Physics for Geoinformatics

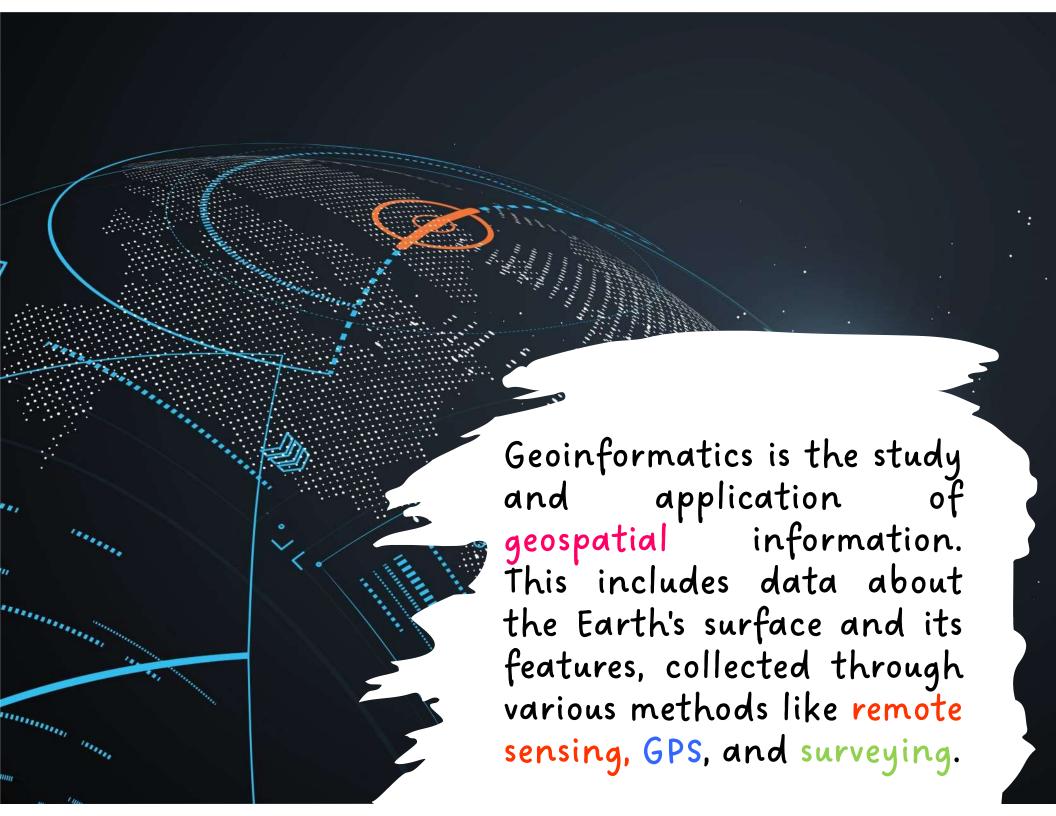
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Geoinformatics?



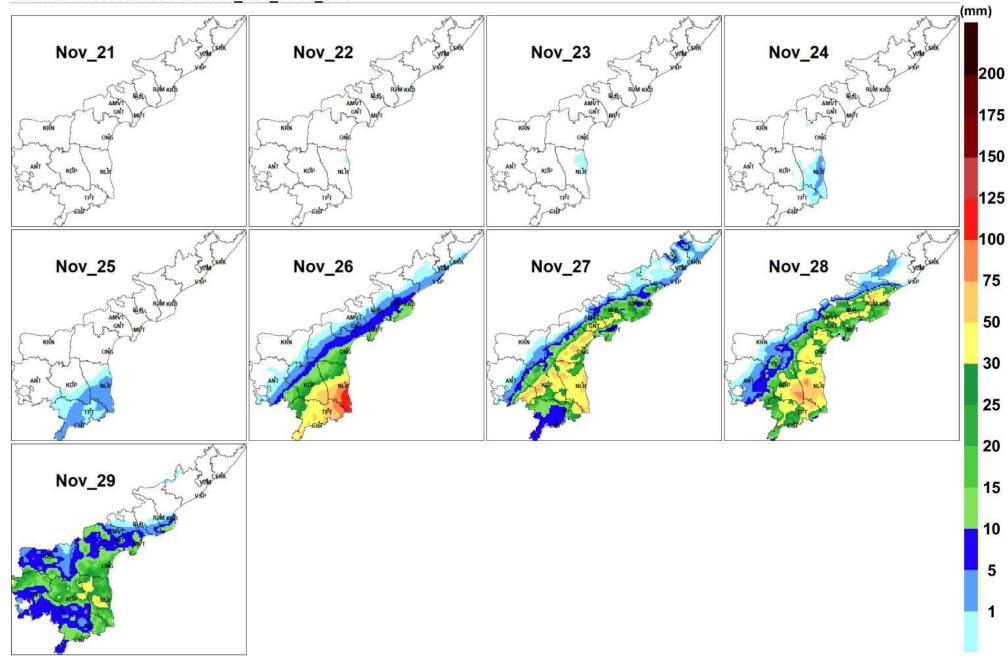


Rainfall forecast

Date: 2024_Nov_21



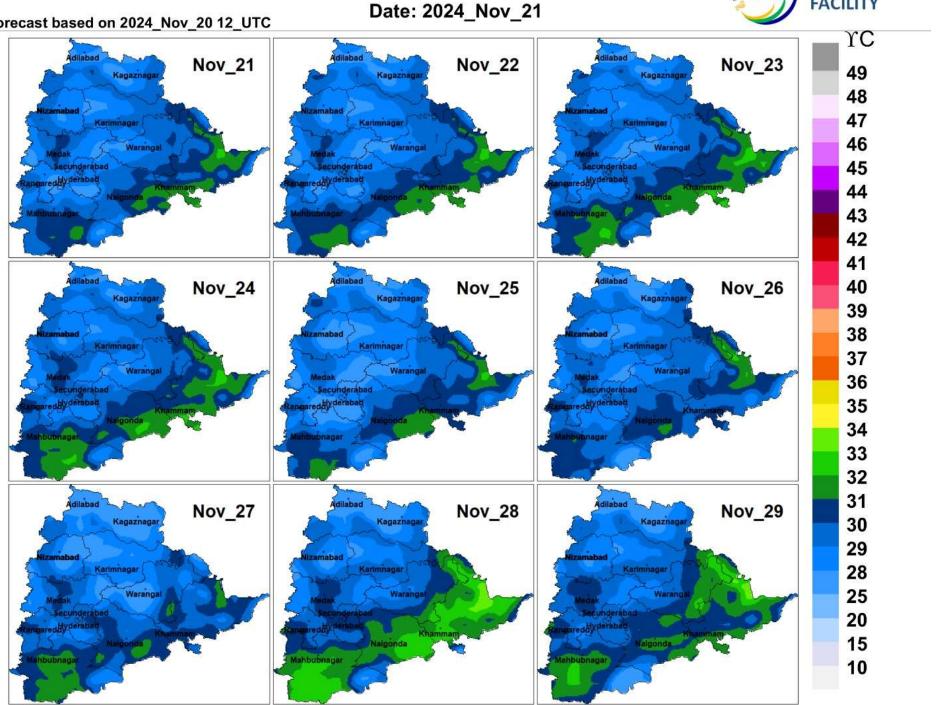
*Rainfall forecast based on 2024_Nov_20 12_UTC



Maximum Temperature Forecast - Telangana

METEOROLOGY FACILITY

*Forecast based on 2024_Nov_20 12_UTC



DATA

SPATIAL DATA

Does not have a geographic component

Has a geographic component

Can be about people, products, or events

Can be about physical objects, events, or both

Can be represented by numbers, text, or images

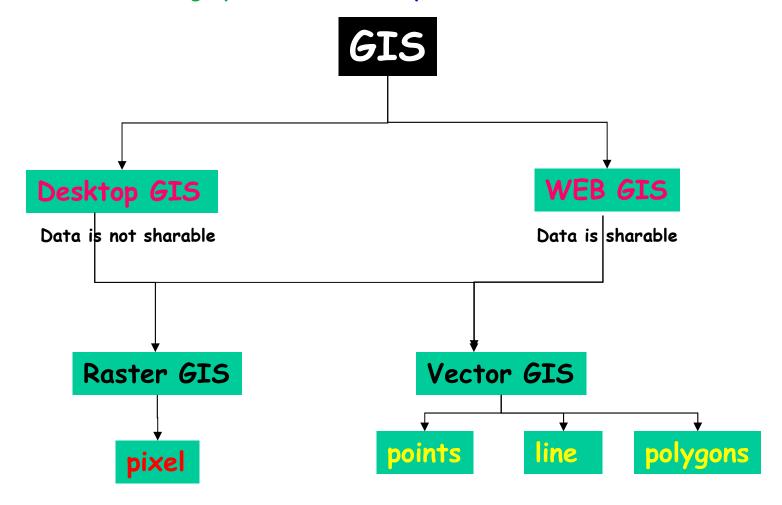
Can be represented by coordinates, shape, or topology

Can be used to answer a variety of questions

Can be used to answer questions about the world around us, such as finding the nearest coffee shop or identifying areas with high crime rates

What is GIS?

√GIS is an abbreviation of Geographic Information System.



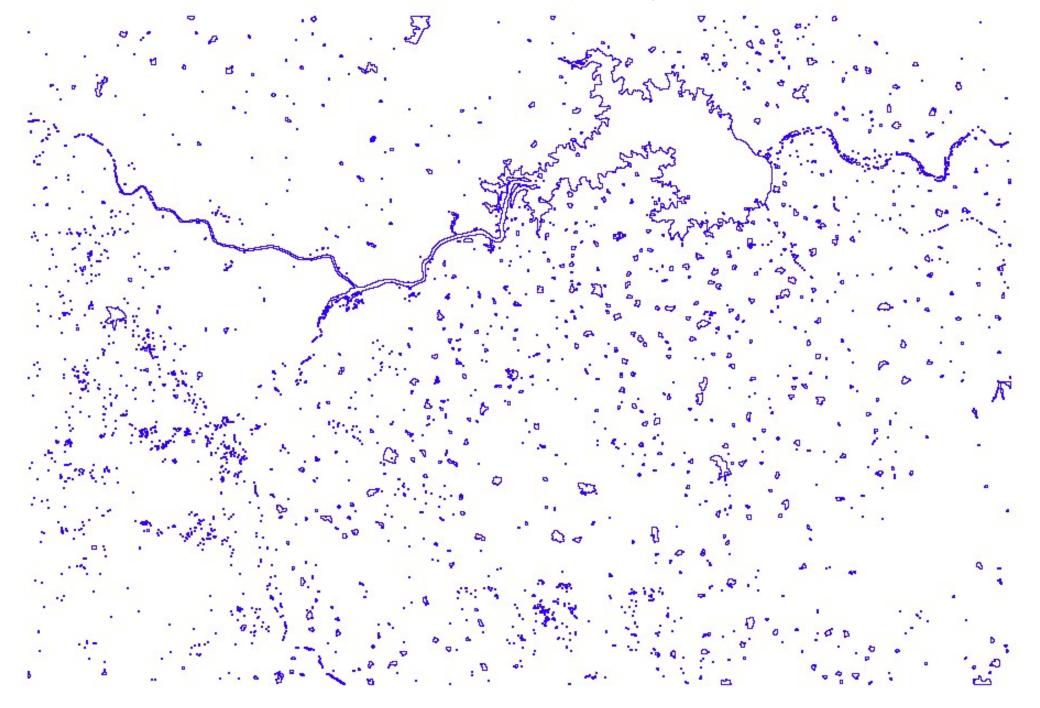
✓GIS, in a very simple term, is a combination of Maps and database (GIS= Maps + Database)

√In other words, GIS is a spatial database.

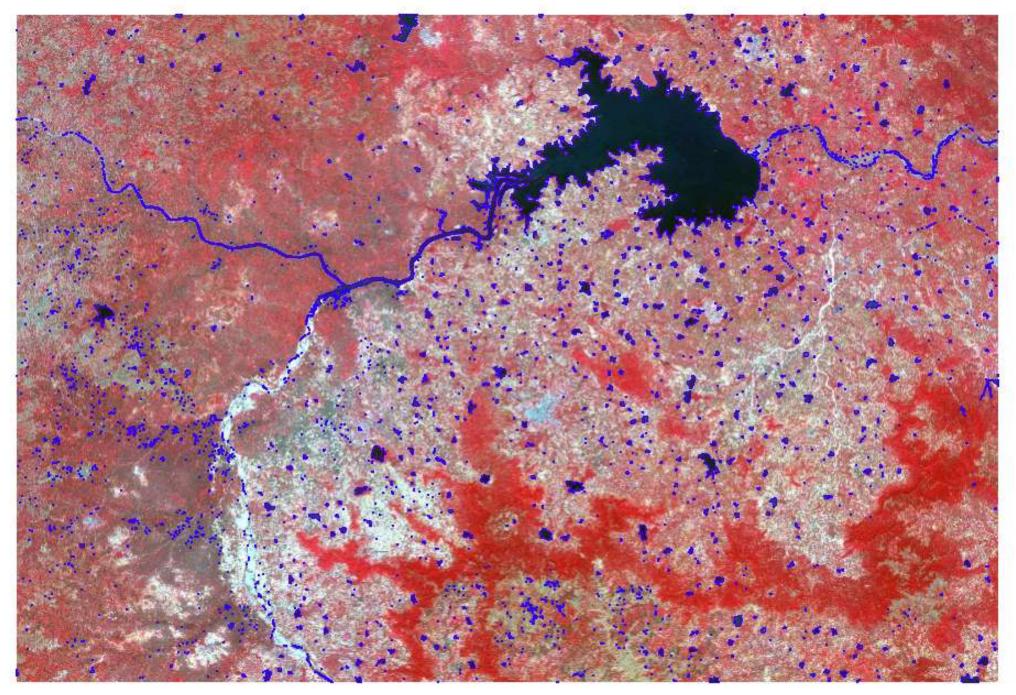
Satellite Image (Raster)



Water bodies (vectors)



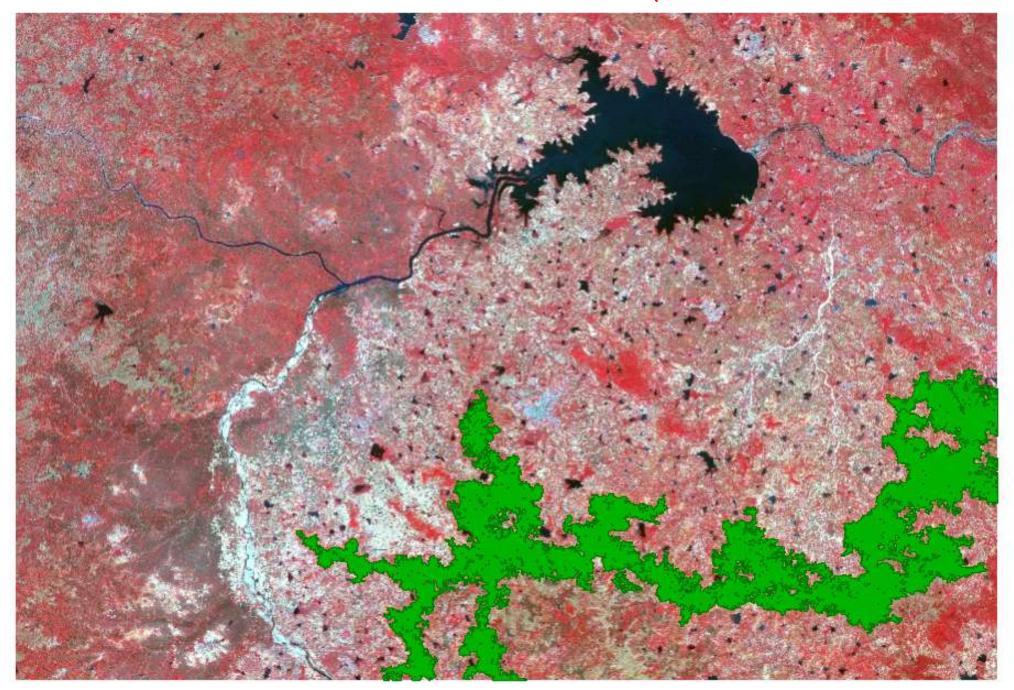
Raster overlaid vectors



Satellite Image (Raster)



Raster overlaid vectors (forest)

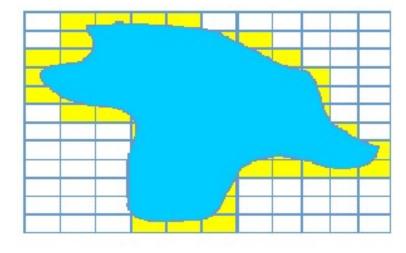


COL COL COL COL COL #1 #2 #3 #4 #5

ROW #1: 15 23 29 32 35 ROW #2: 17 24 25 25 32

ROW #3: 19 27 23 23 30

Example of a simple 5-column by 3-row raster digital image.





Why do we need to study remote sensing?



Remote sensing is essential for understanding and managing our planet's resources, environment, and societal challenges!!!!

What is Remote Sensing?



Remote Sensing

Our five senses

- · Sight
- hearing > Remote sensing
- · Smell

tastetouchOnly sensing





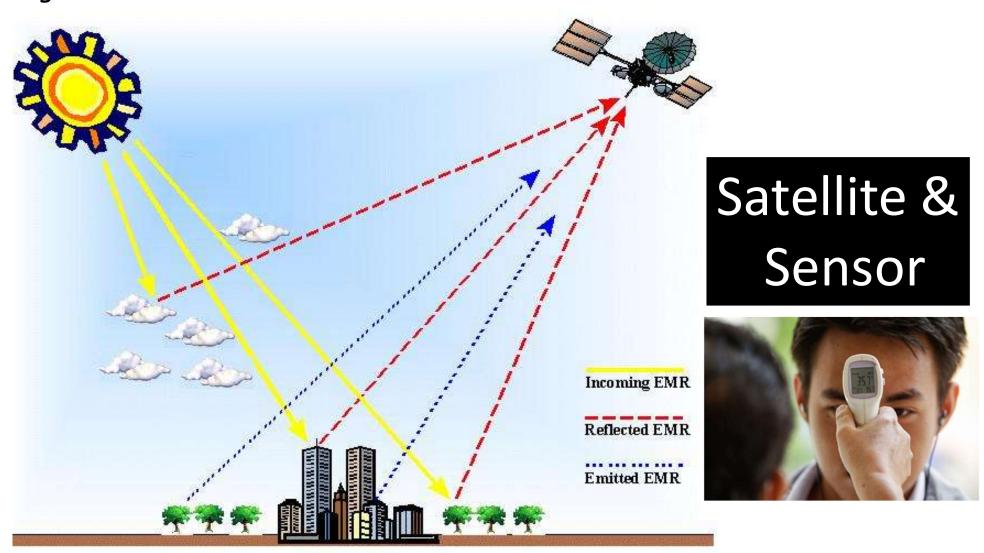


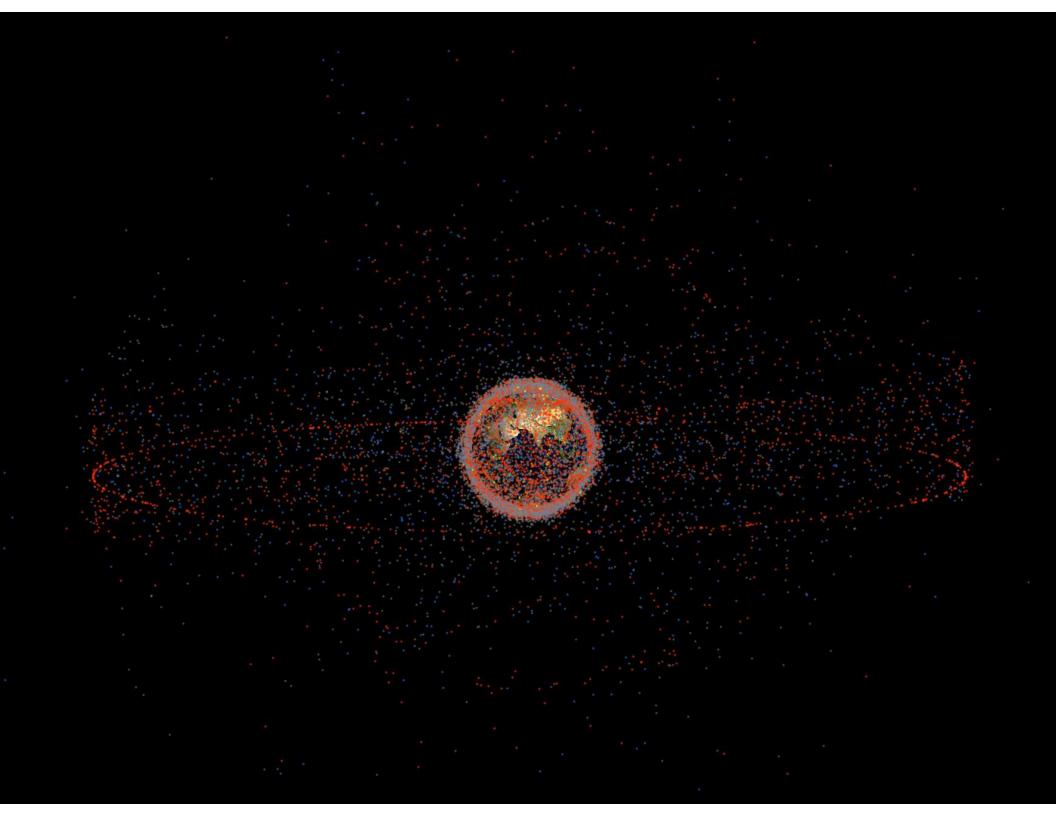




Satellite Remote Sensing?

Remote sensing is the science of acquiring information about the Target without being in contact with it.





Orbit's

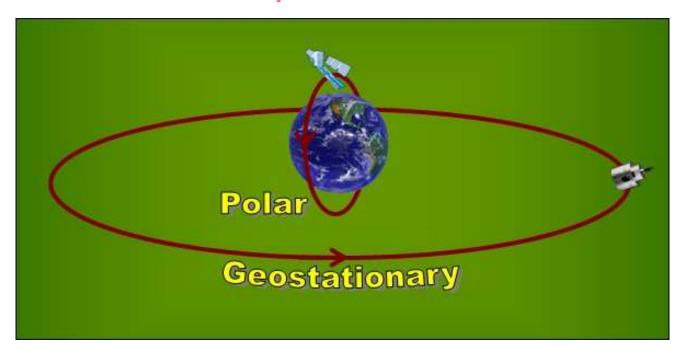
The path followed by a satellite is referred to as its orbit.

Two important types of orbits are

• <u>Geostationary orbits</u> are in the same plane as the equator and are about 36000 km away from the Earth.

Polar orbits

pass very close to the north and south poles (also known as near-polar orbits). They are about 700 to 800 km away from the Earth. Orbits



Geostationary orbits (Geosynchronous Equatorial Orbit)

(Geo = Earth + synchronous = moving at the same rate).

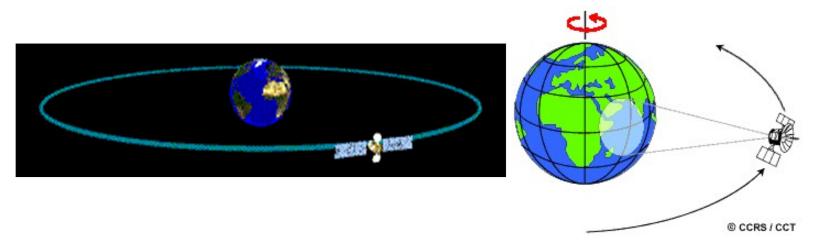
Satellites at very high altitudes, which view the same portion of the Earth's surface, always have *Geostationary orbits*.

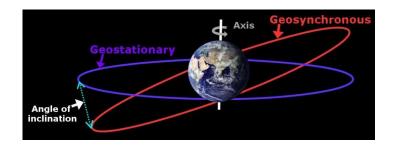
At altitudes of approximately **36,000** kilometres, these geostationary satellites revolve at speeds that match the rotation of the Earth, so they seem stationary relative to the Earth's surface.

This allows the satellites to observe and collect information continuously over specific areas.

Weather and communications satellites commonly have these types of orbits.

Due to their high altitude, some geostationary weather satellites can monitor weather and cloud patterns covering half of the hemisphere of the Earth.

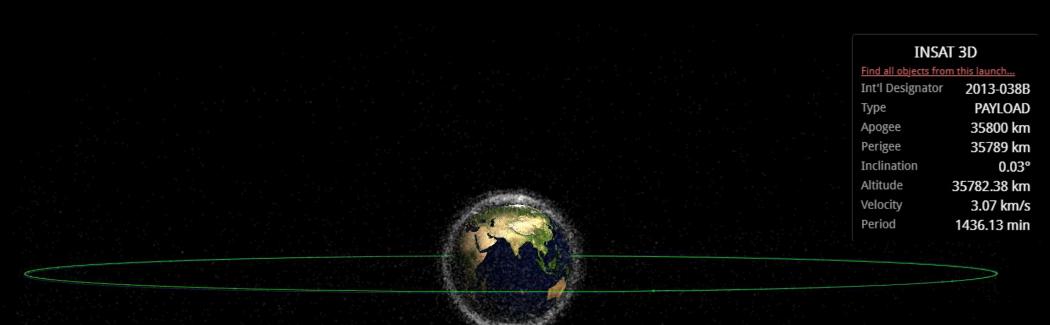


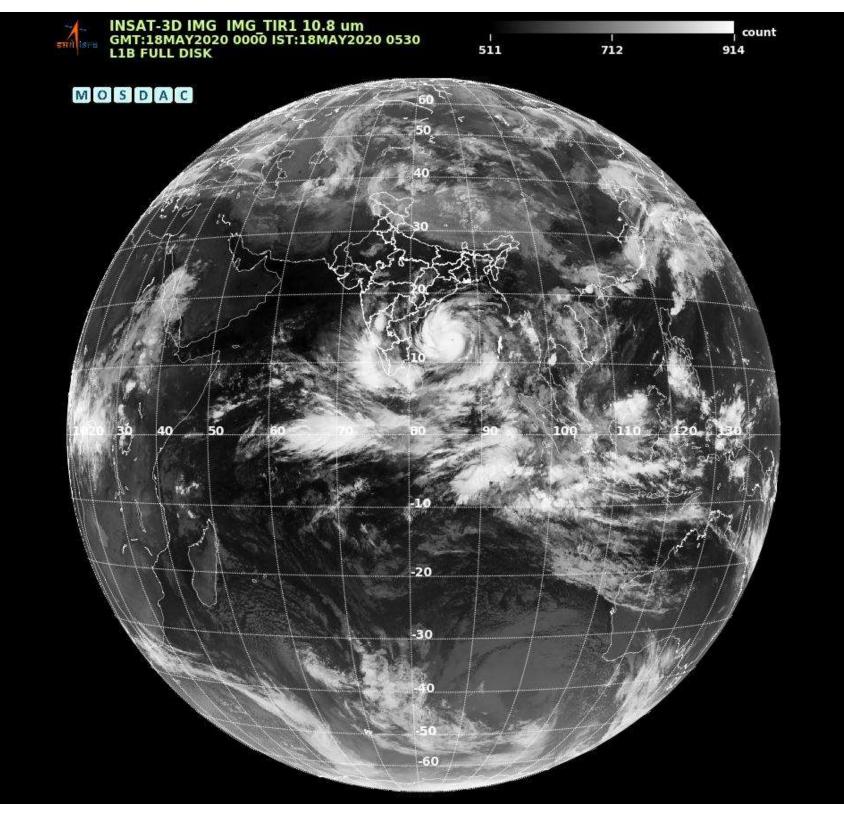


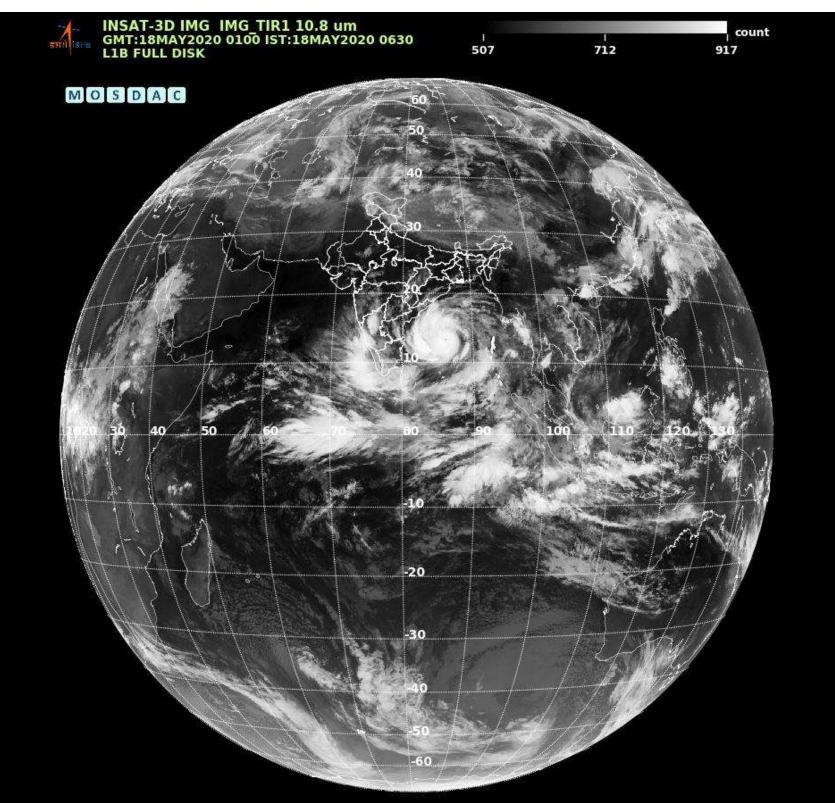
"Geostationary" and "Geosynchronous" are often used interchangeably, but they have slight differences:

Geostationary Orbit (GEO): A geostationary orbit is a type of orbit where a satellite is positioned at a fixed location **above the Earth's equator** and orbits at the same rotational speed as the Earth. As a result, it appears to be stationary relative to the Earth's surface, remaining fixed at a specific point above the equator. Geostationary orbits have an **orbital period of 24 hours**, which allows satellites to maintain a constant position relative to a specific location on the Earth's surface. Geostationary orbits are commonly used for communication, broadcasting, and weather observation.

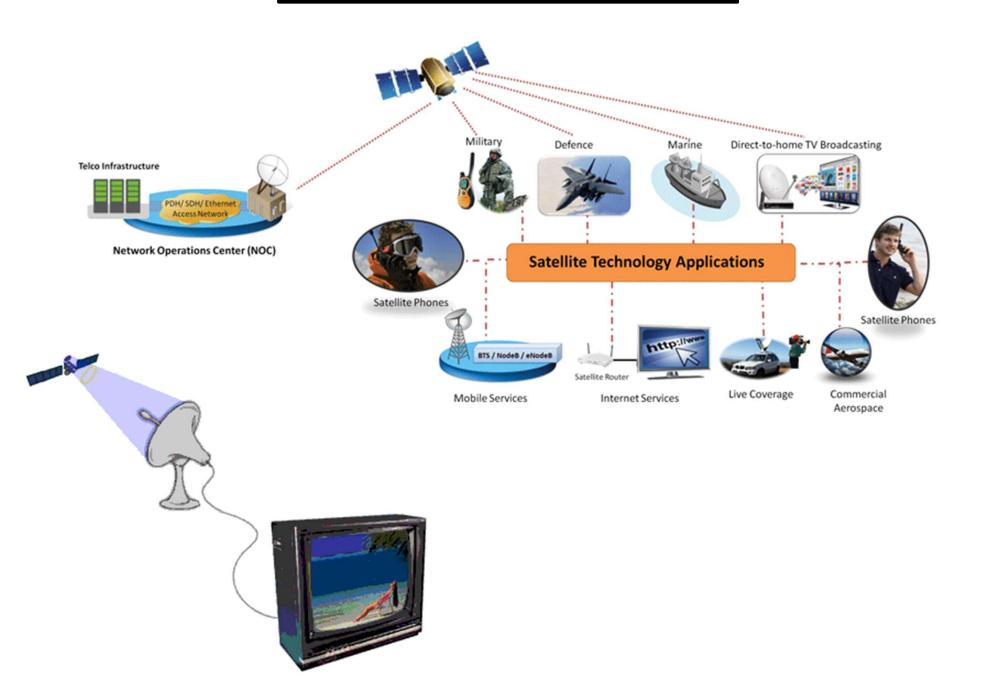
Geosynchronous Orbit (GSO): A geosynchronous orbit is a type of orbit where a satellite takes the same amount of time to complete one orbit as the Earth's rotational period, which is approximately 24 hours. However, unlike geostationary orbits, geosynchronous orbits do not necessarily have to be positioned directly above the Earth's equator, and they may have some degree of orbital inclination. Geosynchronous orbits are also used for communication, navigation, and scientific research.

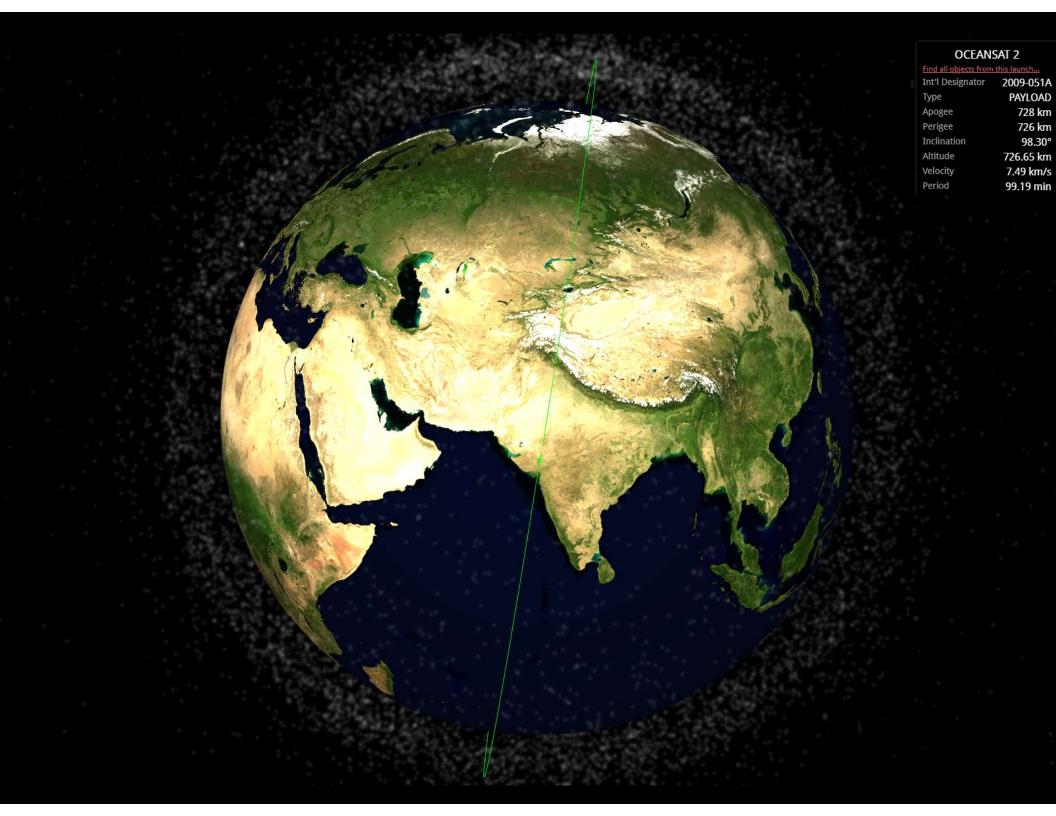


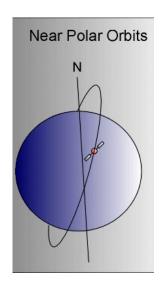




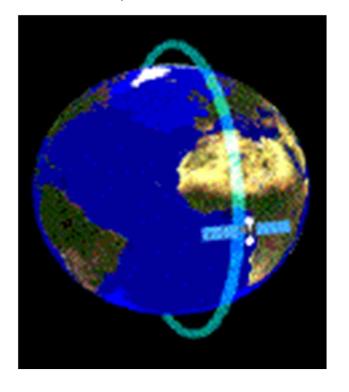
Satellite Communications

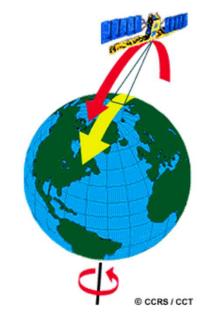


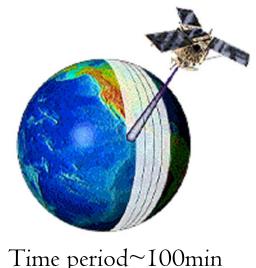












Time period~100min

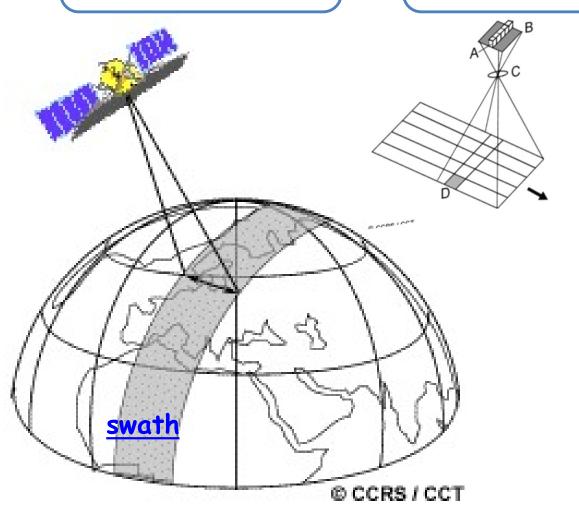
- •Satellites in a polar orbit do not have to pass the North and South Pole precisely; even a deviation within 20 to 30 degrees is still considered a polar orbit.
- •Polar Orbit: Satellites in a polar orbit pass over the Earth's poles and cover the entire Earth's surface over time. They are commonly used for Earth observation, mapping, and scientific research.
- •Sun-Synchronous Orbit (SSO): Satellites in SSO are designed to pass over the exact location on Earth at the same local solar time in each orbit. They are commonly used for Earth observation, remote sensing, and climate monitoring.
- •A satellite in orbit would usually be at an altitude of between 600 to 800 km. It will be travelling at a speed of approximately 7.5 km per second.

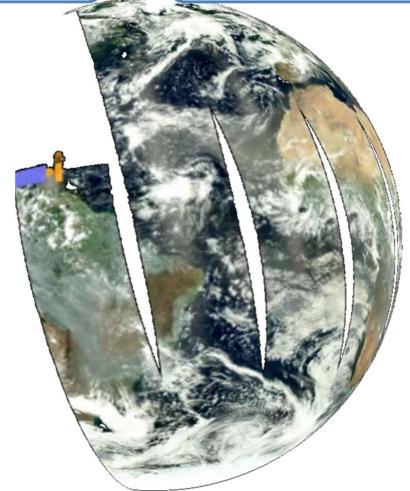
Satellite swath

As a satellite revolves around the Earth, the sensor "sees" a certain portion of the Earth's surface.

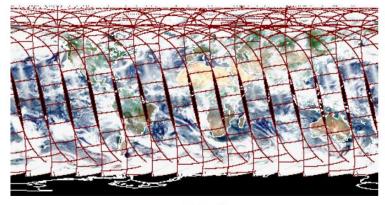
The area imaged on the surface, is referred to as the **swath**.

Imaging swaths for space borne sensors generally vary between tens and hundreds of kilometers wide.

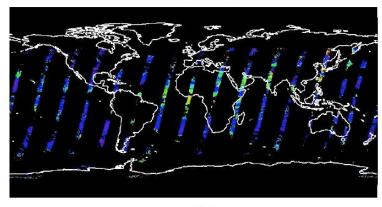




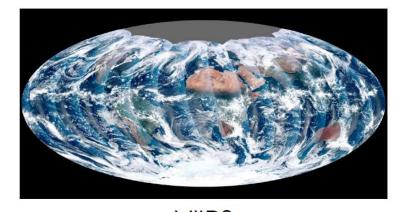
Satellite Coverage

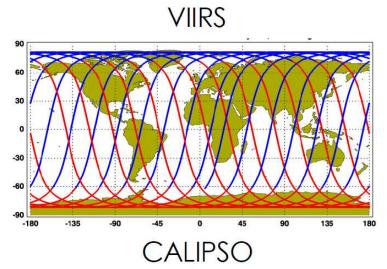


MODIS



MISR





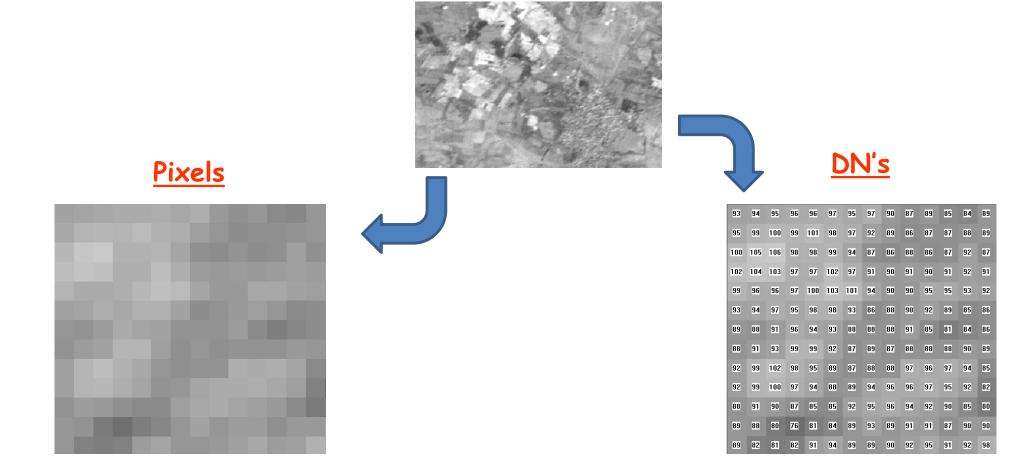


NASA's Applied Remote Sensing Training Program

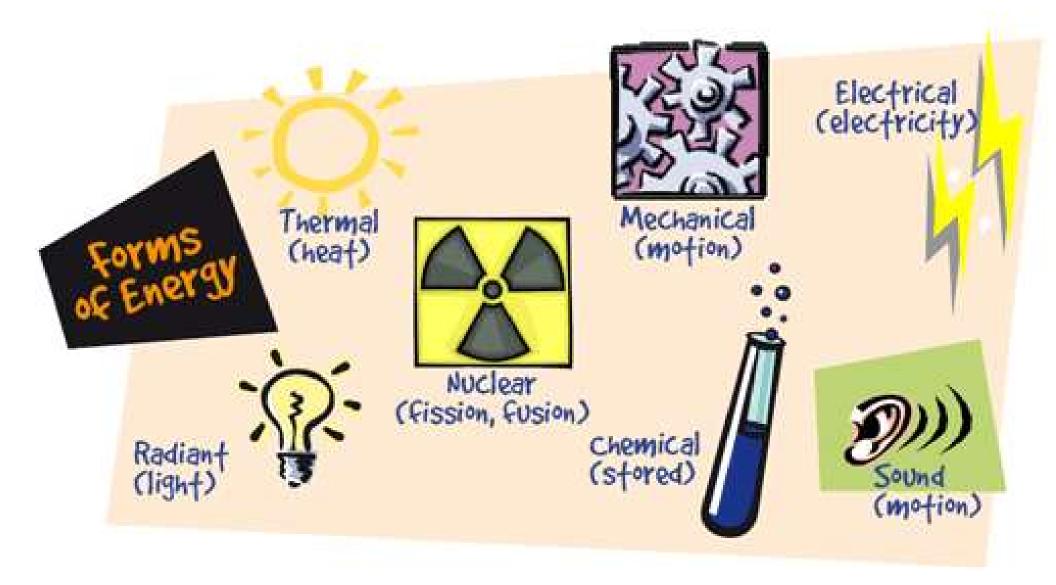
Digital Image

Pixel and digital number (DN)

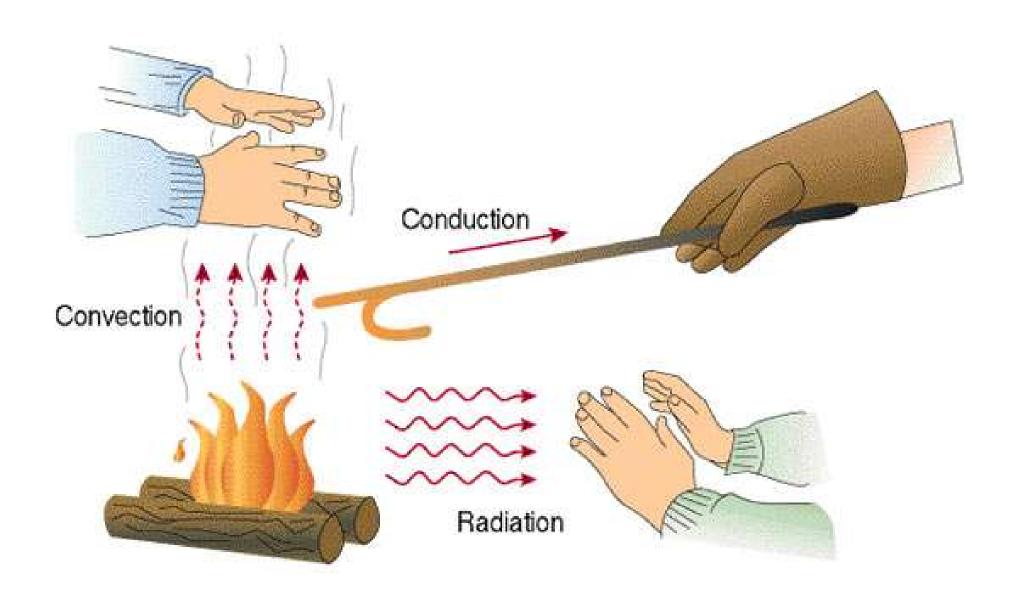
- A typical image derived from sensor consists of small equal areas referred to as picture elements, or 'pixels,' arranged in regular rows and columns.
- •Each pixel has a numeric value called a digital number (DN), which records the intensity of the **Electromagnetic energy** measured over the area of the earth represented by the pixel.



Electromagnetic energy?

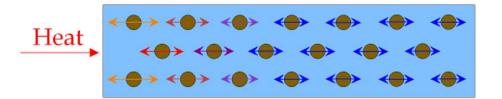


There are three mechanisms by which energy is transferred



Conduction

- Heat transfer through molecular vibrations from warm to cold
- •Medium is required



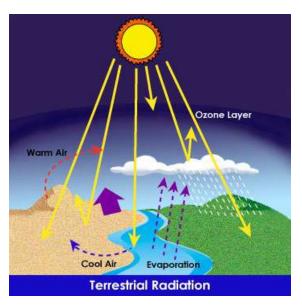
Convection

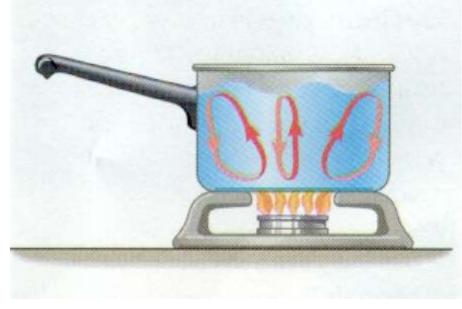
 Transfer of heat through mass movement of a substance

- . Medium is required
- •the "substance" could be air or water

Radiation

- •Radiant energy the transfer of energy via electromagnetic waves.
- Medium is not required



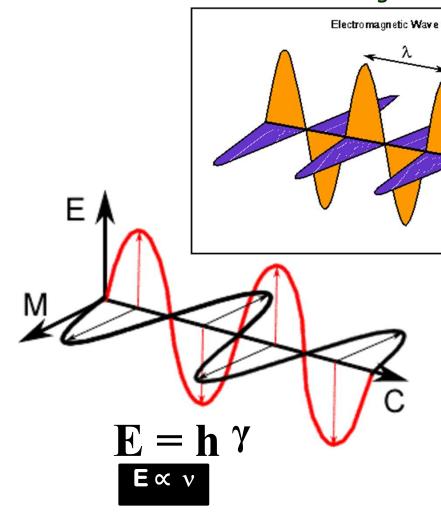




Light or Electromagnetic energy or Electromagnetic radiation Planck's assumption /Quantum energy

The electric and magnetic fields oscillate at right angles to each other, and the combined wave moves in a direction perpendicular to both electric and magnetic field oscillations.

Magnetic field Electric field



h=6.626 × 10^{-34} joule-second C= 3 × 10^8 m s⁻¹

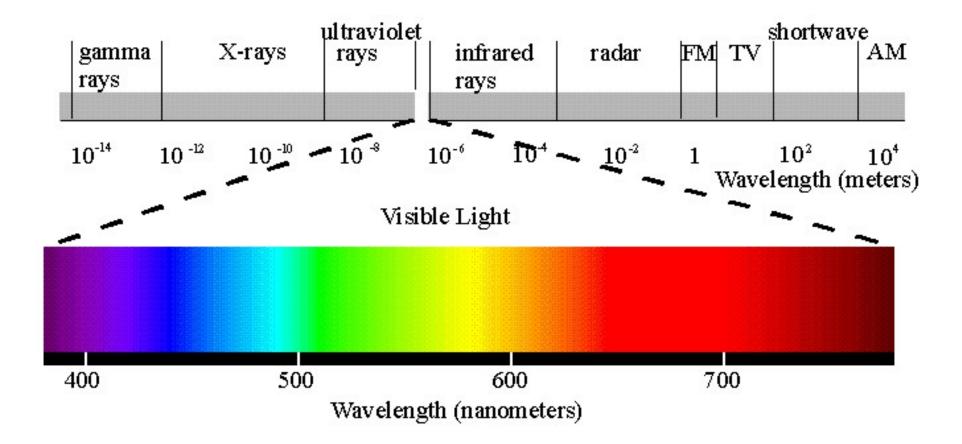
$$v = \frac{c}{\lambda}$$
 $v \propto 1/\lambda$

v = frequency c = speed of light $\lambda = wavelength$

$$E = \frac{hc}{\lambda}$$
$$E \propto 1/\lambda$$

E = energy h = Planck's constant c = speed of light $\lambda = wavelength$

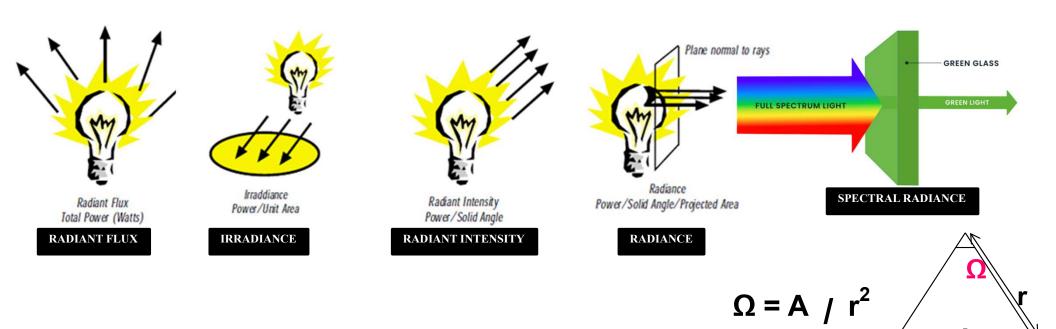
Electromagnetic spectrum



E.M Radiation, as well as Solar radiation, is commonly classified based on radiation wavelengths (λ) into several regions or Bands.

Band	Wavelength(λ) nm	Atmospheric effects	
y -ray	< 0.03	Completely absorbed by the upper atmosphere	
X- ray	0.03 - 3	Completely absorbed by the upper atmosphere	
UV (B)	3 - 300	Completely absorbed by O2, N2, O3 in the upper atmosphere	
UV (A)	300 - 400	Transmitted through the atmosphere, but atmospheric scattering is severe	
Visible	400 - 700	Transmitted through the atmosphere, with moderate atmospheric scattering of the shorter waves	
Reflected-IR	700 - 3000	Mostly reflected radiation, less influence	
Thermal - IR	3000 - 14000	Absorption of specific wave lengths by CO2, O3, AND Water Vapour	
Microwave	1 mm - 1 m	Less atmospheric effects	

Term	Unit	Description		
Radiant energy (Q)	Joule (J)	Energy per quanta		
Radiant flux	Watt (J/S)	Watt (J/S) Energy per unit time		
Irradiance (E)	Watt/ m ²	Incident flux per unit area over all angles		
Radiant Intensity (I)	Watt/sr (Ω)	Energy per unit time in certain solid angle.		
Radiance (L)	Watt/ m ² /sr	Reflected flux per unit area, in certain solid angle.		
Spectral radiance (L)	Watt/ m²/sr/μm	Reflected flux per unit area, in certain solid angle, Over a set range of wave lengths.		
Irradiance (E)= Solid angle (Ω) X Radiance (L)				



Radiation Laws



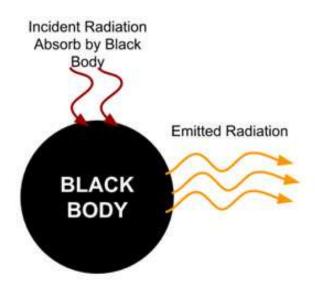
Objects in the universe emit electromagnetic radiation according to well-understood radiation laws.



Any substance (solid, liquid, or gas) emits radiation according to its absolute temperature, measured in Kelvin ($K = {}^{\circ}C + 273.15$) units. The ability to emit radiation varies with the matter.

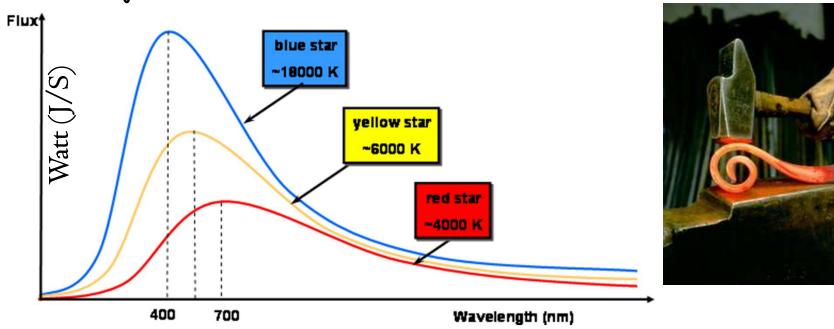
Black Body Radiation

- · Black Body any object that is a perfect absorber and a perfect emitter of radiation.
- Any object in the universe is not perfectly black.
- ·sun and Earth's surfaces behave approximately as black bodies



Radiation emitted by objects

- •If an object emits electromagnetic radiation due to its temperature, the color depends on the temperature.
- •The energy released depends on the temperature.
- ·All objects that have a temperature greater than 0° K emit radiation
- ·hot objects emit more radiation







Humans, at normal body temperature, emit infrared, at a wavelength of 10 μ m

Planck's Radiation Law

The physical law that gives the spectral energy distribution of thermal radiation called the black body at any temperature.

Planck's law is expressed by the following equation.

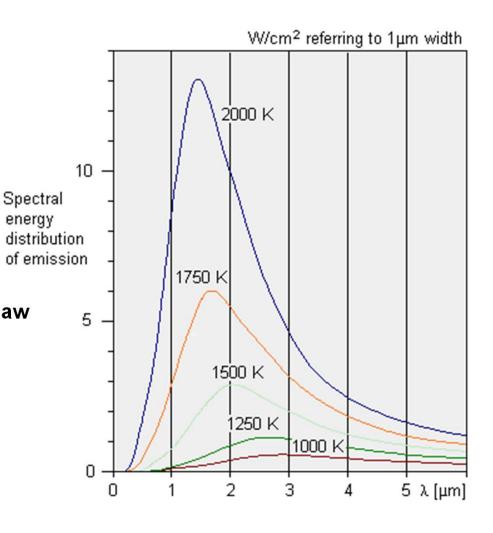
$$E(\lambda, T) = \frac{2\hbar c^2}{\lambda^5} \frac{1}{e^{-\hbar c/\lambda kT} - 1}$$

 $h = 6.625 \times 10^{-34}$ J.Sec Planck Constant

K= 1.38 X 10 = 23 J/K Boltzmann Constant

 $C=3 \times 10^8$ m/s Speed of light

- Integration of Plank's law is Stephan Boltzman's law
- Differentiation of Plank's law is Wean's law



Stefan-Boltzman law

The Sefan-Boltzman law relates the total amount of radiation emitted by an object to its temperature:

 $E=\sigma T^4$

where:

E = total amount of radiation emitted by an object per square meter (Watts m⁻²) σ is a constant called the Stefan-Boltzman constant = 5.67 \times 10⁻⁸ Watts m⁻² K⁻⁴ T is the temperature of the object in K

Consider the Earth and Sun:

Sun: T = 6000 K

 $E = 5.67 \times 10^{-8} \text{ Watts m}^{-2} \text{ K}^{-4} (6000 \text{ K})^4 = 7.3 \times 10^7 \text{ Watts m}^{-2}$

Earth: T = 288K

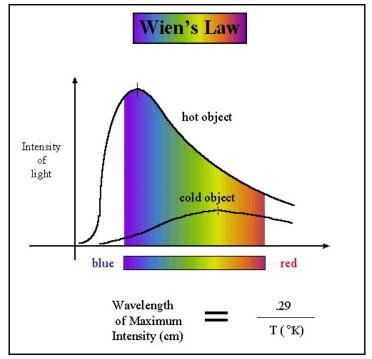
 $E = 5.67 \times 10-8 \text{ Watts m-2 K-4 (288 K)}^4 = 390 \text{ Watts m-2}$

Wien's displacement Law

- Most objects emit radiation at many wavelengths
- ·However, there is one wavelength where an object emits the largest amount of radiation

$$\lambda_{\text{max}}$$
 = 2897 μ m / T(K)

- ·Hotter objects emit most of their radiation at shorter wavelengths; hence they will appear Blue.
- ·Cooler objects emit most of their radiation at longer wavelengths; hence they will appear Red.



At what wavelength does the sun and Earth emit most of its radiation?

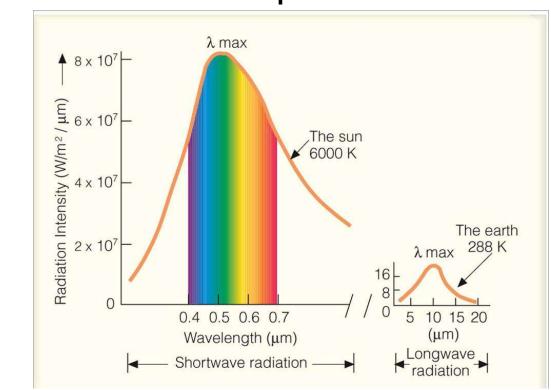
Sun: T = 6000 K

$$\lambda$$
max = 2897 μ m / T(K) \longrightarrow λ max = 2897 μ m / 6000(K) λ max = 0.482 μ m

Earth: T = 288K

$$\lambda_{\text{max}} = 2897 \,\mu \,\text{m} \, / \, T(K) \longrightarrow \lambda_{\text{max}} = 2897 \,\mu \,\text{m} \, / \, 288(K)$$

$$\lambda$$
max = 10 μ m

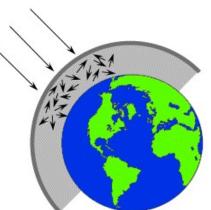


Radiation - Target Interactions

There are three forms of interaction that can take place when energy strikes or is incident upon the surface.

These are:

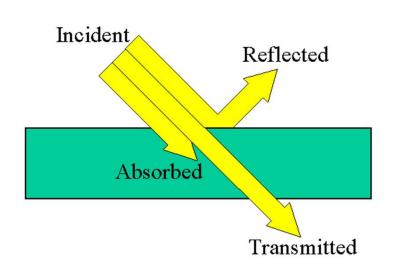
- 1. Absorption (A)
- 2. Transmission (T)
- 3. Reflection (R)

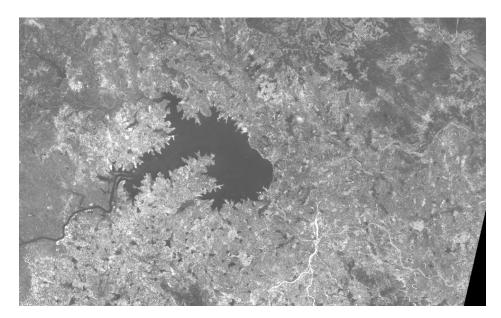


The total incident energy will interact with the surtace in one or more of these three ways.

The proportions of each will depend on the wavelength of the energy and the material and condition of the feature.

- 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.





Total energy (E) = Absorption (A) + Transmission (T) + Reflection (R)

 $\frac{\text{Total energy (E)}}{\text{Total energy (E)}} = \frac{\text{Absorption (A)} + \text{Transmission (T)}}{\text{Total energy (E)}} + \frac{\text{Reflection (R)}}{\text{Total energy (E)}}$

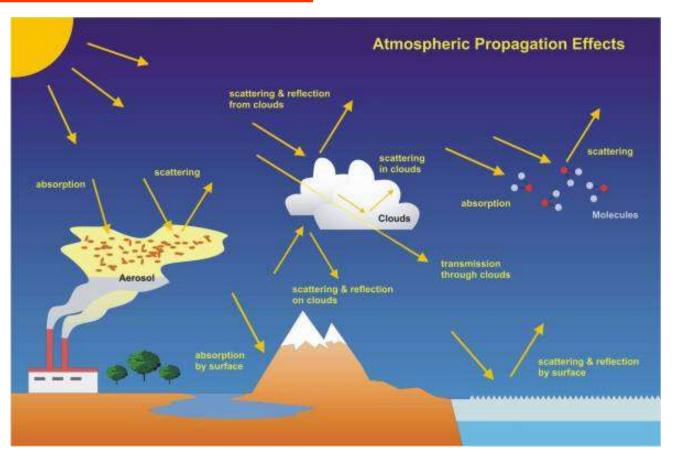
1= Absorbance +Transmittance+Reflectance

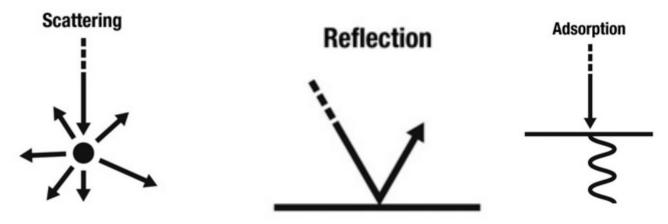
If Transmittance = 0

Reflectance = 1 - Absorbance

Absorbance = 1 - Reflectance

Atmospheric Interactions





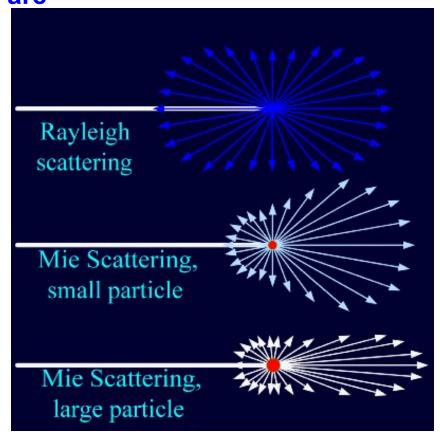
Scattering

Almost all objects scatter light, that means they reflect the light that illuminates them in all directions. If the objects around us would reflect light perfectly without scattering - like polished metal - it would be like in a mirror cabinet.

Scattering is mechanism where by the direction of EMR is changed when it interacts with the various constituents of the atmosphere.

Scattering can take several forms, those are

- Rayleigh scattering
- Mie scattering
- Non-selective scattering



Rayleigh scattering

Particles that are very much smaller then the wavelength of the EMR itself. Such particles include air molecules.

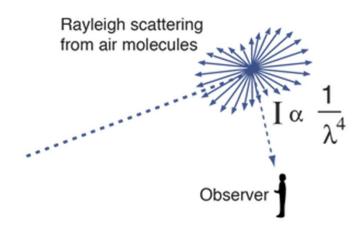
In R.S it's other name of *molecular scattering*.

The magnitude and direction of Rayleigh scattering are well known.

The scattering coefficient due to Rayleigh scattering is given by

Rayleigh scattering coefficient = $0.008735 \times \lambda^{-4.08}$

the degree of scattering is inversely proportional to the 4^{th} power of ' λ '



Blue light = 450 nm

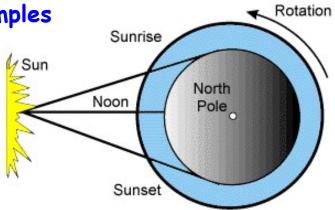
Red light = 650 nm

R.C = 0.2271

R.C = 0.0507

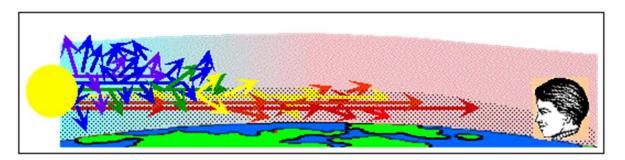
Blue EMR scatters 5 times more than red EMR.

Rayleigh scattering- Examples



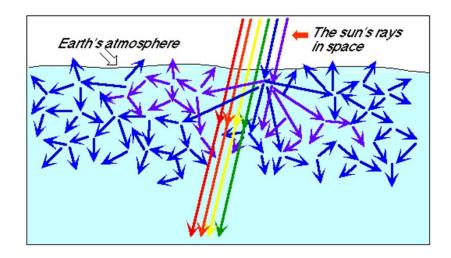


Sunrise and Sunset





Noon



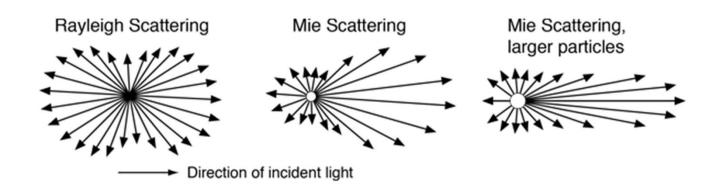
Mie scattering

Molecular size equal to 'λ', molecules are dust, pollutants, smoke, ocean spray, salt particles and water vapour molecules. All are called *AEROSOLS*.

This scattering is called Aerosol scattering

Mie scattering coefficient = $0.008735 \times \lambda^{-1.3}$

Mie scattering is less dependent on 'λ'



95 % of scattered EMR Continue in the forward direction

5% scattered backward

Non-selective scattering

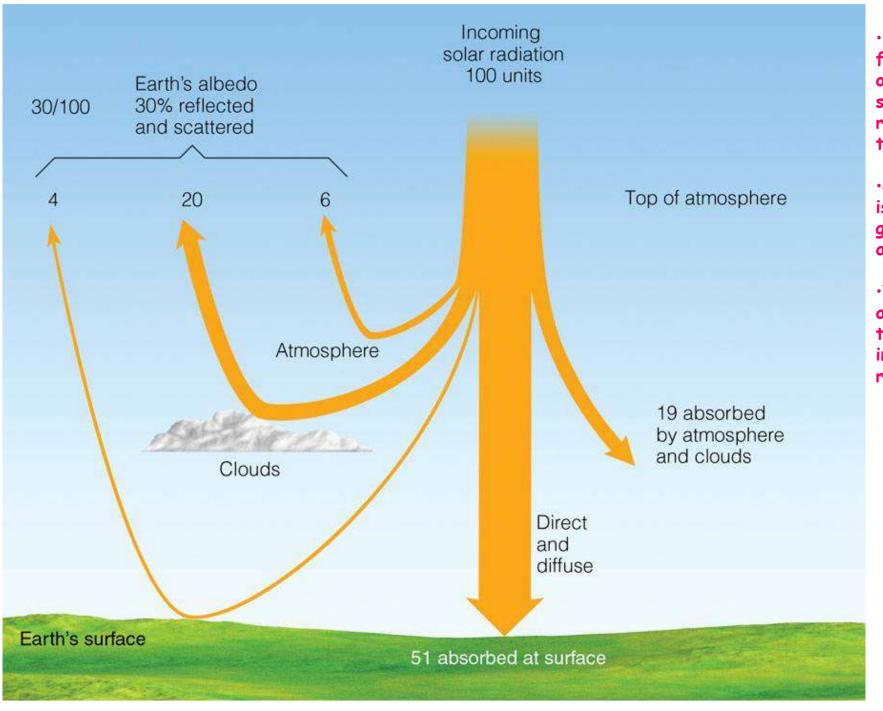
When the diameter of atmospheric particles greatly exceeds the wave length of EMR encountered, scattering is equal for all wavelengths.

Clouds are a good examples of Non-selective scattering.



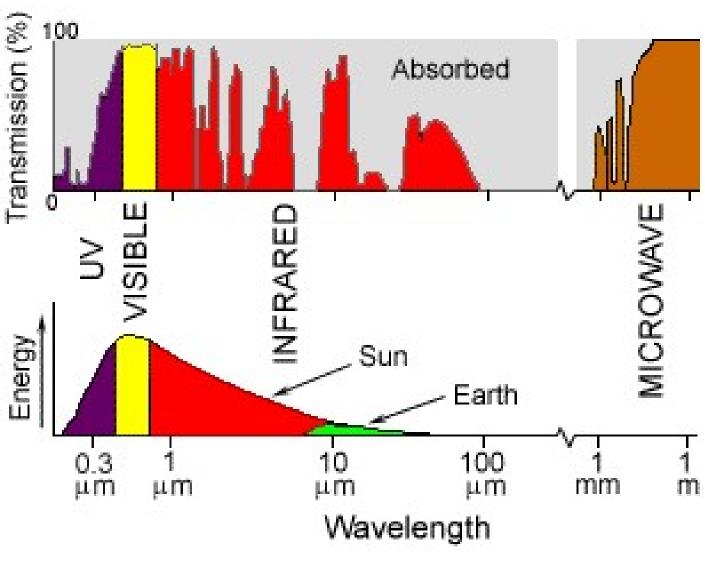


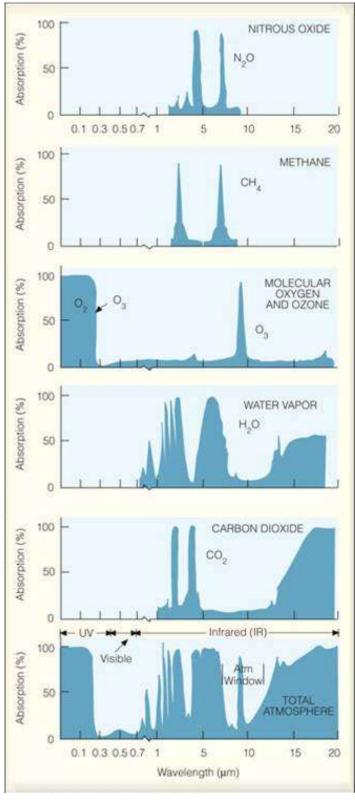
Interaction of incoming solar radiation with the Atmosphere



- ·Based on the figure, about half of the incoming short-wave radiation makes it to the surface
- only about 19% is absorbed by gasses in the atmosphere
- Therefore, the atmosphere is transparent to incoming solar radiation.

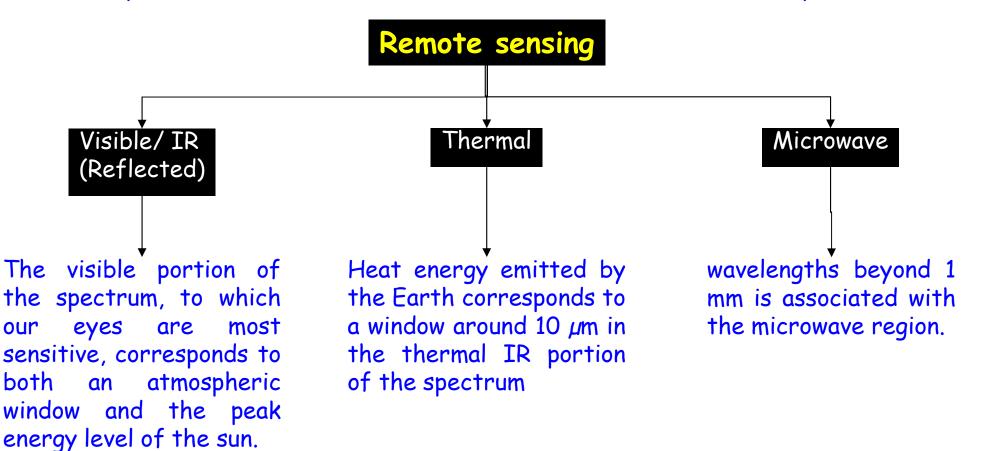
Transmission spectrum:

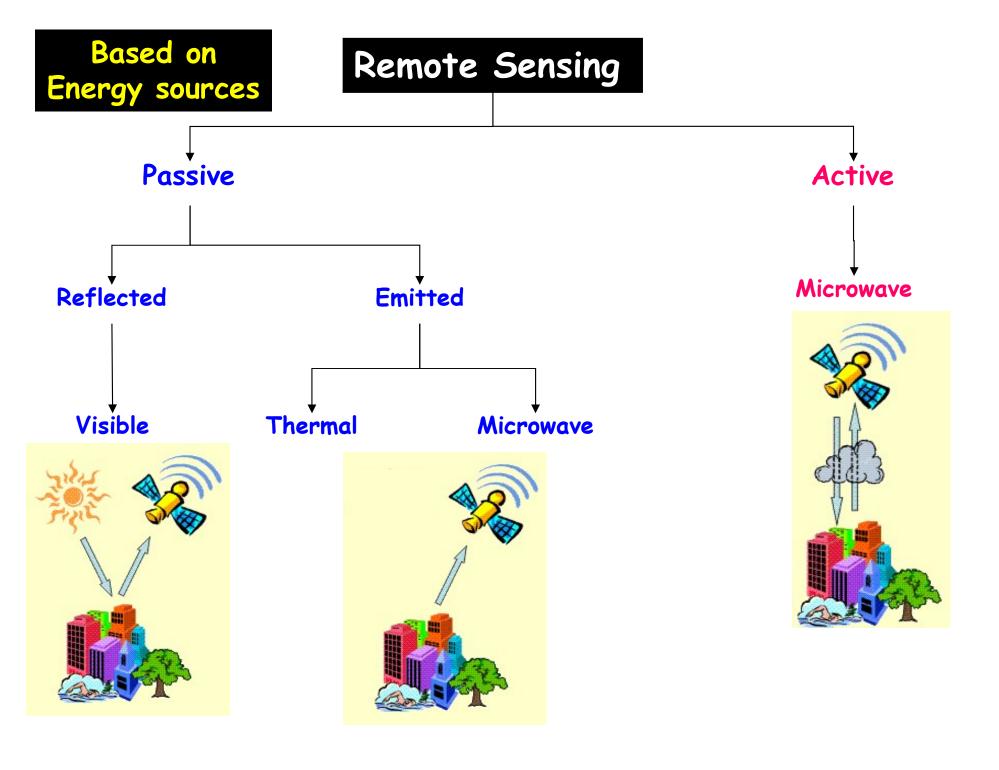




atmospheric windows

- 1. Gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes.
- 2. Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called atmospheric windows.







Satellite sensor characteristics

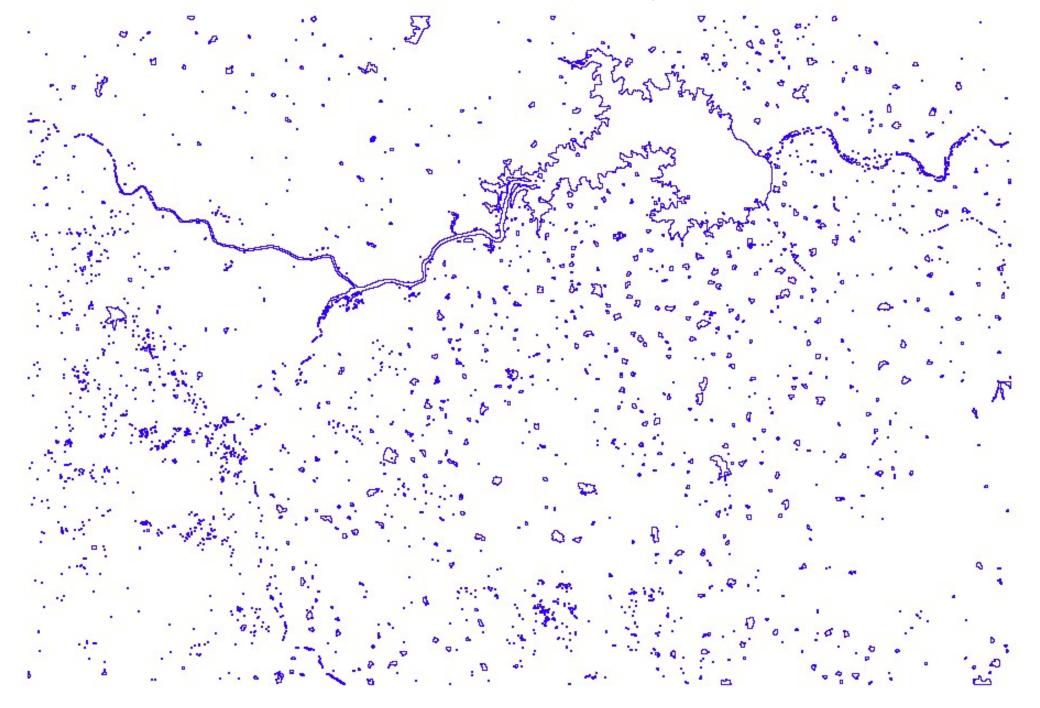
- Spatial Resolution
- Spectral Resolution
- Radiometric Resolution
- Temporal Resolution

Resolution in remote sensing refers to the ability of a sensor to capture finer details or features in an image or data.

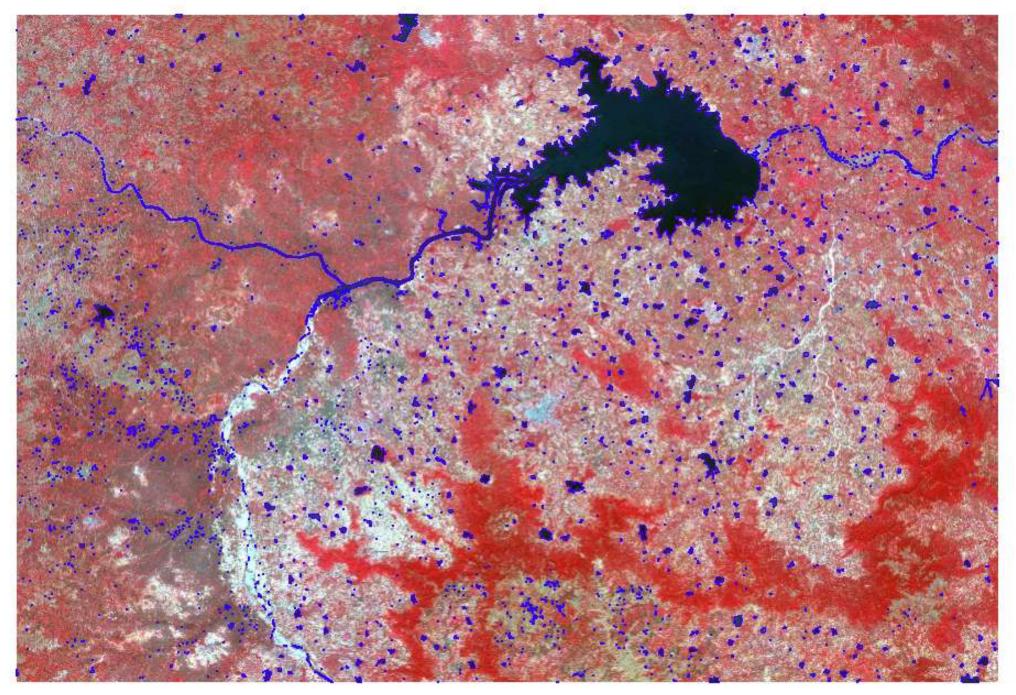
Satellite Image (Raster)



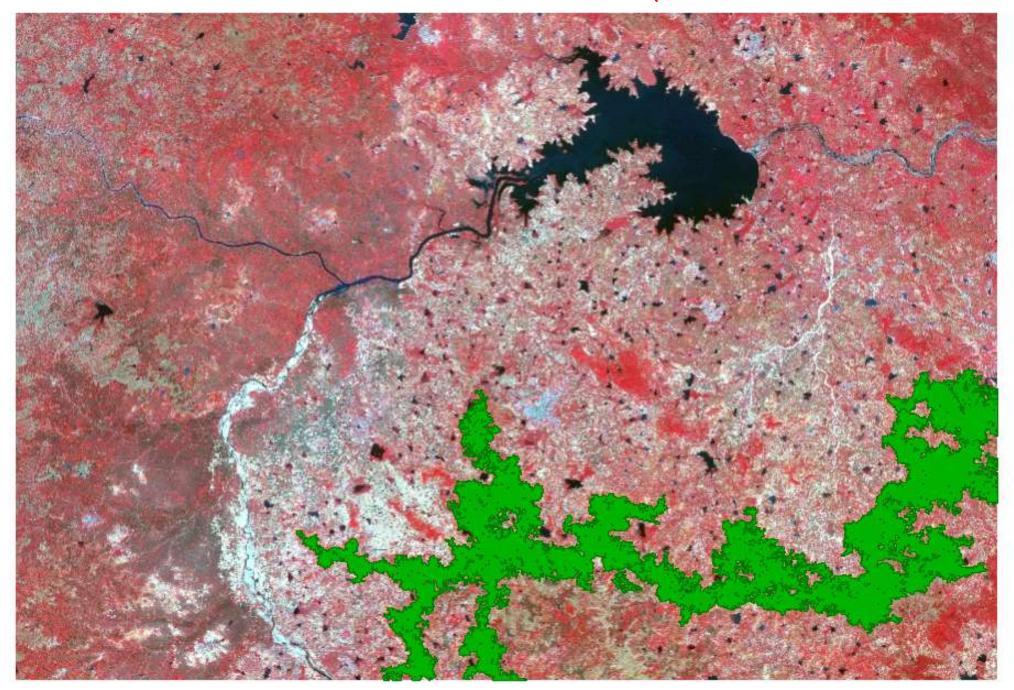
Water bodies (vectors)



Raster overlaid vectors



Raster overlaid vectors (forest)



COL COL COL COL #1 ROW #1: ROW #2: ROW #3:

Example of a simple 5-column by 3-row raster digital image.

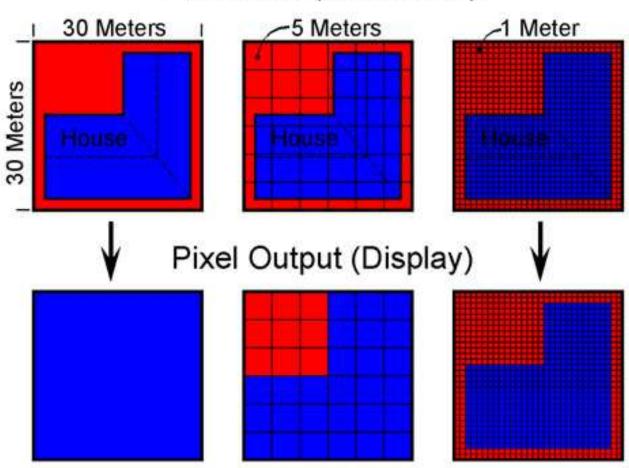
Spatial Resolution

The spatial resolution specifies the pixel size of satellite images covering the Earth's surface. The smallest spatial measurement.

High spatial resolution: 0.6 - 4 m

Medium spatial resolution: 4 - 30 m Low spatial resolution: 30 - > 1000 m

Pixel Size (Resolution)



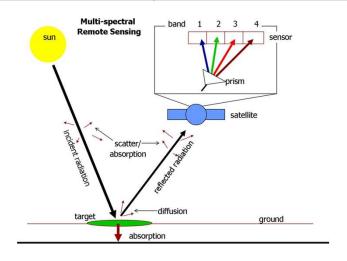
Spectral Resolution

The ability of a sensor to distinguish between different wavelengths of light.

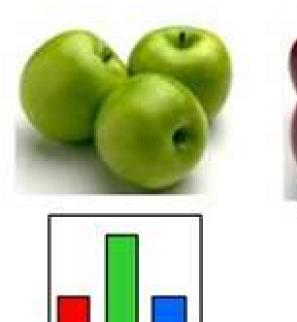
The higher the spectral resolution, the narrower the wavelength bandwidths that the sensor can detect.

Bandwidths allow for more detailed information about the surface of the Earth to be collected.

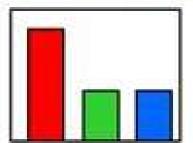
{Ο μЯς Γ΄ Ο ΧΒΈΔΒΗΜΗΔΑ ΧΙ			
⊠. şЊ ї о́ Яµ	/ şЯ β Β Ϛ	! COTO & ABHEX	ьъ ⁄ы́ СВ А ҙѬХ
		Mineral monitoring, water quality	
1 -5	High	assessment	
5 - 20	Medium	Landcover mapping	
20 - 100	Low	Urban applications	



Spectral Resolution





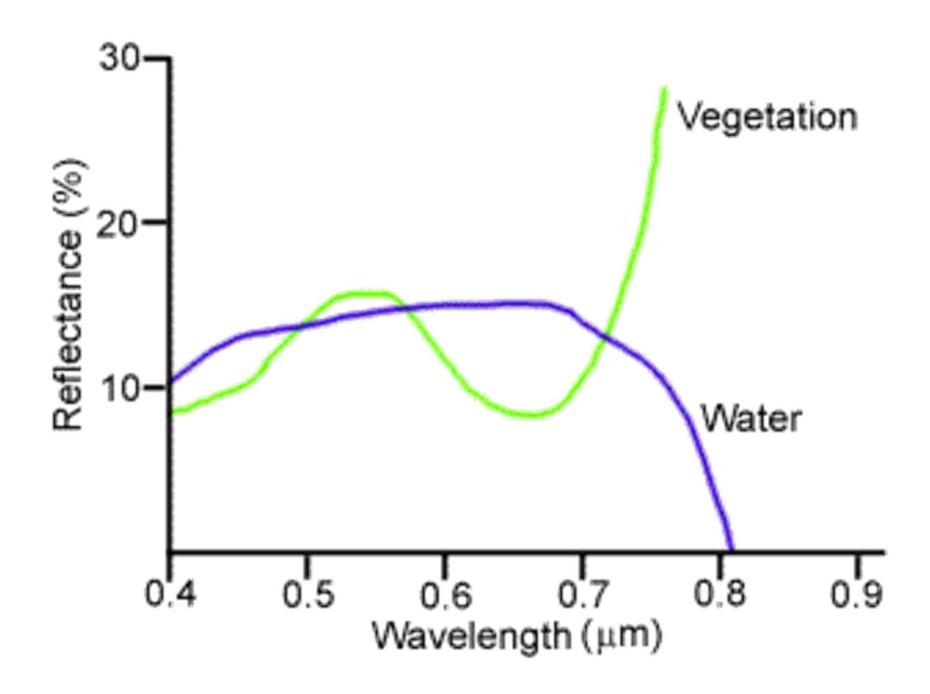


Example:

Assume apple plantation reflection between 500 -650 nm

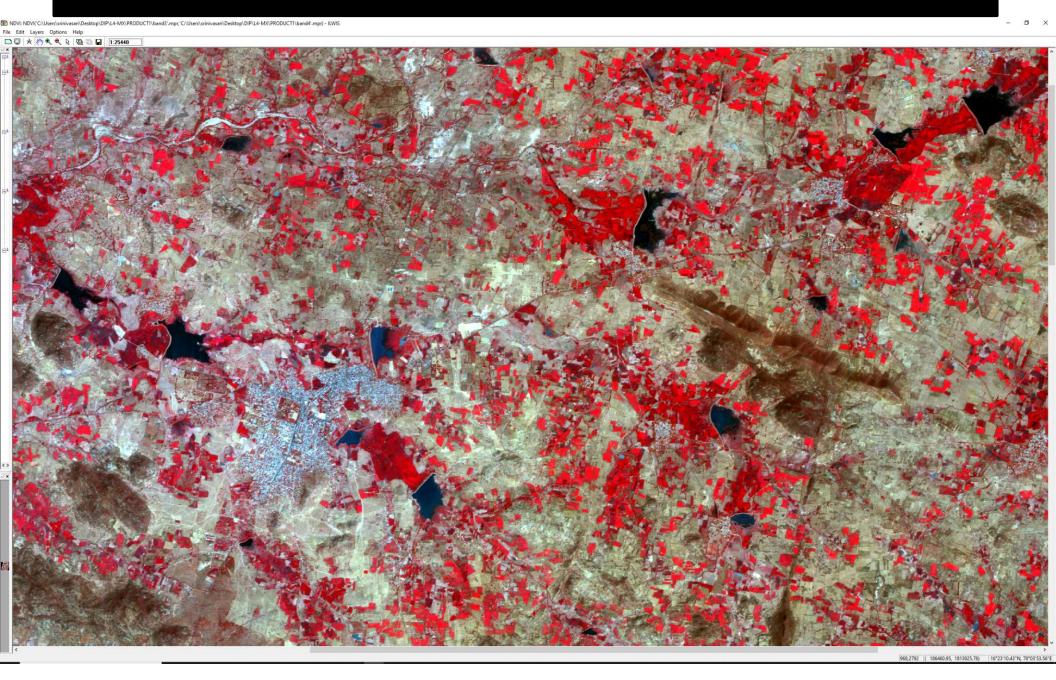
- Green apple 500-550 nm
- Red apples 600-650 nm
- Early green apples 510-520 nm
- Early red apples 660-680 nm

spectral response Or Spectral signatures



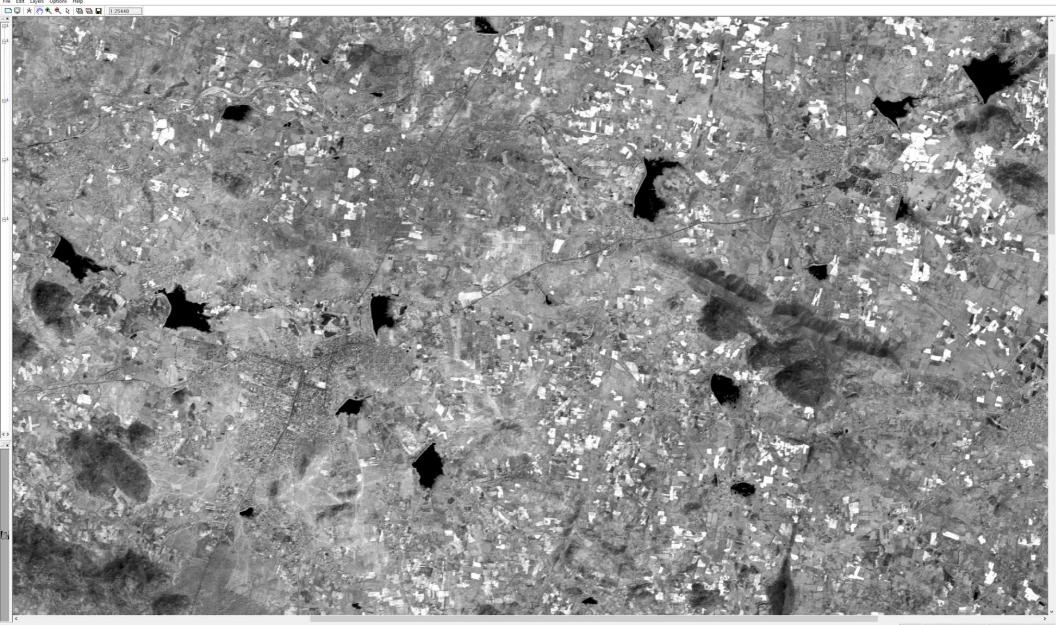
Specifications	LISS-4					
IGFOV	5.8 m at nadir (Across Track)					
Spectral Bands	B2 0.52 - 0.59 B3 0.62 - 0.68 B4 0.77 - 0.86					
Swath	23.9 km (Mx) 70 kms (Mono)					
Integration time	0.877714 msec					
Quantization	10 Bits Selected 7 Bits will be transmitted by the data handling system					

LISS-IV- FCC [(IR 770 - 860 nm), R (620 - 680 nm), G (520 – 590 nm)]



LISS-IV- IR 770 - 860 nm

NDVI: NDVI('C:\Users\srinivasan\Desktop\DIP\L4-MX\PRODUCT1\band4'.mpr) - ILWIS

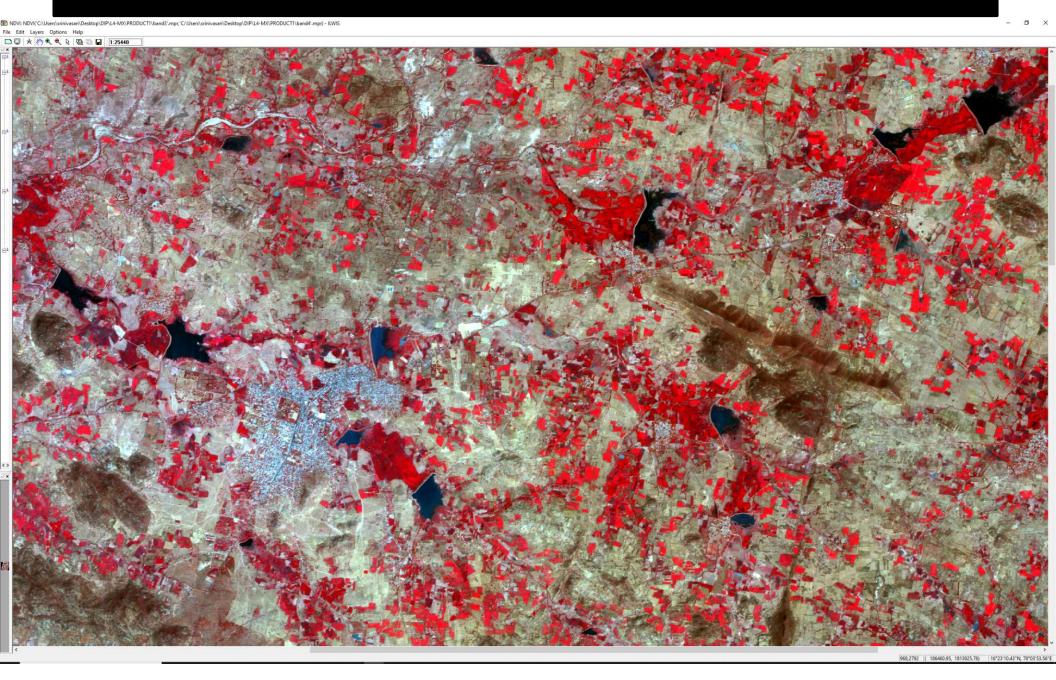


LISS-IV- R 620 - 680 nm

NDVI: NDVI('C:\Users\srinivasan\Desktop\DIP\L4-MX\PRODUCTT\band3'.mpr, 'C:\Users\srinivasan\Desktop\DIP\L4-MX\PRODUCTT\band4'.mpr) - ILWIS

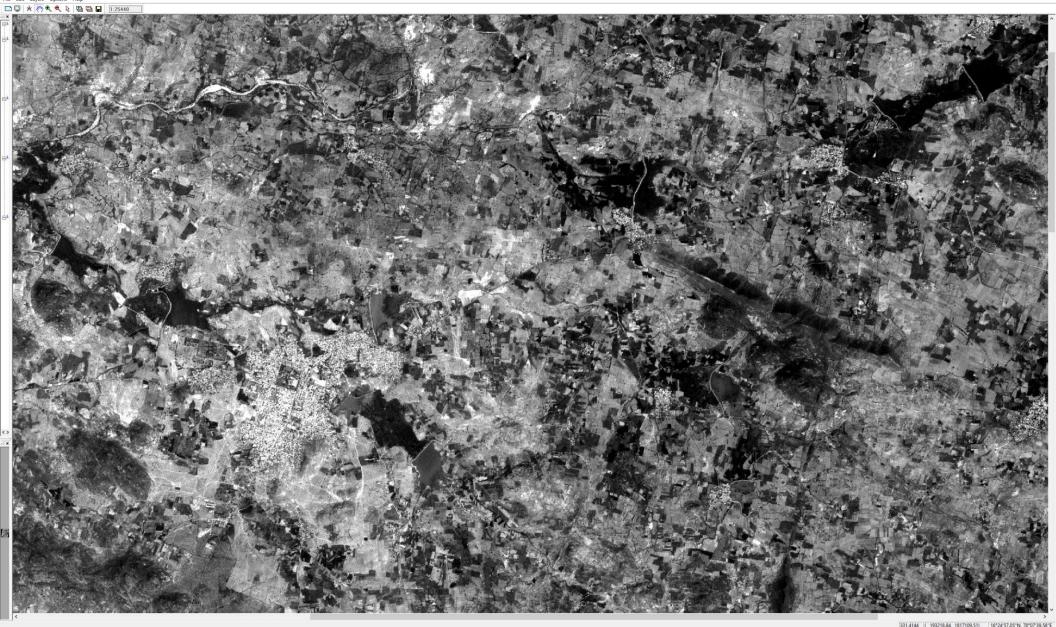
2020 / 102141 00 1017042 201 | 1692454 27981 7090700

LISS-IV- FCC [(IR 770 - 860 nm), R (620 - 680 nm), G (520 – 590 nm)]

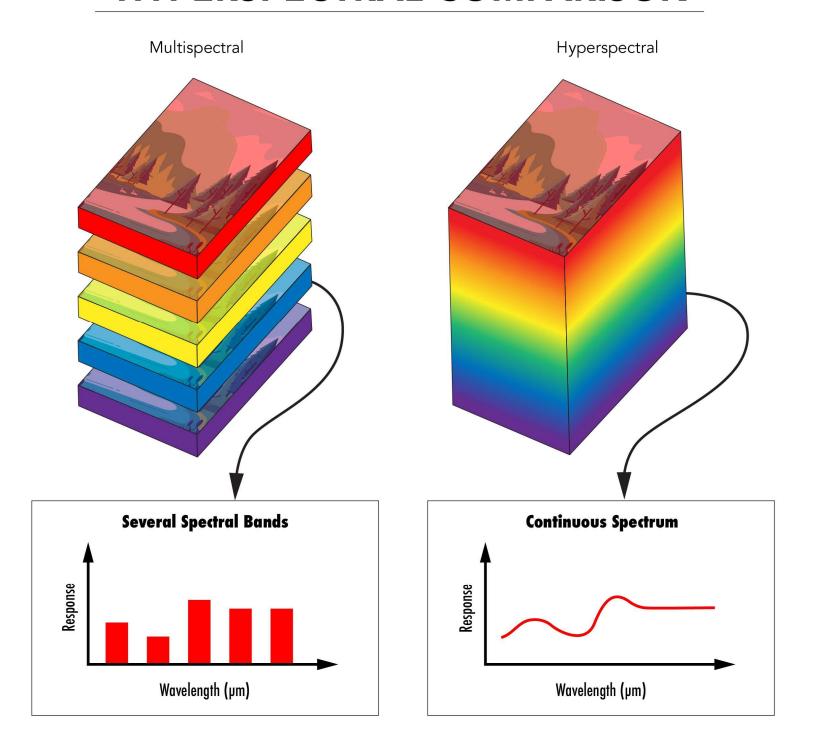


LISS-IV- G 520 - 590 μm

NDVI: NDVI('C:\Users\srinivasan\Desktop\DIP\L4-MX\PRODUCT1\band3'.mpr,'C:\Users\srinivasan\Desktop\DIP\L4-MX\PRODUCT1\band4'.mpr) - ILWIS



MULTISPECTRAL/ HYPERSPECTRAL COMPARISON

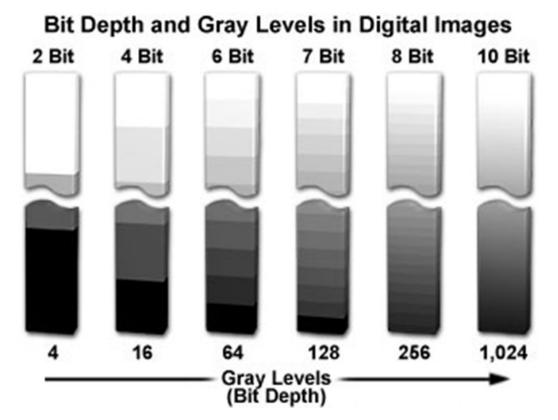


Radiometric Resolution

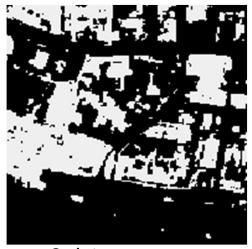
The ability of a sensor to distinguish between different levels of reflected or emitted radiation from the Earth's surface.

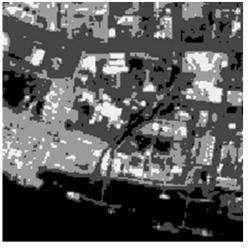
It is measured in bits, and the higher the number of bits, the more precise differences in radiation the sensor can detect.

Radiometric resolution = 2^b its



<u>Data are represented by positive DN's that vary from 0 to a selected power of 2.</u>









2-bit

 $2^2 = 4$ 0-3

4-bit

2⁴=16 0-15

8-bit

2⁸=256 0-255

16-bit

Examples:

OCM sensor 16 Bit

MODIS senor 12 Bit

AVHRR sensor 10 Bit

LISS IV(IRS-P6)8 bit

Temporal Resolution

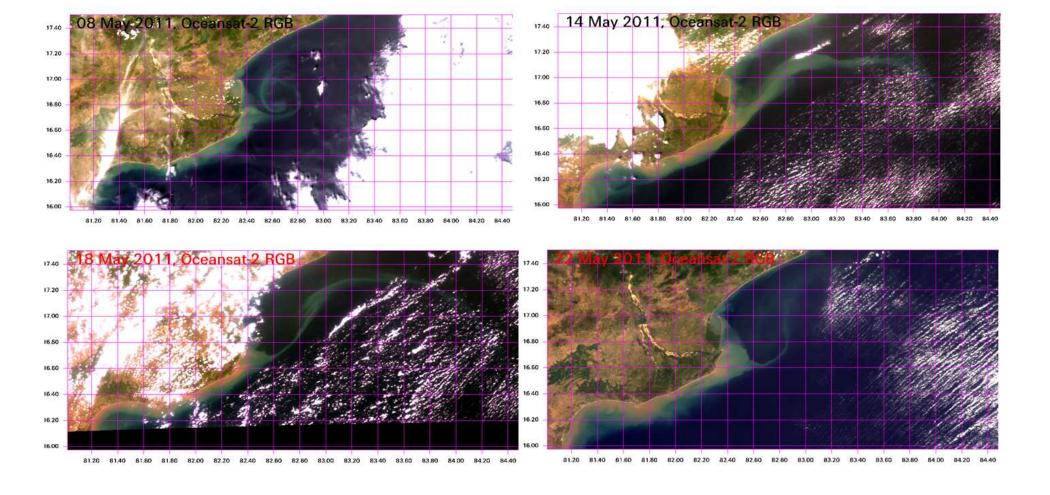
The time between images of the same area.

It is measured in days or hours, and the higher the temporal resolution, the more frequently images of the same area can be obtained.

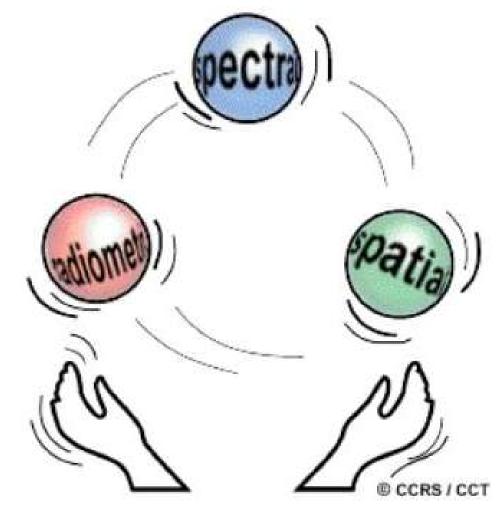
High temporal resolution: < 24 hours - 3 days

Medium temporal resolution: 4 - 16 days

Low temporal resolution: > 16 days



In summary



When engineers design a sensor for remote sensing, they need to take into consideration three key types of resolution: spatial resolution, spectral resolution, and radiometric resolution. These factors play a crucial role in determining the performance and capabilities of the sensor.

"Balancing Spatial, Spectral, and Radiometric Resolution in Remote Sensing Sensor Design"

- High spatial resolution means smaller ground resolution cells, but it reduces radiometric resolution - the ability to detect fine energy differences. To enhance radiometric resolution without sacrificing spatial resolution, the sensor must broaden the wavelength range leading to reduced spectral resolution.
- On the other hand, coarser / low spatial resolution could improve radiometric and spectral resolution. Ultimately, achieving the desired capabilities and objectives of the sensor requires finding the right balance among these three types of resolution.

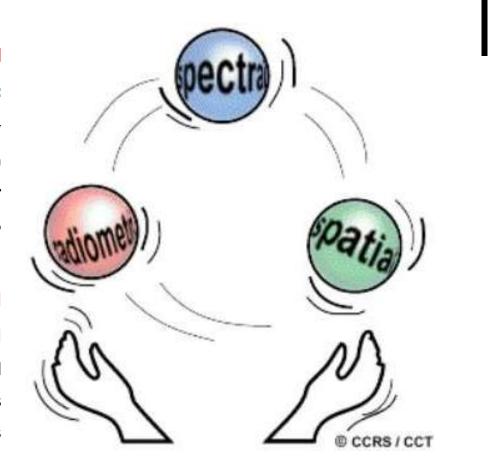


Table 1. Major specifications of present IRS series of satellites

Satellites (year)	Sensor	Spectral bands (μm)	Spatial res. (m)	Swath (km)	Radiometric res. (bits)	Repeat cycle (days)
(1988, 1991)	LISS I	0.45-0.52 (B) 0.52-0.59 (G) 0.62-0.68 (R) 0.77-0.86 (NIR)	72.5	148	7	22
	LISS-II	Same as LISS-I	36.25	74	7	22
IRS-P2 (1994)	LISS-II	Same as LISS-I	36.25	74	7	24
(1995, 1997) V	LISS-III	0.52-0.59 (G), 0.62-0.68 (R) 0.77-0.86 (NIR)	23.5	141	7	24
		1.55-1.70 (SWIR)	70.5 (SWIR)	148	1:	24
	WiFS	0.62-0.68 (R) 0.77-0.86 (NIR)	188	810	7	24 (5)
	PAN	0.50-0.75	5.8	70	6	24 (5)
, ,	MOS-A	0.755-0.768(4 bands)	1570×1400	195	16	24
	MOS-B	0.408-1.010(13 bands)	520 × 520	200	16	24
	MOS-C	1.6 (1 band)	520 × 640	192	16	24
W	WiFS	0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (SWIR)	188	810	7	5
IRS-P4 (1999) OCM	OCM	0.402-0.885 (8 bands)	360 × 236	1420	12	2
	MSMR	6.6, 10.65, 18, 21 GHz (V & H)	150, 75, 50 and 50 km respectively	1360	-	2 2
IRS-P6 (2003) LISS-IV LISS-III AWiFS	LISS-IV	0.52-0.59 (G) 0.62-0.68 (R)	5.8	70	10 (7)	24 (5)
	LISS-III	0.77-0.86 (NIR) 0.52-0.59 (G),	3.8	70	10 (7)	24 (5)
		0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (SWIR)	23.5	141	7	24
	AWiFS	0.52-0.59 (G), 0.62-0.68 (R) 0.77-0.86 (NIR) 1.55-1.70 (SWIR)	56	737	10	24(5)
IRS-P5 (Cartosat-1) 2005	PAN (Fore (+26°) & Aft (-5°)	0.50-0.85	2.5	30	10	5
Cartosat-2 (2007)	PAN	0.50-0.85	0.8	9.6	10	5

Thankyou...

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