REMOTE SENSING LECTURE NOTES 2020-2021

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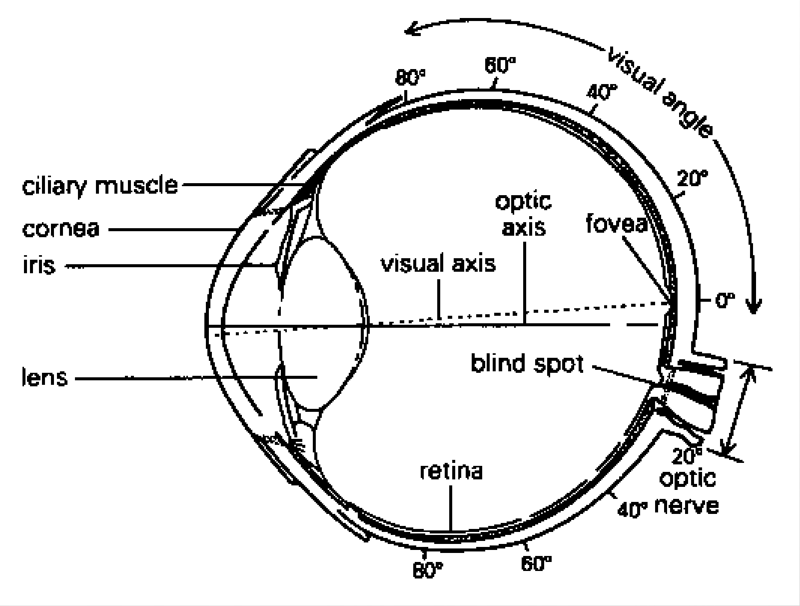
Outline

1. Definition
2. History of remote sensing
3. Principles of radiation
4. Radiation-target interaction
5. Spectral signatures
6. Resolution
7. Satellite orbits
8. Applications

What is remote sensing ?

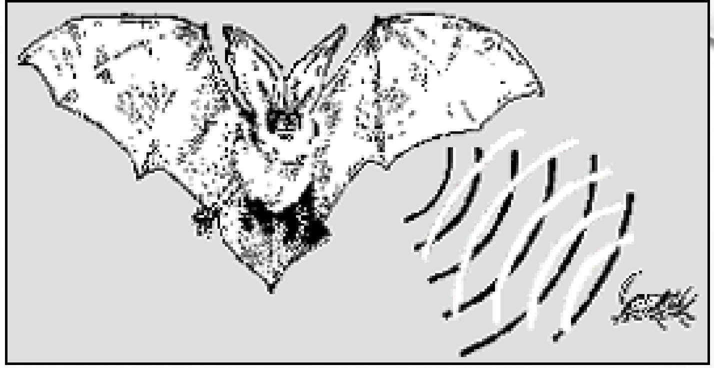
- Remote – away from or at a distance
- Sensing – detecting a property or characteristic



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

Remote Sensing Definitions

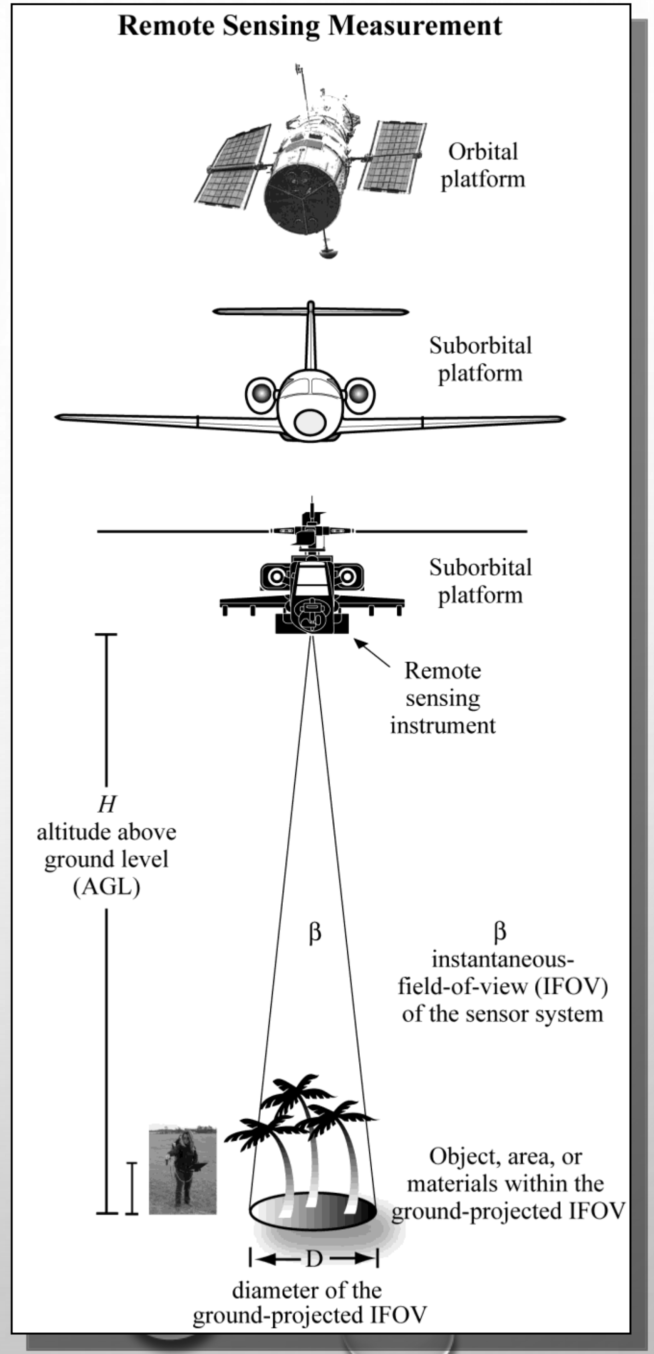


"REMOTE SENSING IS TEACHING US A NEW WAY OF SEEING".

REMOTE SENSING HAS BEEN DEFINED IN MANY WAYS.

Definition 1

Remote sensing is "the acquisition of information about an object, without being in physical contact with that object"



Definition 2

Remote sensing is "the ability to measure the properties of an object without touching it".

Definition 3

Remote sensing can be defined as "the collection of data about an object from a distance. Humans and many other types of animals accomplish this task with aid of eyes or by the sense of smell or hearing".

Definition 4

Remote sensing is "the examination, measurement, and analysis of an object without being in contact with it".

Definition 5

Remote sensing is "the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device not in contact with the object, area, or phenomenon in question".

Definition 6

Remote sensing is "the science (and to some extent, art) of acquiring information about the earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information".

Definition 7

Remote sensing is by definition "the science of gathering information about phenomena using devices that are not in contact with the object. Currently remote sensing technologies include a number of differing air and space borne instruments that gather data about the earth and its features".

Definition 8

Remote sensing is a method for getting information about of different objects on the planet, without any physical contacts with it.

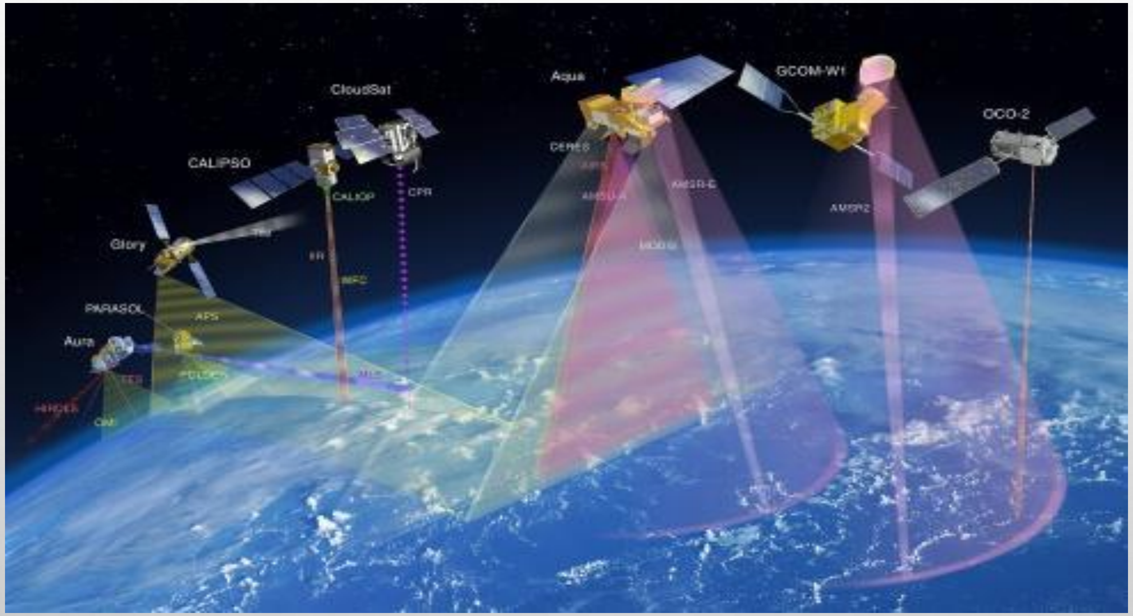


Image Source: cimss.ssec.wisc.edu

Definition 9

Science and art of obtaining information about an object, area or phenomenon through an analysis of data acquired by a device that is not in direct contact with the area, object or phenomenon under investigation.

Lillesand, Thomas M. and Ralph W. Kiefer, "Remote Sensing and Image Interpretation" John Wiley and Sons, Inc, 1979, p. 1

What are some common examples of remote sensors?

Definition 10

Remote sensing is a technology for sampling electromagnetic radiation to acquire and read non-immediate geospatial data from which to pull info more or less features and objects on the earths land surface, seas, and air.

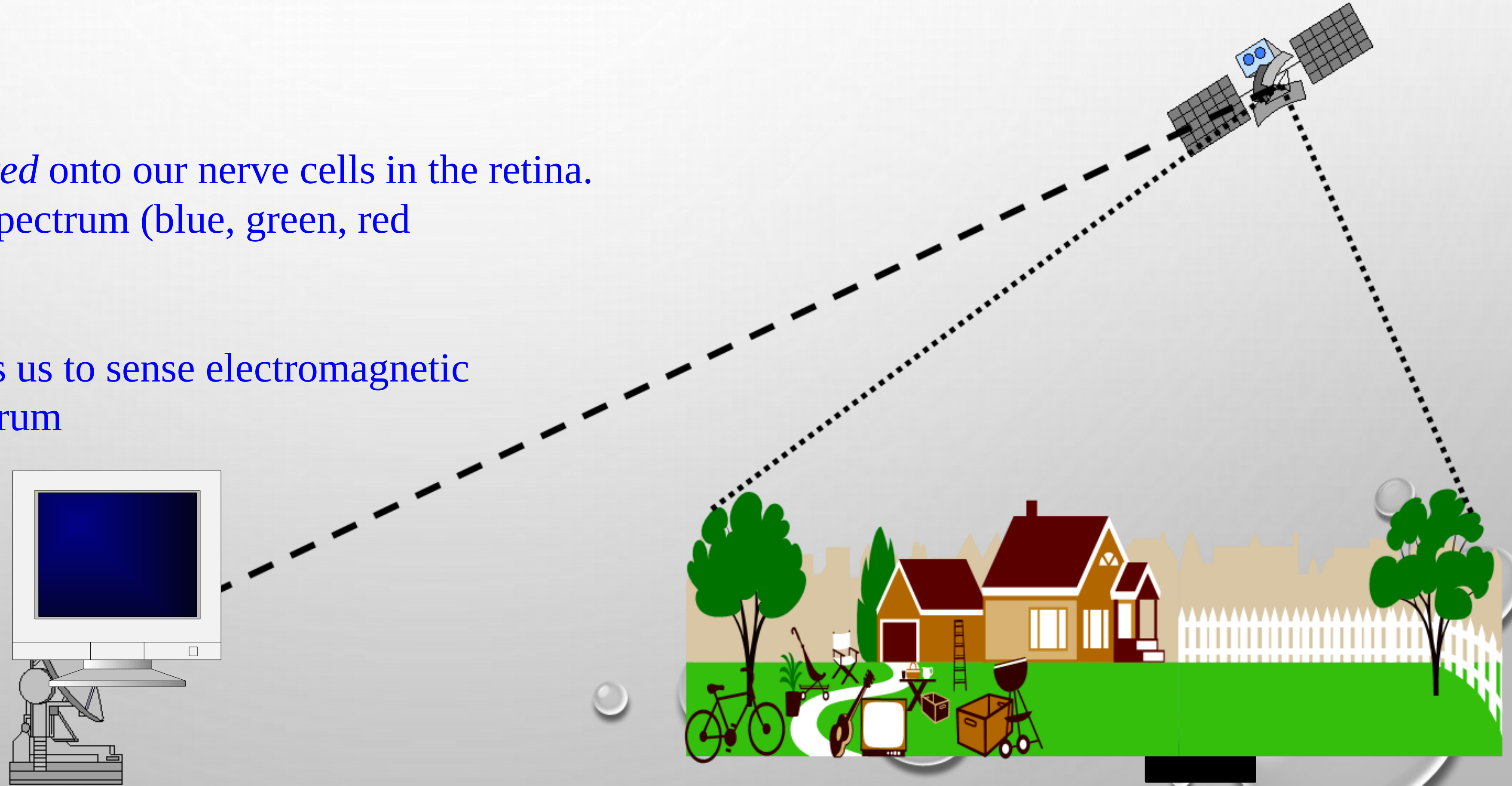
- Dr. Nicholas Short

What we see & why

Eyes: *Sunlight is reflected* onto our nerve cells in the retina.

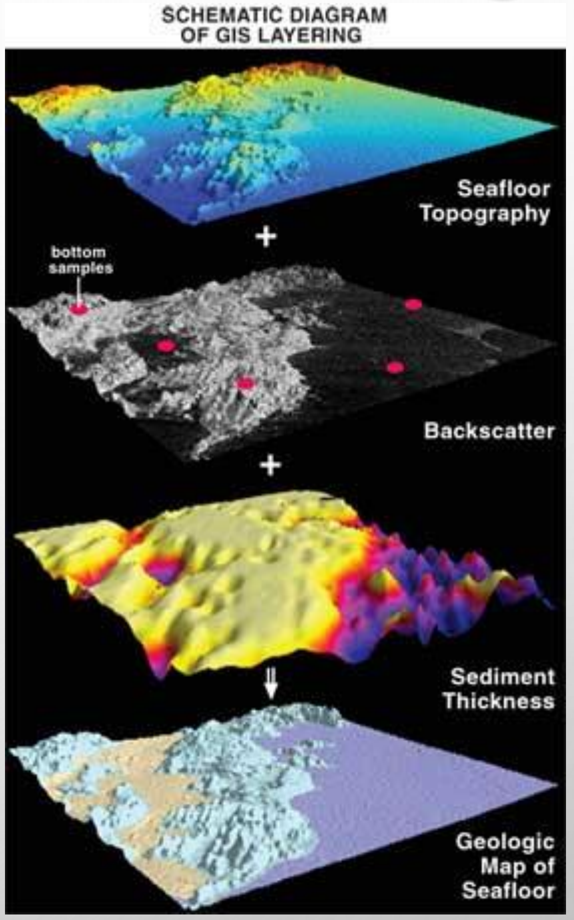
What we see: Visible spectrum (blue, green, red wavelengths)

Remote sensing equipment allows us to sense electromagnetic radiation beyond the visible spectrum



The Importance of RS

- Large amounts of data needed, and Remote Sensing can provide it
- Reduces manual field work dramatically
- Allows retreval of data for regions difficult or impossible to reach:
    - Open ocean
    - Hazardous terrainn (high mountains, extreme weather areas, etc.)
    - Ocean depths
    - Atmosphere
- Allows for the collection of much more data in a shorter amount of time
    - Leads to increased land coverage and
    - Increase ground resolution of a GIS
- Digital imagery greatly enhances a gis
    - DIRECTLY: imagery can serve as a visual and
    - INDIRECTLY: can serves as a source to derive information such as…
        - Land use/land cover
        - Atmospheric emisions
        - Vegetation
        - Water bodies
        - Cloud cover
        - Change detection (ıncludıng sea ıce, coastlines, sea levels, etc.)

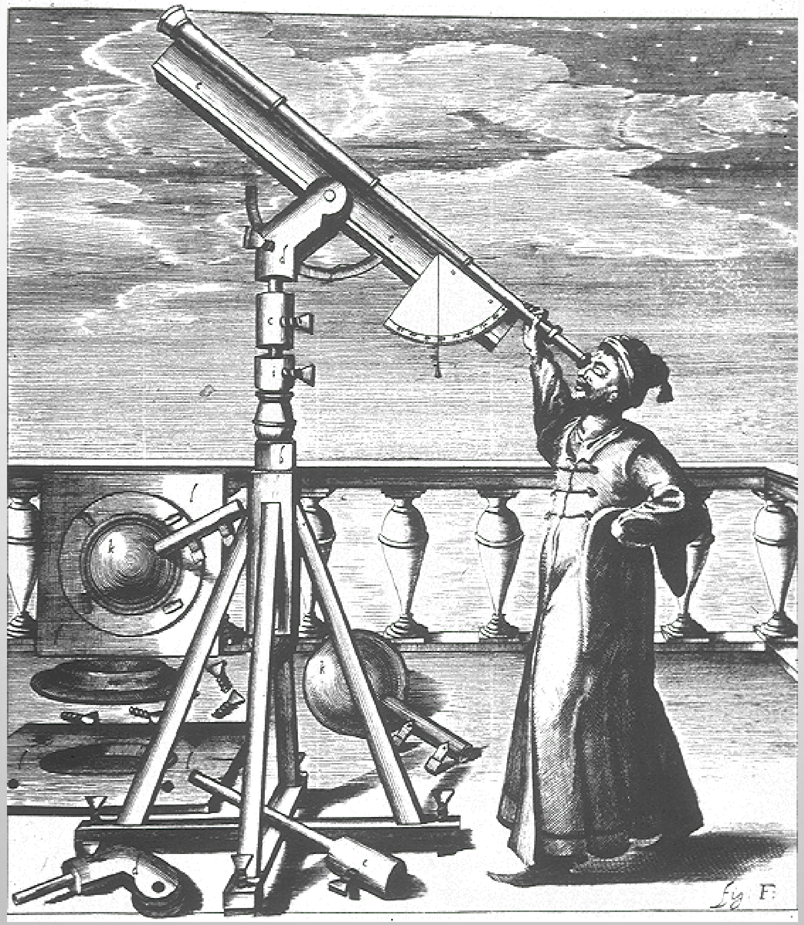


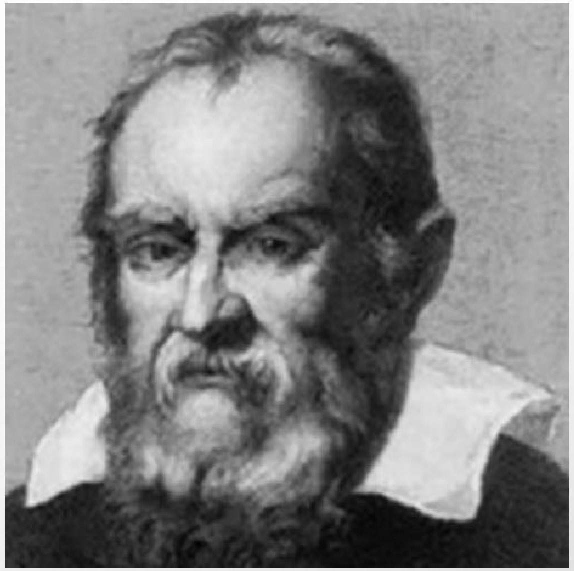
A summary RS

- Provides a view for the large region
- Offers Geo-referenced information and digital information
- Most of the remote sensors operate in every season, every day, every time and even in real tough weather

History of Remote Sensing

1609 - Invention of the telescope

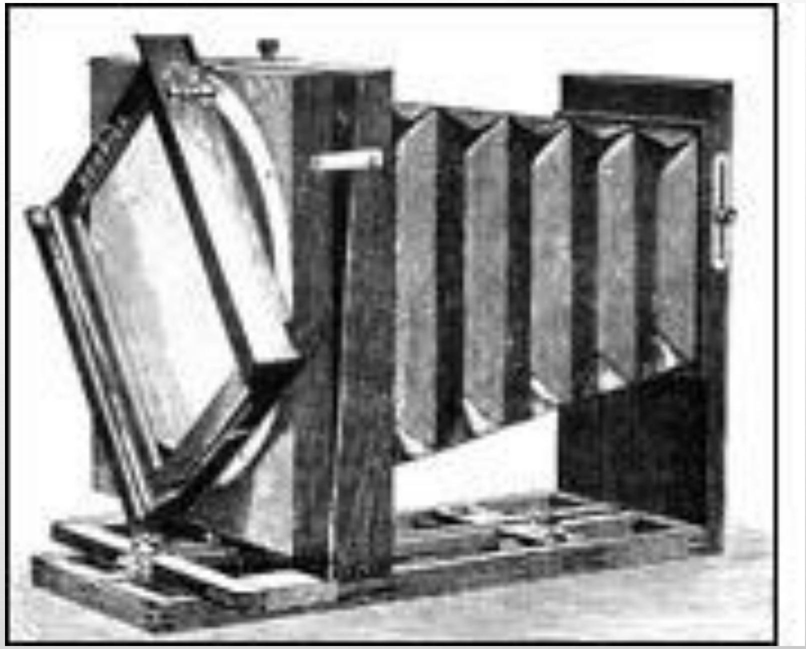




Galileo

History of Remote Sensing

- 1839, the first photographs.
- 1849, used photography in topographic mapping.
- 1858, balloons were being used to acquire photography of large areas.

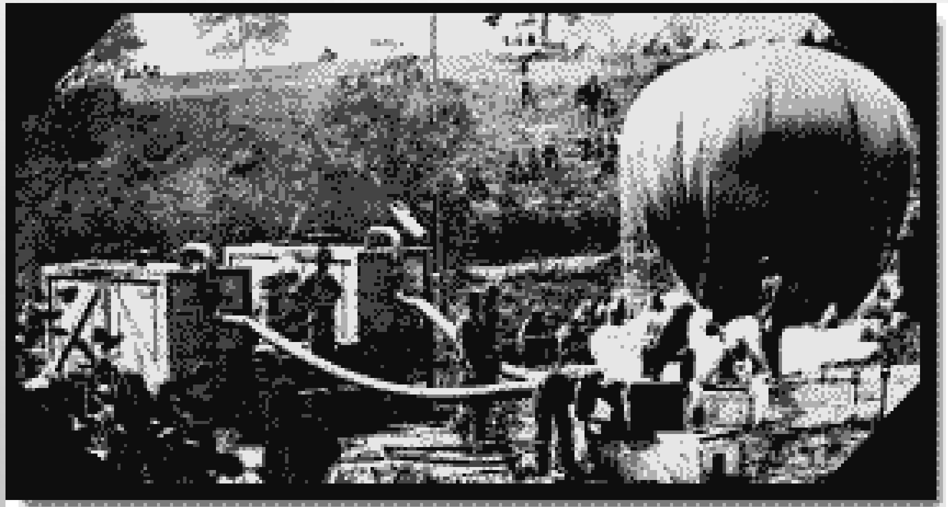


History of Remote Sensing

1859 - First aerial photographer

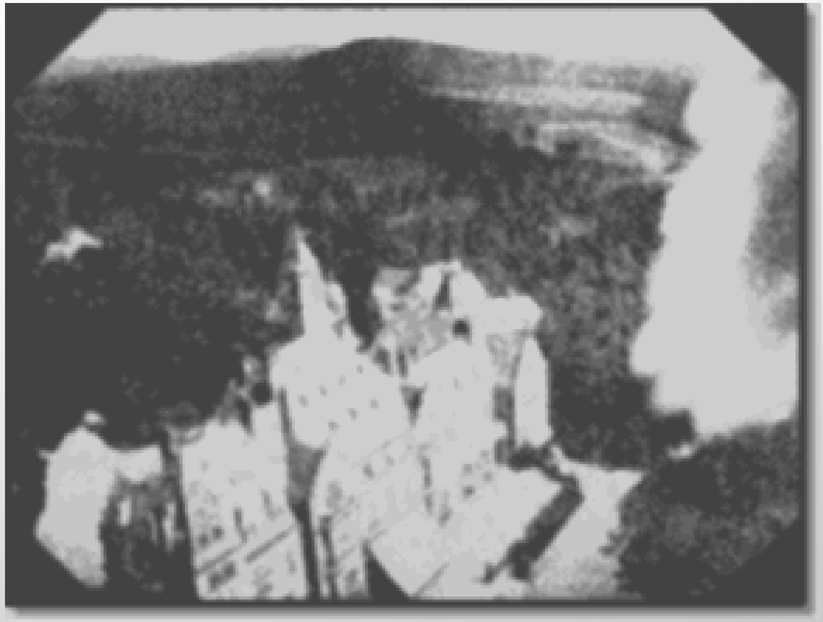
Gaspard Felix Tournachon, also known as Nadar

1862 - US Army balloon corp



History of Remote Sensing

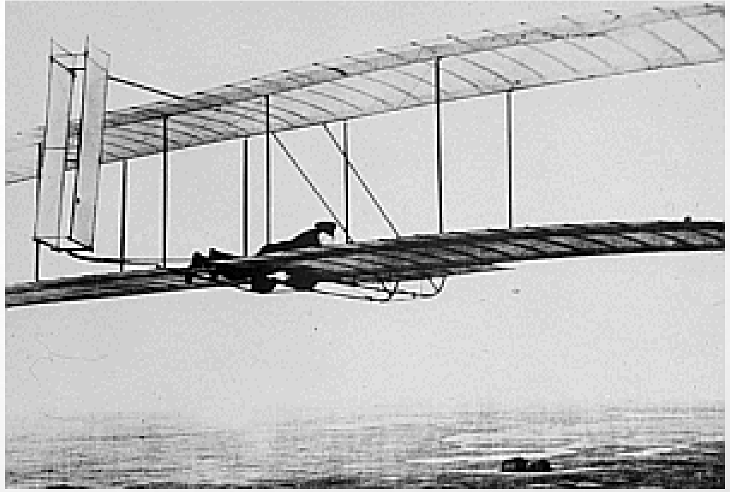
1903 - The Bavarian Pigeon Corps



1909 - Dresden International Photographic Exhibition

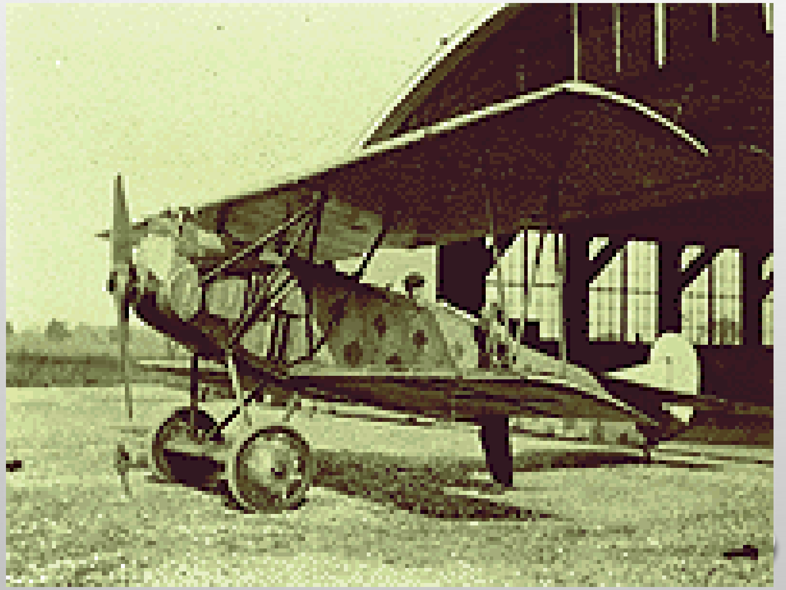
History of Remote Sensing

1908 - First photos from an airplane



First flight, Wright Bros., Dec. 1903

1914-1918 - World War I



History of Remote Sensing

1930-1945

- Mid 1930s, color photography.
- Aerial photography became widespread during world war II, with improved lenses and platform stability, enemy positions and military installations could be identified from aircraft.
- Radar

History of Remote Sensing

1945-1960

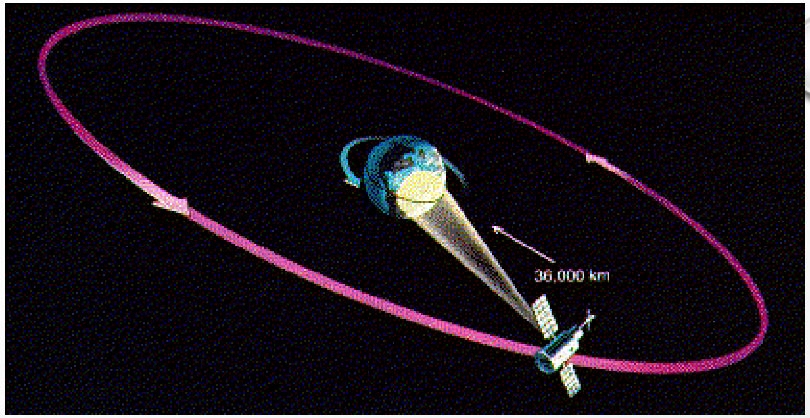
- Cameras were launched on rockets as this science expanded in the post-world war II era.
- In 1957, the Russians launched the first successful earth satellite, Sputnik 1
- In 1958, the US launched its first satellite, Explorer 1.
- In 1959, the first satellite with a meteorological instrument (Vanguard 2) was launched.
- In 1960, the first satellite images ever made of the earth comes from the Tiros 1

History of Remote Sensing

1960-1972

- This was the age of instrument development.
- In 1964, the Nimbus satellite series of experimental meteorological remote sensing was initiated.
- By 1966, meteorological satellites moved from being experimental to being operational with the introduction of the ESA series of satellites which included automatic picture.
- The defense meteorological satellite program (DMSP) was started by the U.S. Air force in 1966.
- 1972, Landsat 1 (also referred to as earth resources technology satellite.

History of Remote Sensing
1972-Present

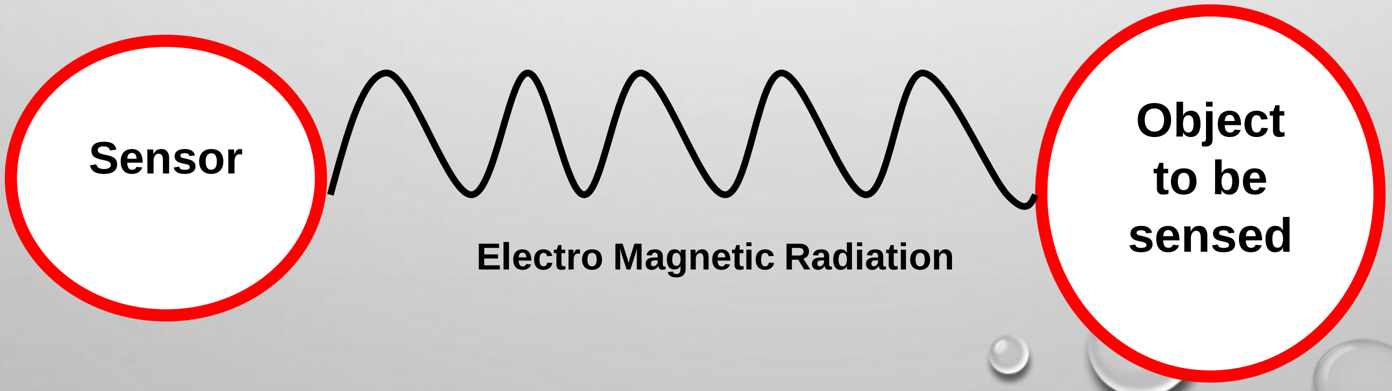


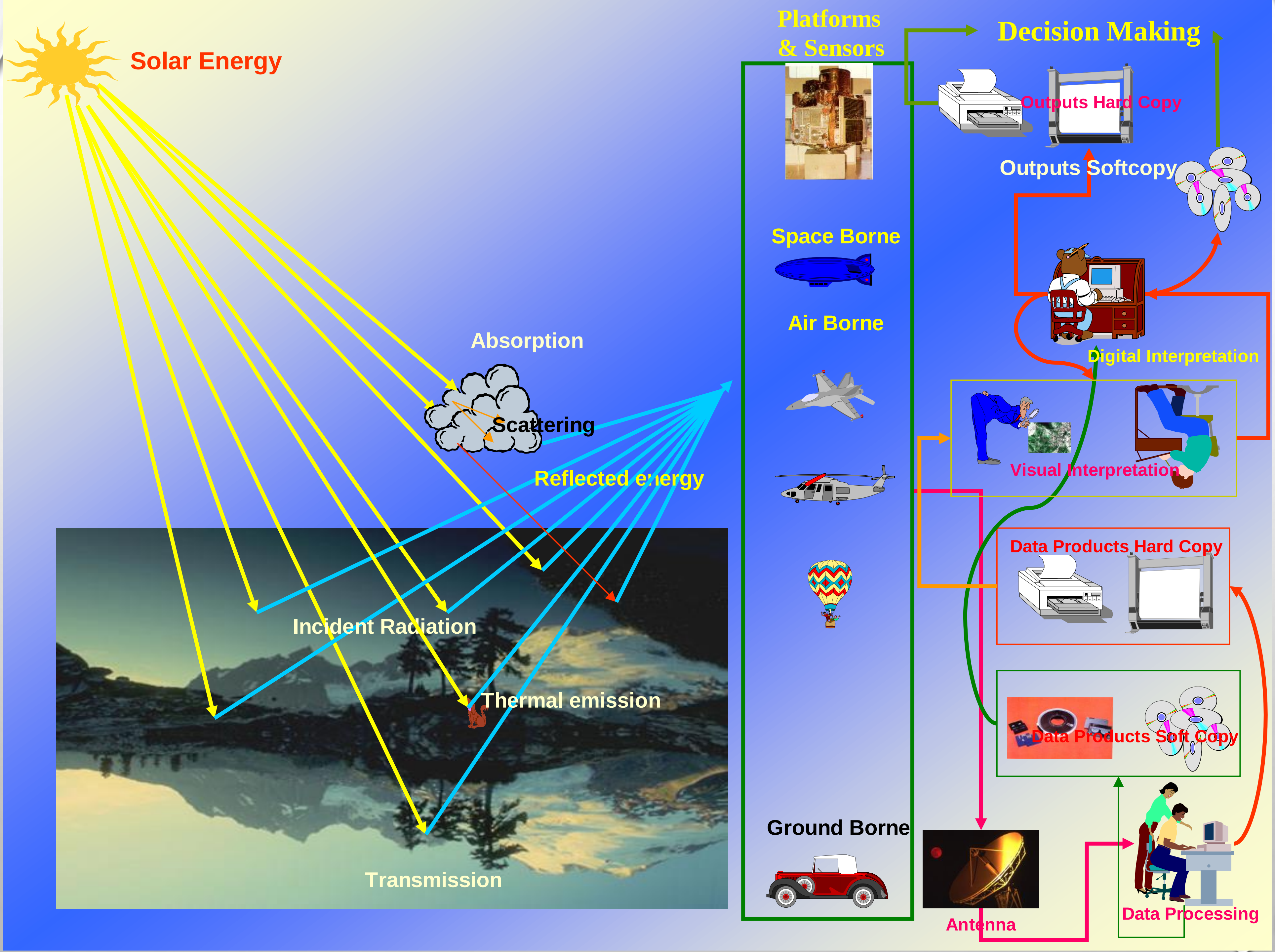
- **1975:** the synchronous meteorological satellites.
- **1976:** laser geodynamic satellite.
- **1978:** the heat capacity mapping mission.
- **1978:** SEASAT demonstrated techniques for global monitoring of the earth's oceans.
- **1978:** NIMBUS 7, the final satellite in that series, was launched.
- **1984:** the earth radiation budget (ERBE) satellite began its study of how the earth absorbs and reflects the sun's energy.
- **1991:** the upper atmosphere research satellite (UARS) began its study of the chemistry and physics of the earth's atmosphere.
- Today, the goes (geostationary operational environmental satellite) system of satellites provides most of the remotely sensed weather information for North America.

REMOTE SENSING

- "Remote sensing is the science of acquiring information about the Earth's surface without actually being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing, and applying that information."

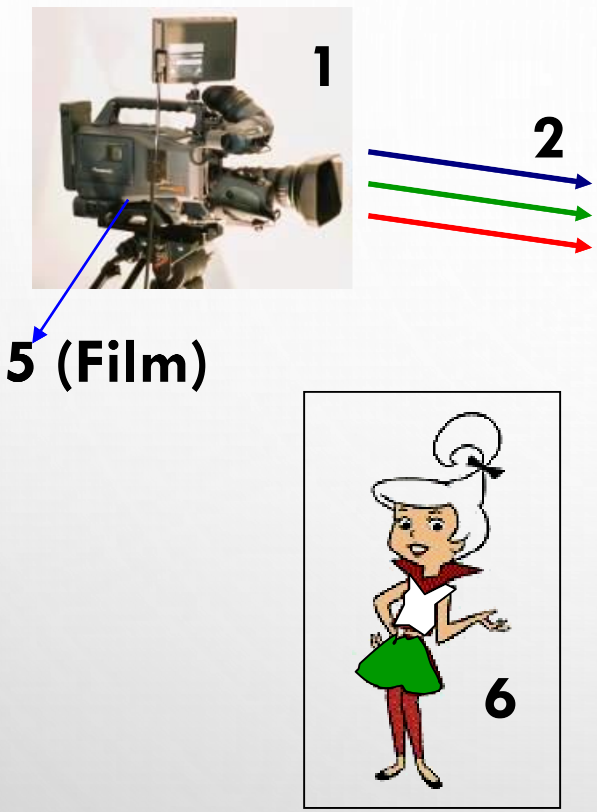
Three Essential Things for Remote Sensing

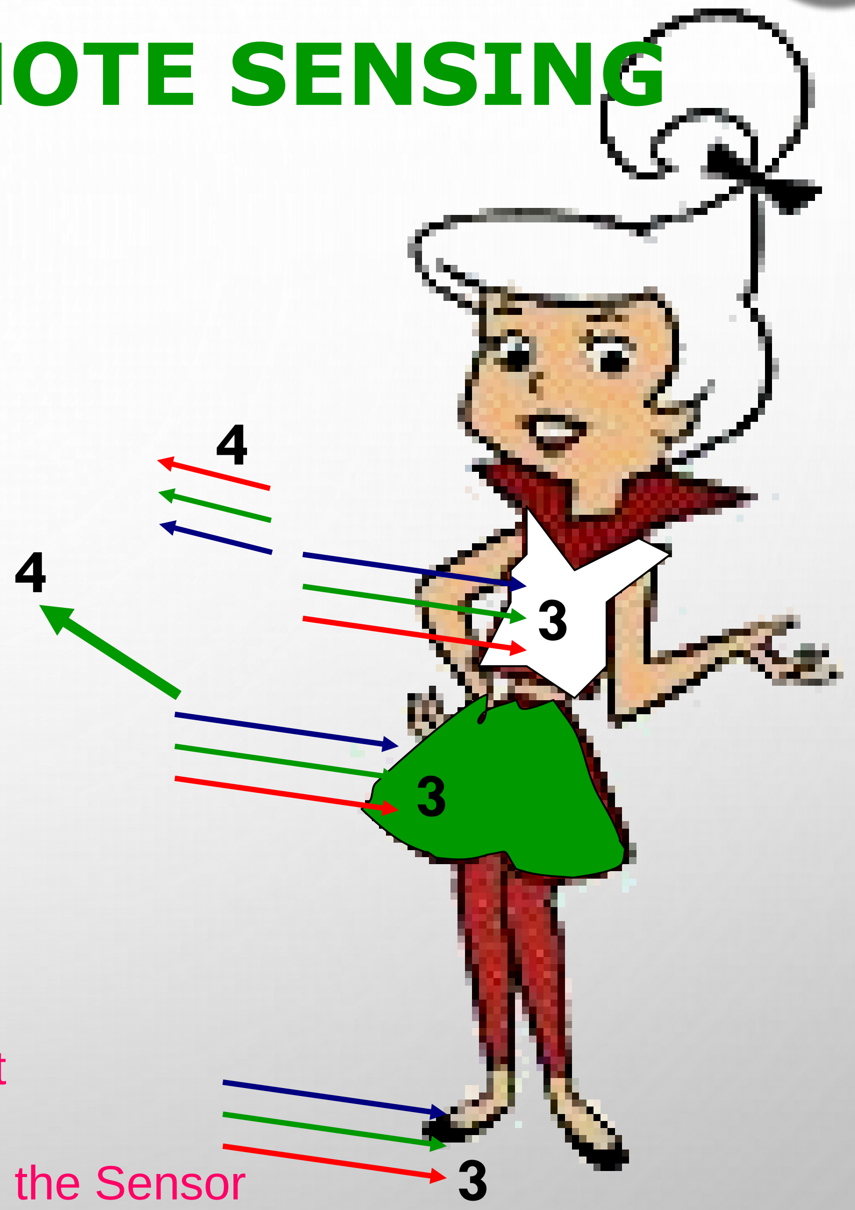




Solar Energy
Absorption
Scattering
Reflected energy
Incident Radiation
Thermal emission
Transmission
Platforms & Sensors
Space Borne
Air Borne
Ground Borne
Antenna
Data Processing
Data Products Soft Copy
Data Products Hard Copy
Visual Interpretation
Digital Interpretation
Outputs Softcopy
Outputs Hard Copy
Decision Making

SIX STAGES IN REMOTE SENSING

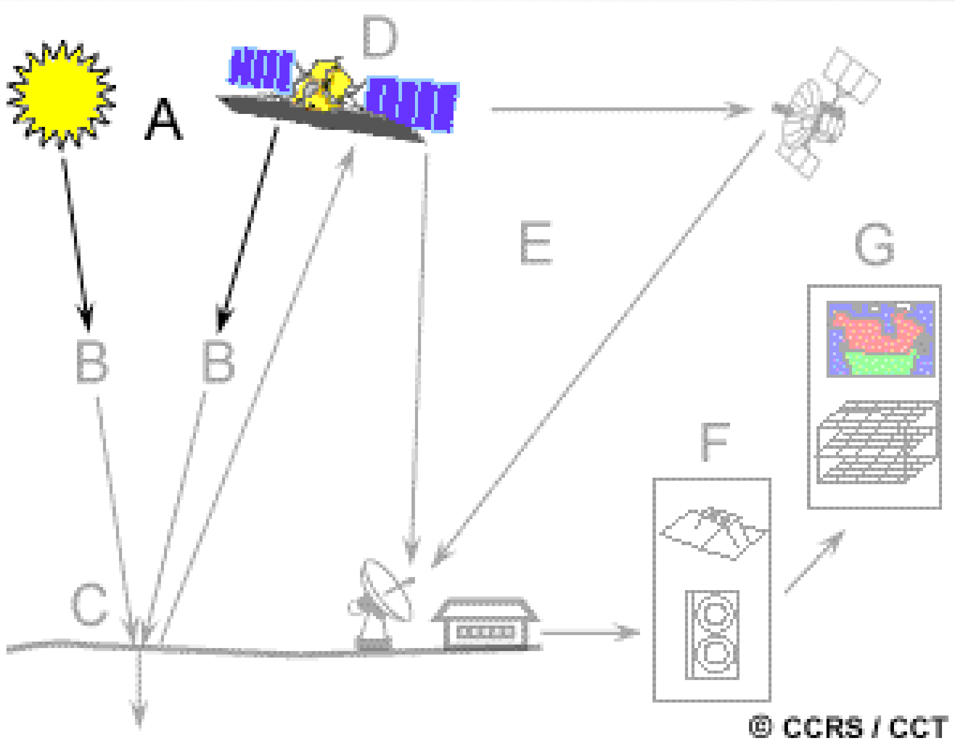




Stage-1. Source of energy
Stage-2. Transmission of EMR towards the Object
Stage-3. Interaction of EMR with the Object
Stage-4. Transmission of Interacted EMR towards the Sensor
Stage-5. Recording of the Image by the Detector
Stage-6. Analysis of the Imagery

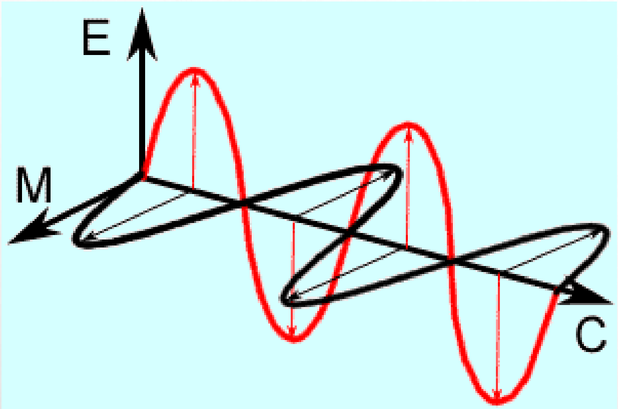
The element of the remote sensing process

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

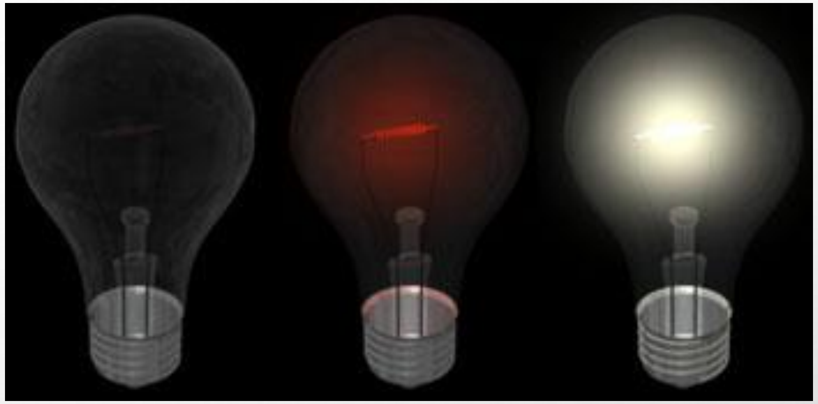


Principles of radiation

Electromagnetic energy is emitted in waves

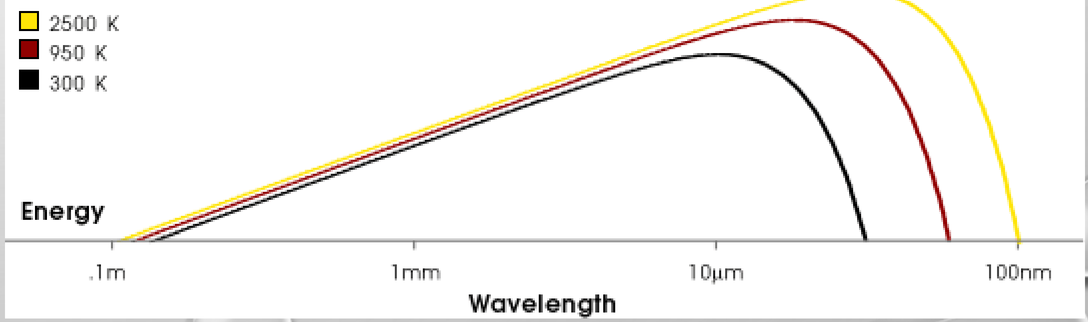


Amount of radiation emitted from an object depends on its temperature

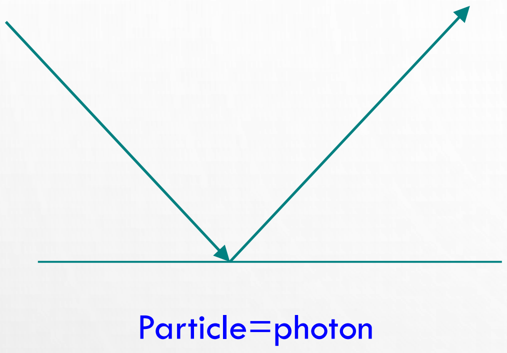


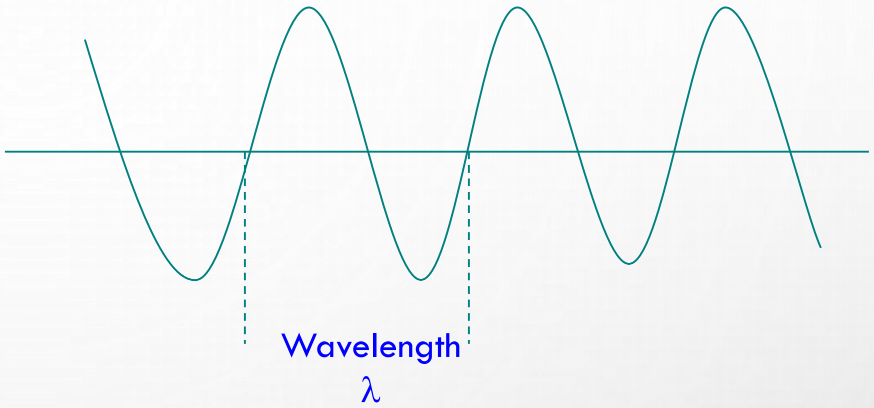
Electromagnetic radiation consists of an electrical field(E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

Planck Curve



Electromagnetic radiation energy: Wave-particle duality.





Light speed: $c = f\lambda$

c = speed of light (186,000 miles/second)

f = light frequency: number of waves passing a reference per unit time (e.g., second).

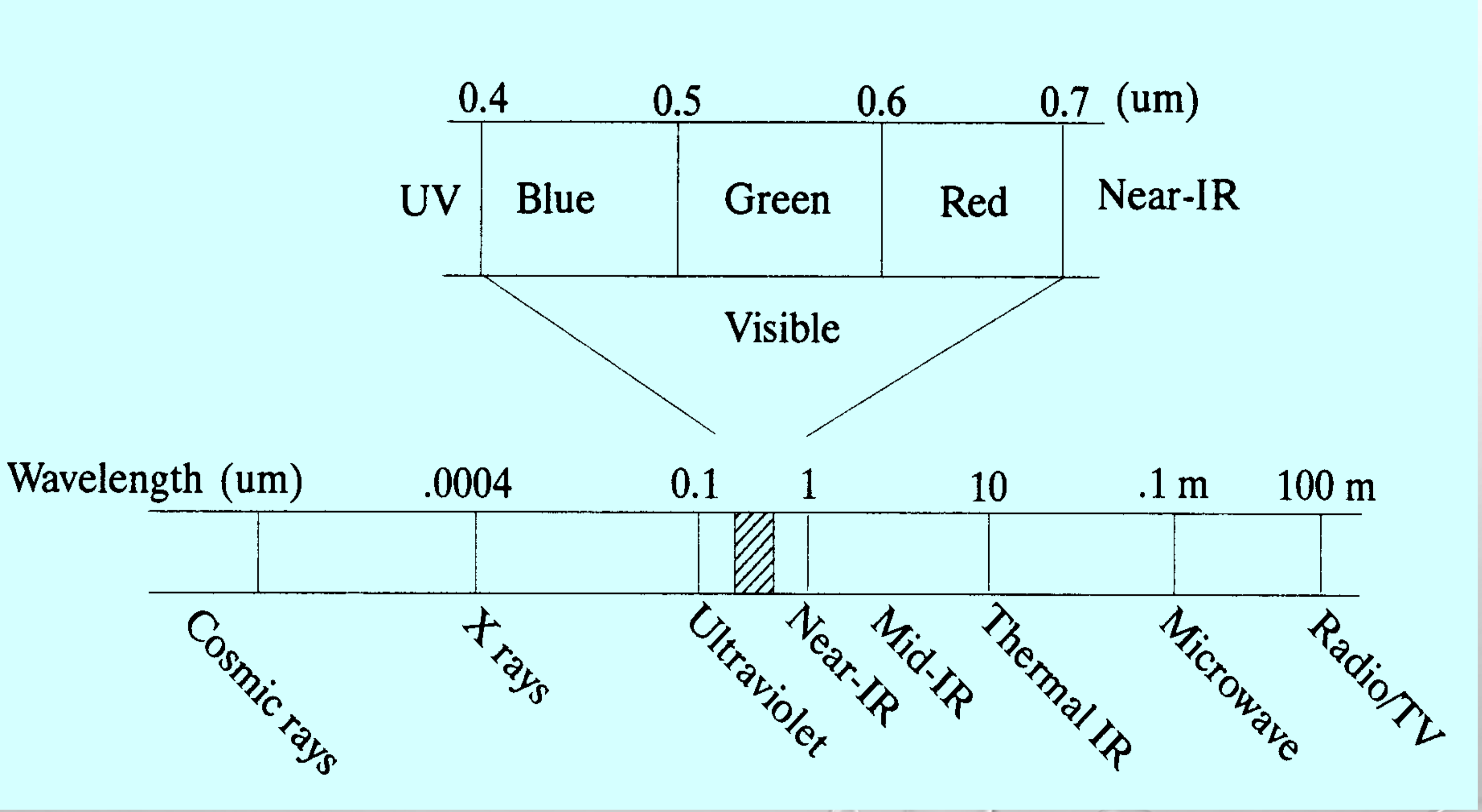
The amount of energy carried by a photon: $\varepsilon = hf$

h=Planck's constant (6.626×10^{-34} Js)

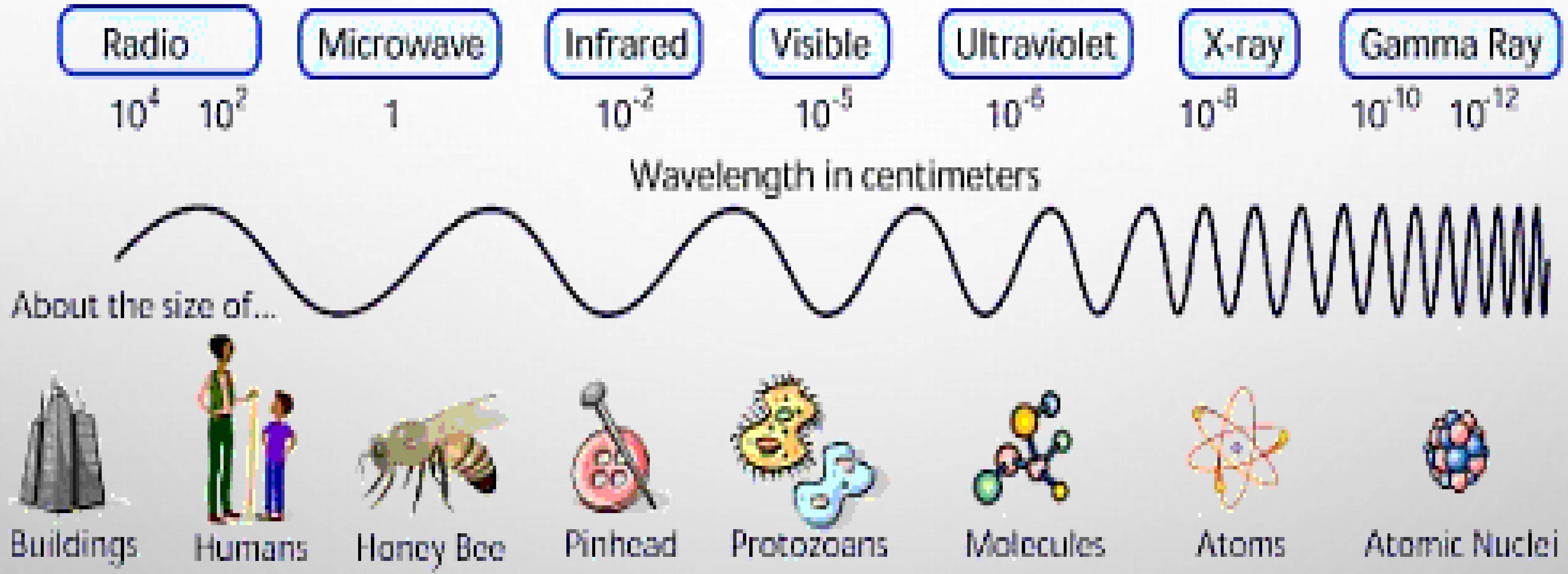
Note: The shorter the radiations' wavelength, the higher its frequency → the more energy a photon carries

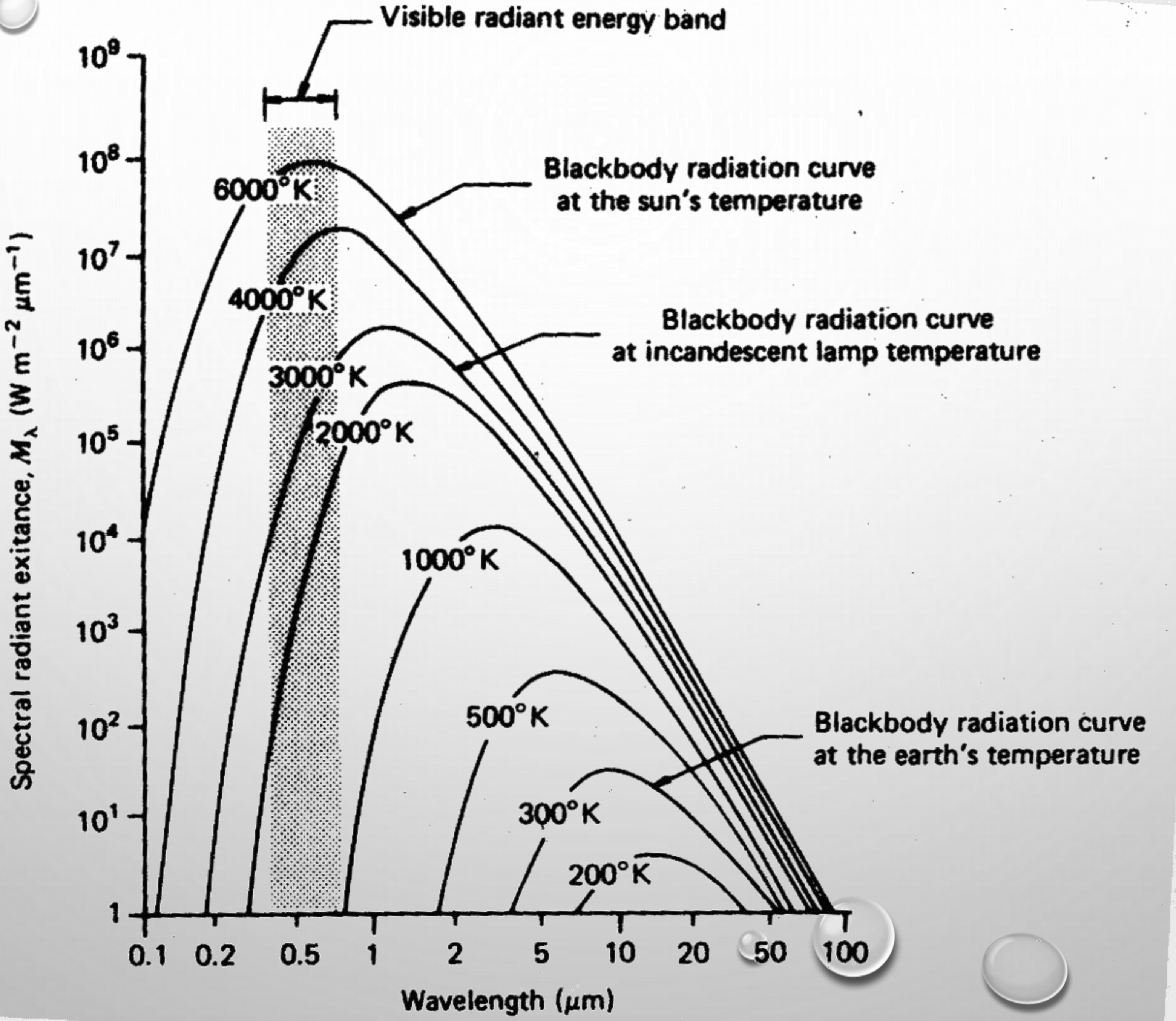
Photons move at the speed of light in wave form

Electromagnetic Spectrum



Electromagnetic Spectrum





Visible radiant energy band
Blackbody radiation curve at the sun's temperature
Blackbody radiation curve at incandescent lamp temperature
Blackbody radiation curve at the earth's temperature
6000°K
4000°K
3000°K
2000°K
1000°K
500°K
300°K
200°K
Spectral radiant exitance, M_λ (W m^{-2} μm^{-1})
Wavelength (μm)
10^9
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
1
0.1
0.2
0.5
1
2
5
10
20
50
100

Electromagnetic Spectrum

INFRARED (IR) REGION

- Covers the wavelength range from approximately 0.7 μm to 100 μm

- Divided into two categories based on their radiation properties – the **reflected IR**(0.7-3.0 μm), **NIR**(0.7-1.1μm), **SWIR**(1.55-1.7 μm) and **TIR**(3-14 μm).

Electromagnetic Spectrum

REFLECTED IR

- 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.

- Photographic IR ranges from 0.7 to 0.9 μm

Electromagnetic Spectrum

REFLECTED IR

- 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.

- Photographic IR ranges from 0.7 to 0.9 μm

Electromagnetic Spectrum

THERMAL IR

- 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. But the heat energy is sensed in windows at 3 to 5.5 μm and 8 to 14 μm.

MICROWAVE REGION

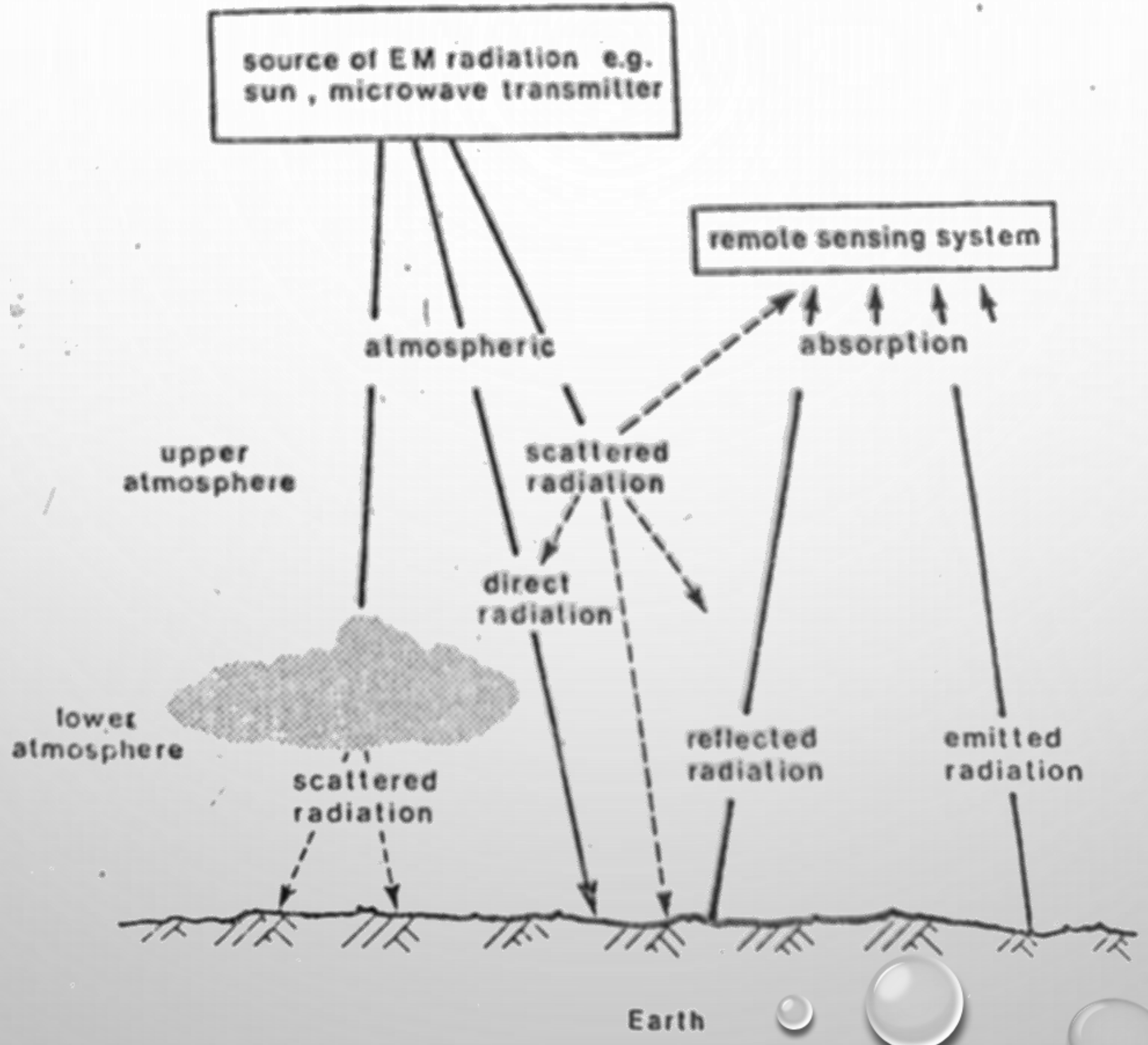
- The microwave region from about 1 mm to 1m

INTERACTION WITH THE ATMOSPHERE

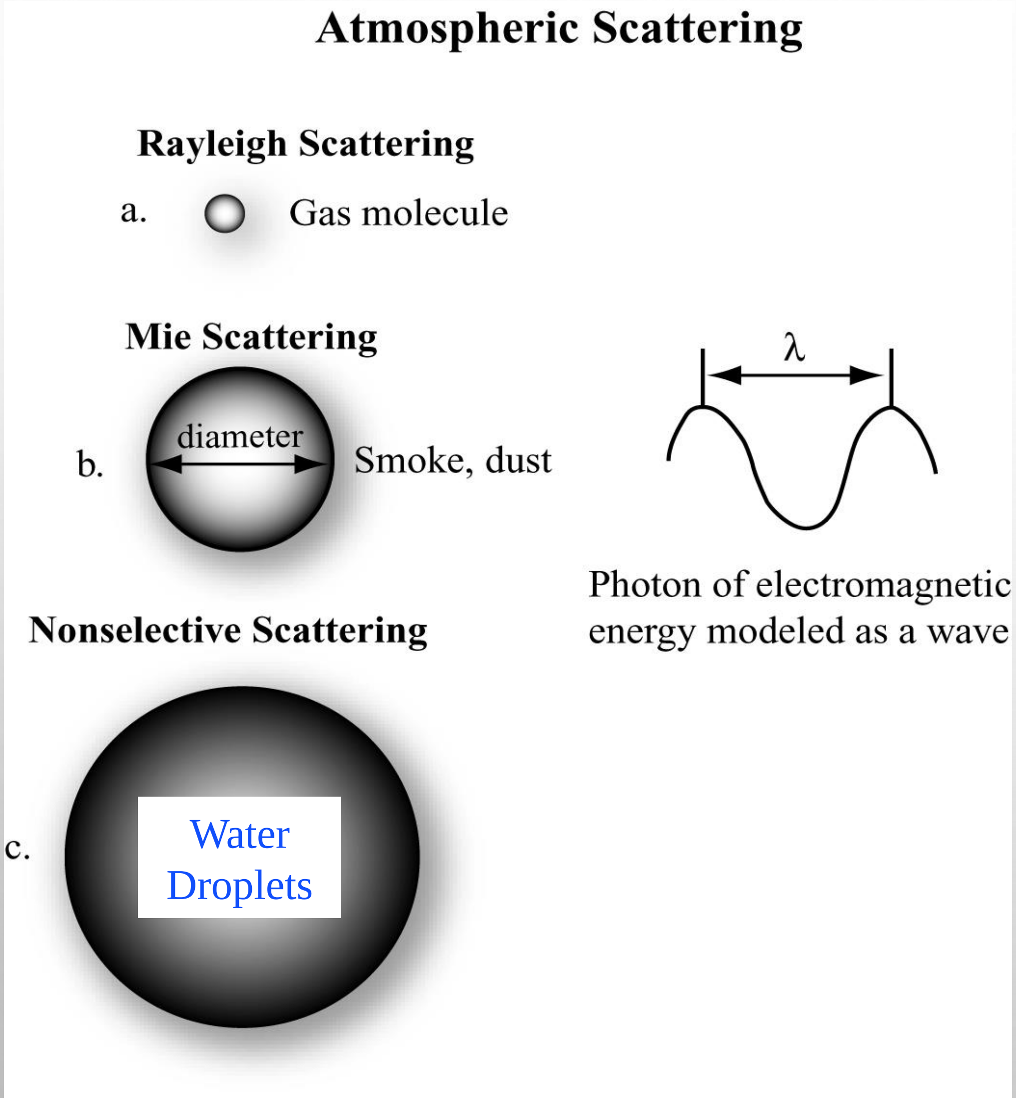
Electromagnetic Spectrum

- Radiation used for remote sensing reaches the Earth's surface it has to travel through some distance of the Earth's atmosphere.
- Particles and gases in the atmosphere can affect the incoming light and radiation.
- These effects are caused by the mechanisms of **scattering** and **absorption**.

Electromagnetic Spectrum



Atmospheric Scattering



Reflection: the direction predictable
Scattering: direction unpredictable

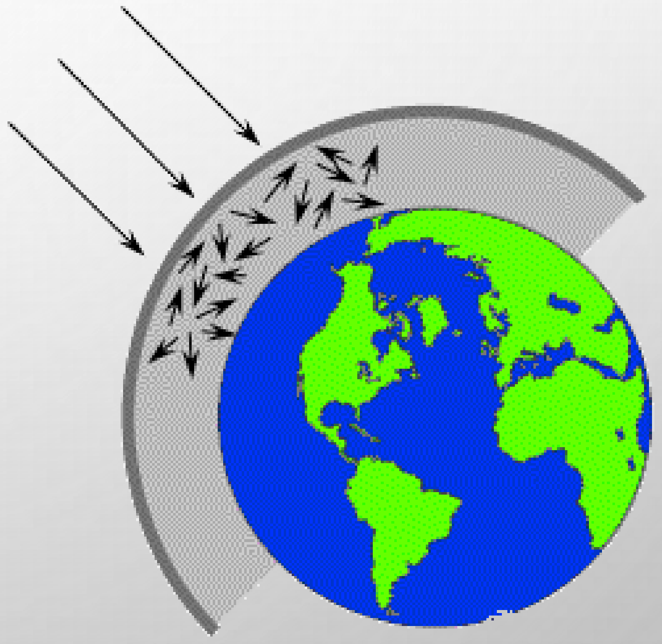
Based on wavelength of incident radiant energy, the size of the gas molecule, dust particle, or water vapor droplet essentially three types of scattering:

- Rayleigh
- Mie
- Non-selective scattering

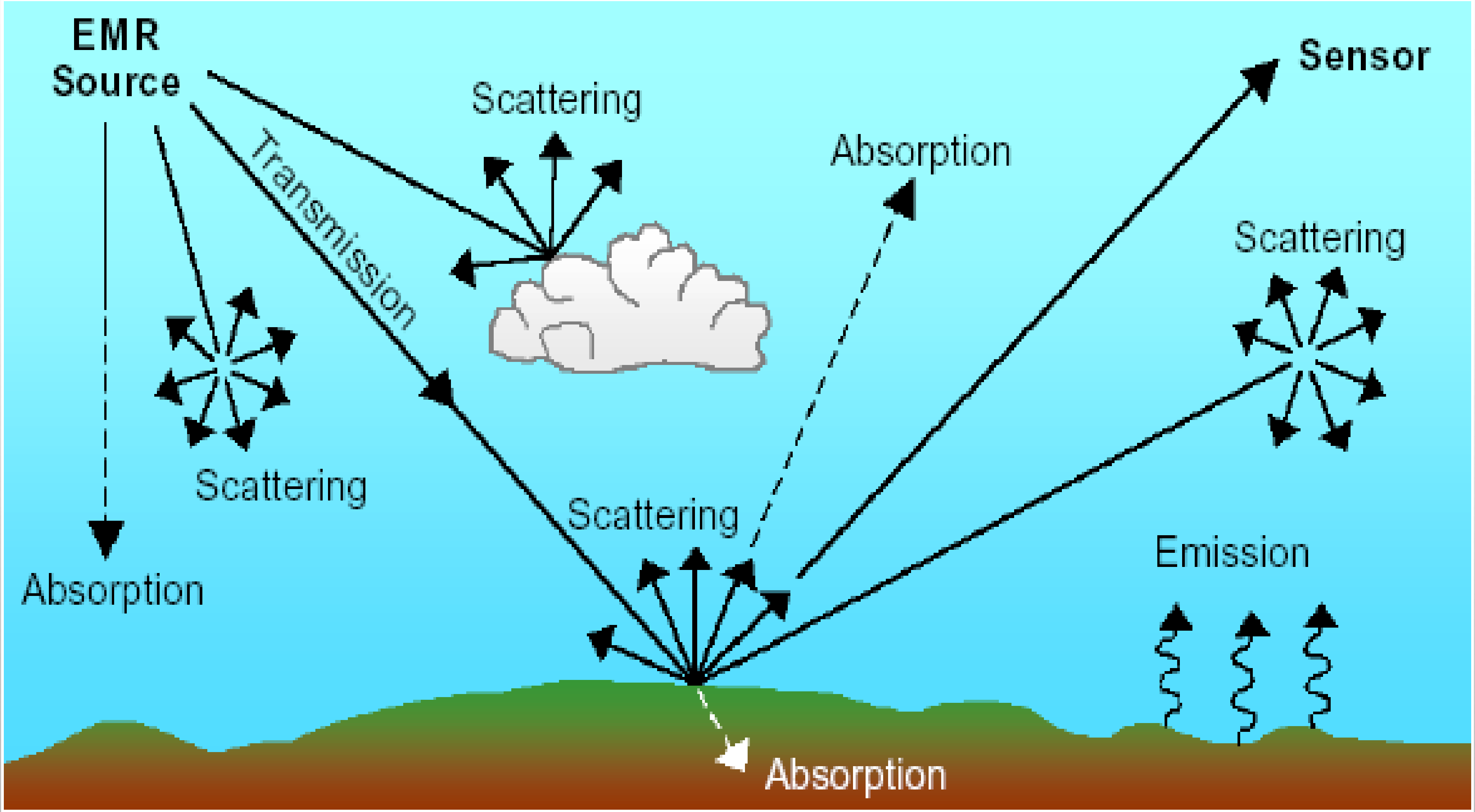
Electromagnetic Spectrum

SCATTERING

- **Scattering** occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path.



Electromagnetic Spectrum



Typical EMR interactions in the atmosphere and at the Earth's surface.

Electromagnetic Spectrum

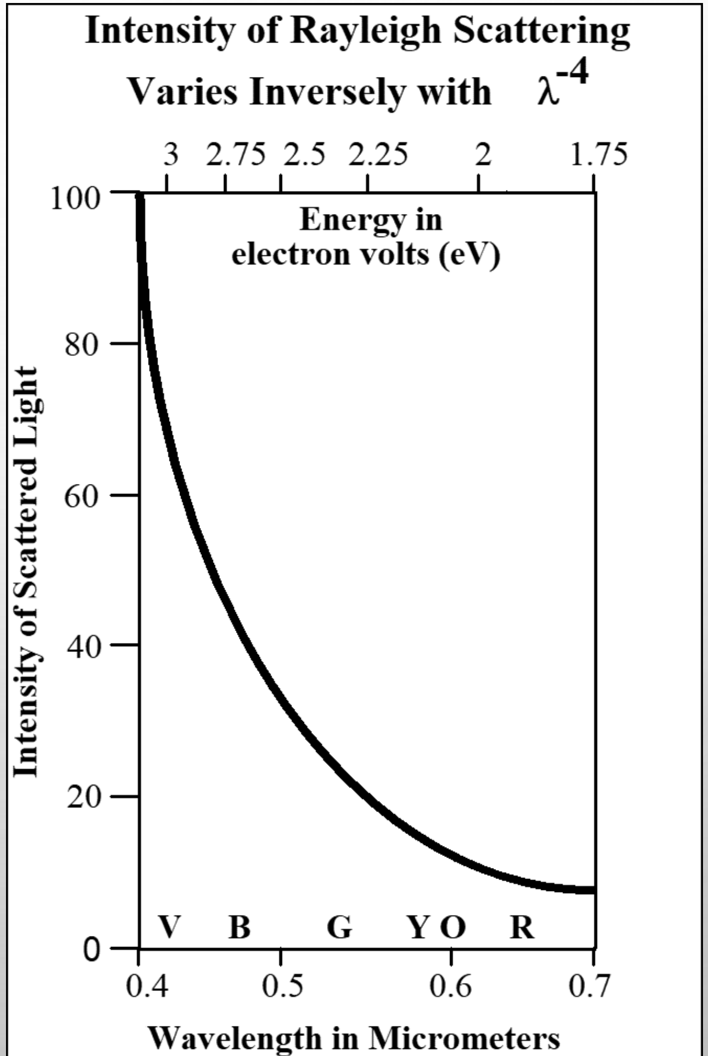
RAYLEIGH SCATTERING

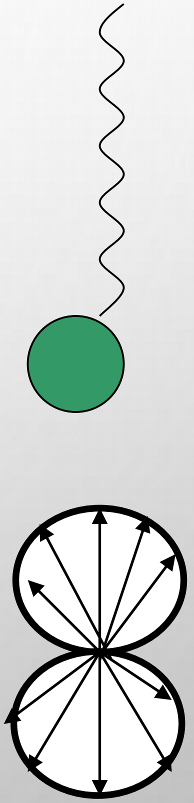
- **Rayleigh scattering** occurs particles are very small compared to the wavelength of the radiation

- Small specks of dust or nitrogen and oxygen molecules

- The fact that the sky appears "blue" during the day is because of this phenomenon.

- Rayleigh **Scattering** ∝ **$1/\lambda^4$**



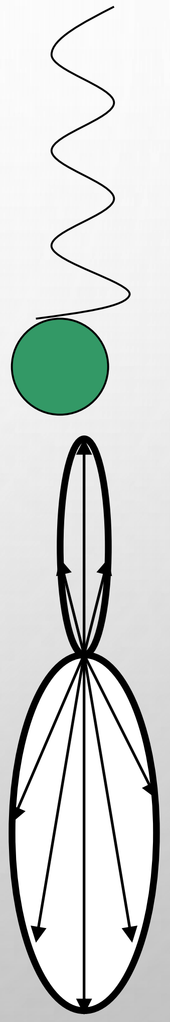


Electromagnetic Spectrum

MIE SCATTERING

- **Mie scattering** occurs when the particles are just about the same size as the wavelength of the radiation. e.g., Dust, pollen, smoke and water vapour

- **Mie Scattering ∝ 1/ λ to 1/λ²**



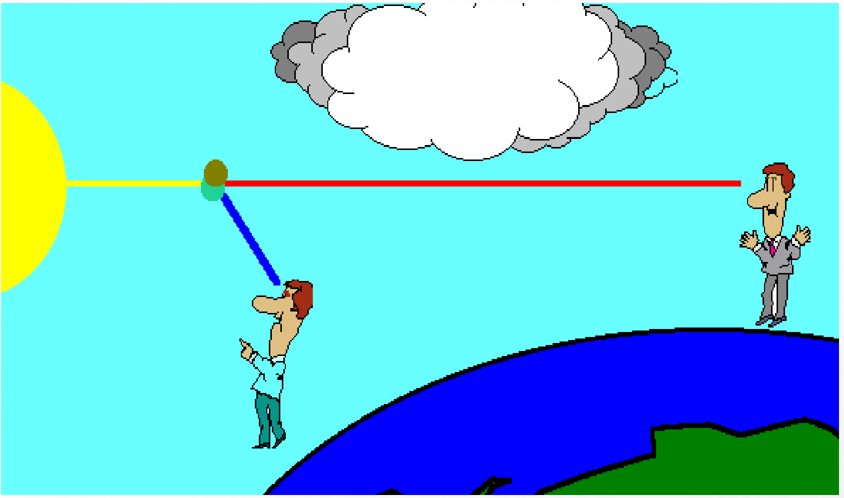
Electromagnetic Spectrum

NONSELECTIVE SCATTERING

- This occurs when the particles are much larger than the wavelength of the radiation. Water droplets and large dust particles can cause this type of scattering.

- Nonselective scattering gets its name from the fact that all wavelengths are scattered in all directions without following any law.

Color of the Sky



Two questions:

- Why is the sky blue?
- Why is the sunset orange?

Color of the Sky

- Why is the sky blue?
  - –A clear cloudless day-time sky is blue because molecules in the air scatter blue light from the sun more than they scatter red light

- Why is the sunset orange ?
  - –When we look towards the sun at sunset, we see red and orange colors because the blue light has been scattered out and away from the line of sight

- http://math.ucr.edu/home/baez/physics/General/BlueSky/blue_sky.html

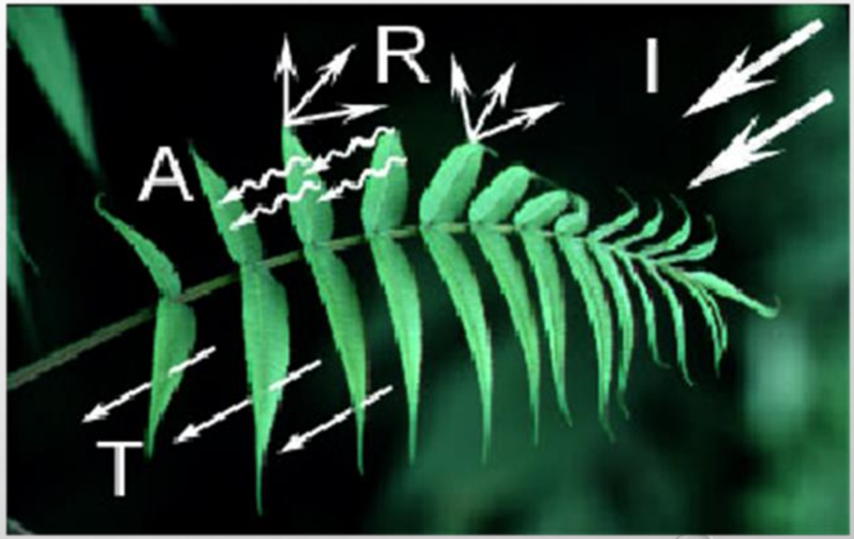
RADIATION
TARGET INTERACTIONS

Radiation - Target Interactions

The first requirement for remote sensing is to have an energy source to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation.

Radiation that is not absorbed or scattered in the atmosphere can reach and interact with the Earth's surface. There are three (3) forms of interaction that can take place when energy strikes, or is incident (I) upon the surface. These are:

- Absorption (A)
- Transmission (T) and
- Reflection (R)



The total incident energy will interact with the surface in one or more of these three ways. The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

Radiation - Target Interactions

Incident energy (I) from the source

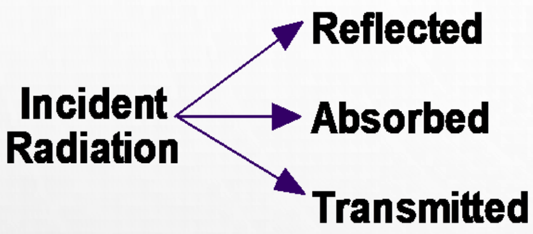
Absorption (A) occurs when radiation (energy) is absorbed into the target

Transmission (T) occurs when radiation passes through a target

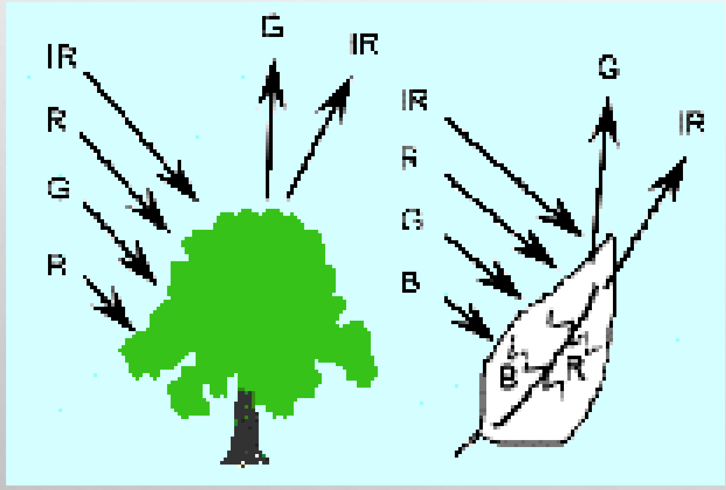
Reflection (R) occurs when radiation "bounces" off the target and is redirected.

Radiation - target interactions

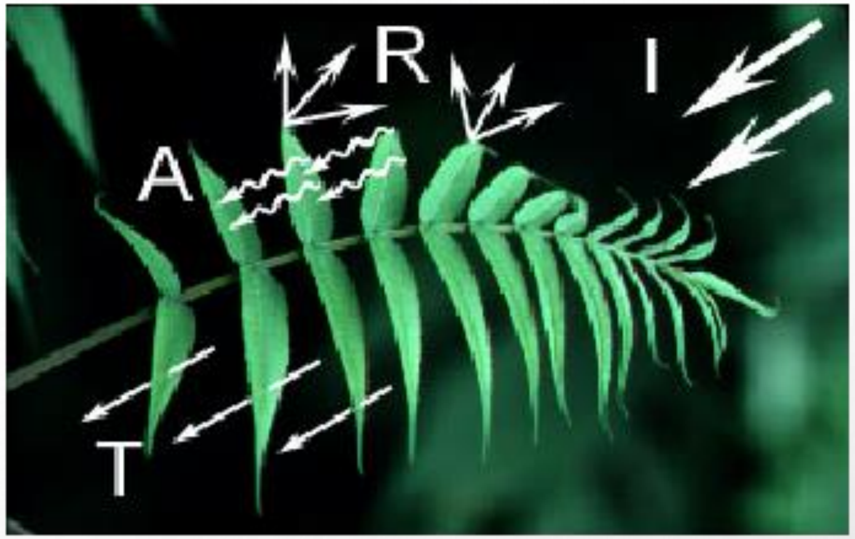
- Spectral response depends on target

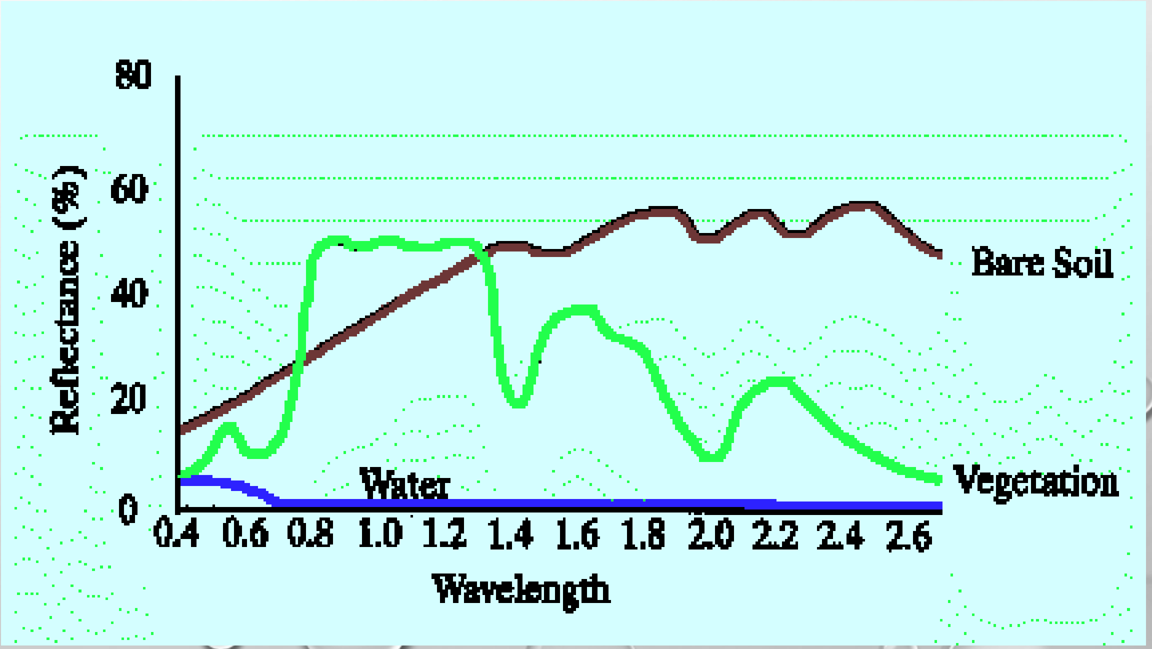


- Leaves reflect green and near IR

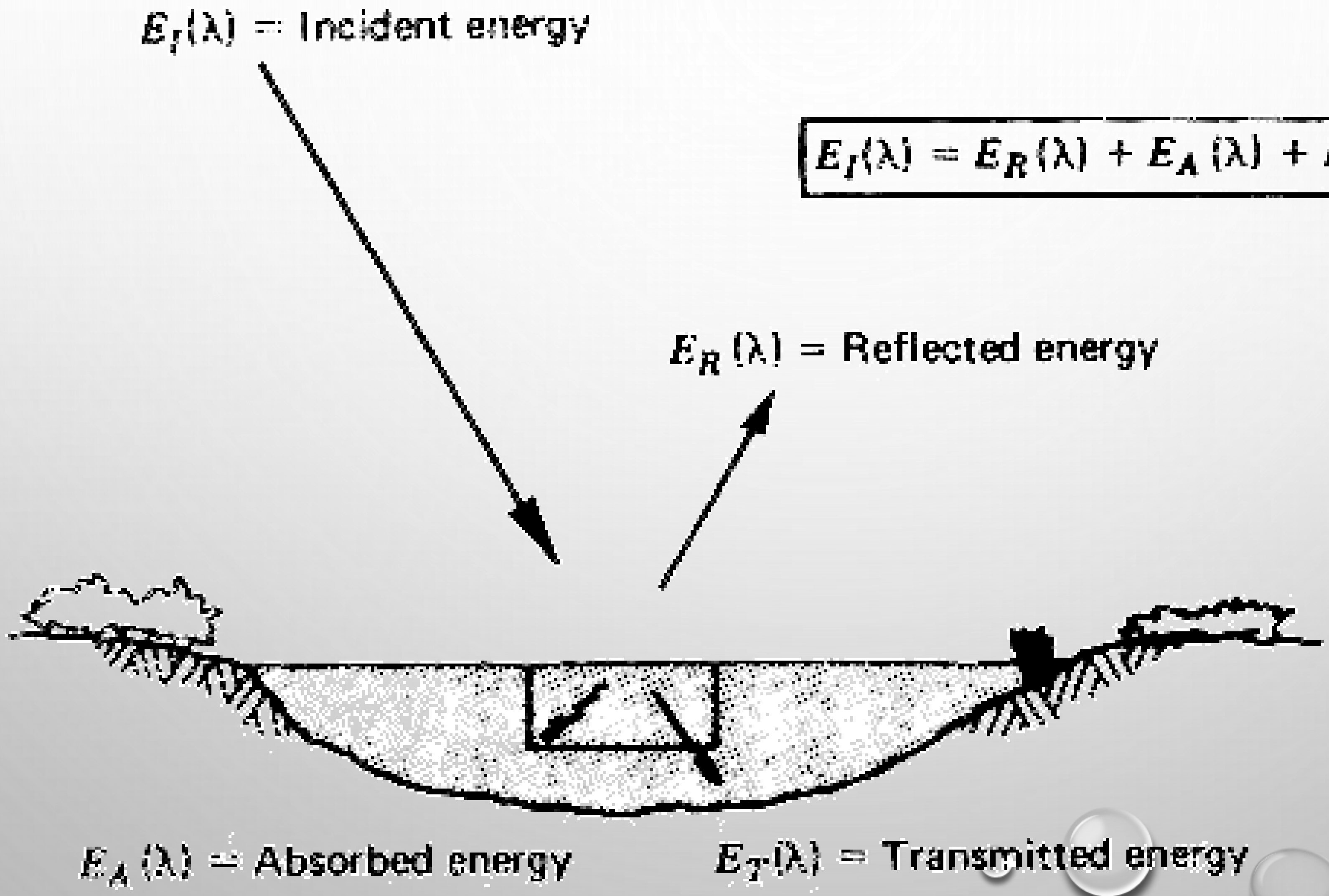


- Water reflects at lower end of visible range





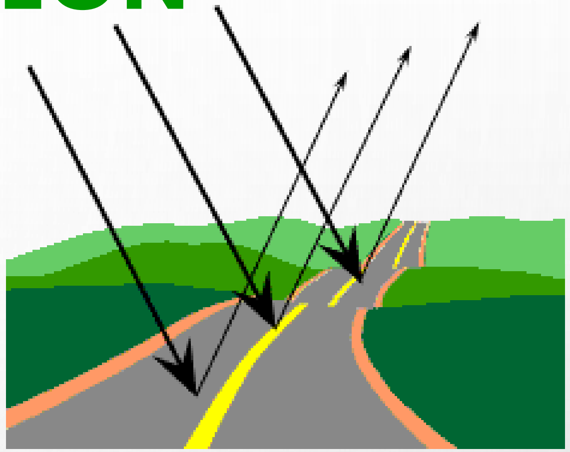
Radiation - target interactions



TWO TYPES OF REFLECTION

SPECULAR REFLECTION

When a surface is smooth we get **specular** or mirror-like reflection where all (or almost all) of the energy is directed away from the surface in a single direction.

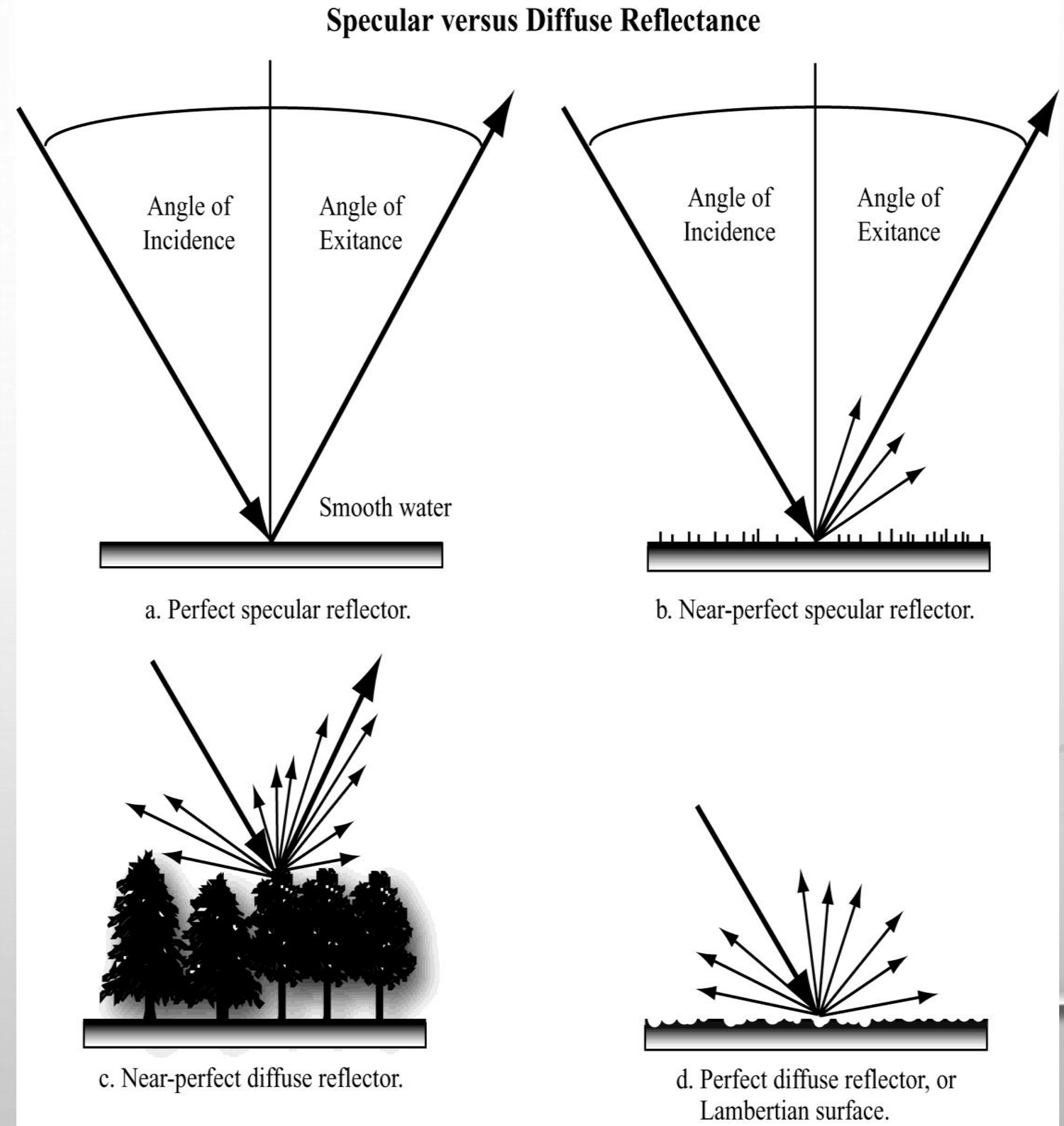


DIFFUSE REFLECTION

When the surface is rough and the energy is reflected almost uniformly in all directions.

REFLECTANCE

- Specular reflection (a): smooth (i.e., the average surface profile is several times smaller than the wavelength of radiation)
- Diffuse reflection (b): rough, the reflected rays go in many directions
- Lambertian surface (d) the radiant flux leaving the surface is constant for any angle of reflectance to the surface normal



ATMOSPHERIC WINDOWS

- Because certain gases absorb electromagnetic energy in very specific regions of the spectrum, they influence the wavelengths, which reach the Earth available for remote sensing.

- Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.

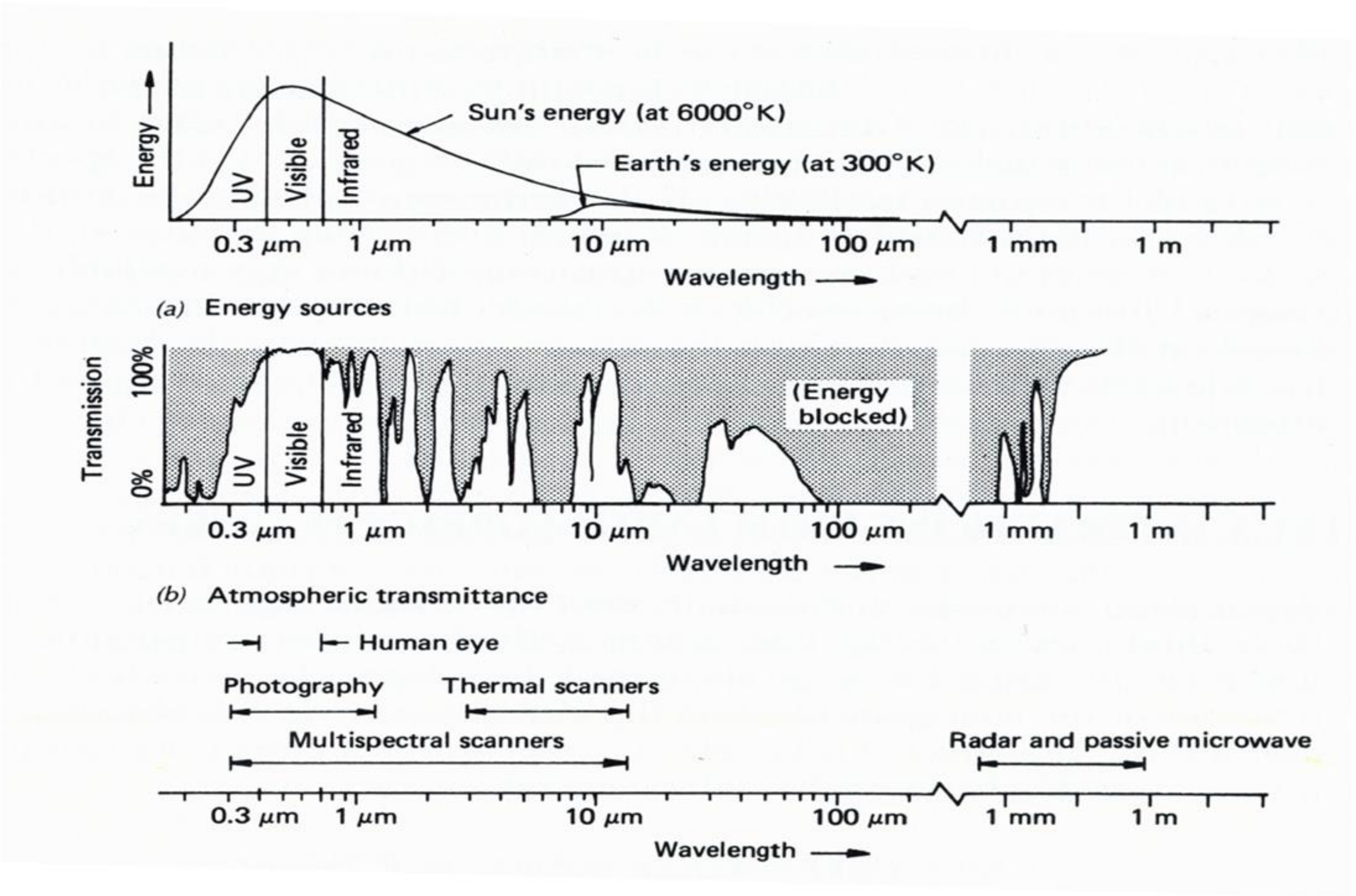
Atmosferic windows

Atmospheric windows:

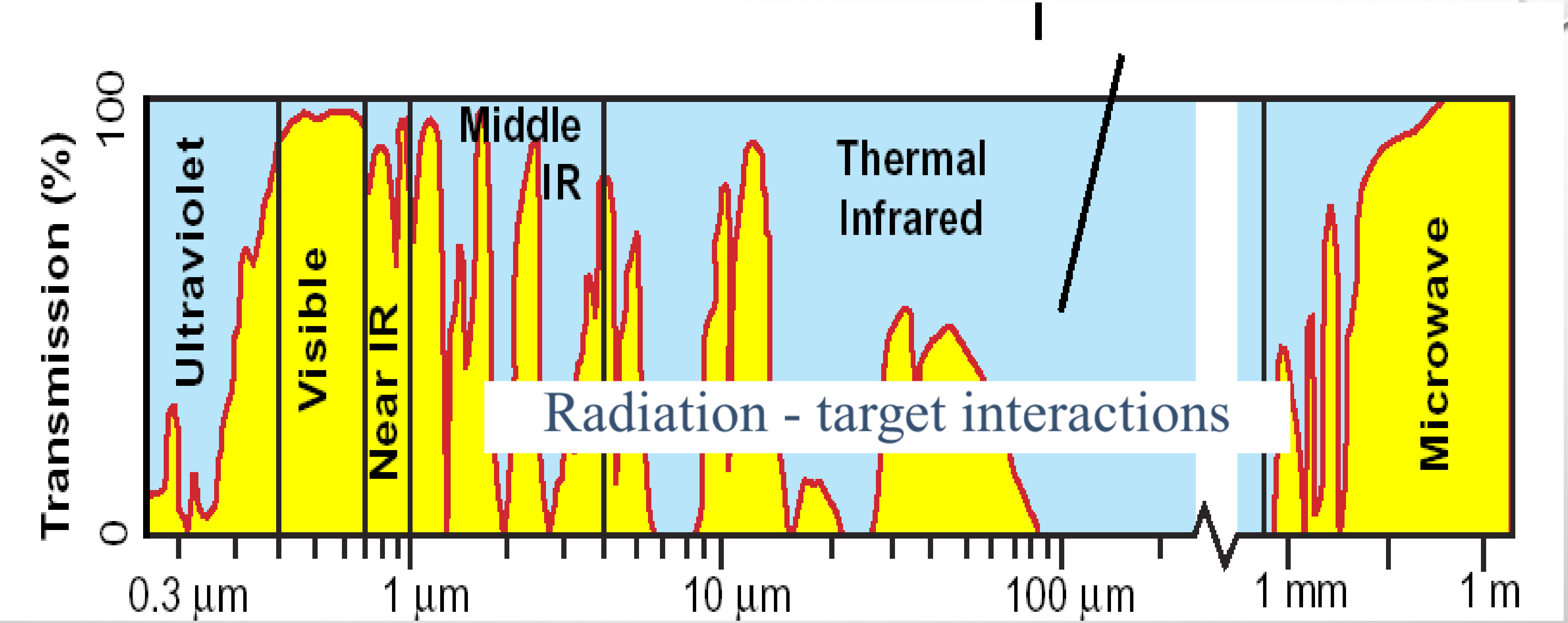
Spectral regions in which the atmosphere blocks the energy are shaded. Remote-sensing data acquisition is limited to the unblocked spectral regions called atmospheric windows

Each type of molecule has its own set of absorption bands in various parts of the electromagnetic spectrum. As a result, only the wavelength regions outside the main absorption bands of the atmospheric gases can be used for remote sensing.

Atmosferic windows

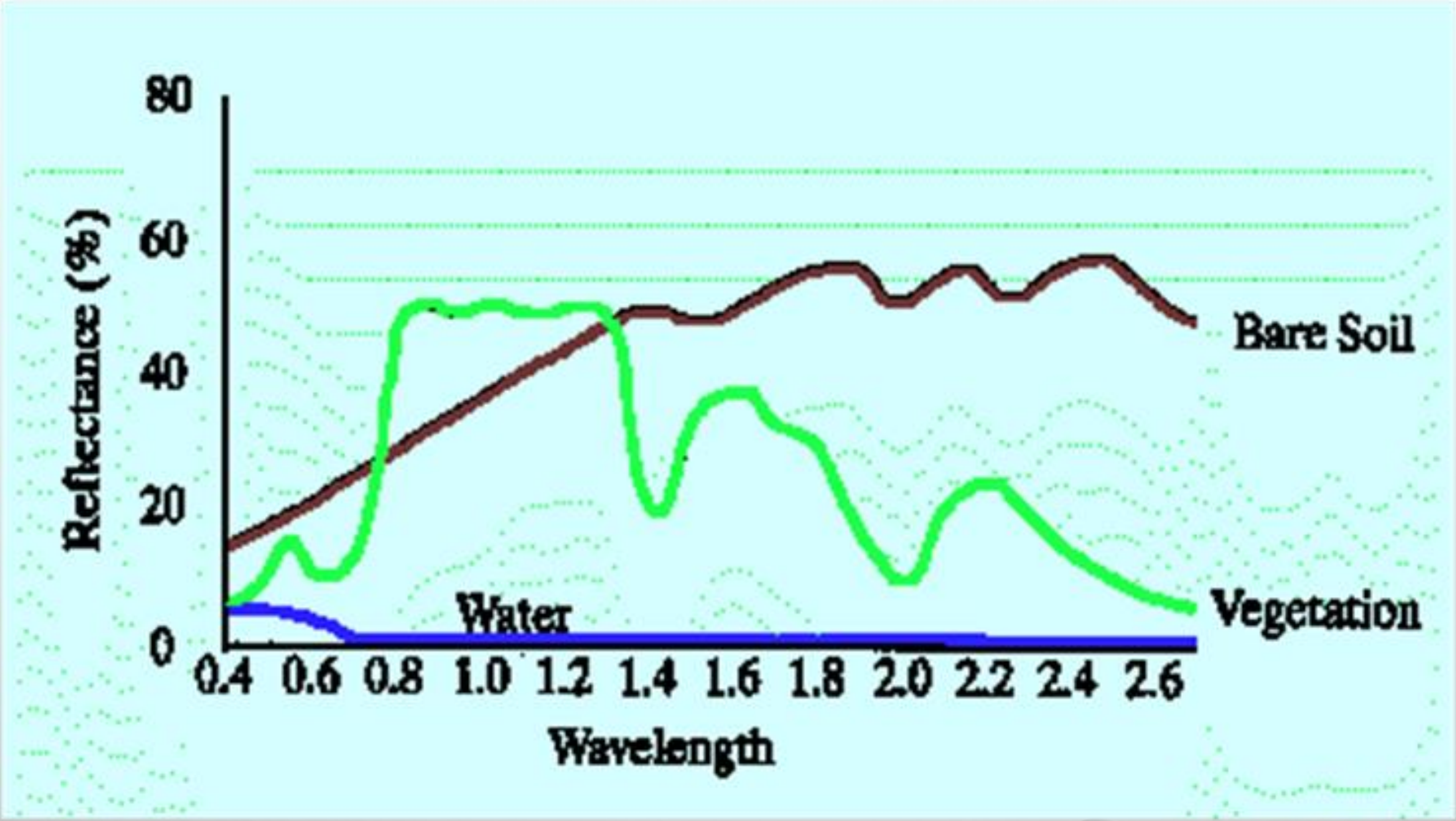


Atmosferic windows

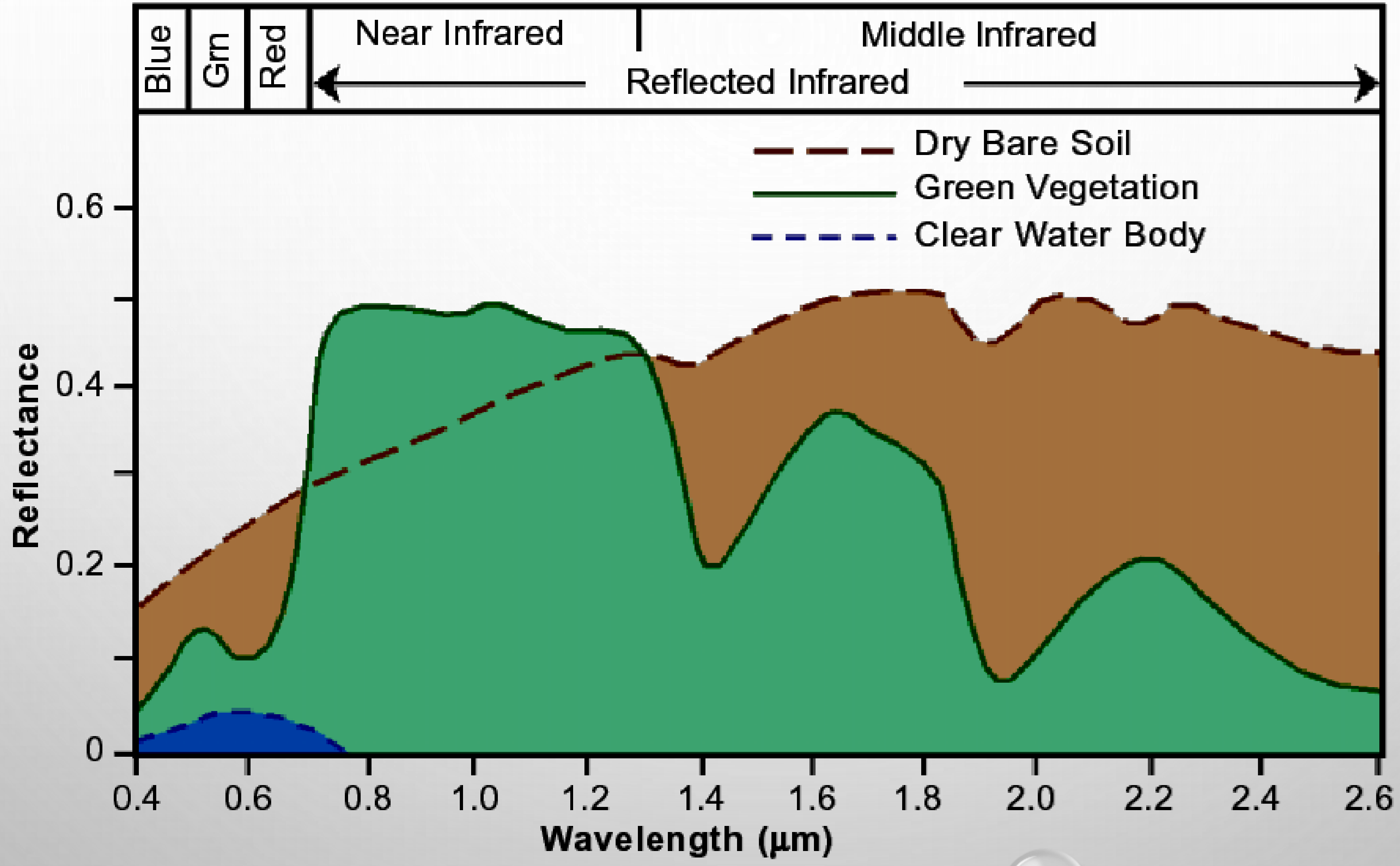


The transmission and absorption phenomenon varying with the wavelength

Radiation - target interactions



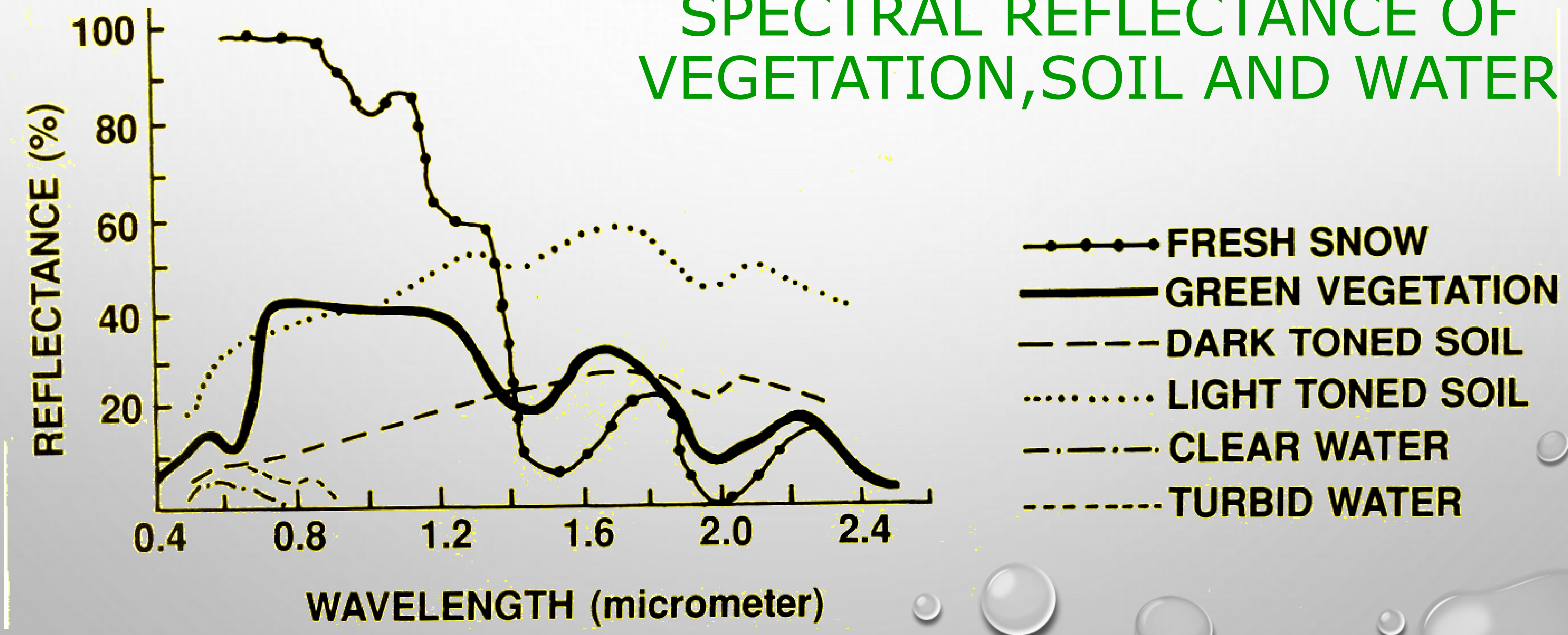
Radiation - target interactions



Spectral reflectance curve

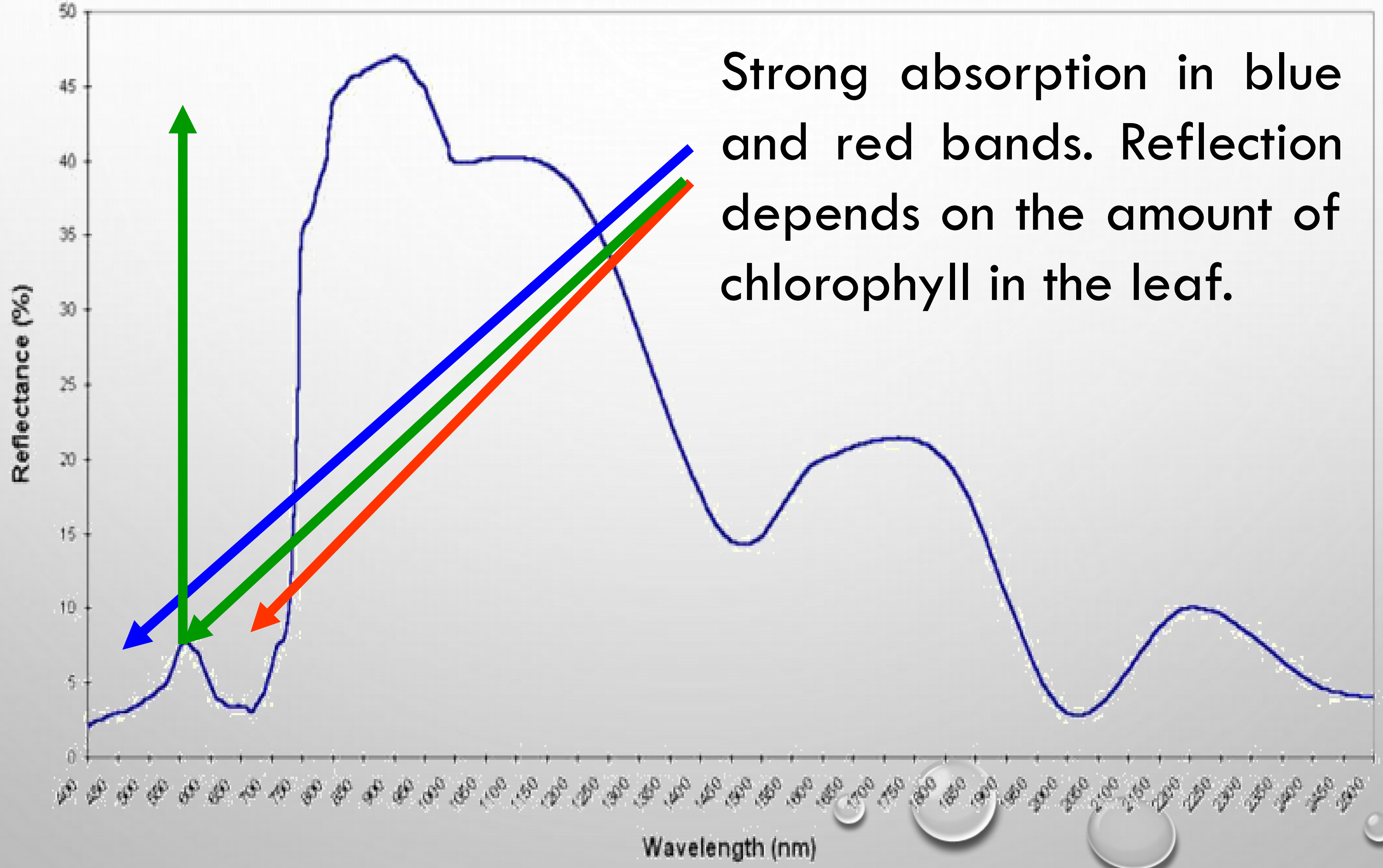
Radiation - target interactions

SPECTRAL REFLECTANCE OF VEGETATION,SOIL AND WATER



Radiation - target interactions

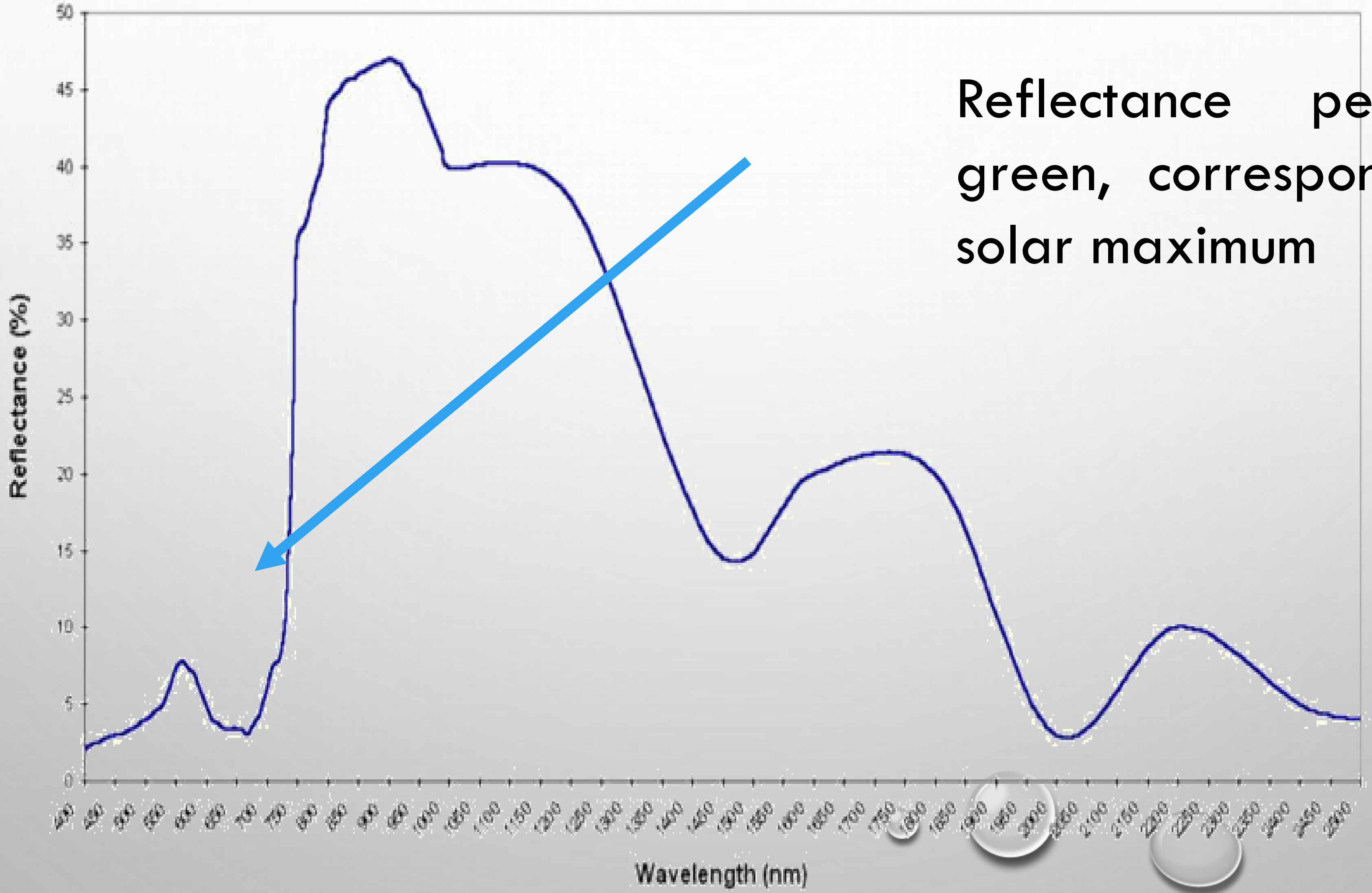
SPECTRAL REFLECTANCE OF VEGETATION



Strong absorption in blue and red bands. Reflection depends on the amount of chlorophyll in the leaf.

Radiation - target interactions

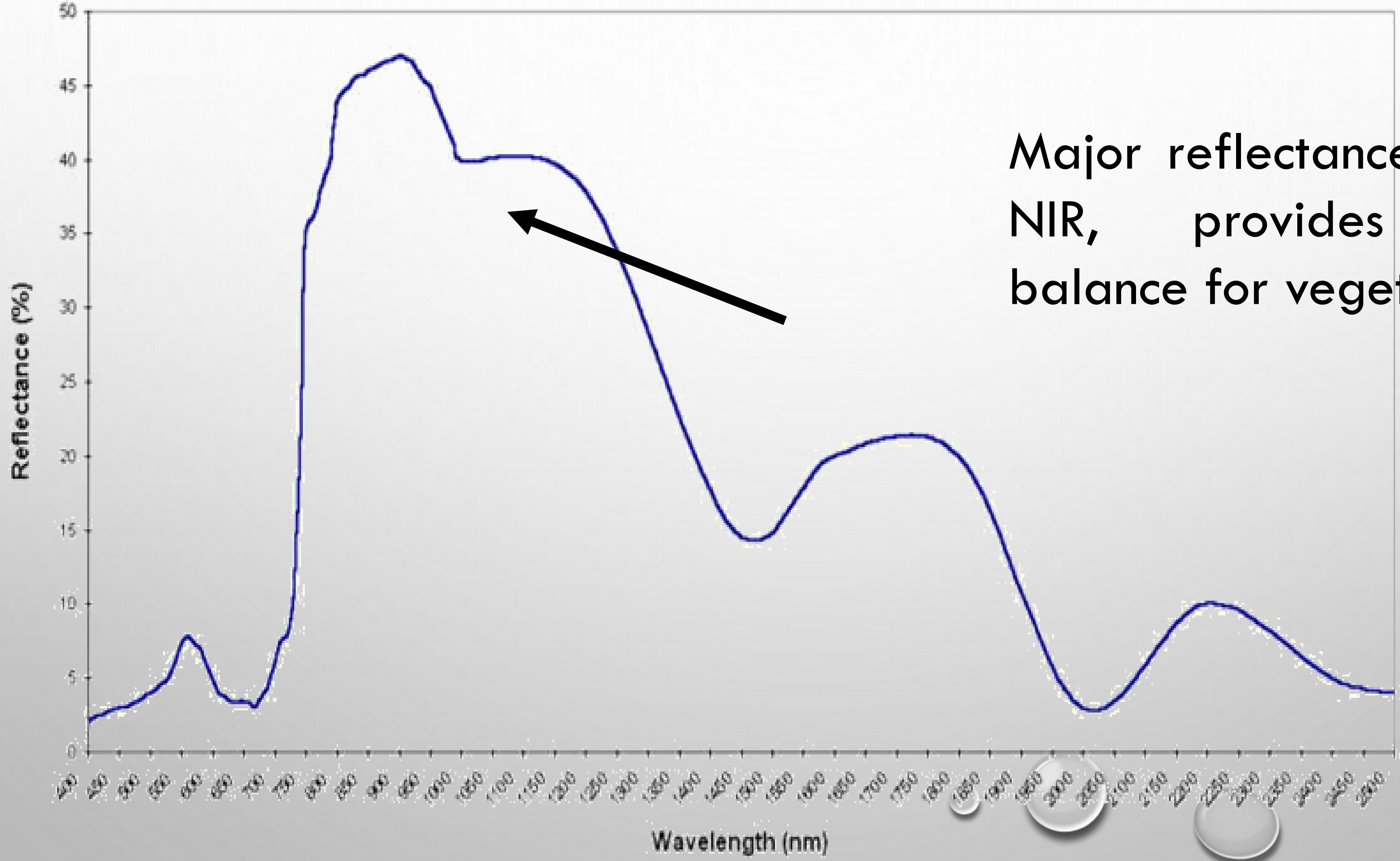
SPECTRAL REFLECTANCE OF VEGETATION



Reflectance peaks in green, corresponds with solar maximum

Radiation - target interactions

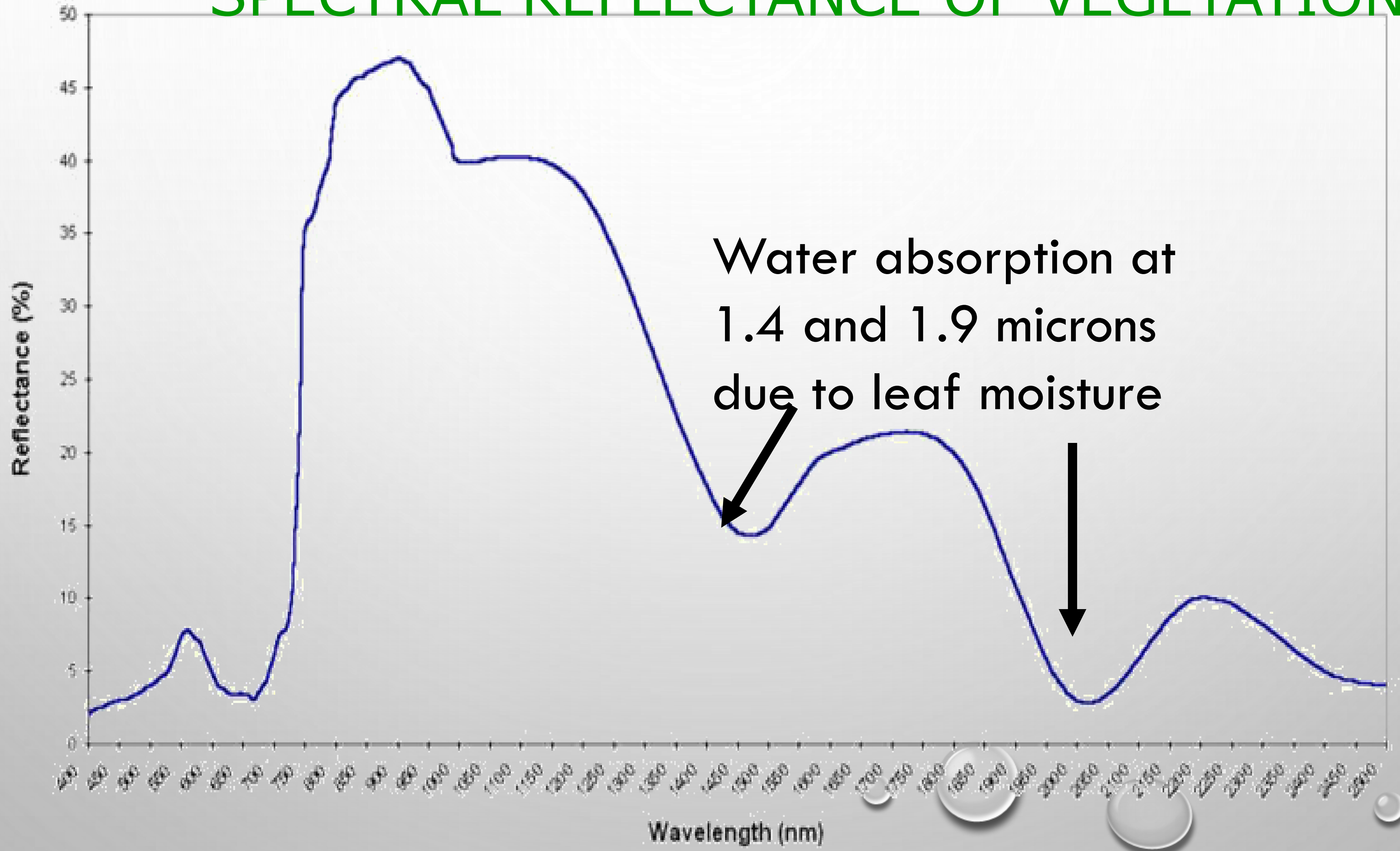
SPECTRAL REFLECTANCE OF VEGETATION



Major reflectance peaks in NIR, provides energy balance for vegetation

Radiation - target interactions

SPECTRAL REFLECTANCE OF VEGETATION

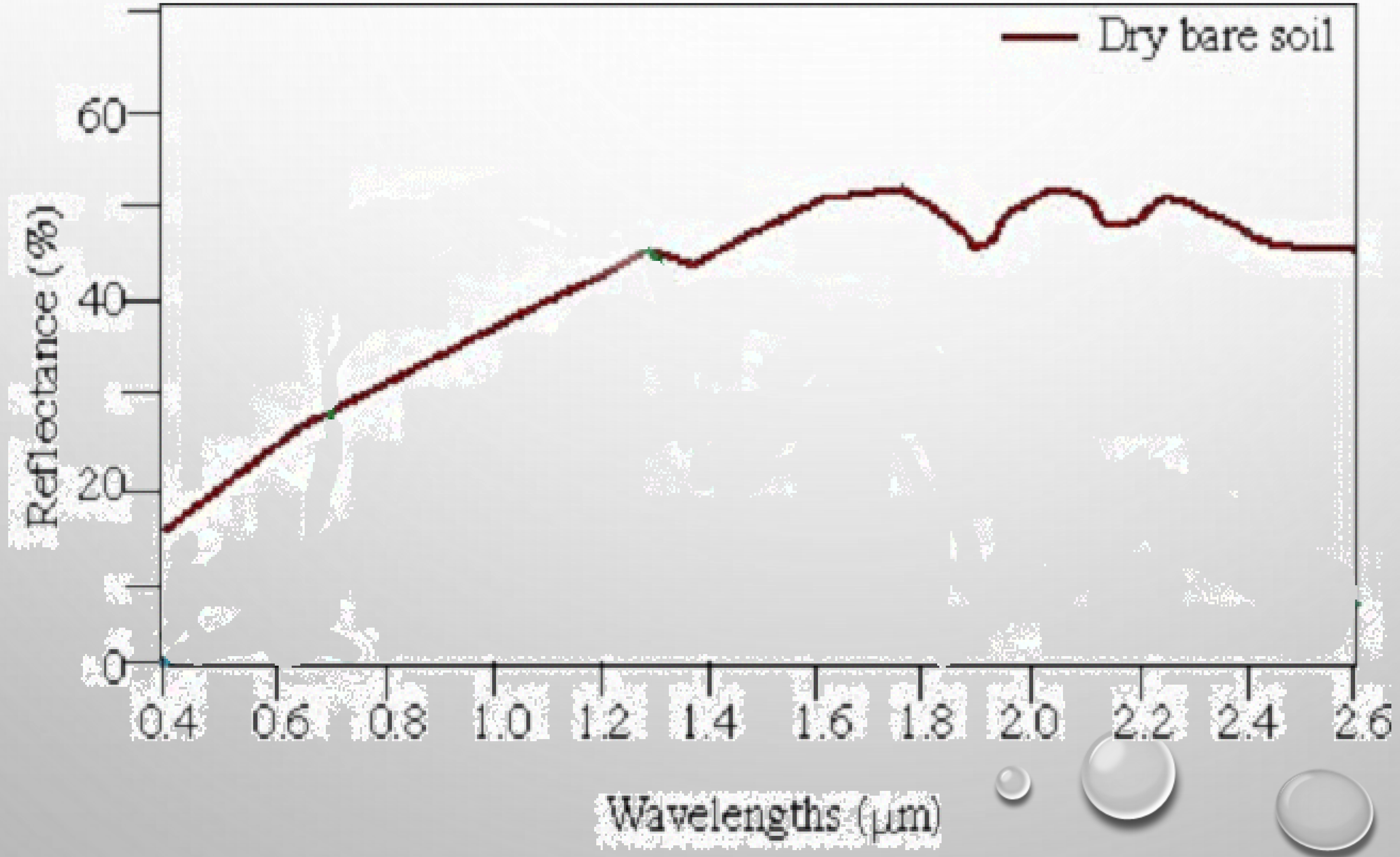


Water absorption at 1.4 and 1.9 microns due to leaf moisture

Radiation - target interactions

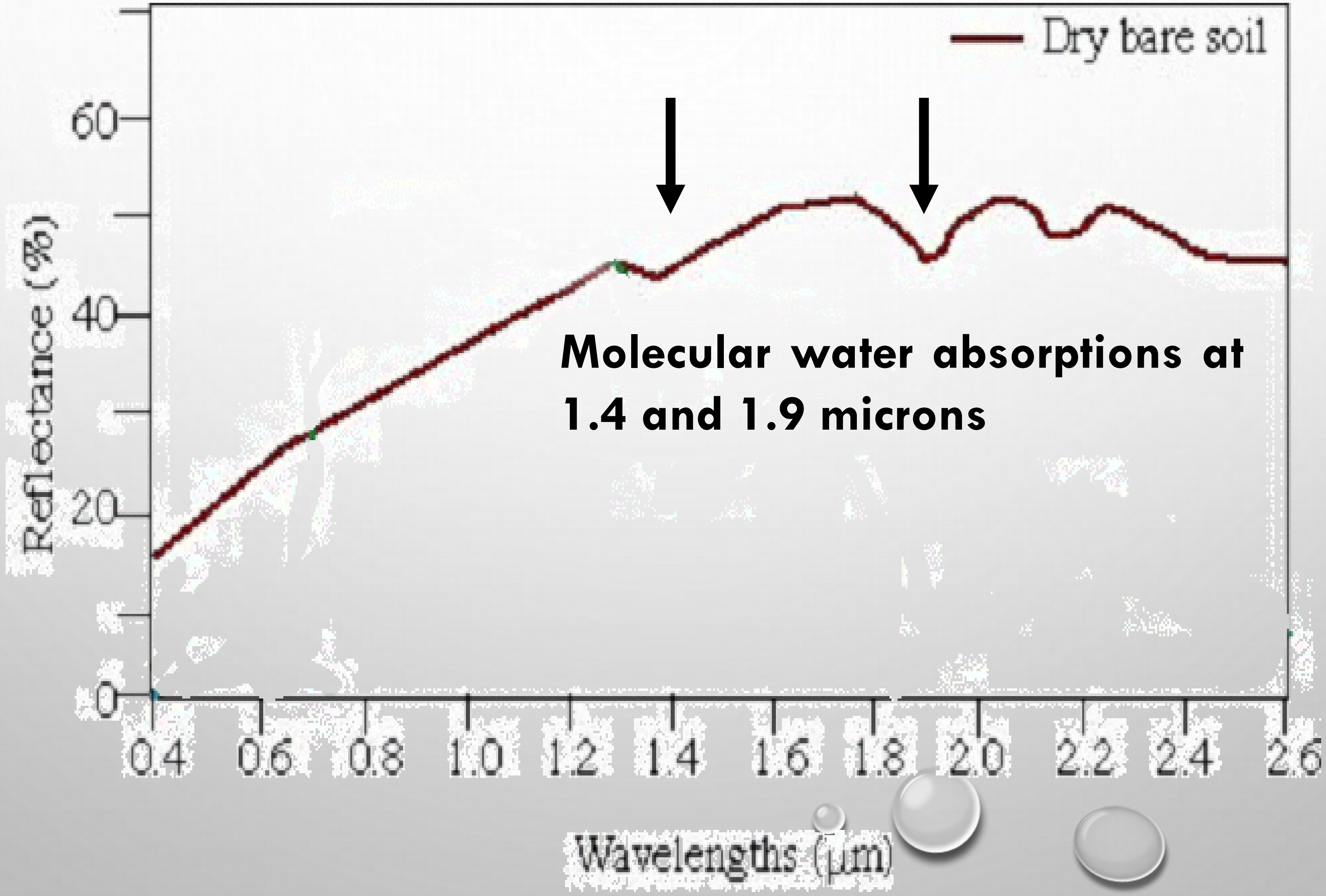
SPECTRAL REFLECTANCE OF SOIL

Soil reflectance generally increases gradually from visible to infrared.

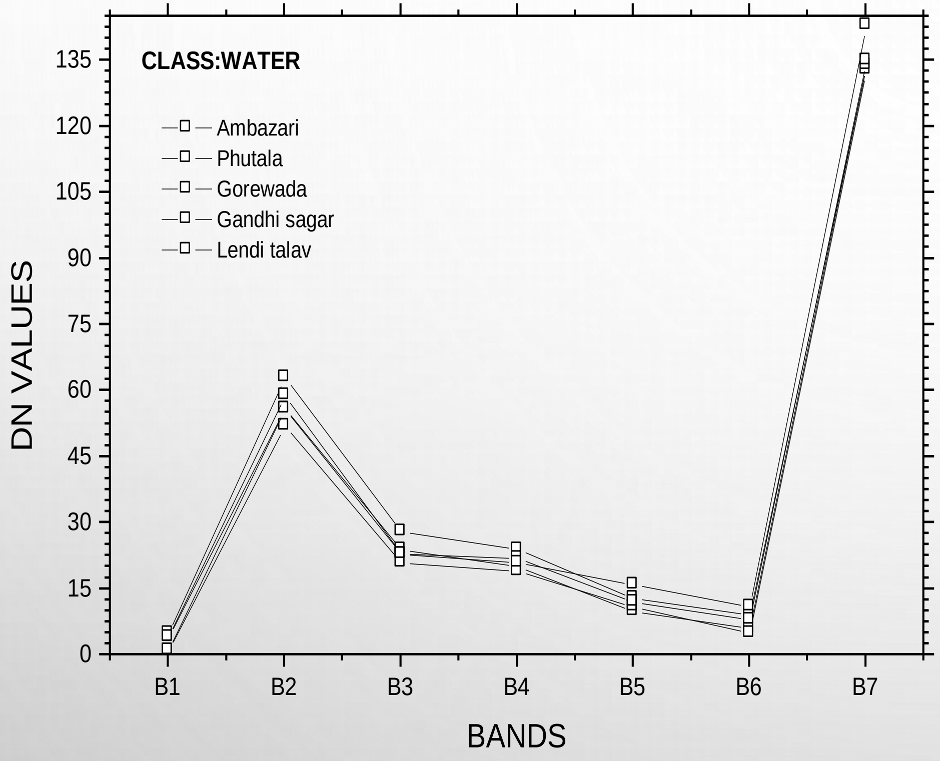


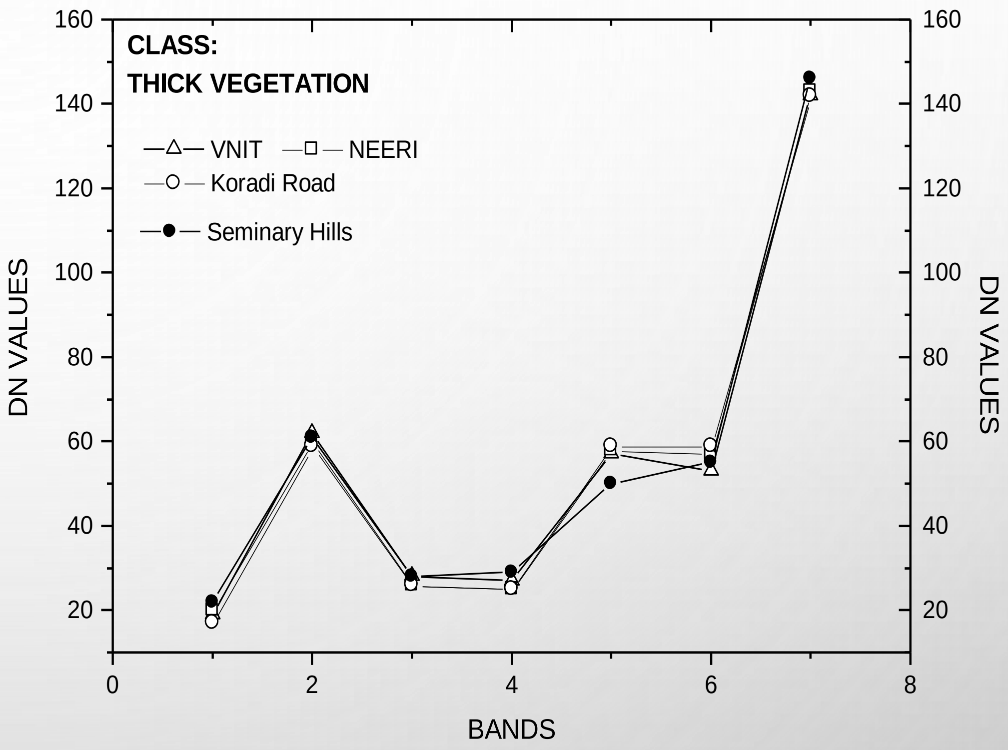
Radiation - target interactions

SPECTRAL REFLECTANCE OF SOIL



Spectral Signature Curves





Class: Water

Class: Thick vegetation

THE BASIC ELEMENTS AND SAMPLING CHARACTERISTICS OF SATELLITE ORBITS

The basic principles of space technology;

1. The basic elements and sampling characteristics of satellite orbits;

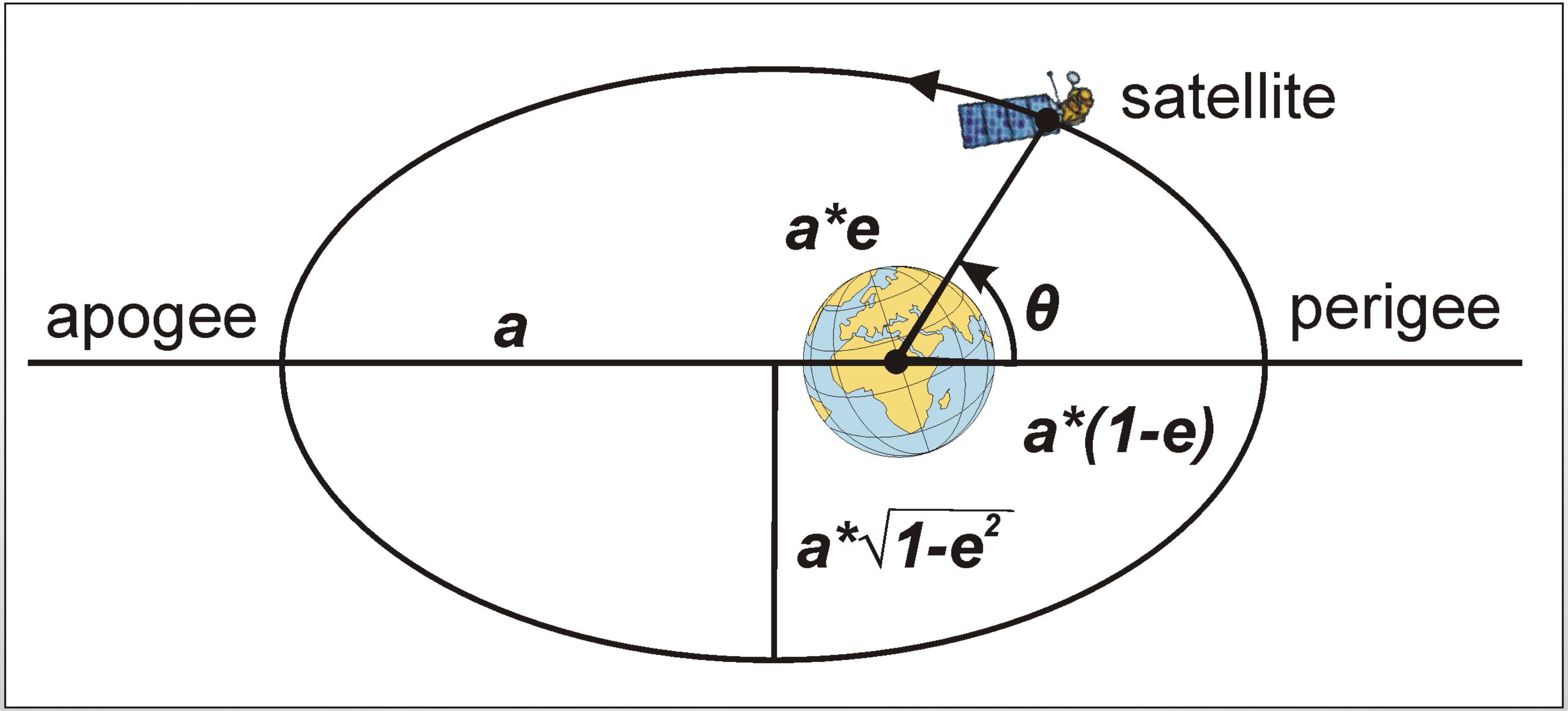
2. Electromagnetic spectrum and satellite sensors;

3. Active and passive sensors;

4. Data transmission to the Earth;

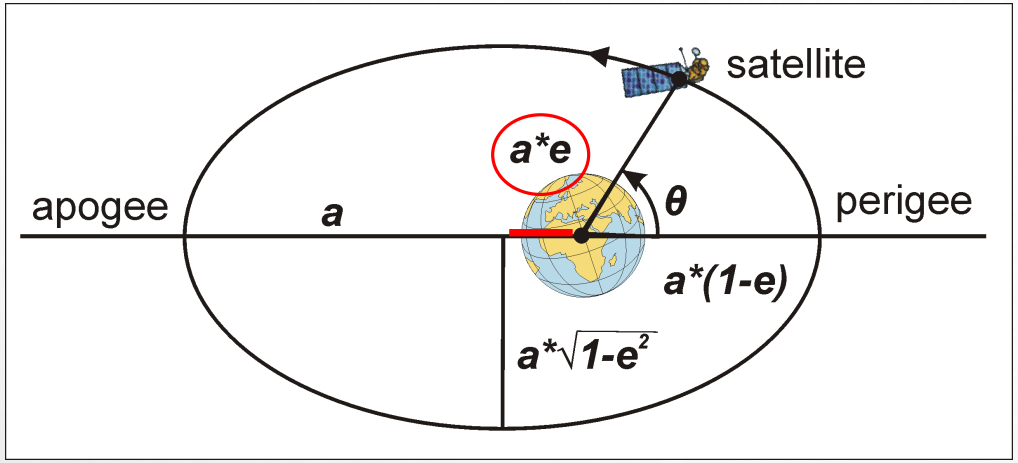
5. Orbit determination techniques.

The basic principles of space technology



All Earth-orbiting satellites have **elliptical orbit**, or the special case of a **circular orbit**.

The basic principles of space technology



a is the semi-major axis of the ellipse;

e is the eccentricity of the ellipse;

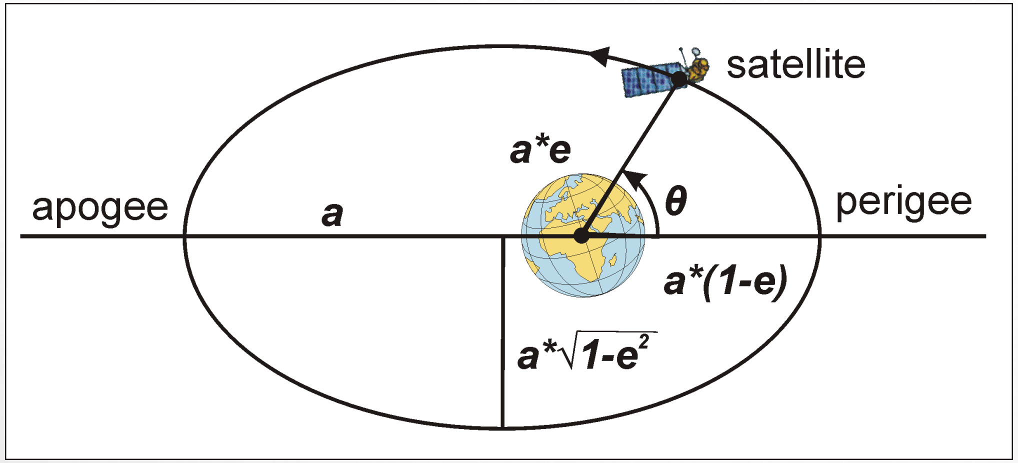
a*e is the displacement of the ellipse center from the center of the Earth;

θ is the angle between the satellite's present radius vector and that at perigee (the orbit's closest point to the Earth).

For the elliptical orbit the distance r of the satellite from the center of the Earth is given by the equation:

$$r = \frac{a \cdot (1 - e^2)}{(1 + e \cdot \cos\theta)}$$

The basic principles of space technology



From Newtonian dynamics, the period *T* for the satellite to travel round the orbit is

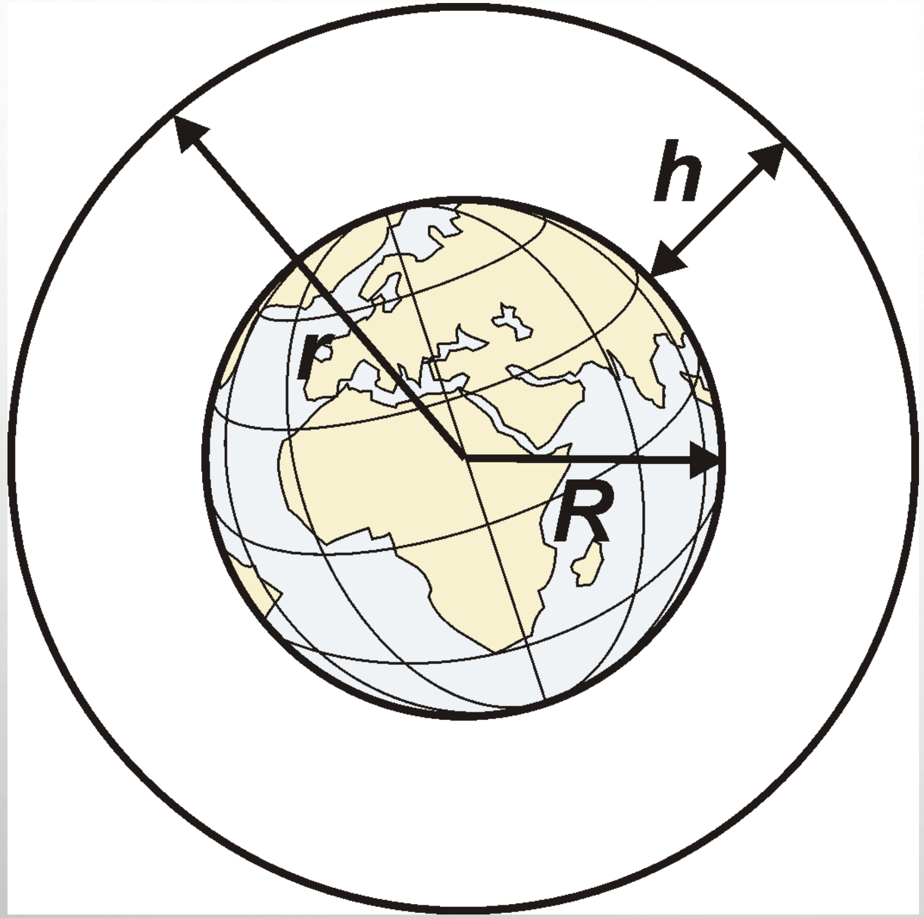
$$T = 2\pi\ (a^3\ /GM)^{1/2}$$

where G is the constant of gravitation and M the mass of the Earth, and $G * M = 3.98603 * 10^{14}\ m^3\ s^{-2}$.

The instantaneous rate at which the satellite describes its orbit is

$$d\theta\ /\ dt = [G * M * a\ (\ 1 - e^2\ )\ ]^{1/2} * r^{-2}.$$

The basic principles of space technology



When e is small, $a = a * (1 - e)$ and the orbit is called
"circular orbit".

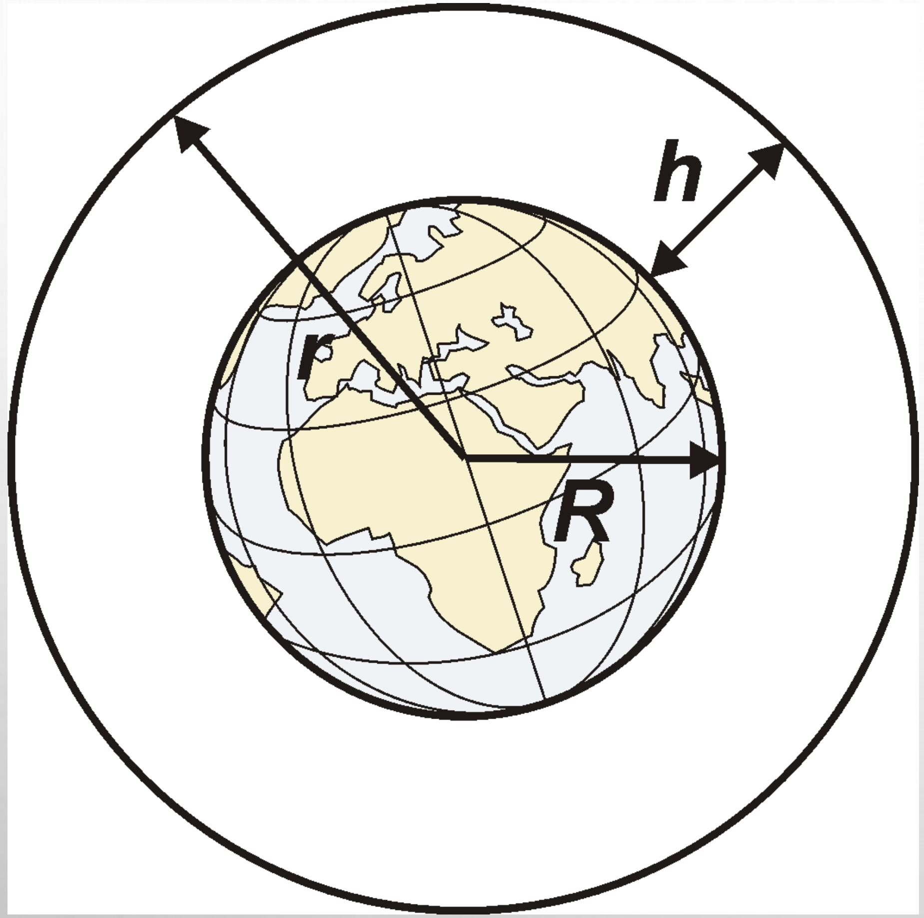
In this case the horizontal speed of the satellite is

$V_0 = (G * M / a)^{1/2}$.

Taking into account:
$R = 6378$ km - Earth's mean equatorial radius;
$g = G * M / R^2$ - the acceleration due to gravity.

Hence, $V_0 = R * [g / (R + h)]^{1/2}$.

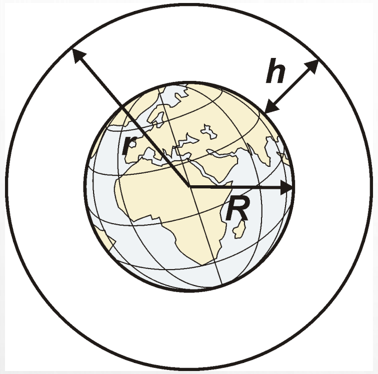
The basic principles of space technology



The instantaneous orbital rate of the satellite V_0 and the period it travels round the orbit T (i. e., the spatial and temporal resolution of satellite observations) directly depend on its orbital axis a (i. e., the height above the Earth h).

Higher orbit has longer period and lower orbit has shorter period.

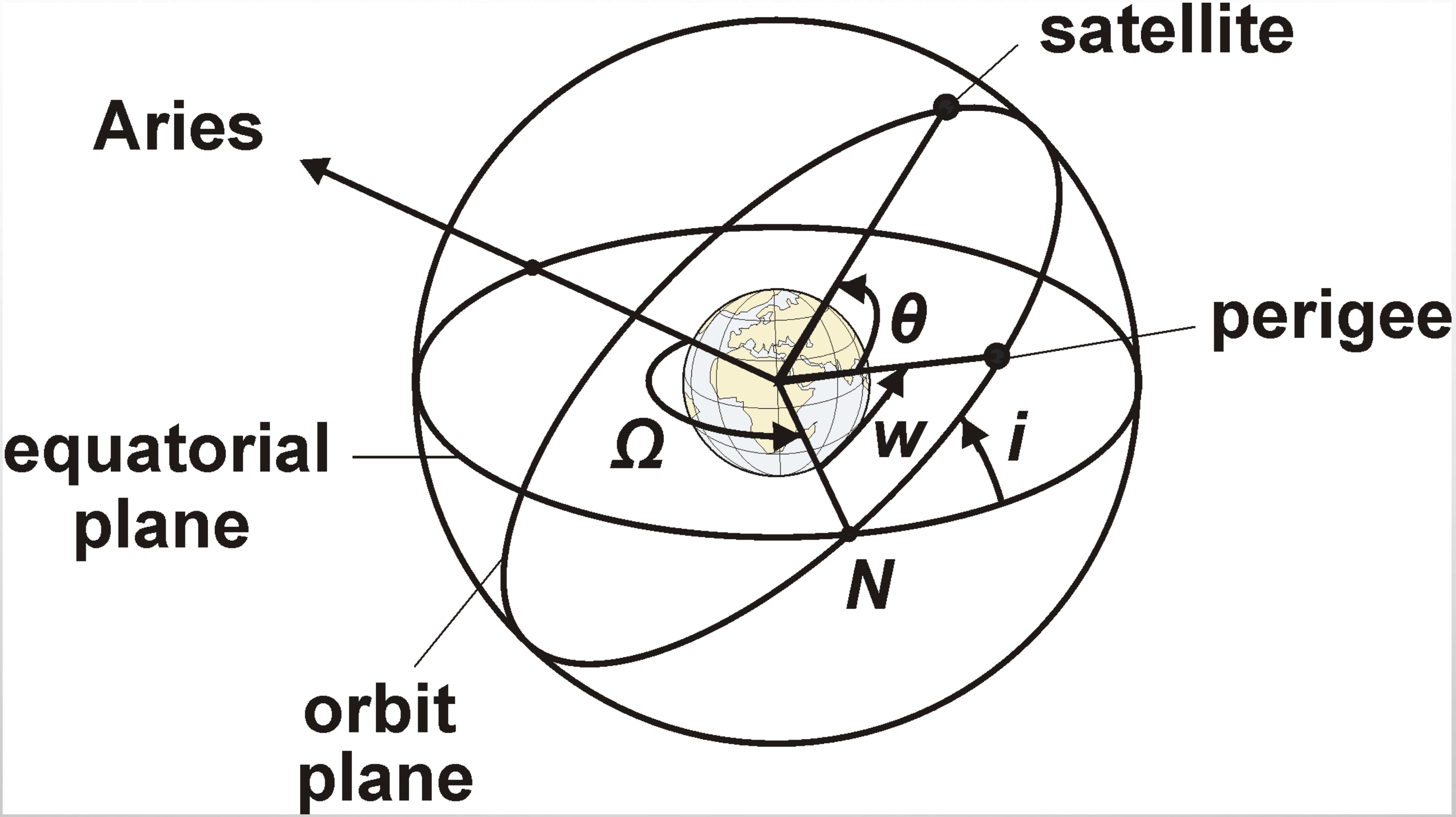
The basic principles of space technology



During launch the rocket must be fired to obtain a trajectory such that at the desired height h of the satellite, its speed is V_0 , assuming that a circular orbit is required.

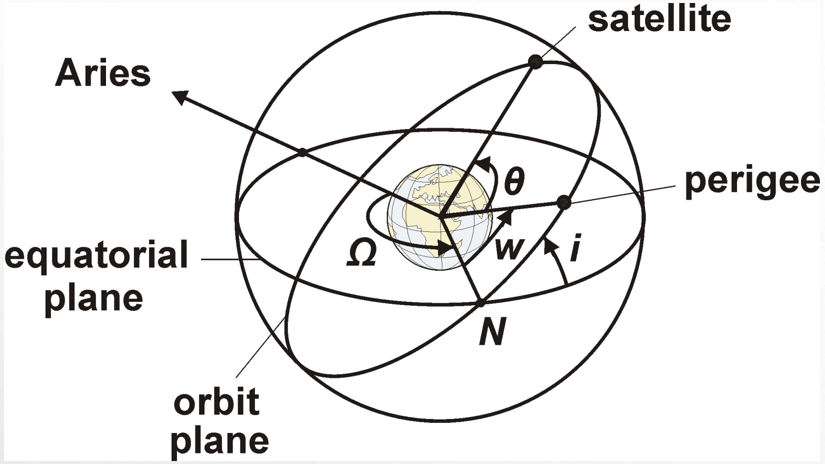
- If when the satellite reaches h it is traveling horizontally at speed V, then if $V<V_0$ the satellite will fall into an elliptical orbit for which $a<(h+R)$.
- Alternatively if $V>V_0$, the satellite moves out into a higher ellipse and $a>(h+R)$.
- If $V>2 * V_0$ then the elliptical orbit becomes parabolic and the satellite reaches escape velocity and never returns.

The basic principles of space technology



Satellite orbital elements on the celestial shell

The basic principles of space technology



So far we have identified six orbital elements which characterize a satellite's position:

θ - the angular position of the satellite in its orbit,

a - the semi-major axis of the ellipse,

e - the eccentricity of the ellipse,

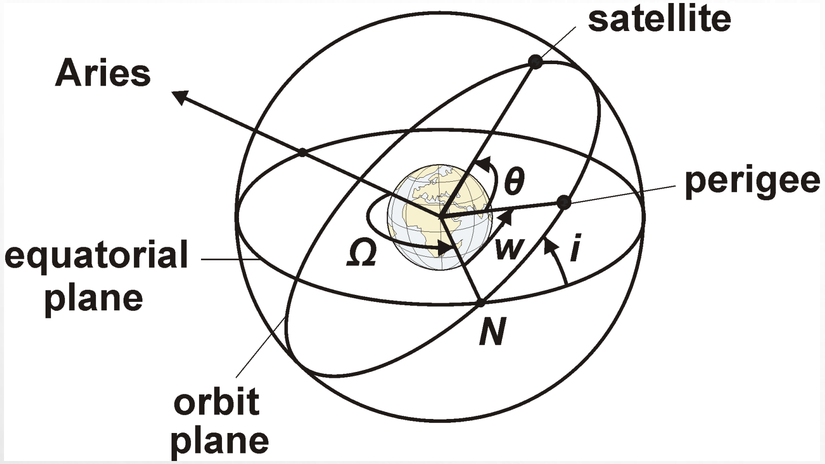
i - the inclination of the orbital plane to the Earth equatorial plane,

Ω - the right ascension of the ascending node *N*, measured eastward from the point of Aries which is a fixed point in the heavens,

w - the angular distance of perigee around the orbit, measured from the ascending node.

In fact $d\Omega/dt \propto -(G^*M)^{1/2} R^2 * a^{-7/2} (1-e^2)^{-2} * \cos(i)$.

The basic principles of space technology
Orbit types



For Earth observation, three types of orbit are most useful:

1. Geostationary orbit

The satellite orbits in the same direction as the Earth with a period of one day. It is positioned in a circular orbit above the equator. Therefore, it becomes stationary relative to the Earth and always views the same area of the Earth's surface.

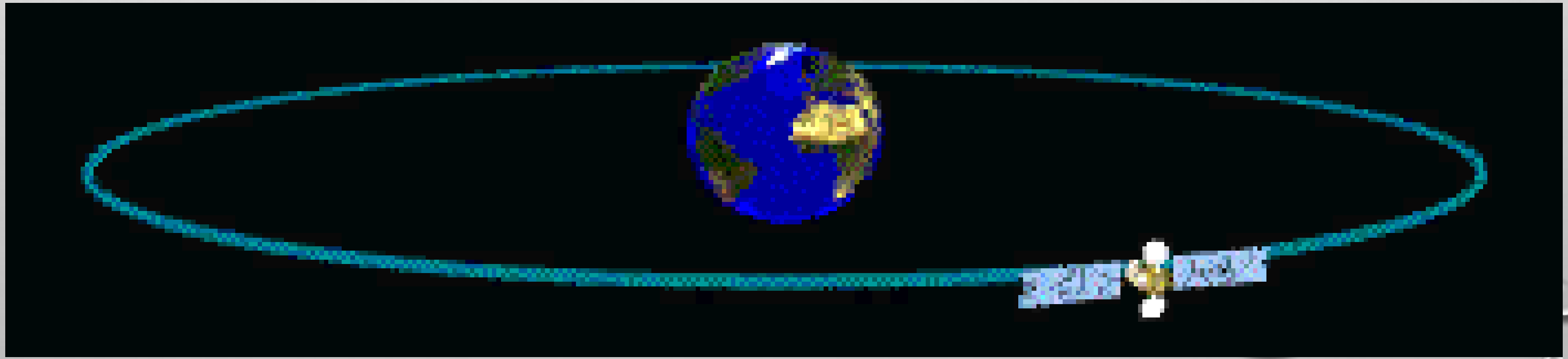
From equation $T = 2\pi\ (a3\ /GM)1/2$:

T = 1 day = 86400 seconds => a = 42,290 km =>

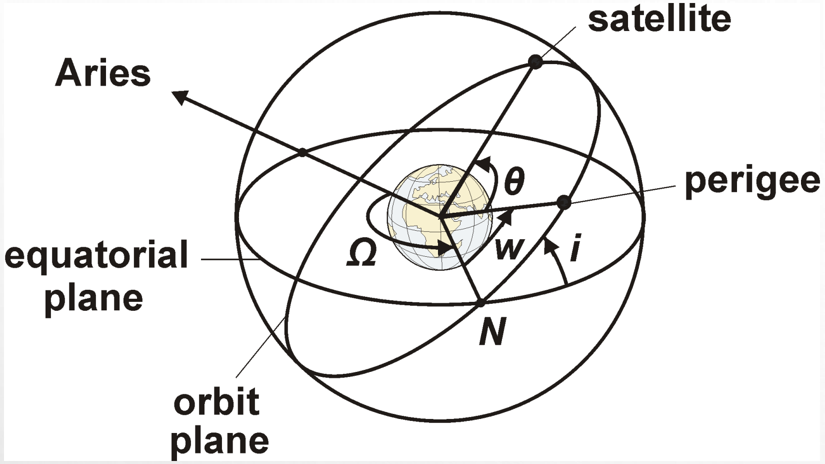
h = a - R = 35,910 km.

SATELLITE OBSERVATONS

- Geosynchronous
  - Orbital period of 1 day, i.e., satellite stays over the same spot on the Earth
  - Orbital radius is 42,164 km or 35,786 km above the Earth's surface at the Equator where the Earth's radius is 6.378 * 10^6 m
  - Used for many communication satellites;
    - > Cover a country like Australia
    - > Don't require complex tracking dishes to receive the signals; Note: satellite stay stationary relative to Earth



The basic principles of space technology
Orbit types



For Earth observation, three types of orbit are most useful:

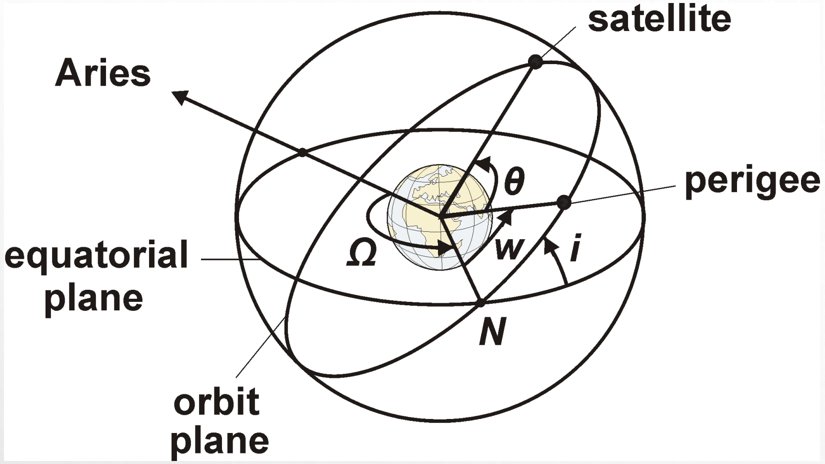
2. Polar orbit

i (inclination) ~ □90°.

Usually these satellites have height between 500 and 2,000 km and a period of about1 to 2 hours.

As the Earth rotates under this orbit the satellite effectively scans from north to south over one face and south to north across other face of the Earth, several times each day, achieving much greater surface coverage than if it were in a non-polar orbit.

The basic principles of space technology
Orbit types



For Earth observation, three types of orbit are most useful:

3. Nearly polar sun-synchronous orbit

From equation for $d\Omega/dt$ it is possible for a given orbit height by a suitable selection of the inclination i to achieve $d\Omega/dt = 0.986°$ per day, which is equivalent to one rotation of the orbit plane per year.
In this way the orbit plane is not fixed relative to stars, but fixed relative to the sun. The result is sun-synchronous orbit, in which the satellite crosses the equator at the same local solar time on each pass throughout the year.
In practice i is about 100°, i. e., the orbit is not polar, but nearly polar.

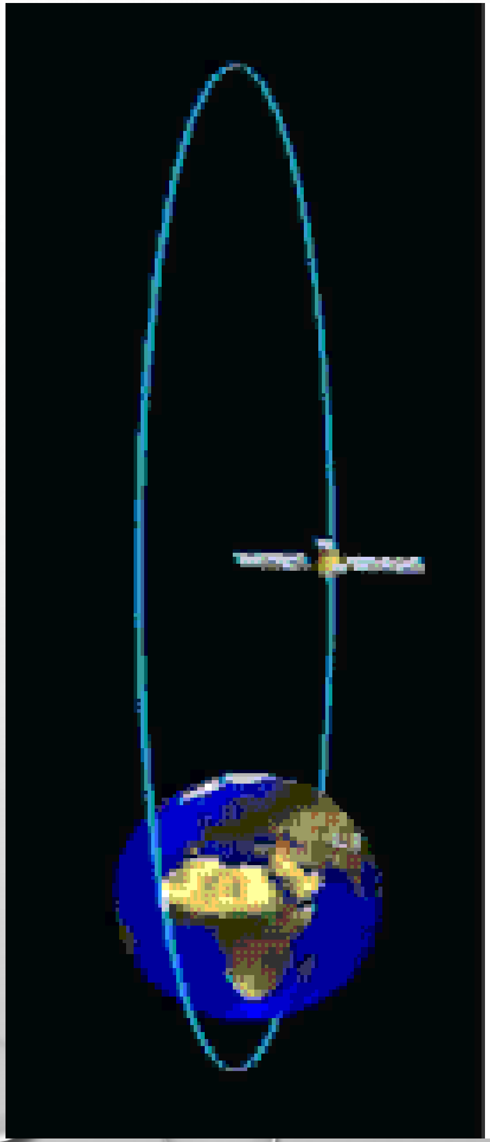
SATELLITE OBSERVATIONS

- **Highly Elliptical Orbits (HEO)**

  - Typically pass low (1,000 km) over the southern regions, then loop high over the northern regions

  - One pass every 4 to 12 h

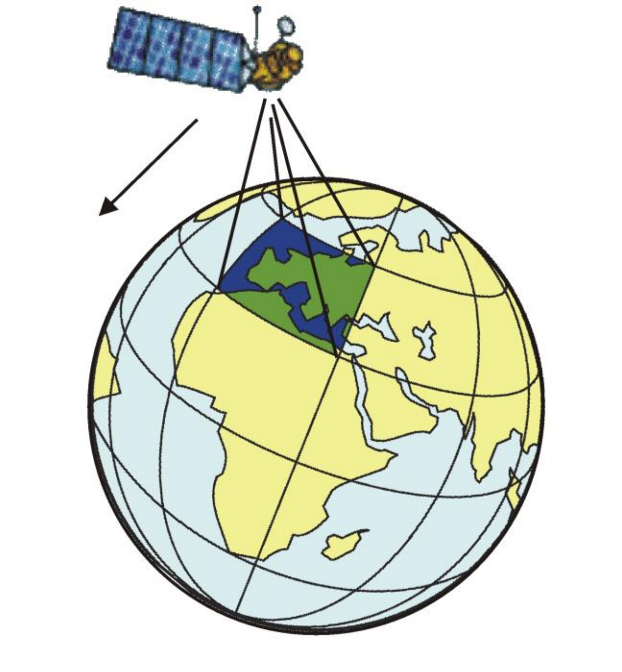
  - Used in communications to provide coverage of the higher latitudes and the polar regions



Orbit characteristics of oceanographic near-polar sun-synchronous satellites

Satellite	TIROS-N	NOAA-6	NOAA-7	NIMBUS-7
Semi-major axis ***a*** (km)	7244	7202	7250	7335
Semi-minor axis (km)	7229	7185	7232	7174
Nominal height ***h*** (km)	855	815	860	950
Orbit inclination ***i*** (°)	98.9	98.7	98.9	99.3
Period (min)	102.2	101	102.3	104.9
Local equator crossing time	07.30 south-bound	15.00 north-bound	07.30 south-bound	12.00 north-bound
Orbits per day	14.1	14.2	14.1	13.7

Spatial and temporal sampling characteristics of orbits



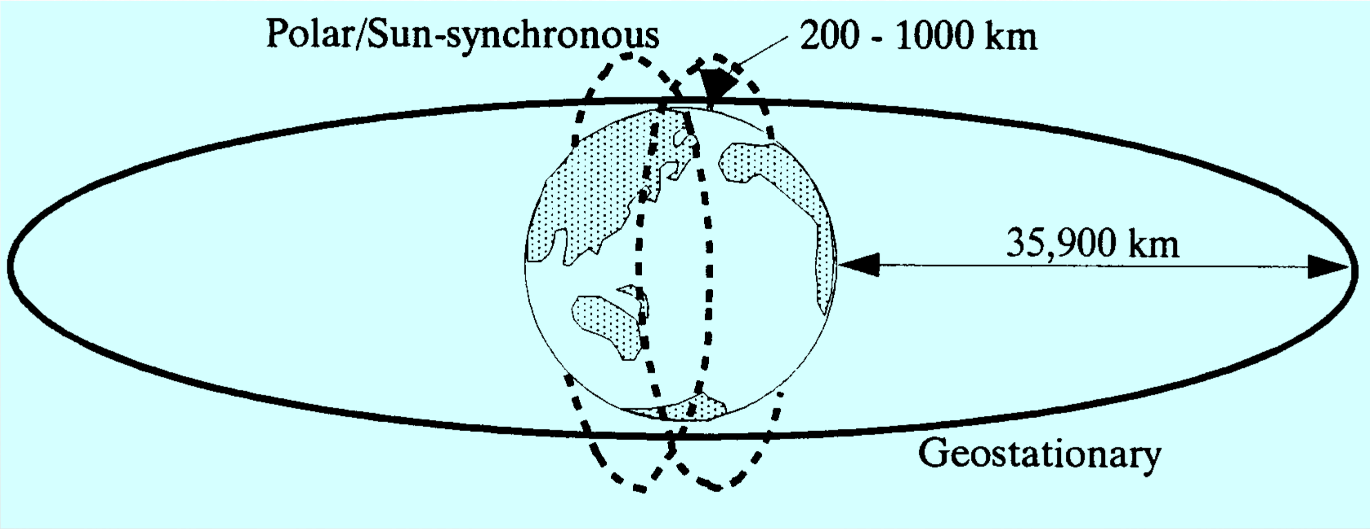
From the orbital period of sun-synchronous satellite we can estimate the distance between successive ground tracks. For example, for Landsat 1 the period is 103.2 min, and the distance is 25.8 degrees, which corresponds to a spacing at the equator of about 2,865 km. The distance between tracks decreases with latitude.

Another important characteristic of remotely sensed data is the swath-width of the sensor. Typical swath-width is 1,500-2,000 km.

Satellite Orbit Determines...

- …what part of the globe can be viewed.
- …the size of the field of view.
- …how often the satellite can revisit the same place.
- …the length of time the satellite is on the sunny side of the planet.

Data acquisition - satellite orbits



Satellites:

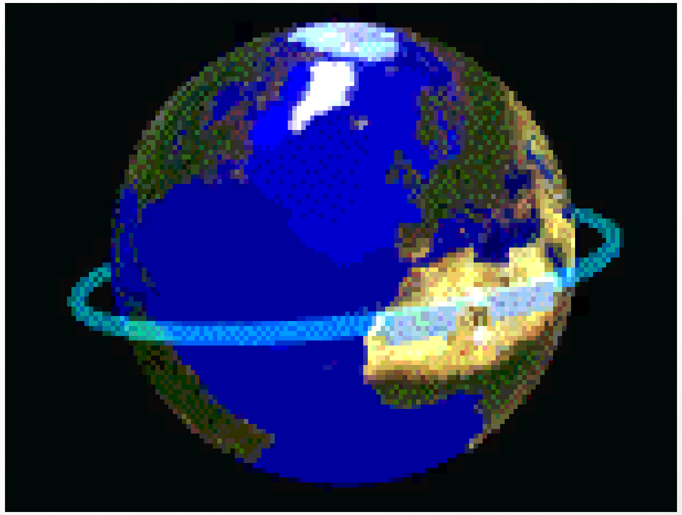
•Sun-synchronous (Landsat, SPOT)

•Geostationary (TIROS)

Satellites:
Sun-synchronous (Landsat, SPOT)
Geostationary (TIROS)

Satellite Observations

Types of Orbits acording to the ***<u>height</u>***

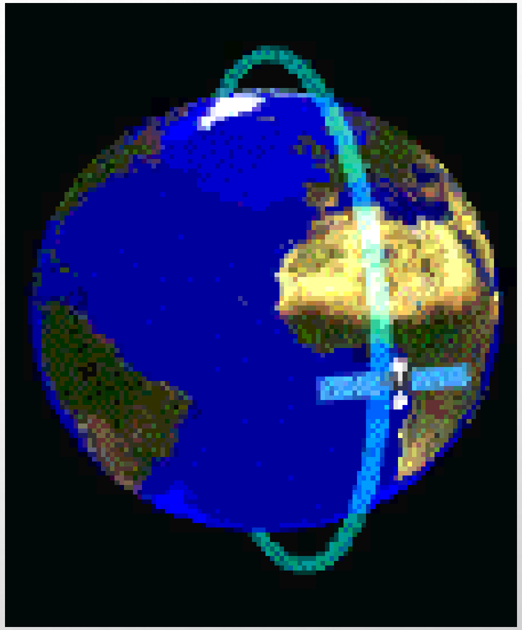


- Lower Earth Orbit (LEO)
  - Orbit at 500 - 3,000 km above the Earth (definition varies)
  - Used for reconnaissance, localized weather and imaging of natural resources.
  - Space shuttle can launch and retrieve satellites in this orbit
  - Now coming into use for personal voice and data communications
  - Weather satellites
    - > Polar orbit - Note, as the satellite orbits, the Earth is turning underneath. Current NOAA satellites orbit about 700 - 850 km above Earth's surface
    - > Orbital period about every 98 - 102 min

Satellite Observations

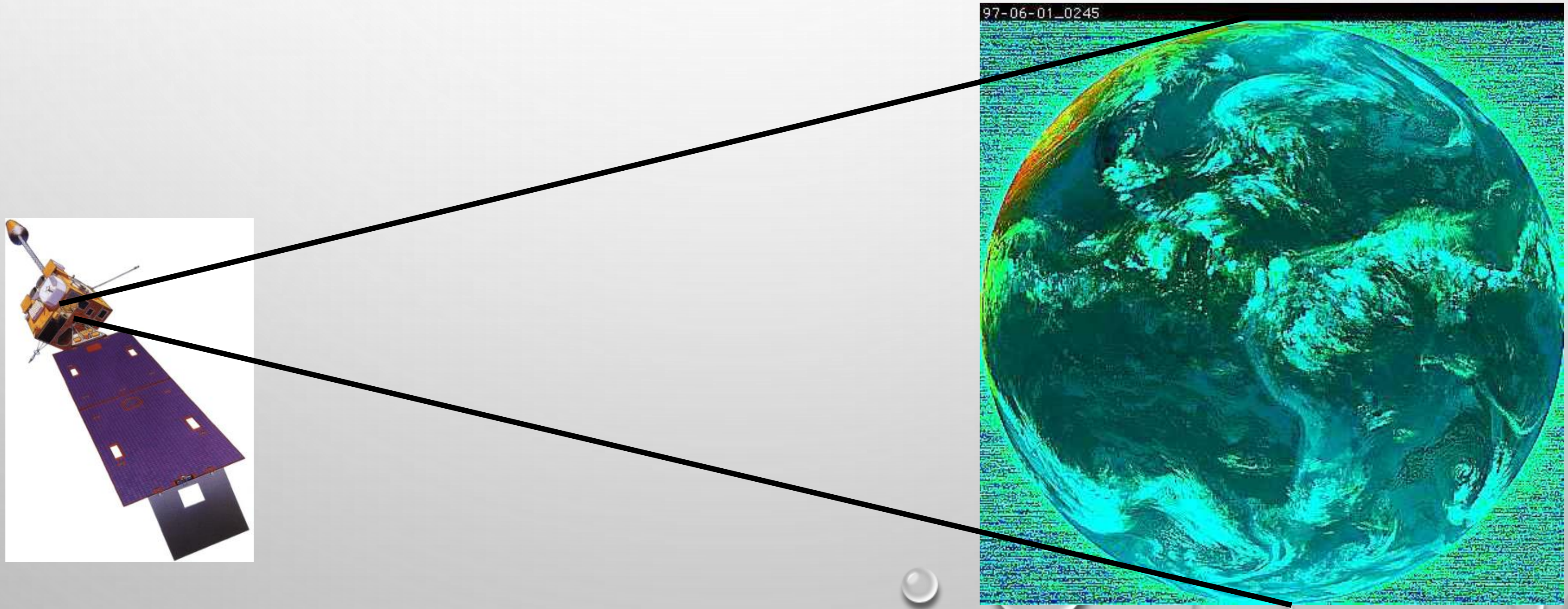
Types of Orbits acording to the **height**

- Medium Earth Orbit (MEO)
  - Orbit at 3,000 - 30,000 km (definition varies)
  - Typically in polar or inclined orbit
  - Used for navigation, remote sensing, weather monitoring, and sometimes communications
    - > GPS (Global Position System) satellites
      - ‡ 24-27 GPS satellites (21+ active, 3+ spare) are in orbit at 20,000 km (about 10,600 miles) above the Earth; placed into six different orbital planes, with four satellites in each plane
      - ‡ One pass about every 12 h

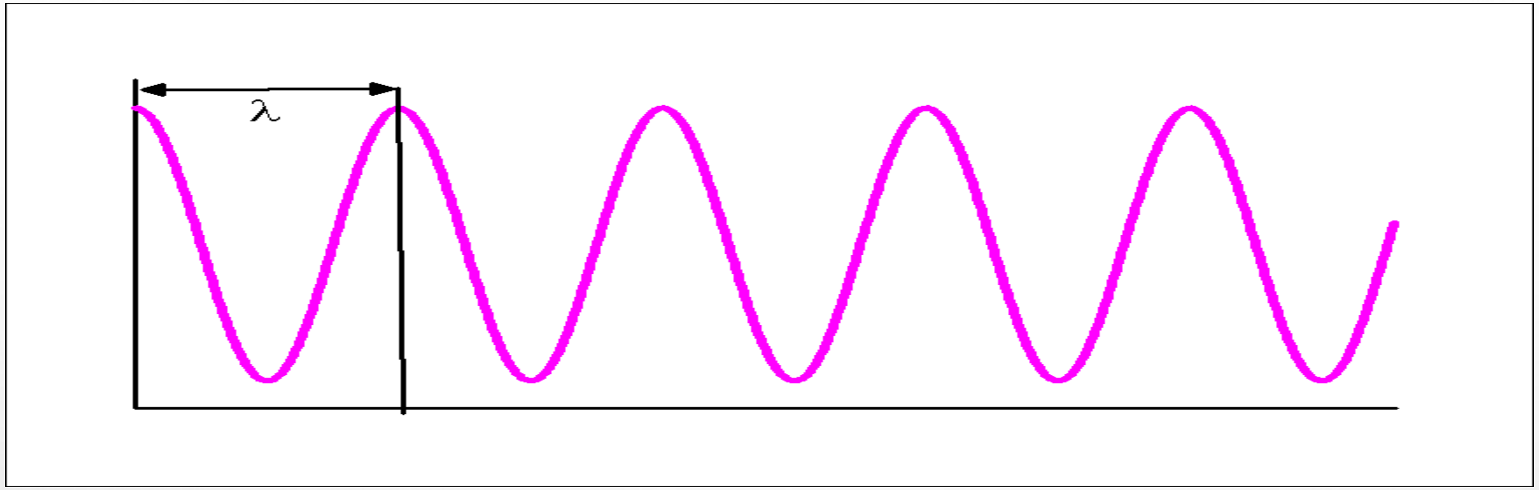


Satellite Observations

- Geosynchronous
  - Weather satellites
    > GOES (Geosynchronous Operational Environmental Satellites) Satellite



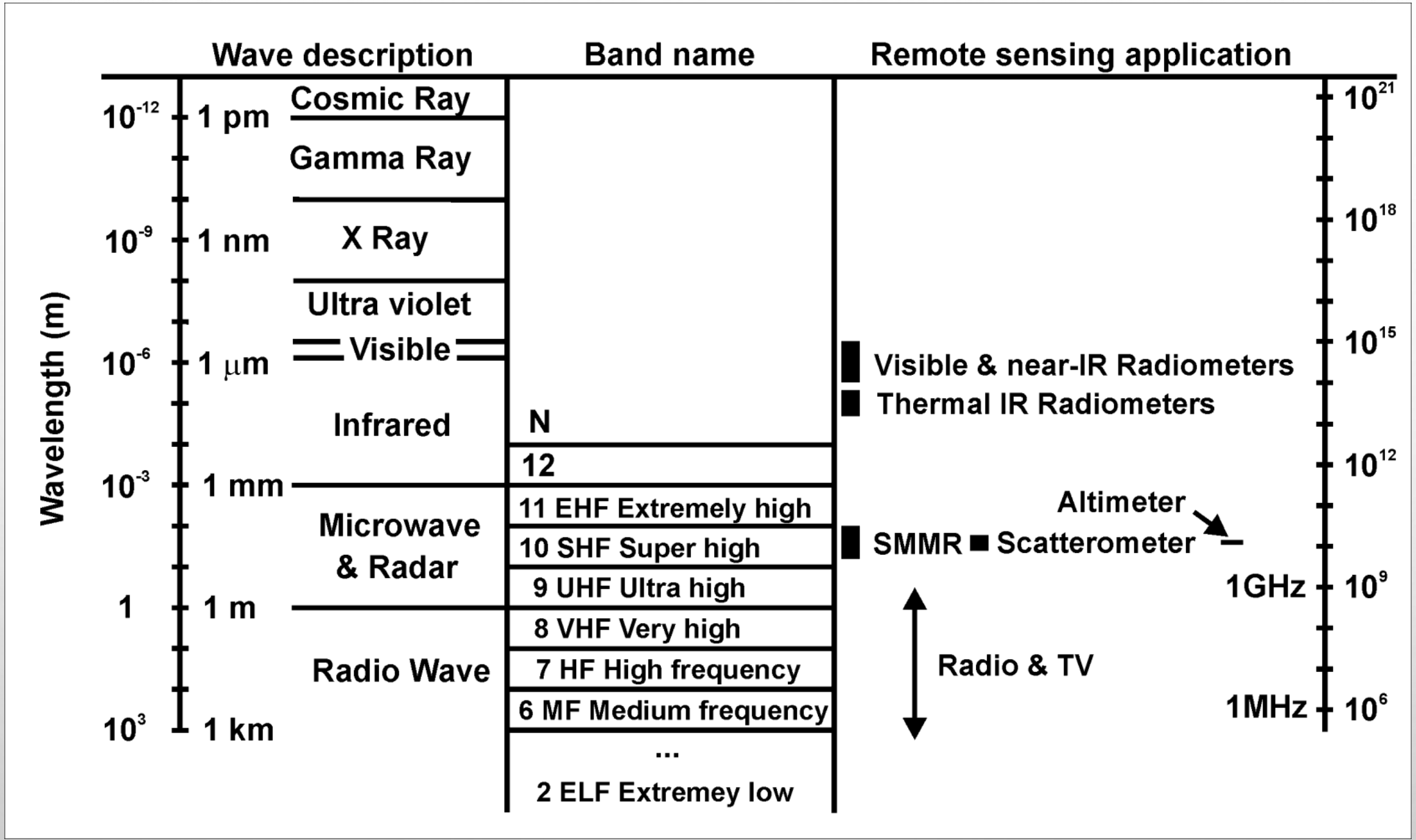
2. Sensors on satellites



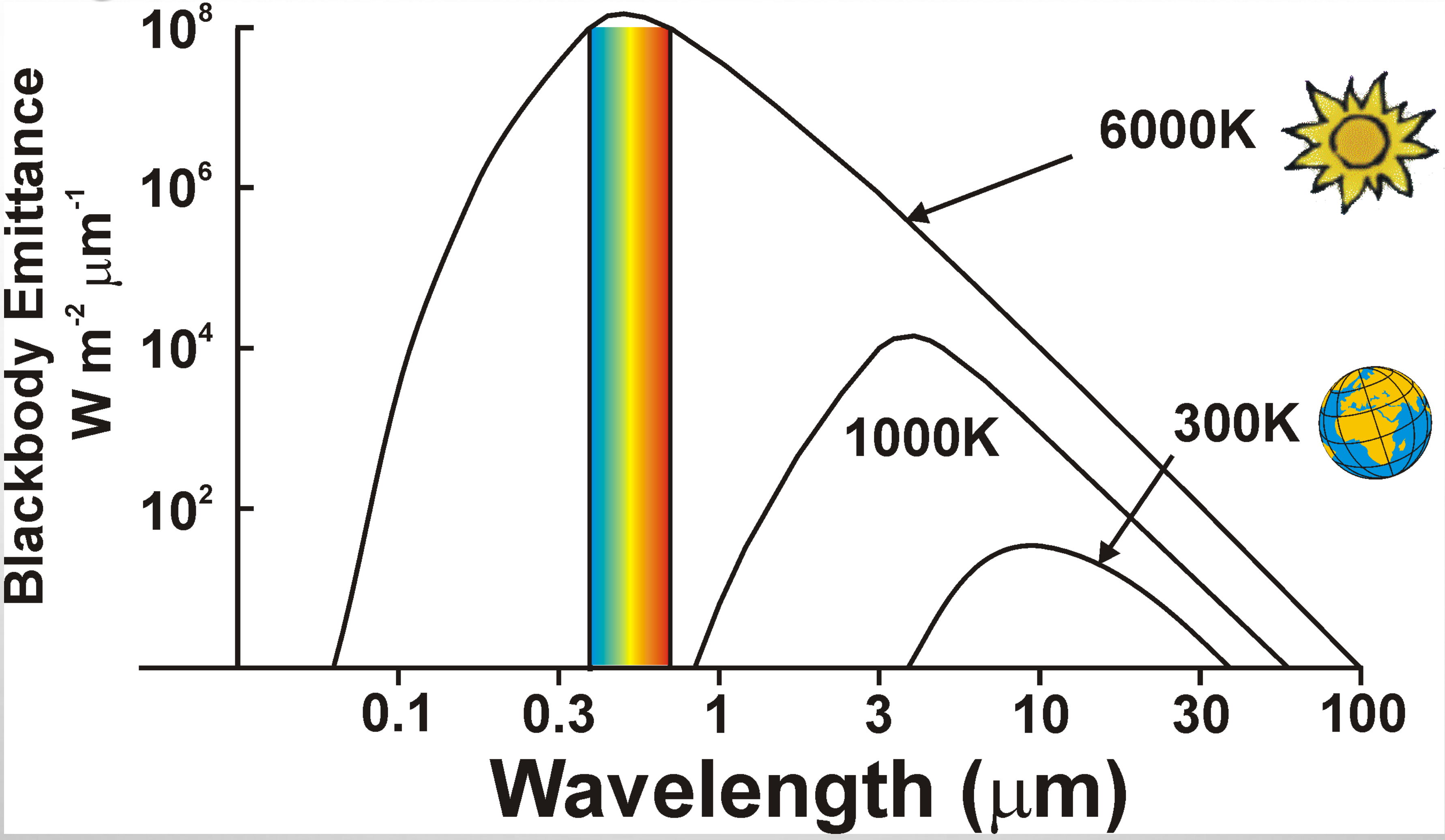
All sensors employed on ocean-observing satellites use electromagnetic radiation to view the sea. This radiation travels through free space at the speed of light $c \sim 3*10^8 m\ s^{-1}$.

The frequency f and wave length λ are related by $f * \lambda = c$.

So, the electromagnetic spectrum used in the sensor can be characterized by wavelength λ and/or frequency f.

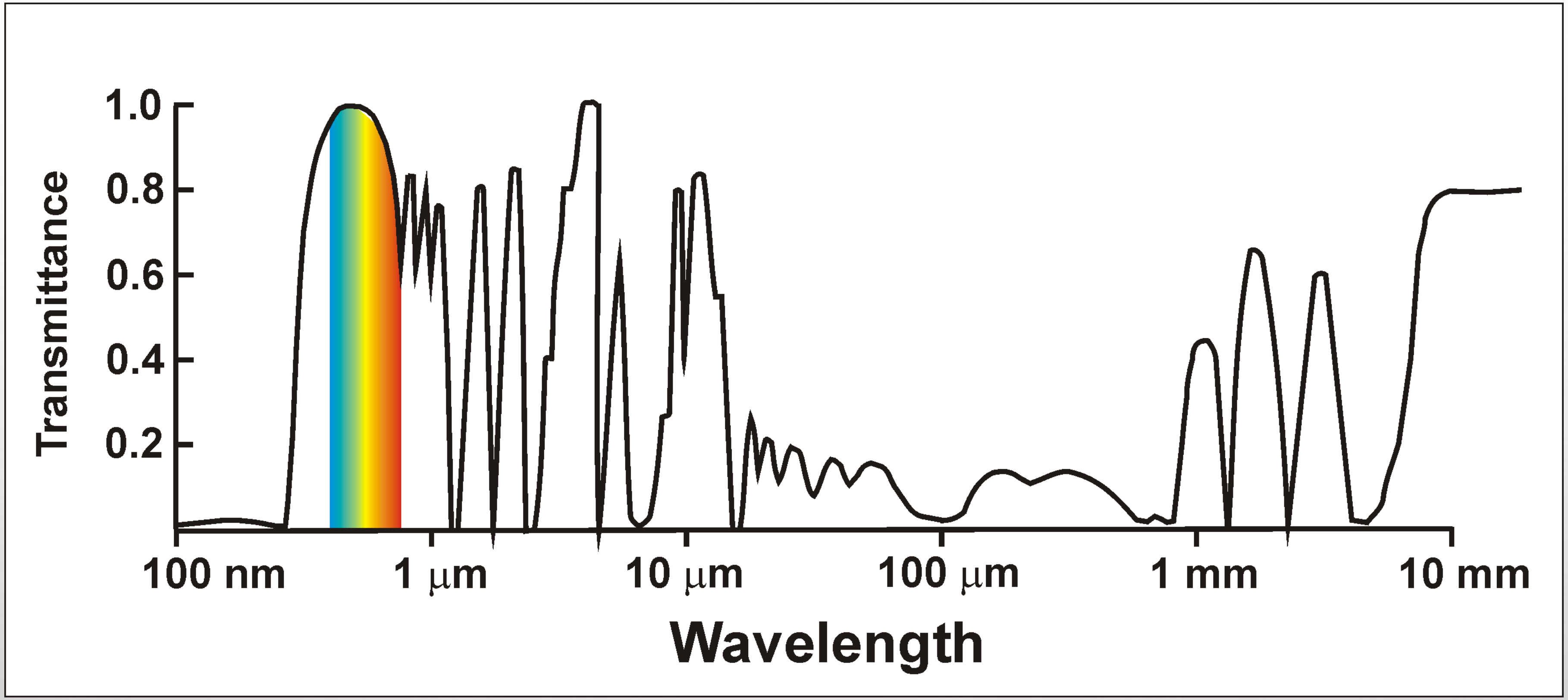


The electromagnetic spectrum, showing some bands definitions and typical remote-sensing applications.

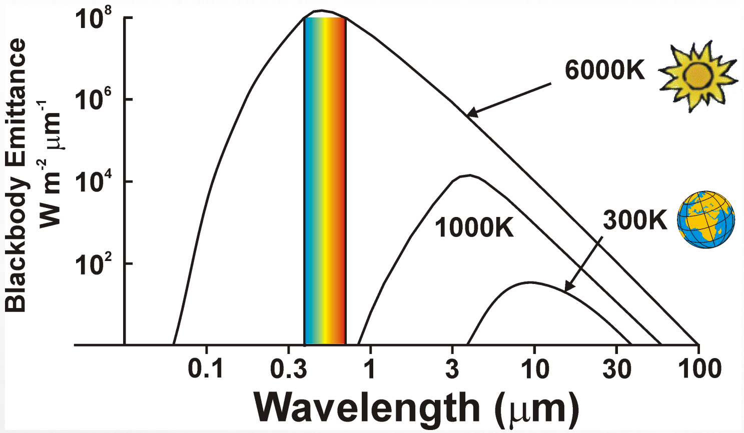


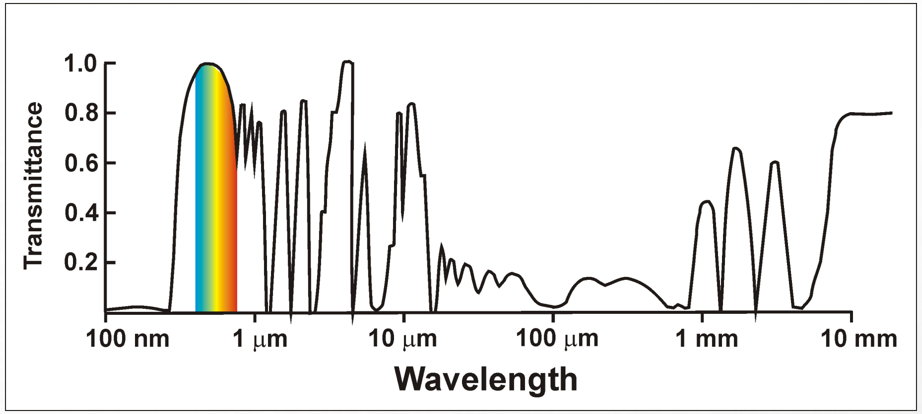
Emission spectra at different temperatures.

2. Sensors on satellites

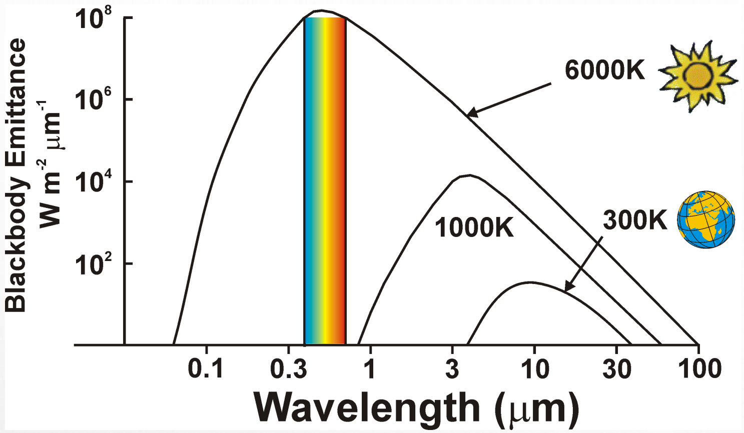


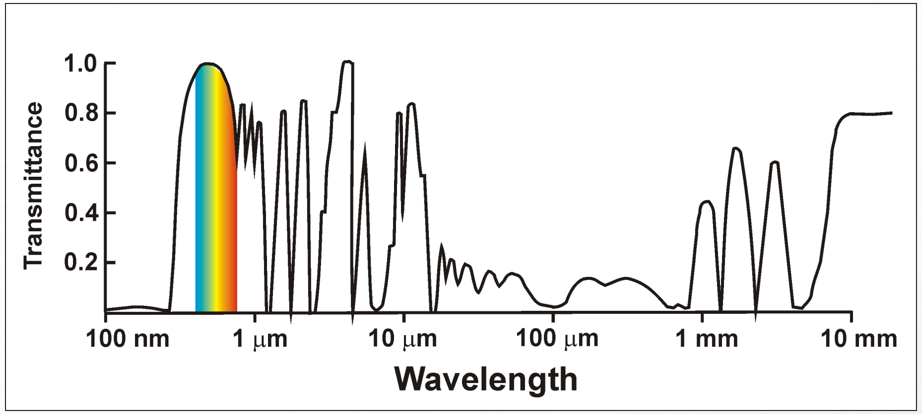
Approximate transmittance of electromagnetic waves through the atmosphere.





The choice of bands for remote-sensing application is governed by both the application and the atmospheric transmission spectrum. Hence, if features of the land and sea are to be observed by the reflection of incident solar radiation in the same way as the human eye observes, then the frequency range 100 nm - 100 μm should be used. Alternatively, if the self-emission of radiation by the sea is to be means of remote sensing, sensors should be used for the 3 to 40 μm wavelength range. However, not all the parts of these ranges are useful, since the atmosphere will not transmit them, as illustrated by the typical transmission spectrum of the atmosphere.

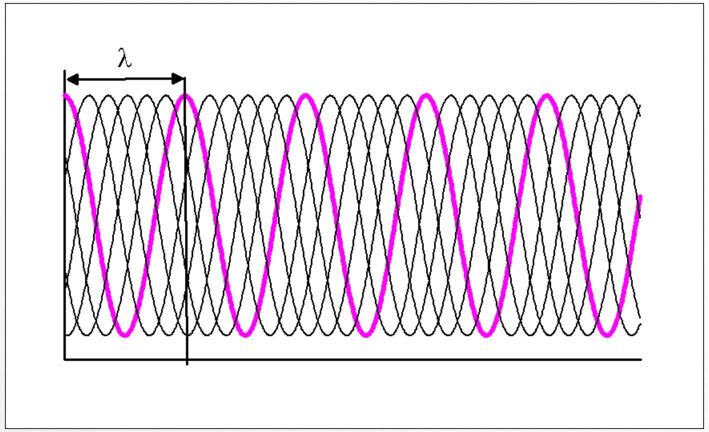




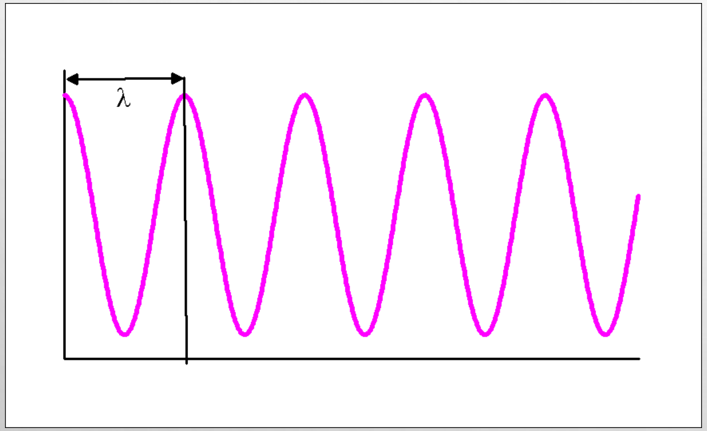
Usually the range 400 nm - 1 µm is used to measure visible waves and about 10 µm for infrared measurements.

Above 10 mm there is very little absorption. These radar bands are exploited by active microwave sensors which create their own radiation with which to illuminate the target, and then observe the nature of the reflected signal, in contrast to passive IR and visible wavelength sensors which rely on naturally occurring radiation.

Passive sensors	Wavelength	Information
Visible wavelength radiometers	400 nm - 1 μm	Solar radiation reflected by Earth surface
Infrared (IR) radiometers	about 10 μm	Thermal emission of the Earth
Microwave radiometers	1.5 - 300 mm	Thermal emission of the Earth in the microwave
Active devices		
Altimeters	3 - 30 GHz	Earth surface topography
Scatterometers	3 - 30 GHz	Sea surface roughness
Synthetic aperture radars	3 - 30 GHz	Sea surface roughness and movement

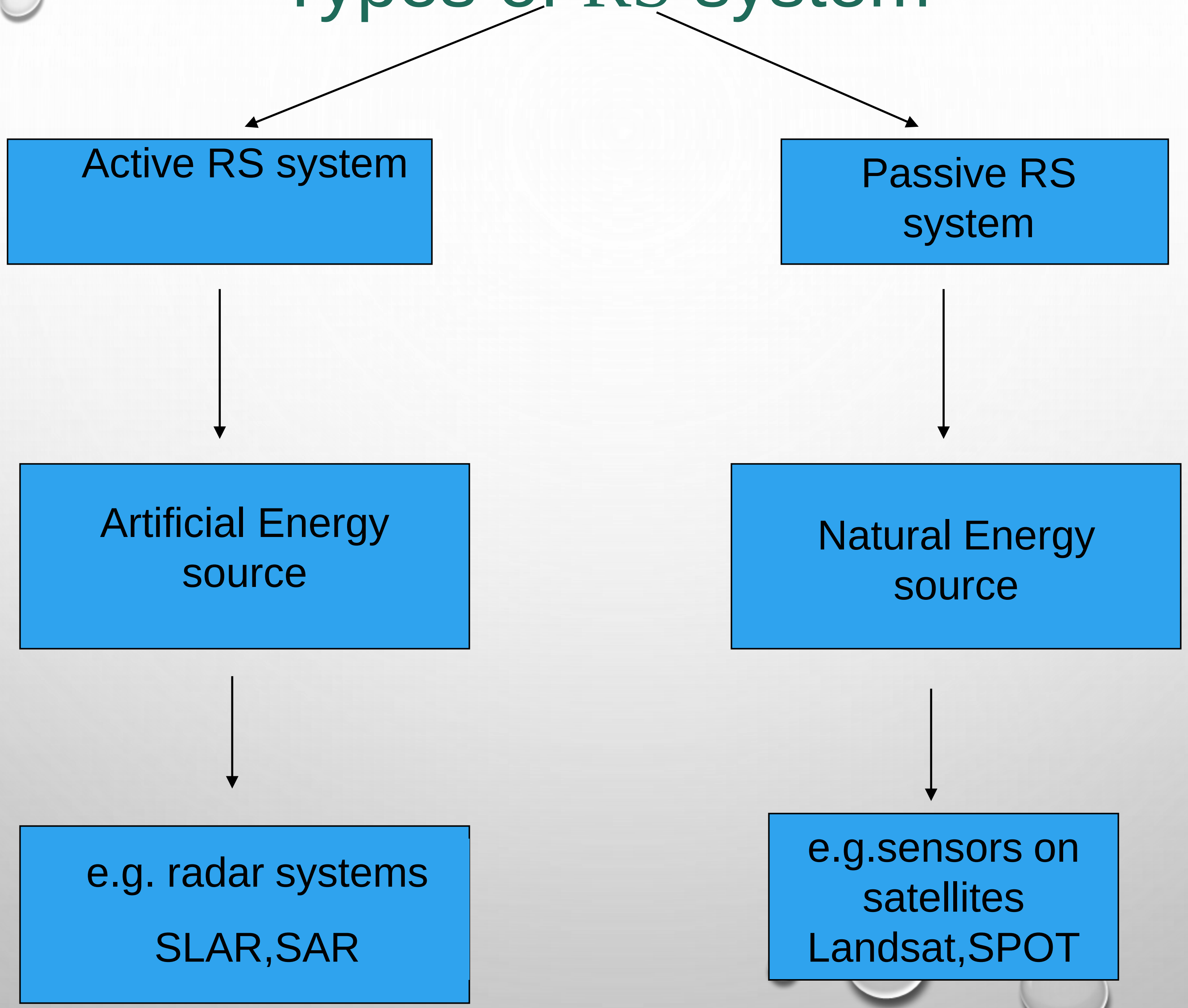


Passive sensors measure incoherent electromagnetic radiation.



Active sensors illuminate the target (the sea) with their own pulse of electromagnetic radiation; hence, they measure not only the amplitude but also the phase of the reflected signal and the travel time of the pulse.

Types of RS system



Remote sensing systems

- Passive

Human eye

Camera

Radiometer

- Active

Radar

Sonar

Laser

Remote sensing systems

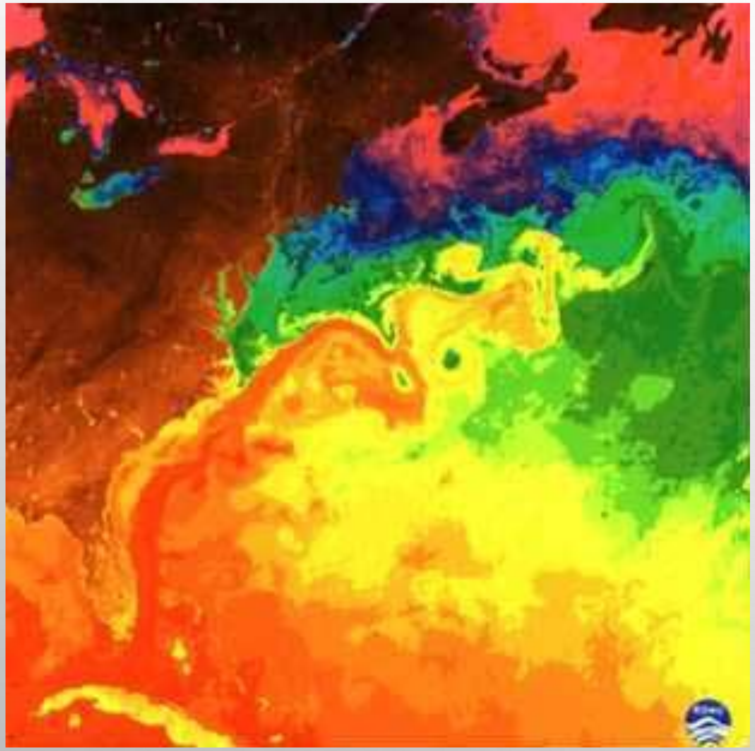
Type → Based on source of the energy recorded by the sensor

1. **Passive Remote Sensing:** Energy collected by sensors is either reflected or emitted solar radiation.
    - Reflected – must be collected during daylight hours
    - Emitted – day or night as long as emissions large enough to record

2. **Active Remote Sensing:** Energy collected by sensors is actively generated by a man-made device.
   Examples: Radar, LIDAR (Light Detection and Ranging)

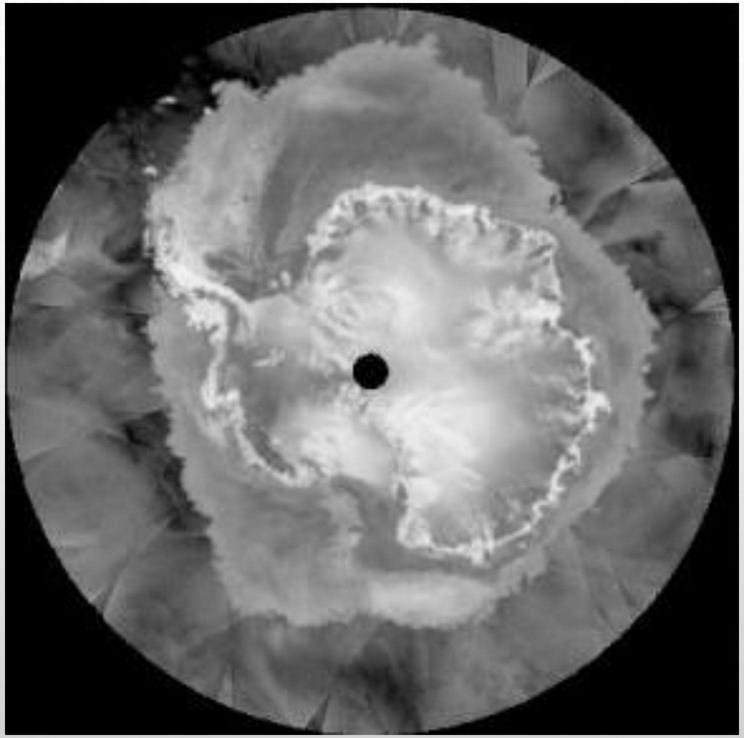
Remote sensing systems

Active and Passive Remote Sensing



AVHRR Thermal Image

http://www.coml.org/edu/tech/count/srs1.htm



QuikSCAT radar image

http://nsidc.org/seaice/study/active_remote_sensing.html

A **thermal image** taken by a geostationary satellite positioned over the western Atlantic; warmer water moved along by the Gulf Stream current is denoted in reddish-orange.

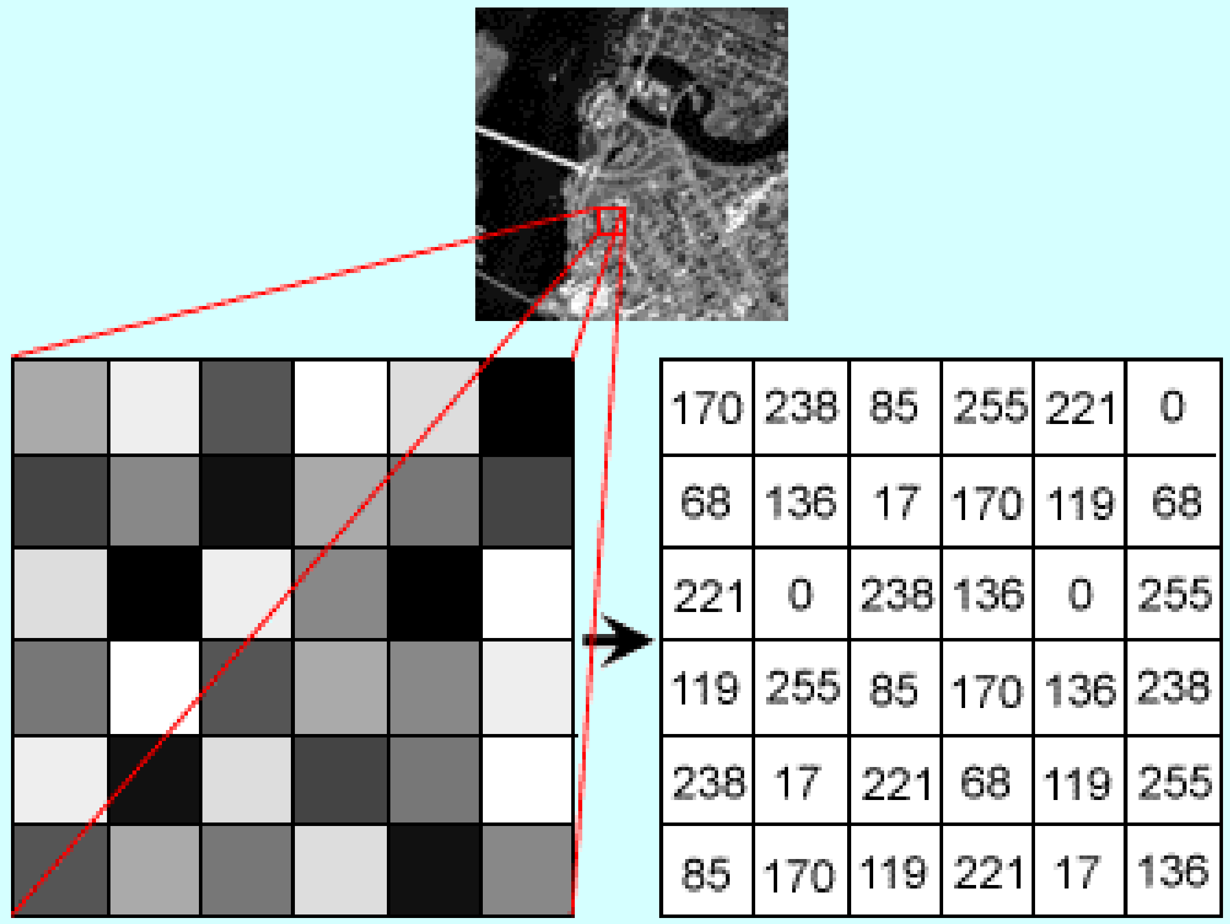
Infrared imaging: Method of remote sensing in which optical sensors produce visible representations of infrared rays or radiated heat from the observed objects and the temperature variations are represented by different colors in the image.

Scatterometer image of Antarctica, 19 July 2003, from the QuikSCAT (quick scattterometer) satellite. This composite image is centered over the South Pole. Antarctica stands out with a white outline. Surrounding Antarctica is a large region of sea ice, shown in medium grey. Sea ice typically reflects more of the radar energy emitted by the sensor than the surrounding ocean, so it appears brighter in a scatterometer image. The black hole over the South Pole is a region that the QuikSCAT satellite does not reach. Image courtesy of David Long, Brigham Young University Center for Remote Sensing.

Remote sensing platforms

- Ground based
- Aircraft
- Space shuttle
- Satellite

Pixels


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

Satellite Remote Sensing

- Resolutions
  - Spatial: Area visible to the sensor
  - Spectral: Ability of a sensor to define fine wavelength intervals
  - Temporal: Amount of time before site revisited
  - Radiometric: Ability to discriminate very slight differences in energy
- Scanner types
  - Along-track
  - Across-track

Four fundamental properties for design

- Image depends on the wavelength response of the sensing instrument (radiometric and spectral resolution) and the emission or reflection spectra of the target (the signal).

  - Radiometric resolution

  - Spectral resolution

- Image depends on the size of objects (spatial resolution) that can be discerned

  - Spatial resolution

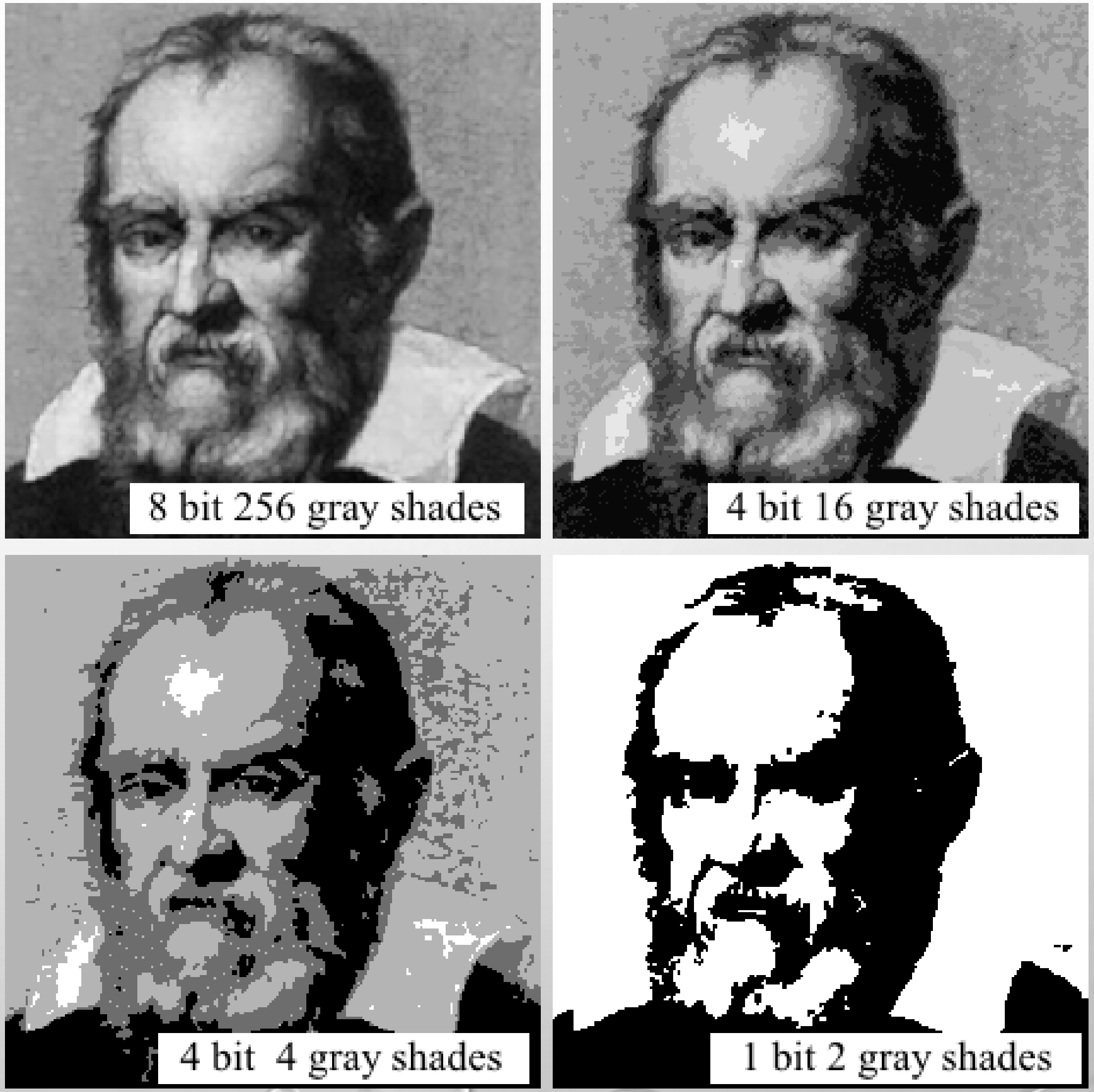
- Knowledge of the changes in the target depends on how often (temporal resolution) the target is observed

  - Temporal resolution

Radiometric resolution

- Number of shades or brightness levels at a given wavelength

- Smallest change in intensity level that can be detected by the sensing system



Spatial Resolution

40 x 40

80 x 80

320 x 320

Coarser resolution satellite sensors used

<u>LANDSAT Thematic Mapper</u>

Good for regional coverage

30m MS resolution

15 m panchromatic resolution

Most Common Use:

Land Cover/Land Use Mapping

<u>MODIS</u>

36 spectral bands

Most Common Uses:

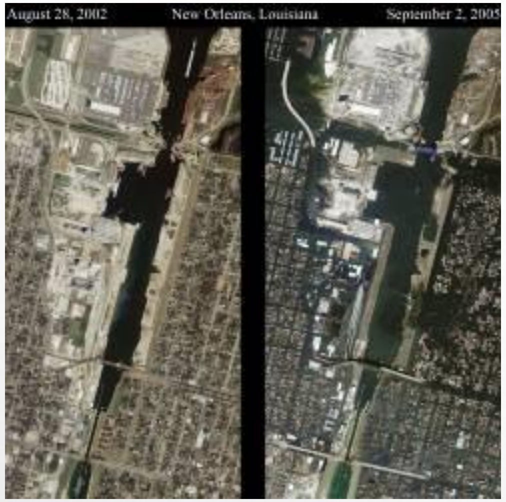
Cloud/Aerosol Properties

Ocean Color

Atmospheric Water Vapor

Sea/Atmospheric Temperatures

Higher Resolution Satellite Sensors Used



<u>IKONOS</u>

4 m visible/infrared resolution

1 m panchromatic resolution

<u>Quickbird</u>

2.5 m multispectral resolution

61 cm (~2 ft.) panchromatic resolution

<u>MOST COMMON USES FOR HIGH RESOLUTION:</u>

Accurate Base Maps

Infrastructure Mapping

Disaster Assessment (Smaller Scale)

Spectral response differences

TM Band 3 (Red)

TM Band 4 (NIR)

Spectral resolution

- Example: Black and white image

  - Single sensing device

  - Intensity is sum of intensity of all visible wavelengths

0.4 µm 0.7 µm

Black & White Images

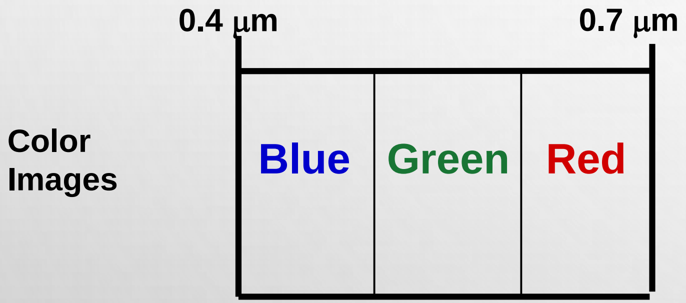
Blue + Green + Red

Can you tell the color of the platform top?

How about her sash?

Spectral resolution

- Example: Color image
  - Color images need least three sensing devices, e.g., red, green, and blue; RGB

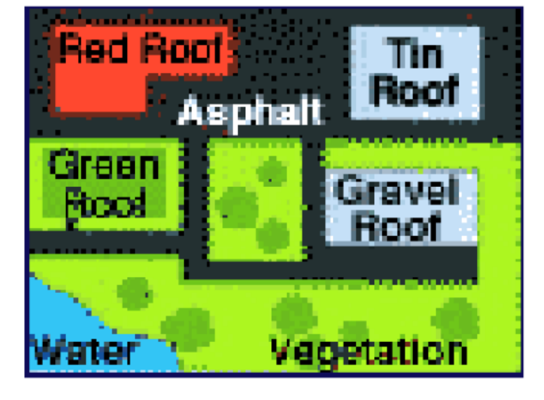


Using increased spectral resolution (three sensing wavelengths) adds information

In this case by “sensing” RGB can combine to get full color rendition

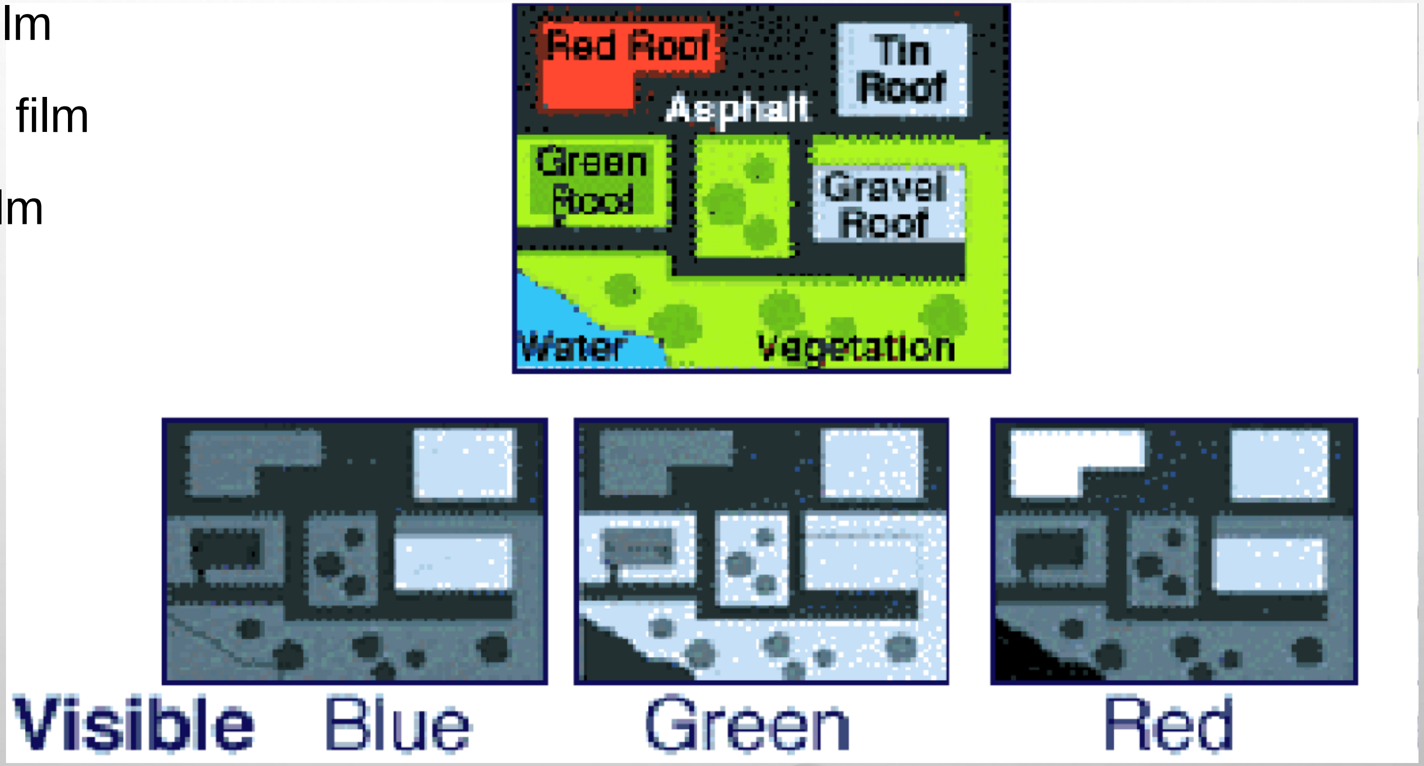
Spectral resolution

- Example
  - What do you believe the image would look like if you used a blue only sensitive film?
  - What do you believe the image would look like if you used a green only sensitive film?
  - What do you believe the image would look like if you used a red only sensitive film?



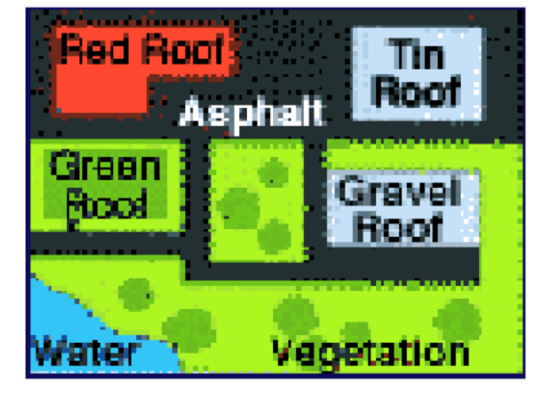
Spectral resolution

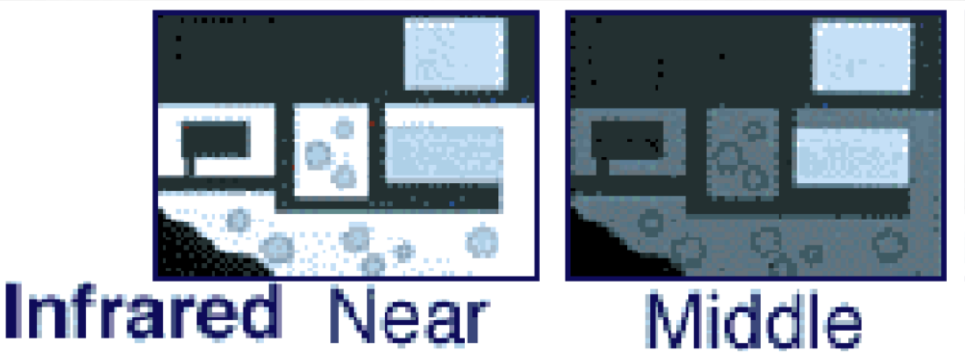
- Example
  - Blue only sensitive film
  - Green only sensitive film
  - Red only sensitive film



Spectral resolution

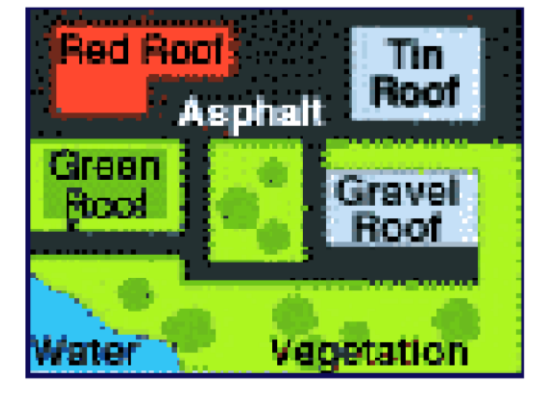
- Example
  - What do you believe the image would look like if you used near and middle infrared sensitive film?





Spectral resolution

- Example
  - What do you believe the image would look like if you used a thermal infrared sensitive film?

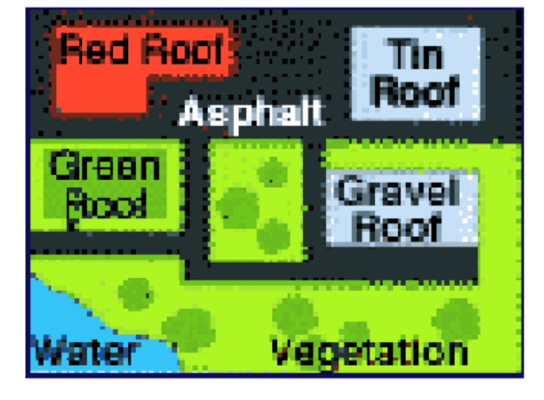


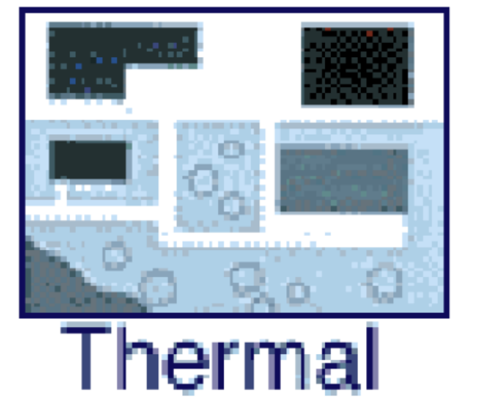
Blinded in the darkness, he extended his arms, felt around for obstacles, both to avoid and to hide behind. The men wearing infrared monocular night-vision units, the lenses strapped against their eyes by means of a head harness and helmet mount, were doubtless also carrying handguns. The others had rifles fitted with advanced infrared weapon sights. Both allowed the user to see in total darkness by detecting the differentials in thermal patterns given off by animate and inanimate objects.

Ludlum, Robert, 2000: The Prometheus Deception, p. 96.

Spectral resolution

- Example
  - What do you believe the image would look like if you used a thermal infrared sensitive film?

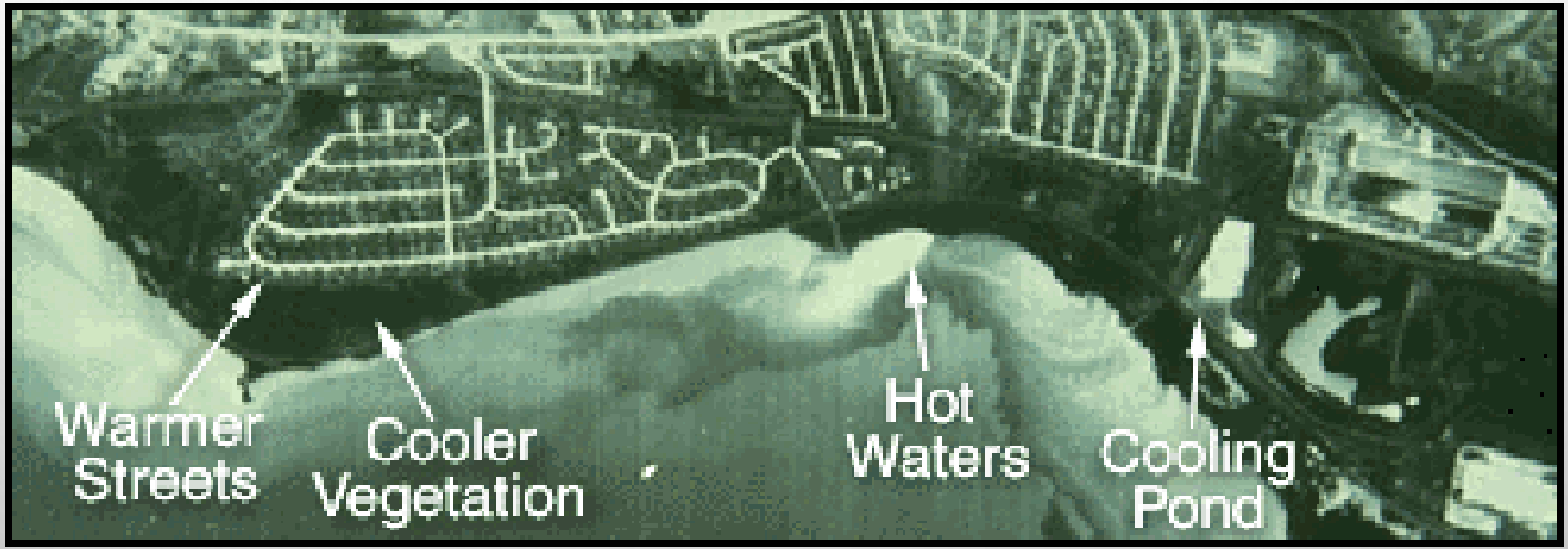




Heat - energy transfer

- Example - Thermal infrared view

  Note warmer objects are brighter



Spectral resolution

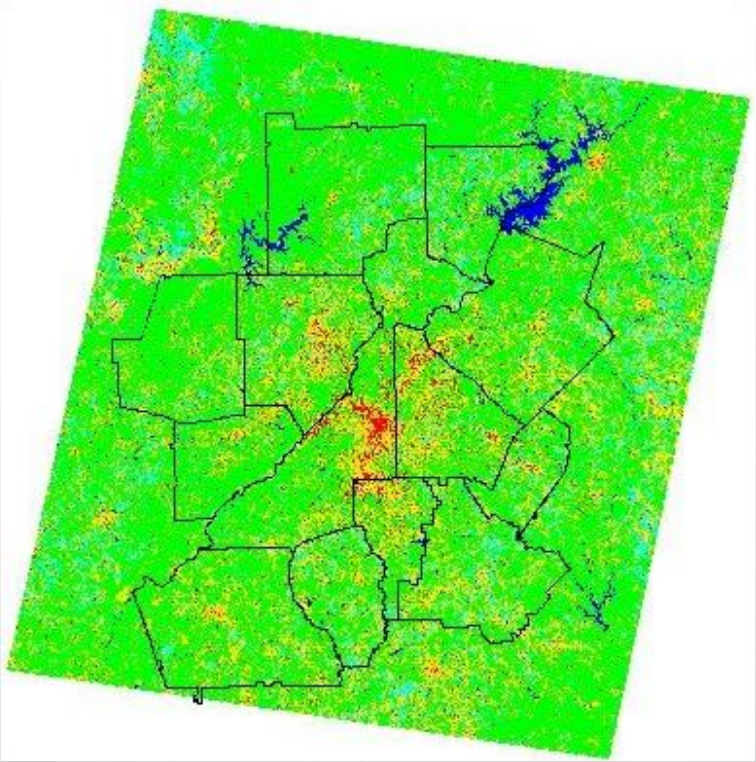
Example of sampling wavelengths

Band	Wavelength	Description	Characteristics and Notes
1	.45-.52	Visible Blue	Maximum water penetration; vegetation vs soil; deciduos vs. conifers
2	.52-.60	Visible Green	Plant vigor (reflectance peak for plants)
3	.63-.69	Visible Red	Chloropyll absorption; vegetation discrimination
4	.76-.90	Near Infrared	Reflected IR; biomass and shoreline mapping
5	1.55-1.75	Middle Infrared	Reflected IR; moisture content of soil and vegetation; cloud/smoke penetration; vegetation mapping
7	2.08-2.35	Middle Infrared	Reflected IR; mineral mapping
6	10.4-12.5	Thermal Infrared	Thermal IR; soil moisture; thermal mapping

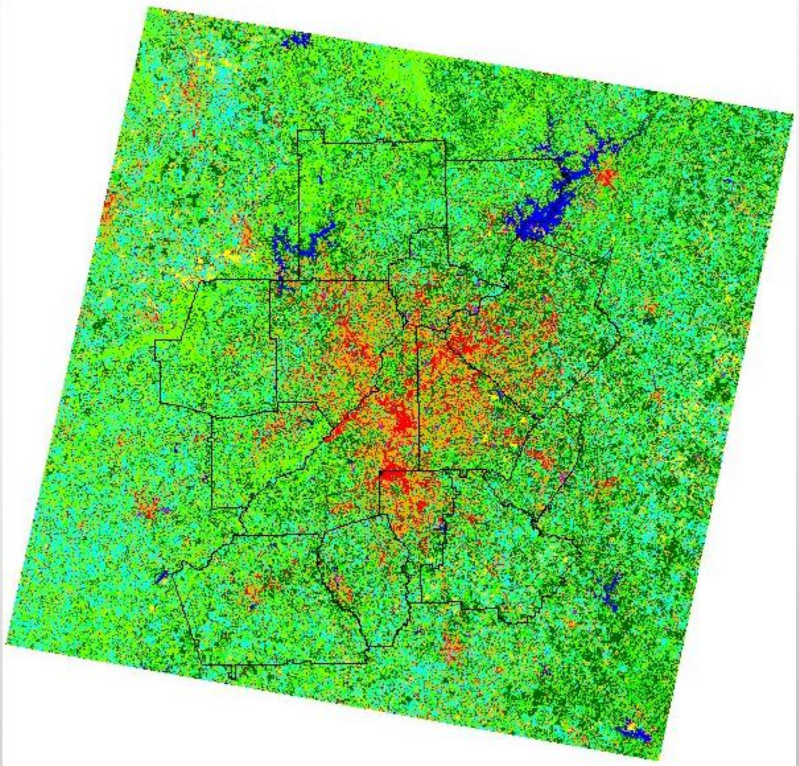
Application of Temporal Data: Urban Sprawl

Atlanta, GA

1973



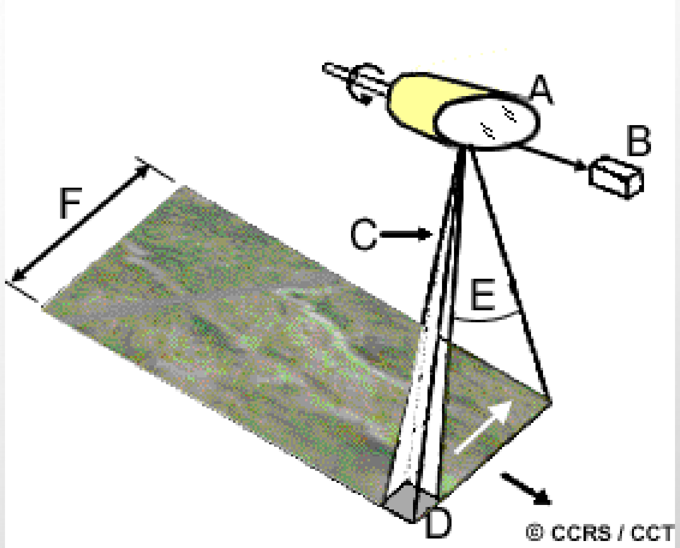
1987



Scanner types

Across-track scanning

- Scan the Earth in a series of lines
  - Lines perpendicular to sensor motion
  - Each line is scanned from one side of the sensor to the other, using a **rotating mirror (A)**.
- Internal **detectors (B)** detect & measure energy for each spectral band, convert to digital data
- **IFOV or Instantaneous Field of View (C)** of the sensor and the altitude of the platform determine the **ground resolution cell viewed (D)**, and thus the spatial resolution.
- The **angular field of view (E)** is the sweep of the mirror, measured in degrees, used to record a scan line, and determines the width of the imaged **swath (F)**.

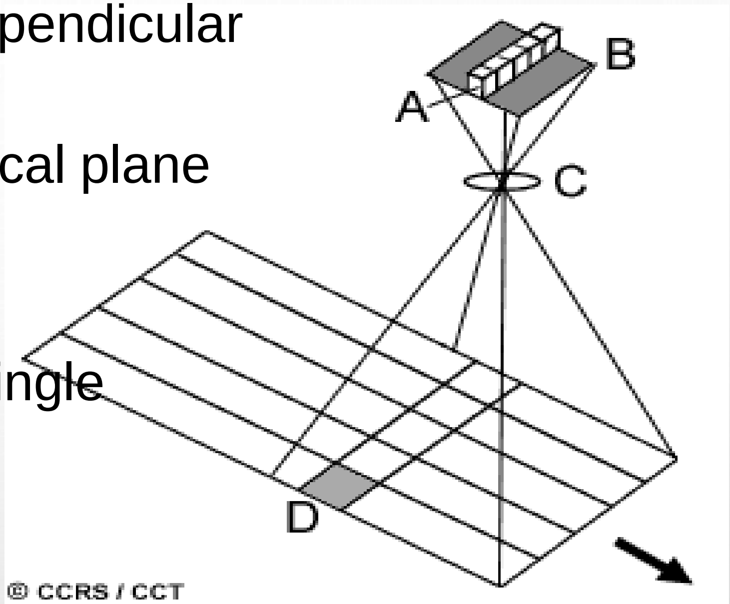


http://ccrs.nrcan.gc.ca/resource/tutor/fundam/chapter2/08_e.php

Scanner types

Along-track scanning

- Uses forward motion to record successive scan lines perpendicular to the flight direction
  - **Linear array of detectors** (A) used; located at the focal plane of the image (B) formed by lens systems (C)
    - Separate array for each spectral band
  - Each individual detector measures the energy for a single ground resolution cell (D)
    - May be several thousand detectors
    - Each is a CCD
    - Energy detected and converted to digital data
  - “Pushed" along in the flight track direction (i.e. along track).
  - **“Pushbroom scanners”**

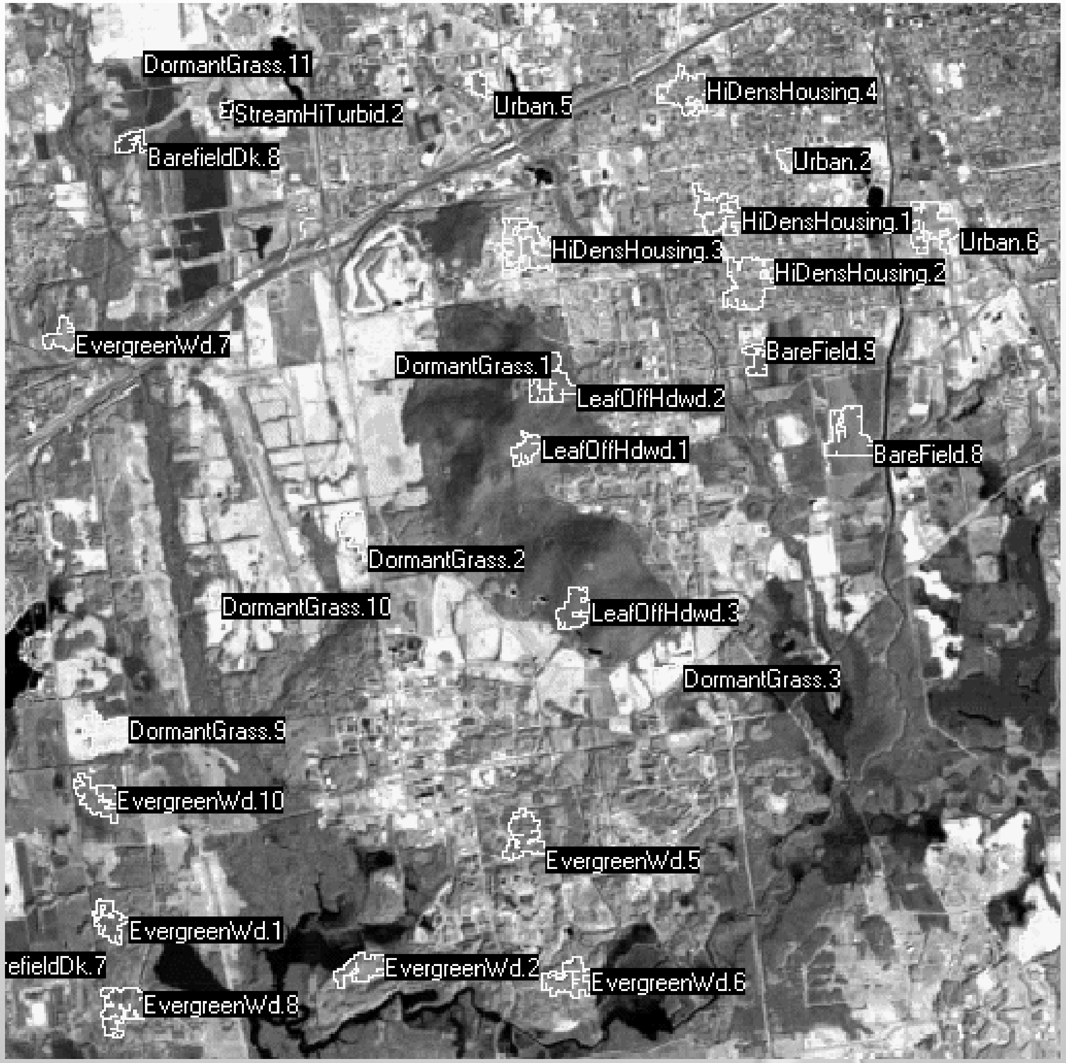


Along-track scanners also use the forward motion of the platform to record successive scan lines and build up a two-dimensional image, perpendicular to the flight direction. However, instead of a scanning mirror, they use a linear array of detectors (A) located at the focal plane of the image (B) formed by lens systems (C), which are "pushed" along in the flight track direction (i.e. along track). These systems are also referred to as **pushbroom scanners**, as the motion of the detector array is analogous to the bristles of a broom being pushed along a floor. Each individual detector measures the energy for a single ground resolution cell (D) and thus the size and IFOV of the detectors determines the spatial resolution of the system. A separate linear array is required to measure each spectral band or channel. For each scan line, the energy detected by each detector of each linear array is sampled electronically and digitally recorded.

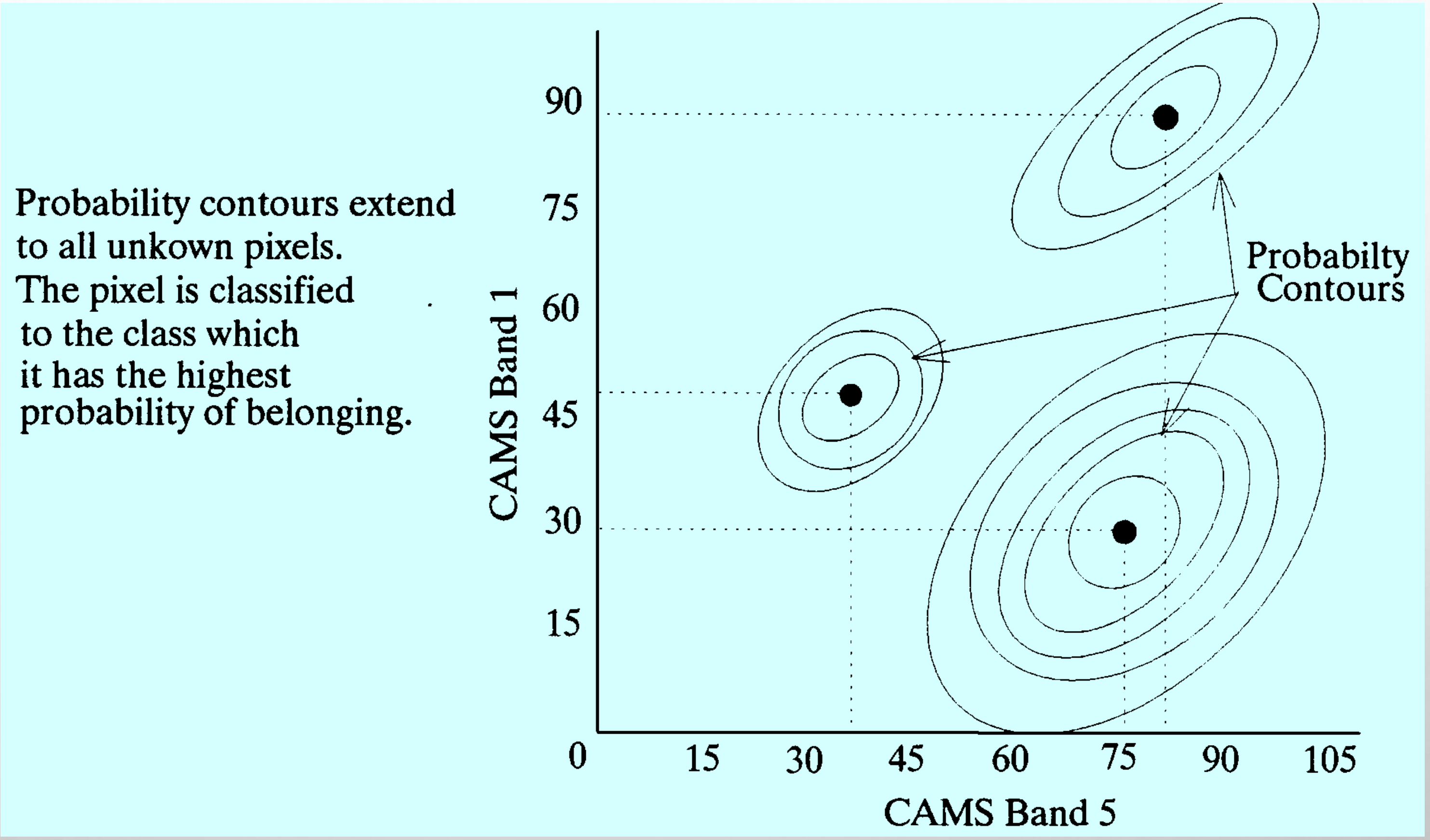
Along Track mode does not have a mirror looking off at varying angles. Instead there is a line of small sensitive detectors stacked side by side, each having some tiny dimension on its plate surface; these may number several thousand. Each detector is a charge-coupled device (CCD), as described in more detail below on this page. In this mode, the pixels that will eventually make up the image correspond to these individual detectors in the line array. As the platform advances along the track, at any given moment radiation from each ground cell area along the ground line is received simultaneously at the sensor and the collection of photons from every cell impinges in the proper geometric relation to its ground position on every individual detector in the linear array equivalent to that position. The signal is removed from each detector in succession from the array in a very short time (milliseconds), the detectors are reset to a null state, and are then exposed to new radiation from the next line on the ground that has been reached by the sensor's forward motion. This type of scanning is also referred to as pushbroom scanning (from the mental image of cleaning a floor with a wide broom through successive forward sweeps). As signal sampling improves, the possibility of sets of linear arrays, leading to area arrays, all being sampled at once will increase the equivalent area of ground coverage.

Digital Image Processing

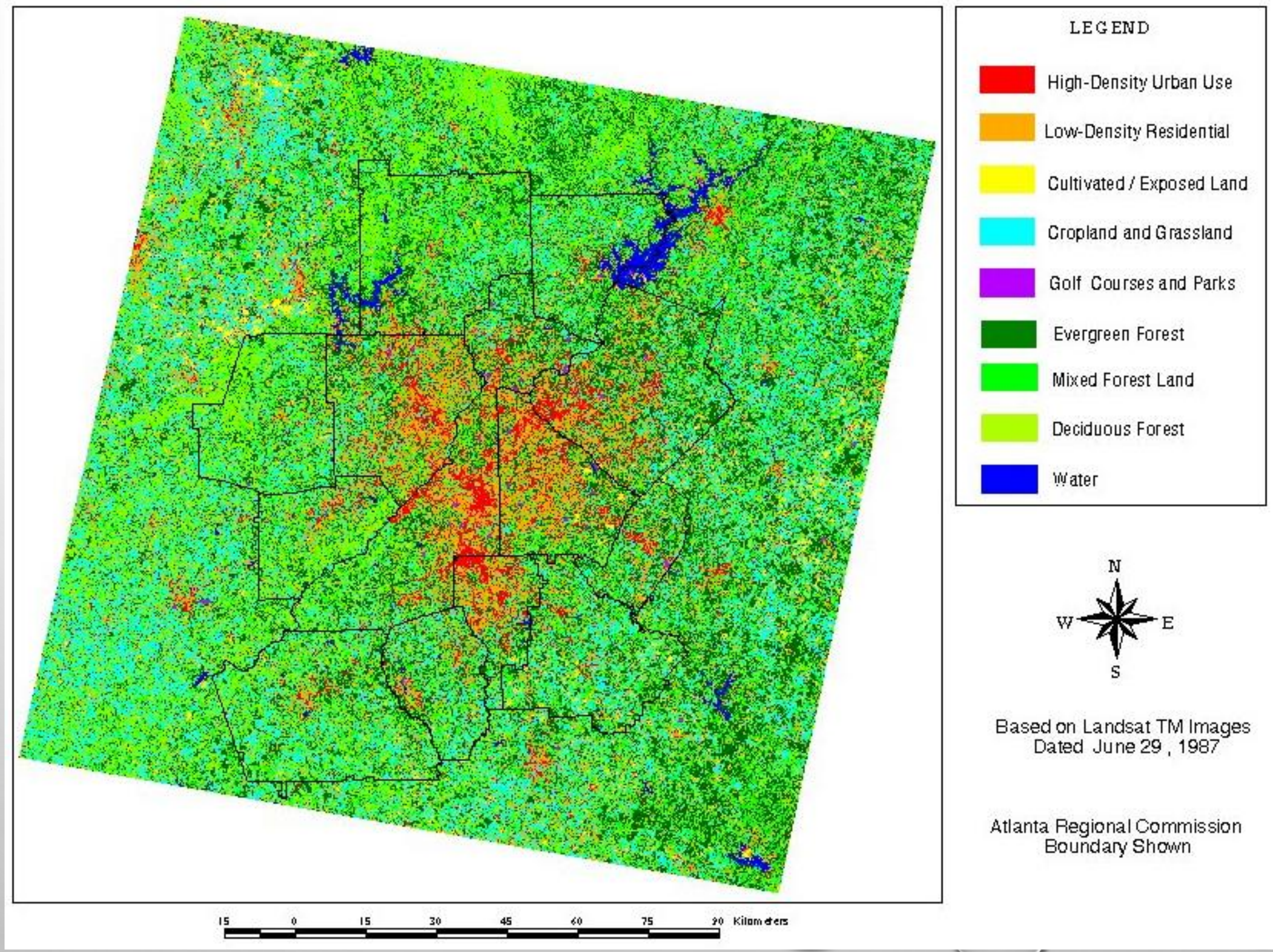
CLASSIFICATİON - SUPERVISED TRANING



MAXIMUM LIKELIHOOD



Classification



Applications of Remote Sensing

- Images serve as base maps
- Observe or measure properties or conditions of the land, oceans, and atmosphere
- Map spatial distribution of “features”
- Record spatial changes

Satellite Images

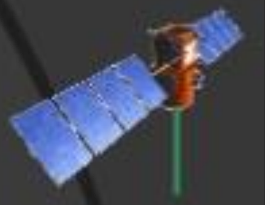
Advantages

- Covers large areas
- Cost effective
- Time efficient
- Multi-temporal
- Multi-sensor
- Multi-spectral
- Overcomes inaccessibility
- Faster extraction of GIS-ready data

Disadvantages

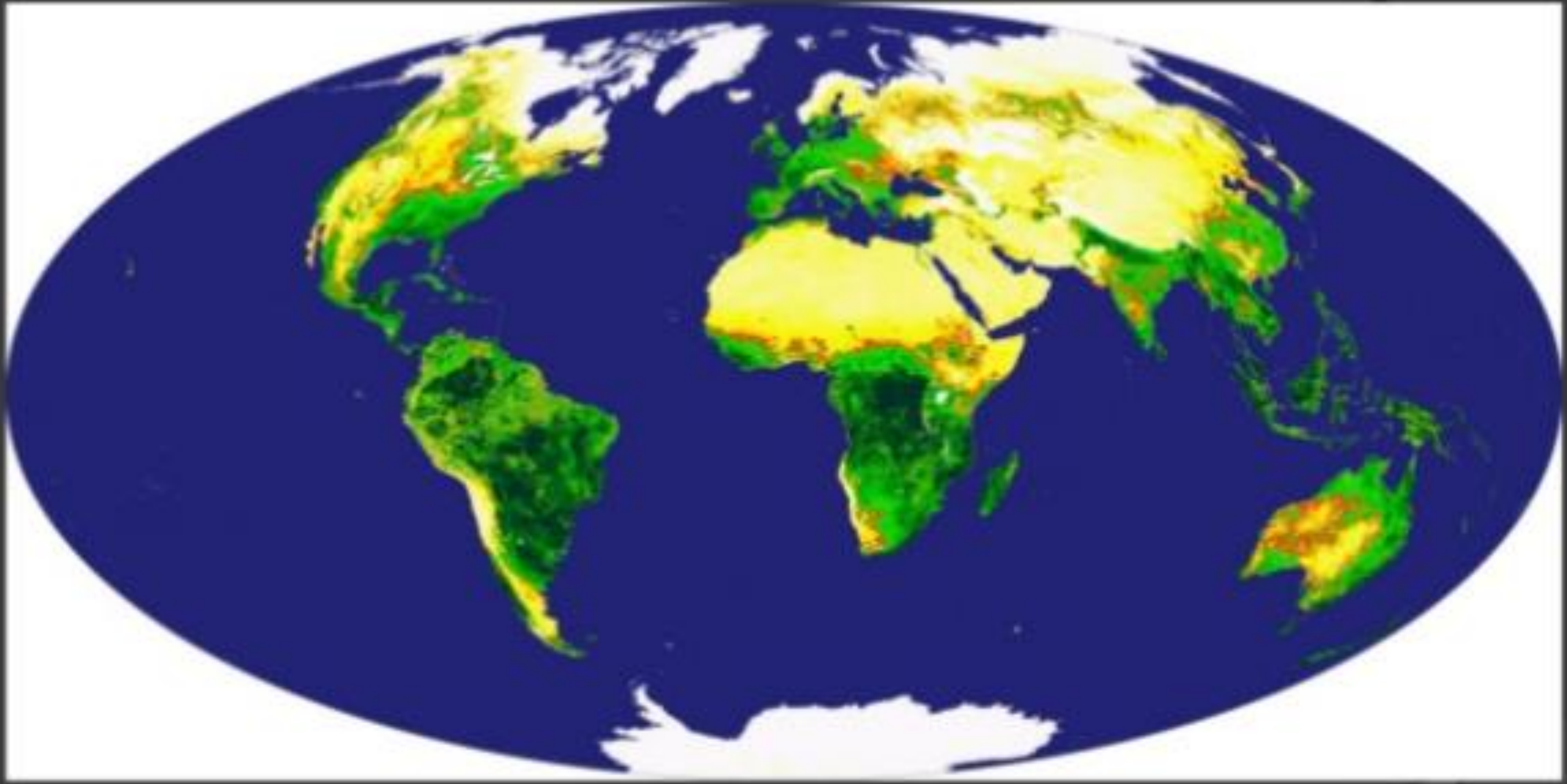
- Needs ground verification
- Doesn't offer details
- Not the best tool for small areas
- Needs expert system to extract data

Why use Satellites to Study the Earth?



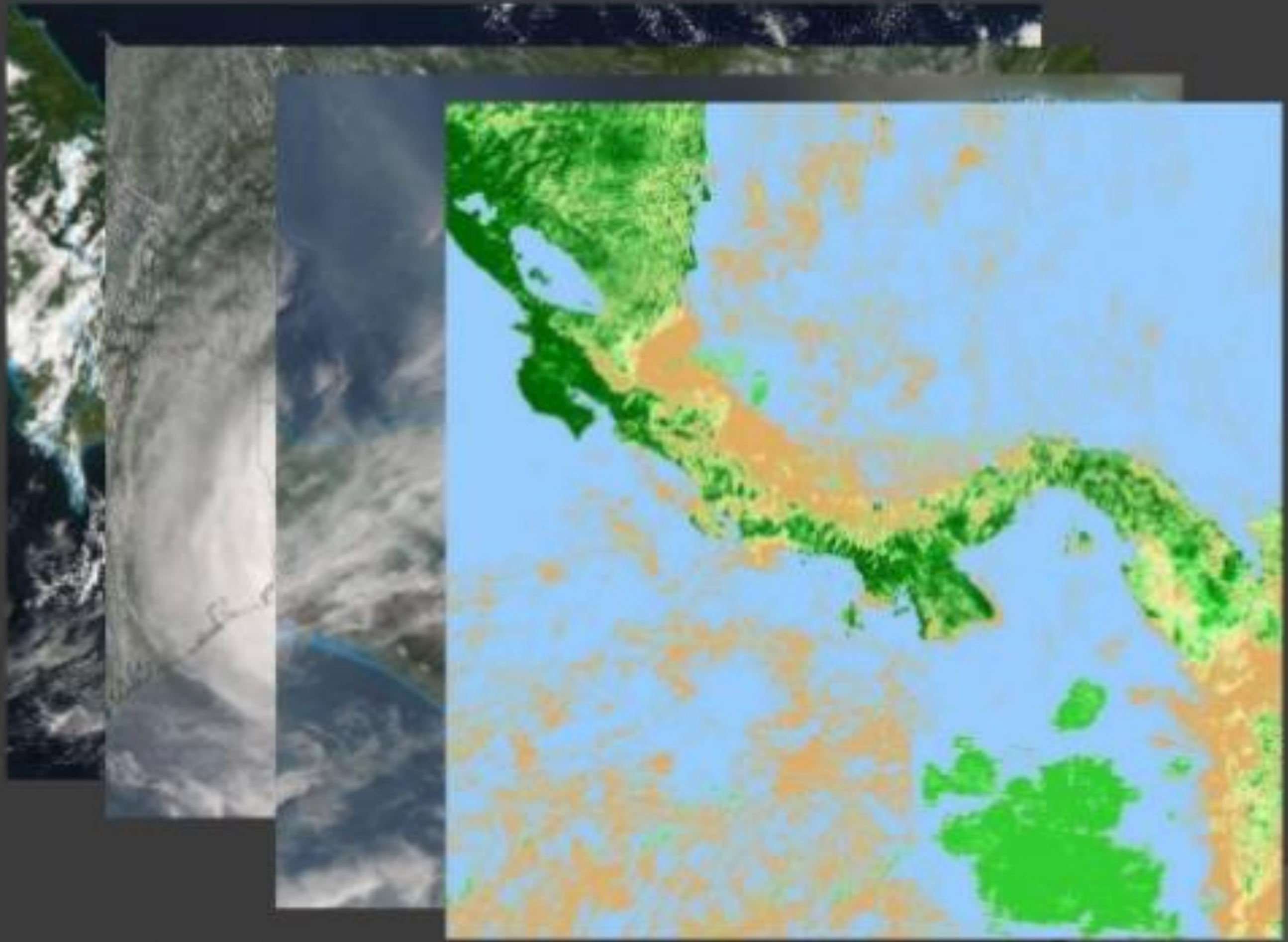
- Consistent, routine, global measurements
- Overview of information on the hemispheric, regional, national, and local scales – the “big picture”
- Provide information in areas where there are no ground-based measurements
- Advance warning of impending environmental events and disasters
- Visual appeal: a picture is worth a thousand words

Satellites Provide a Global View



Satellite data are used for many applications, including monitoring global weather, studying climate change, and observing the environment.

A Picture is Worth a Thousand Words!

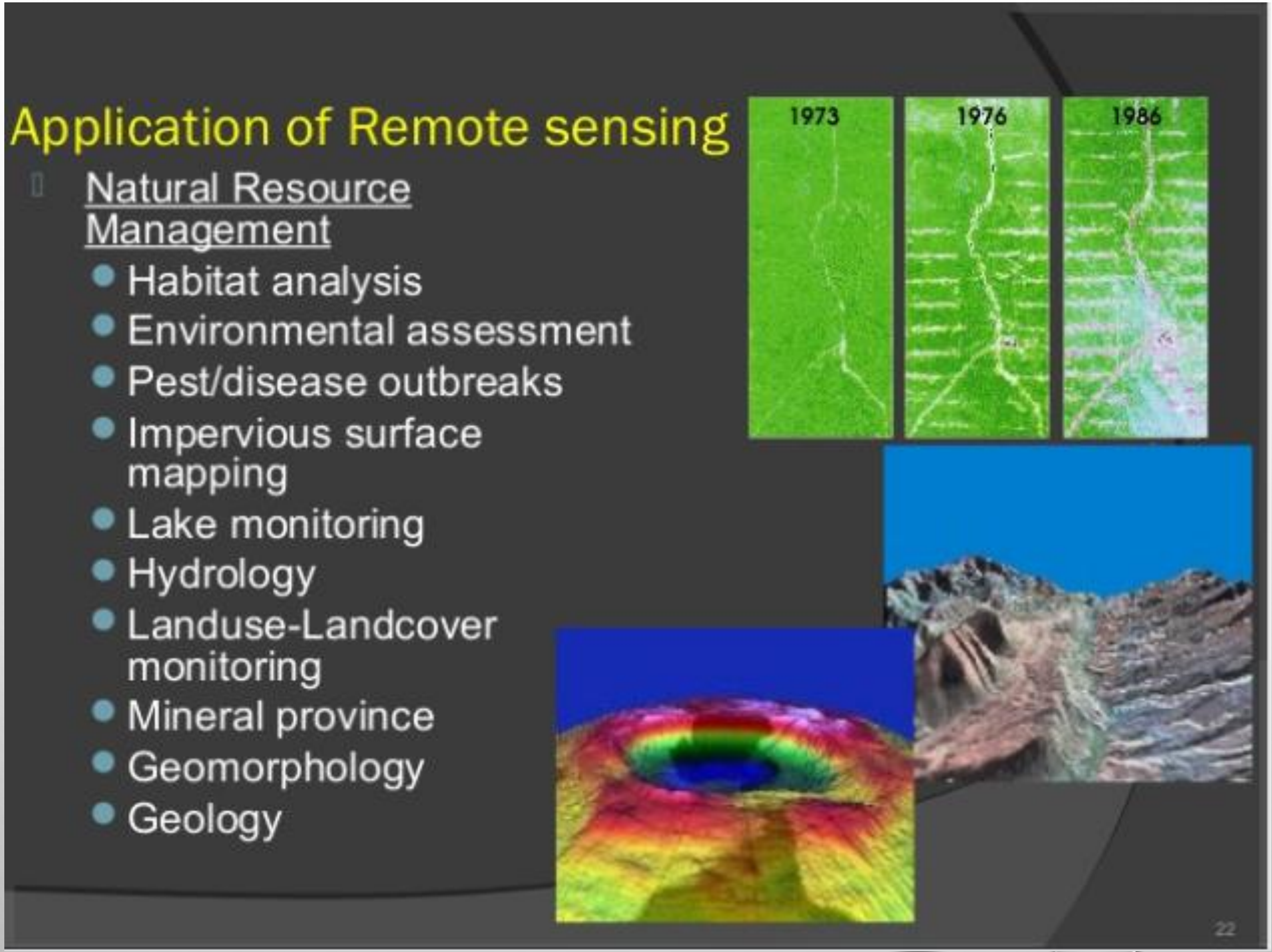


Satellites provide consistent, routine, global coverage of environmental events

Remote sensing basic processes

- Data acquisition (energy propagation, platforms)
- Processing (conversion of energy pattern to images)
- Analysis (quantitative and qualitative analysis)
- Accuracy assessment (radiometric and geometric correction)
- Information distribution to users (hard copy, CCT, CD-ROM, X-BYTE)

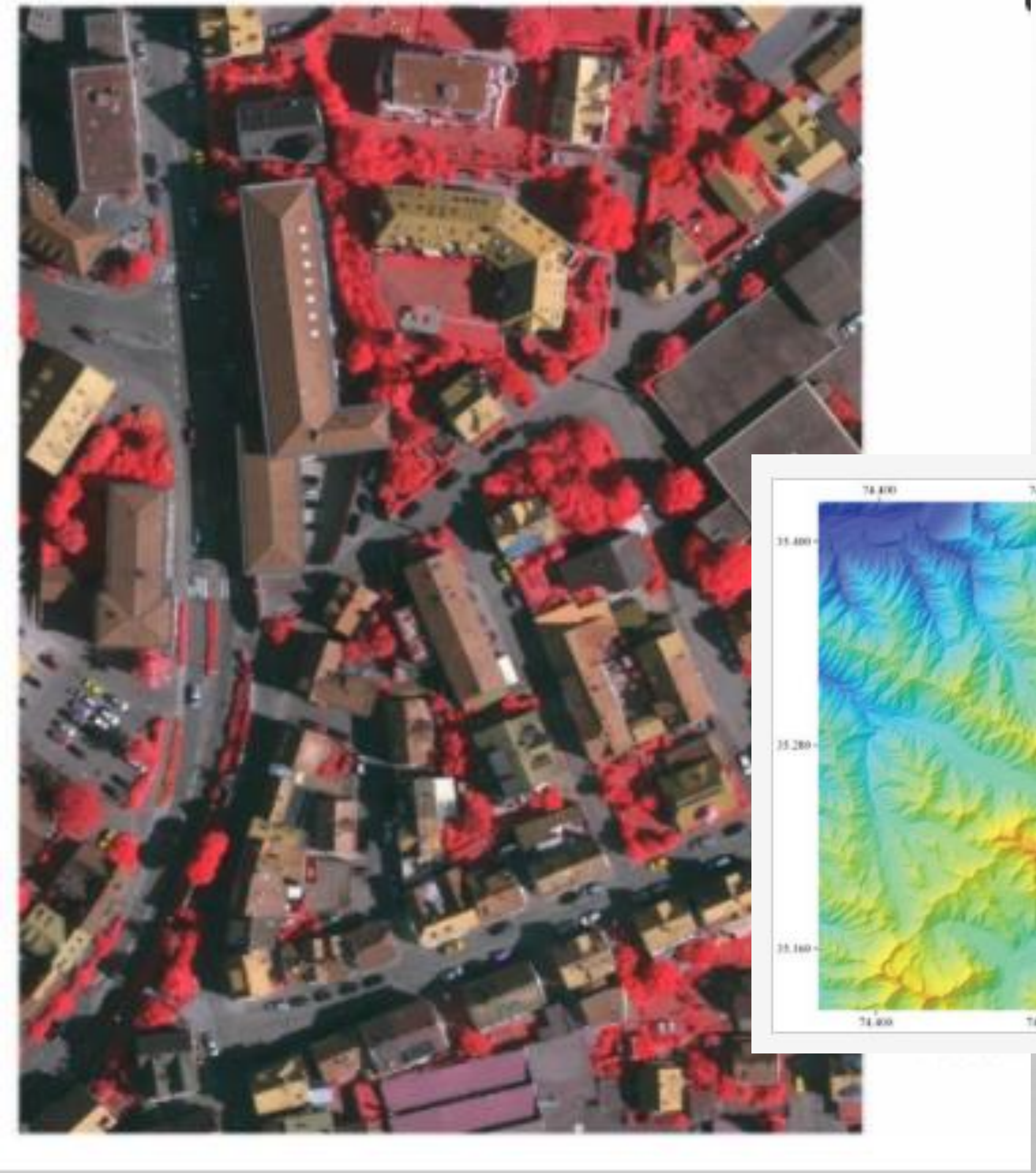
Applications of Remote Sensing



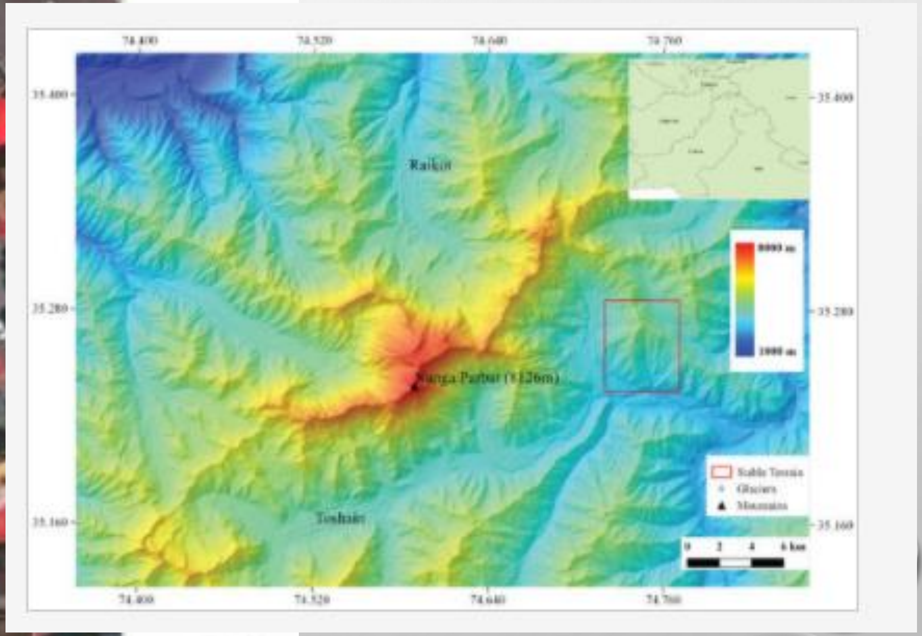
Applications of Remote Sensing

Generating Topographic Map Data

DSM-based ortho-image (false-color).



DEM



Applications of Remote Sensing

Agriculture:

- Crop type classification.
- Crop condition assessment.
- Crop yield estimation.
- Mapping of soil characteristics.
- Soil moisture estimation.

Satellite image : **Source NRSC Hyderabad**

Applications of Remote Sensing

- **Agriculture**
  - Crop health analysis
  - Precision agriculture
  - Compliance mapping
  - Yield estimation
  - Forest application

Applications of Remote Sensing

Geology:

- Mineral exploration.
- Environmental geology.
- Sedimentation mapping and monitoring.
- Geo-hazard mapping.
- Glacier mapping.

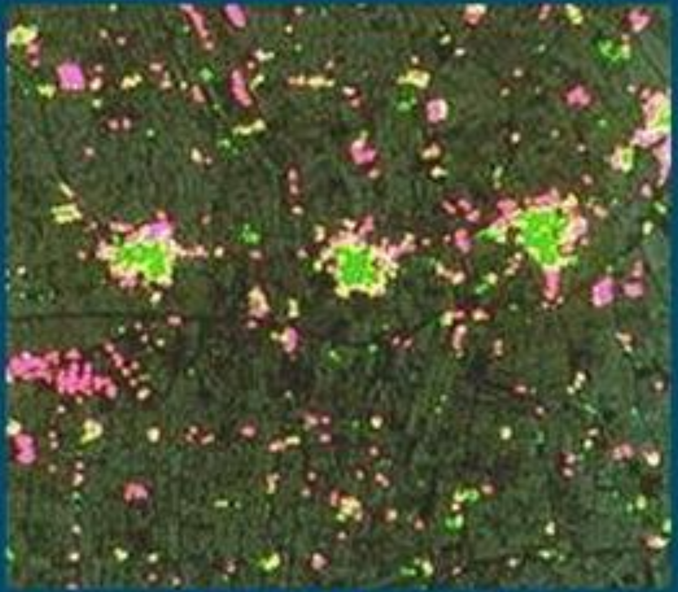
Geological Map
Source NRSC Hyderabad

Applications of Remote Sensing

Applications of Remote Sensing

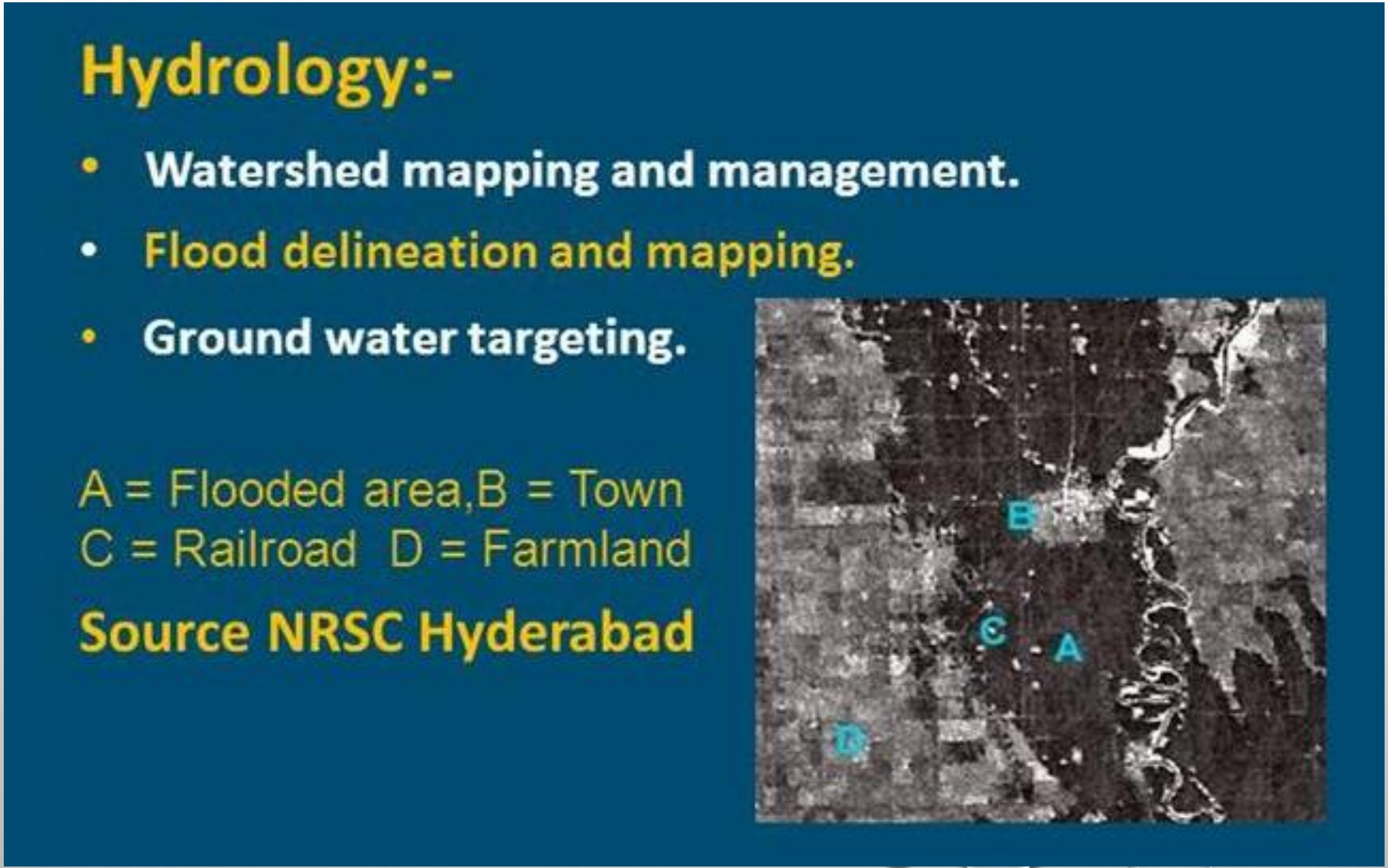
Urban Planning:-

- Land parcel mapping.
- Infrastructure mapping.
- Land use change detection.
- Future urban expansion.
- Natural resource management.
- Wildlife protection.
- Encroachment.



Source NRSC Hyderabad

Applications of Remote Sensing



Applications of Remote Sensing

Forestry And Ecosystem:-

- Forest cover and density mapping.
- Deforestation mapping.
- Forest fire mapping.
- Wetland mapping and monitoring.
- Biomass estimation.
- Species inventory.

(Photograph and a radar image of deforestation along a road)

Source :NRSC Hyderabad

Applications of Remote Sensing

Forestry And Ecosystem:-

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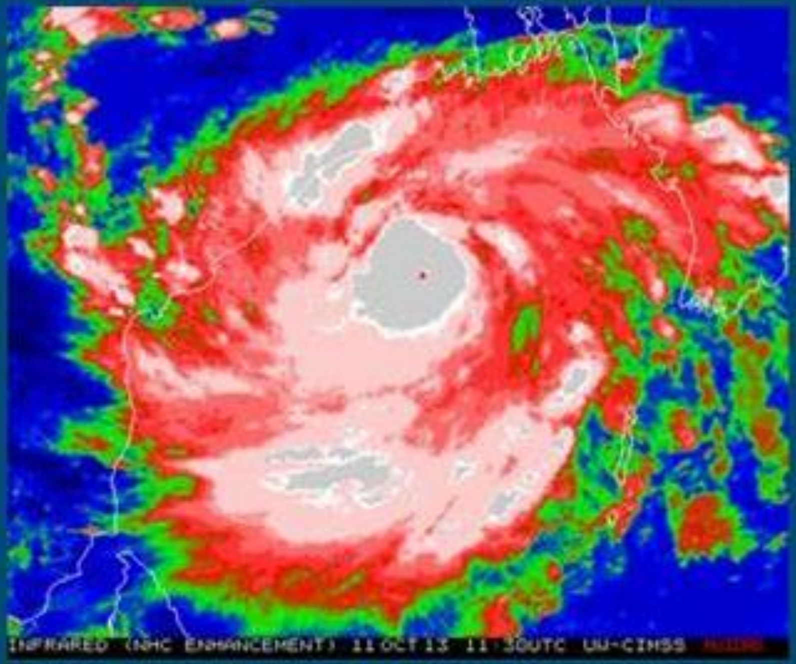
(Photograph and a radar image of deforestation along a road)

Source :NRSC Hyderabad

Applications of Remote Sensing

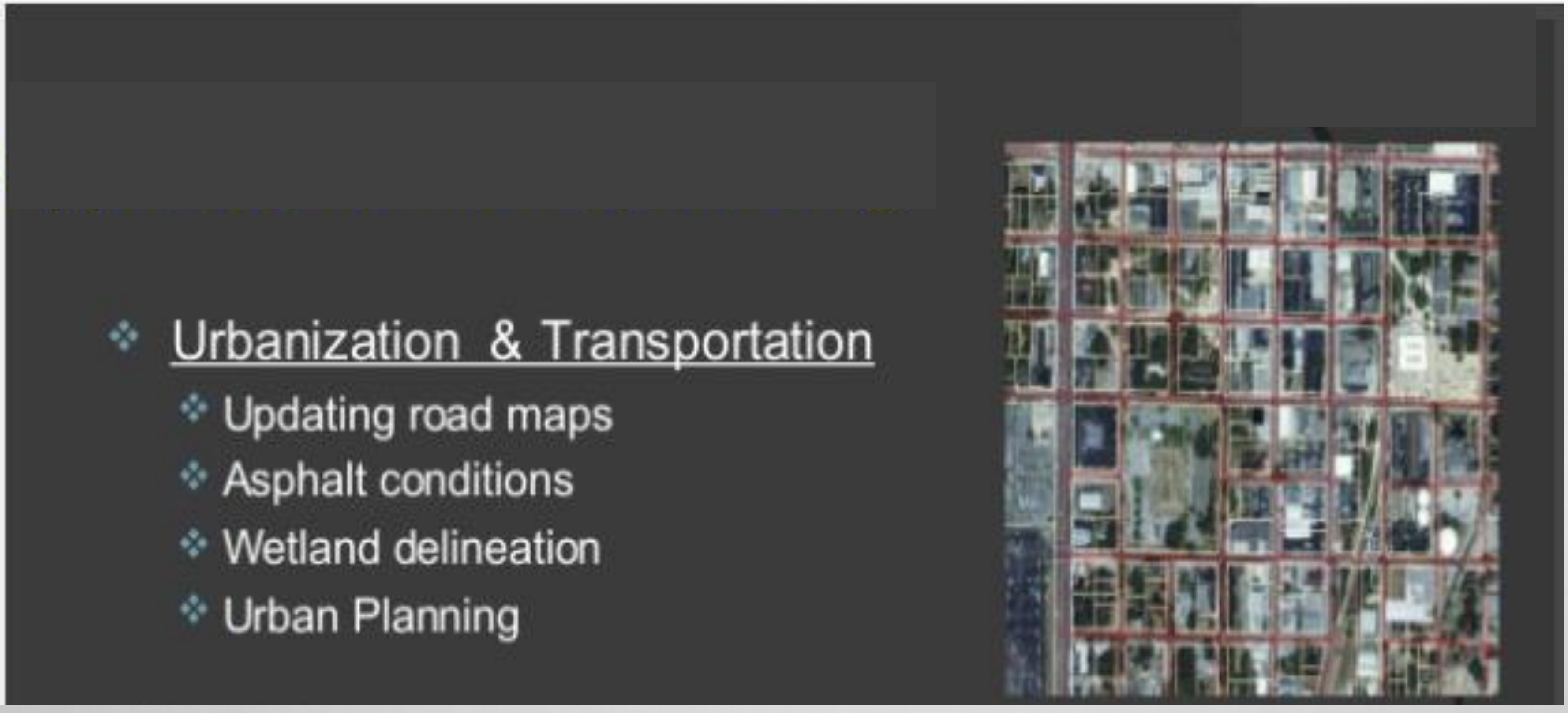
Ocean Applications:

- Storm forecasting.
- Water quality monitoring.
- Aquaculture inventory and monitoring.
- Navigation routing.
- Coastal vegetation mapping.
- Oil spill.

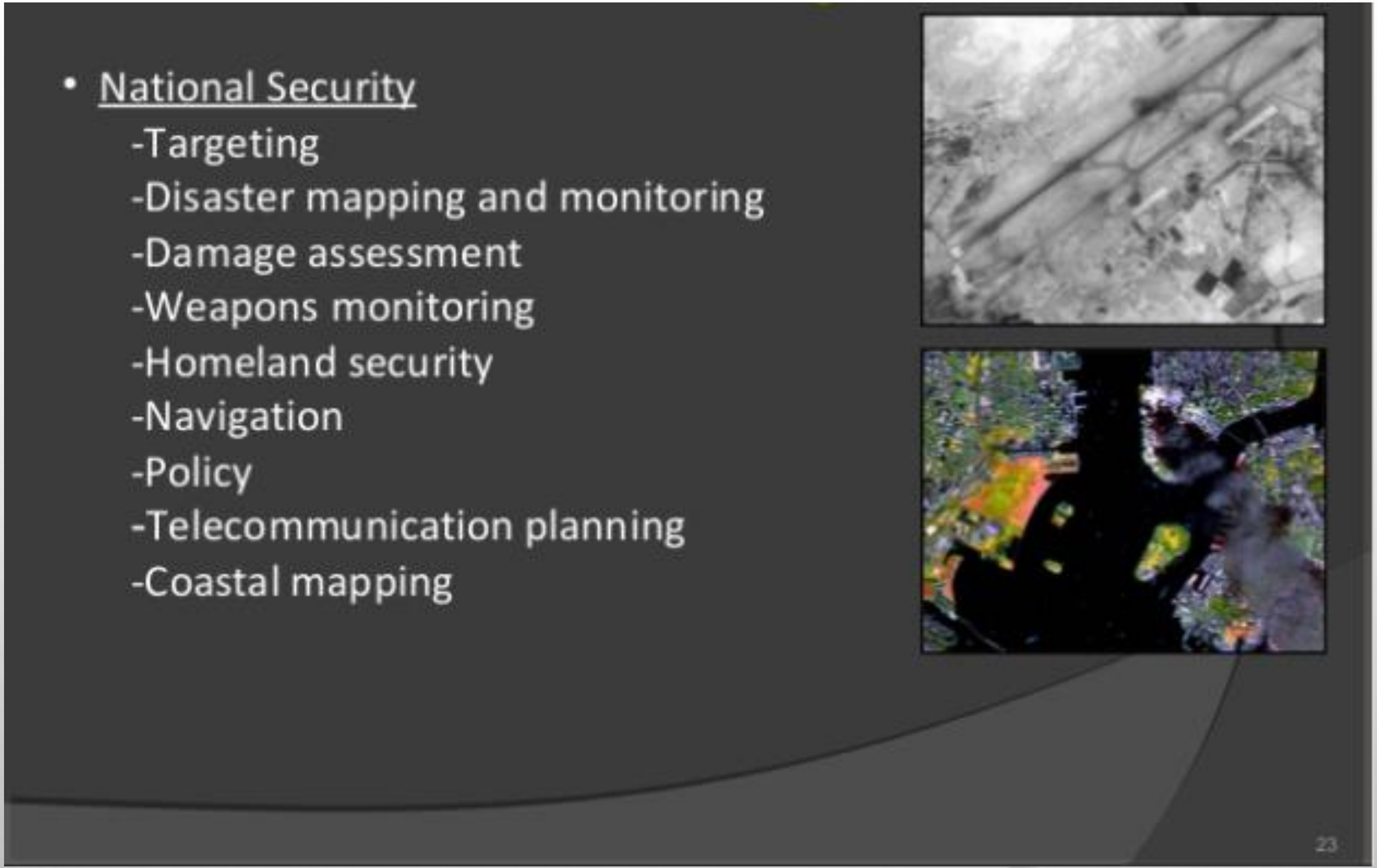


(Super Cyclonic Storm PHAILIN. IR Satellite Image recorded at 11:30UTC on October 11, 2013.
Source: CIMSS/SSEC/WISC

Applications of Remote Sensing



Applications of Remote Sensing



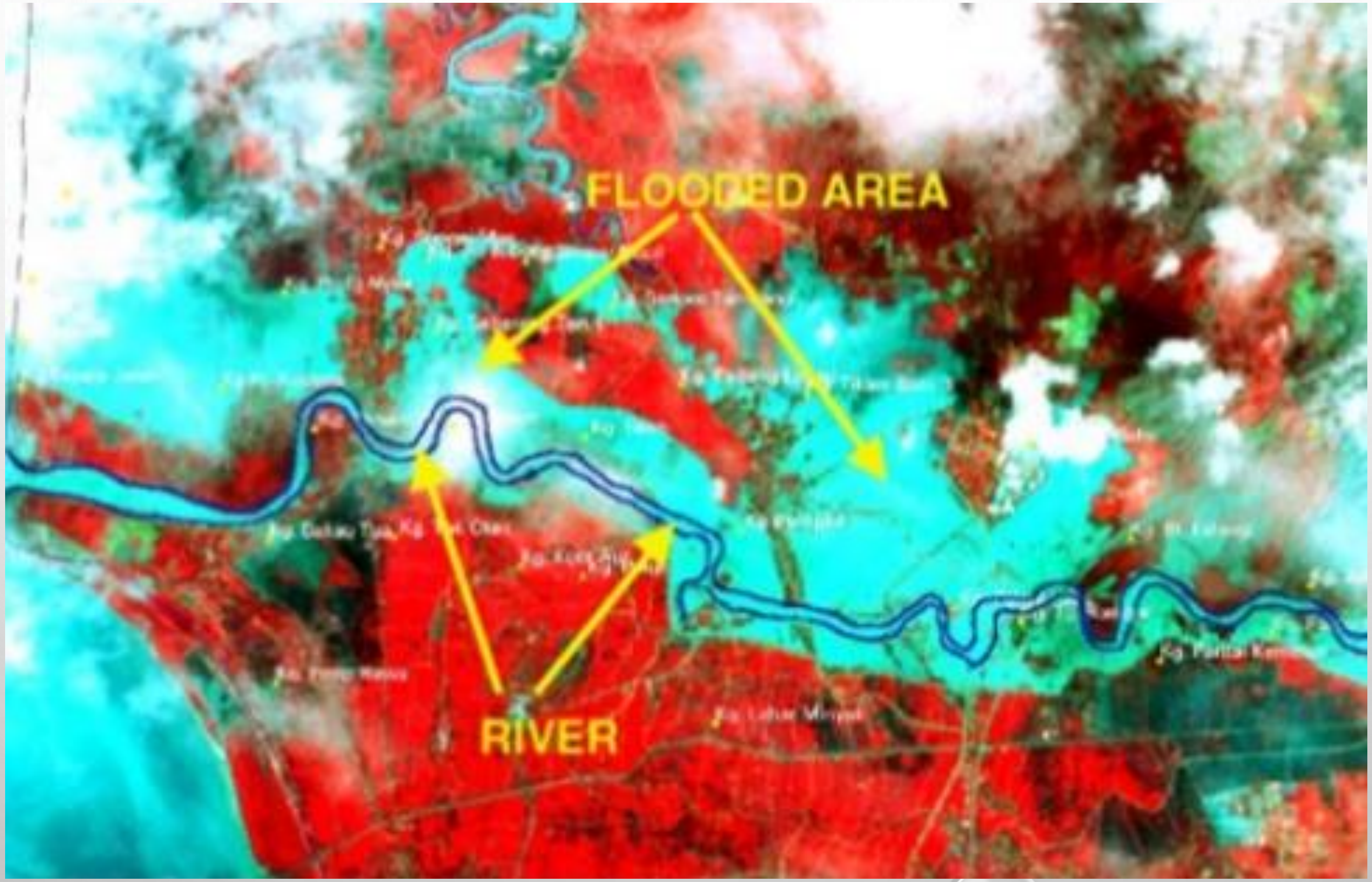
Applications of Remote Sensing

Change Detection - Flooding

Landsat imagery of the 1993 Mississippi flood

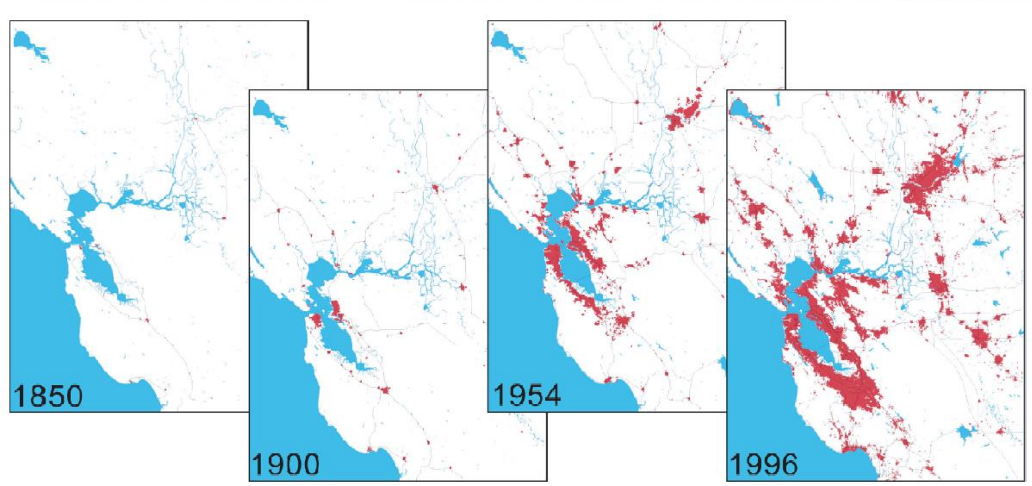
Applications of Remote Sensing

Change Detection - Flooding

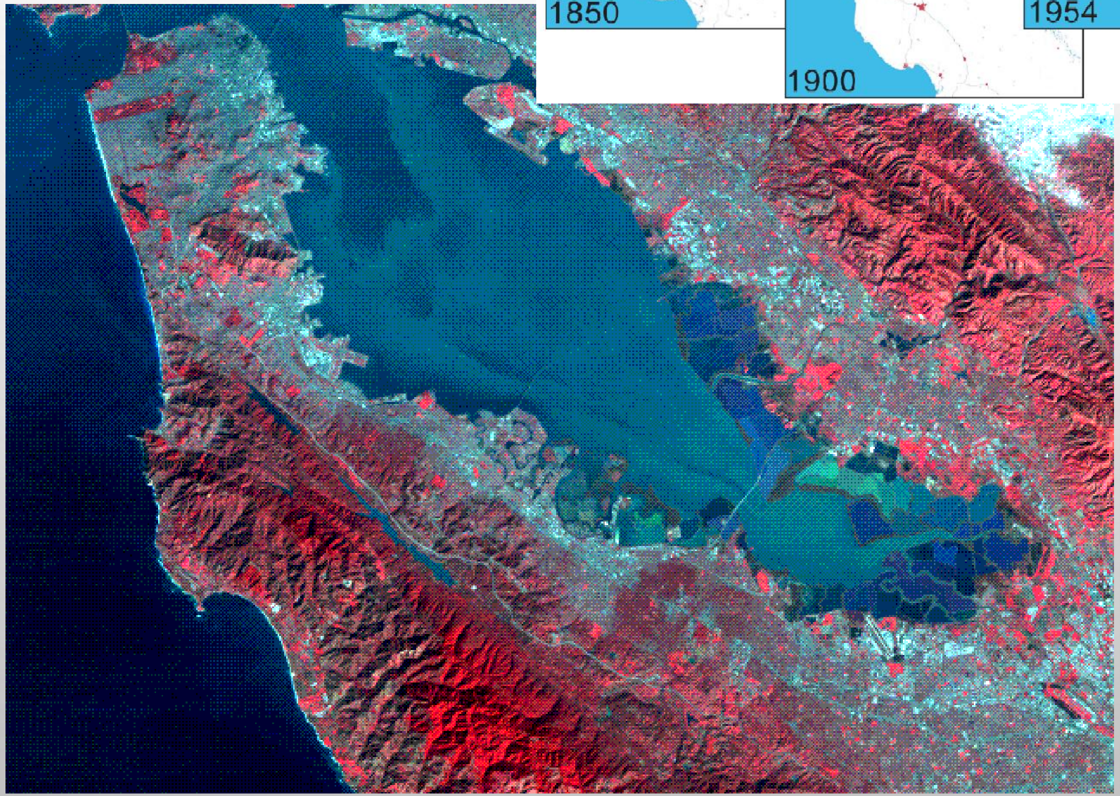


Applications of Remote Sensing

Quantifying Urban Sprawl

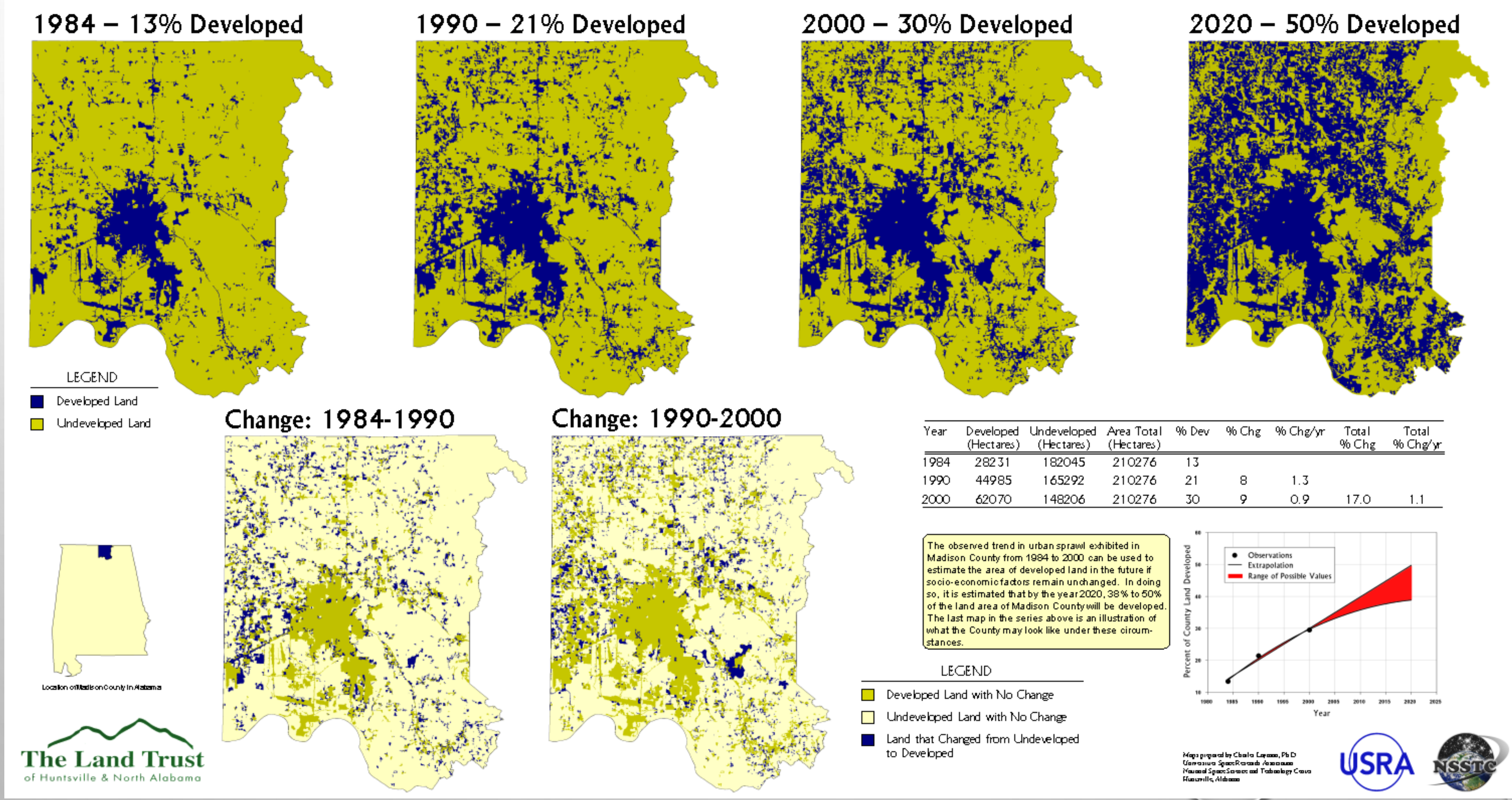


San Francisco Bay



Applications of Remote Sensing

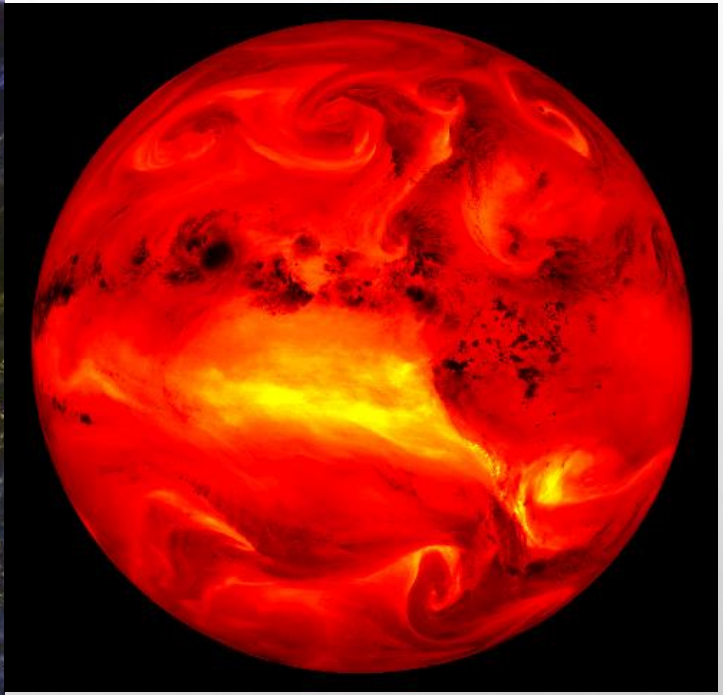
Change Detectıon -Urban Sprawl



Year	Developed (Hectares)	Undeveloped (Hectares)	Area Total (Hectares)	% Dev	% Chg	% Chg/yr	Total % Chg	Total % Chg/yr
1984	28231	182045	210276	13				
1990	44985	165292	210276	21	8	1.3		
2000	62070	148206	210276	30	9	0.9	17.0	1.1

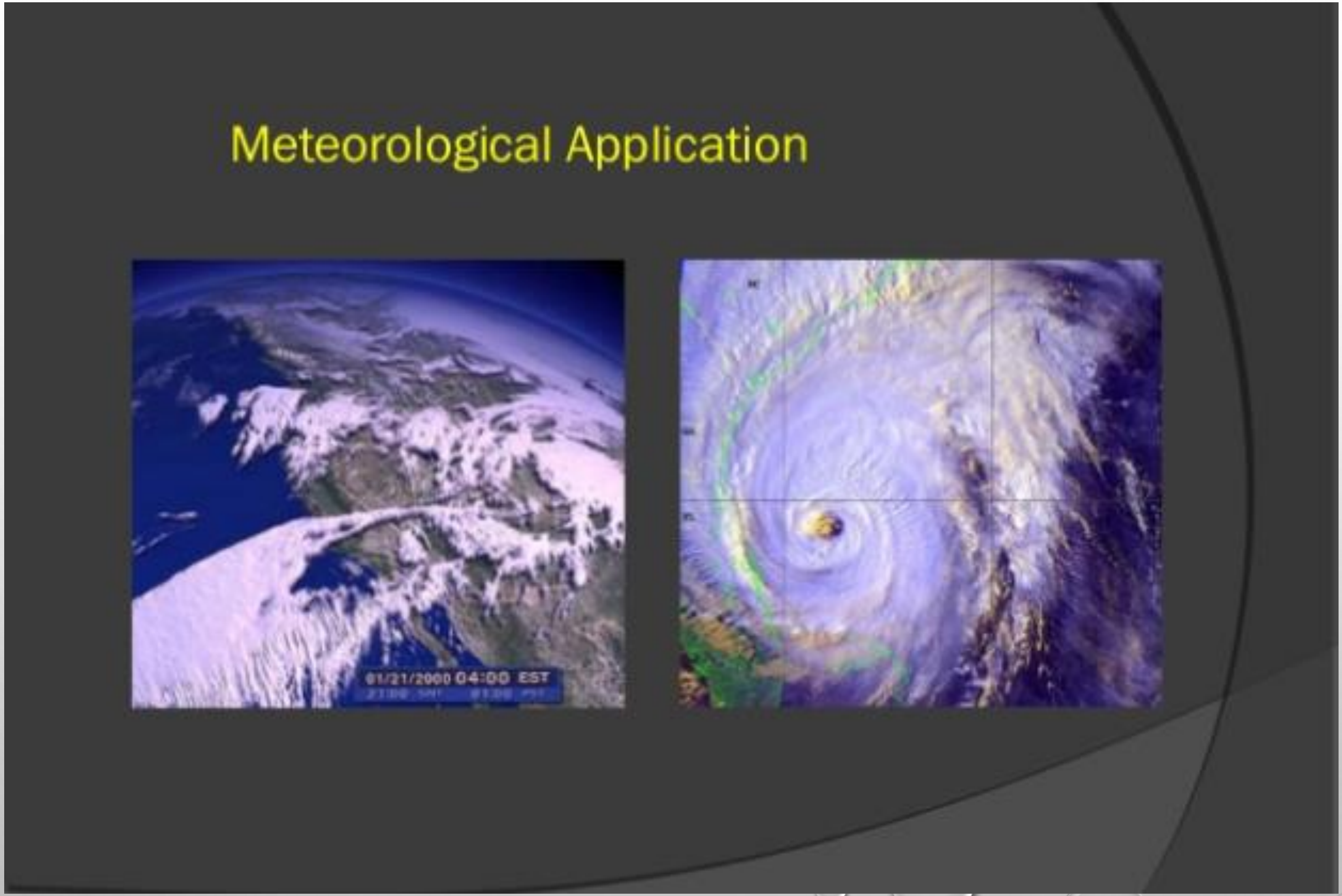
Applications of Remote Sensing

MONITORING WEATHER



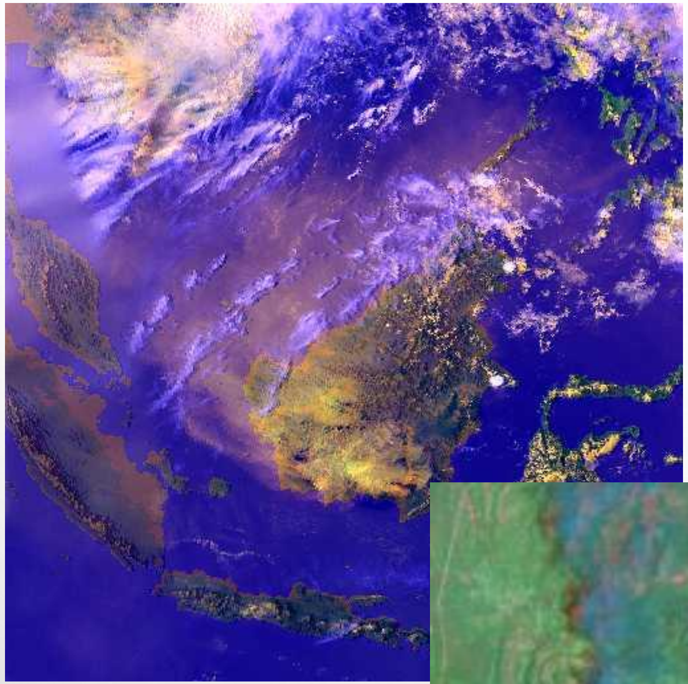
GOES-8 Water Vapor

Applications of Remote Sensing



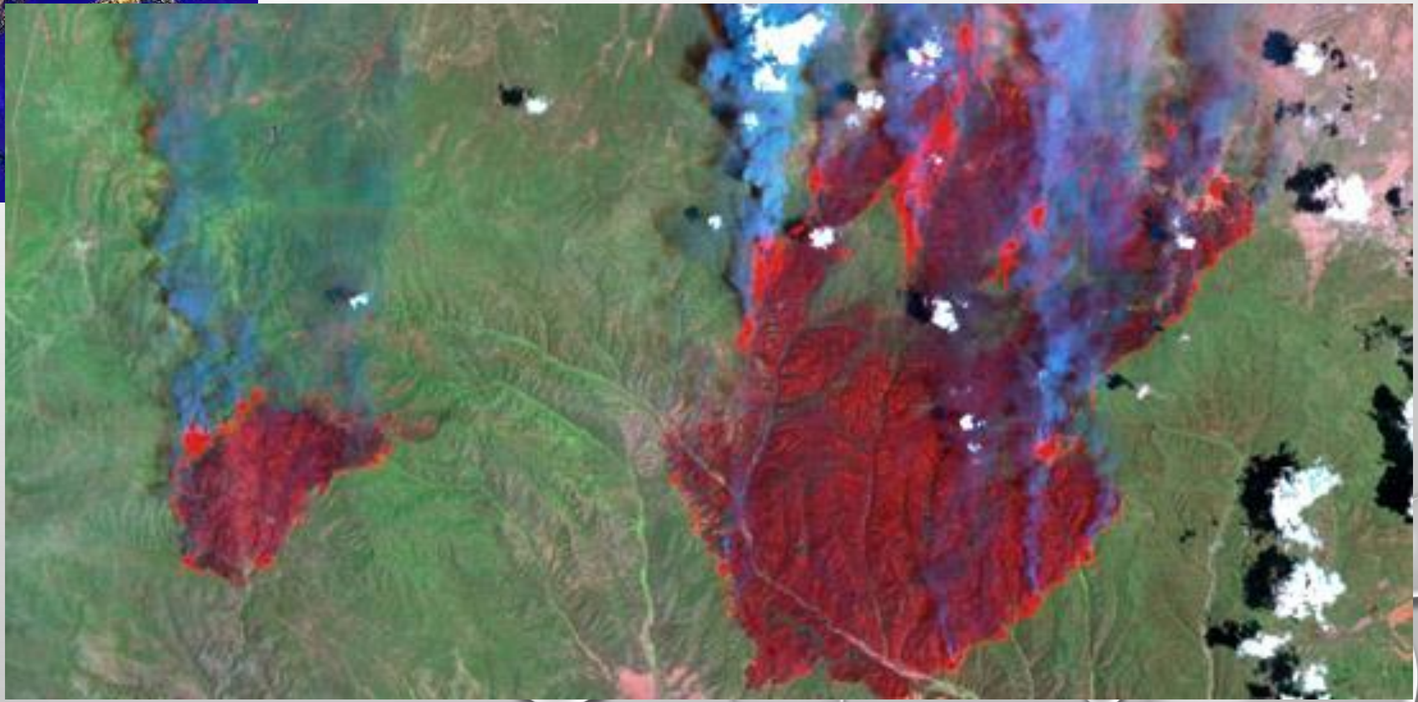
Applications of Remote Sensing

DETECTING AND MONITORING WILDLAND FIRES



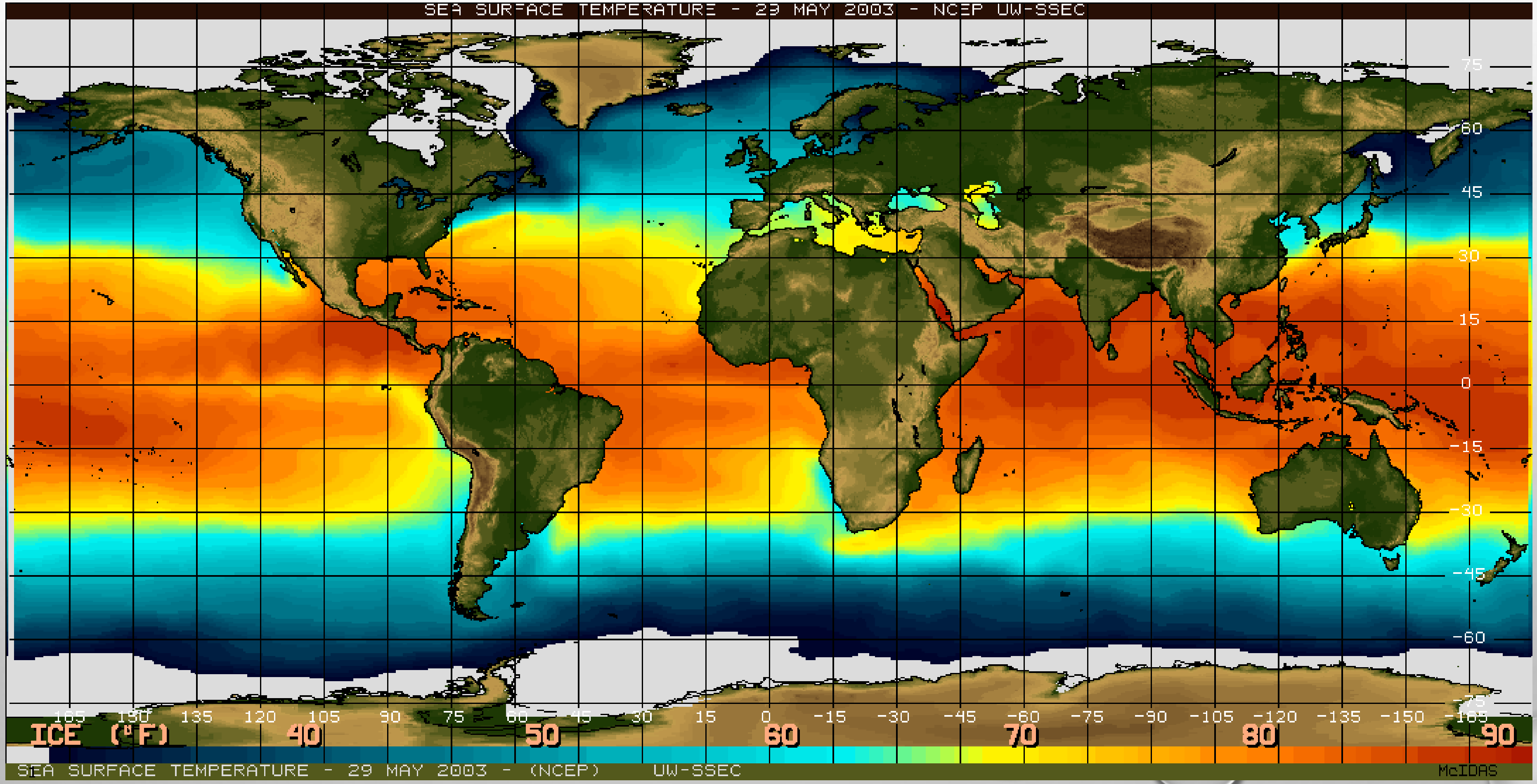
Borneo

Arizona, June 2002



Applications of Remote Sensing

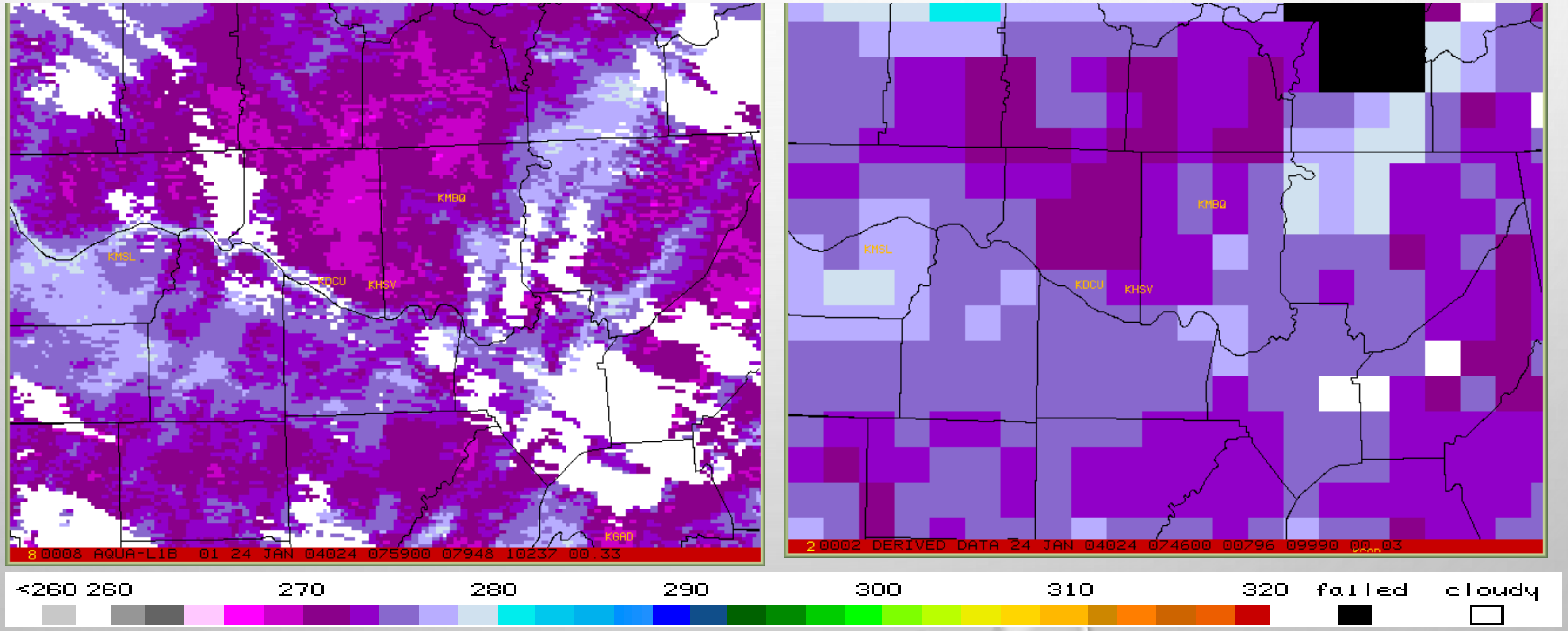
MONITORING SEA SURFACE TEMPERATURE



Applications of Remote Sensing

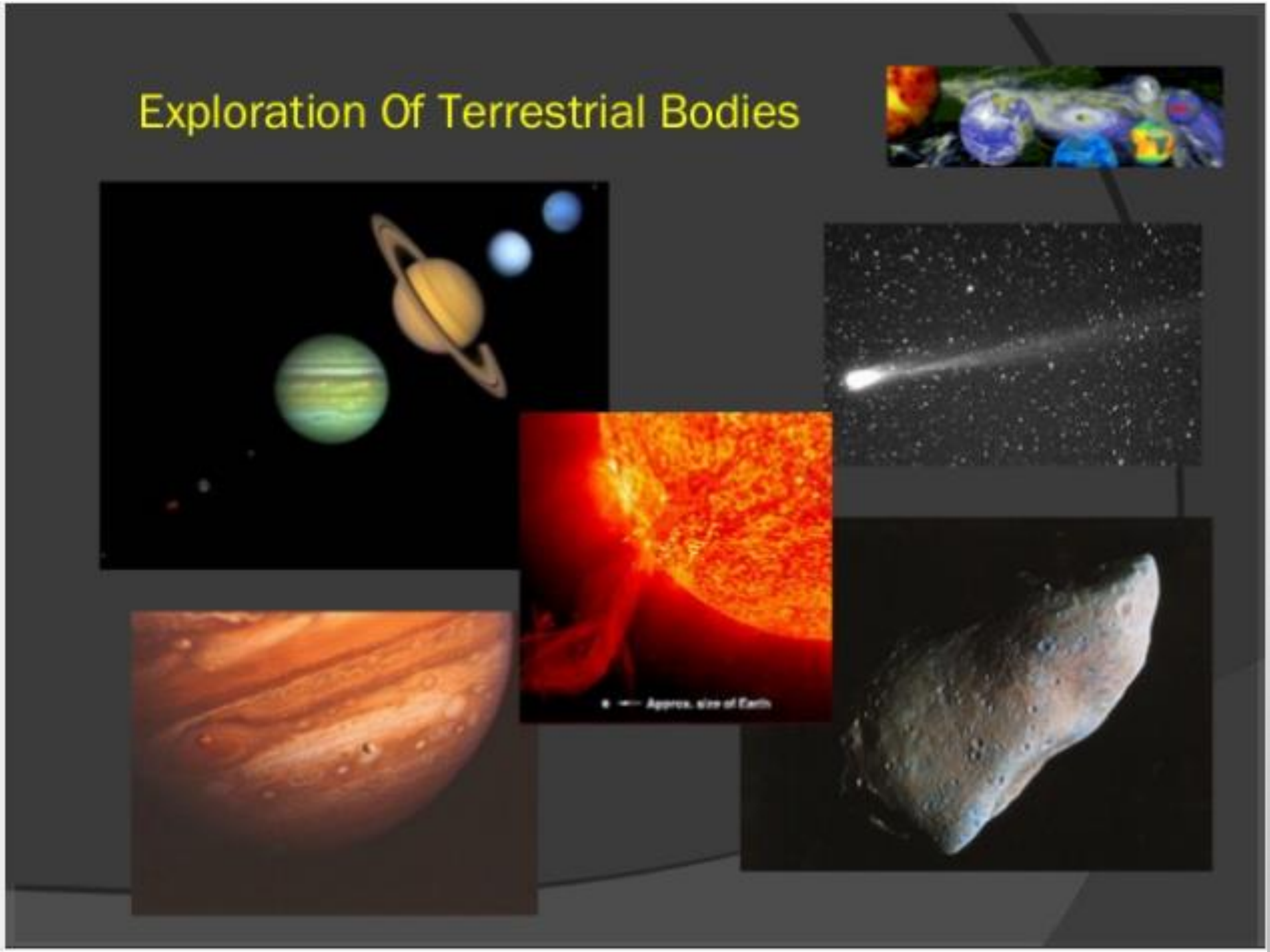
GOES AND MODIS SPATIAL AND TEMPORAL RESOLUTION

- GOES sounder – temporal resolution every hour; spatial resolution (10 km)
- MODIS instrument on the polar orbiting platforms - up to four passes a day, two daytime and two nighttime; spatial resolution (1 km)

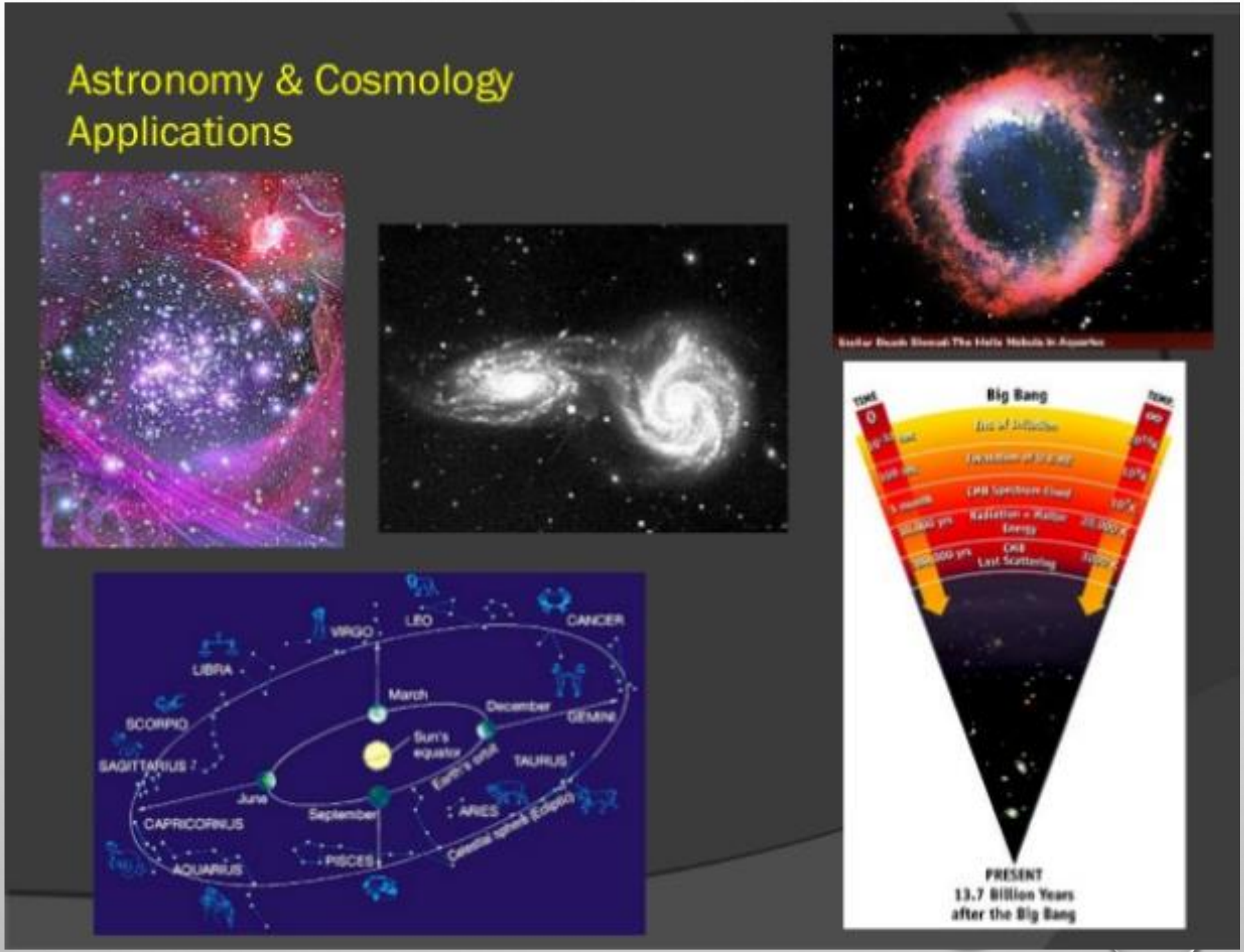


AQUA MODIS 24 JAN 2004 **GOES LST 2 AM CST**

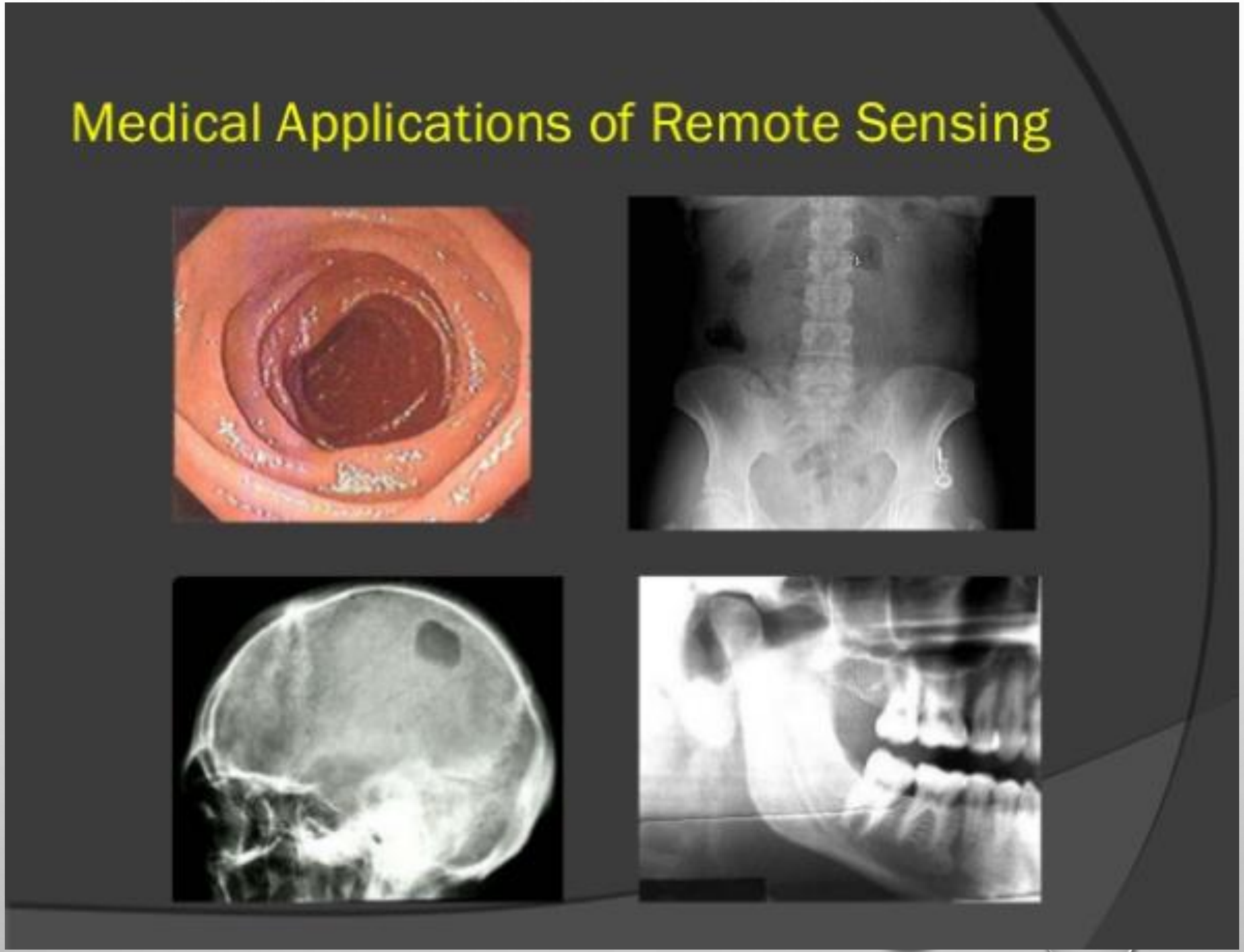
Applications of Remote Sensing



Applications of Remote Sensing



Applications of Remote Sensing



Remote Sensing Organizations

- **ISPRS**- **I**nternational **S**ociety for **P**hotogrammetry and **R**emote **S**ensing
- **IGARSS**- **I**nternational **Geosciences** **A**nd **R**emote **S**ensing **S**ymposium
- **NASA** -National Aeronautic and Space Administration (USA)
- **ESA**- **E**uropean **S**pace **A**gency (Europe)
- **NASDA**- National Space Development Agency (Japan)
- **CNES**- Centre National d'Etudes Spatiales (France)
- **DARA**- German Space Agency
- **CSA** - Canadian Space Agency
- **NRSA**- National Remote Sensing Agency of India

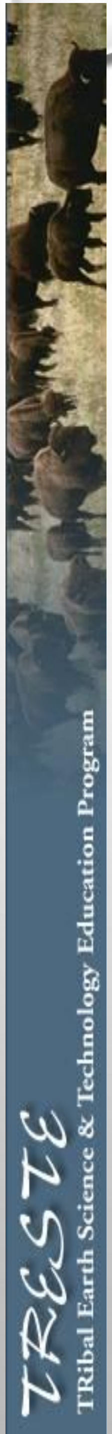
Remote sensing web sites

- http://ftp.geog.ucl.ac.be/~patrick/geogr/Eteledetec.html - remote sensing index
- http:// www.esrin.esa.it - Eurpopean Space Agency
- http://geo.arc.nasa.gov - NASA program http://www.spot.com
- http://www.nasda.go.jp/ - Japan space agency
- http://www.rka.ru./ Russian Space Agency (RSA)
- http://www.coresw.com - Russian imagery source
- http://www.space.gc.ca/ Canadian Space Agency (CSA)
- http://www.ccrs.nrcan.gc.ca/ccrs/ -Canada Center for Remote Sensing
- http://www.inpe.br/ National Institute for Space Research (Brazil)
- http://www.asprs.org - American Society
- http://www.man.ac.uk - Manshester Univ.
- http://www.idrisi.clarku.edu - Idrisi site
- http://www.amazon.com - Bookstore
- http://www.brevard.cc.fl.us/BTR_Labs/bober/martin/rs/overview.htm Dr. Martin McClinton,

GOES AND MODIS SPECTRAL RESOLUTION

MODIS observes 36 separate frequencies of radiation, ranging from visible to infrared. GOES detects only five frequencies.

http://science.nasa.gov/headlines/y2004/09jan_sport.htm



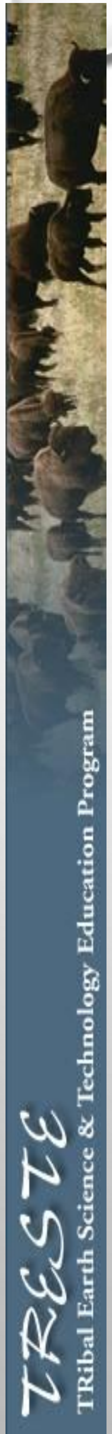
LAND SURFACE TEMPERATURE (LST) COMPARISON

DRY PERIOD

- JUNE 25-JULY 3, 2004
- JULY 25-AUGUST 3, 2004

WET PERIOD

- JUNE 26-JULY 3, 2005
- JULY 23-31, 2005



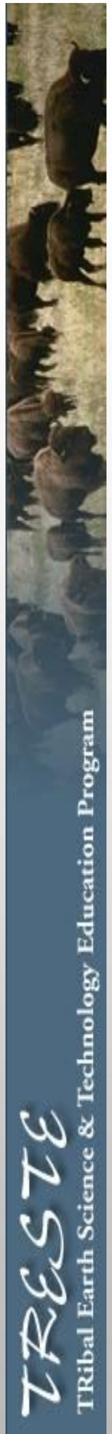
LST PRODUCTS

MODIS/TERRA LAND SURFACE TEMPERATURE/EMISSIVITY DAILY L3 GLOBAL 1 KM SIN GRID (MOD11A1)

DATA SET CHARACTERISTICS

- AREA = ~ 1100 X 1100 KM IMAGE DİMENSİONS = 2 (1200 X 1200 ROW/COLUMN)
- AVERAGE FILE SIZE = 24 MB
- RESOLUTION = 1 KILOMETER (ACTUAL 0.93 KM)
- PROJECTION = SINUSOIDAL
- LAND SURFACE TEMPERATURE (LST) DATA TYPE =16-BİT UNSİGNED INTEGER
- EMISSIVITY DATA TYPE = 8-BİT UNSİGNED INTEGER
- DATA FORMAT = HDF-EOS
- SCİENCE DATA SETS (SDS) = 12

THE MODIS/TERRA LAND SURFACE TEMPERATURE/EMISSIVITY DAILY L3 GLOBAL 1KM SIN GRID PRODUCT, MOD11A1, IS A GRIDDED VERSİON OF THE LEVEL-2 DAILY LST PRODUCT. IT IS GENERATED BY PROJECTING MOD11_L2 PİXELS TO EARTH LOCATIONS ON A SINUSOIDAL MAPPING GRID.



MODIS/TERRA LAND SURFACE TEMPERATURE/ EMISSIVITY DAILY L3 GLOBAL 1 KM SIN GRID

SDS	Units	Data Type-bit	Fill Value	Valid Range	Multiply By Scale Factor	Add Additional Offset
Daily daytime 1 km grid Land-Surface Temperature	Kelvin	16-bit unsigned integer	0	7500-65535	0.0200	na
Daily nighttime 1 km grid Land-Surface Temperature	Kelvin	16-bit unsigned integer	0	7500-65535	0.0200	

LAND COVER PRODUCTS

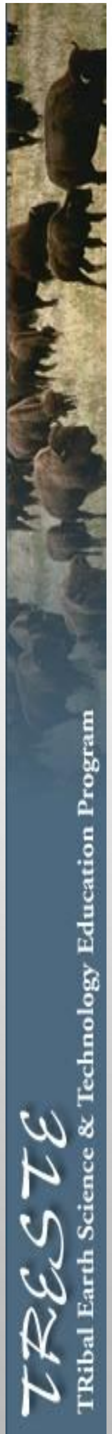
MODIS/TERRA LAND COVER TYPE YEARLY L3 GLOBAL 1 KM

SIN GRID

VERSION V004

- THE MOD12 CLASSIFICATION SCHEMES ARE MULTITEMPORAL CLASSES DESCRIBING LAND COVER PROPERTIES AS OBSERVED DURING THE YEAR (12 MONTHS OF INPUT DATA).

- THESE CLASSES ARE DISTINGUISHED WITH A SUPERVISED DECISION TREE CLASSIFICATION METHOD



LEGEND MOD12Q1 LAND COVER TYPE 5

Land Cover	**Class**
Fill Value	255
Water	0
Evergreen needleleaf trees	1
Evergreen broadleaf trees	2
Deciduous needleleaf trees	3
Deciduous broadleaf trees	4
Shrub	5
Grass	6
Cereal crop	7
Broadleaf crop	8
Urban and built up	9
Snow and ice	10
Barren or sparse vegetation	11

How data is extracted:

- Layers such as roads (yellow) and rivers (blue) can be easily seen from air/satellite photos
- This information is digitized (see next slide), separated into layers, and integrated into a GIS