# Geospatial Data Analytics

by

**Dr. Dubacharla Gyaneshwar**

Department of Computer Science and Engineering

Indian Institute of Information Technology Raichur (IIIT-R)

**C slot – CS321 – 3 credit course**

# Contents

- Introduction to remote sensing
- Importance and overview of application
- Principles of remote sensing
- Types of remote sensing
- Remote sensing platforms
- Q&A session

# Course Syllabus

- Introduction to geospatial data
- Remote sensing and image analysis
- Point cloud data and LiDAR
- Spatial data analysis and modelling
- Geospatial data visualization and applications

# What is Remote sensing?

What is remote sensing ?

What is sensing ?

Is it important?

# Remote sensing

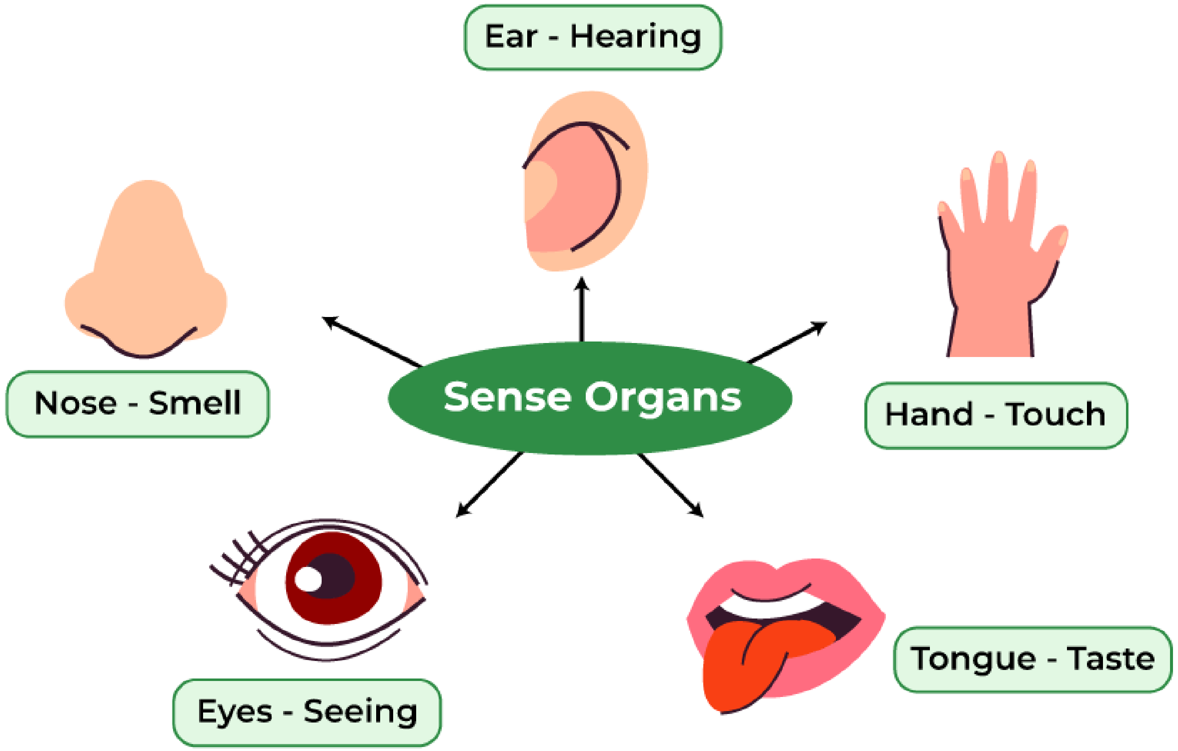
## Our five senses

- ❑ Sight
- ❑ Hearing
- ❑ Smell

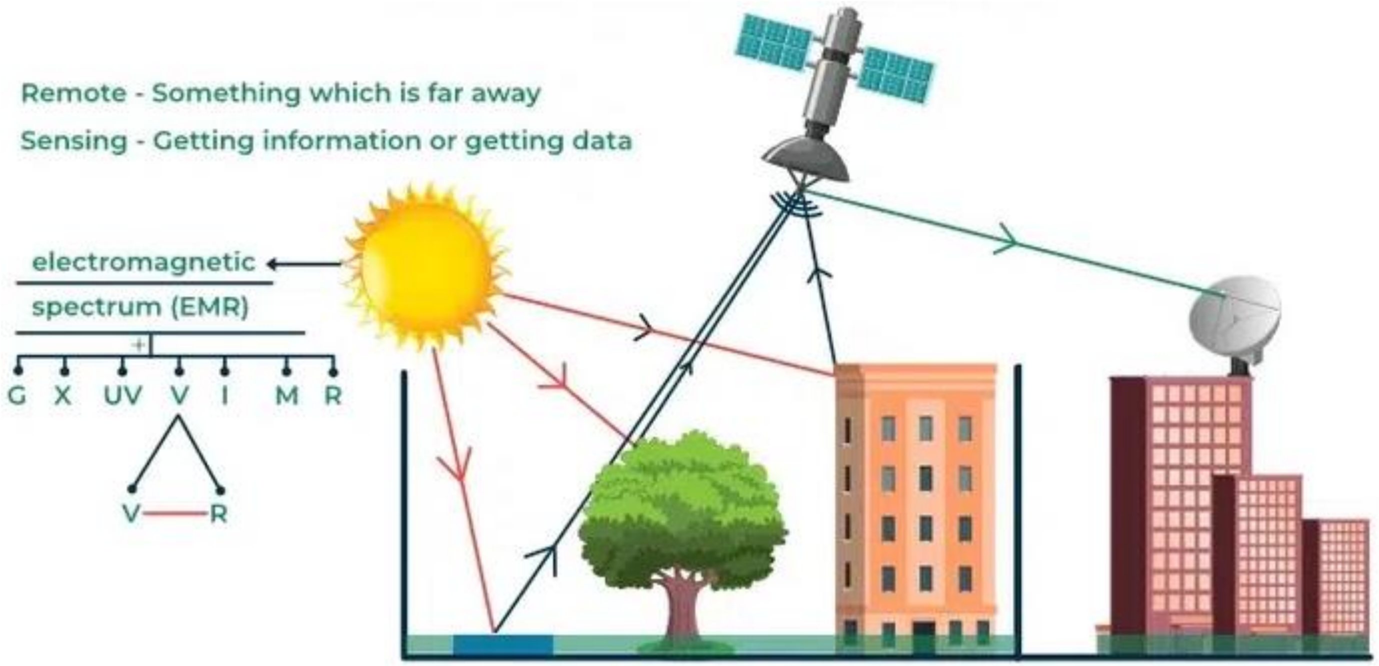
Remote sensing

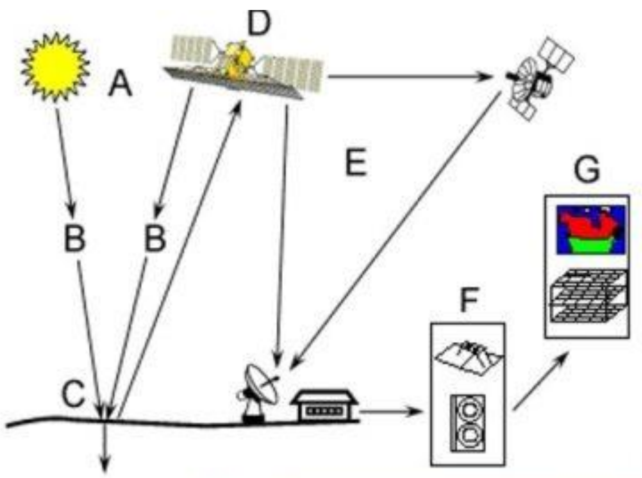
- ❑ Touch
- ❑ Taste

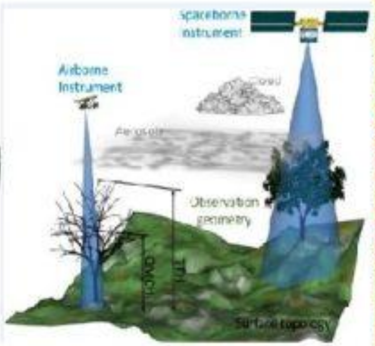
Only sensing



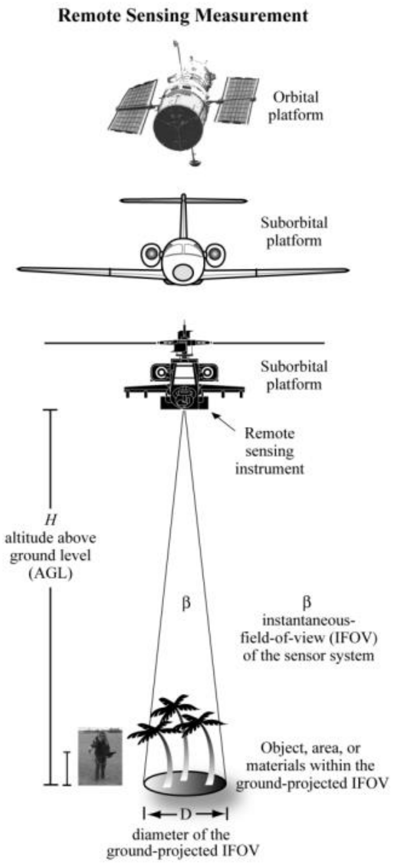
# What is Remote sensing?

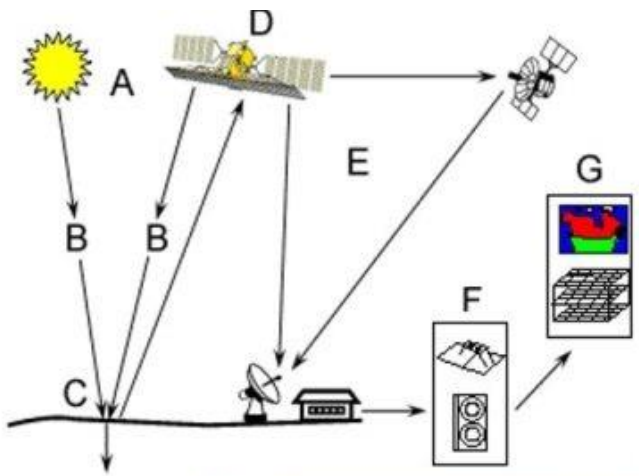


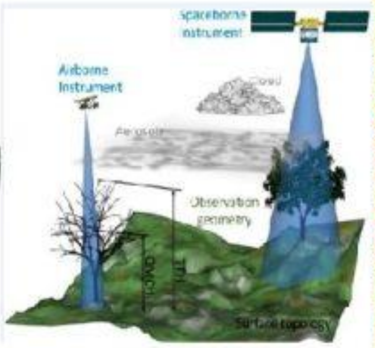



# What is Remote sensing?



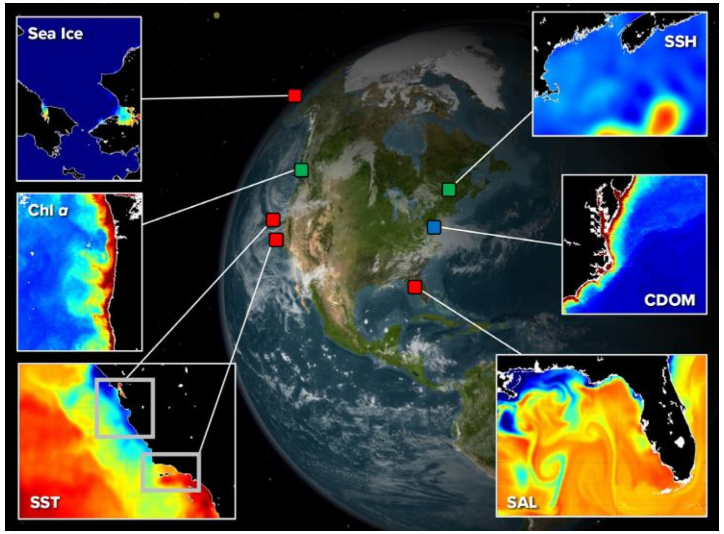




**<u>Elements of remote sensing:</u>**

1. Energy Source or Illumination (A)
2. Radiation and the Atmosphere (B)
3. Interaction with the Target (C)
4. Recording of Energy by the Sensor (D)
5. Transmission, Reception, and Processing (E)
6. Interpretation and Analysis (F)
7. Application (G)

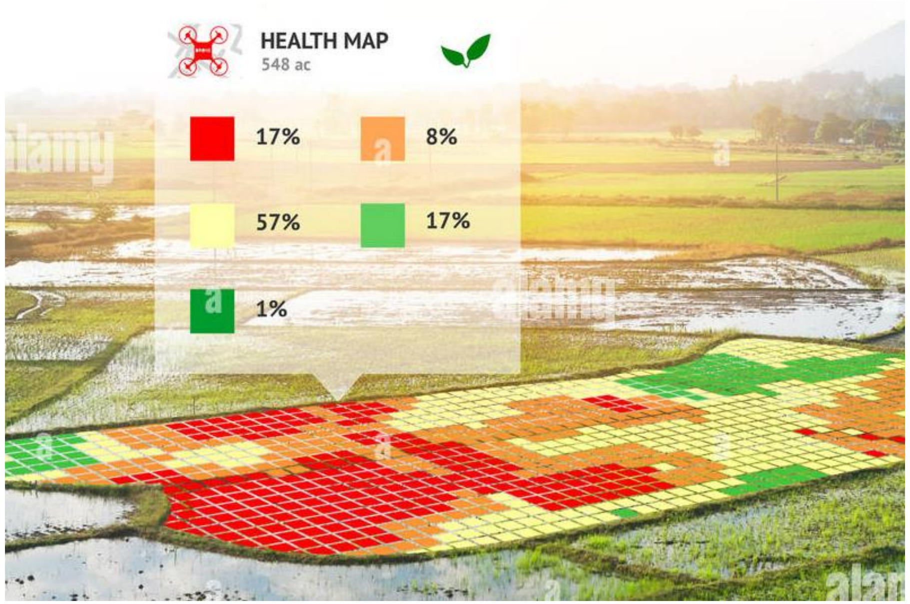
# Why is Remote sensing Important?

- Remote sensing makes it **possible to collect data on dangerous or inaccessible areas**.
- It provides **real-time updates**, and **does not require active human assistance**.
- Examples like monitoring deforestation, tracking ocean oil spills, mapping terrain, and so on.

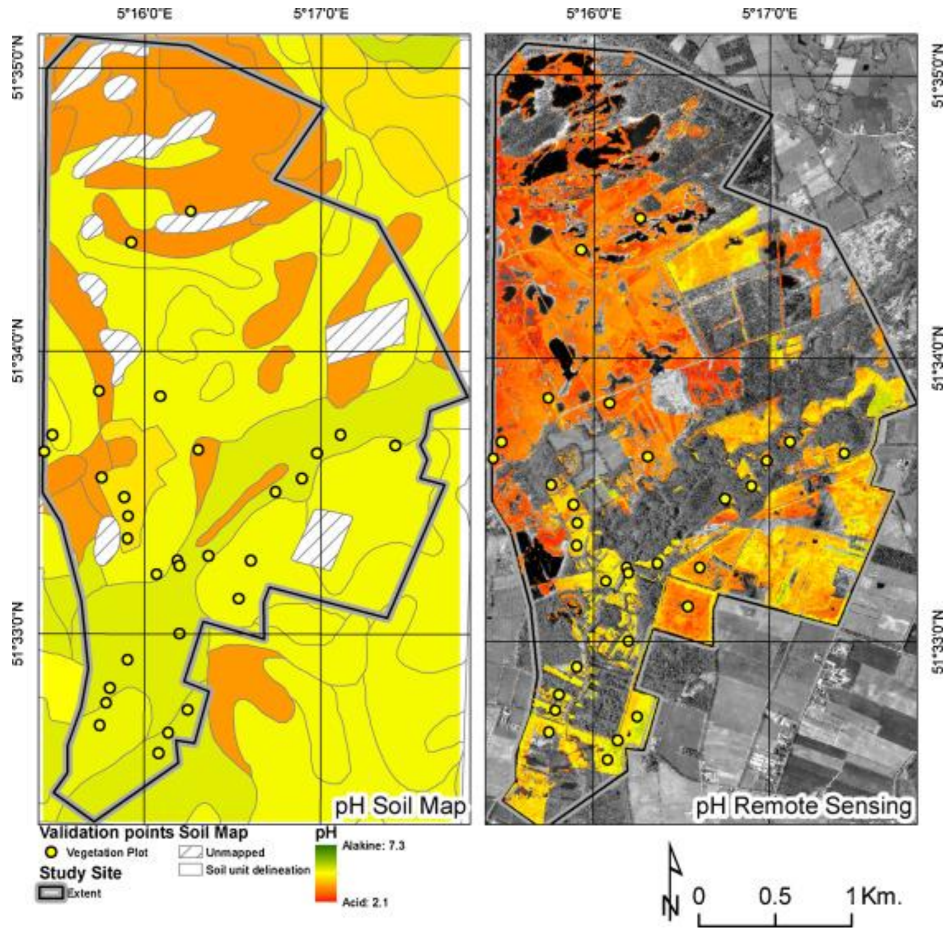


# Remote sensing Applications

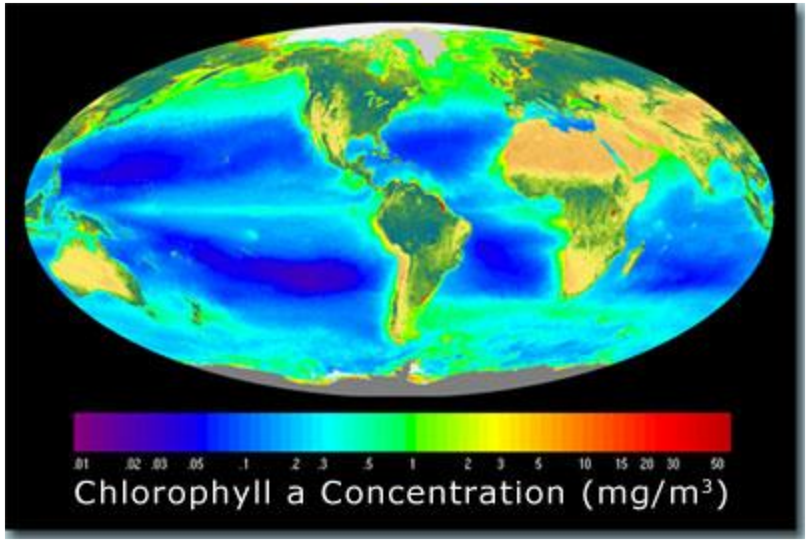
## Precision farming




## Observing soil conditions



# Remote sensing Applications

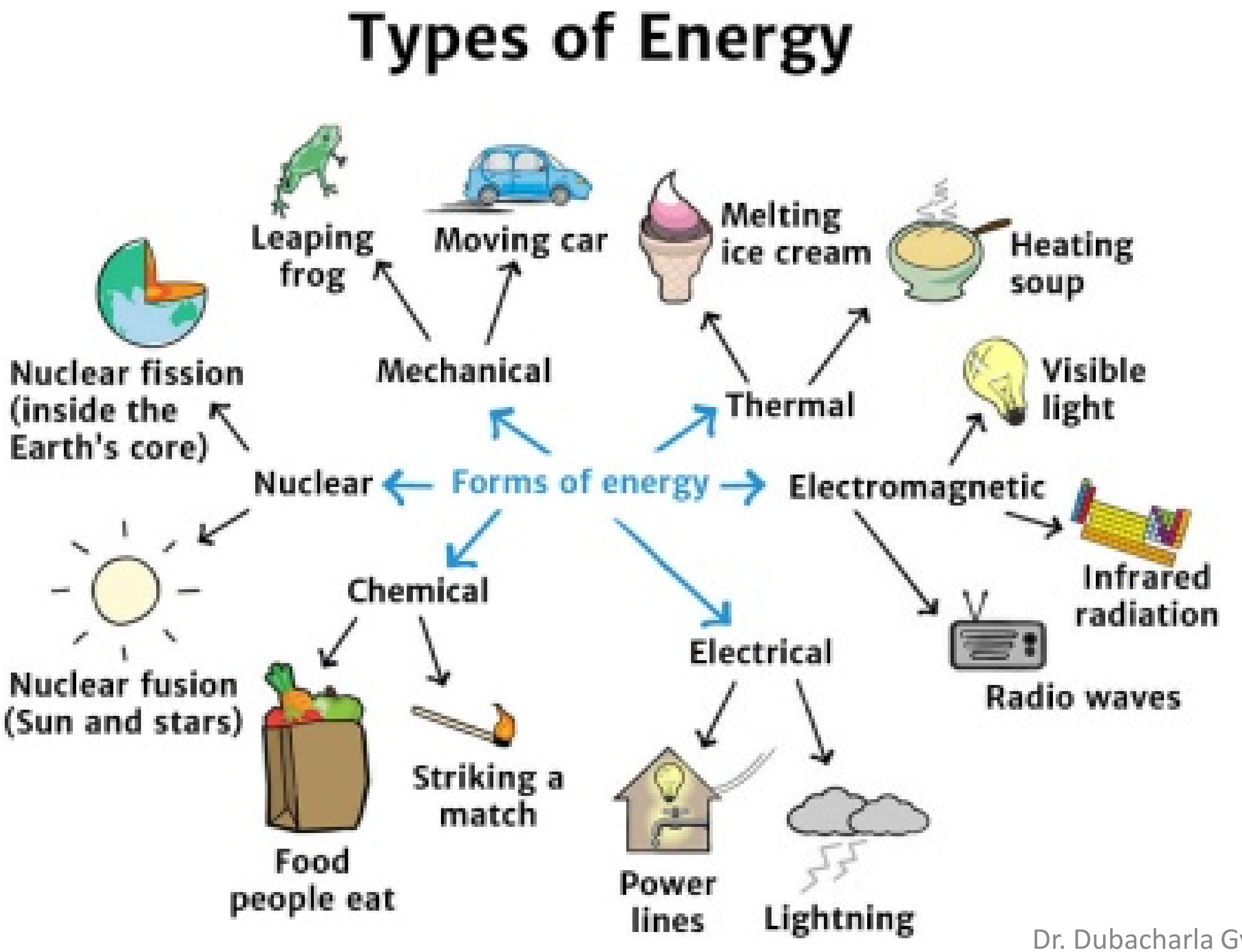



- **Measuring chlorophyll in the surface water is an indication of how much primary production is occurring in the surface of the ocean.**

A food web displaying the connections between primary producers (phytoplankton) and consumers of increasing trophic levels (zooplankton – top predators).
Credit: MBARI

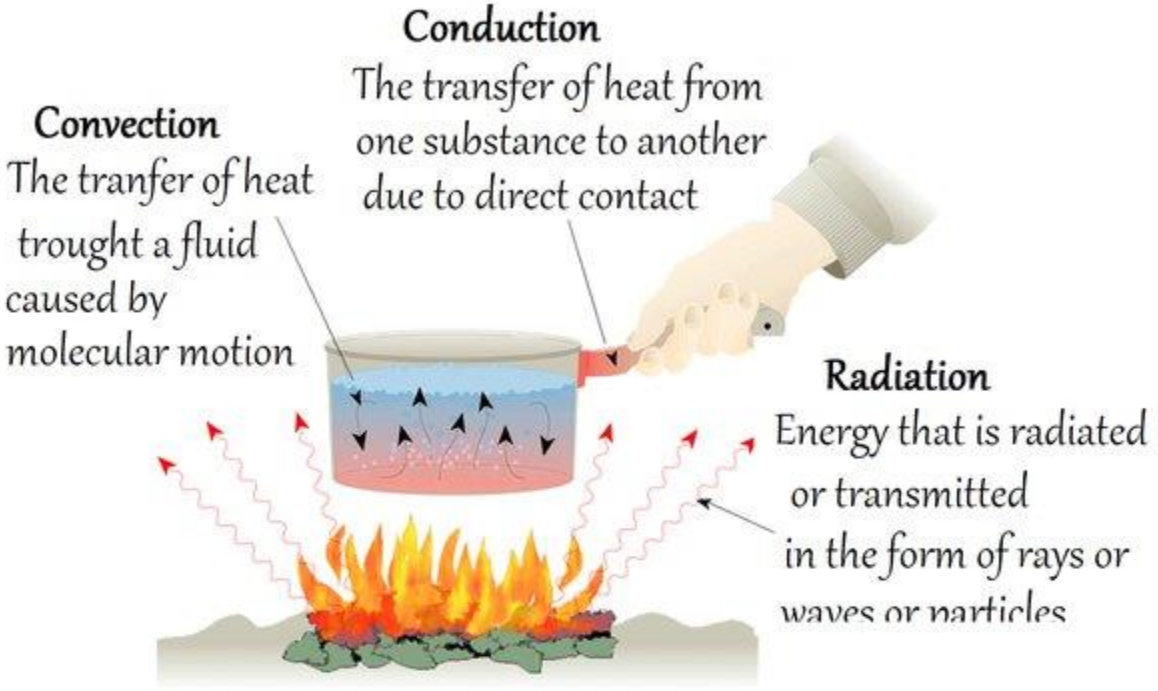
- **Remote sensing for <u>disaster management</u> relies on various technologies, including satellite imagery, aerial photography, LiDAR, synthetic aperture radar (SAR), and thermal sensors.**

# Forms of Energy



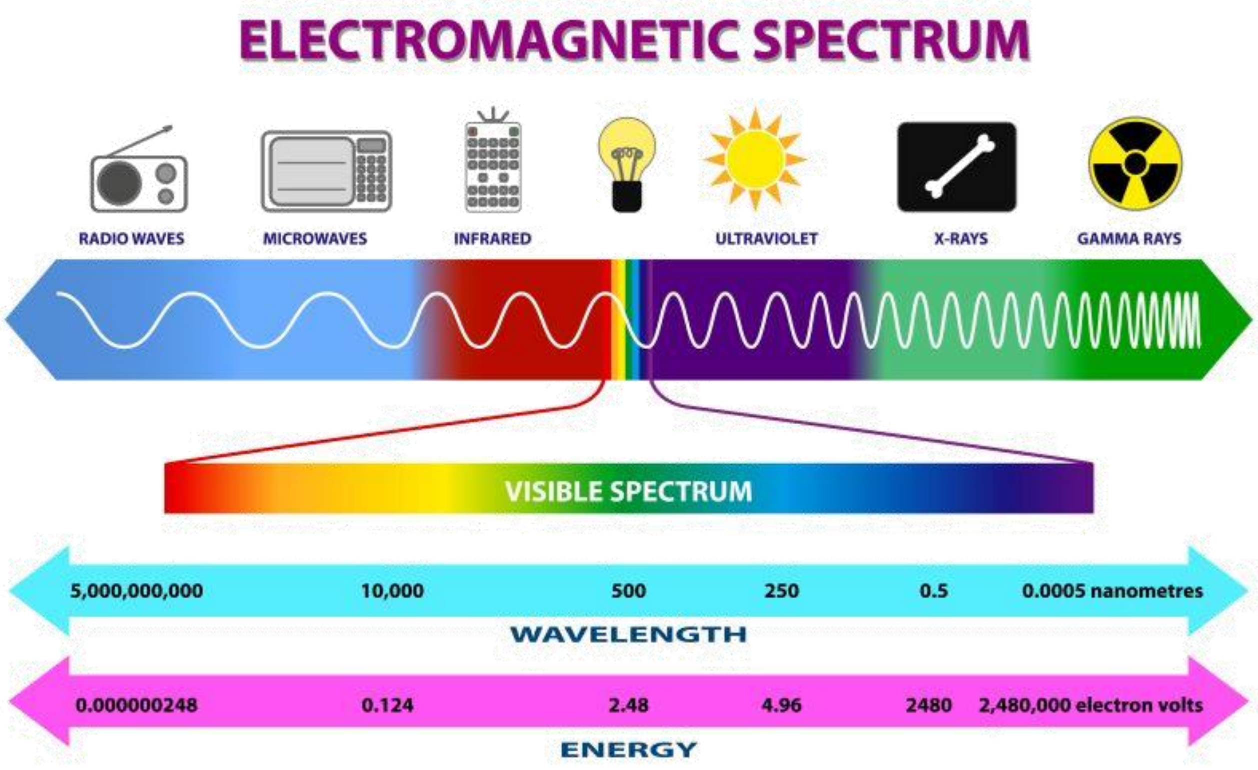

- ❑ **Visible light (optical energy)**
- ❑ **Infrared (IR) energy**
- ❑ **Microwave energy**
- ❑ **UV**
- ❑ **X-ray and many more forms**

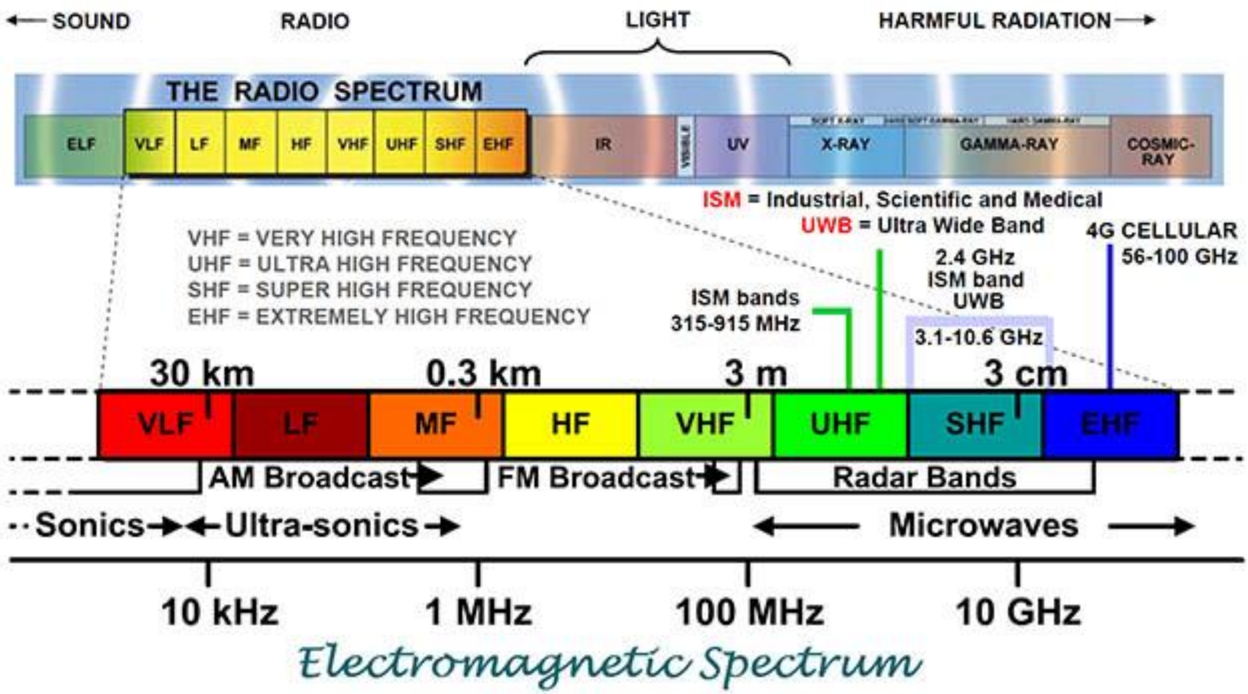
# Energy transfer in Remote sensing




- ❖**Electromagnetic radiation (EMR) is the form of energy transfer <u>that works in a vacuum</u> (like the space between the sun and earth).**
- ❖**EMR is our cosmic courier, shuttling data across the universe.**

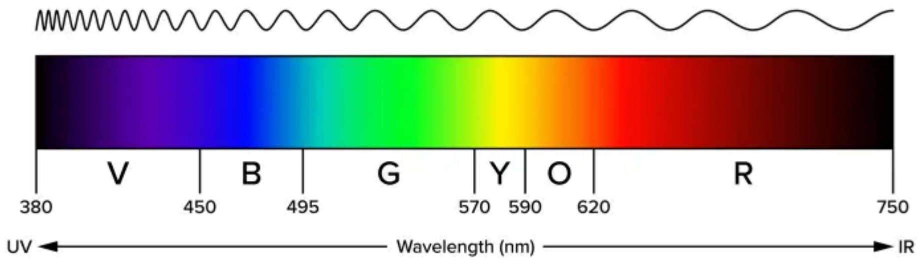
# Electromagnetic spectrum



# Electromagnetic spectrum

## Visible Spectrum

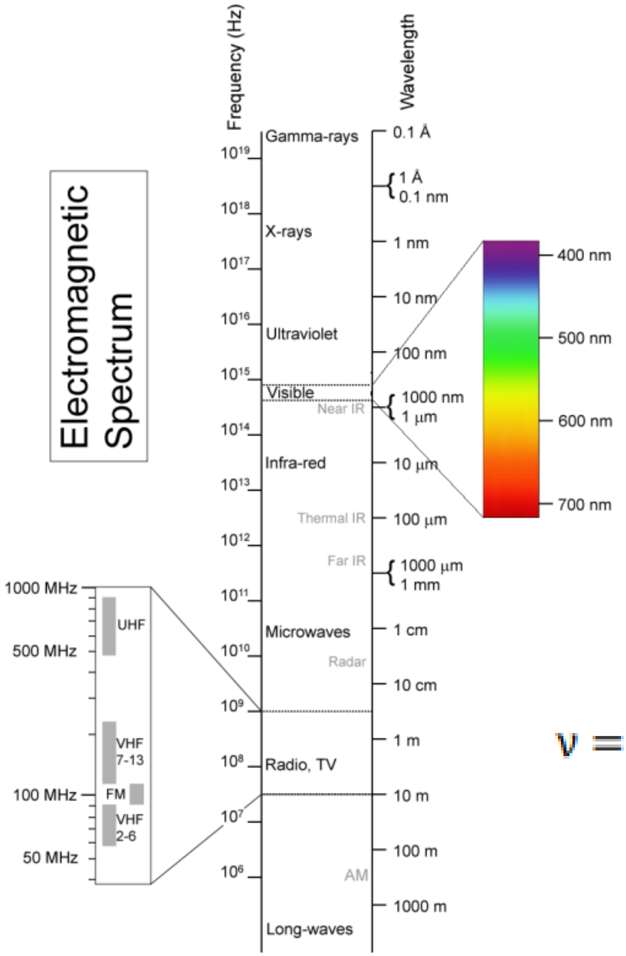



| Color | Wavelength (nm) | Frequency (THz) | Photon Energy (eV) |
|---|---|---|---|
| Violet | 380 – 450 | 670 – 790 | 2.75 – 3.26 |
| Blue | 450 – 485 | 620 – 670 | 2.56 – 2.75 |
| Cyan | 485 – 500 | 600 – 620 | 2.48 – 2.56 |
| Green | 500 – 565 | 530 – 600 | 2.19 – 2.48 |
| Yellow | 565 – 590 | 510 – 530 | 2.10 – 2.19 |
| Orange | 590 – 625 | 480 – 510 | 1.98 – 2.10 |
| Red | 625 – 750 | 400 – 480 | 1.65 – 1.98 |

E.M Radiation, as well as Solar radiation is commonly classified on the basis of radiation wave lengths (λ) into several regions or Bands.

| Band | Wave length(λ) nm | Atmospheric effects |
|---|---|---|
| γ -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 |
| Thermal - IR | 3000 - 14000 | Absorption of specific wave lengths by CO2, O3, AND Water Vapour |
| Micro wave | 1 mm - 1 m | Less atmospheric effects |

# Electromagnetic spectrum




There are a number of classifications of infrared IR:

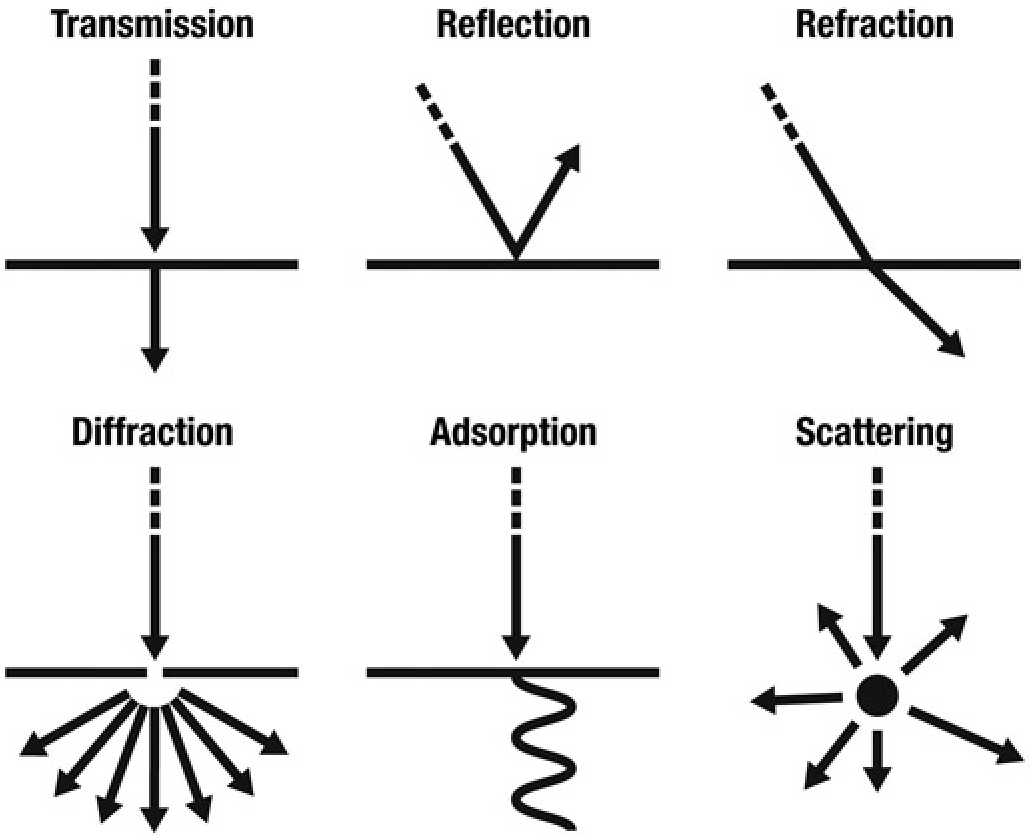
| | | |
|---|---|---|
| VNIR = visible light and near-IR | 400 to 1400 nm | 0.4 to 1.4 µm |
| SWIR = Shortwave Infrared | 1400 to 3000 nm | 1.4 to 3 µm |
| TIR =-Thermal Infrared | 8000 to 15000 nm | 8 to 15 µm |

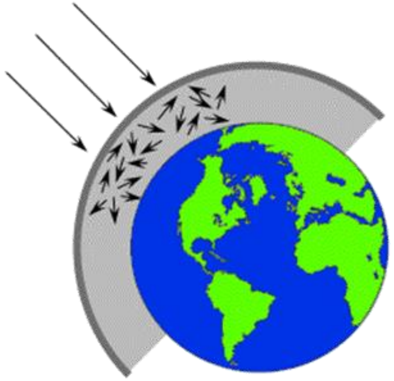
| Designation | Abbreviation | Wavelength |
|---|---|---|
| Near-Infrared | NIR | (0.7–1) to 5 µm |
| Mid-Infrared | MIR | 5 to (25–40) µm |
| Far-Infrared | FIR | (25–40) to (200–350) µm. |

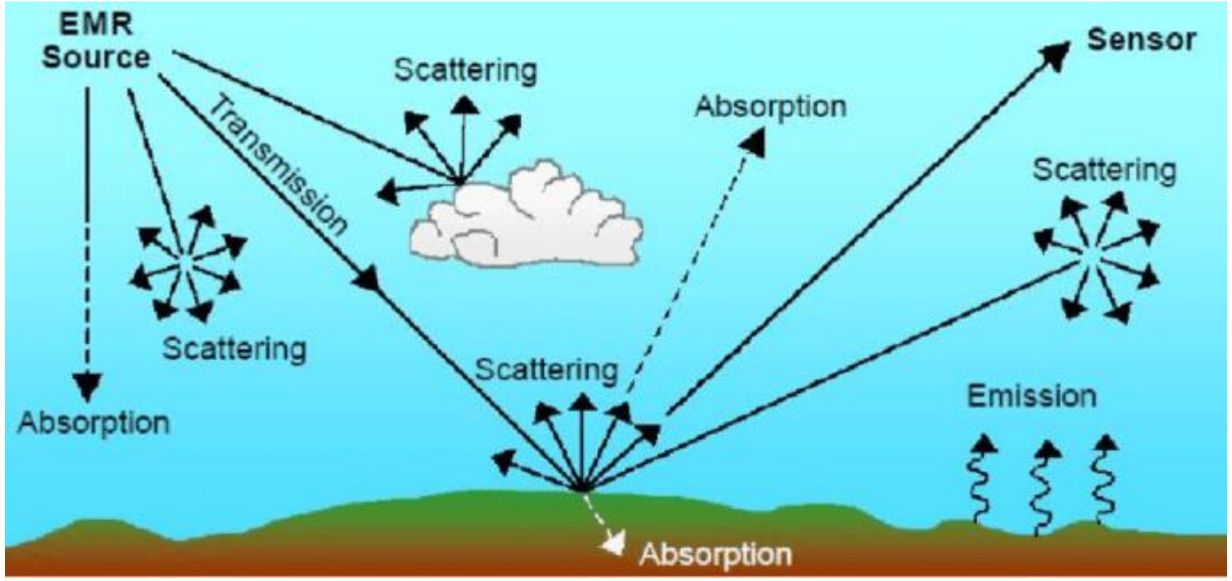
$$\nu = \frac{c}{\lambda} \text{ and } \lambda = \frac{c}{\nu}$$

| name | wavelength range | radiation source | surface property of interest |
|---|---|---|---|
| Visible (V) | 0.4–0.7 µm | solar | reflectance |
| Near InfraRed (NIR) | 0.7–1.1 µm | solar | reflectance |
| Short Wave InfraRed (SWIR) | 1.1–1.35 µm<br>1.4–1.8 µm<br>2–2.5 µm | solar | reflectance |
| MidWave InfraRed (MWIR) | 3–4 µm<br>4.5–5 µm | solar, thermal | reflectance, temperature |
| Thermal or LongWave InfraRed (TIR or LWIR) | 8–9.5 µm<br>10–14 µm | thermal | temperature |
| microwave, radar | 1 mm–1 m | thermal (passive), artificial (active) | temperature (passive), roughness (active) |

# Interaction of Light





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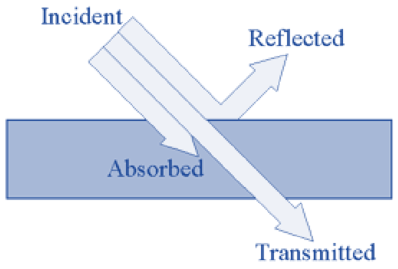



Total energy (E) = Absorption (A) + Transmission (T) + Reflection (R)

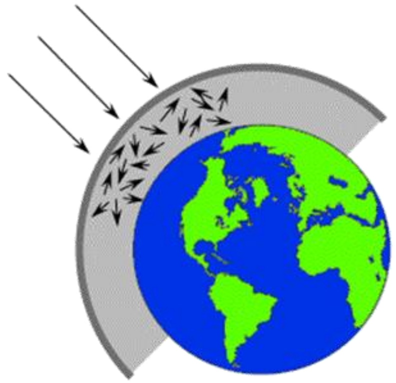
$$\frac{\text{Total energy (E)}}{\text{Total energy (E)}} = \frac{\text{Absorption (A)}}{\text{Total energy (E)}} + \frac{\text{Transmission (T)}}{\text{Total energy (E)}} + \frac{\text{Reflection (R)}}{\text{Total energy (E)}}$$

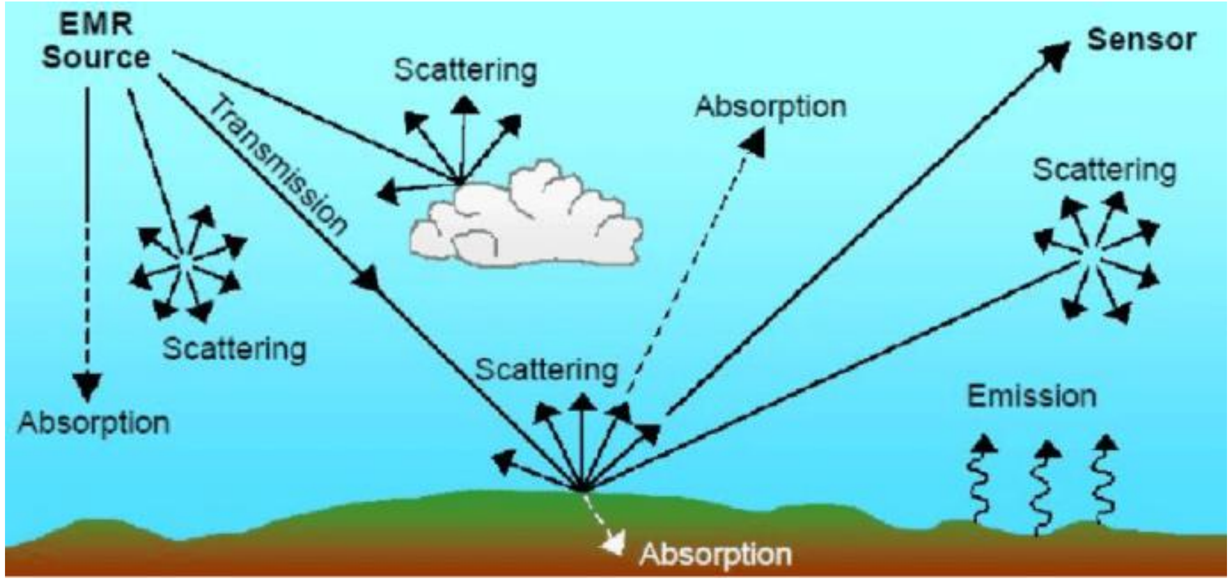
1= **Absorbance +Transmittance+Reflectance**

If Transmittance = 0

Reflectance = 1 - Absorbance

Absorbance = 1 - Reflectance





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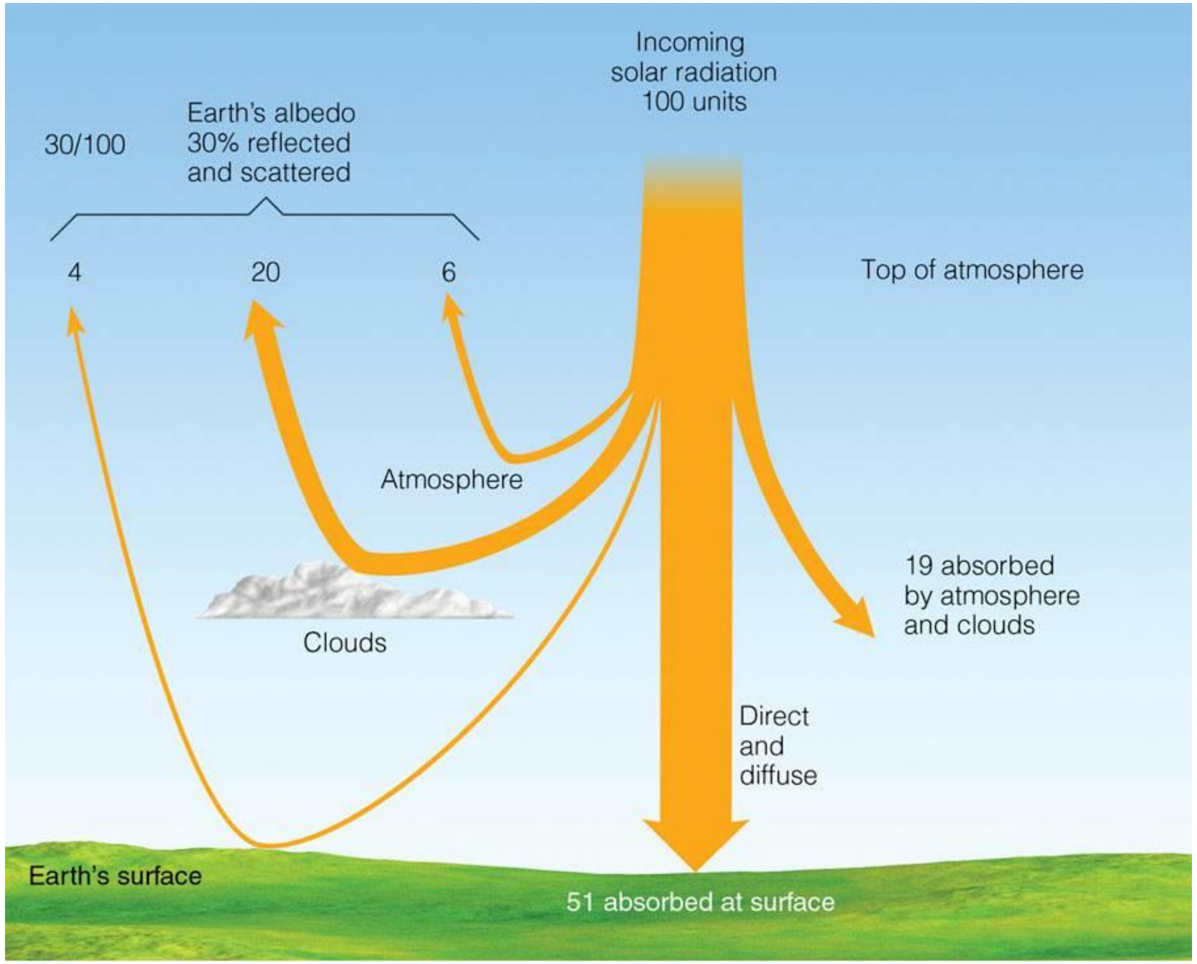
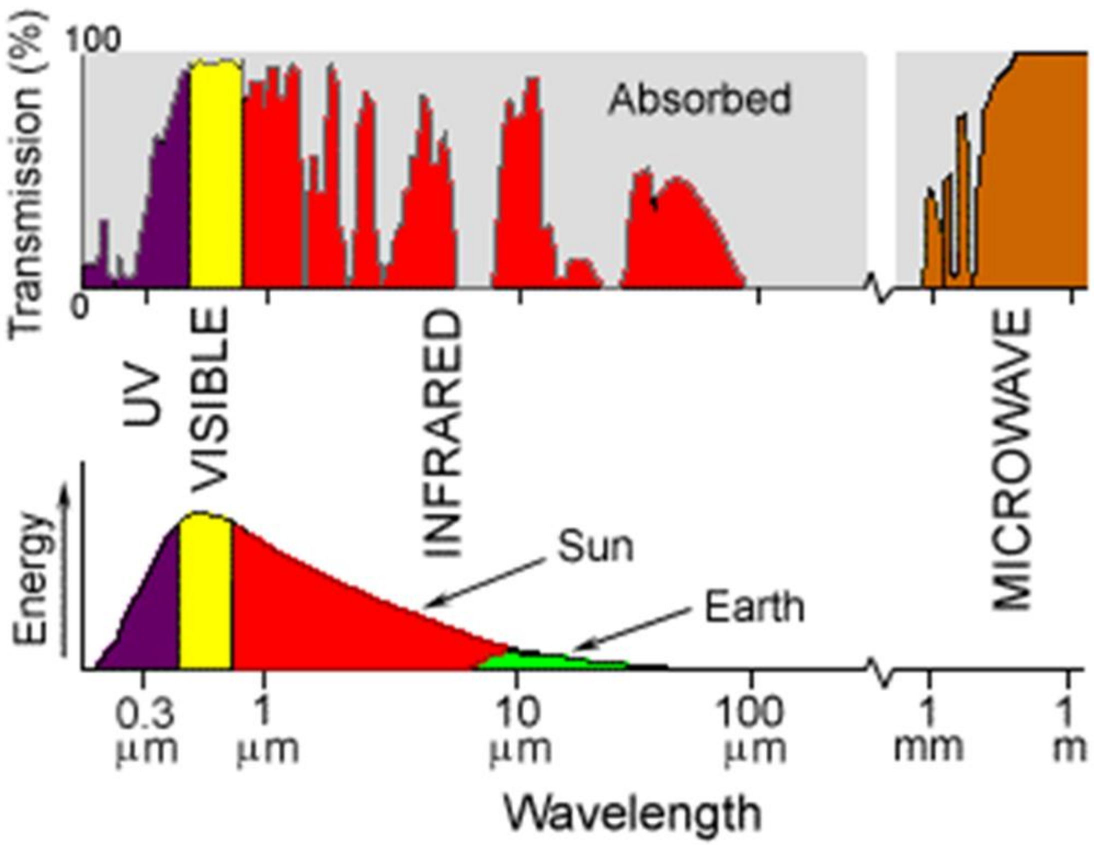
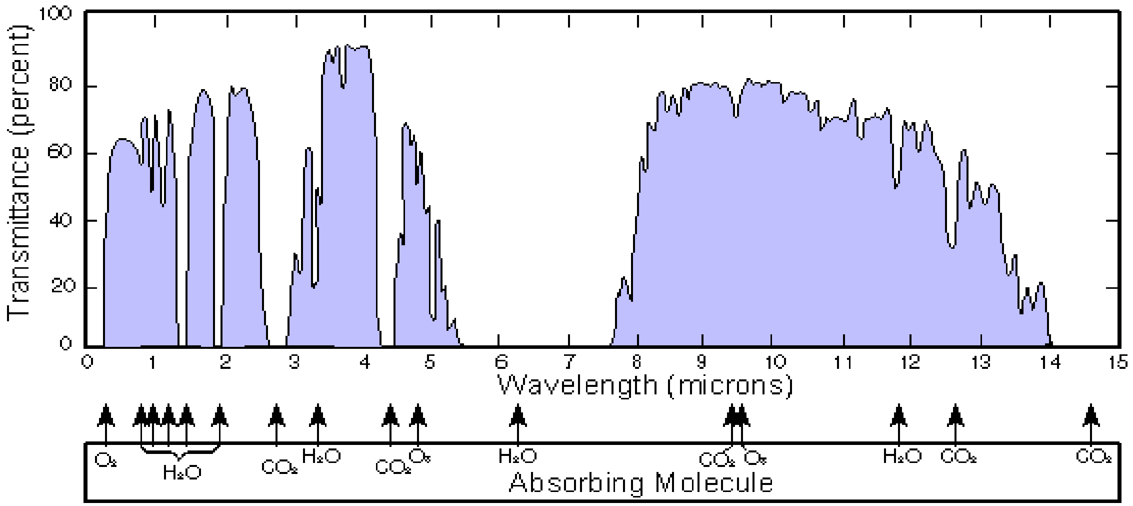
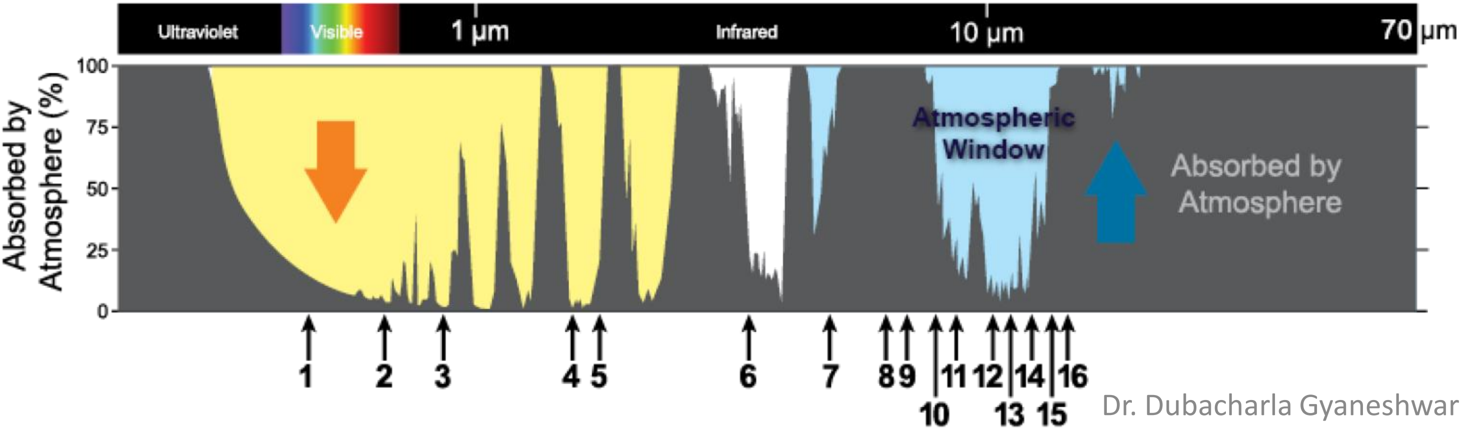
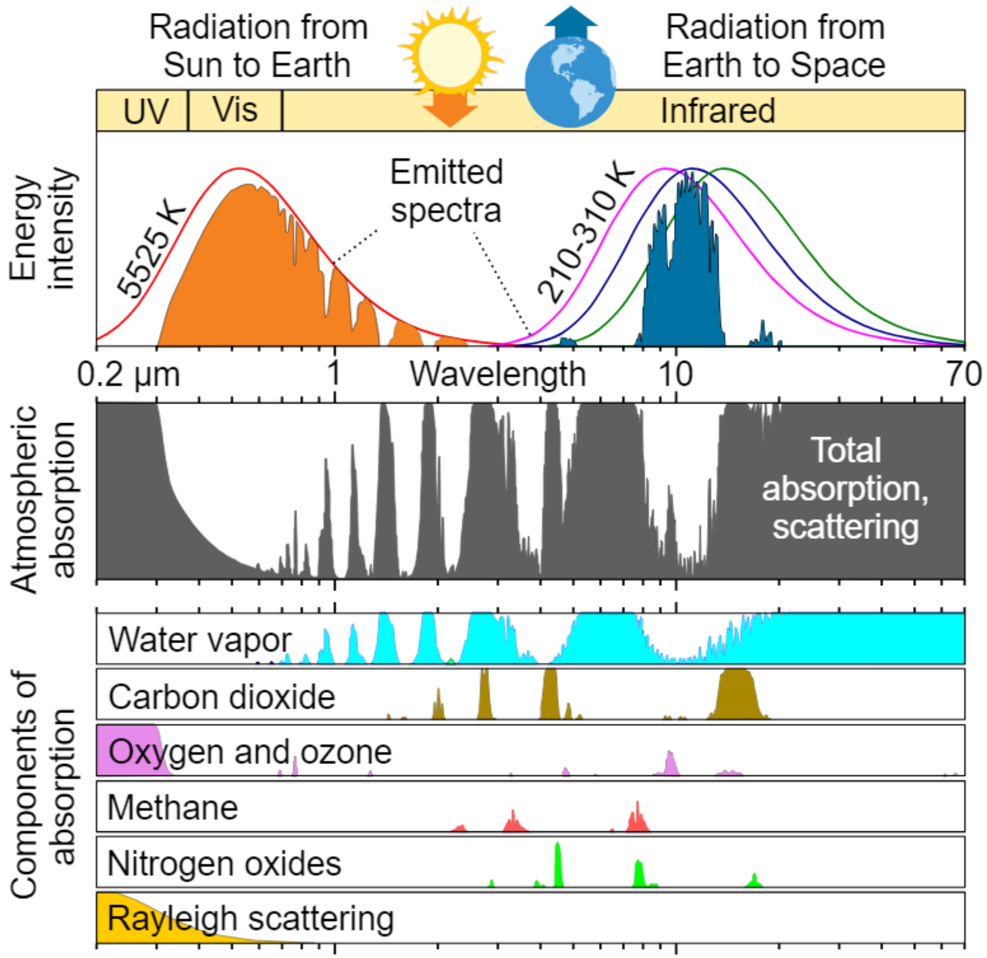


# Interaction of Light

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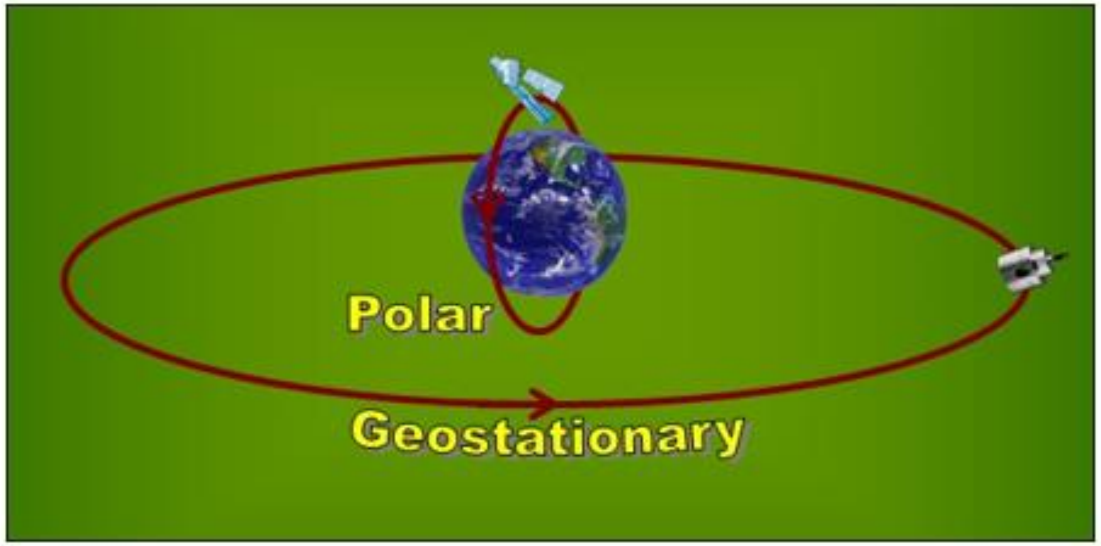
# Spaceborne platforms

- ***Geostationary orbits***

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.



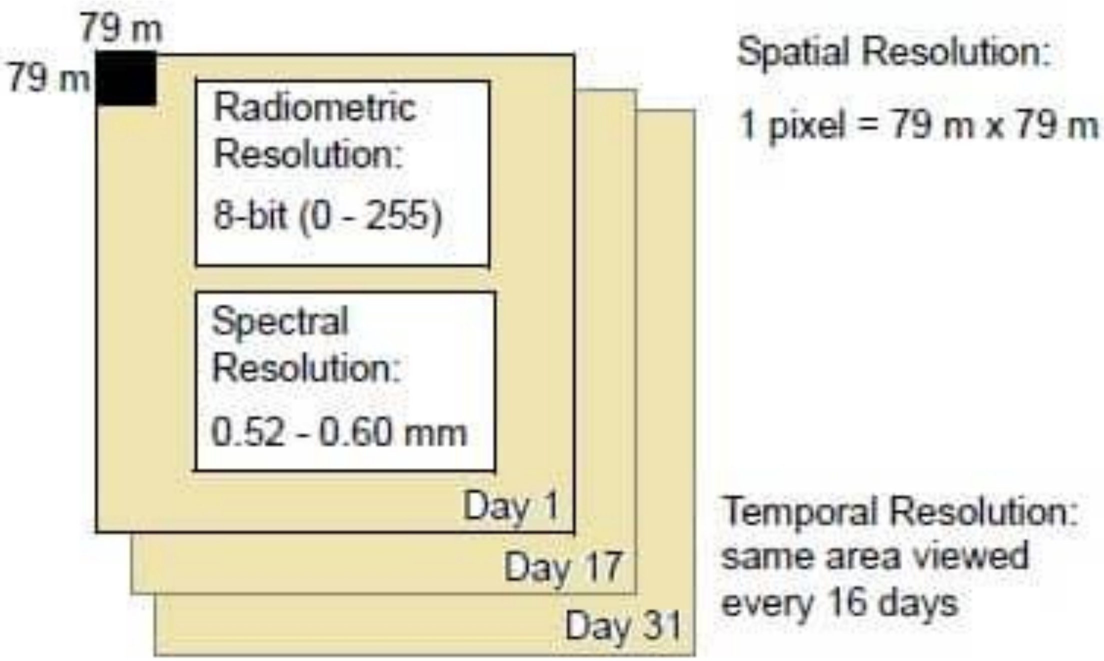
# Resolution

Sensor Resolution

- Resolution: a measure of the ability of an optical system to distinguish between signals that are spatially near or spectrally similar

**Satellite sensor characteristics**

1. Spatial Resolution
2. Spectral Resolution
3. Radiometric Resolution
4. Temporal Resolution



# Spatial Resolution

The size of the field of view of a single pixel/detector element/cell, e.g., 10 x 10m.

## Spatial Resolution

– a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor

**Fig. 1: Spatial Resolution**


A) Land Surface

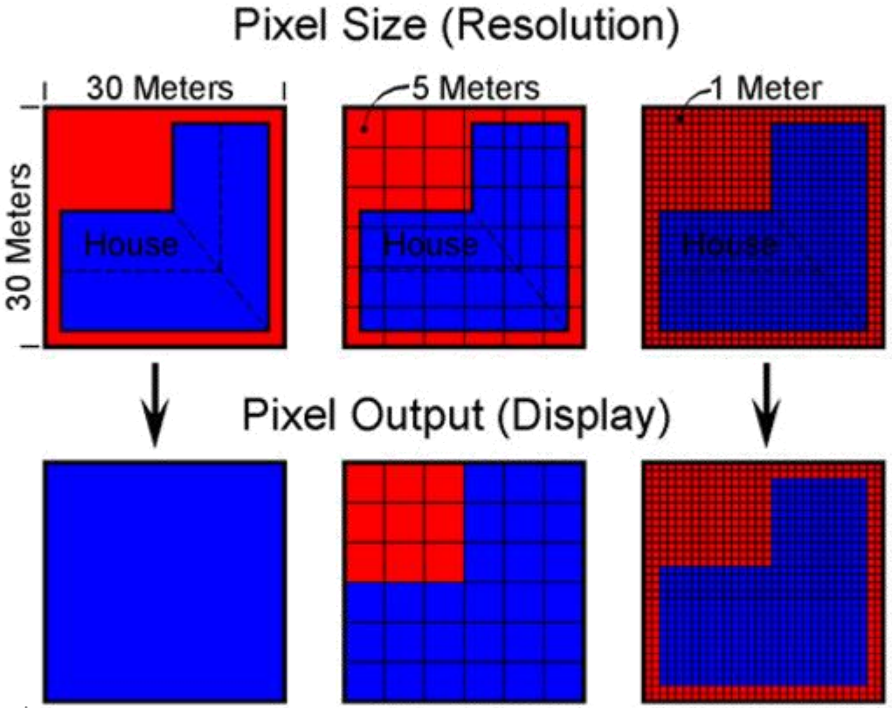
B) Satellite Imagery 1 pixel = 1 $Km^2$

C) Satellite Imagery 1 pixel = 250 $m^2$

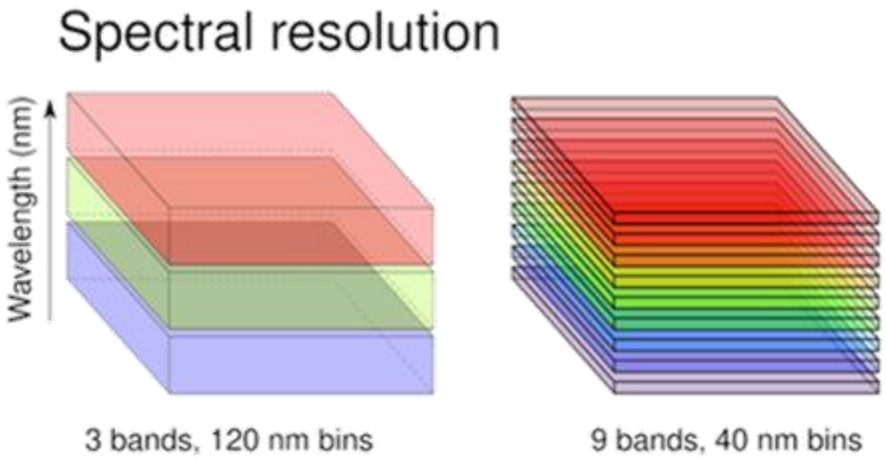
low spatial resolution | medium spatial resolution | high spatial resolution

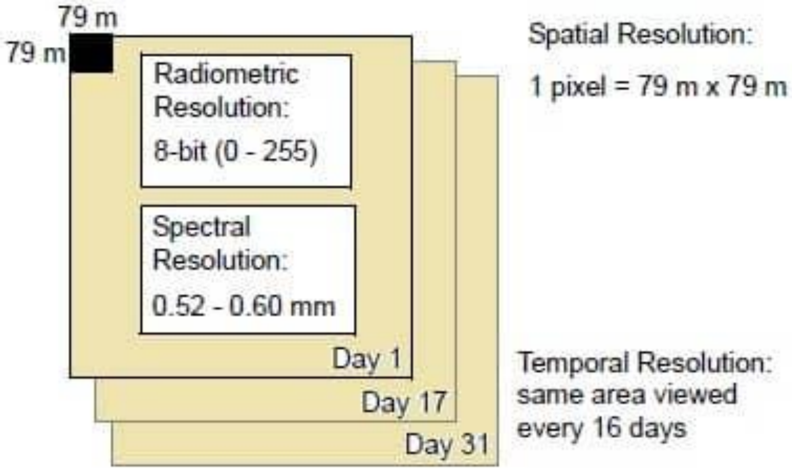
**The spatial resolution specifies the pixel size of satellite images covering the earth surface.**

**High spatial resolution: 0.6 - 4 m**
**Medium spatial resolution: 4 - 30 m**
**Low spatial resolution: 30 - > 1000 m**



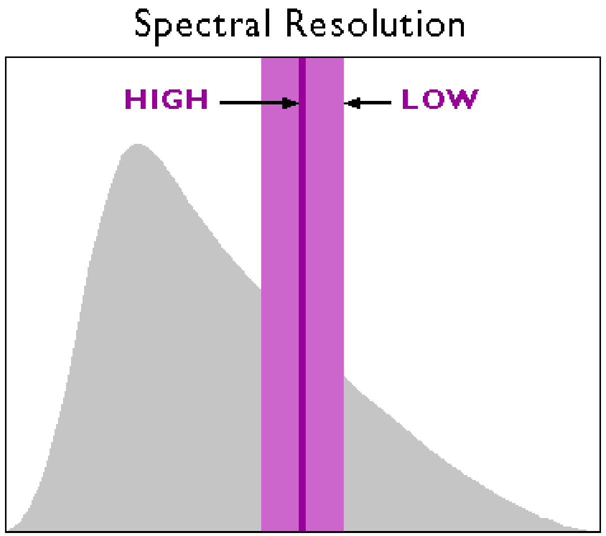
# Spectral Resolution

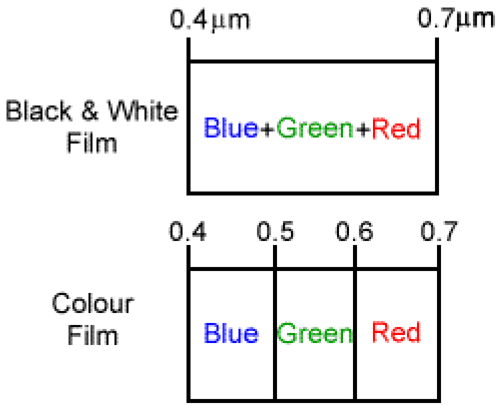



## Spectral Resolution

- the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive

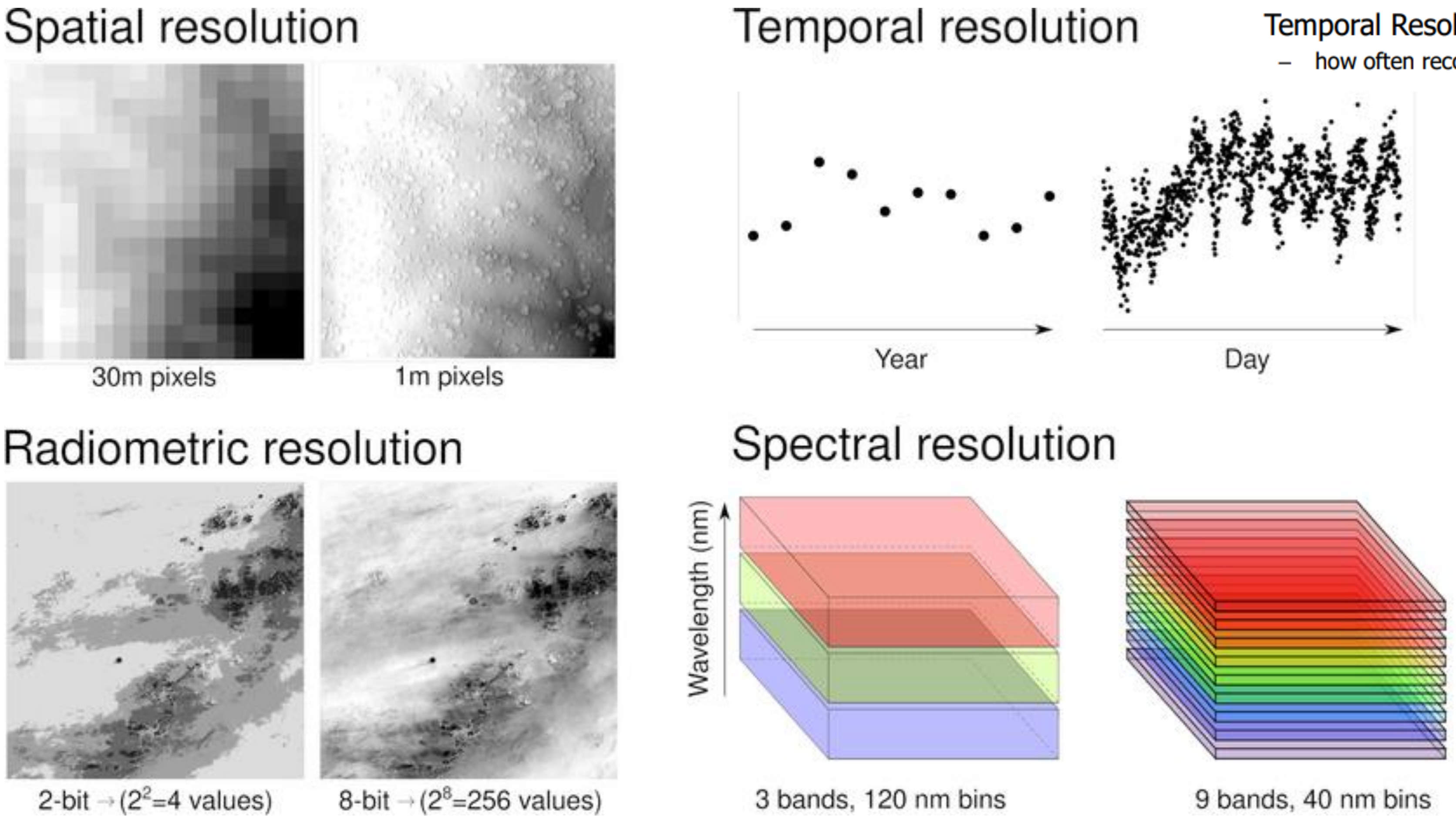


# Resolution

**Spatial Resolution**
- a measure of the smallest angular or linear separation between two objects that can be resolved by the sensor

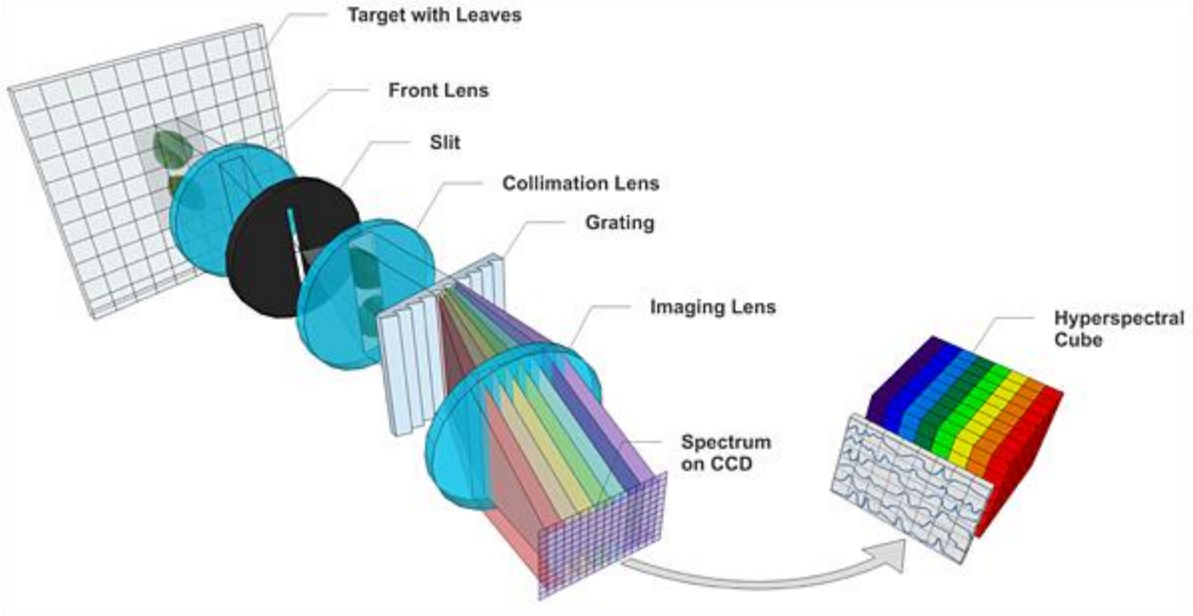
**Temporal Resolution**
- how often records imagery of a particular area

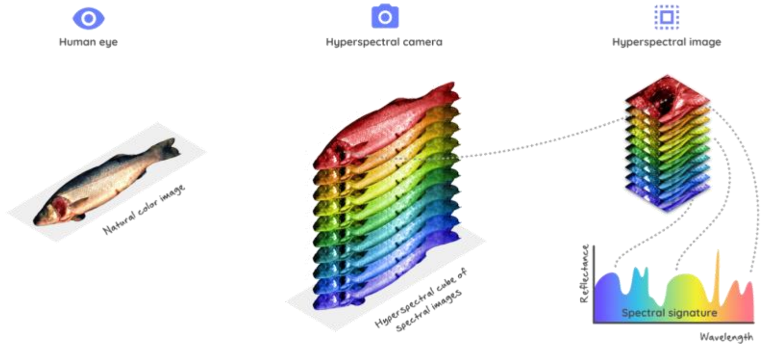


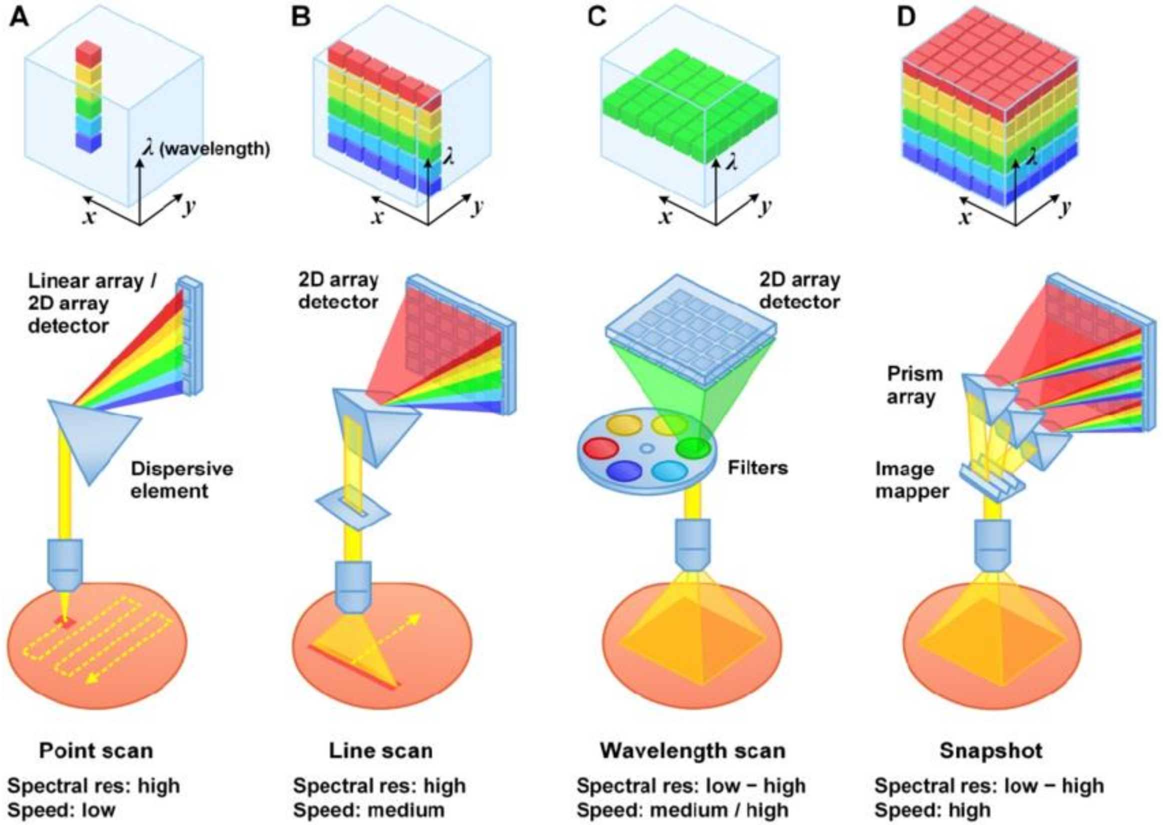

**Spectral Resolution**
- the number and dimension of specific wavelength intervals in the electromagnetic spectrum to which a remote sensing instrument is sensitive

**Radiometric Resolution**
- the sensitivity of a remote sensing detector to differences in signal strength as it records the radiant flux reflected or emitted from the terrain

# Spectral imaging



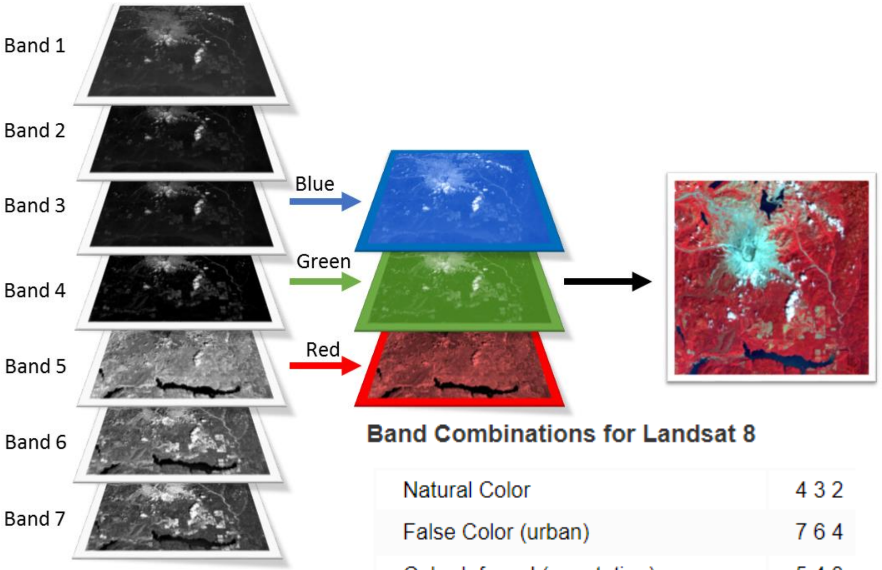



# Natural/True and False Color Composites

## True color composite

Also known as a natural-color image, this type of image uses red, green, and blue to represent colors that appear natural to the human eye.



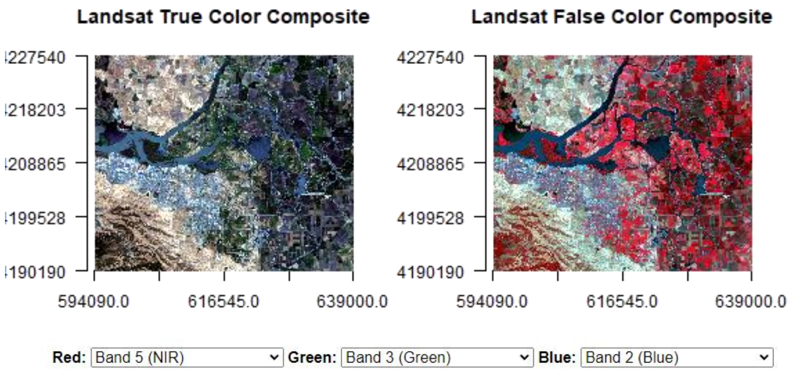

**Band Combinations for Landsat 8**

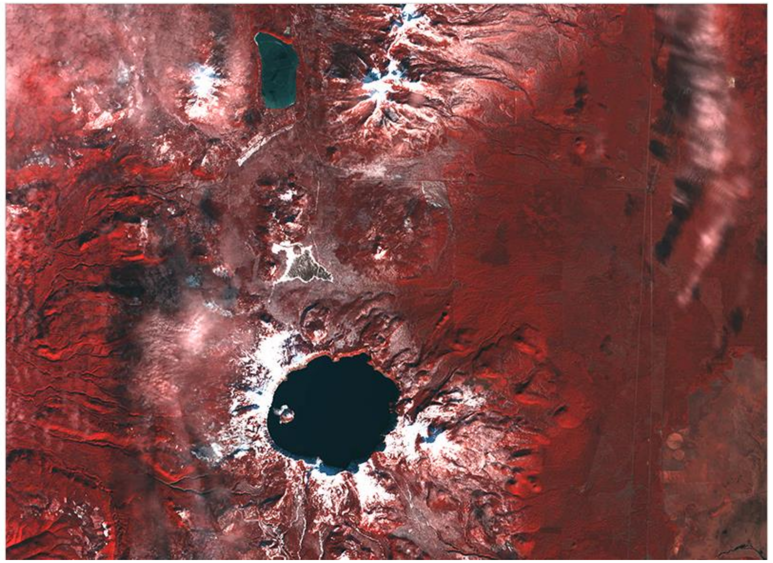
| | |
|---|---|
| Natural Color | 4 3 2 |
| False Color (urban) | 7 6 4 |
| Color Infrared (vegetation) | 5 4 3 |
| Agriculture | 6 5 2 |
| Healthy Vegetation | 5 6 2 |
| Land/Water | 5 6 4 |
| Natural With Atmospheric Removal | 7 5 3 |
| Shortwave Infrared | 7 5 4 |
| Vegetation Analysis | 6 5 4 |

## False color composite

This type of image uses wavelengths outside of the visible red, green, and blue range, or other types of data. False color composites allow us to see wavelengths that the human eye can't see.

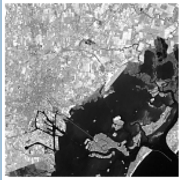
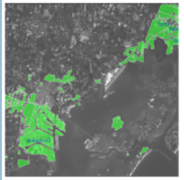
| Band # | Band Name | Wavelength (micrometers) |
|---|---|---|
| Band 1 | Coastal aerosol | 0.43 - 0.45 |
| Band 2 | Blue | 0.45 - 0.51 |
| Band 3 | Green | 0.53 - 0.59 |
| Band 4 | Red | 0.64 - 0.67 |
| Band 5 | Near Infrared (NIR) | 0.85 - 0.88 |
| Band 6 | Shortwave Infrared (SWIR1) | 1.57 - 1.65 |
| Band 7 | Shortwave Infrared (SWIR2) | 2.11 - 2.29 |

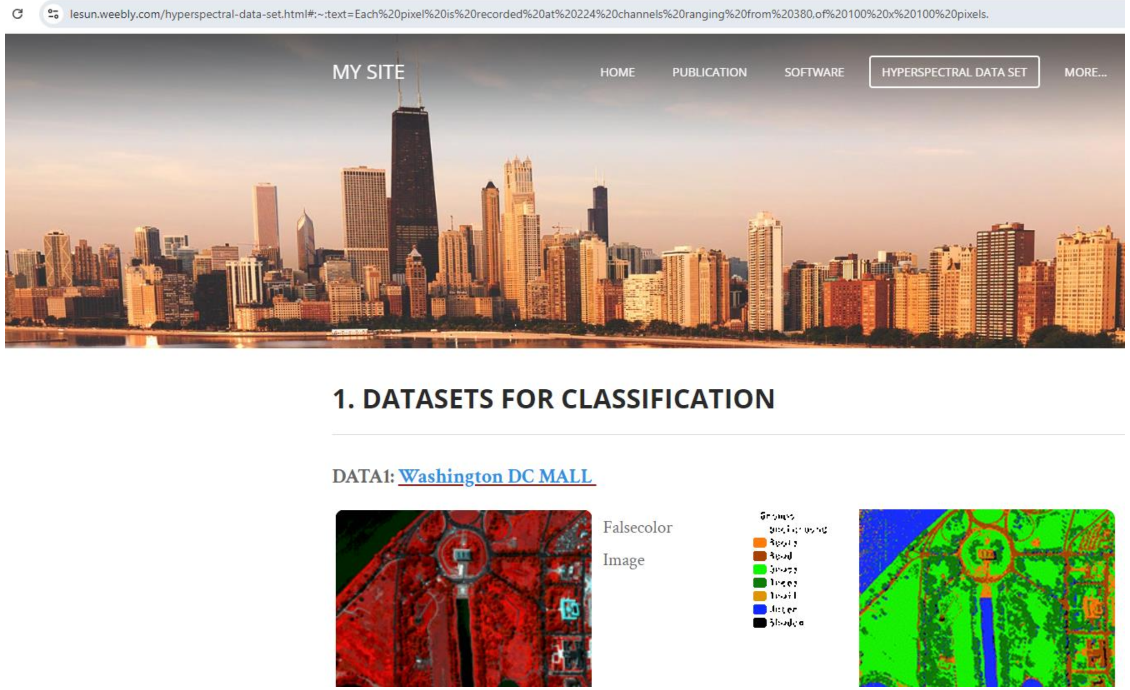


# Data download

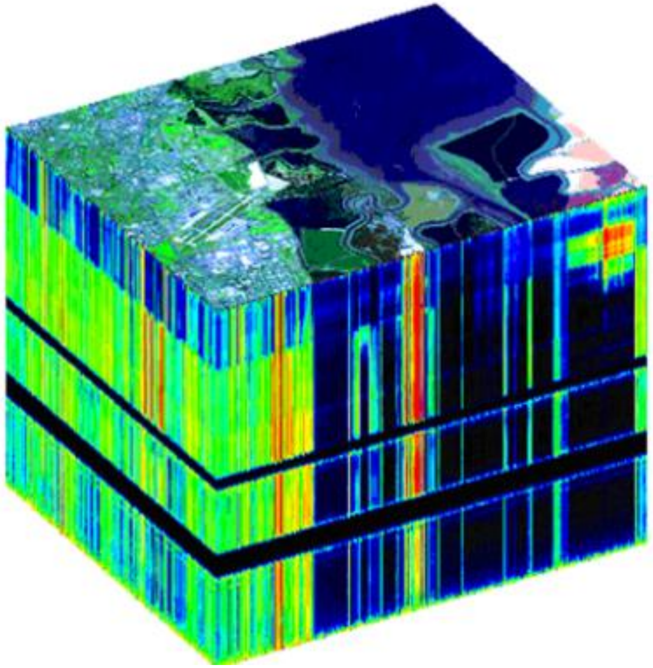
- Type “**geotiff sample images**” and “**Weebly Hyperspectral data**”

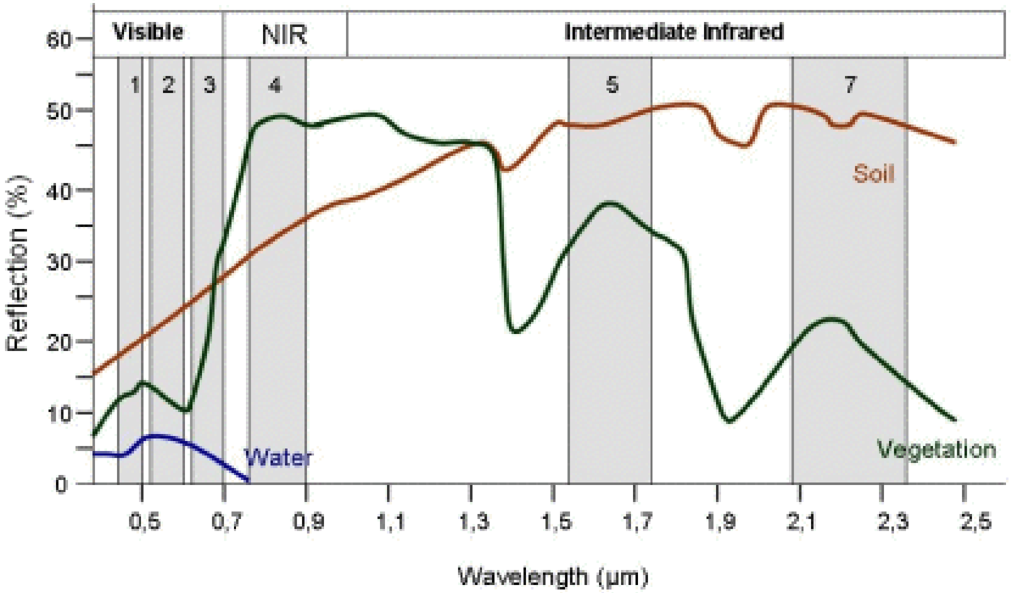
| Dataset name | Description | Download File | Preview |
|---|---|---|---|
| Venice - optic | Multispectral and pancromatic Landsat ETM images over the Venice region in Italy. | GeoTiff - multispectral<br>GeoTiff - panchromatic |   |
| Venice - radar | Single band (Intensity) Tiff image of an Advanced Synthetic Aperture Radar (ASAR) image from Envisat mission over Venice region in Italy. | GeoTiff |  |
| Venice - GIS | UTM subset of GIS shapefiles over Venice region in Italy. | Shp (zip archive) |  |



# Spectral Signature

A spectral signature is a function of the wavelength and is defined as the ratio of reflected radiation energy $[E_r(\lambda)]$ to incident radiation energy $[E_t(\lambda)]$ on an object. All matter on earth's surface has separate values of spectral reflectance characteristics.



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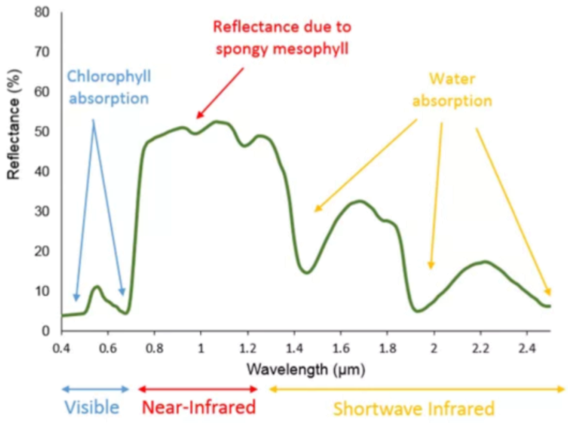
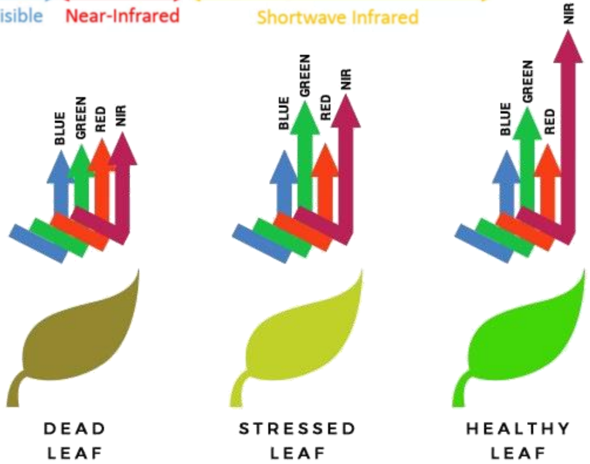


# Basic image processing

```
array_2d = np.array([[1, 2, 3], [4, 5, 6], [7, 8, 9]])
```

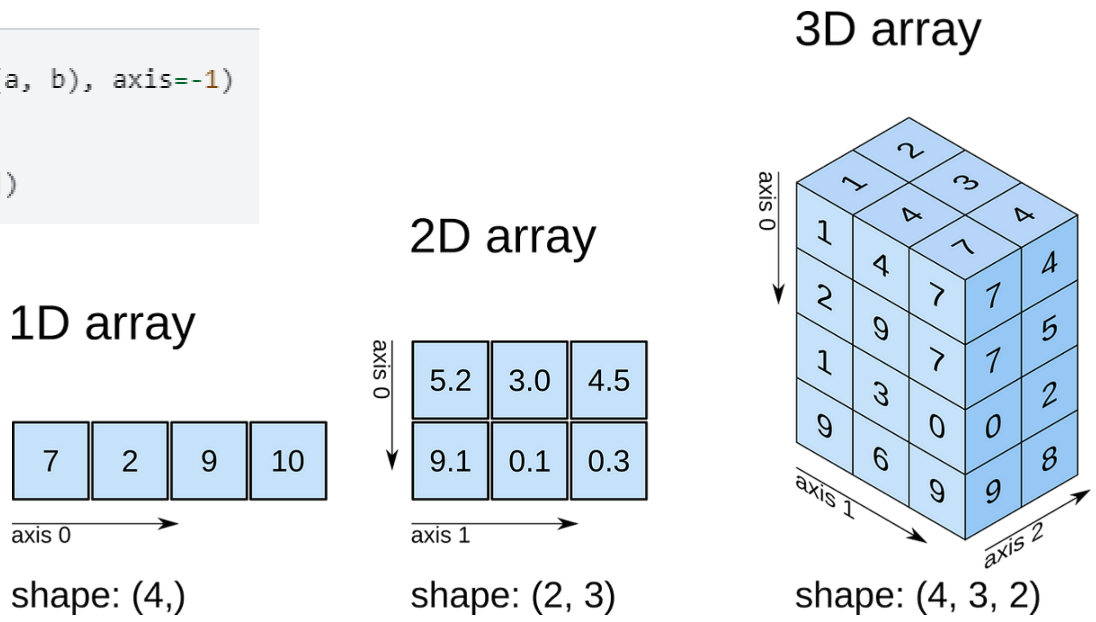
```
>>> a = np.array([1, 2, 3])
>>> b = np.array([4, 5, 6])
>>> np.stack((a, b))
array([[1, 2, 3],
       [4, 5, 6]])
```

```
>>> np.stack((a, b), axis=-1)
array([[1, 4],
       [2, 5],
       [3, 6]])
```

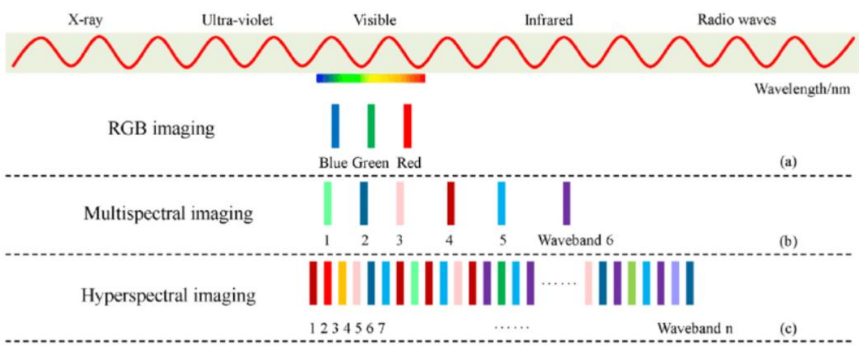
## Observe Basic Properties of Image

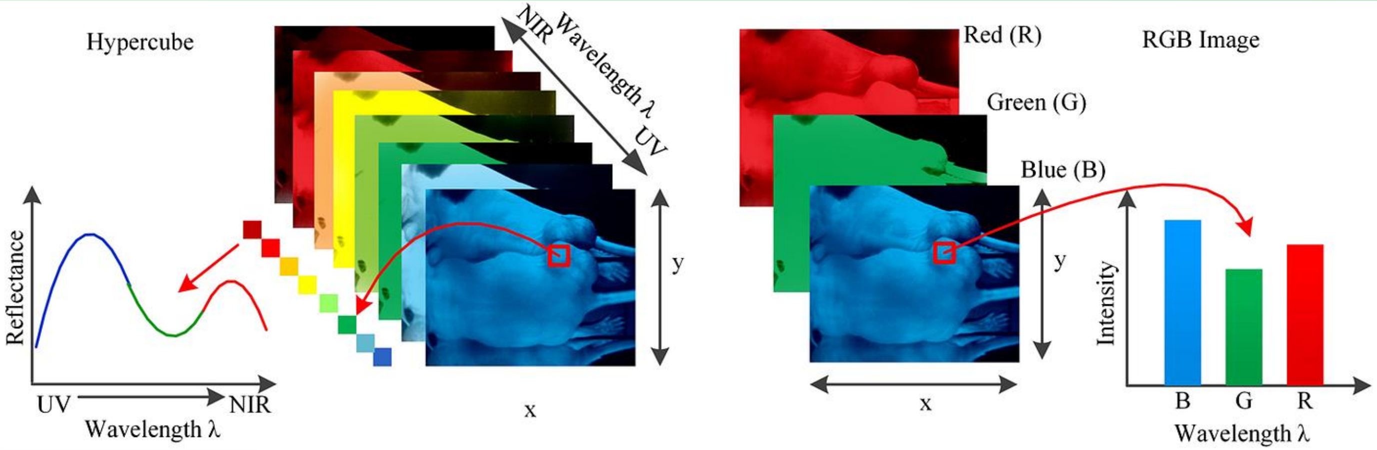
```
print('Type of the image : ' , type(pic))
print()
print('Shape of the image : {}'.format(pic.shape))
print('Image Hight {}'.format(pic.shape[0]))
print('Image Width {}'.format(pic.shape[1]))
print('Dimension of Image {}'.format(pic.ndim))
```

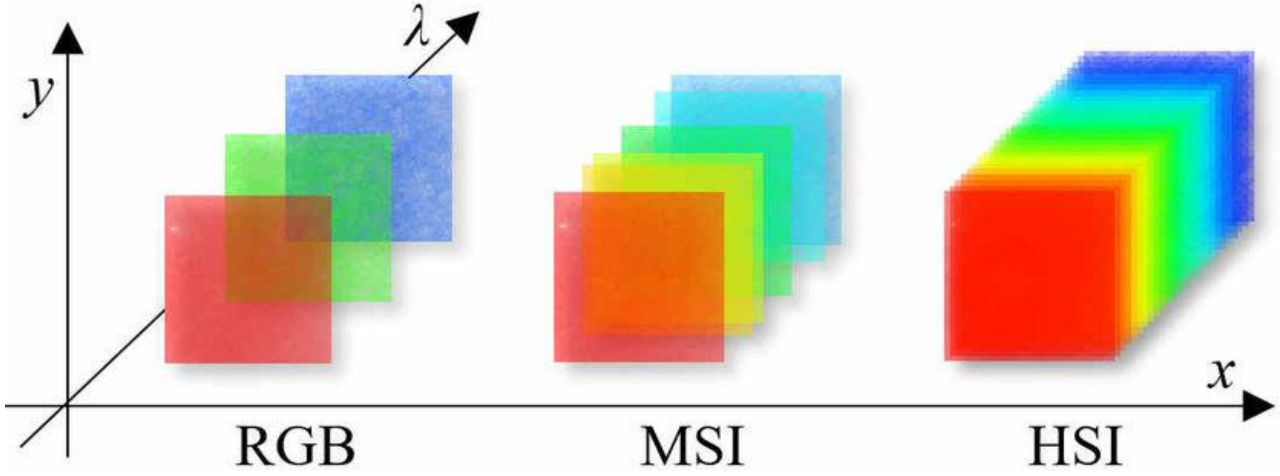
```
# A specific pixel located at Row : 100 ; Column : 50
# Each channel's value of it, gradually R , G , B
print('Value of only R channel {}'.format(pic[ 100, 50, 0]))
print('Value of only G channel {}'.format(pic[ 100, 50, 1]))
print('Value of only B channel {}'.format(pic[ 100, 50, 2]))
```

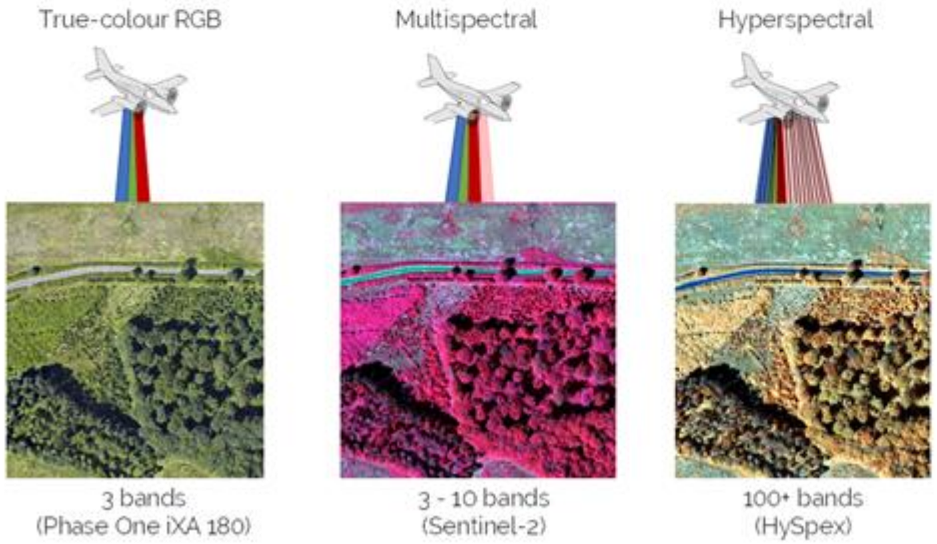


# Basic image processing



# Q&A session

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# Thank you!