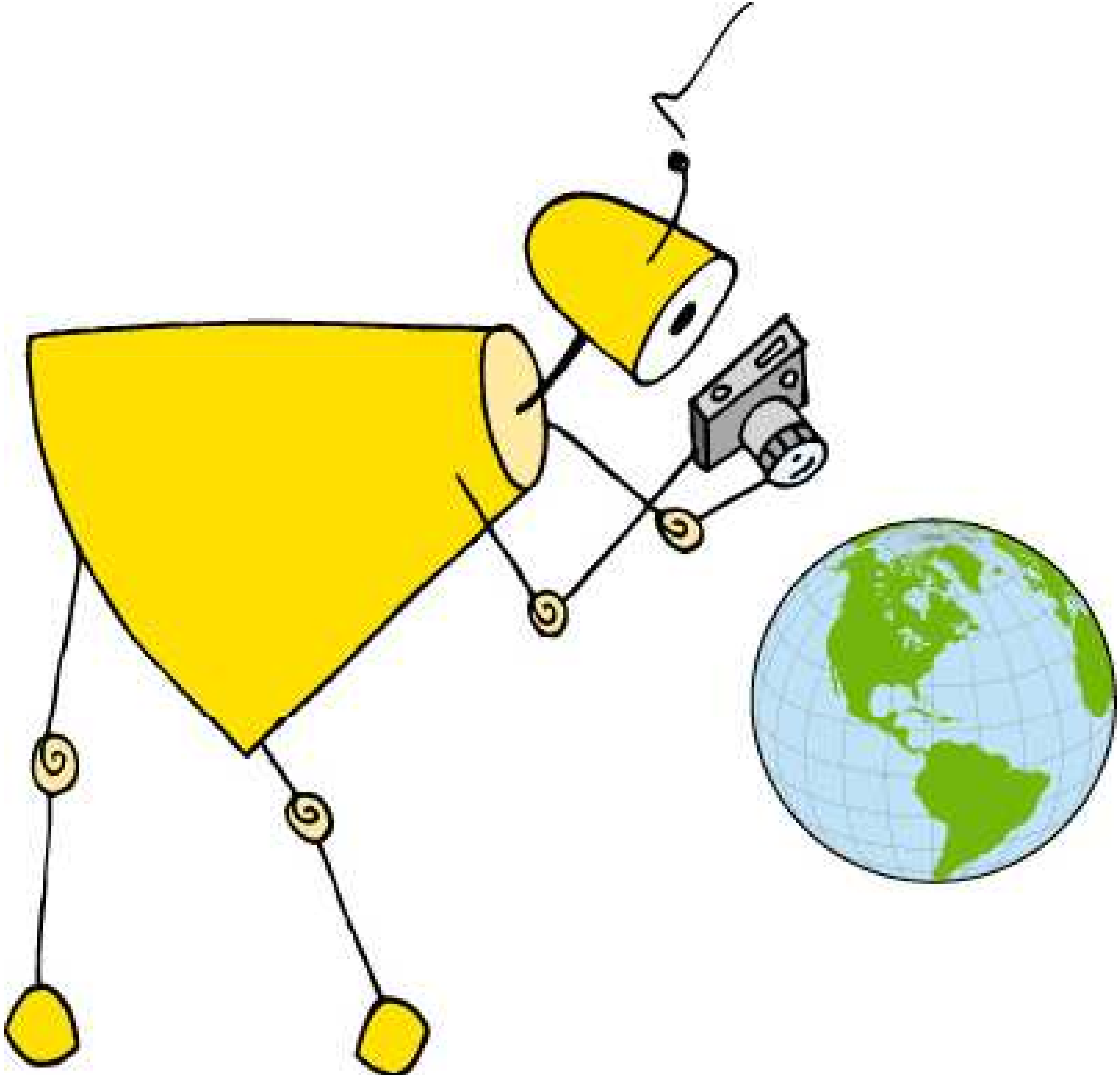
Introduction to

Remote Sensing



Definition of Remote Sensing

Remote sensing refers to the activities of recording/observing/perceiving (**sensing**) objects or events at far away (**remote**) places. In remote sensing, the **sensors** are not in direct contact with the objects or events being observed. The information needs a **physical carrier** to travel from the objects/events to the sensors through an intervening medium. The **electromagnetic radiation** is normally used as an information carrier in remote sensing.

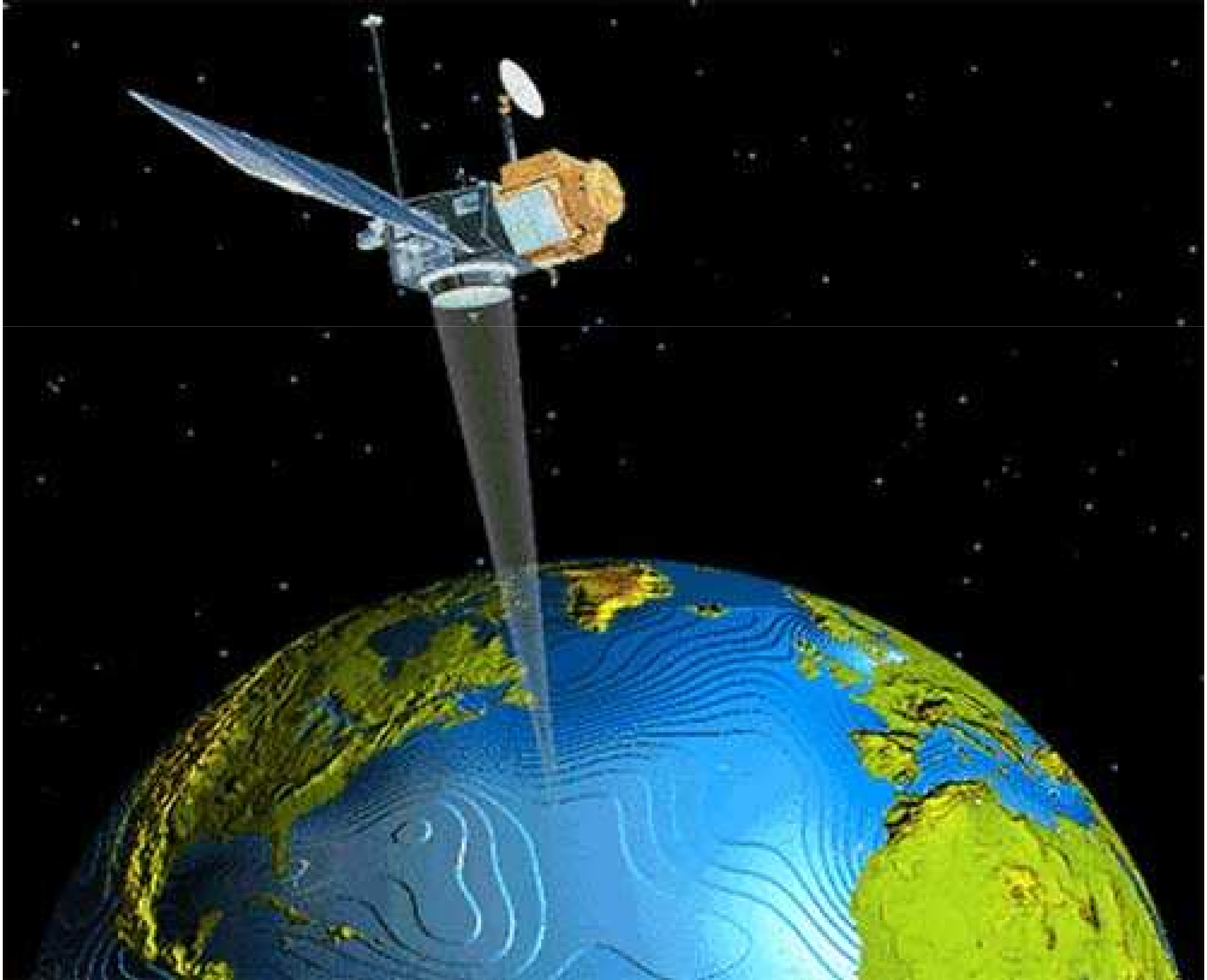
Definition of Remote Sensing

The output of a remote sensing system is usually an **image** representing the scene being observed. A further step of **image analysis and interpretation** is required in order to extract useful information from the image.

The human **visual system** is an example of a remote sensing system in this general sense.

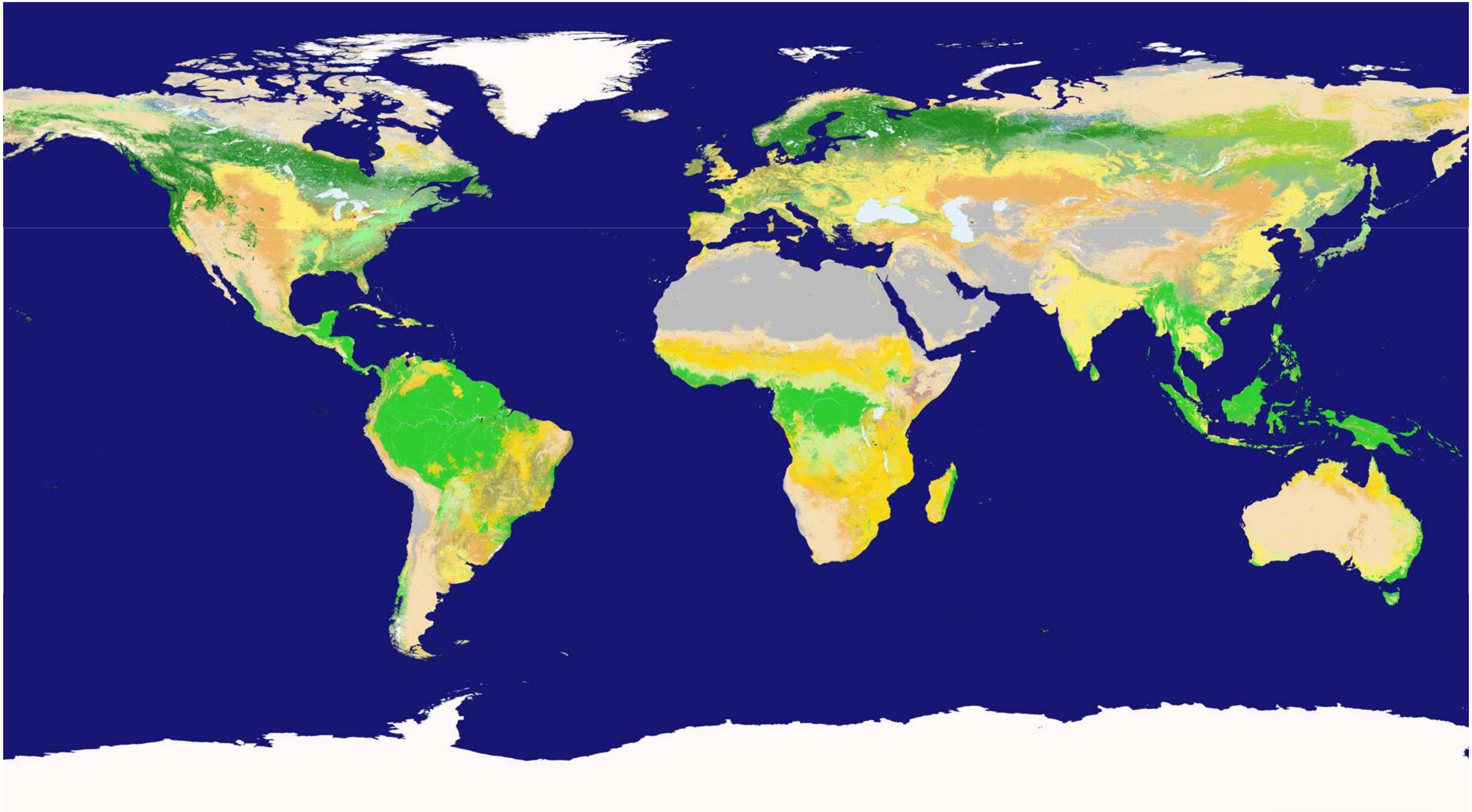
Definition of Remote Sensing

In a more restricted sense, remote sensing usually refers to the technology of acquiring information about the **earth's** surface (land and ocean) and **atmosphere** using sensors onboard **airborne** (aircraft, balloons) or **space borne** (satellites, space shuttles) platforms.

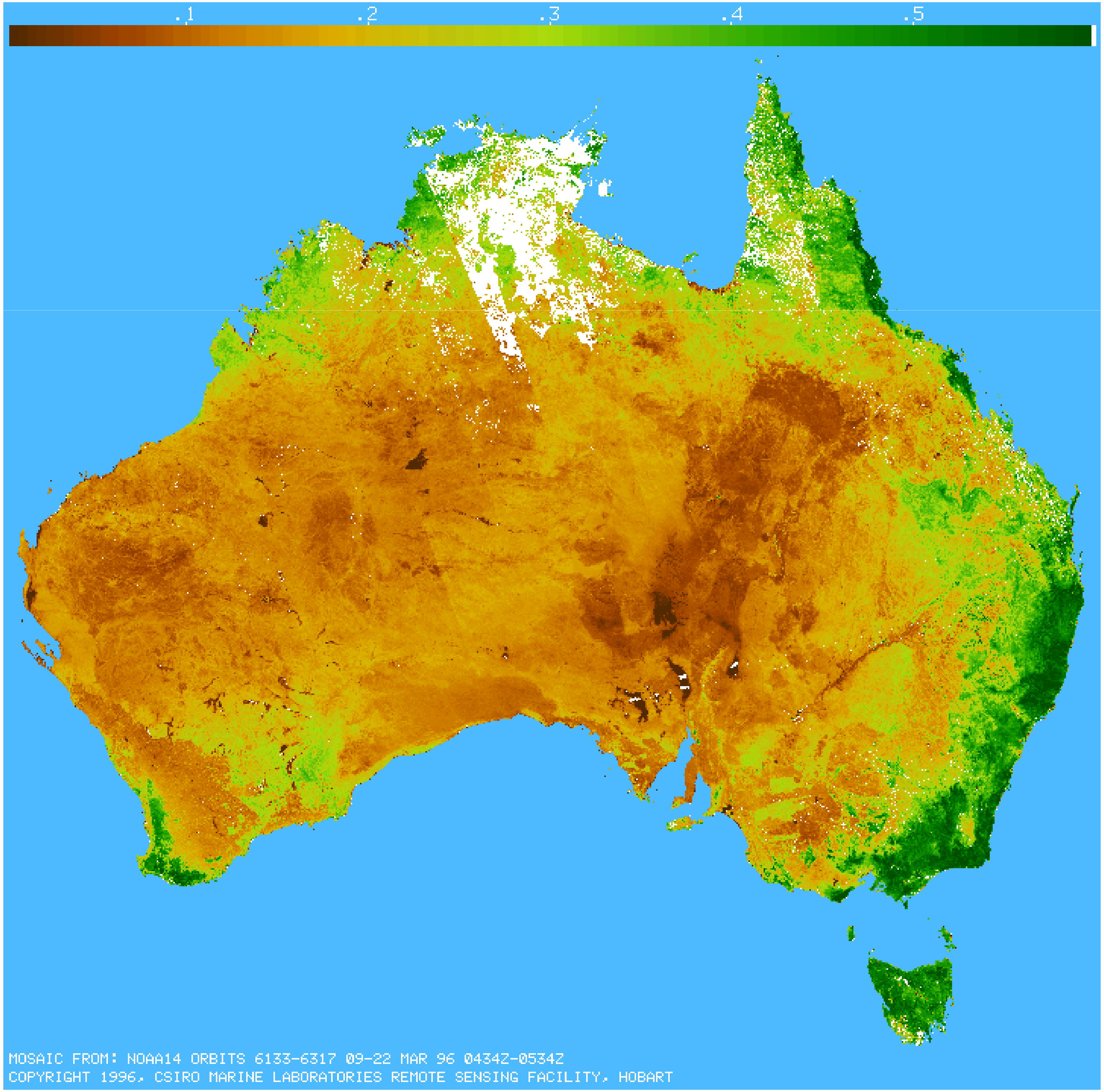


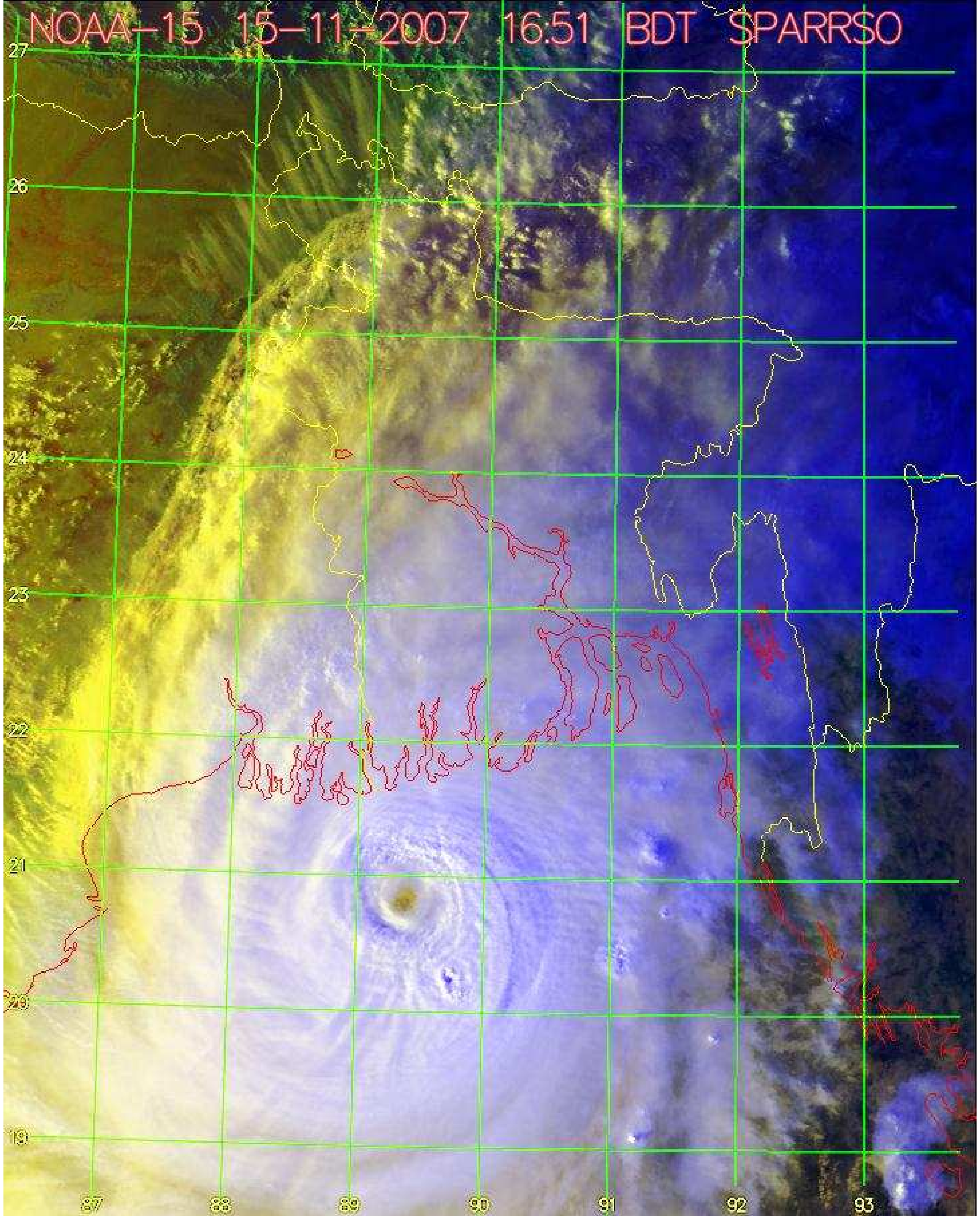
Application of Remote Sensing

Satellite Image of Entire Globe: Global Landcover



Satellite Image of a Region (Australia)




NOAA-15 15-11-2007 16:51 BDT SPARRSO
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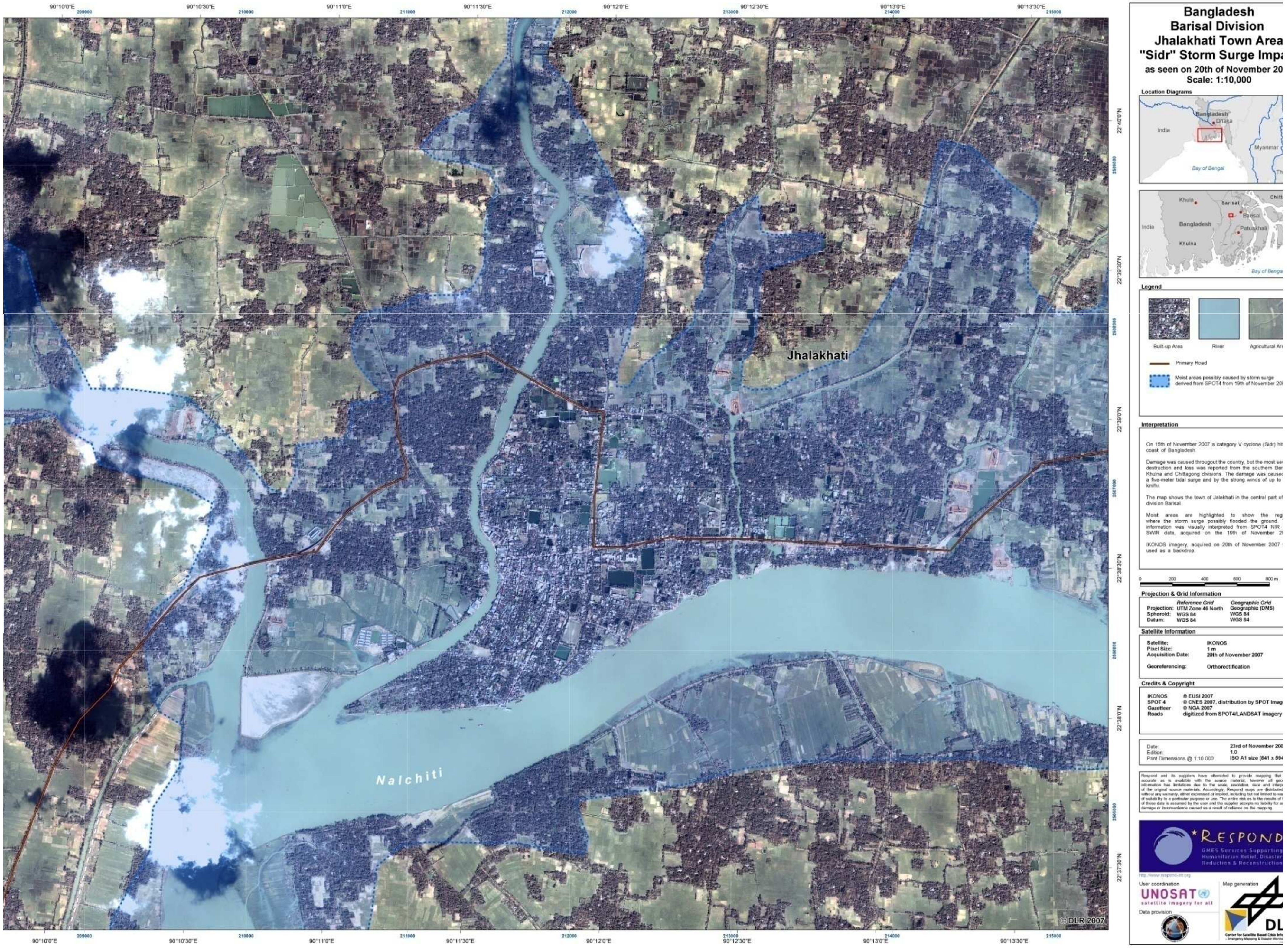
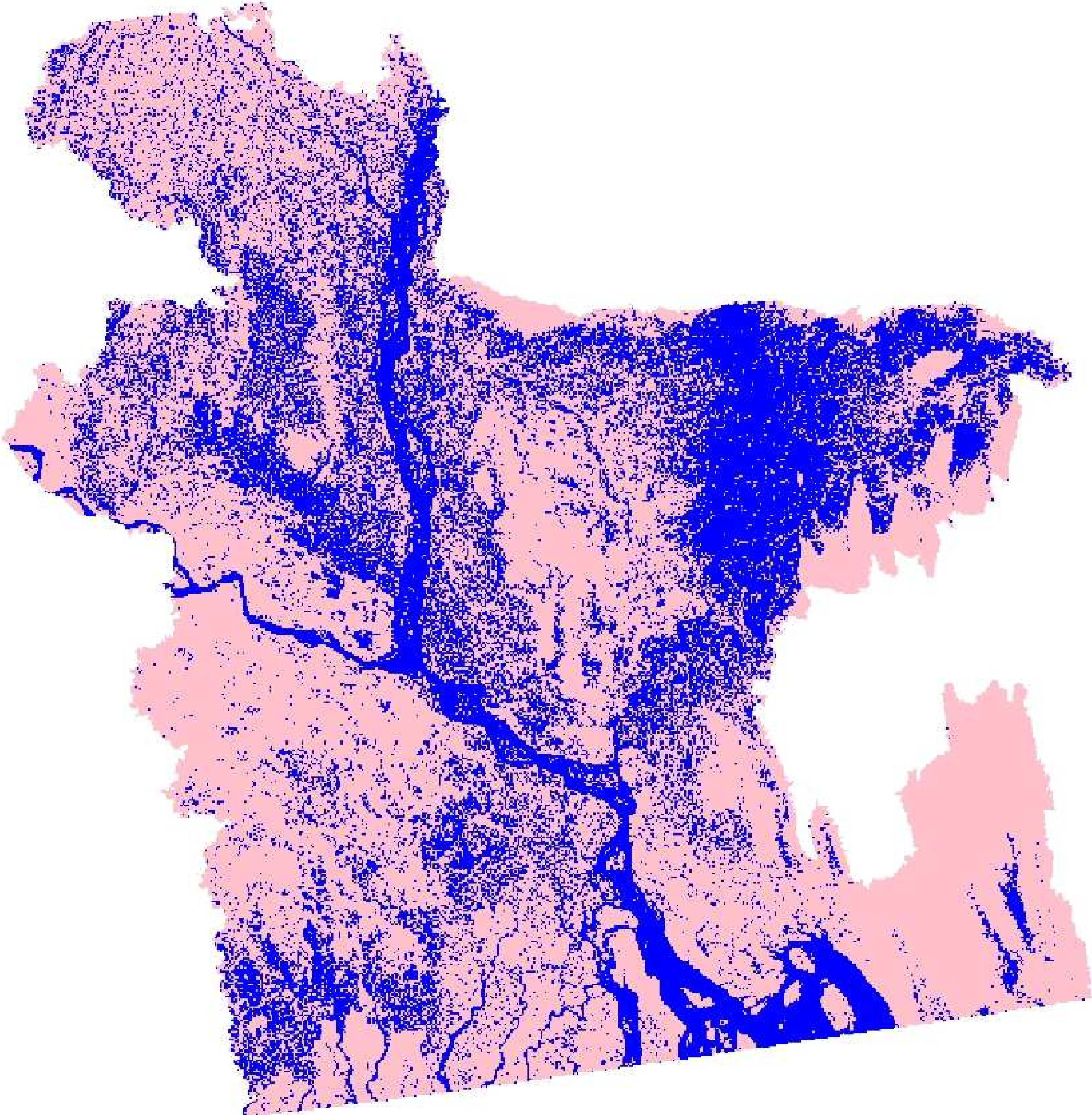

Bangladesh
Barisal Division
Jhalakhati Town Area
"Sidr" Storm Surge Impa
as seen on 20th of November 20
Scale: 1:10,000
Location Diagrams
Bangladesh
Dhaka
India
Myanmar
Bay of Bengal
Khula
Barisal
Bangladesh
Patuakhali
Khulna
Bay of Bengal
Legend
Built-up Area
River
Agricultural Are
Primary Road
Moist areas possibly caused by storm surge derived from SPOT4 from 19th of November 20
Interpretation
On 15th of November 2007 a category V cyclone (Sidr) hit coast of Bangladesh.
Damage was caused througout the country, but the most se destruction and loss was reported from the southern Bar Khulna and Chittagong divisions. The damage was cause a five-meter tidal surge and by the strong winds of up to km/hr.
The map shows the town of Jalakhati in the central part of division Barisal.
Moist areas are highlighted to show the reg where the storm surge possibly flooded the ground. information was visually interpreted from SPOT4 NIR SWIR data, acquired on the 19th of November 2
IKONOS imagery, acquired on 20th of November 2007 used as a backdrop.
0 200 400 600 800 m
Projection & Grid Information
Reference Grid | Geographic Grid
Projection: UTM Zone 46 North | Geographic (DMS)
Spheroid: WGS 84 | WGS 84
Datum: WGS 84 | WGS 84
Satellite Information
Satellite: IKONOS
Pixel Size: 1 m
Acquisition Date: 20th of November 2007
Georeferencing: Orthorectification
Credits & Copyright
IKONOS © EUSI 2007
SPOT 4 © CNES 2007, distribution by SPOT Imag
Gazetteer © NGA 2007
Roads digitized from SPOT4/LANDSAT imagery
Date: 23rd of November 200
Edition: 1.0
Print Dimensions @ 1:10,000 ISO A1 size (841 x 594
RESPOND
GMES Services Supporting Humanitarian Relief, Disaster Reduction & Reconstruction
User coordination
UNOSAT
Map generation
Data provision
Jhalakhati
Nalchiti
© DLR 2007



Main Goal of Remote Sensing

The main goal of *Remote Sensing (RS) is the production of:*

- ***Thematic map***
- ***Topographic map***

Definitions: Topographic Map

A topographic map is a type of map characterized by **large-scale detail** and **quantitative representation** of relief or terrain, usually using **contour lines**.

Definitions: Thematic Map

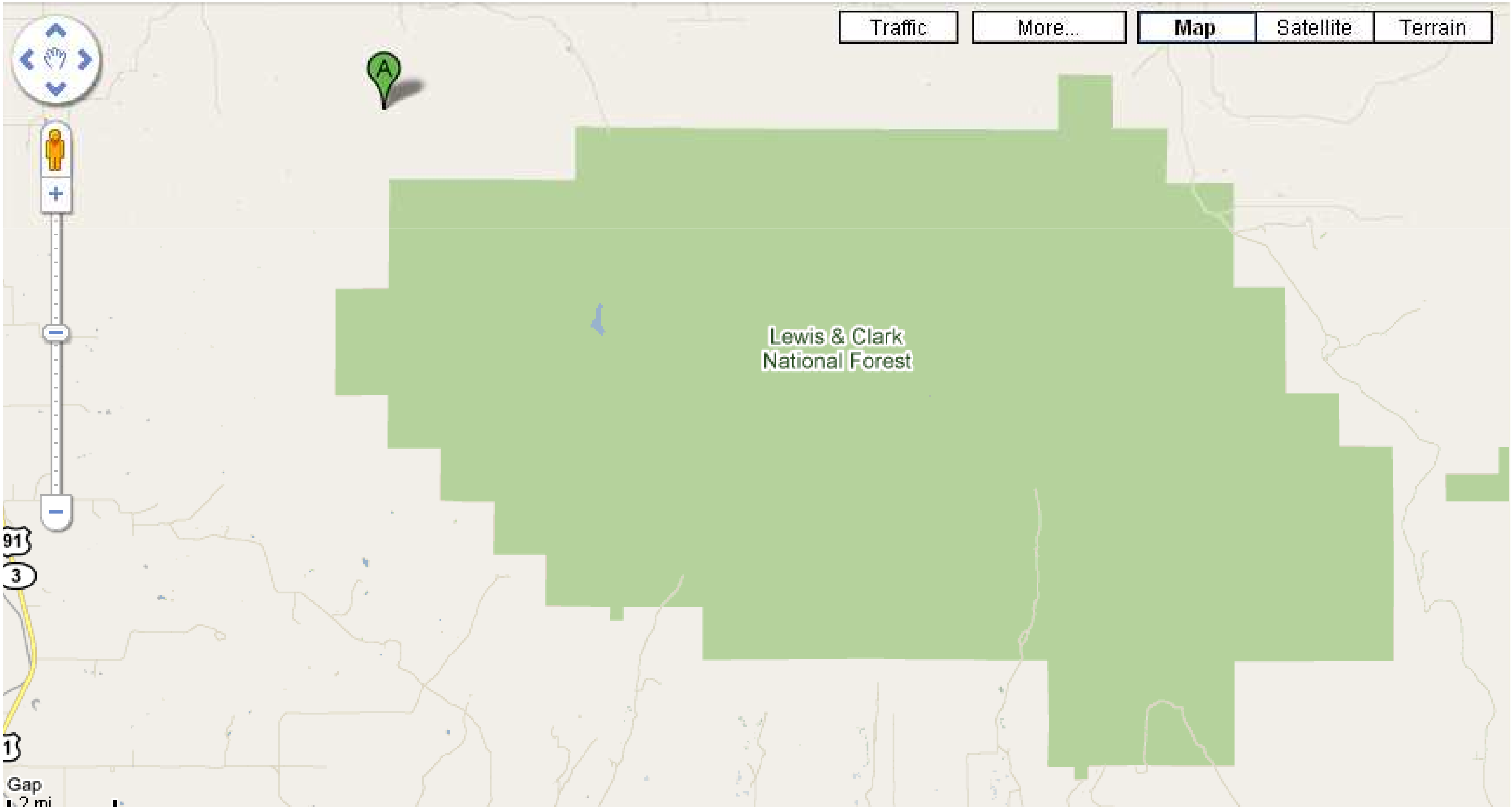
A **thematic map** is a type of map or chart especially designed to show a particular **theme** connected with a specific geographic area. These maps can portray physical, social, political, cultural, economic, sociological, agricultural, or any other aspects of a city, state, region, nation , or continent

Definitions: Contour Map

In cartography, a contour line (often just called a "contour") joins points of equal elevation (height) above a given level, such as mean sea level. A **contour map** is a map illustrated with contour lines. The **contour interval** of a contour map is the difference in elevation between successive contour lines.

Example of Topographic Map

A Park: Map Representation

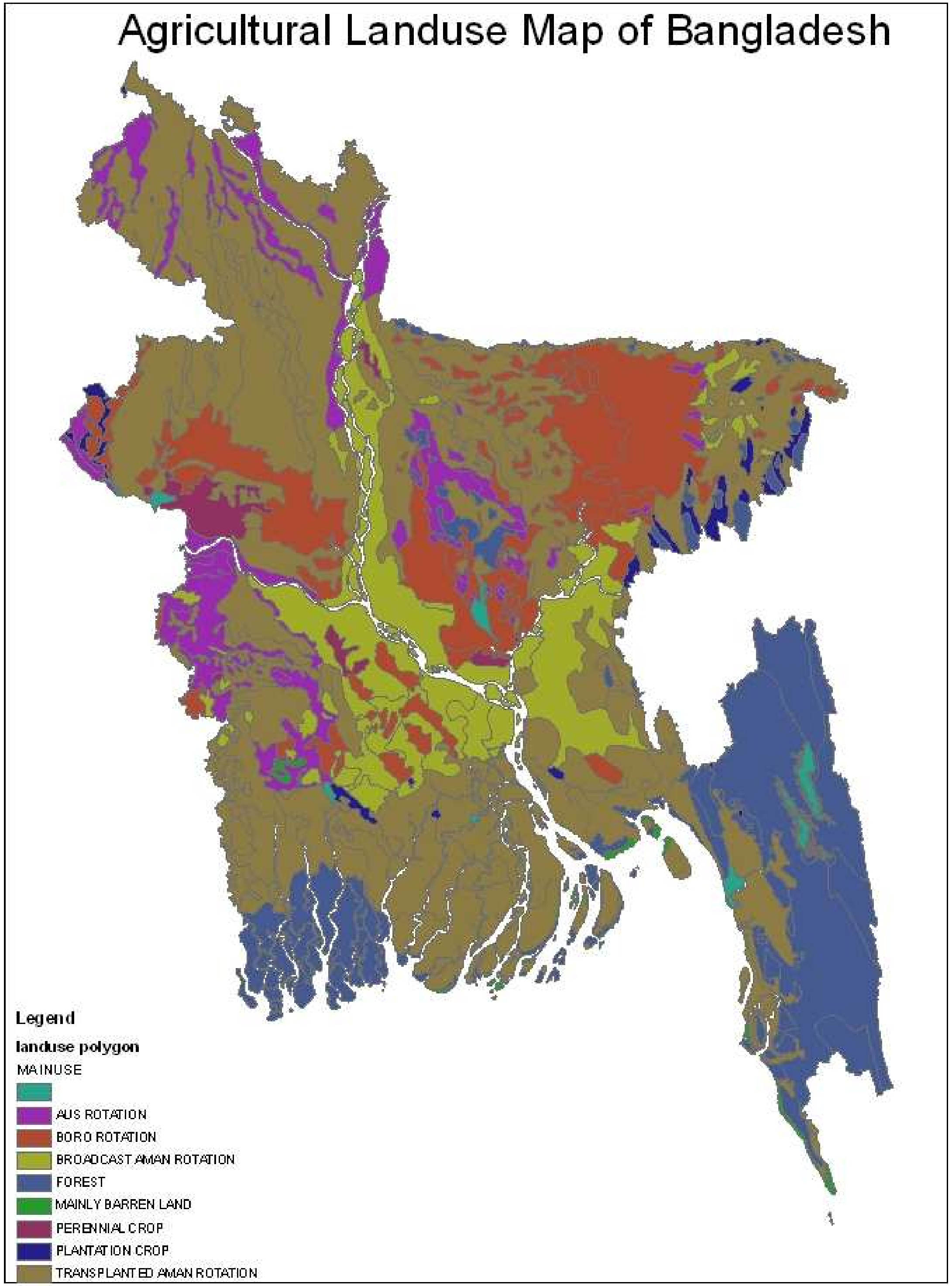


Satellite Image of the Park

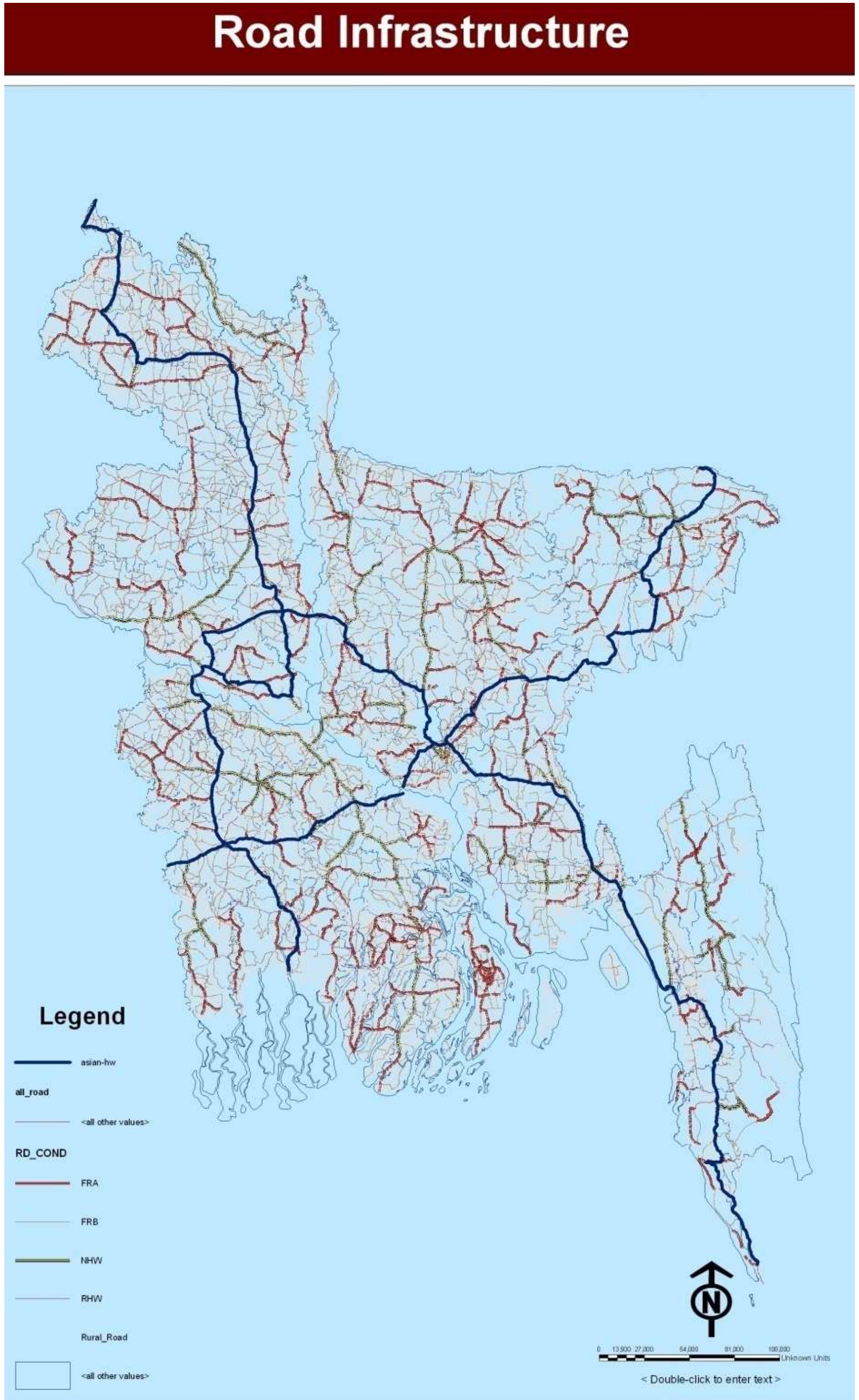
Terrain Information of the Park

Example of Thematic Map

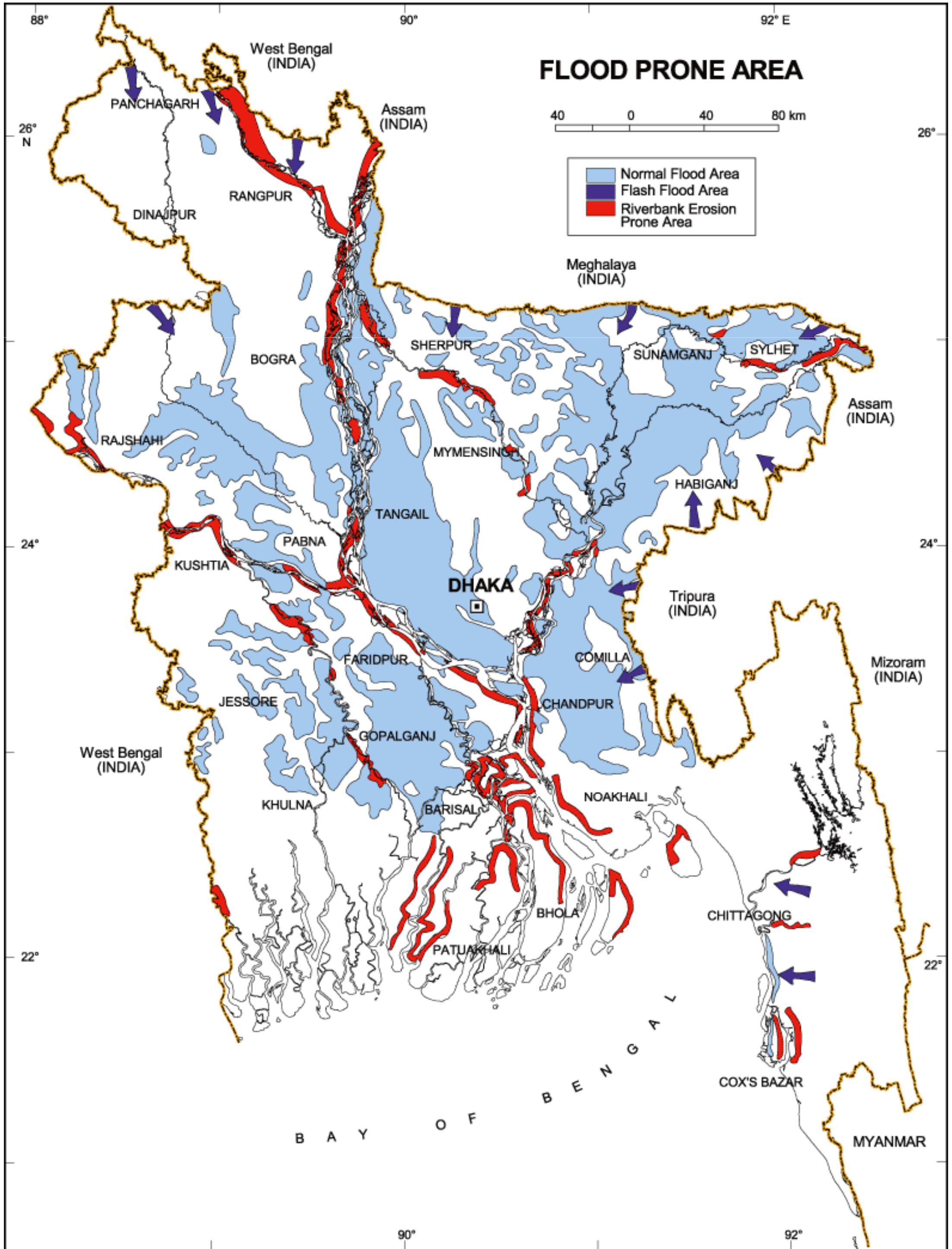
Thematic Map of Bangladesh: Landuse Map



Thematic Map of Bangladesh: Road Network



Thematic Map of Bangladesh: Flood Prone Area

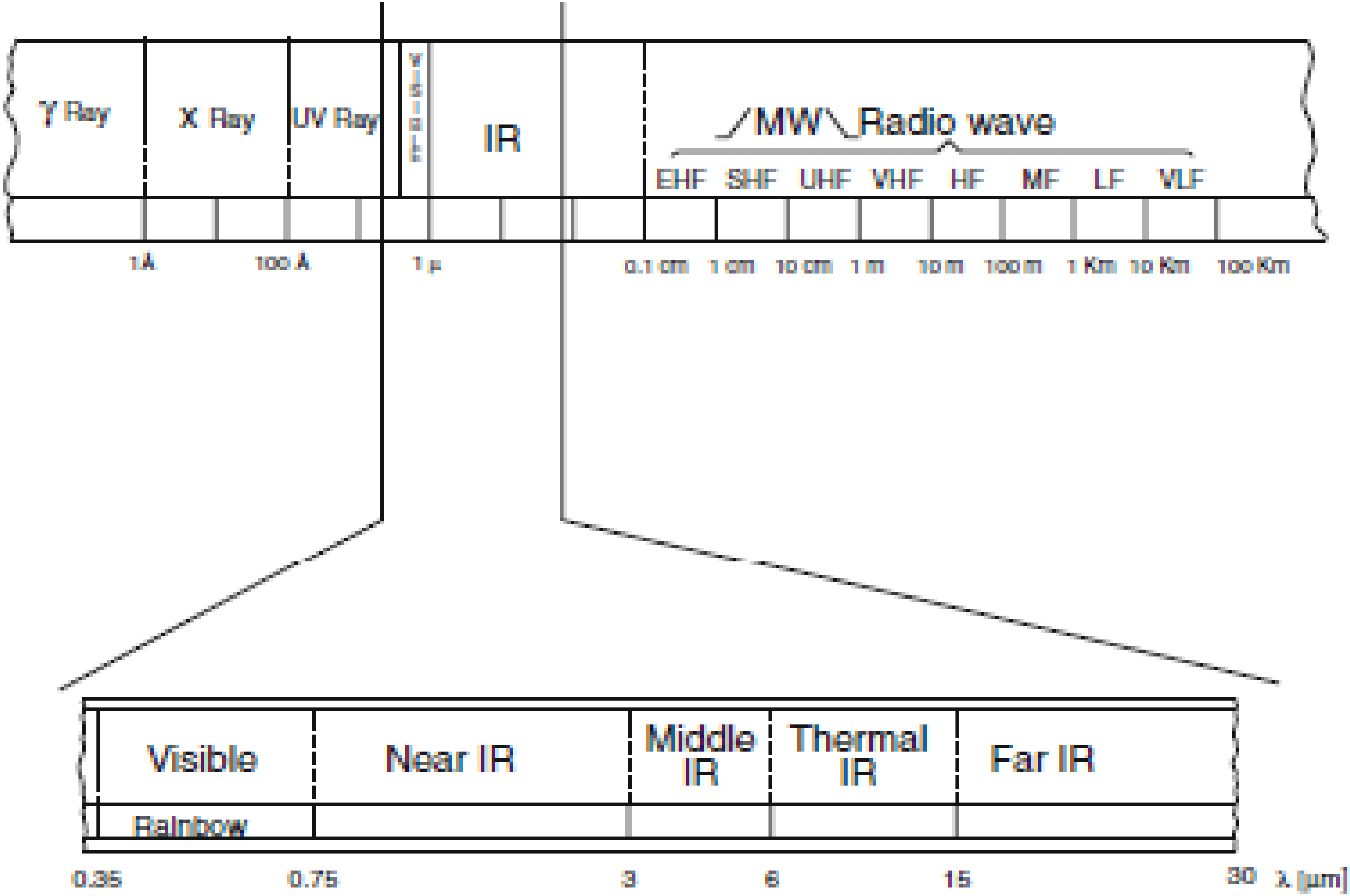


Basics of
Remote Sensing

Remote Sensing Basics: EM Spectrum

Electromagnetic (EM) spectrum is mono-dimensional continuous, consisting of a set of radiations ordered according to wavelength, frequency or photonic energy; it includes waves of any wavelength, ranging from fractions of Angstrom (one tenth of a millimicron Å = 10^{-10} m) to many kilometers.

Remote Sensing Basics: EM Spectrum

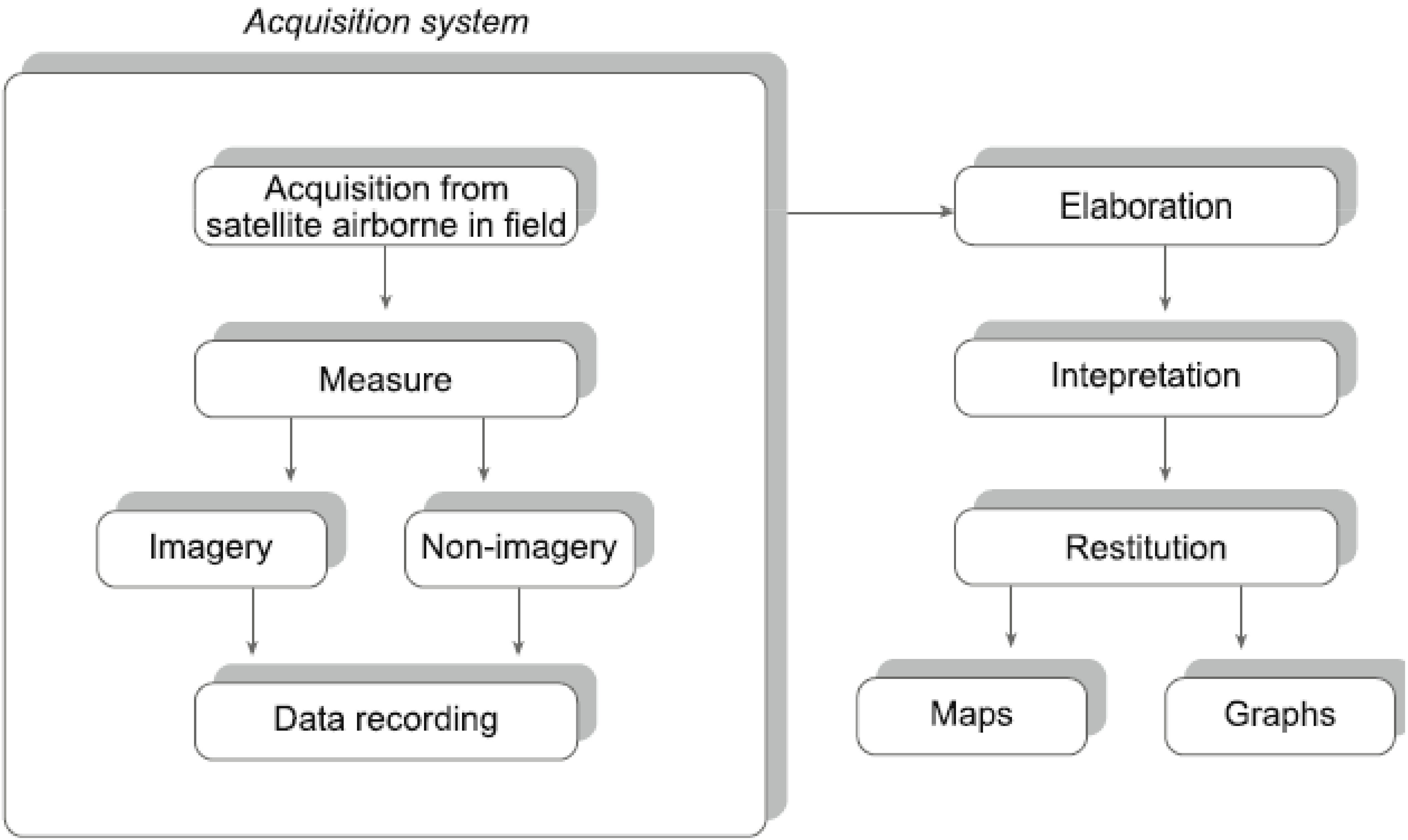


Remote Sensing Processes

Information acquisition with techniques of remote sensing is developed in three phases

- ***Collection of data*** *from the ground, aerial and/or satellite acquisition stations;*
- ***Processing*** *of the collected data;*
- ***Data interpretation****, followed by map production*

Remote Sensing Processes



Instrument Types

The **instruments** are divided into:

- ***passive sensors***
- ***active sensors***

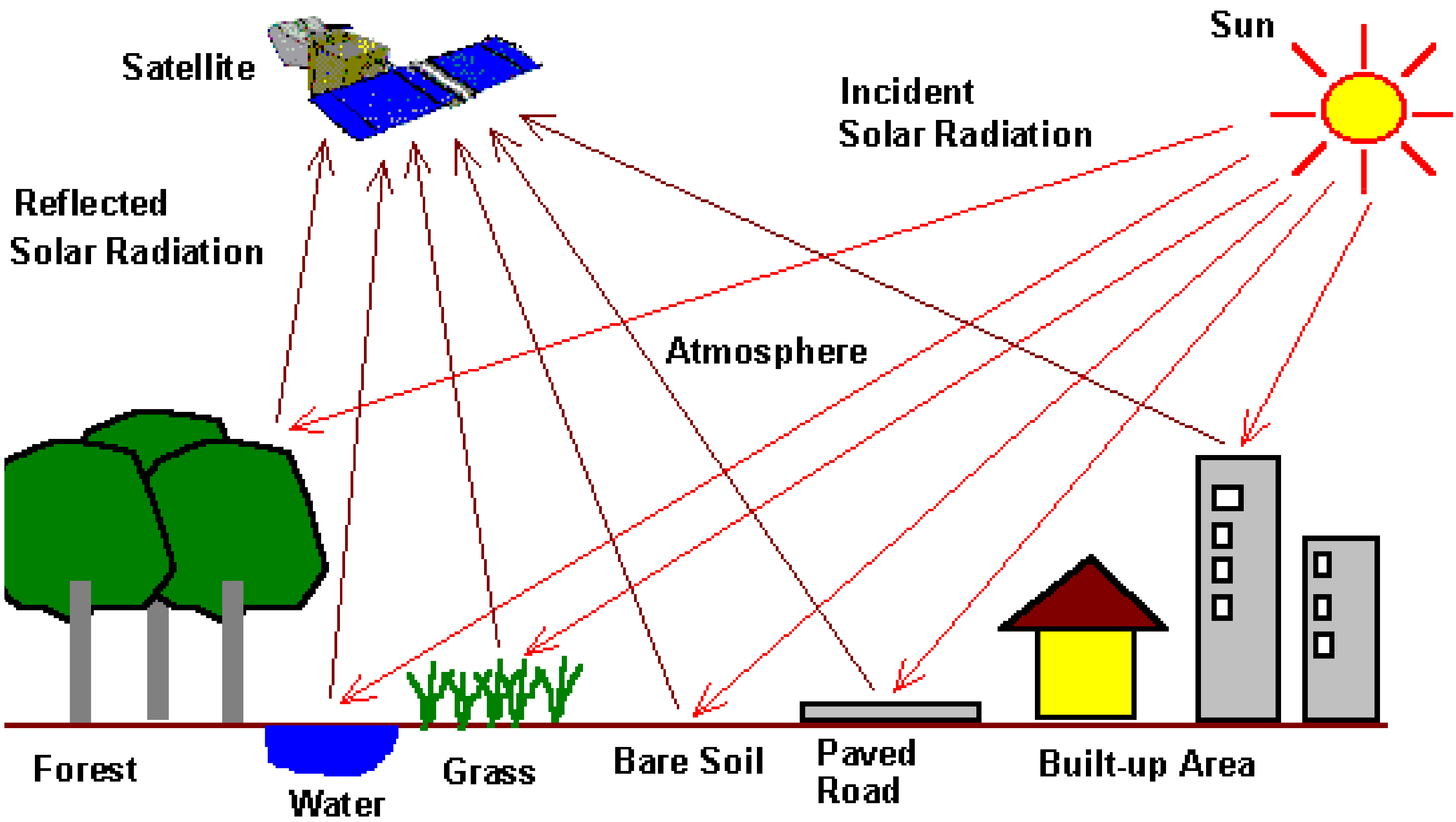
Passive Sensors

Records the intensity of the reflected electromagnetic energy coming from the Sun or emitted by the Earth.

Sensors types: photo cameras, scanners, thermal cameras and video cameras

Sensors operate in wavelength intervals from ***ultraviolet to thermal infrared***

Passive Remote Sensing: Energy from Sun

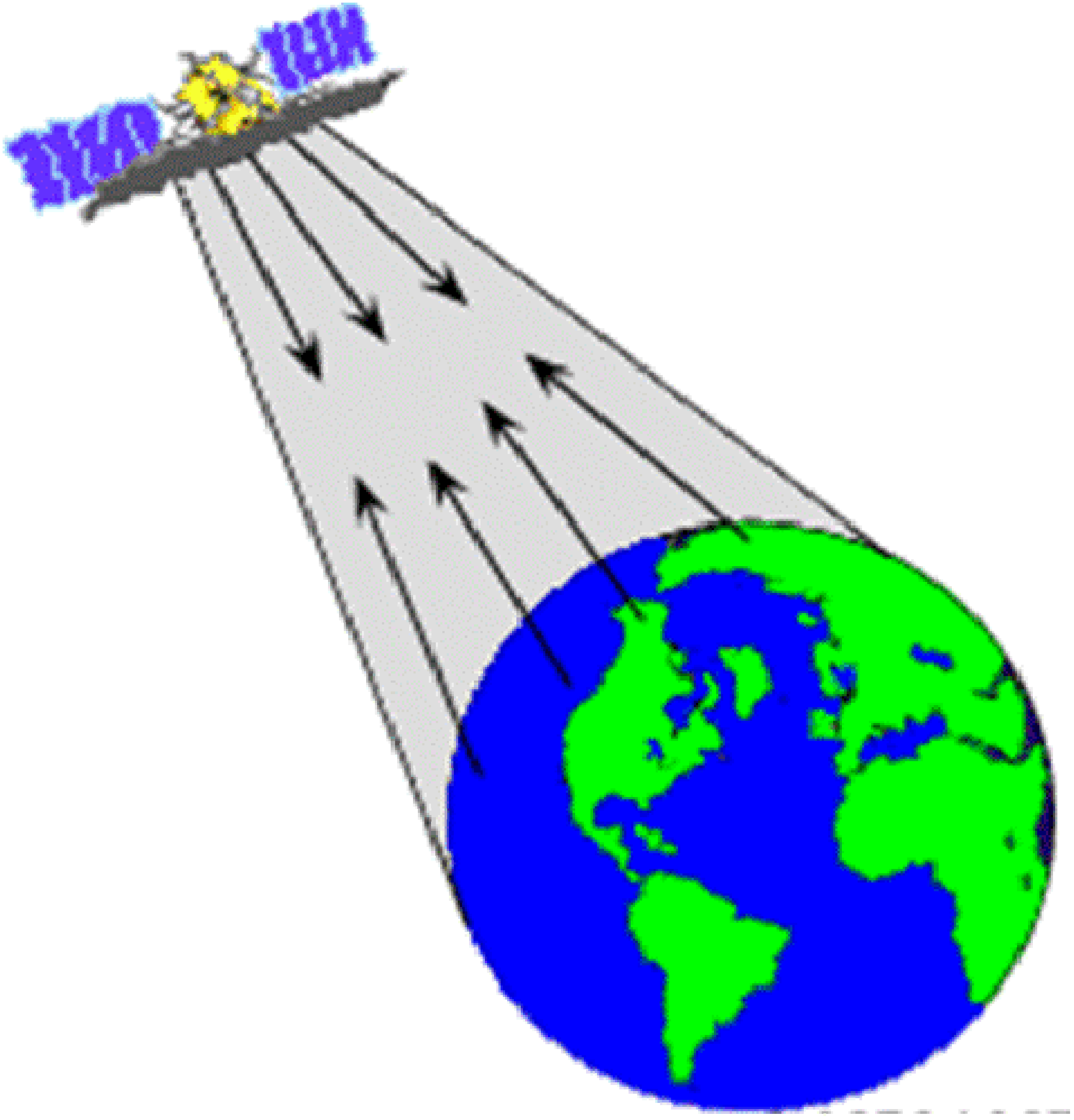


Active Sensors

The acquisition systems emit radiation themselves, collecting the back signal (radar); the radiation is backscattered to the sensor with intensity depending on the structural characteristics of the examined surface and on the wavelength (λ) of the incident radiation.

Active sensors operate in microwave intervals

Active Remote Sensing: Energy Emitted from Satellite itself



Types of Remote Sensing

- ***optical:*** *spectral range in the interval 0.3–15 μm, (typical of passive remote sensing)*
  - ***panchromatic:*** *one band including the visible range and in some cases part of the* near infrared;
  - ***multispectral:*** *2–9 spectral bands;*
  - ***super-spectral:*** *10–16 spectral bands;*
  - ***hyperspectral:*** *more than 16 spectral bands;*

- ***radar*:** microwaves ranging from 1 mm to 1 m

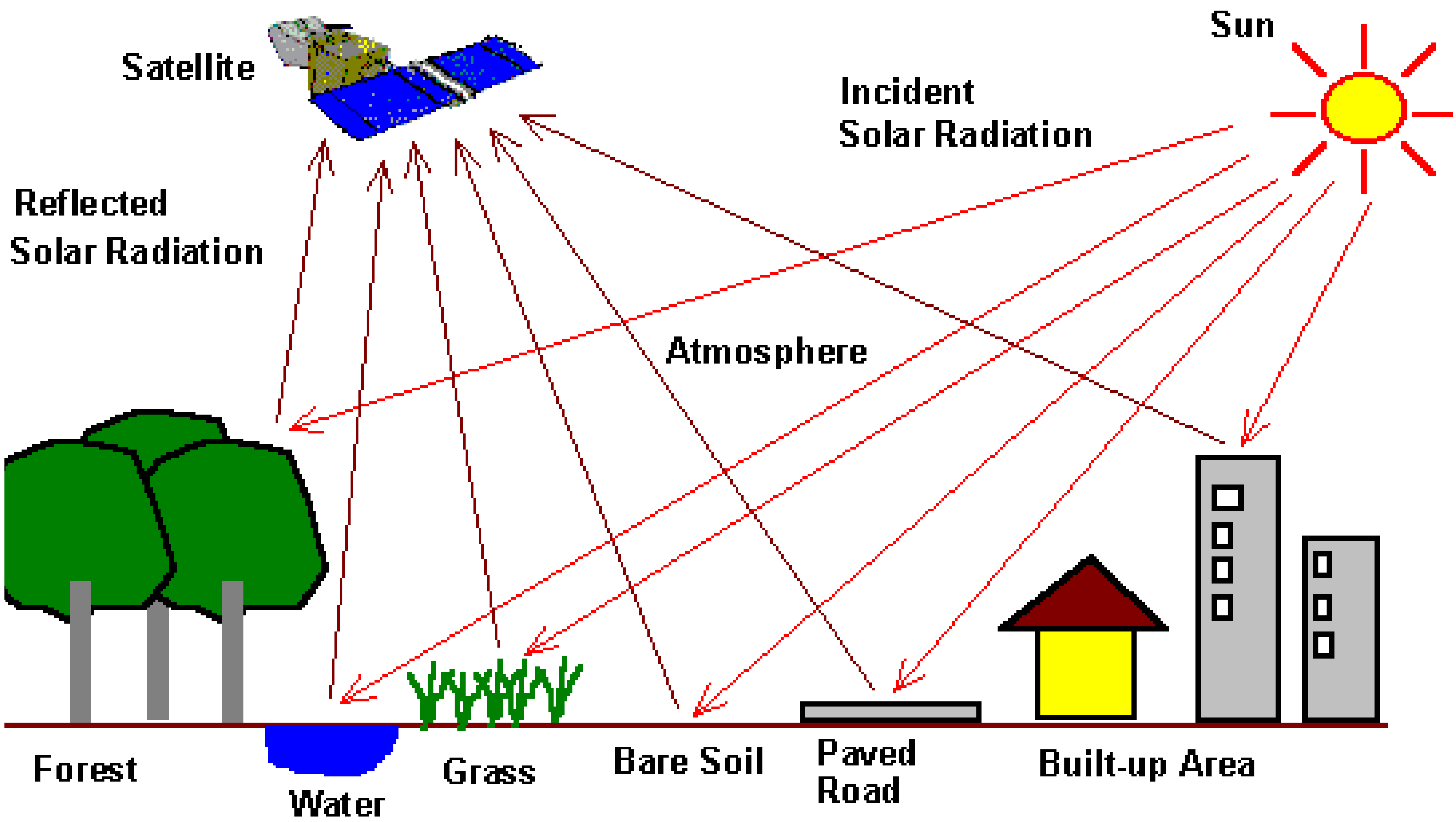
Optical Passive Remote Sensing

Source of Energy for Optical Passive RS

Main Source: The Sun and Earth

- The electromagnetic radiation emitted by the Sun ranges from cosmic rays to radio waves.
- Visible spectral range is about 50%
- The Earth, with an average surface temperature of about 15^{o}C, mostly **radiates in the thermal infrared** band, ranging from 8 to 14 μm
- **EM** radiation is affected by:
  - Earth–Sun distance;
  - Absorption and scattering processes characterizing the atmosphere.
- about **1/200,000 of the energy** emitted by Sun reaches the external limit of the atmosphere

Reflected Energy Recorded by Sensors in Satellite



Physical Principles for Optical Passive RS

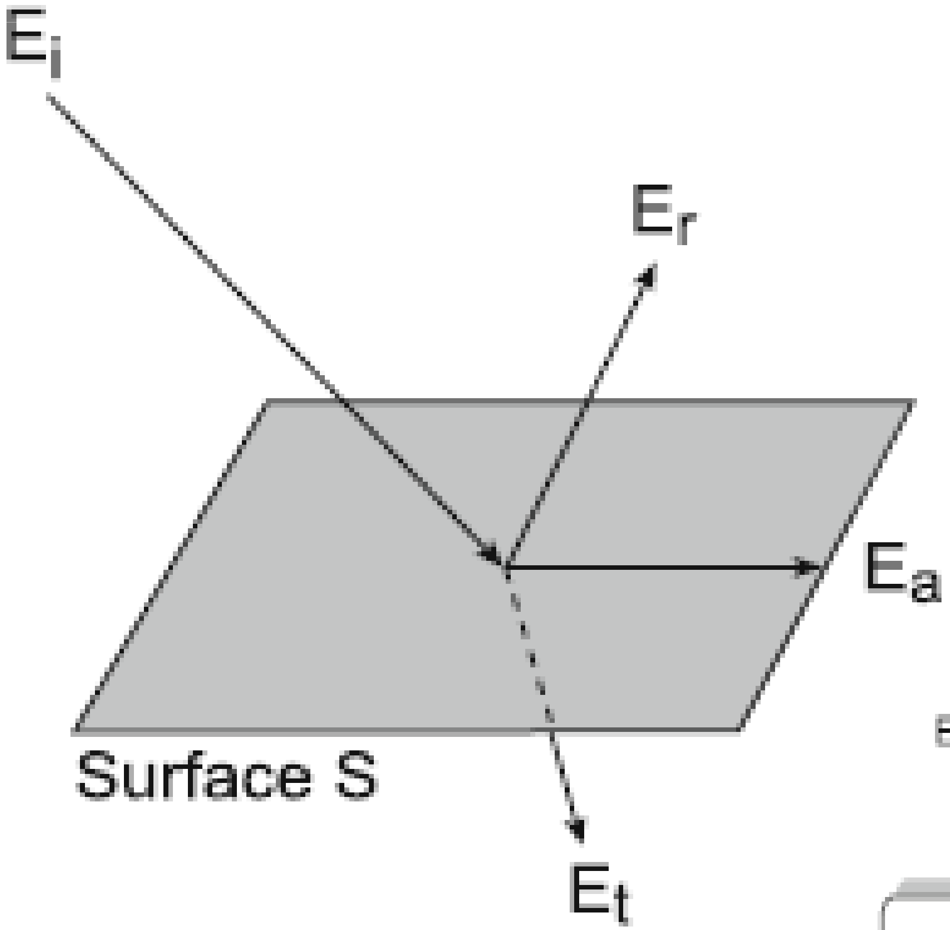
Remote sensing is based on electromagnetic energy properties. The **fundamental laws of radiation** defining its quantitative aspects are

- ***Kirchhoff's radiation law****:* regulates the relationship among the coefficients of reflection, transmission, absorption and emission;
- ***Planck's radiation law***
- ***Stefan–Boltzmann's radiation law***
- ***Wien's displacement*** *law*

Physical Principles for Optical Passive RS

Kirchhoff's radiation law

Every radiation incident on a real surface reacts following three phenomena: ***reflection***, ***absorption* and *transmission***. From the principle of the conservation of energy:



Ei = Er + Ea + Et

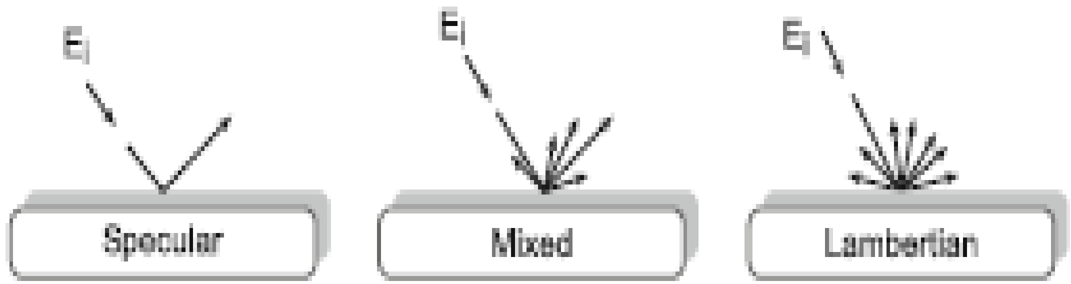
Where

Ei : incident radiation

Er : reflected radiation

Ea : absorbed radiation

Et : transmitted radiation



Terrestrial Albedo

The *albedo* is defined as the ratio of the electromagnetic energy reflected or diffused by a surface to the total incident energy. This relationship is usually expressed as a percentage. The values of albedo vary with the Sun’s angle.

Terrestrial Albedo

The following table provides albedo value for different surfaces:

Surface	Albedo (%)
Coniferous	10–20
Broadleaf	15–25
Cultivated field	15–30
Light soil (sand)	35–40
Dark soil (organic soil)	5–10
Desert	25–30
Recent snow	75–95
Water (incidence angle $< 45^{\circ}$)	5–10
Water (incidence angle $> 45^{\circ}$)	5–99

Radiometry

Radiometry is concerned with defining and **measuring radiometric units**, variable in function of the wavelength. Therefore when radiometric units are used, the interval of wavelengths to which they refer must be specified.

Radiometric Terminology

Radiant Energy: energy of the electromagnetic waves

Radiant Power: radiant energy transferred from a point or from a surface to another in the time

Radiant Exitance: radiation that is leaving an object or a surface

Irradiance: radiation that is incident on an object or a surface

Radiometric Terminology

Radiance: The *radiance* (*L*) is the most important radiometric unit, as it describes what in the real world is measured by the sensors used in remote sensing. The **optical-passive sensors** are sensitive only to the *radiance*.

The *radiance* refers to the radiation according to a **certain angle of observation**, indicating the radiant outgoing flux per surface unit and per solid angle unit, measured on a perpendicular plane to the considered direction.

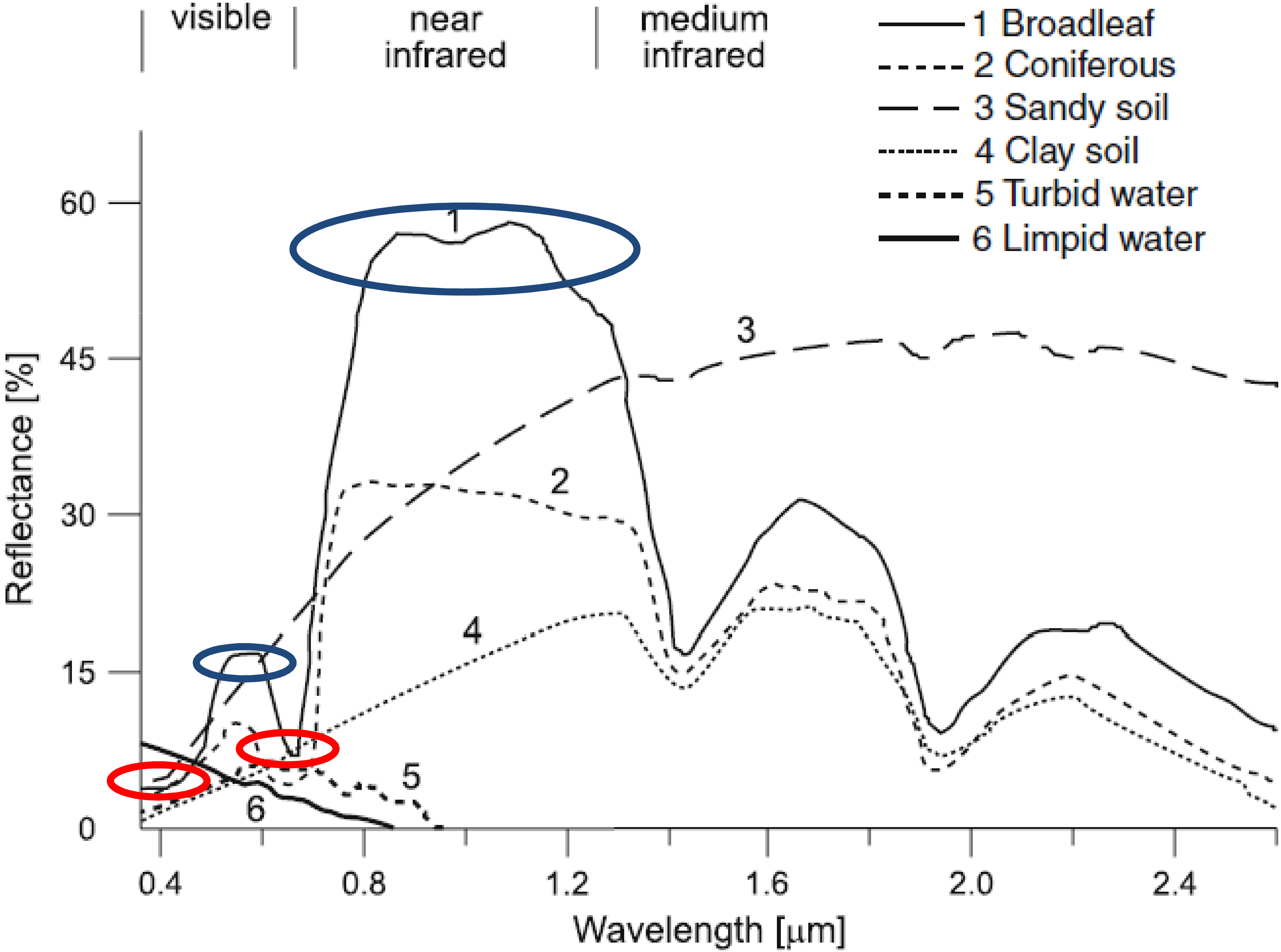
Spectral Response

The visualization of satellite digital images is the result of the conversion of the **signal** recorded by the sensor into discrete value or **Digital Number (DN)** associated to each **pixel**.

Since this signal is a function of the **physical–structural characteristics** of the detected object, it is possible to establish a correspondence between the **quantity** and the **quality** of the **reflected energy** and the **nature** of the **objects**, in relation to the **different wavelengths**.

Spectral Response

The signal recorded by the sensor can be represented in graphical terms as **reflection capability** in function of the **wavelength** known as the ***spectral response***, which is a key instrument for satellite image **quantitative analysis**. Spectral responses of some natural terrestrial elements are shown in the following figure:


visible
near infrared
medium infrared
1 Broadleaf
2 Coniferous
3 Sandy soil
4 Clay soil
5 Turbid water
6 Limpid water
60
45
30
15
0
Reflectance [%]
1
2
3
4
5
6
0.4
0.8
1.2
1.6
2.0
2.4
Wavelength [µm]

Spectral Response

The energy reflected in the visible contains spectral information also concerning the color of the reflecting surface. The reflectance is determined by the:

- geometric structure of the surfaces
- bodies' nature,
- vegetation pigmentation, etc.

For example, **chlorophyll** strongly **absorbs** the radiant energy in wavelength intervals near 0.45 μm (**blue**) and 0.65 μm (**red**), while **reflecting** the **green** radiation, near 0.55 μm wavelength, **visually perceived as the leaves' color** and reflects more in the region of **near infrared** from 0.8 to 1.3 μm.

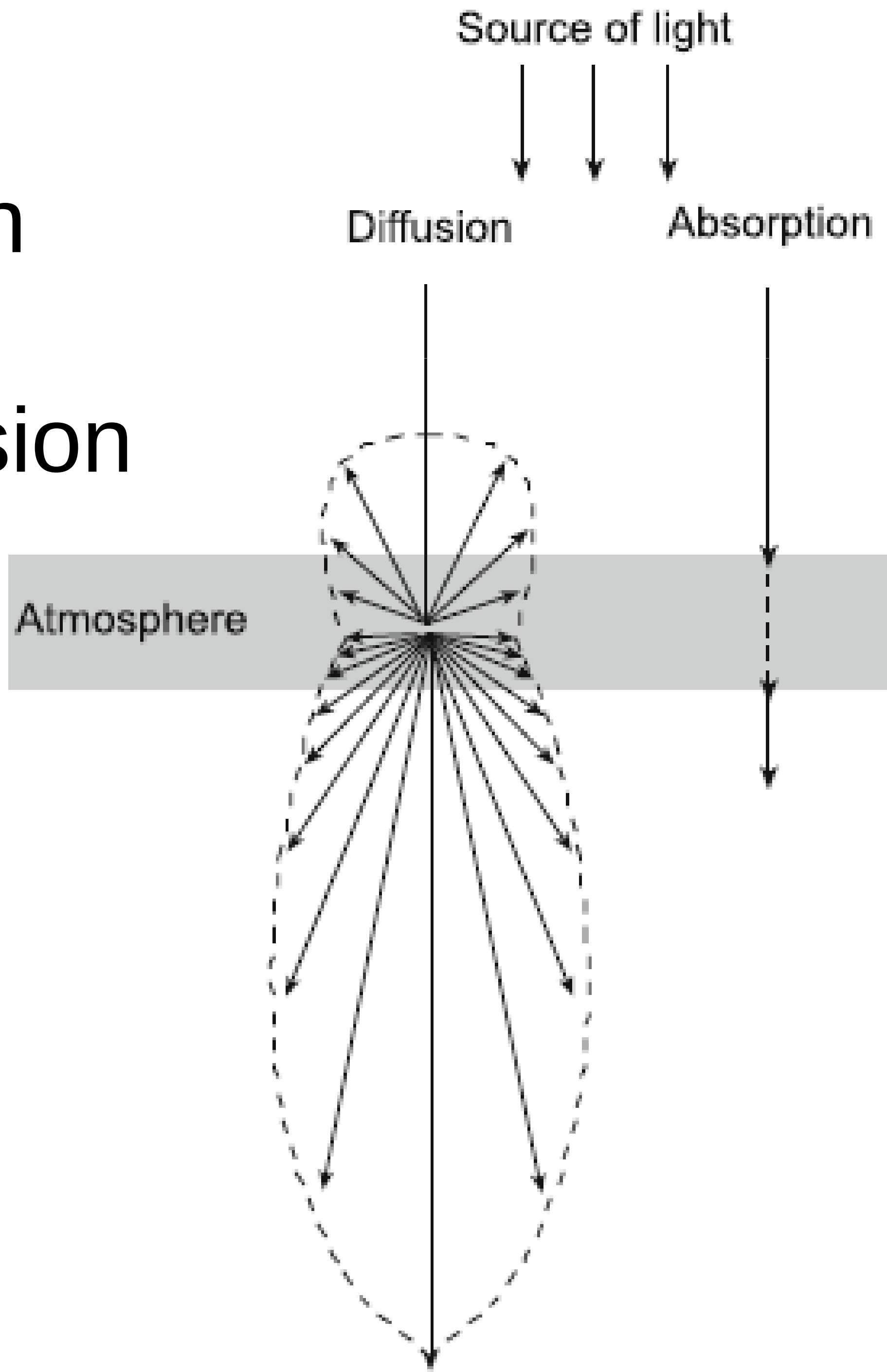
Spectral Response

The spectral behaviors of objects belonging to the same class can generate different spectral responses. The factors that produce variations in the spectral reflectance curves can be:

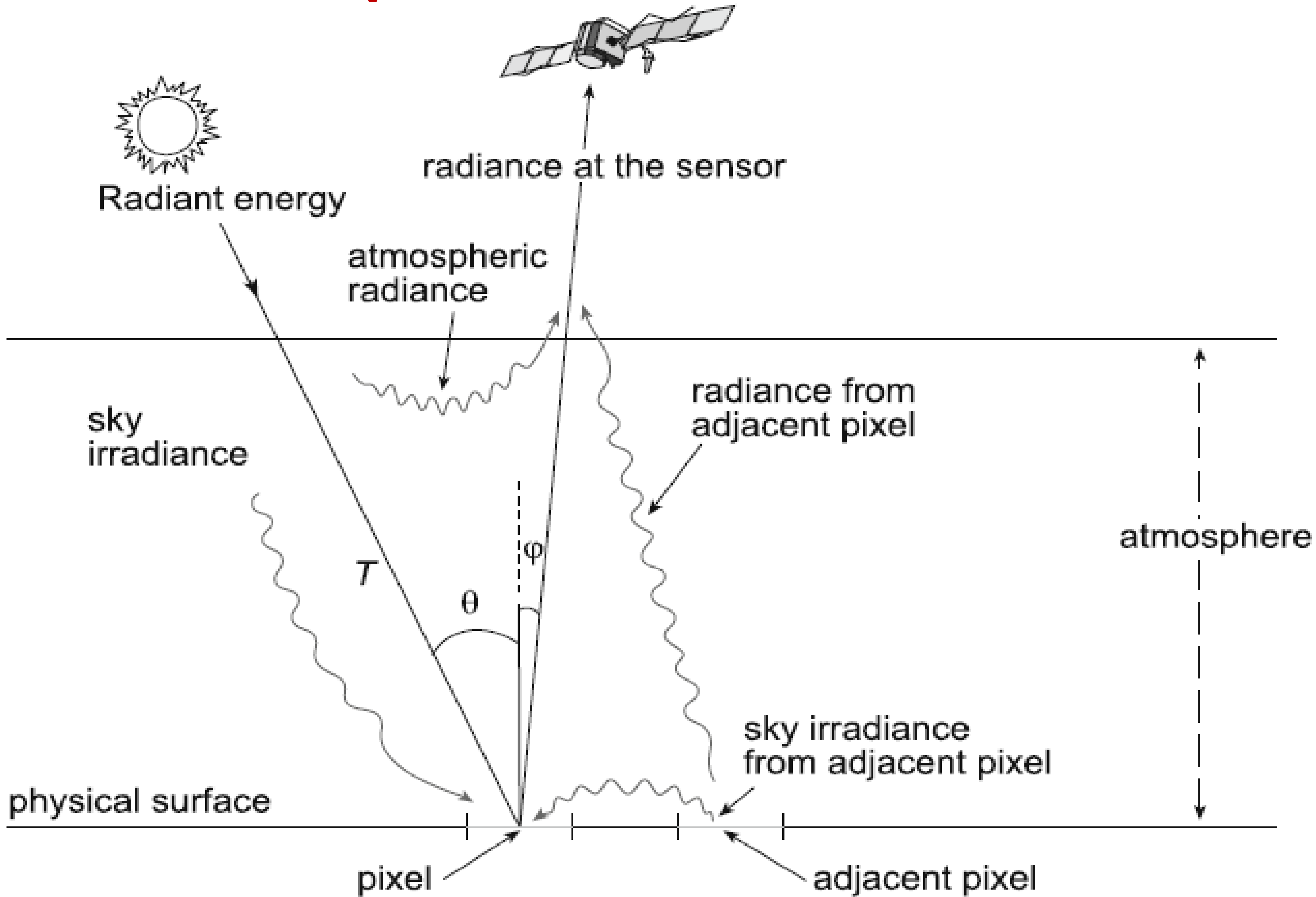
- ***Static*: ** such as slope and ground exposition;
- ***Dynamic*: ** inducing differences in spectral behavior of the same elementary cell over time. Among them are vegetation phenological phase, phytosanitary conditions and fractional cover, soil surface humidity, atmospheric transparency, Sun position, etc.

Interaction of EM Radiation with Atmosphere

- Absorption
- Reflection
- Transmission



Atmospheric Effect in the Visible



Atmospheric Effect in the Visible: Absorption

Absorption is very selective: each atmospheric component (aerosols and chemical species in general) absorbs the radiation in function of its wavelength. The chemical compounds responsible for the absorption of **X-ray and ultraviolet (UV) radiations are O, O_2 and O_3**, while **H_2O. and O_3 absorb in the visible range**, and **H_2O and CO_2 in the infrared**. As a consequence, atmosphere **transmissivity** (or transparency) of radiation is **variable**, limiting the possibility to collect signals in the EM intervals.

Atmospheric windows define wavelength ranges in which the atmosphere is particularly *transmissive* of energy

Atmospheric Window

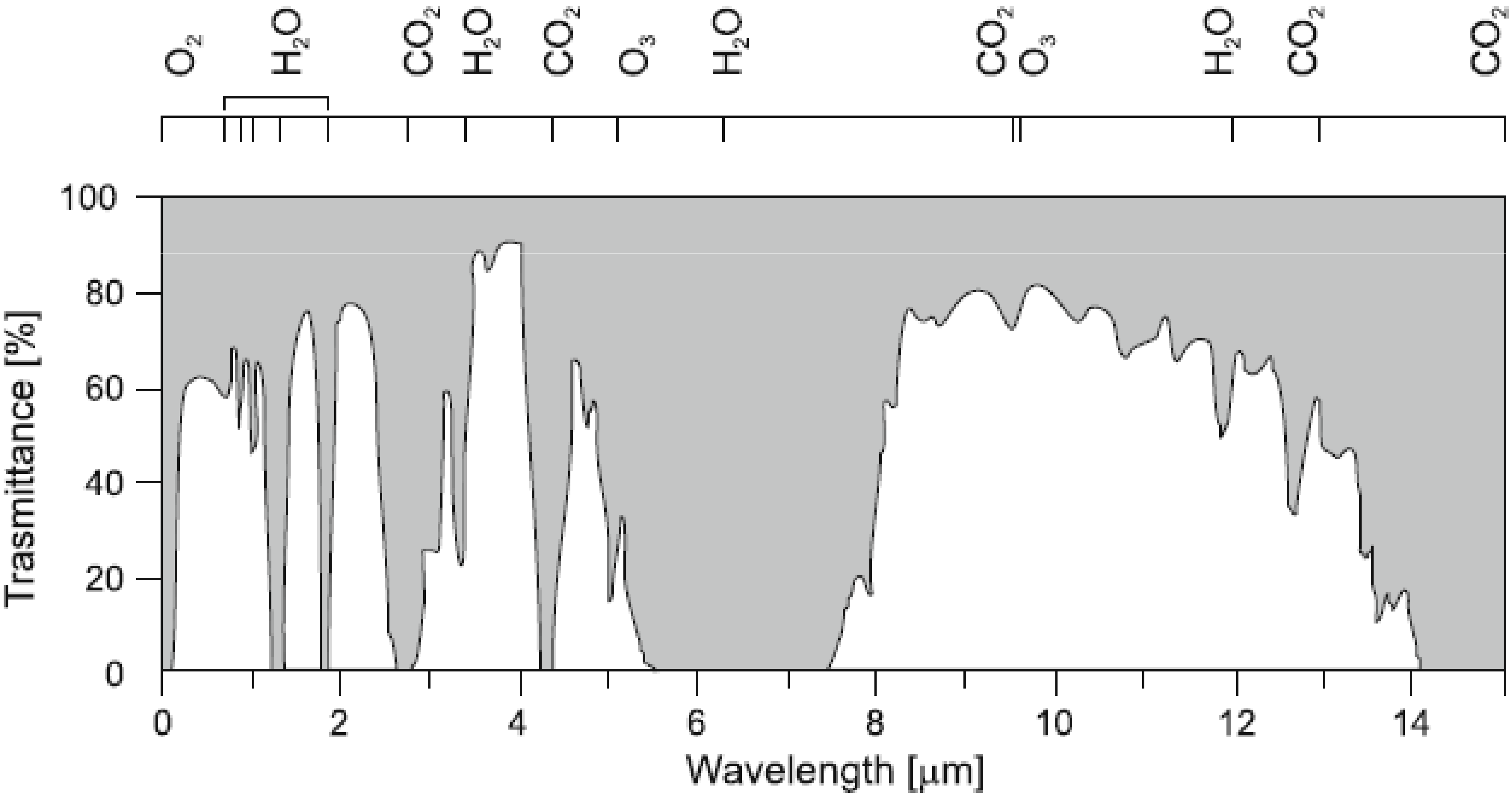


Figure : Atmospheric windows of electromagnetic radiation transmission referred to the gas absorption. The white area represents the atmospheric windows, where the radiation passes through

Remote Sensing Platform and Sensors

Orbits and Swath

Orbit: The path followed by a satellite is referred to as its orbit.

Swath Width: It is defined as the width of the strip, parallel to satellite's track, from which radiation is received

Geostationary Orbits: Satellites which view the same portion of the earth's surface at all times have geostationary orbit.

Geostationary satellites orbit in the equatorial plane of the earth at a speed equivalent to the earth's rotation. **Weather** and **Communication Satellites** commonly have these types of orbits.

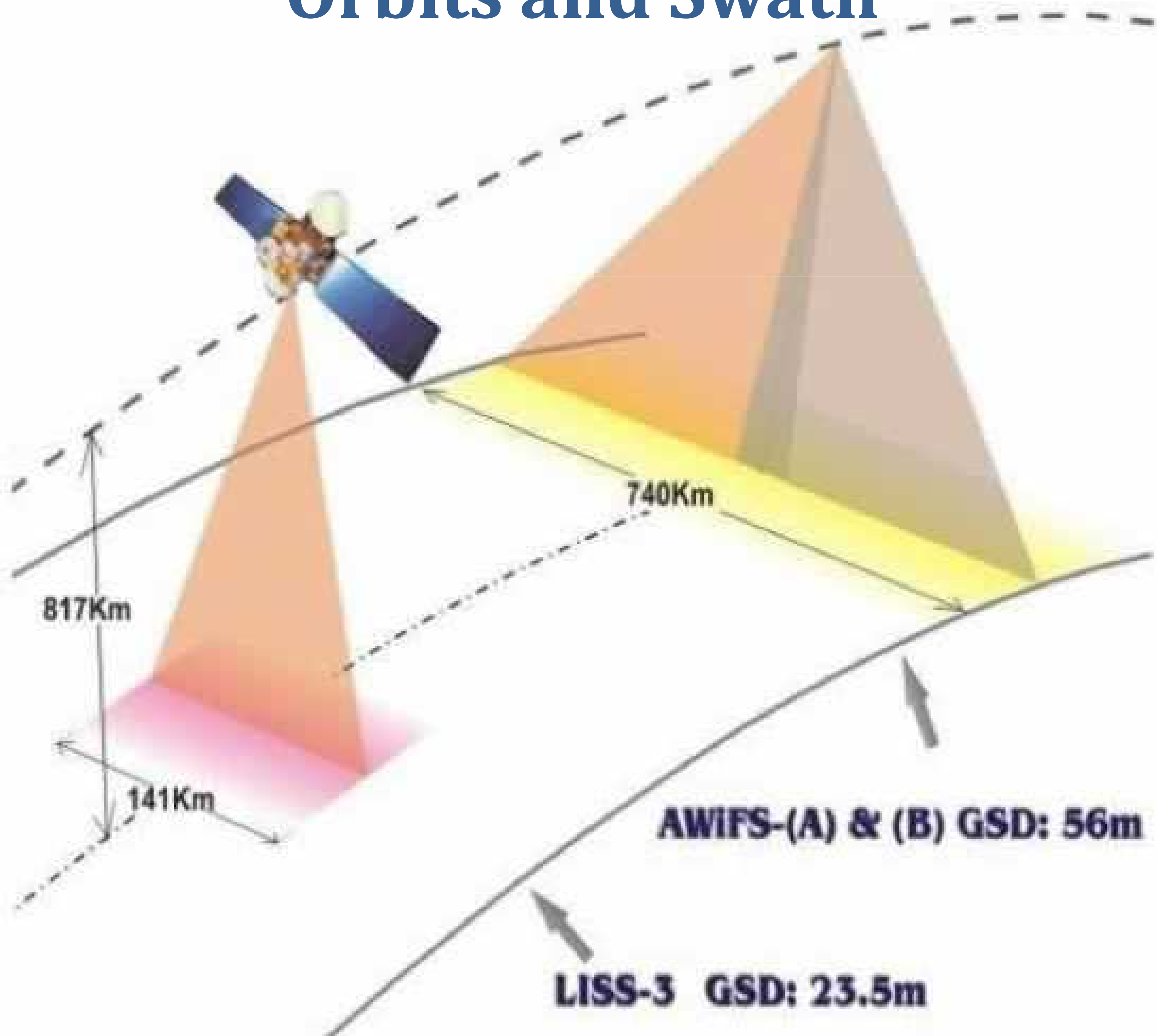
Many satellites are designed to follow a north south orbit which, in conjunction with the earth's rotation (west-east), allows them to cover most of the earth's surface over a period of time. These are **Near-polar** orbits.

Near polar orbits also mean that the satellite travels northward on one side of the earth and the southward on the second half of its orbit. These are called **Ascending** and **Descending** passes.

Many of these satellites orbits are also **Sun-synchronous** such that they cover each area of the world at a constant local time of day.

The surface directly below the satellite is called the **Nadir Point.**

Orbits and Swath



Satellite Sensor Characteristics

The basic functions of most satellite sensors are to collect information about the reflected radiation along a pathway, also known as the **field of view (FOV)**, as the satellite orbits the Earth. The smallest area of ground that is sampled is called the **instantaneous field of view (IFOV)**. The IFOV is also described as the **pixel size** of the sensor. This sampling or measurement occurs in one or many spectral bands of the EM spectrum. The data collected by each satellite sensor can be described in terms of spatial, spectral and temporal resolution.

Spatial Resolution

Spatial resolution refers to the size of the smallest object that can be resolved on the ground.

In a digital image, the resolution is limited by the pixel size, i.e. the smallest resolvable object cannot be smaller than the pixel size.

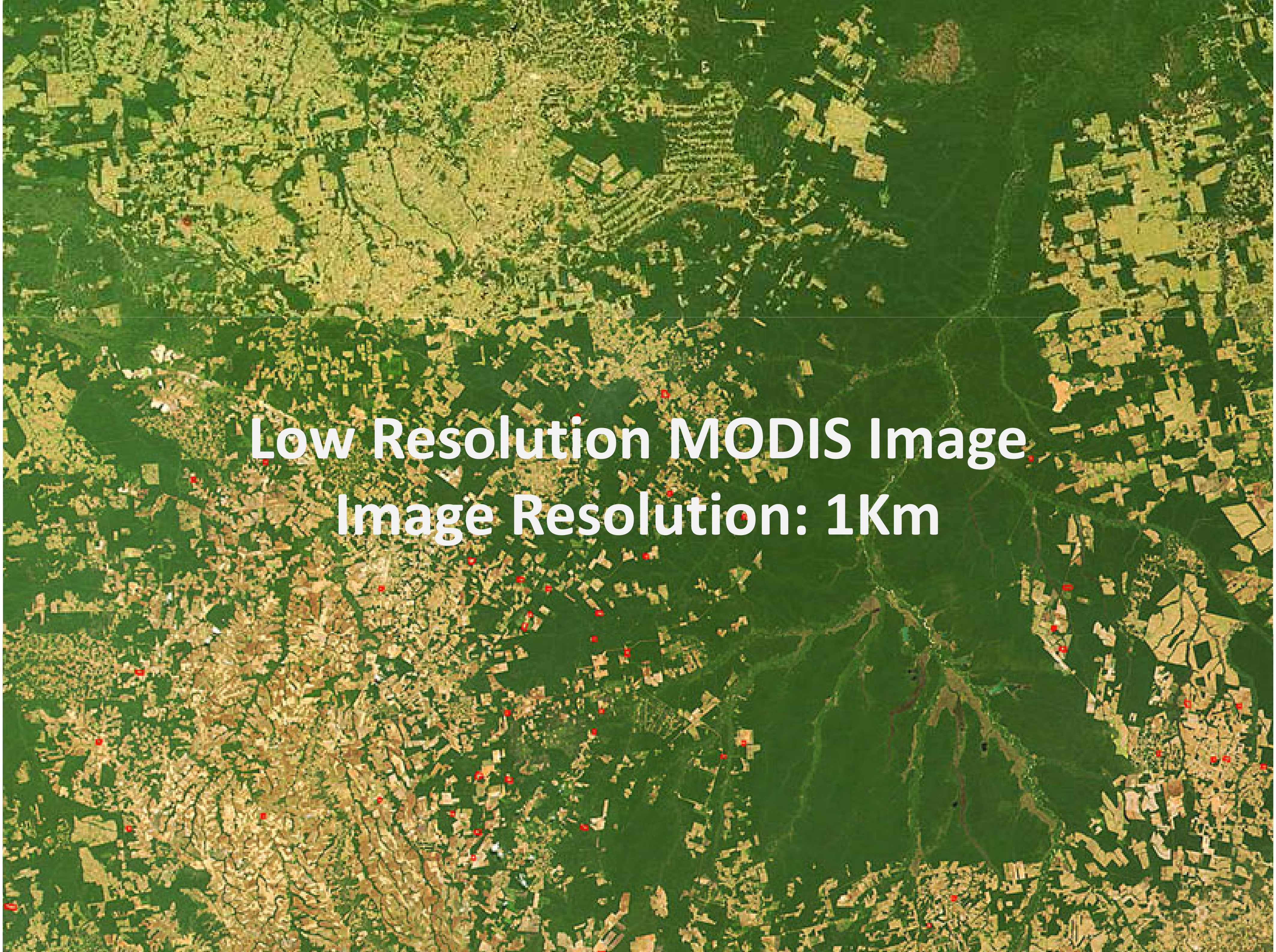
Spatial resolution can be **degraded** by factors which introduce **blurring** of the image, such as **improper focusing**, **atmospheric scattering** and **target motion**.

Spatial Resolution

The pixel size is determined by the sampling distance.

"High Resolution" image refers to one with a small pixel size. Fine details can be seen in a high resolution image.

"Low Resolution" image is one with a large pixel size, i.e. only coarse features can be observed in the image.


Low Resolution MODIS Image
Image Resolution: 1Km


Medium Resolution SPOT Image
Image Resolution: 20m


High Resolution IKONOS Image
Image Resolution: 4m


Super High Resolution Quickbird Image
Image Resolution: 0.6m


Super High Resolution Geoeye1 Image
Image Resolution: 0.4m

Radiometric Resolution

Refers to the smallest change in intensity level that can be detected by the sensing system.

- It is the capability to differentiate the spectral reflectance between various targets.

Radiometric Resolution

- This depends on the number of quantization levels within the spectral band
  - In other words, the number of bits of digital data in the spectral band or number of grey level value will decide sensor sensitivity
- It is commonly expressed as the number of binary digits required to store the maximum level value. Thus the number of bits required for 2, 4, 8, 16, 256 levels is 1, 2, 4, 6, 8 respectively


Panchromatic Image

Spectral Resolution

The **spectral resolution** of a sensor system is the **number and width of spectral bands** in the sensing device.

The **simplest form of spectral resolution** is a sensor with **one band only**, which senses **visible light**. An image from this sensor would be **similar in appearance** to a **black and white** photograph from an aircraft.

A sensor with **three spectral bands** in the visible region of the EM spectrum would collect similar information to that of the human vision system.

Spectral Resolution

Panchromatic image:

- Consists of only one band.
- It is usually displayed as a **grey scale image or black-and-white** (i.e. the displayed brightness of a particular pixel is proportional to the pixel digital number which is related to the intensity of solar radiation reflected by the targets in the pixel and detected by the detector)

Spectral Resolution

Multispectral and hyperspectral images consist of several bands of data.

For visual display, each band of the image may be displayed one band at a time as a **grey scale image**

Or in combination of three bands at a time as a **color composite image**.

Interpretation of a multispectral color composite image will require the knowledge of the **spectral reflectance signature** of the targets in the scene.

Temporal Resolution

Temporal resolution is a measure of the **repeat cycle or frequency** with which a sensor revisits the same part of the Earth's surface. The frequency will vary from several times per day, for a typical weather satellite, to 8-20 times a year for a moderate ground resolution satellite, such as Landsat TM. The frequency characteristics will be determined by the design of the satellite sensor and its orbit pattern.

Different Types of Satellites

Satellites	Camera Mode	Spatial Resolution	Repeat Cycle day	Swath Width Km	Single Point Scene	Altitude Km	Application
GeoEye1	• Simultaneous Panchromatic and Multispectral, • Panchromatic • Multispectral	0.41m(P) 1.65	2.8	15.2	15 x 15	684	Earth Observation Satellite (Environmental Monitoring, Meteorology, Map making)
WorldView-2	• Panchromatic • 8 Multispectral	0.46m(P) 1.8m	3.7	16.4	256	770	• Land use Planning • Disaster Relief • Defense & Intelligence
WorldView-1	• Panchromatic	0.55m(P)	5.9	17.6	17.6 x 14	496	• geo-location capabilities • Rapid targeting, Stereo Collection.
QuickBird	• Panchromatic • Multispectral	0.61m(P) 2.4m	3.5	16.5	16.5 x 16.5	450	• Land use Change • Agriculture, Forest Climate • Oil & Gas Exploration
IKONOS	• Panchromatic • Multispectral	0.82m(P) 3.2m	14.7	11.3	11.3 x 11.3	681	• Natural Resource Mapping • Forestry • Agriculture
Landsat TM	7 spectral bands	30m	16	185		705	• Thematic Mapping
MODIS	Multispectral	250-1000	1		2230x10		• Surface Temperature

Infrared Image