IIT Bombay

GNR607 Principles of Satellite Remote Sensing

Prof. B. Krishna Mohan
CSRE, IIT Bombay
bkmohan@csre.iitb.ac.in

Lecture-3 5th August 2023

Lecture – 3 Contents

- *Introduction to Remote Sensing*
- *Stages in Remote Sensing*
- *Concept and types of Resolution*
- *Indian and International Space Programs*

What is remote sensing?

Remote sensing is the art and science of making measurements about an object or the environment without being in physical contact with it

Importance of Remote Sensing

Remote Sensing provides vital data for many critical applications

- *Resources management*
- *Environmental monitoring*
- *Defence*
- *Urban / rural development and planning*
- *Crop yield forecasting*
- *Hazard zonation and disaster mitigation*
- *Insurance*

Resources Management

- *Mapping water resources*
- *Mapping forest cover*
- *Mapping open and unused areas*
- *Mapping coastline*
- *Mapping hilly and mountainous areas*
- *Mapping desert and snow capped areas*
- *Mapping landuse*

Environmental Monitoring

- *Sedimentation and pollution of waterbodies*
- *Afforestation*
- *Deforestation and forest degradation*
- *Air pollution monitoring*

IIT Bombay

Defence Applications

- *Landuse change monitoring in enemy territories*
- *Camouflaging and camouflage detection*
- *Mapping strategic assets across the border*

Urban/Rural Development and Planning

- *Urban growth monitoring*
- *Urban growth prediction*
- *Site selection for locating new industries and facilities*
- *Monitoring developments in rural areas such as new roads and infrastructure (bus stations, railway stations, …)*

Crop Yield Forecasting

- *Repeated observations over major agricultural areas (in Haryana, Punjab, Maharashtra, Tamil Nadu, Andhra Pradesh, …)*
- *Change monitoring in crop areas using images from sowing till crop maturing*
- *Forecasting expected yield BEFORE harvest*

Disaster Mitigation and Hazard Zonation

- *Mapping landslide, earthquake and avalanche affected areas*
- *Mapping flood affected areas and drought affected areas to target relief measures*
- *Marking areas likely to be affected by floods, earthquakes, landslides and avalanches*

IIT Bombay

Point to ponder…

How can remote sensing help the insurance industry?

Remote Sensing Platforms

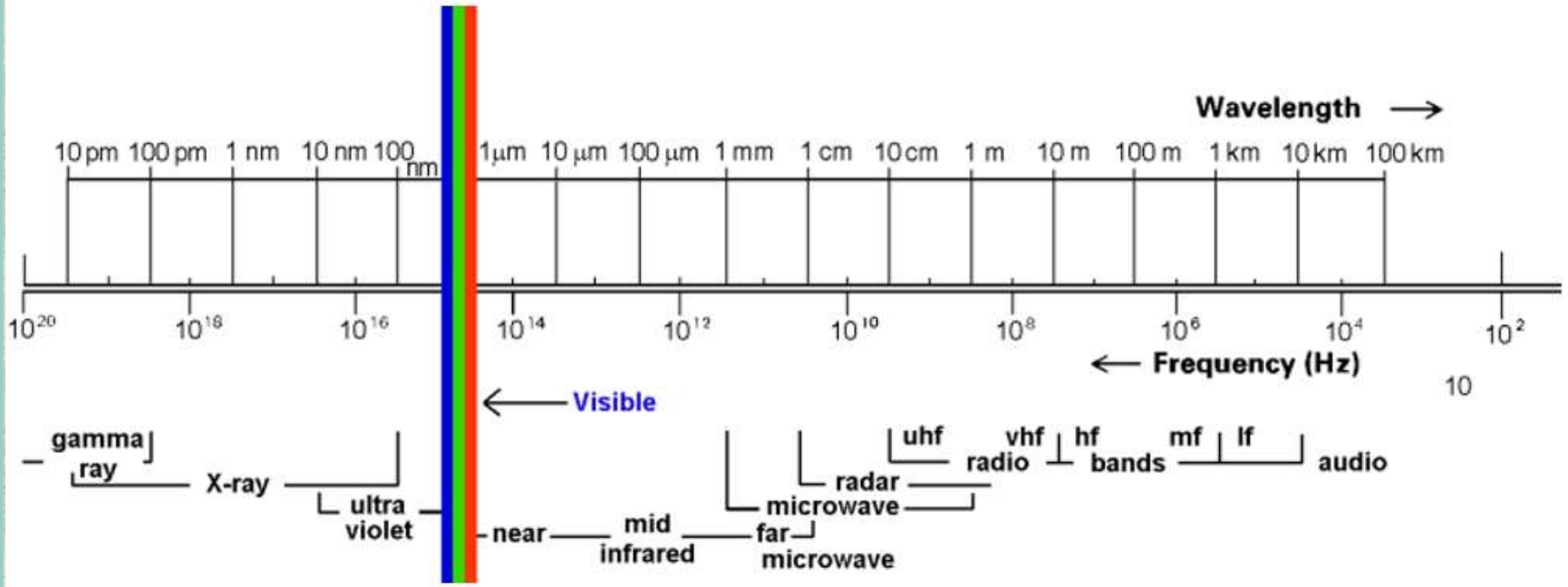
- Earth orbiting geostationary satellites
  - Mainly for communication purposes, some satellites also carry imaging cameras
- Polar sun-synchronous orbiting remote sensing satellites
  - Cover the entire globe from pole to pole maintaining same local time for constant illumination
- Low earth orbiting satellites
  - For security applications, providing very high resolution, operating over a short time period
- Airborne systems – mounted on small airplanes, for terrain mapping, covered using two cameras
- Drones/UAVs – very low altitude flying personal image acquisition systems

IIT Bombay

Stages in Remote Sensing

- *Electromagnetic energy reflected / emitted by earth surface features*
- *Energy received by the remote sensors*
- *Energy converted to electrical signal*
- *Electrical signal converted to DIGITAL form*
- *Digital signal transmitted to ground*
- *Ground station organizes data on CDs/DVDs*
- *Data distributed to users*
- *Users analyze data and produce information products*

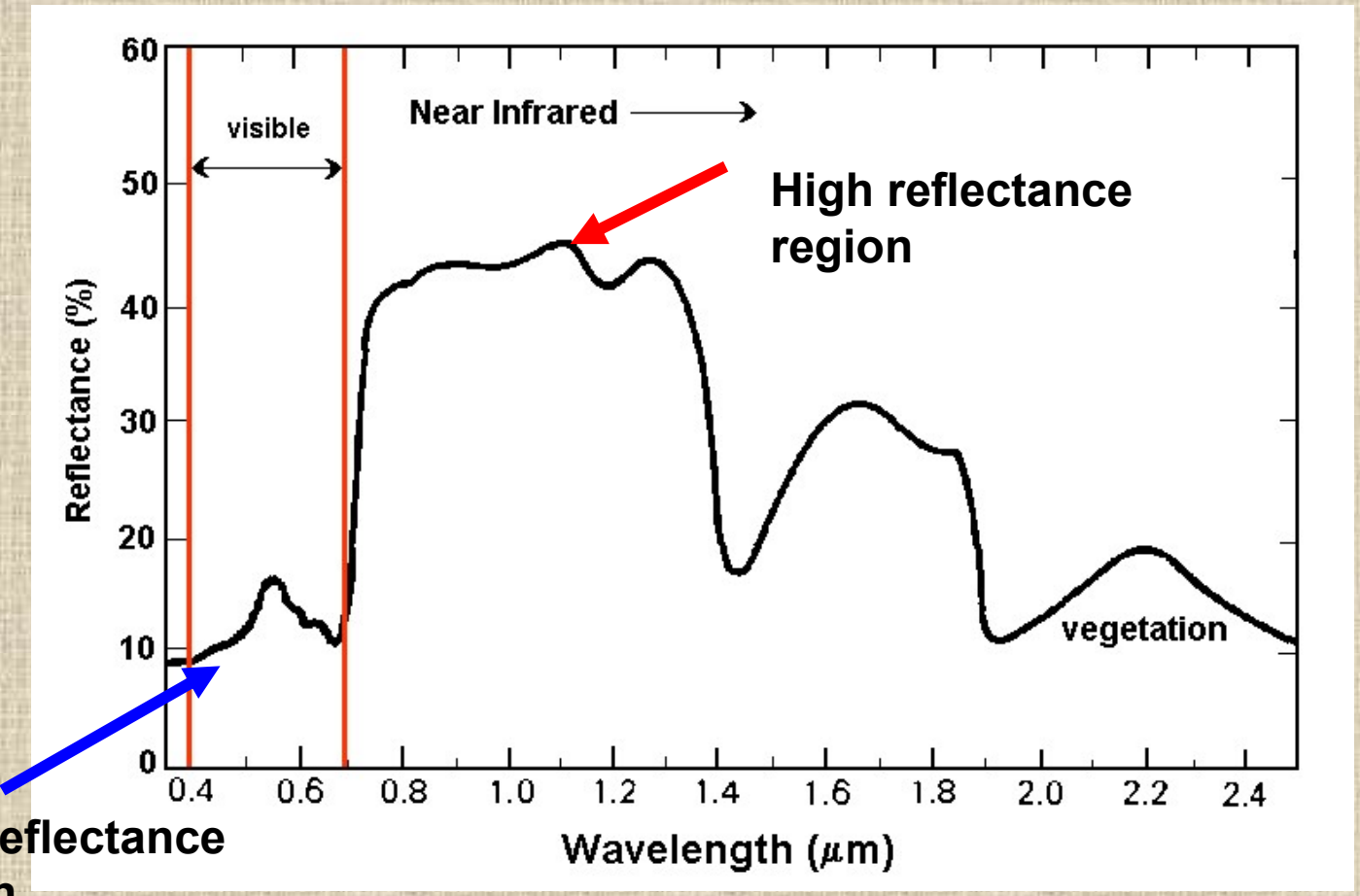
Electromagentic Spectrum



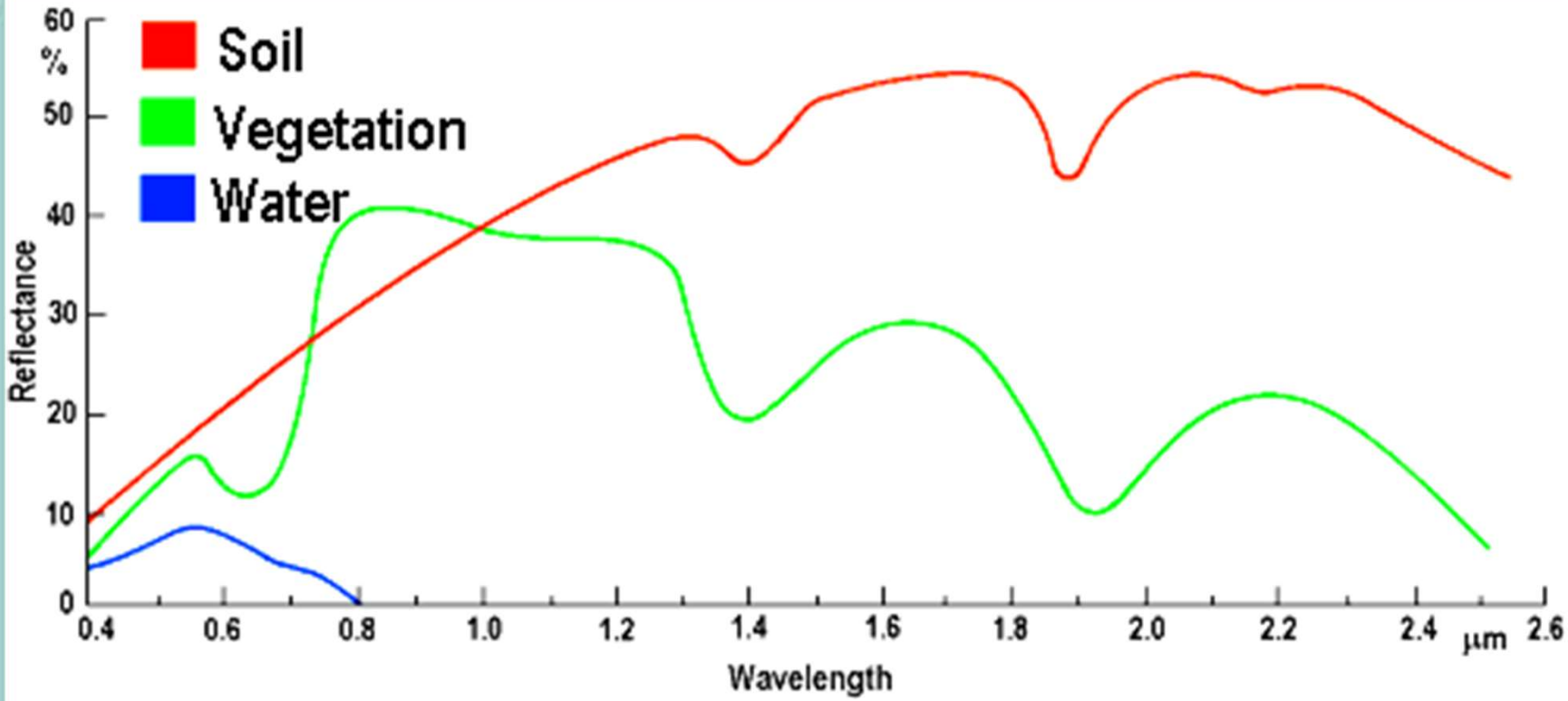
Visible and Reflective Infrared

- *Reflectance measurements in different wavelengths*
  - *ratio of incident to reflected energy*
  - *Ranges 0% to 100%*
  - *Highly wavelength dependent*
- *Basic Premise of RS*
  - *Each object on the earth surface has a unique reflectance pattern as a function of wavelength*

Vegetation Reflectance Spectrum



Reflectance Spectra of Earth Objects

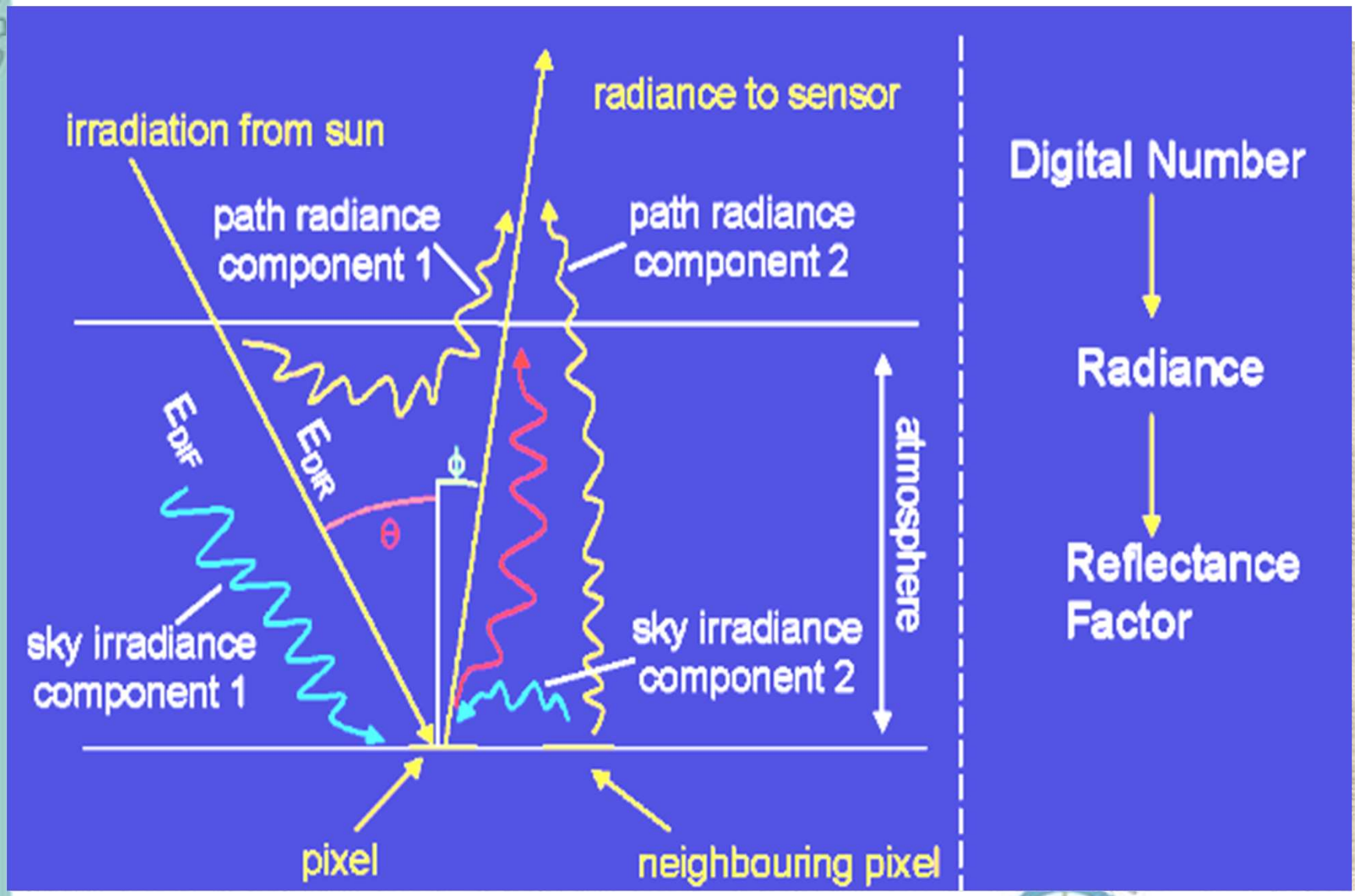


- *Different objects respond differently!*

Atmospheric Windows

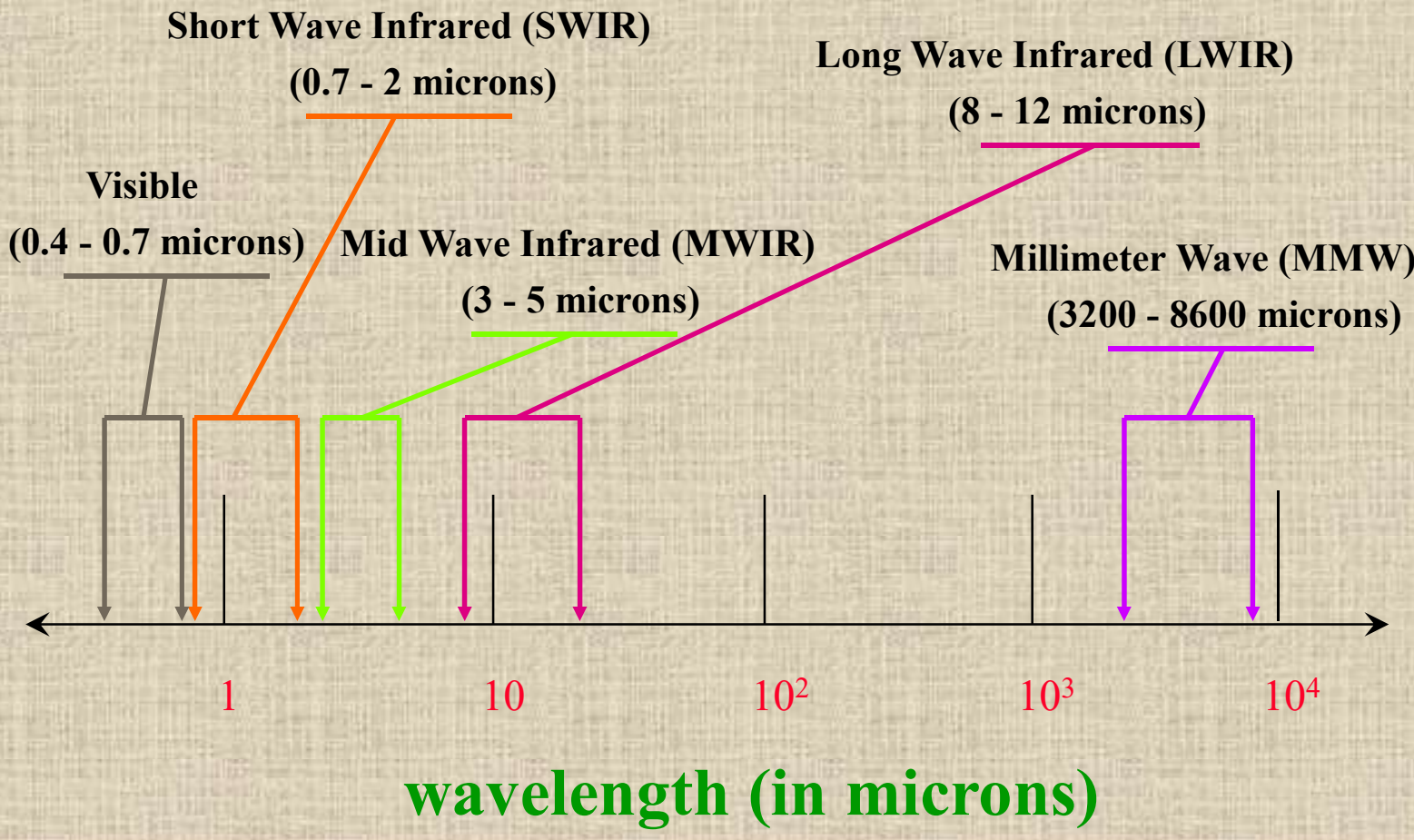
- *The atmosphere interferes with the radiation passing through it*
- *It is essential to block the harmful UV rays in solar radiation from reaching the earth*
- *Should not block the radiation in in wavelengths used for earth observation*
- *Choice of wavelengths should ensure*
  - *Clear response recorded from Earth surface features*
  - *Minimal interference from atmospheric constituents*

Radiation Propagation thro' Atmosphere

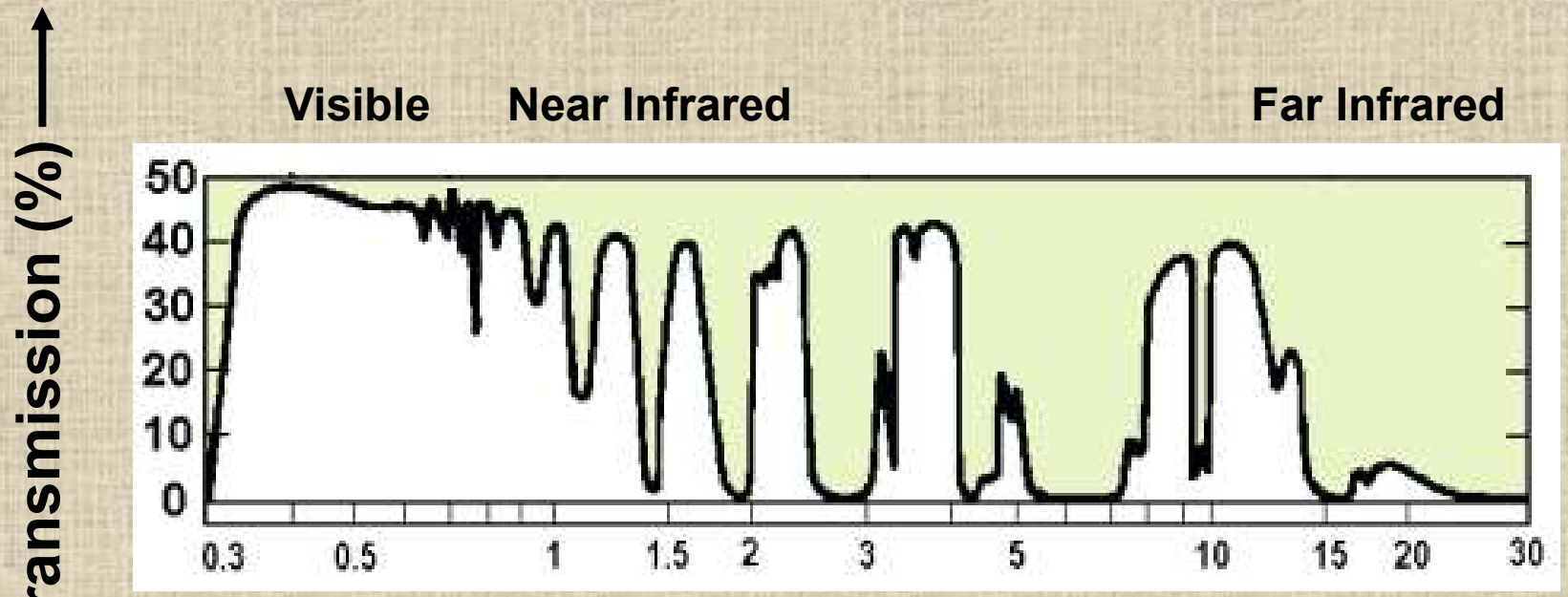


Atmospheric Characteristics

- **Wavelength Bands**



Atmospheric Windows



Role of Atmosphere

- Wavelengths less affected by atmosphere are chosen to design the sensors to operate in:
- Visible 400 nm – 700 nm
- Near infrared – 700 nm – 2500 nm with a few gaps
- Thermal infrared – 8 microns – 15 microns
- Microwave – 1 cm – 30 cm (approx.)

- Other wavelengths are blocked by atmosphere

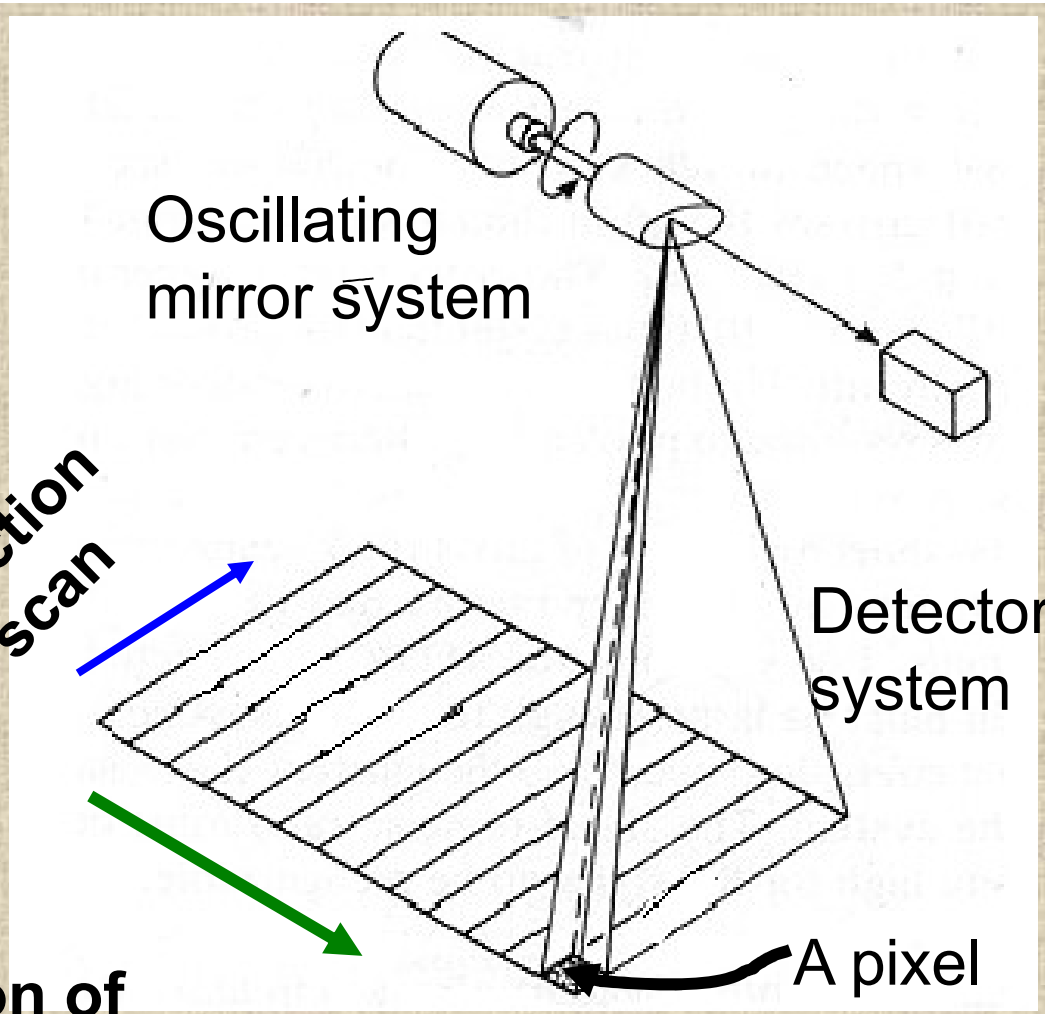
Specifications of Remote Sensors

- Technology used – Solid state / Electro-mechanical
- Resolution
  - IFOV of sensing element
  - Number of wavelengths in which data are recorded
  - Number of levels in which data values are quantized
  - Frequency of data collection over a given area

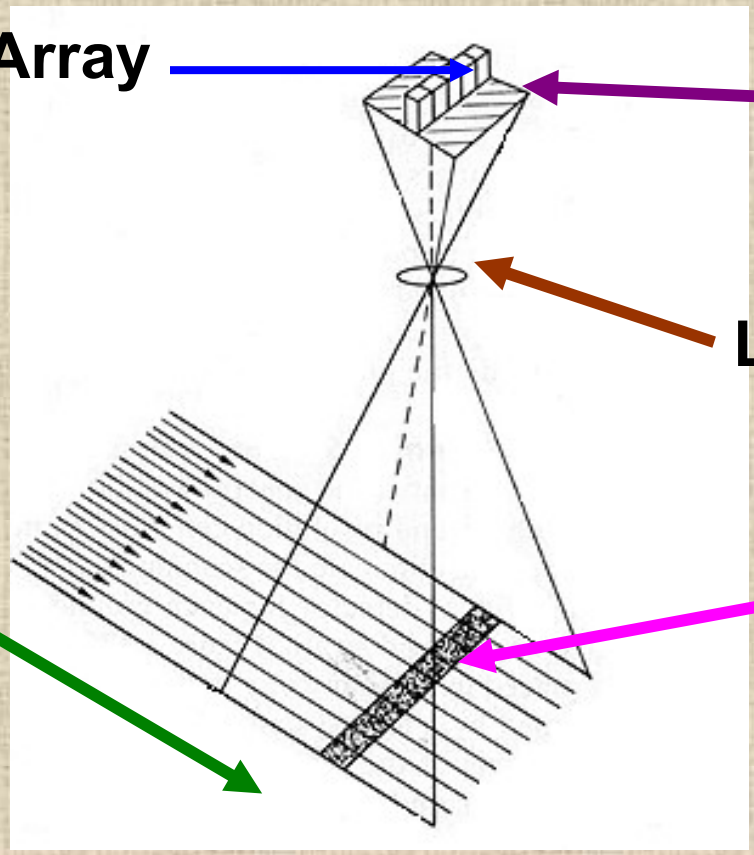
Sensor Technology

- Sensors are broadly of two types:
  - Electromechanical – scanning is performed by an oscillating mirror deflecting upwelling radiation from earth onto wavelength sensitive photodetectors. Maintaining constant angular velocity of the mirror is a problem
  - Solid state – sensor consists of a linear array of detectors, equal in number to the number of pixels in a row of the image. Much more stable compared to electromechanical scanning

Electromechanical Technology



Solid State Technology



IIT Bombay

Points to ponder…

- Electromechanical scanner – advantage and limitation
- Fully solid state pushbroom scanner – advantage and limitation

IIT Bombay

Concept of Resolution

- Four types of resolution in remote sensing:
  - Spatial resolution
  - Spectral resolution
  - Radiometric resolution
  - Temporal resolution

Spatial Resolution

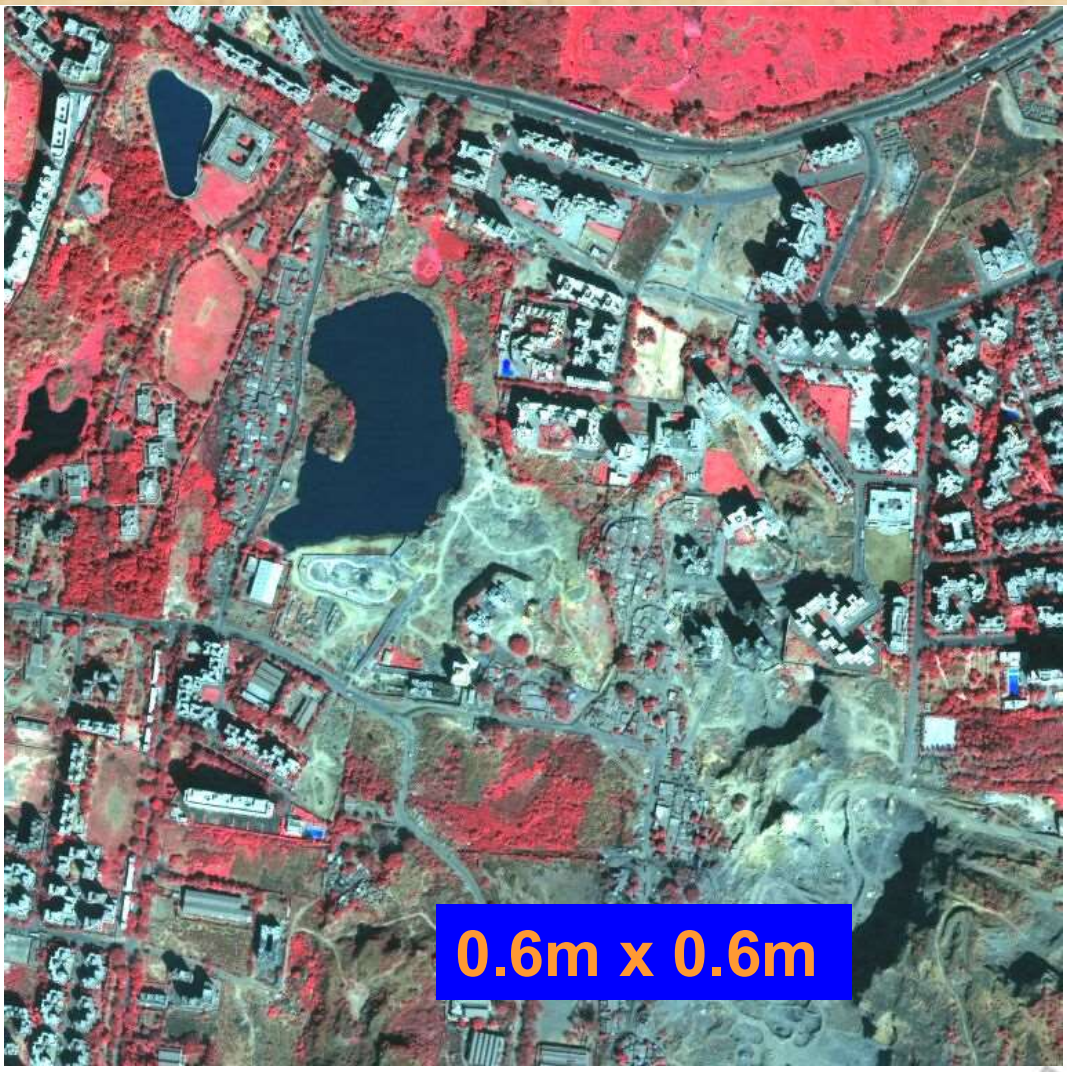
- Ability of the sensor to observe closely spaced features on the ground
- Function of the instantaneous field of view of the sensor
- Large IFOV ←→ Coarse spatial resolution – pixel covers more area on ground
- Small IFOV ←→ Fine spatial resolution – pixel covers less area on ground
- **A sensor with pixel area 5x5 metres has a higher spatial resolution than a sensor with pixel area 10x10 metres**

IIT Bombay

Effect of Spatial Resolution

- When resolution is very high we perceive individual objects such as buildings or roads
- When resolution is medium, we perceive very large objects as individual features, and areas as textured regions
- When resolution is coarse, we perceive color or tone variations, and large area based features.

Very High Spatial Resolution



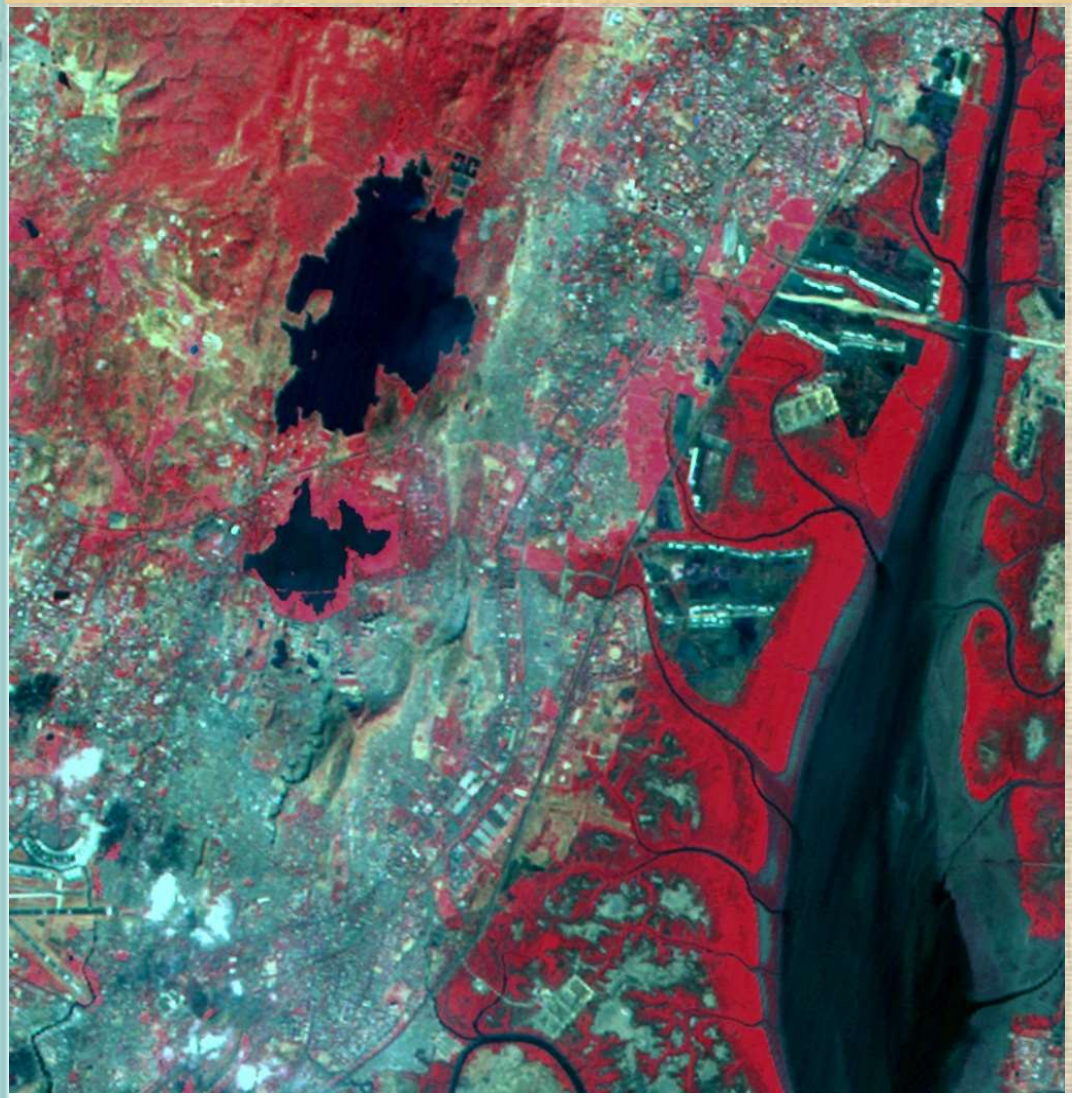
Another Very High Spatial Resolution Image

IIT Campus image from Ikonos Satellite

Medium Resolution Image

Portion of Resourcesat Satellite data
Pixel size: 5.8m x 5.8m

Low Resolution Image



23.25m x 23.25m

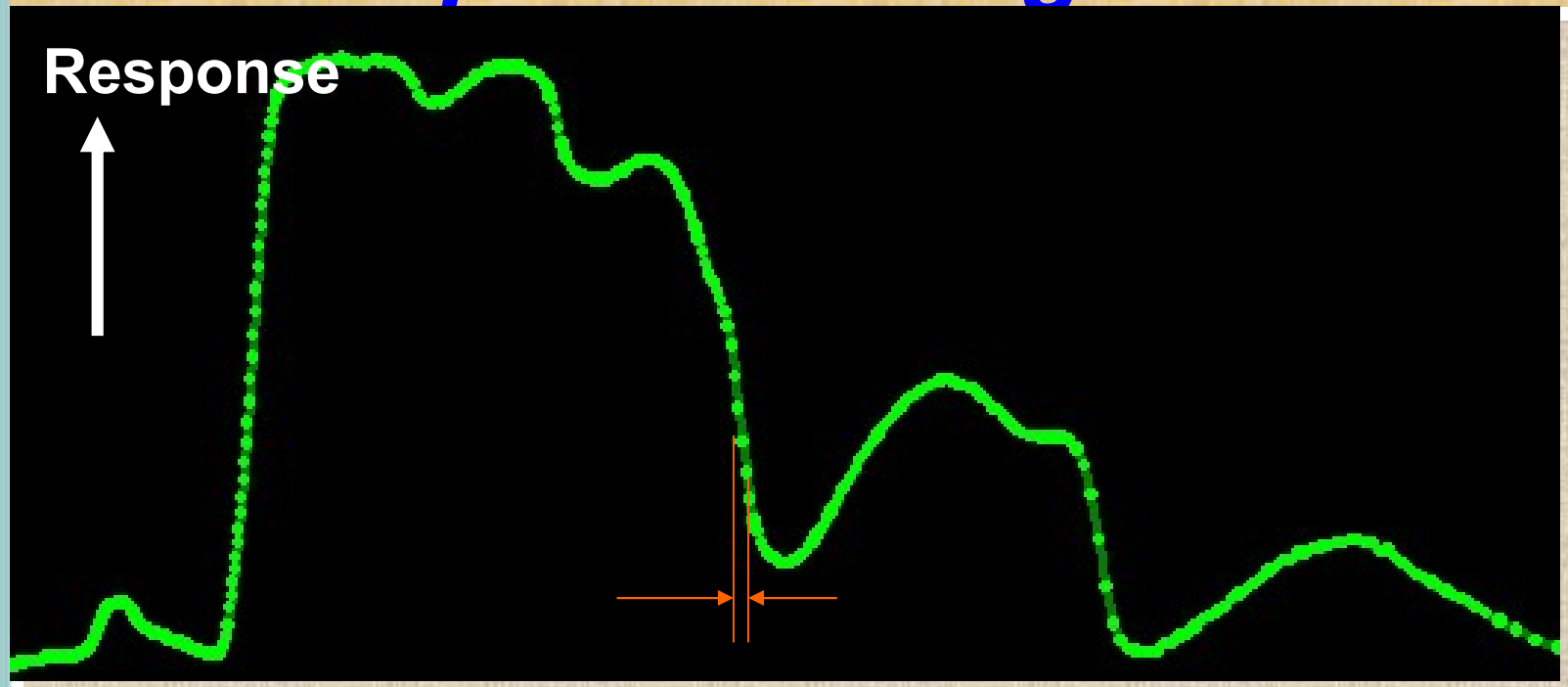
Effect of High Spatial Resolution

- *High resolution images are information rich*
  - *Spatial information*
  - *Multispectral information*
  - *Textural information*
- *Image can be viewed as a collection of objects with spatial relationships – adjacent, north of, south of, …*

Spectral Resolution

- *Ability of the sensor to distinguish differences in reflectance of ground features in different wavelengths*
- *Characterized by many sensors, each operating in a narrow wavelength band*
- *Essential to discriminate between sub-classes of a broad class such as vegetation*
- *Helpful in detecting objects under camouflage*
- *Essential in identifying state of objects such as waterbodies, vegetation, road surface material, elements in top soil of a mineralized area, …*

High spectral resolution response of vegetation

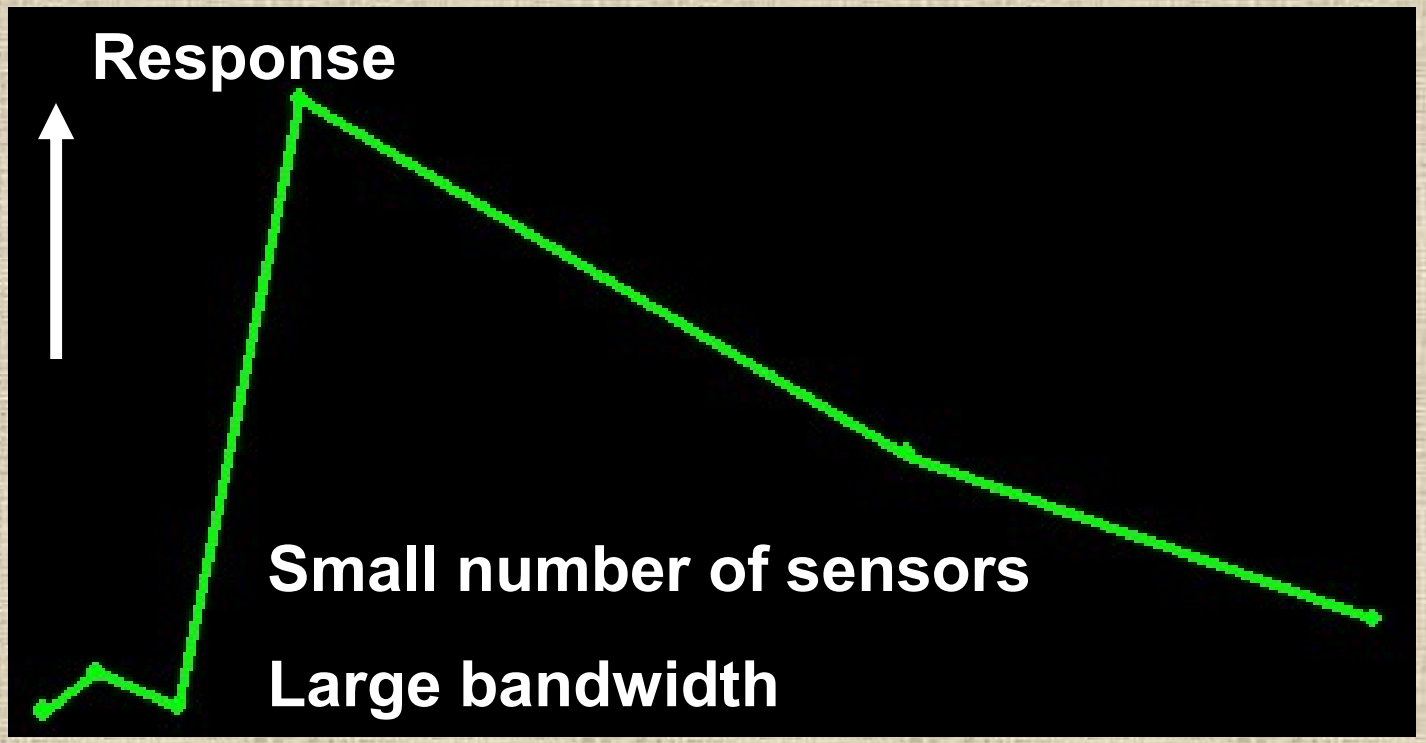


Large number of contiguous sensors

Narrow bandwidth (~ a few nanometers)

Coarse Spectral Resolution

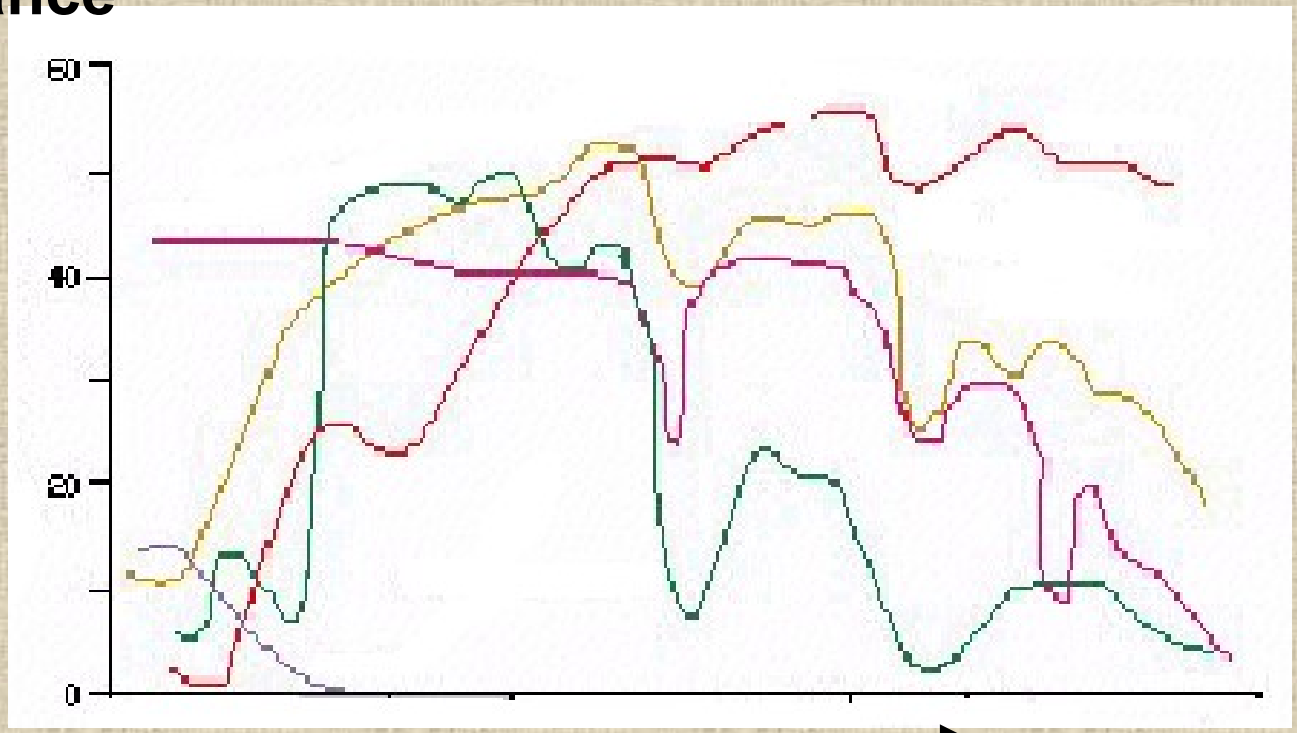
- **Most satellites provide multispectral images with very few spectral bands**



Reflectance Spectra

-

Reflectance



Unique spectra of objects

wavelength

Points to ponder…

- Suppose an area of 10km x 10km is captured by remote sensors
- Suppose spatial resolution of different sensors corresponds to pixel area on ground: 20 metres x 20 metres, 5 metres x 5 metres, 1 metre x 1 metre, 25cm x 25cm; 4 wavelength bands in each case
- How does the size of the image data vary?
- Suppose one sensor collects data in 4 wavelengths, another in 8 wavelengths, how does the data size change? Pixel area on ground is 20 metres x 20 metres

IIT Bombay

Temporal Resolution

- This depends on the return time of the satellite
- Return time is a function of the altitude at which the satellite is launched
- Higher the altitude, more circumference of orbit, longer to orbit the earth
- For frequent coverage, such as coverage of areas of military conflict, areas affected by natural disasters, of areas of massive human gatherings the images should be acquired asynchronously
- Steerable sensor systems make this feasible today

IIT Bombay

Wavelengths used for Imaging

- Gamma Rays
- X-Rays
- Visible/Infrared Rays
- Microwaves
- Radio waves
- Ultrasound waves
- Seismic waves

IIT Bombay

High Temporal Resolution Coverage

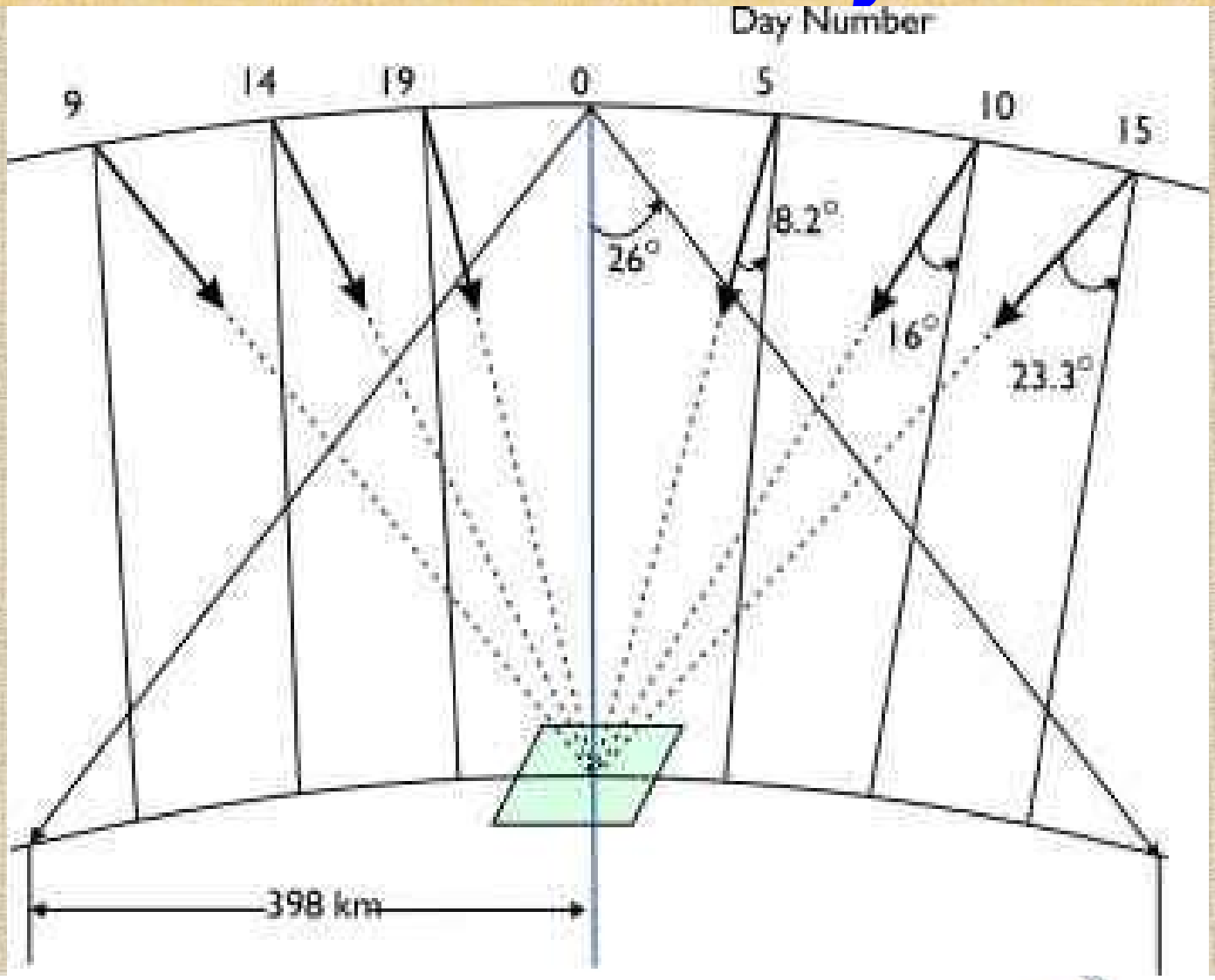
- *Lower altitude satellites have a higher frequency of revisit of the same area on earth*
- *Normal revisit time is approximately 16-25 days for different satellites*
- *Some satellites are launched in pairs with a time gap, e.g., IRS 1C / 1D*
- *Temporal resolution doubles, revisit time decreases by 50%*

IIT Bombay

Steerable sensor systems for high temporal resolution coverage

- *Some sensors have steerable control mechanism*
- This enables revisit over any area whenever desired
- *Useful in applications like disaster mitigation, military reconnaissance*
- *Steerable sensors also provide multiple views of the terrain for stereo modeling*

Steerable Sensor Systems



International Space Programs

USA	China/Brazil
Russia	Nigeria
France	Canada
India	European Space Agency
Japan	South Korea
Taiwan	Thailand

http://www.itc.nl/research/products/sensordb/searchsat.aspx

Useful Links

- www.isro.gov.in
- www.nrsc.gov.in
- www.digitalglobe.com
- http://global.jaxa.jp
- http://glovis.usgs.gov
- http://www.itc.nl/research/products/sensordb/searchsat.aspx
- http://www.geo-airbusds.com/en/
- https://directory.eoportal.org/web/eoportal/satellite-missions/k/kompsat-5
- http://www.geo-airbusds.com/en/160-formosat-2
- http://bhuvan.nrsc.gov.in
- https://vedas.sac.gov.in/vedas/

IIT Bombay

To be continued …