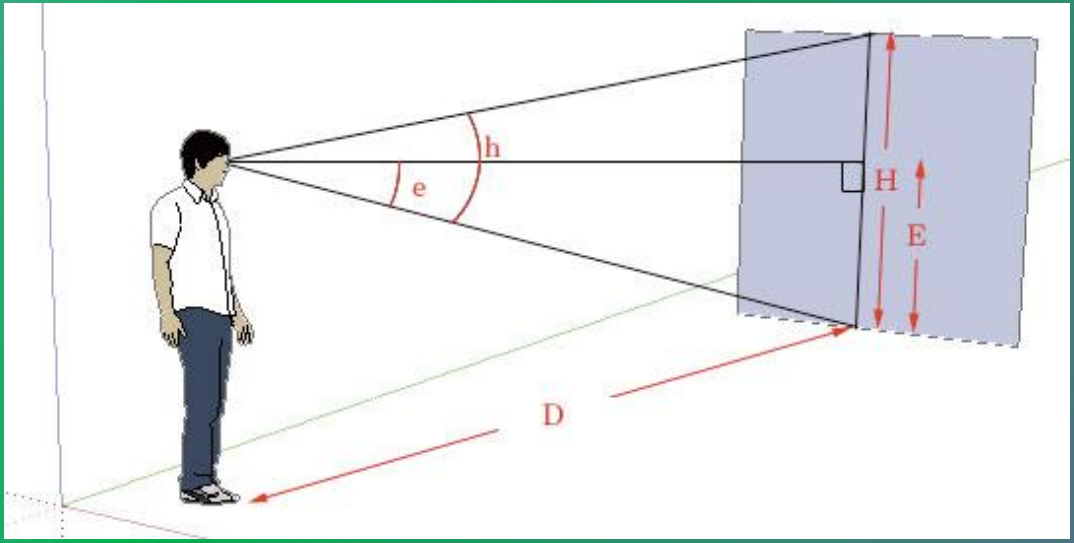
An Intro to Remote Sensing

Dr. Marios Spiliotopoulos

What is remote sensing ?

- Remote – away from a distance
- Sensing – detecting a property or characteristic



Remote Sensing

The term "remote sensing," first used in the United States in the 1950s by Ms. Evelyn Pruitt of the U.S. Office of Naval Research

Definition

Remote sensing → The acquisition of information about an object, without being in physical contact with that object.

Reading with our eyes is a form of remote sensing.

Actually, remote sensing includes not only what is visual, but also what can't be seen with the eyes, which can be for example sound or heat.

Definition

Remote Sensing generally involves the detection and measurement of radiation at different wavelengths

Radiation may be reflected or emitted from distant objects or materials

Wavelengths can identify and categorize the objects by class/type, substance, and spatial distribution

Early History of Remote Sensing

- 1839 → the first photographs. The term "photography" is derived from two Greek words meaning "light" (phos) and the art of drawing or "writing" (graphien). Photographic camera captures an image by concentrating visible light through a lens onto a recording medium.
- 1849 → photography in topographic mapping (Colonel A. Laussedat)
- 1858 → use of balloons for large area mapping
- Mid 1930s → color photography
- 1939→ the term RADAR is used for the first time
- World War II → aerial photography became widespread

Aerial Photo

Labrugauere, France→(A. Balut 1889)

Post-War History

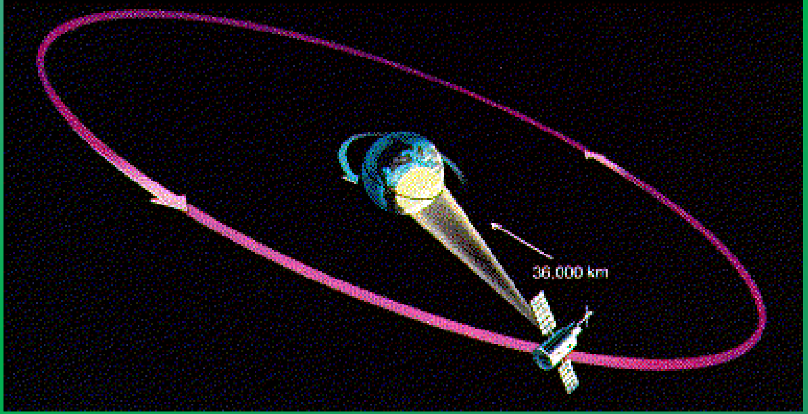
- After World War II → Cameras were launched on rockets
- 1957 → Russians launched the first successful Earth satellite, Sputnik 1
- 1958 → US launched its first satellite, Explorer 1
- 1959 → Vanguard 2, the first satellite with a meteorological instrument, was launched
- 1960 → the first satellite images comes from the TIROS 1

The age of instrument development

1964-1972

- 1964 → Nimbus satellite series of experimental meteorological remote sensing was initiated.
- 1966→ meteorological satellites moved from being experimental to being operational
- 1966→The Defense Meteorological Satellite Program (DMSP) was started by the U.S. Air Force
- 1972→ Landsat 1 was launched

1972-1993



- **1975→** The Synchronous Meteorological Satellites.
- **1976→** Laser Geodynamic Satellite I.
- **1978 →** The Heat Capacity Mapping Mission.
- **1978 →** Seasat demonstrated techniques for global monitoring of the Earth's oceans.
- **1978 →** Nimbus 7, the final satellite in that series, was launched.
- **1984 →** The Earth Radiation Budget (ERBE) satellite began its study of how the Earth absorbs and reflects the Sun's energy.
- 1991 → Launch of European Radar Satellite ERS-1, the first satellite with an altimeter able to map the earth surface to within 5 cm
- 1993→ Launch of SPOT-3, Landsat 6 fails to achieve orbit, Launch of Meteosat-6

1994-today

- 1994→ First G.P.S. constellation
- 2012→ 1000 satellites orbit the Earth
- 2014,2015 → Sentinel Mission

Product per satellite/instrument (Toulios *et al*., 2008)

Product	Type of satellite / instrument
NDVI	(MODIS/TERRA-AQUA,AVHRR/NOAA,VEGETATION/SPOT,TM/LANDSAT,SEVIRI/ METEOSAT)
Surface temperature	(AVHRR/NOAA,TM/LANDSAT,ASTER/TERRA,MODIS/TERRA-AQUA, SEVIRI /METEOSAT)
LAI	(MODIS / TERRA)
MSAVI	(VEGETATION / SPOT)
Cloud products	(SEVIRI / METEOSAT, NOAA / AVHRR)
Snow cover	(MODIS / TERRA, SEVIRI / METEOSAT)
Radiation	(SEVIRI / METEOSAT)
Vegetation/land cover	(TM-ETM / LANDSAT, ASTER /TERRA, SEVIRI / METEOSAT)
Precipitation	(SEVIRI / METEOSAT, GEO / LEO satellites, TOVS/NOAA)
SAF products	(METEOSAT, NOAA, AQUA)
Air-stability	(SEVERI / METEOSAT)
Storm detection	(SEVERI / METEOSAT)
Ozone	(TOVS / NOAA)
Evapotranspiration	(TM/LANDSAT,ASTER/TERRA, AVHRR/NOAA)
Soil moisture	(ASCAT / METOP)
VCI,TCI,VHI,TVDI	(AVHRR / NOAA)
Degree days	(AVHRR / NOAA)
CCD	(METEOSAT)
Albedo	(SEVIRI / METEOSAT, AVHRR / NOAA)
Sea ice	(AVHRR / NOAA)
Sea wind	(METOP)

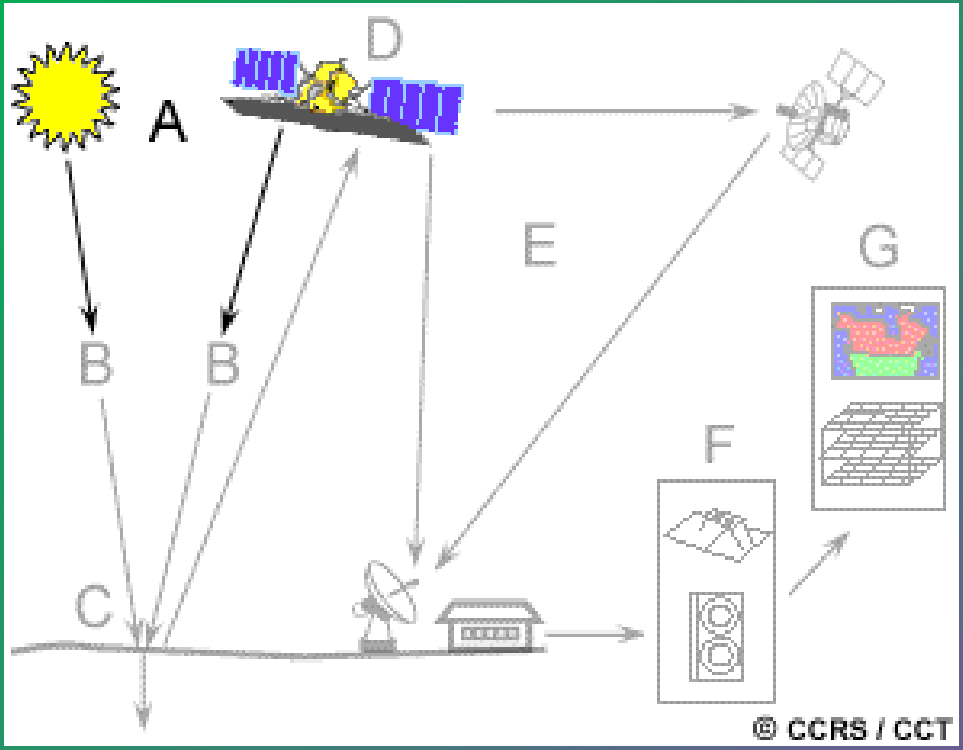
Sensor Types

Land Observing Sensors and their Features

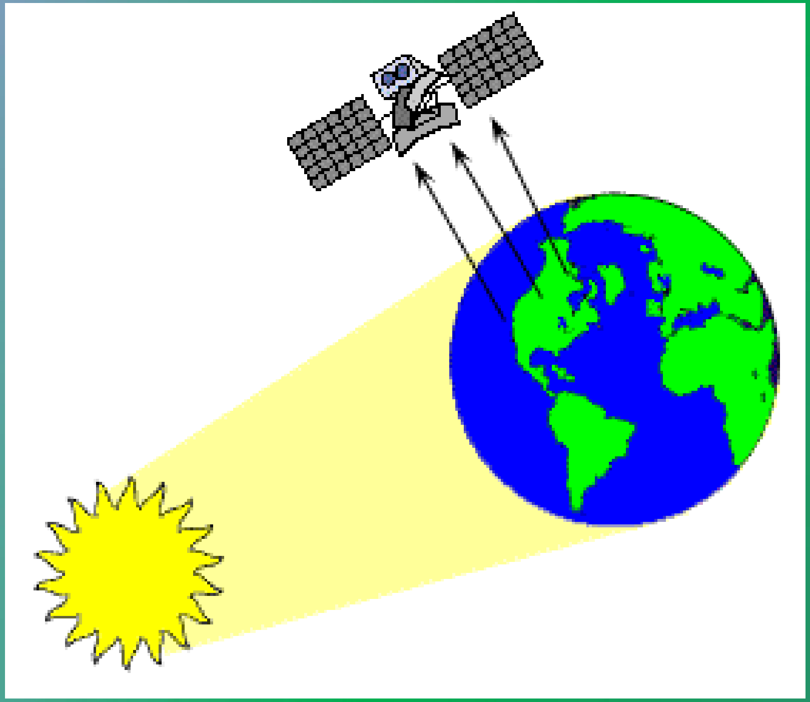
Sensor Name	Pixel Resolution	Swath Width, km	No. Spectral Bands	Spectral Coverage	Temporal Repeat, days
Weather, Global Coverage Satellites					
AVHRR	1.1km	2700	5	VNIR, TIR	4*day
SPOT Vegetation	1.15km	2250	4	VNIR, SWIR	26
MODIS	0.25,0.5,1km	2330	36	VNIR, SWIR, TIR	2* day
Regional Satellites					
Sensor	m	km	bands	Spectral	Repeat
ASTER	15, 30, 90	60	16	VNIR, SWIR, TIR	16
Landsat TM	30, 120	185	7	VNIR, SWIR, TIR	16
Landsat ETM+	30, 60, 15	185	8	Pan + TM	16
SPOT HRV	10, 20	60	4	Pan, VNIR	26
SPOT HRVIR	10, 20	60	5	SWIR + HRV	26
Local Coverage Satellites					
Sensor	m	km	bands	Spectral	Repeat
Quickbird	0.61 Pan, 2.44	16.5	5	Pan, VNIR	2 to 11
IKONOS	1.0 Pan, 4	11.3	5	Pan, VNIR	3
AIRBORNE Instruments					
Sensor	m	km	bands	Spectral	Repeat
AVIRIS, Hymap	4, 20	2 km, 10 km	168 - 224	VNIR, SWIR	on demand
CASI-2	5-Jan	1 km - 2.5 km	48-288	VNIR	on demand
ADAR-5500	0.5 - 3	1 km - 2.5 km	4	VNIR	on demand

The remote sensing process

1) *Energy Source or Illumination*
2) *Radiation and the Atmosphere*
3) *Interaction with the Target*
4) *Recording of Energy by the Sensor*
5) *Transmission, Reception, and Processing*
6) *Interpretation and Analysis*
7) *Application*



Passive and Active Remote Sensing Systems

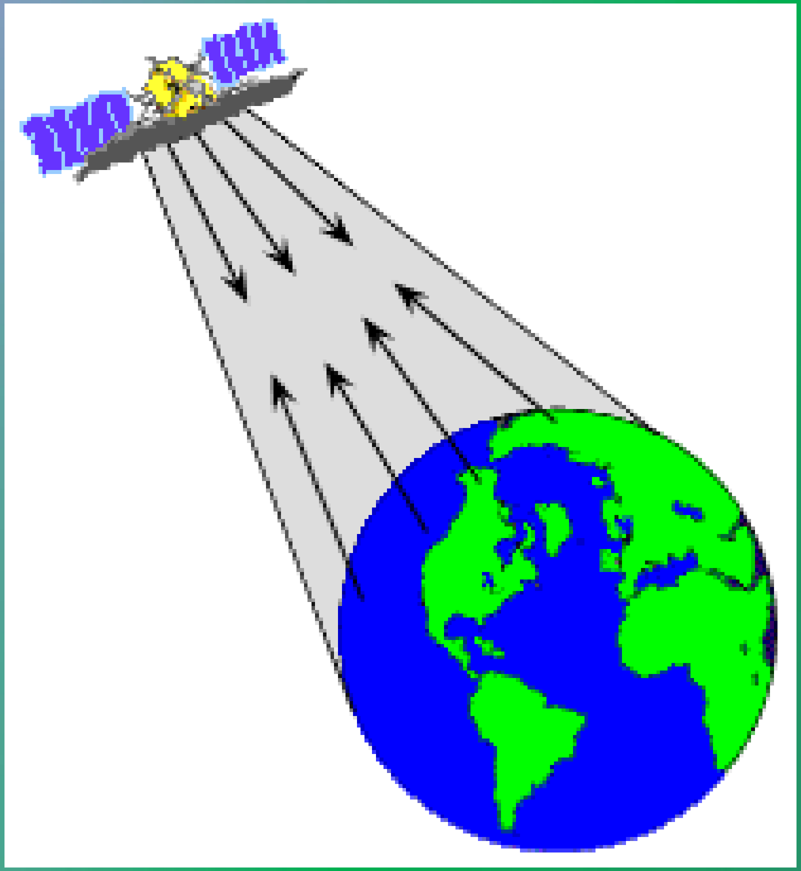


<u>Passive</u>: The sensor records energy that is reflected or emitted from the source, such as light from the sun. This is the most common system.

Passive Remote Sensors

- *Radiometer*
- *Imaging Radiometer*
- *Spectrometer*
- *Spectroradiometer*

Active Remote Sensing systems



Active: where the object is illuminated by radiation produced by the sensors, such as radar or microwaves.

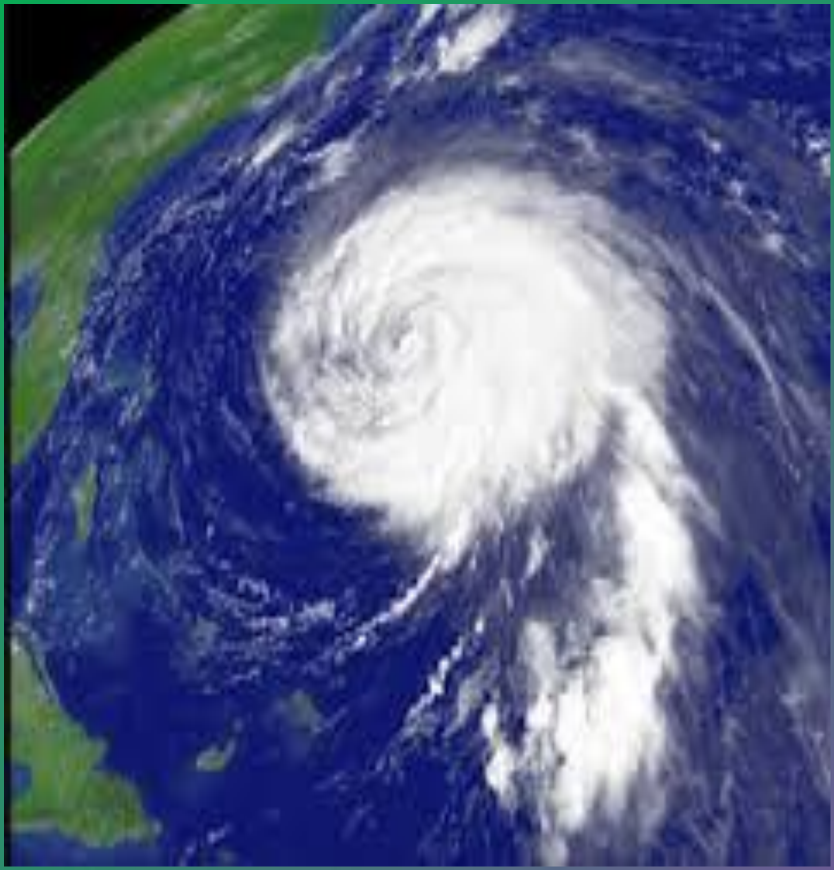
Active remote sensors

- ***Radar (Radio Detection and Ranging)***
- ***Scatterometer***
- ***Lidar (Light Detection and Ranging)***

Remote Sensing Applications

- ***Weather Systems:***

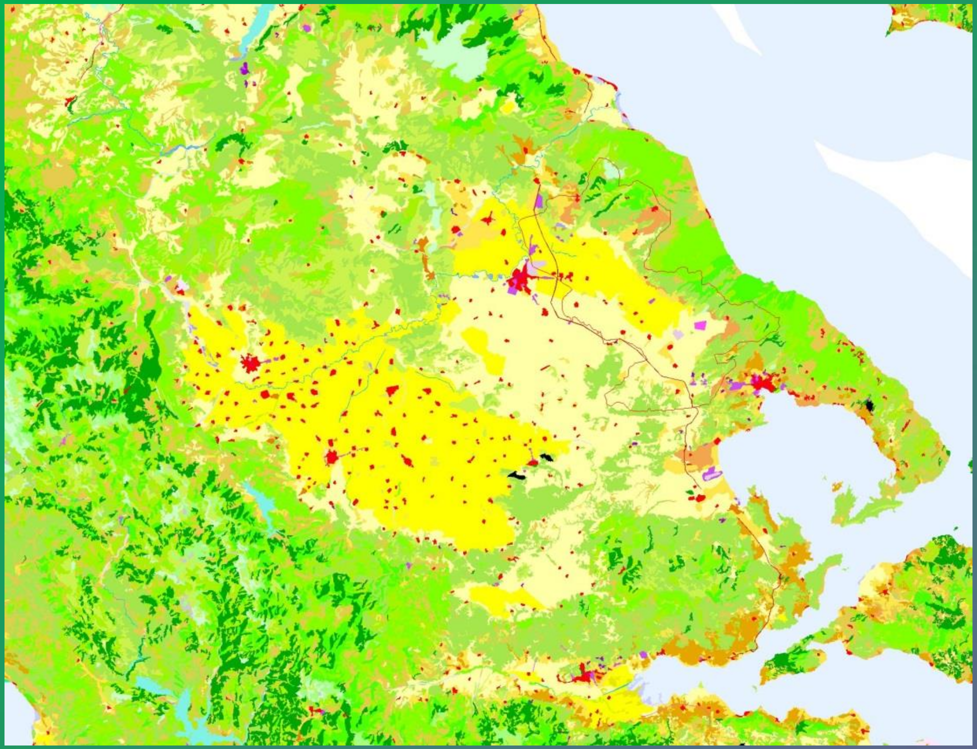
It is possible to monitor weather and climate conditions using information from satellites. Acquisition of images over time allow us to make weather forecast.



Remote Sensing Applications

- ***Agriculture:***

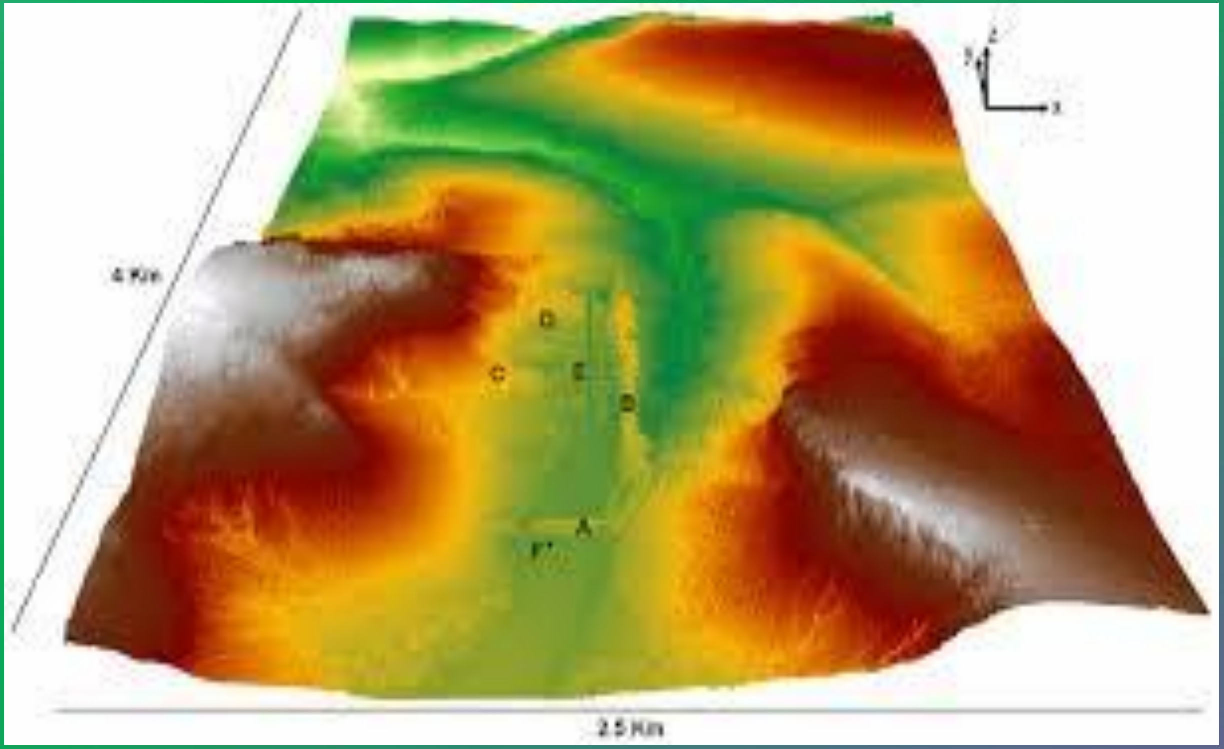
Crop mapping and yield prediction; crop damage due to storms, droughts or insects/diseases.



Remote Sensing Applications

- *Environmental Impacts*:

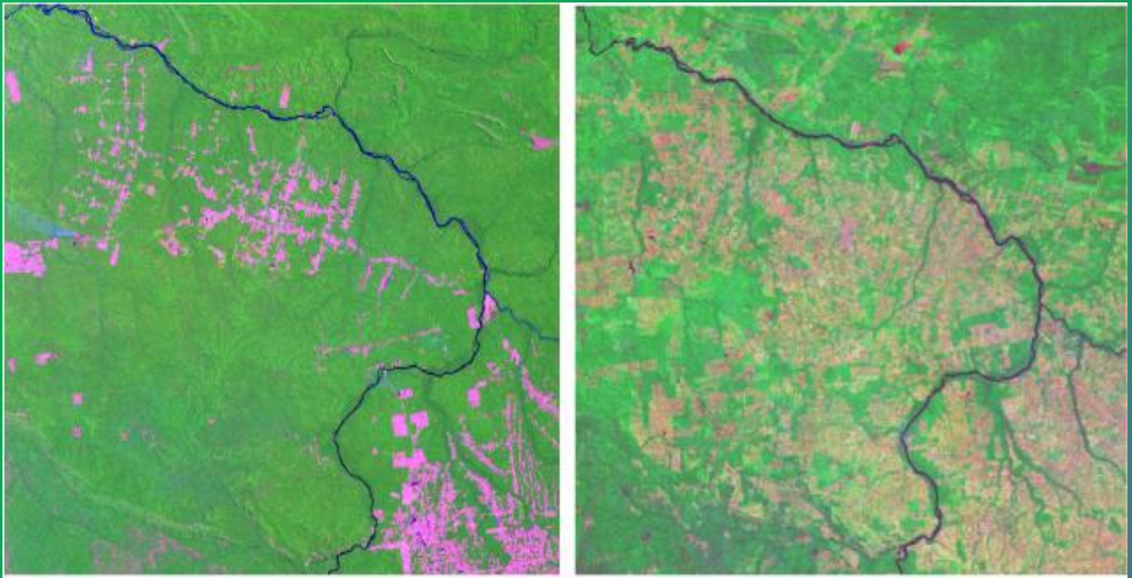
determine oil spill size, location, direction and magnitude of movement.



Remote Sensing Applications

- ***Forests Monitoring***:

Forest inventory, mapping cut-overs, forest fire mapping, species identification.



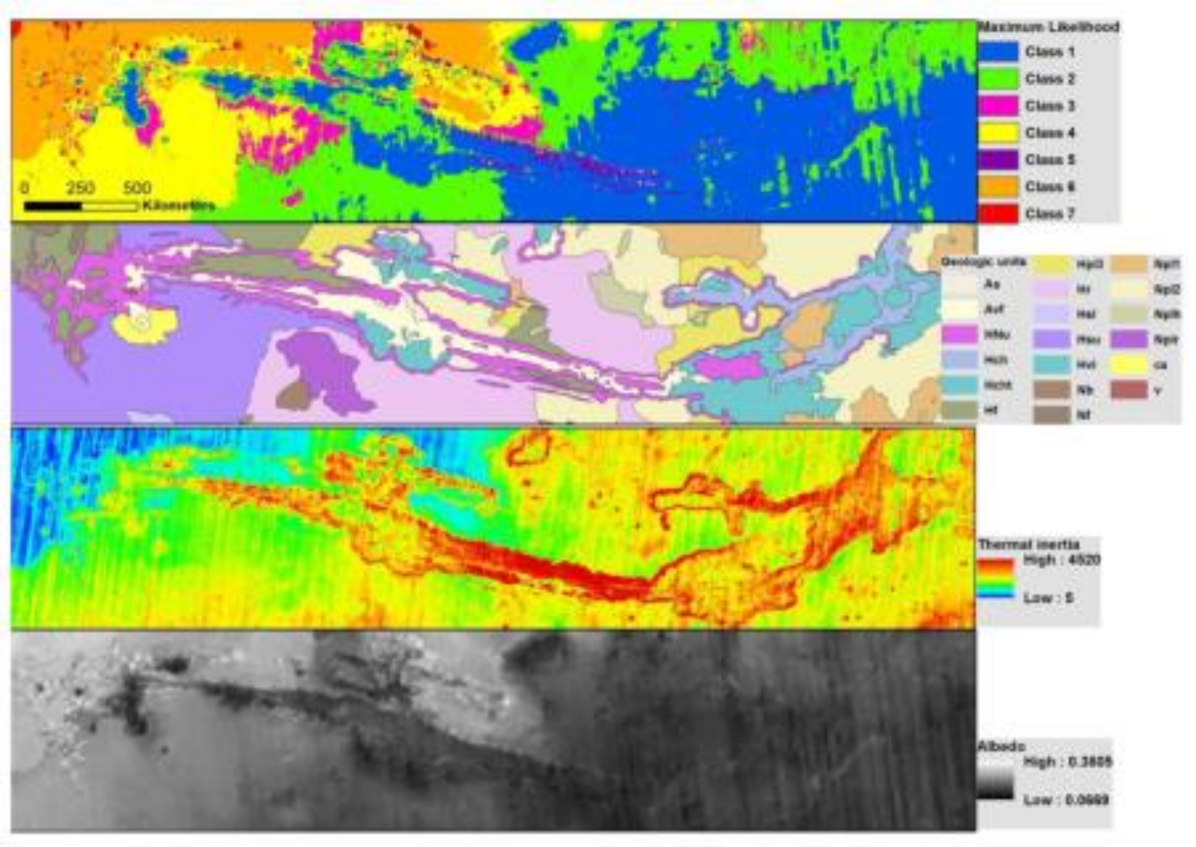
Landsat TM imagery (30 m resolution)
Year 1984
Image size: circa 150 km x 150 km

ENVISAT MERIS image (300 m resolution)
Year 2005
Image size: circa 150 km x 150 km

Remote Sensing Applications

- ***Geological Mapping*:**

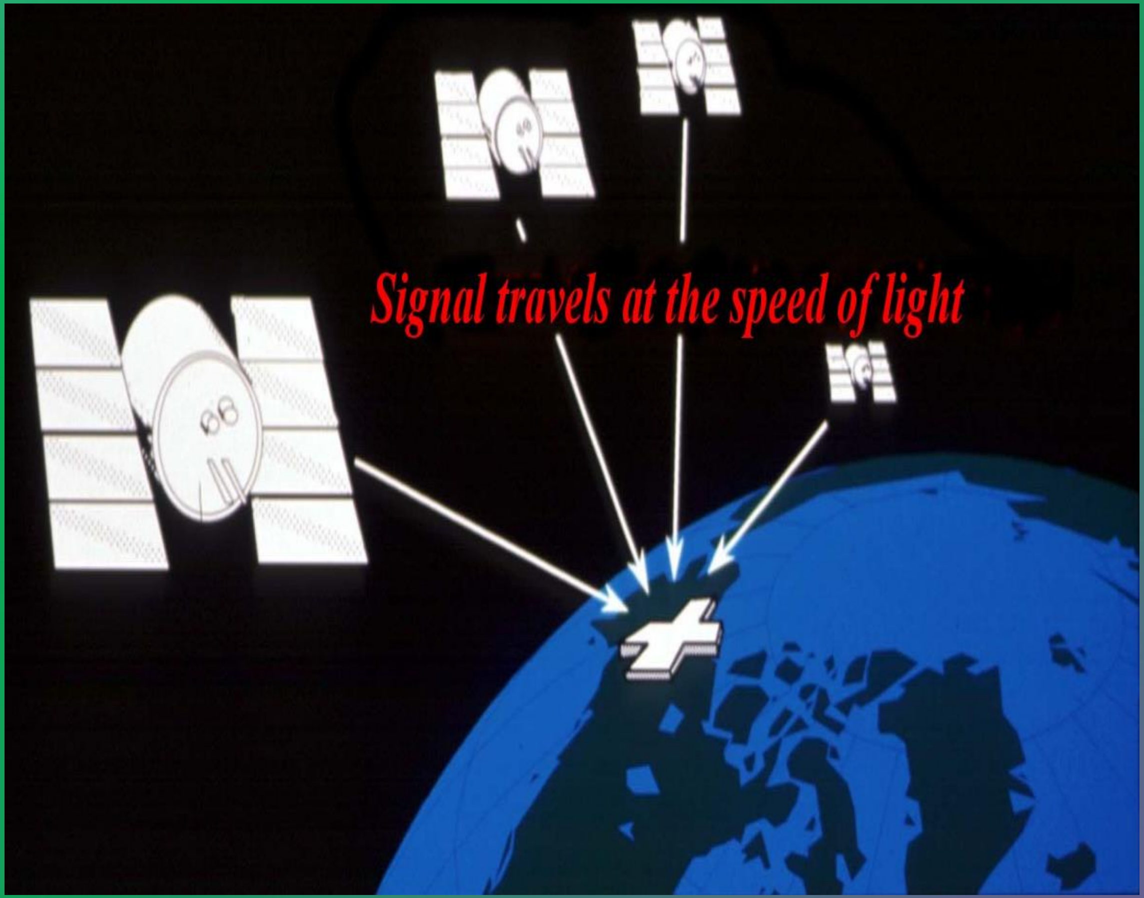
Mapping faults, folds, and rock types.



G.P.S. – Global Positioning System

Uses measurements from 4+ satellites

Distance = travel time x speed of light



G.P.S. – Global Positioning System

GPS:
4 or more satellites must be available all of the time.

About 32 satellites

Very high orbits

Several replaced every year.

Maps & Cartography

Maps have generally three main characteristics:

- Scale
- Projection
- Symbolization

Scale

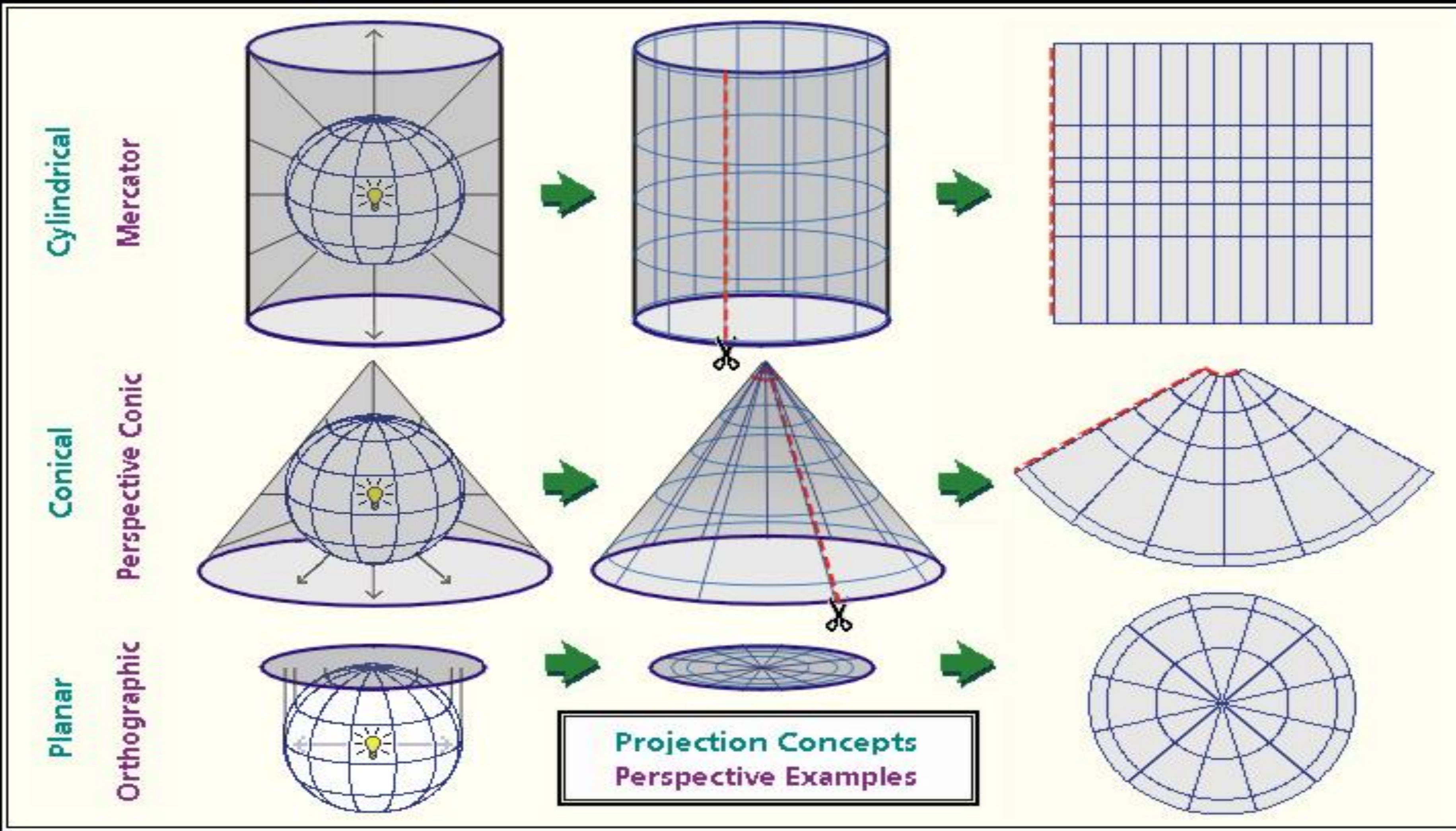
Scale Representation: There are three ways to represent map scales;

•as a **Ratio** or **Representative Fraction** (RF):
for example: 1:12,000 or 1/12,000
(NOTE that the Numerator and Denominator must be in the same units, making the RF a unitless representation.)

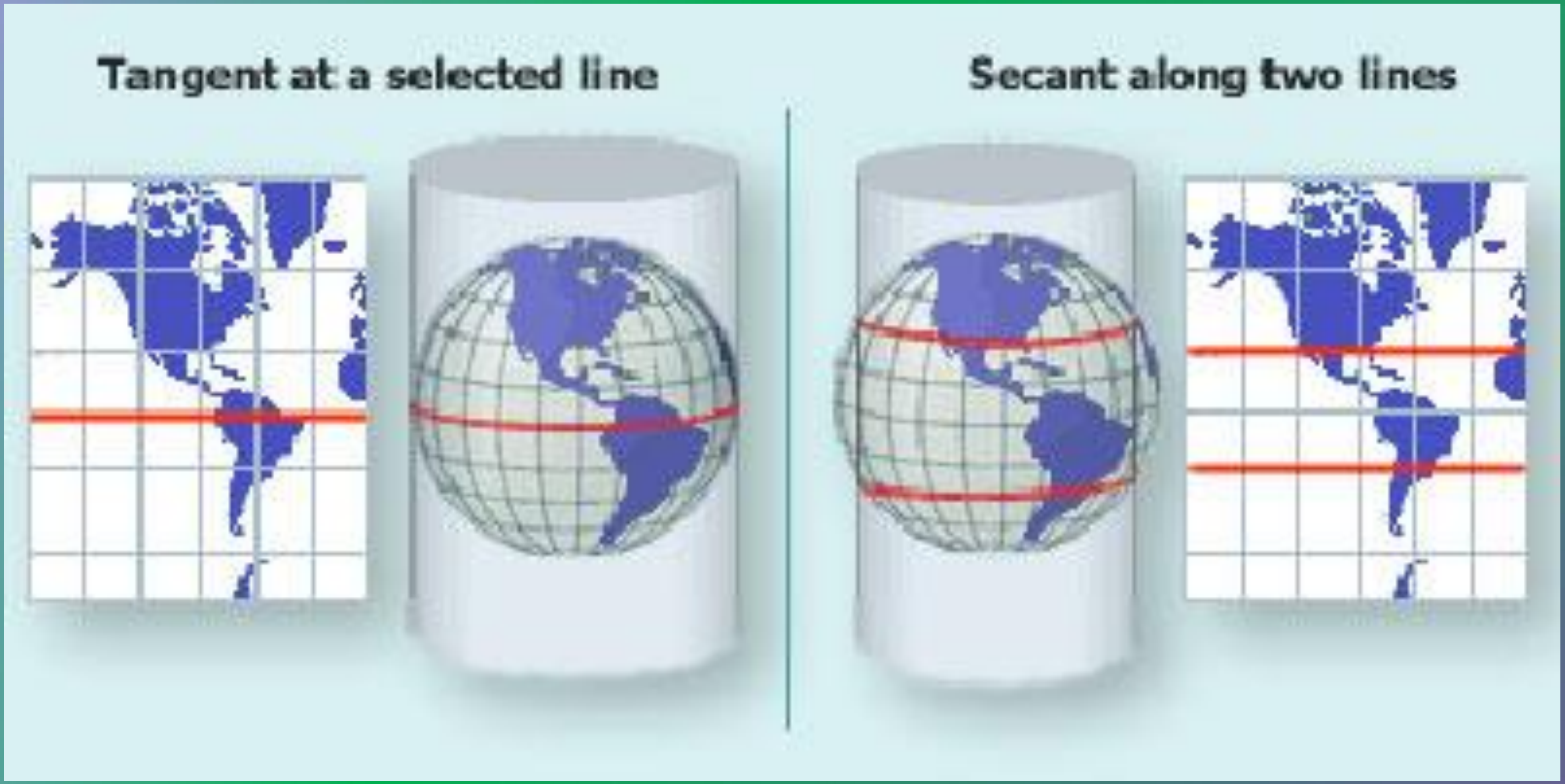
•as a **sentence demonstrating equivalence** (verbal scale):
for example: 1 inch equals 12,000 inches

•as a **Graphic or Bar Scale**:
for example:

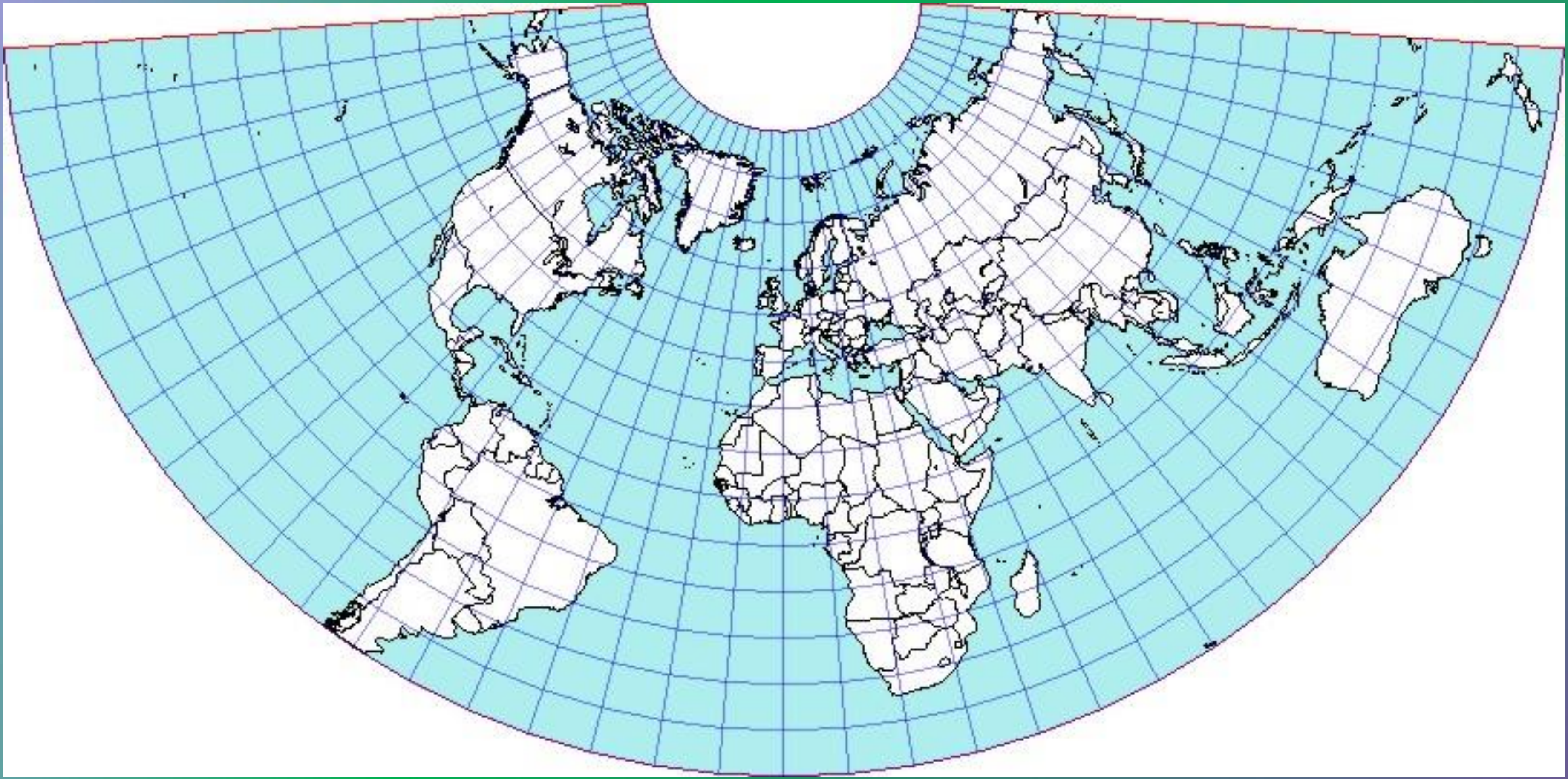
Map projections



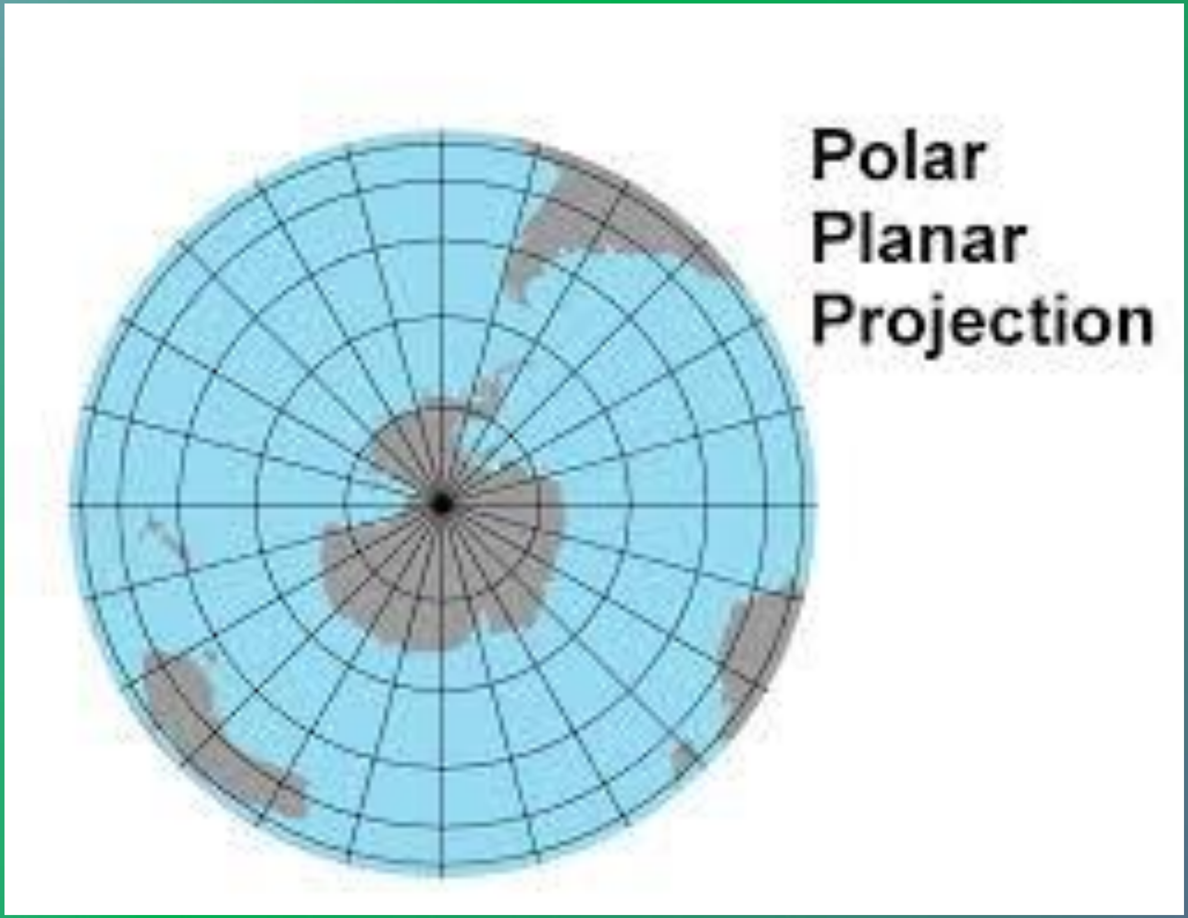
Cylindrical Projection



Conic Projection

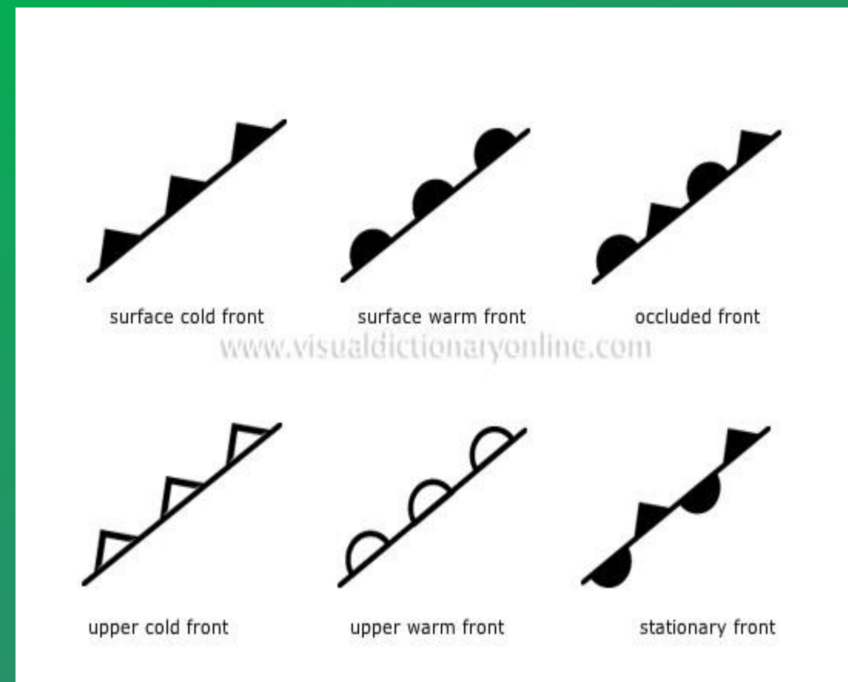


Planar Projection



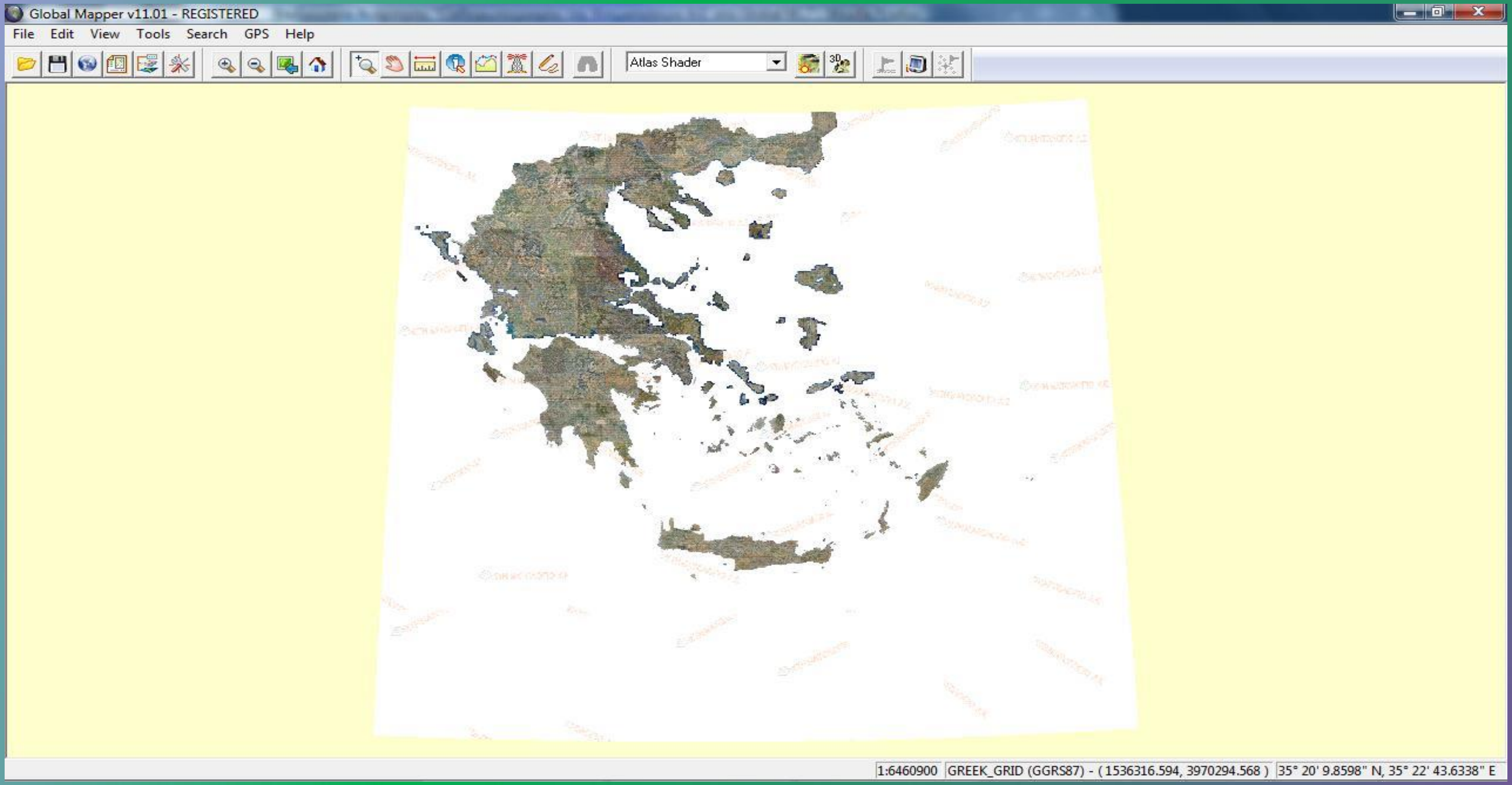
Map Symbolization

Feature Type	Visual Variable		
	Shape	Orientation	Color Hue
Point	Spring House Tower	Live Tree Dead Tree	Live Tree Dead Tree
Line	National Border Trail Section Line	Asphalt Road Concrete Road	National Border State Border
Area	Gravel Sand	Orchard Field Crop	Land Water



EGSA 87:
The Greek Grid

EGSA 87 → the Greek Geodetic Reference System

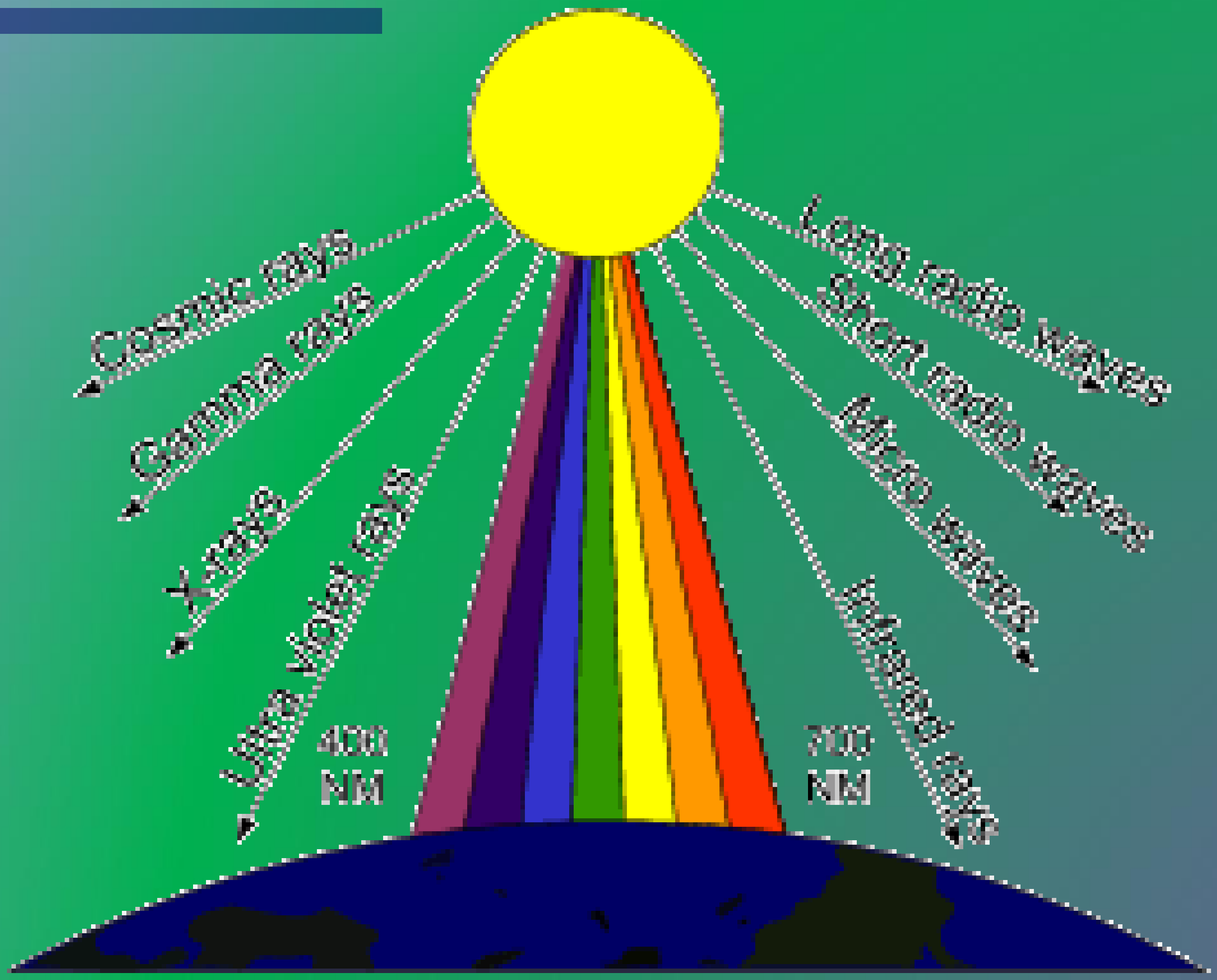


EGSA 87: The Greek Grid

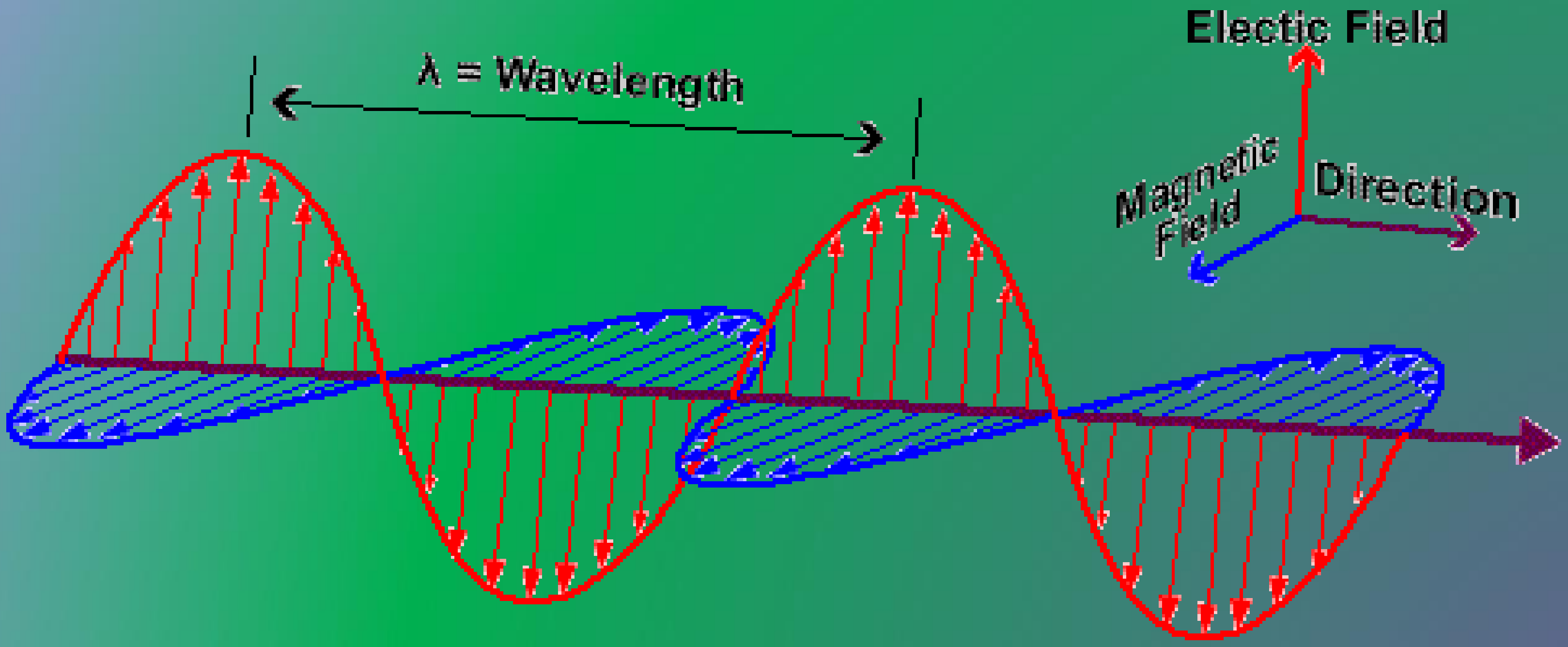
EGSA 87 Projection System	
Datum:	EGSA 87, defined by the Dionysos Satellite Observatory (DSO) northeast of Athens (38.078400º N & 23,932939º E).
Reference ellipsoid:	GRS'80
Major Axis a:	6378137.000m
Factor (1/f):	1/298.25722101
Scale factor Ko	0.9996

The entire Greek territory (stretching to approximately 9° of longitude) is projected in one zone. References are in meters. Northings are counted from the equator. A false easting of 500000 m is assigned to the central meridian (24° east), so eastings are always positive

Energy from the sun

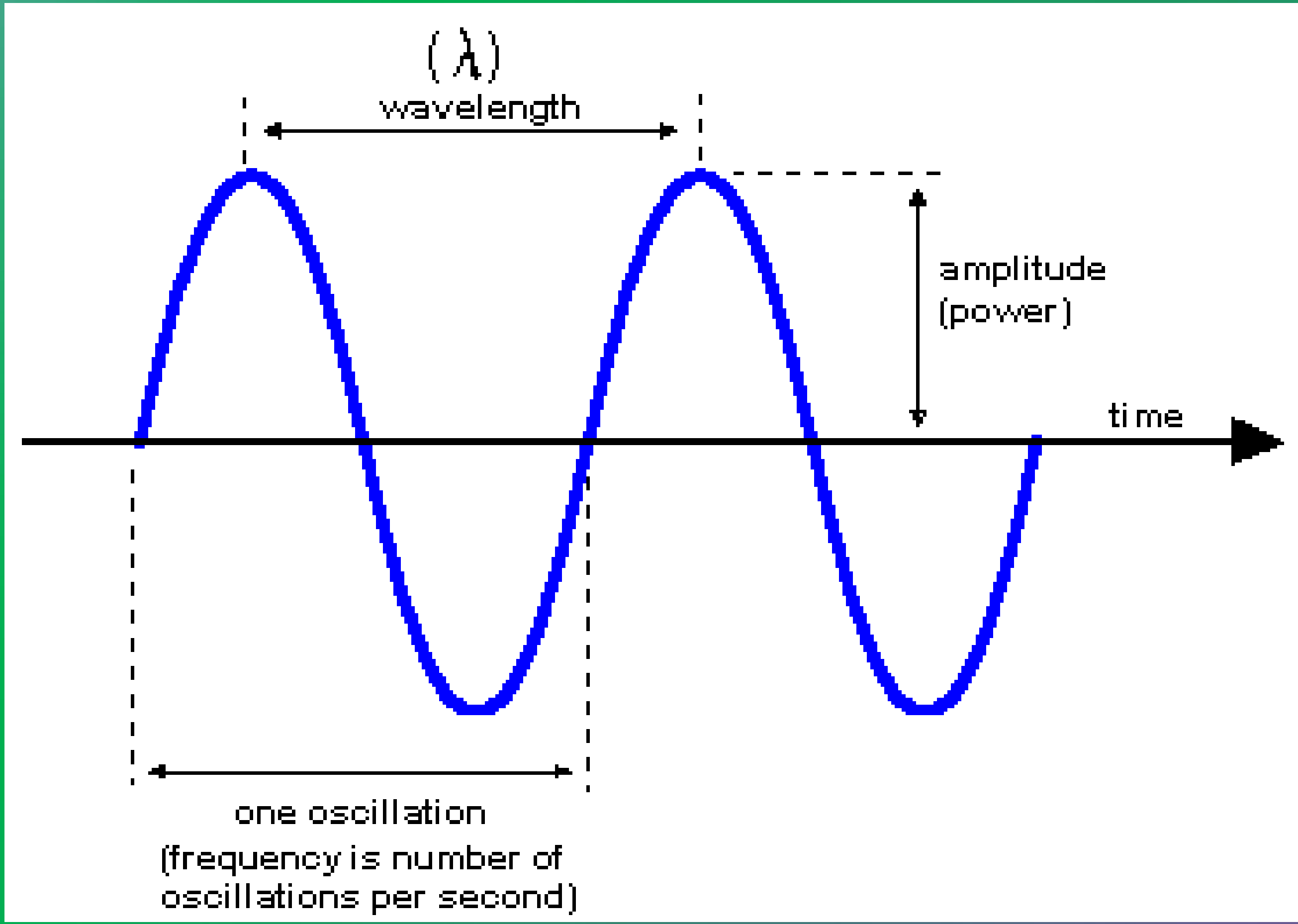


Electromagnetic radiation



What is wavelength?

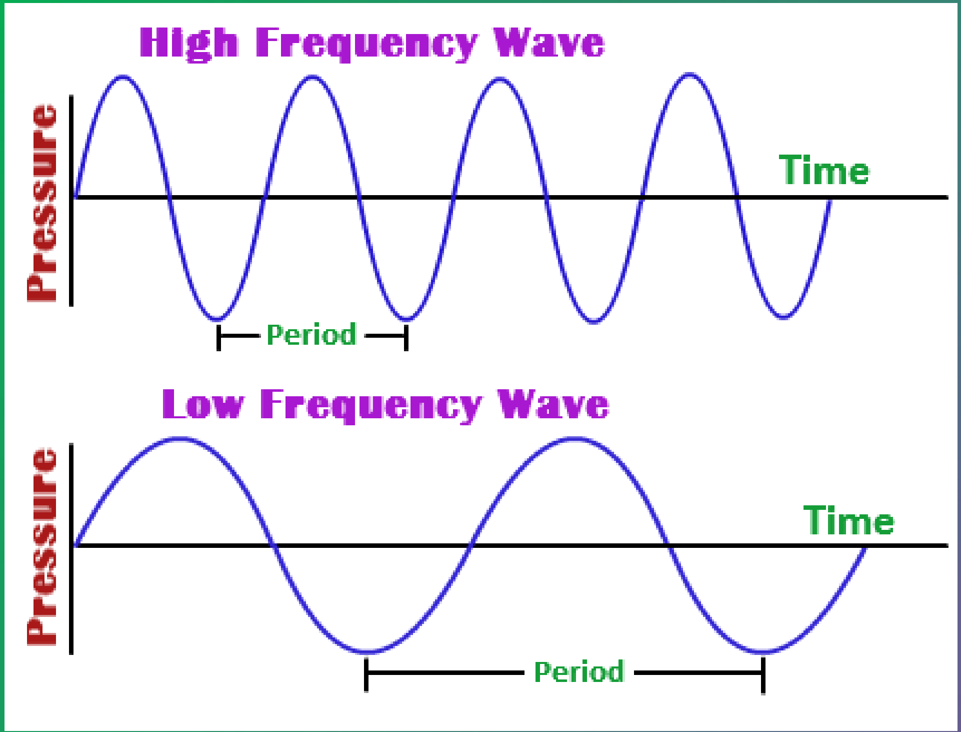
Wavelength is the length of one way cycle



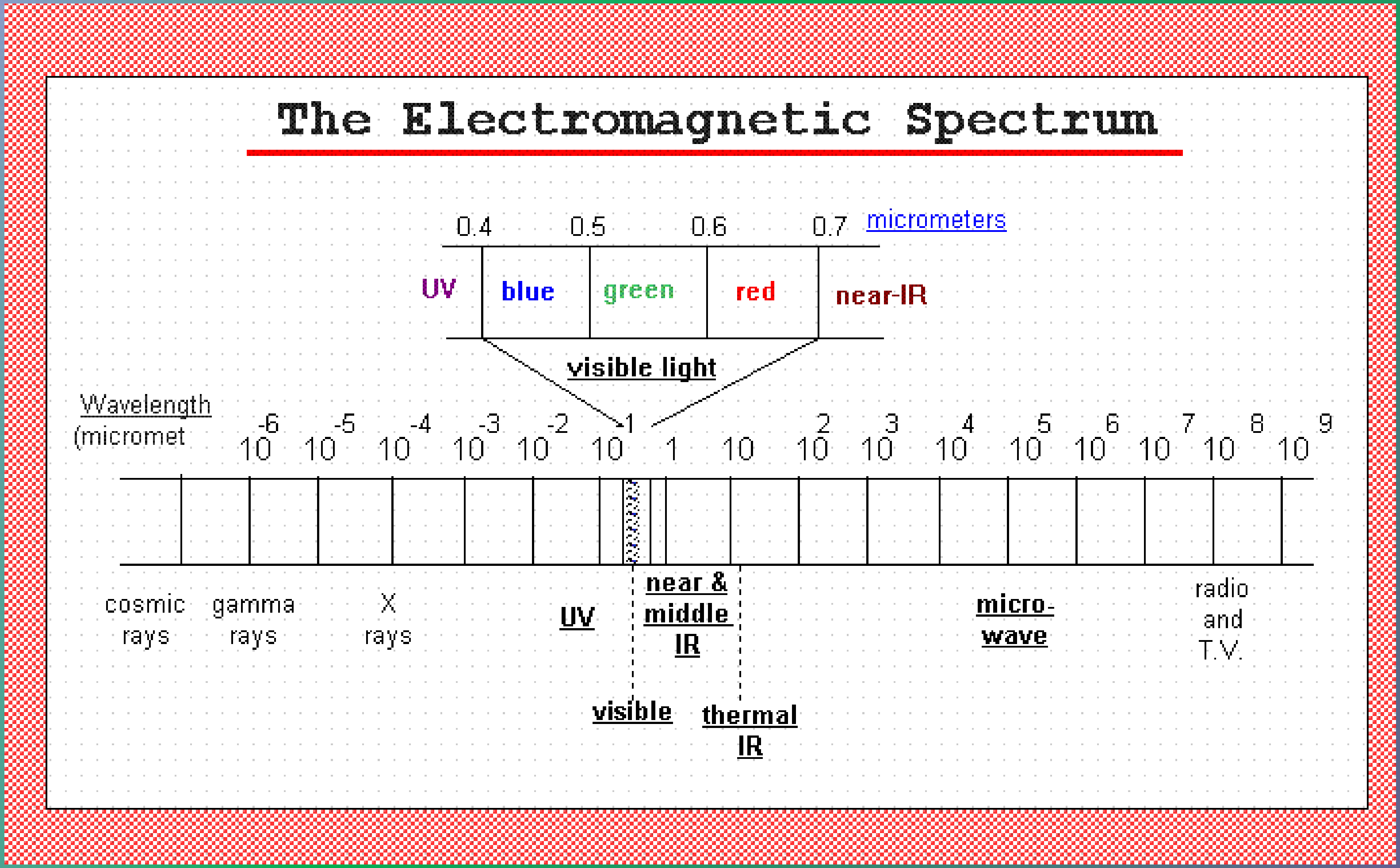
What is Frequency?

- Frequency → the number of cycles of a wave passing a fixed point per unit of time.
- Frequency → measured in **hertz** (Hz)

Frequency, *ν*, is inversely proportional to wavelength, λ The longer the wavelength, the lower the frequency, and vice-versa.

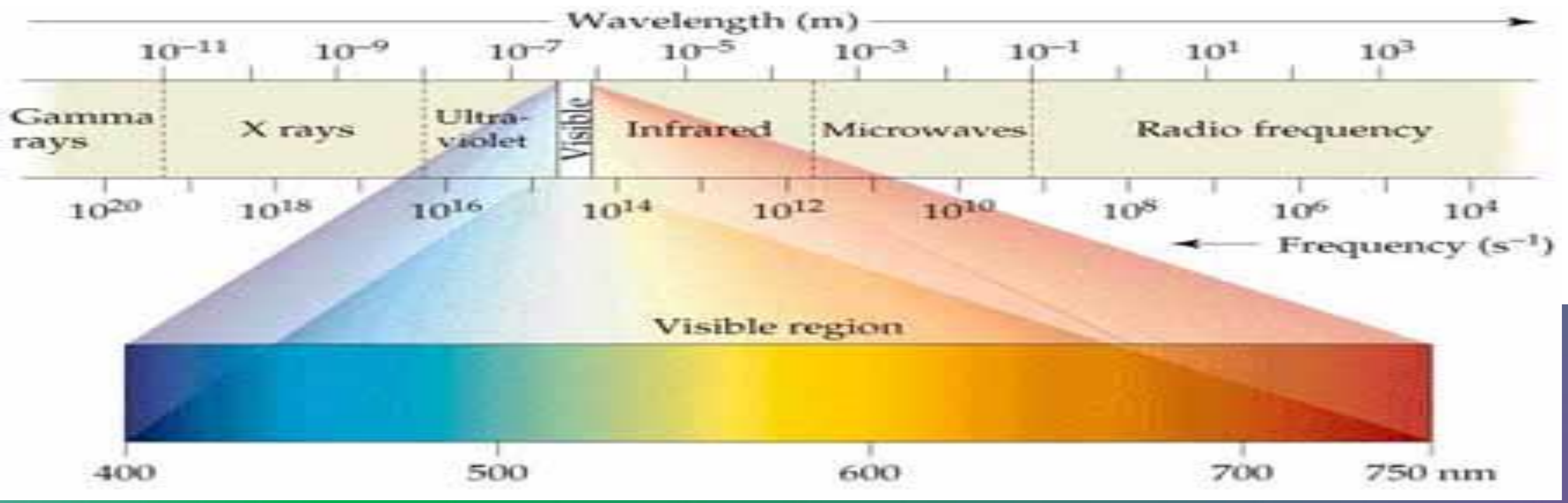


The Electromagnetic Spectrum

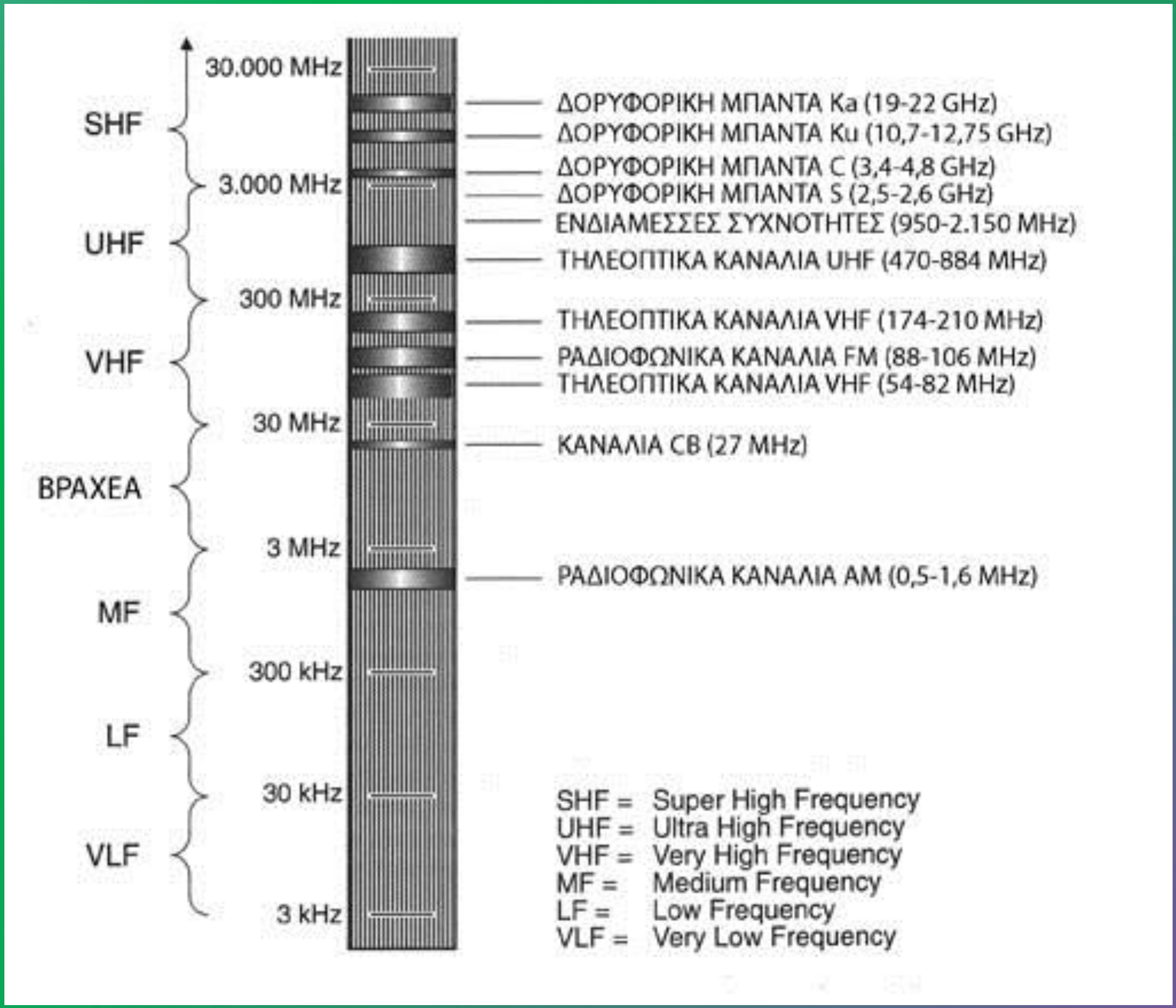


Units

Unit	Symbol	Length (m)	Type of Radiation
Angstrom	Å	10^{-10}	X ray
Nanometer	nm	10^{-9}	Ultraviolet, visible
Micrometer	μm	10^{-6}	Infrared
Millimeter	mm	10^{-3}	Infrared
Centimeter	cm	10^{-2}	Microwave
Meter	m	1	TV, radio

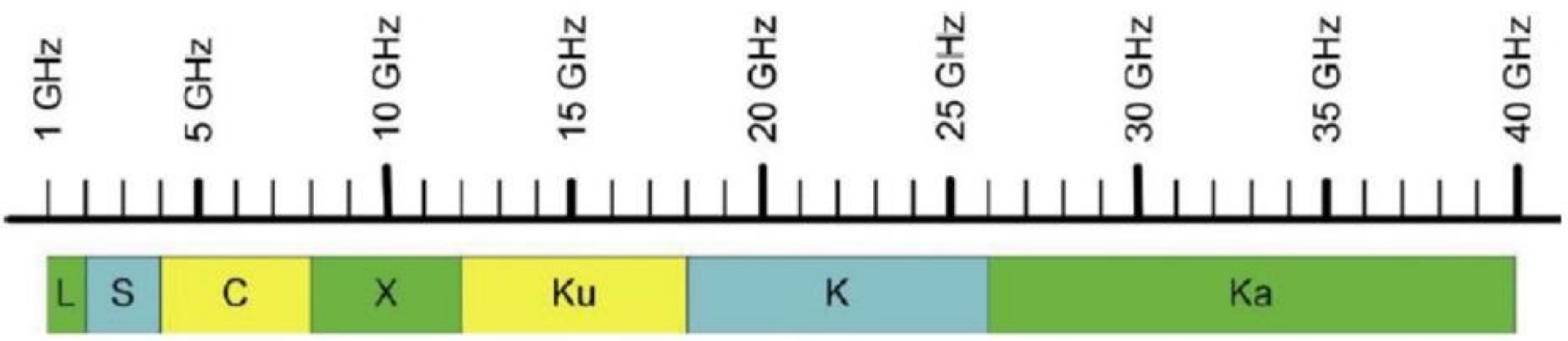


Satellite TV



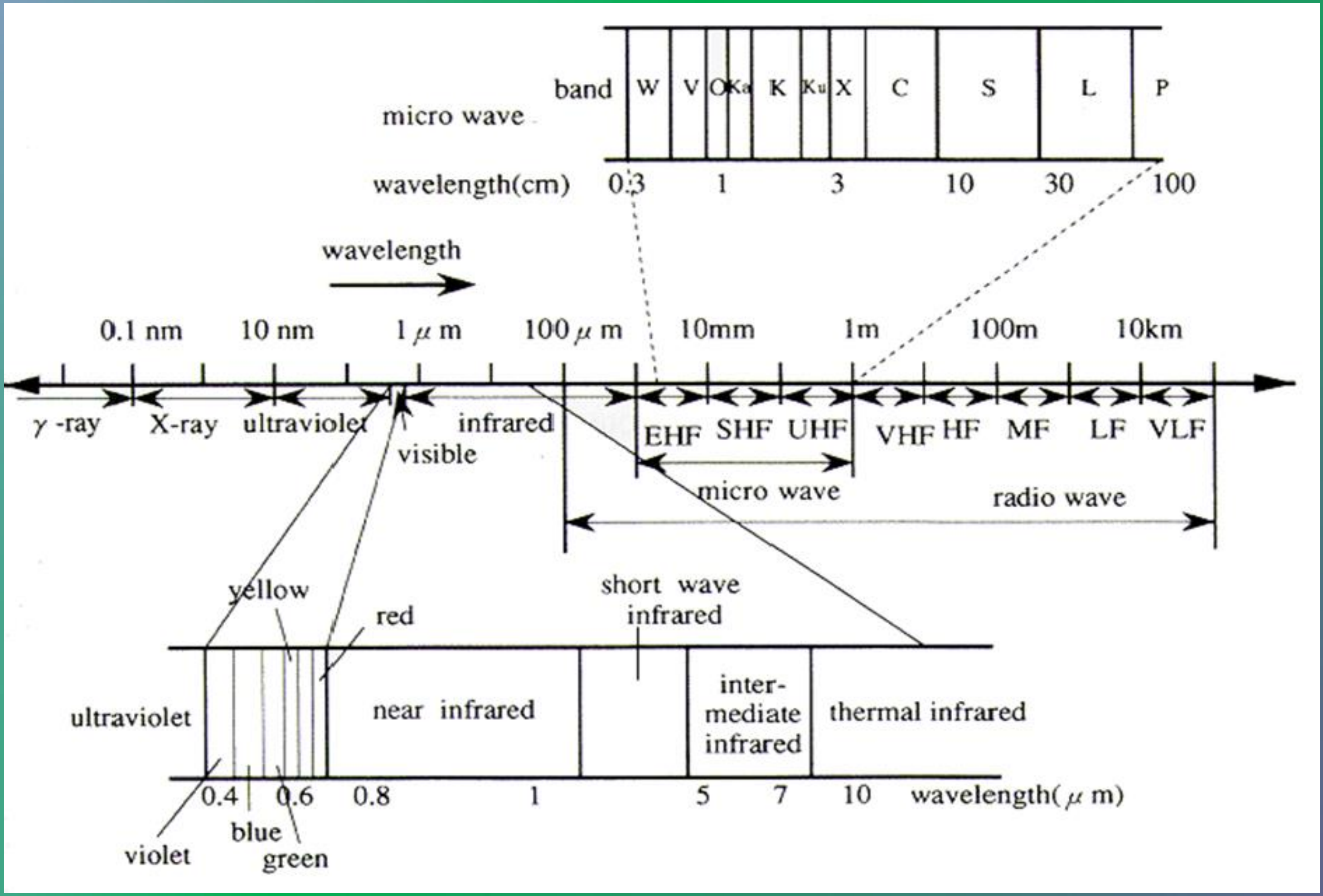
Satellite TV – Rain Fade

Rain Fade → absorption of microwave radio frequency (RF) signal by atmospheric rain, snow or ice, and losses (> 11GHz).

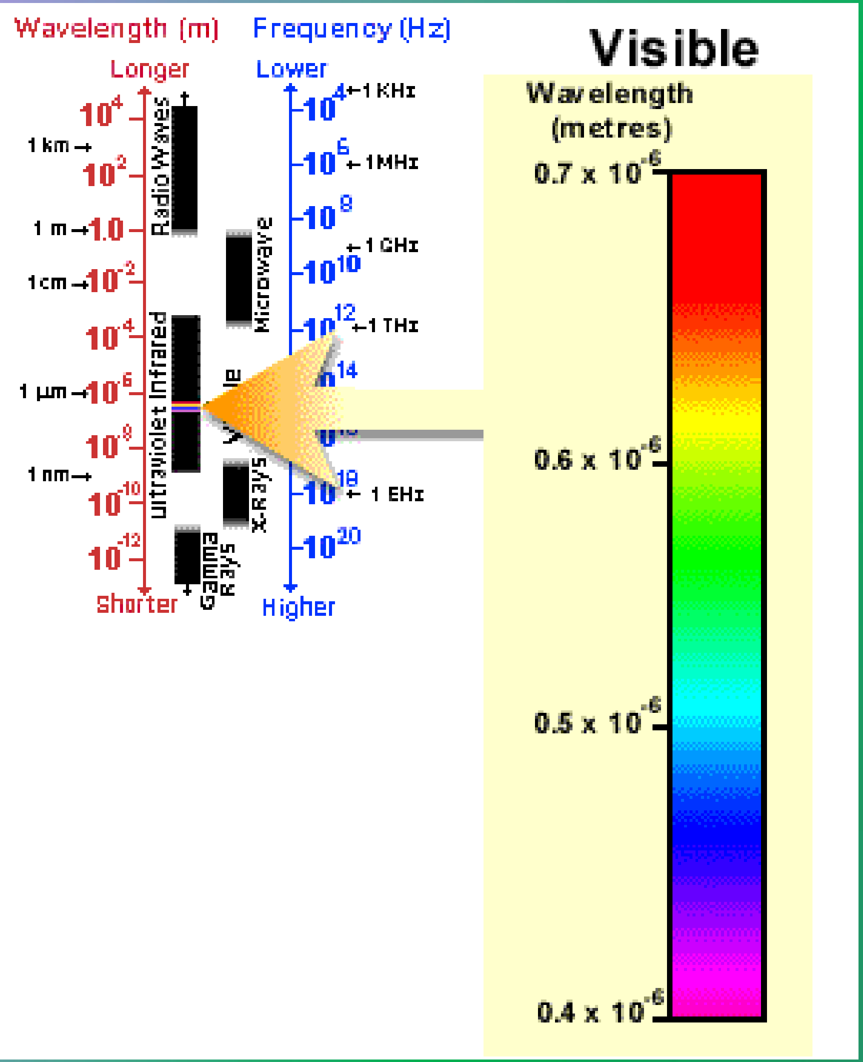


When high frequencies are transmitted and received in a heavy rain fall area, noticeable signal degradation occurs and is proportional to the amount of rain fall (known as rain fade).

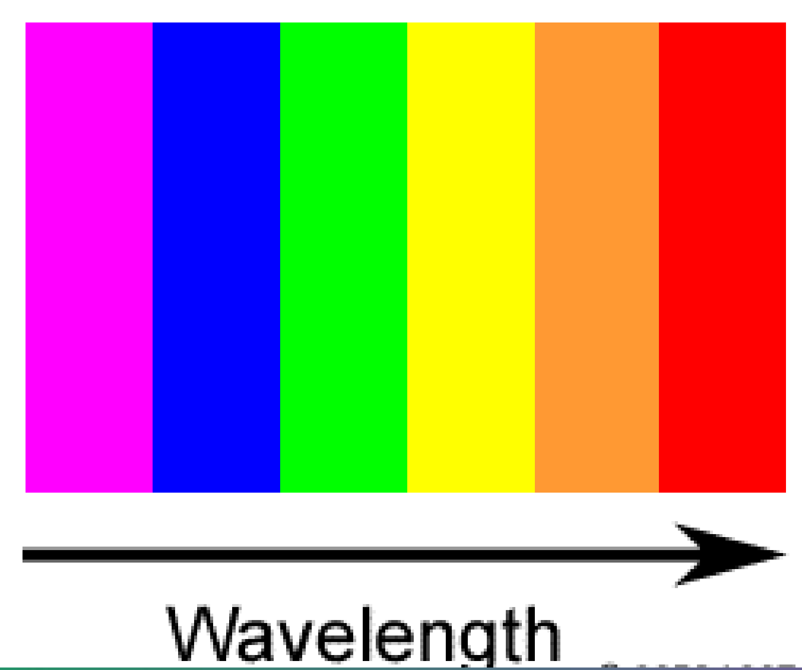
Bands used in Remote Sensing



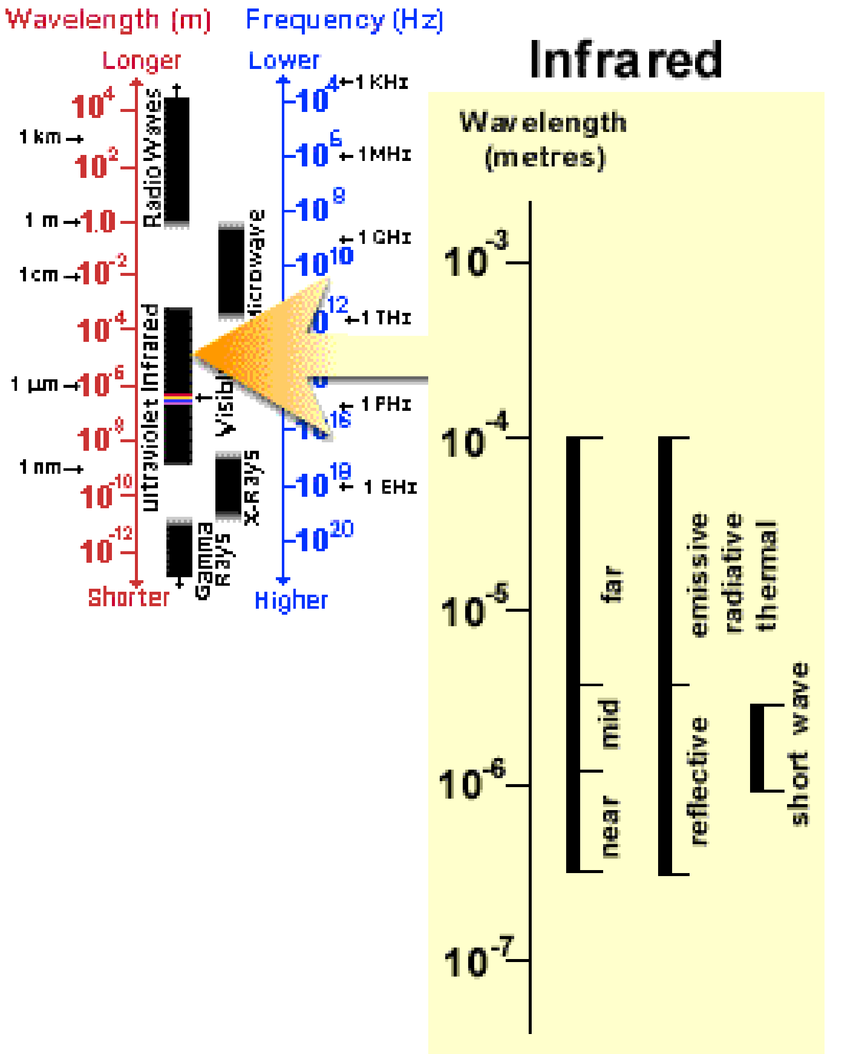
The Visible Spectrum



This is what our eyes see. The visible wavelengths cover a range from 0.4 to 0.7 µm.



The Infrared Spectrum



IR region covers the wavelength range from approximately 0.7 µm to 100 µm → more than 100 times as wide as the visible portion.

IR can be divided into two categories based on their radiation properties - the **reflected IR**, and the emitted or **thermal IR**.

The Infrared Spectrum

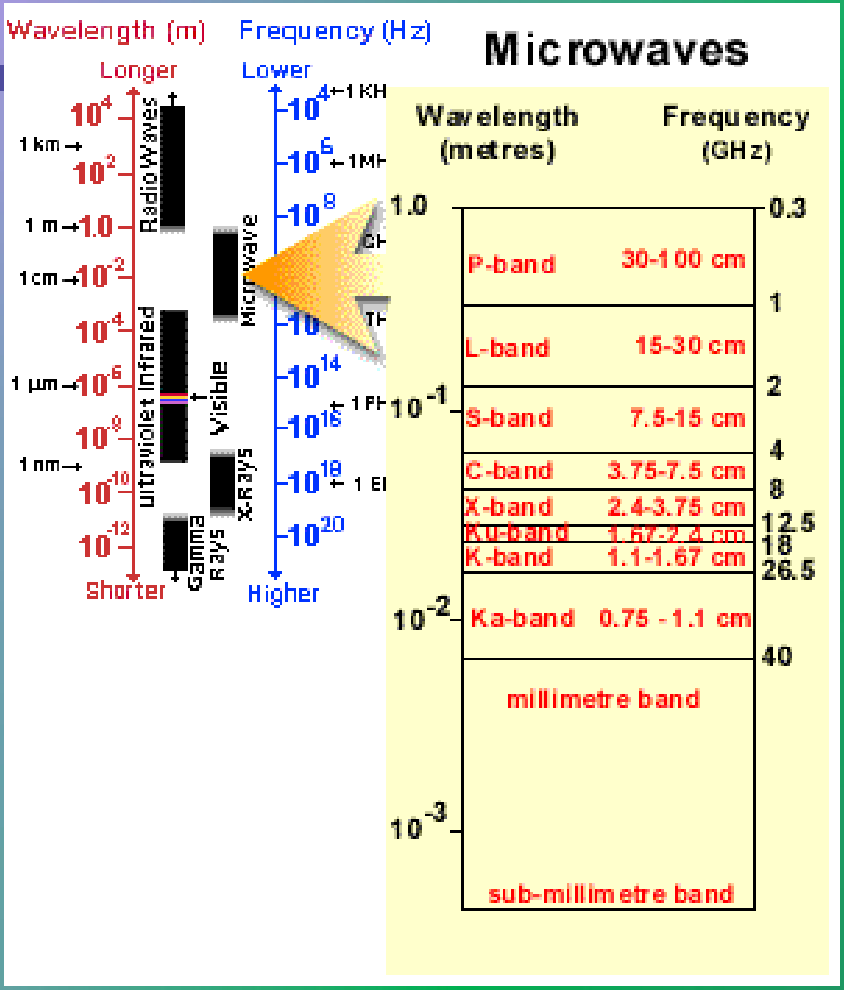
Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion.

The reflected IR covers wavelengths from approximately ***0.7 μm to 3.0 μm***.

The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat.

The thermal IR covers wavelengths from approximately ***3.0 μm to 100 μm***.

The Microwave Spectrum



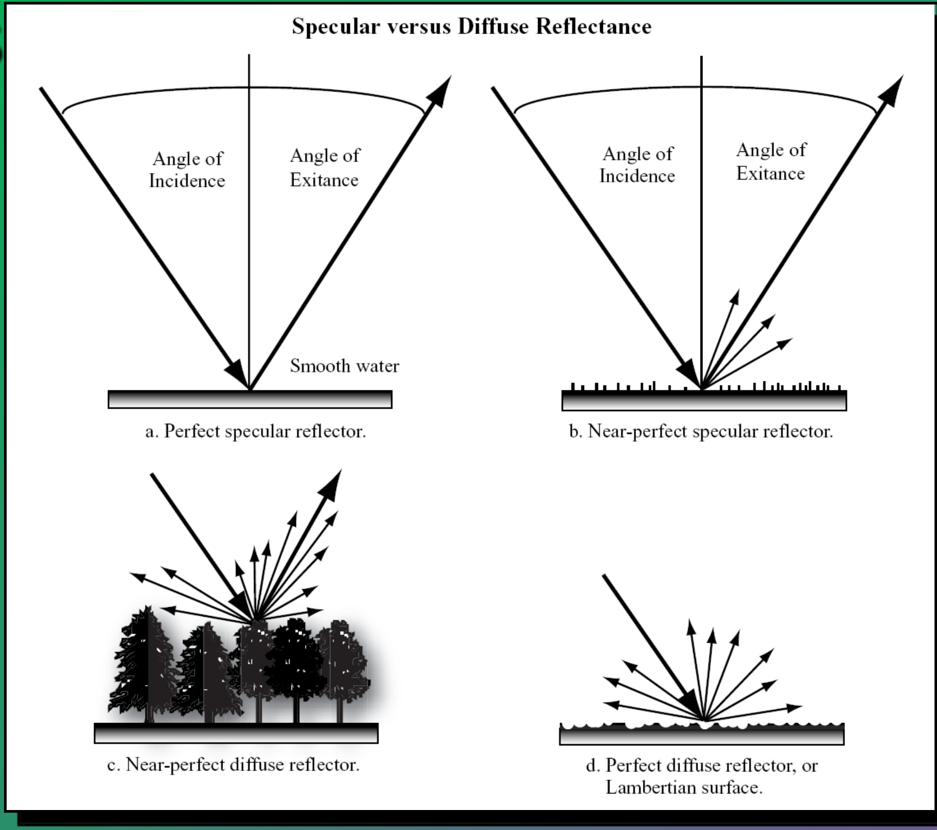
Microwave region → 1 mm to 1 m.

This covers the longest wavelengths used for remote sensing.

The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcast.

Reflectance

- *Reflectance* is the process whereby radiation "bounces off" an object like a cloud or the terrain.
- The angle of incidence and the angle of reflection are equal.



Scattering

- Electromagnetic radiation is generated and propagated through the earth's atmosphere almost at the speed of light
- The atmosphere may affect not only the speed of radiation but also its wavelength, intensity, spectral distribution, and/or direction.

Scattering vs Reflection

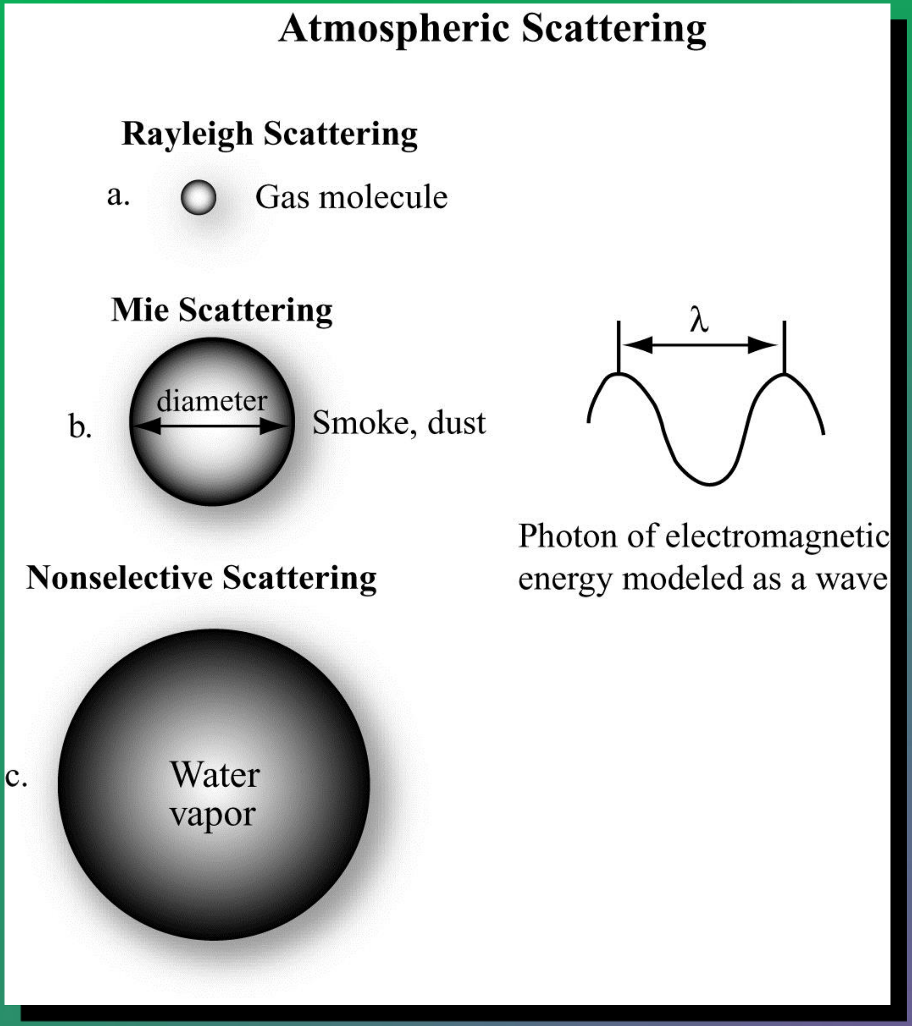
*T*he direction associated with scattering is ***un***predictable, while the direction of reflection is predictable. There are essentially three types of scattering:

- Rayleigh,
- Mie, and
- Non-selective.

Atmospheric Scattering

Scattering is related with the:

- *wavelength* of the incident radiant energy, and
- *size* of the gas molecule, dust particle, and/or water vapor droplet encountered.



Rayleigh Scattering

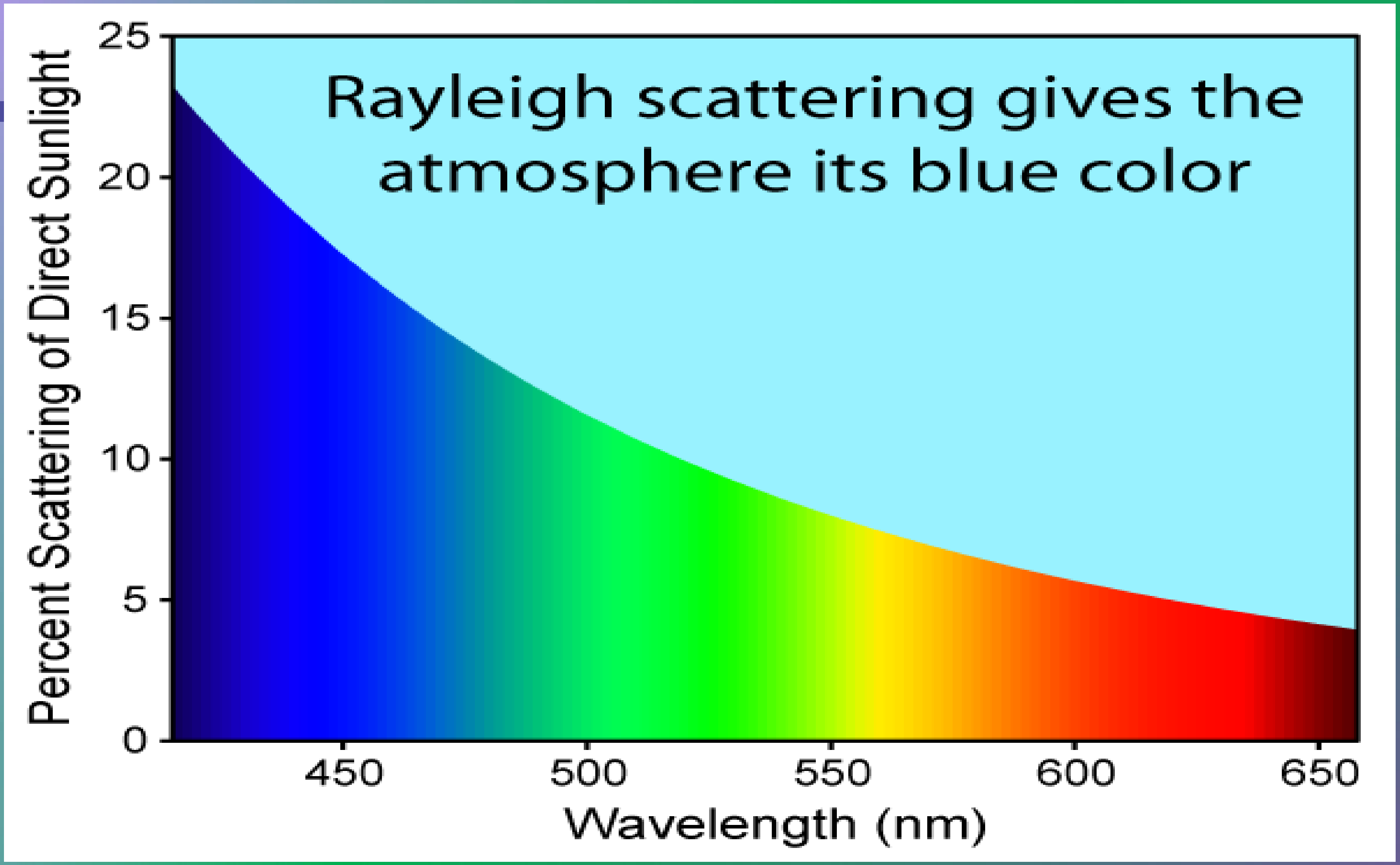
- Rayleigh scattering occurs when the diameter of the matter (usually air molecules) are many times smaller than the wavelength of the incident electromagnetic radiation.
- If we take the intensity of scattered violet light at the 400nm limit of visibility to be 100, then red light at 700 nm is scattered only at an intensity of 10.7. So, blue is much more strongly scattered than red.

Rayleigh Scattering

When a particle is hit by a light wave, it creates new wave that propagates in all directions. The intensity of the scattered light (I_s) is related to that of the incident light (I_0) by the inverse fourth power of the wavelength:

$$\mathbf{I_s/I_o = constant\ \lambda^{-4}}$$

Rayleigh Scattering



Rayleigh Scattering

Sun's rays at sunset → more than 30 times the distance at midday→ amplifies the effect of the Rayleigh scattering that makes the sky blue, so that the violets and blues in sunlight are lost.

Mie scattering

Mie scattering →spherical particles *with diameters approximately equal to the wavelength of radiation being considered*.

Mie scattering → greater than Rayleigh scatter. Dust, pollen, smoke and water vapour are common causes of Mie scattering which tends to affect longer wavelengths than those affected by Rayleigh scattering.

Mie scattering → occurs mostly in the lower portions of the atmosphere where larger particles are more abundant, and dominates when cloud conditions are overcast.

Non-selective scattering

Non-selective scattering → particles *several times the diameter of the wavelength being transmitted.*

Non-selective scattering → *all wavelengths are scattered about equally*

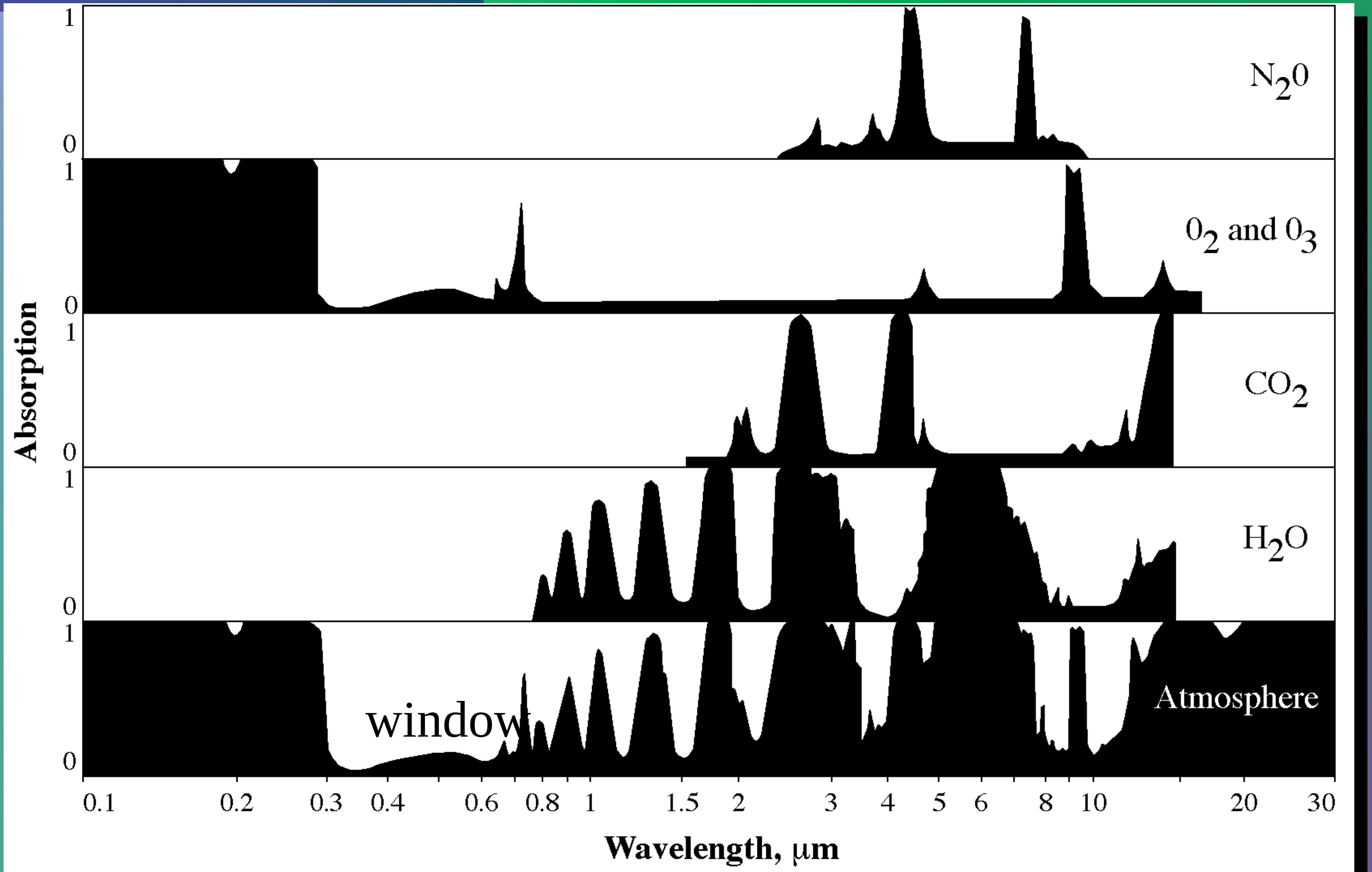
Non-selective scattering → reduces the information content of remotely sensed data → images loose contrast → objects are difficult to differentiate

Non-selective scattering → *fog and clouds appear white to our eyes because blue, green, and red light are all scattered in approximately equal quantities (blue+green+red light = white light).*

Absorption

- *Absorption* →radiant energy is absorbed and converted into other types of energy.
- the atmosphere does not absorb all of the incident energy but transmits it effectively. Parts of the spectrum that transmit energy effectively are called “atmospheric windows”.

Absorption of the Sun's Incident Electromagnetic Energy in the Region from 0.1 to 30 μm by Various Atmospheric Gases

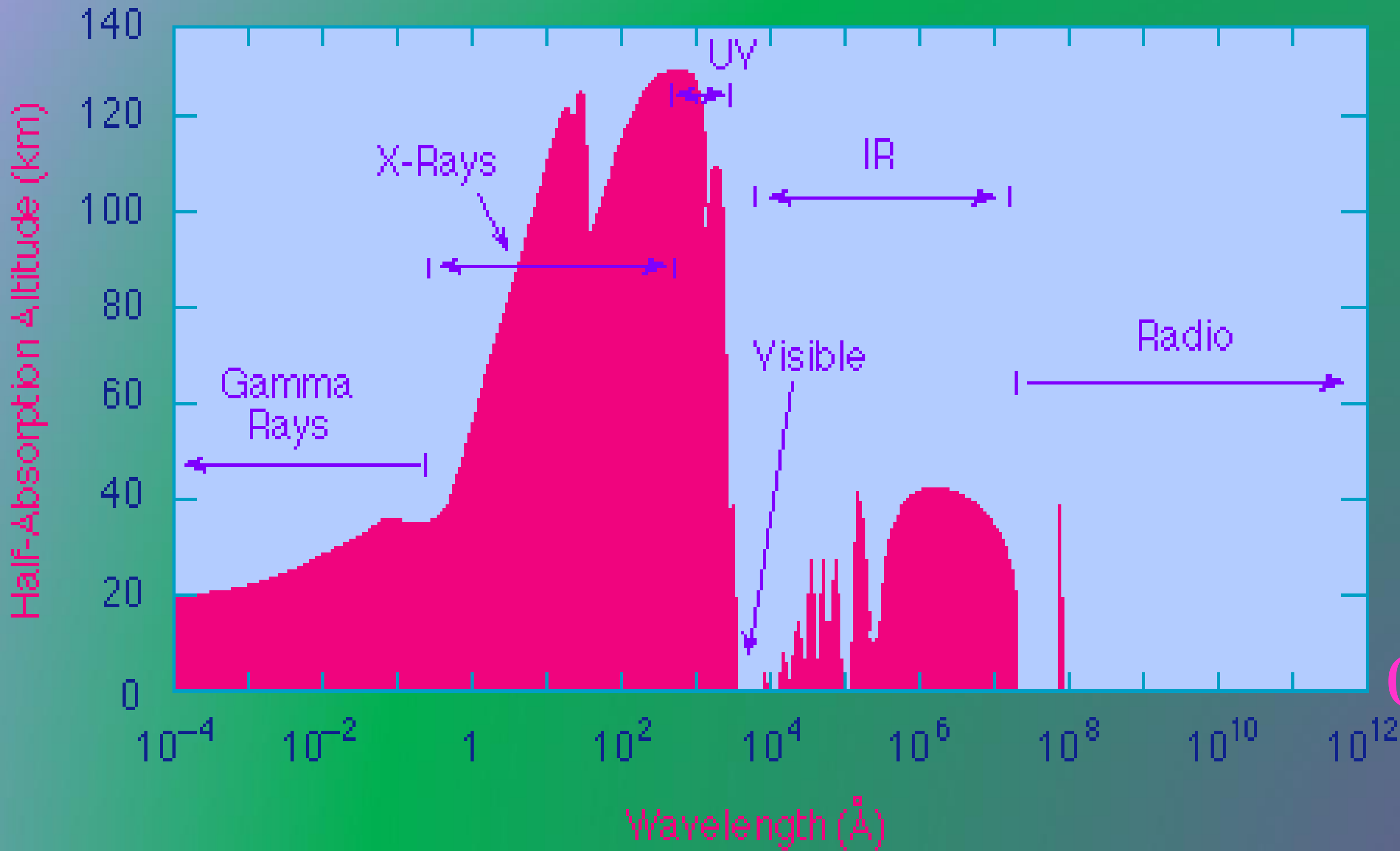


Atmospheric Windows

Areas of the spectrum not severely influenced by atmospheric absorption, useful to remote sensors, are called **atmospheric windows.**

The dominant windows in the atmosphere are in the ***visible*** *and* ***radio frequency regions***, while X-Rays and UV are seen to be very strongly absorbed and Gamma Rays and IR are somewhat less strongly absorbed.

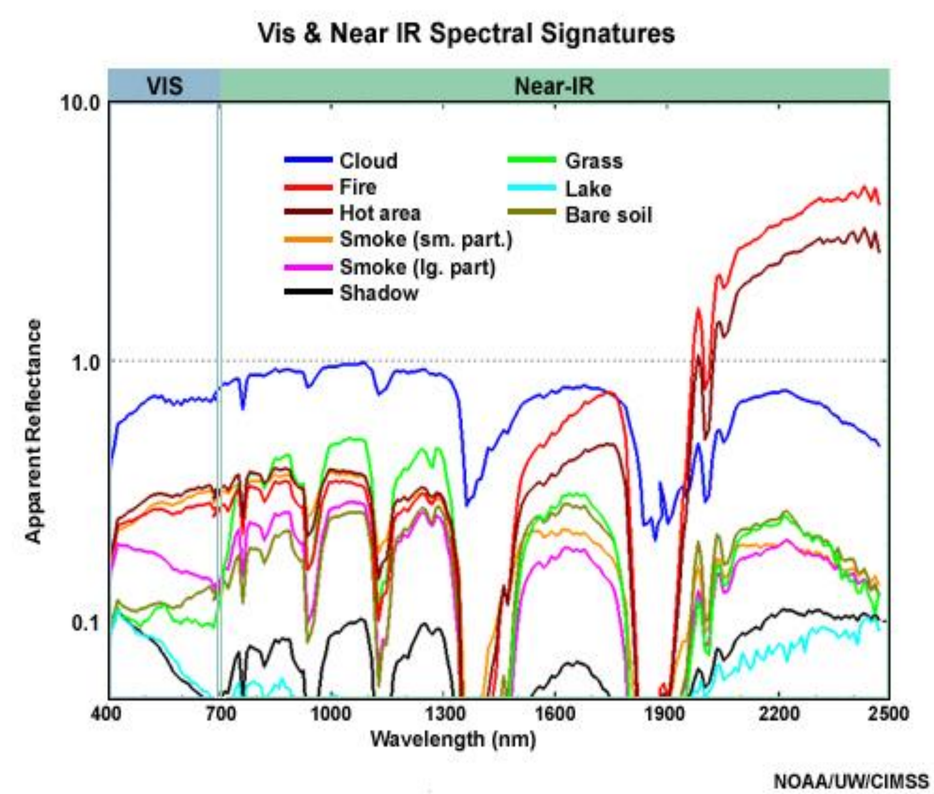
Atmospheric Windows – Half Absorption Altitude

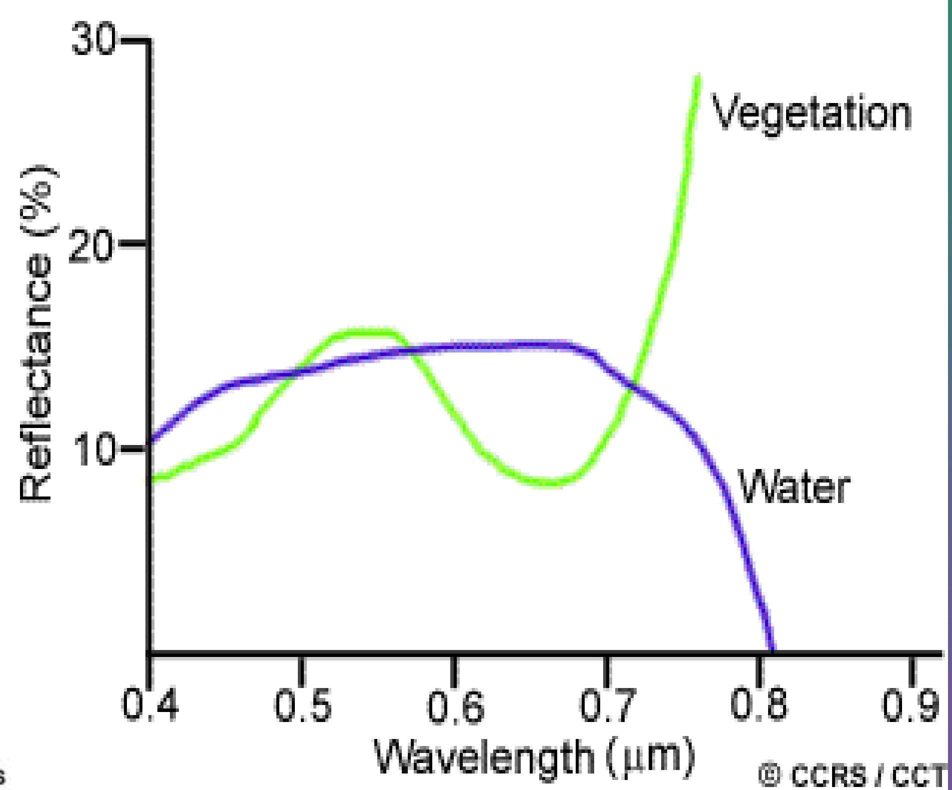


(x 10^{-10} m)

Spectral Signatures

By measuring the energy that is reflected (or emitted) by targets on the Earth's surface over a variety of different wavelengths, we can build up a **spectral response** for that object. After that we may be able to distinguish between different objects.

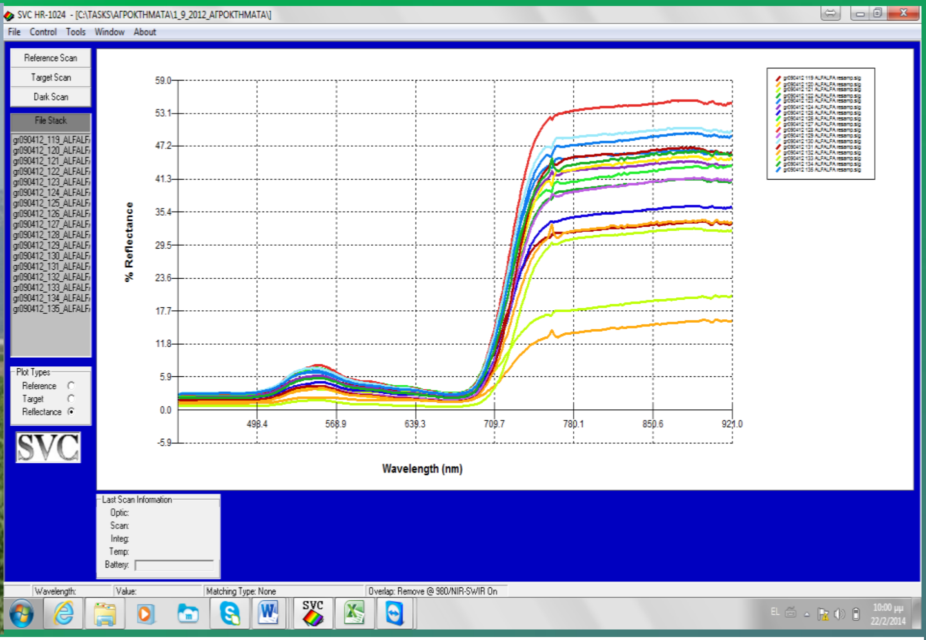


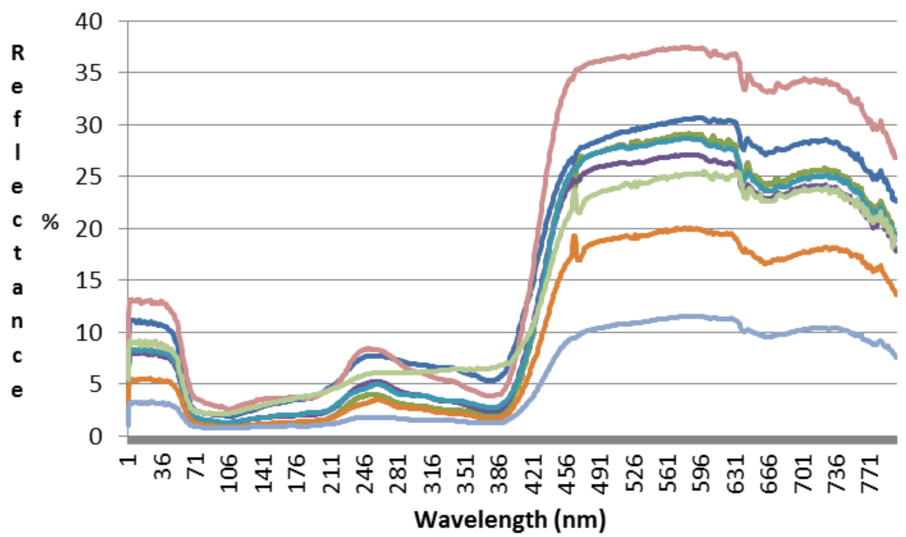


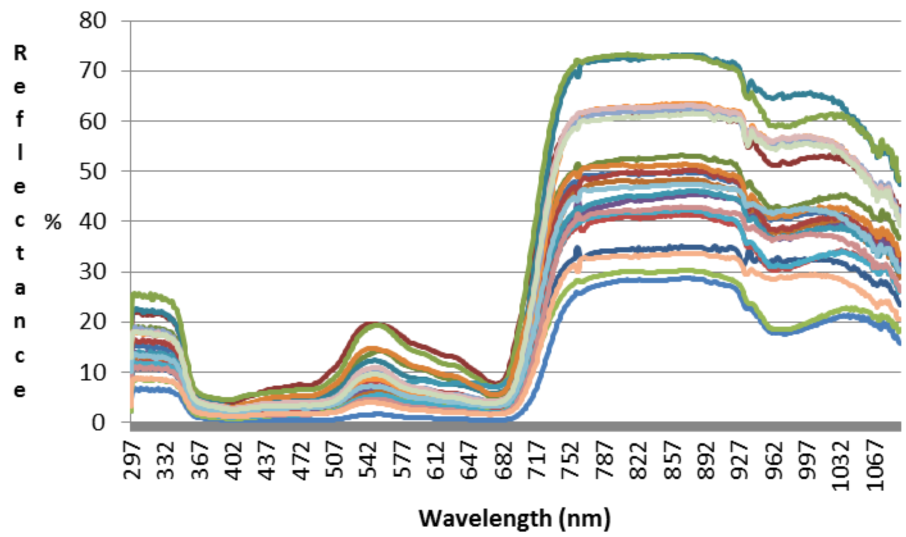
Spectroradiometers

Light-weight, high performance instrument covering the ultraviolet, visible and near-infrared wavelengths from 350 nm to 1050 nm.
e.g. GER 1500 → 512 spectral bands.
GER1500 uses the idea of «lambertian» surface as a panel

Spectroradiometers

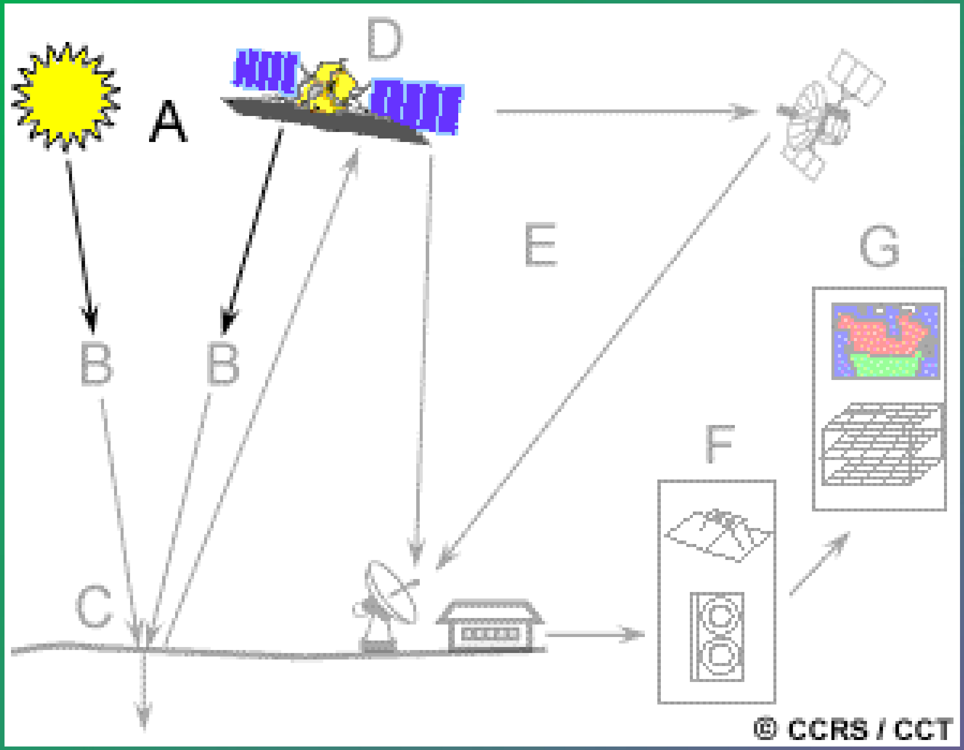






The element of the remote sensing process

1) ***Energy Source or Illumination***
2) ***Radiation and the Atmosphere***
3) ***Interaction with the Target***
4) ***Recording of Energy by the Sensor***
5) ***Transmission, Reception, and Processing***
6) ***Interpretation and Analysis***
7) ***Application***



The elements of the remote sensing process

1. Energy Source or Illumination (A) - the first requirement for remote sensing is to have an energy source which illuminates or provides electromagnetic energy to the target of interest.

2. Radiation and the Atmosphere (B) - as the energy travels from its source to the target, it will come in contact with and interact with the atmosphere it passes through. This interaction may take place a second time as the energy travels from the target to the sensor.

3. Interaction with the Target (C) - once the energy makes its way to the target through the atmosphere, it interacts with the target depending on the properties of both the target and the radiation.

4. Recording of Energy by the Sensor (D) - after the energy has been scattered by, or emitted from the target, we require a sensor (remote - not in contact with the target) to collect and record the electromagnetic radiation.

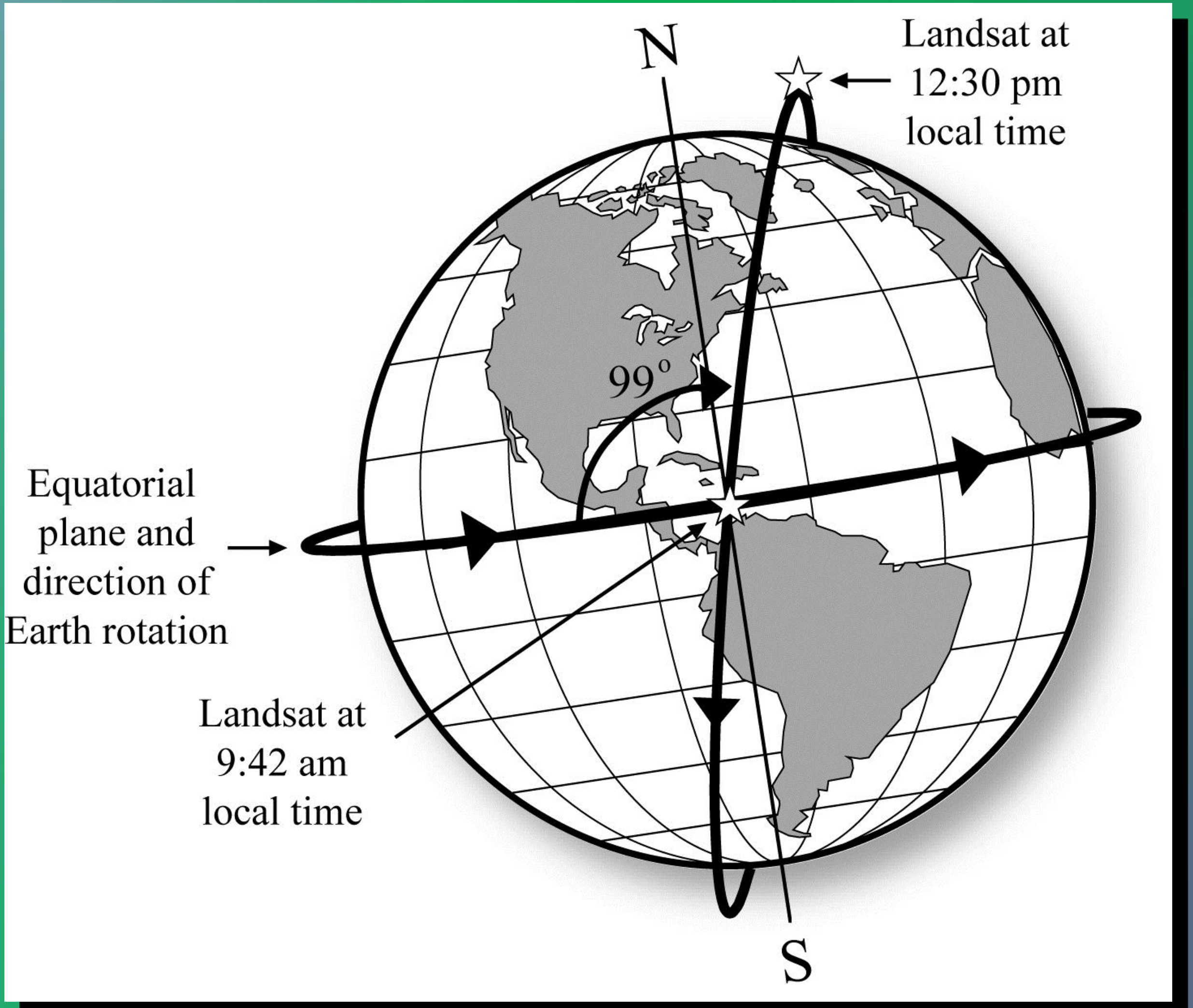
The elements of the remote sensing process

5. Transmission, Reception, and Processing (E) - the energy recorded by the sensor has to be transmitted, often in electronic form, to a receiving and processing station where the data are processed into an image (hardcopy and/or digital).

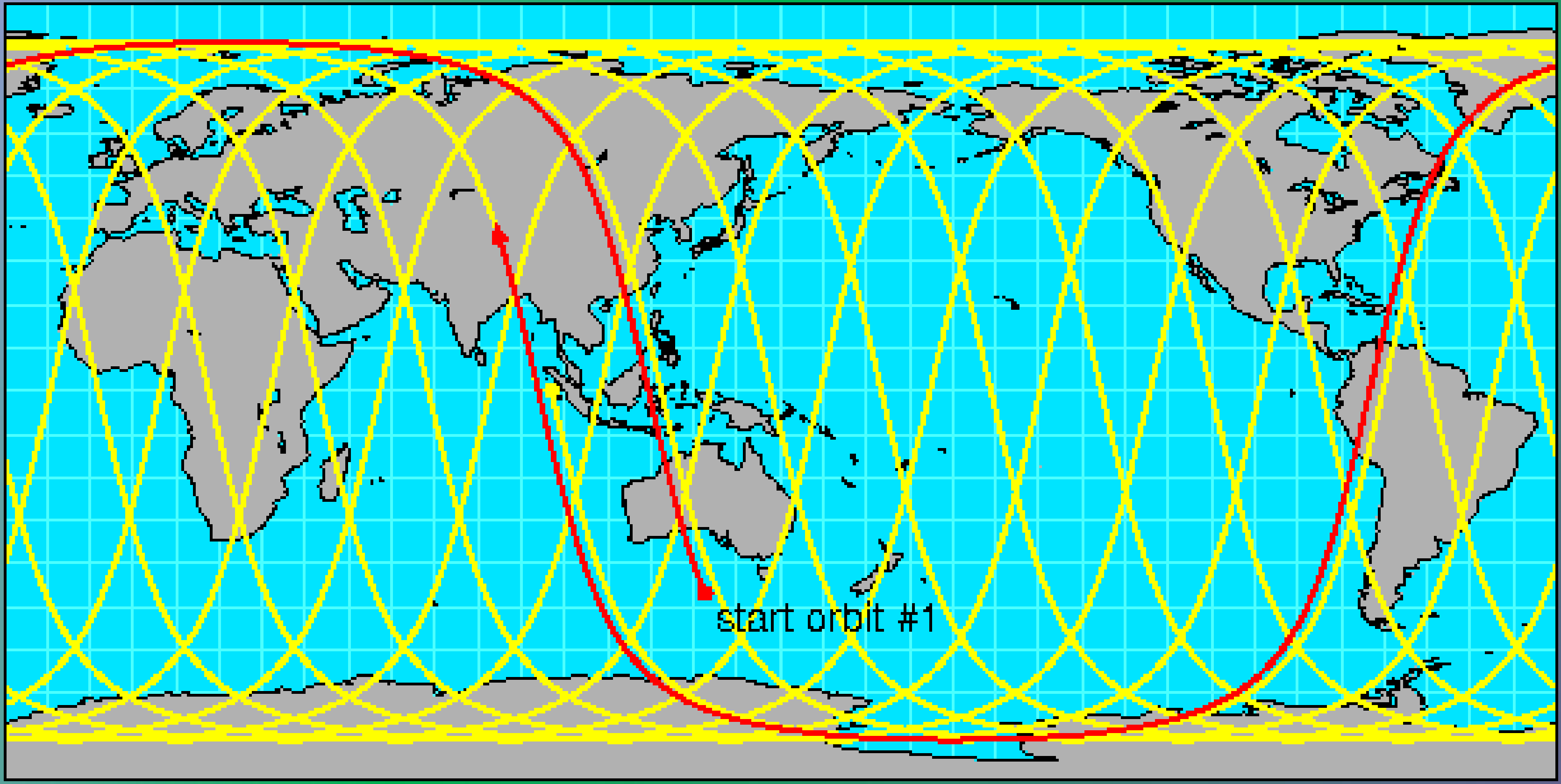
6. Interpretation and Analysis (F) - the processed image is interpreted, visually and/or digitally or electronically, to extract information about the target which was illuminated.

7. Application (G) - the final element of the remote sensing process is achieved when we apply the information we have been able to extract from the imagery about the target in order to better understand it, reveal some new information, or assist in solving a particular problem.

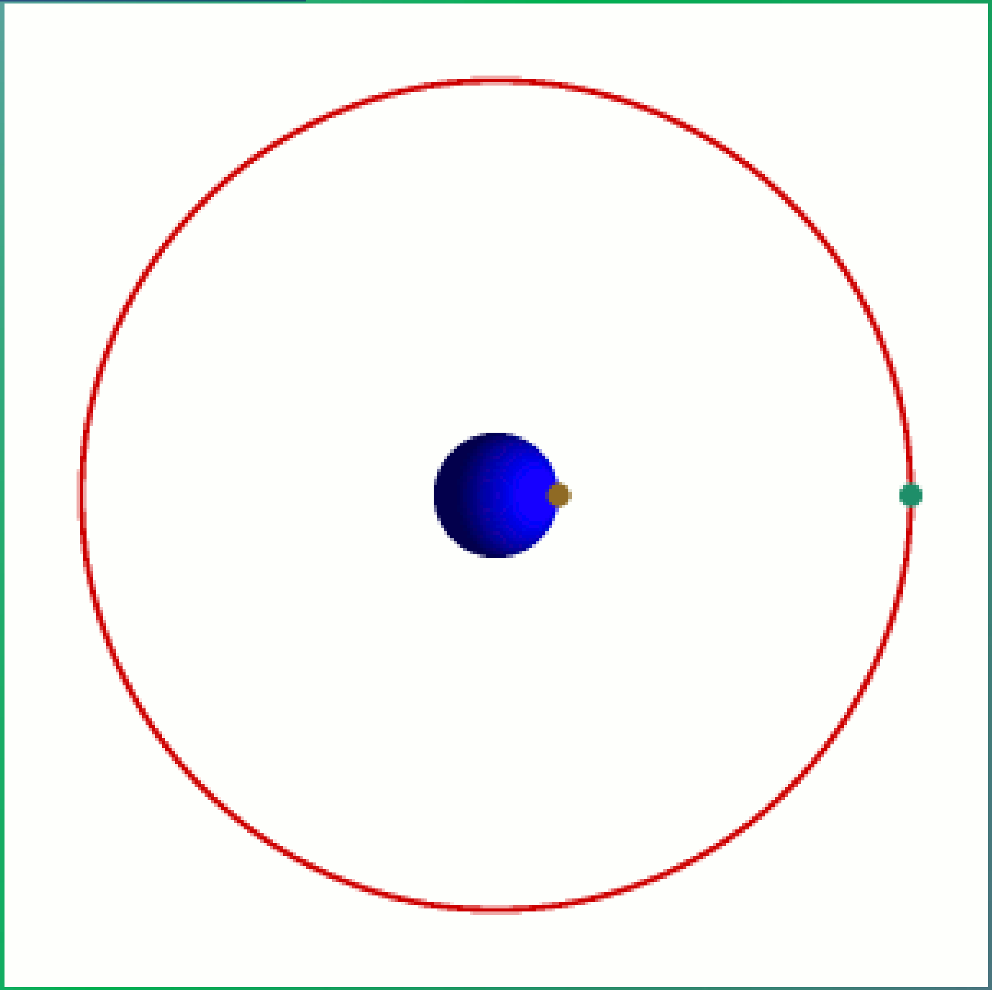
Orbits


N
Landsat at
12:30 pm
local time
99°
Equatorial
plane and
direction of
Earth rotation
Landsat at
9:42 am
local time
S

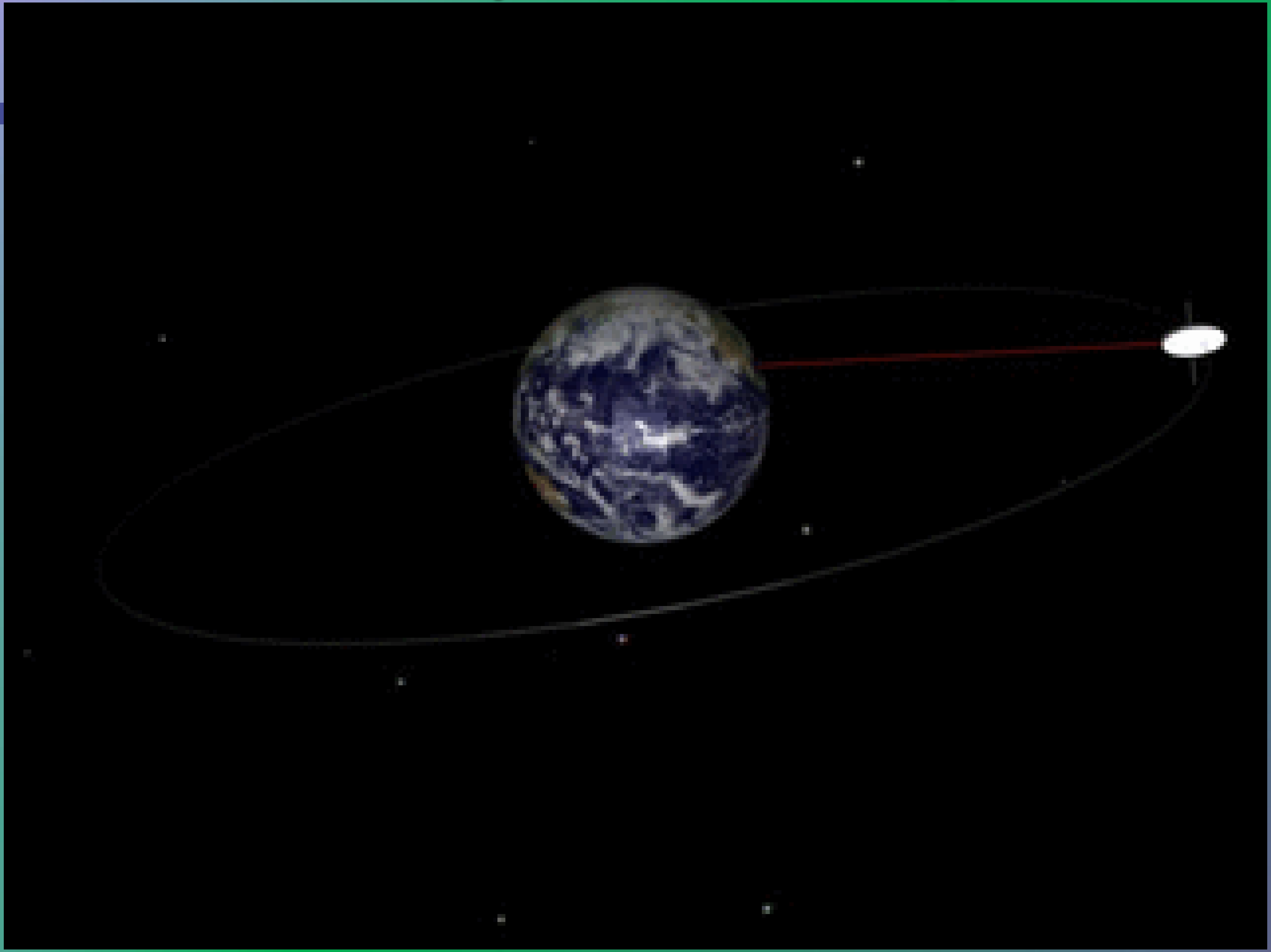
Orbital period of about 100 minutes/14 orbits per day.



Geostationary Satellites (35.786 km)



Geostationary Satellites (35.786 km)



Resources

- **Chuvieco, E, 2007**: Fundamentals of Satellite Remote Sensing, CRC-Press.
- **Cracknel, A. P, 2006:** Introduction to Remote Sensing. Taylor & Francis, 2nd Edition.
- **Elachi, C. and van Zyl, J. J,** 2006: Introduction to The Physics and Techniques of Remote Sensing. Wiley-Interscience.
- **Kilic, O., 2008.** Theory and Principles of Remote Sensing. The Catholic University of America. **http://faculty.cua.edu**
- **Mashat, A.W., 2014 .** Introduction to Remote Sensing. King Abdulaziz University. **http:// amashat.kau.edu.sa**
- **http://scijinks.jpl.nasa.gov/orbit/**