Satellites – Digital Image - Preprocessing and classification

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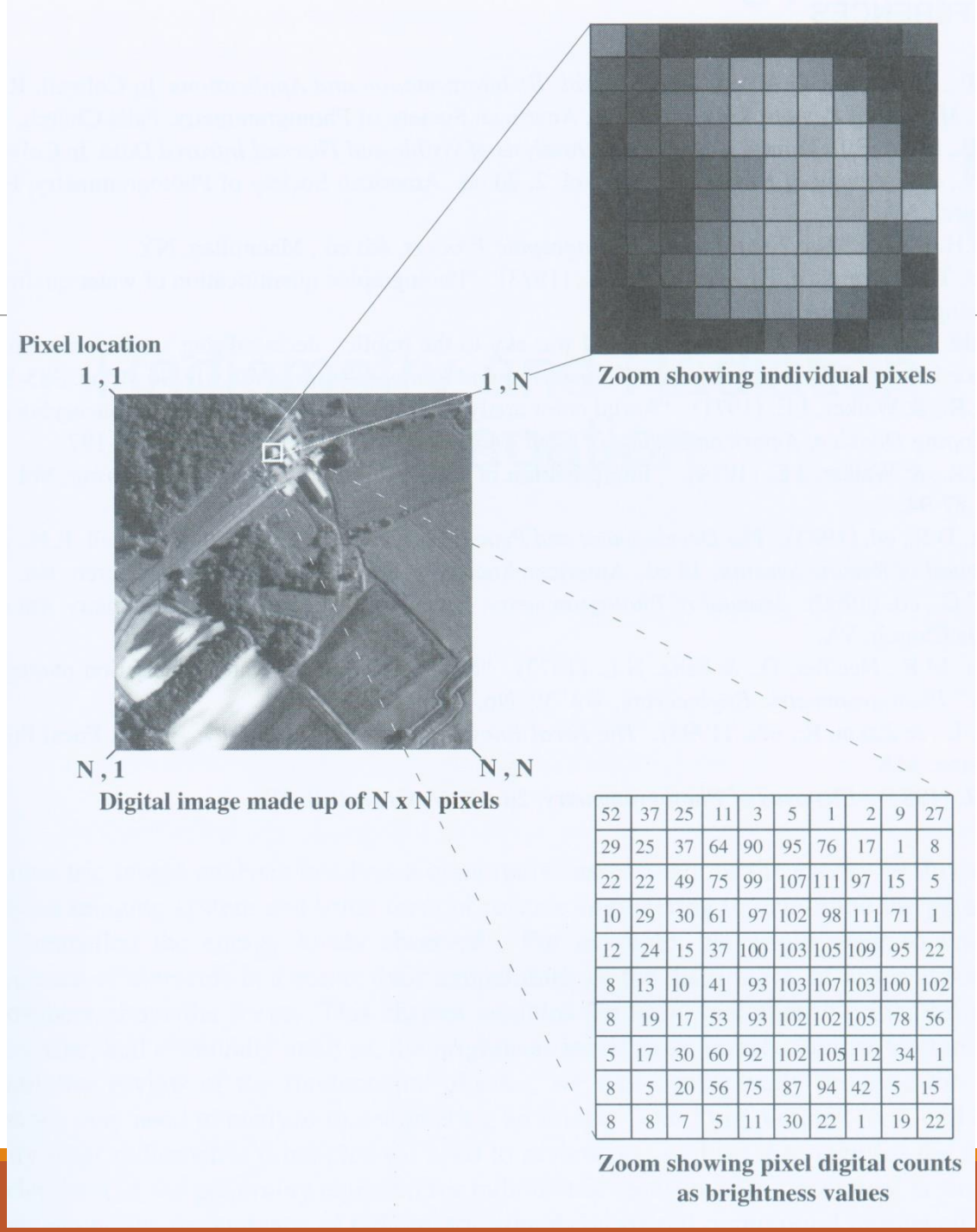
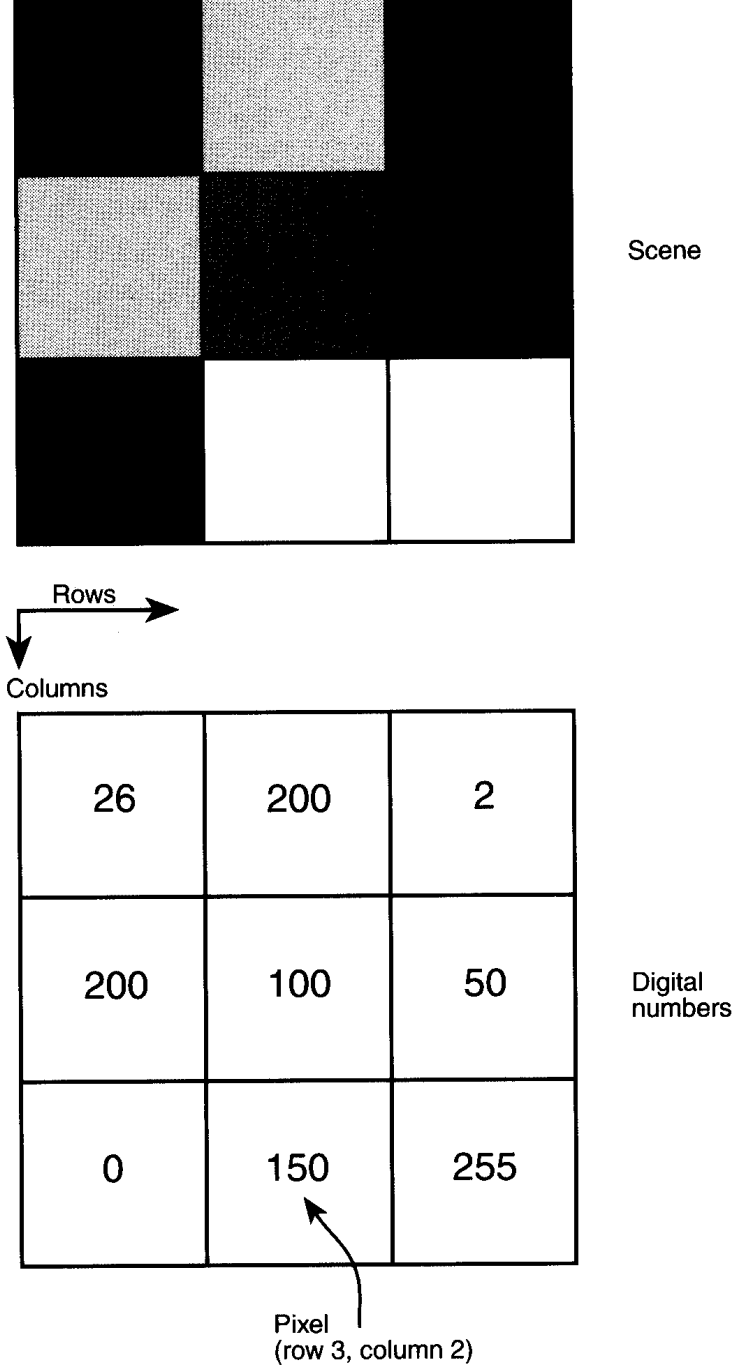
Digital Image



Digital Images

- Digital image is a regular grid array of squares (**Pixels**) where each gird cell is assigned a digital number (**DN**)

- Low DN indicates Low reflectance and high DN indicates high reflectance
- Convention: Origin at the Top left corner
- CCDs: Charge Coupled Devices
- Systems employed to acquire digital data
  - Transverse Scanning System
  - Pushbroom System



Resolutions

Spatial Resolution

Spectral Resolution

Radiometric Resolution

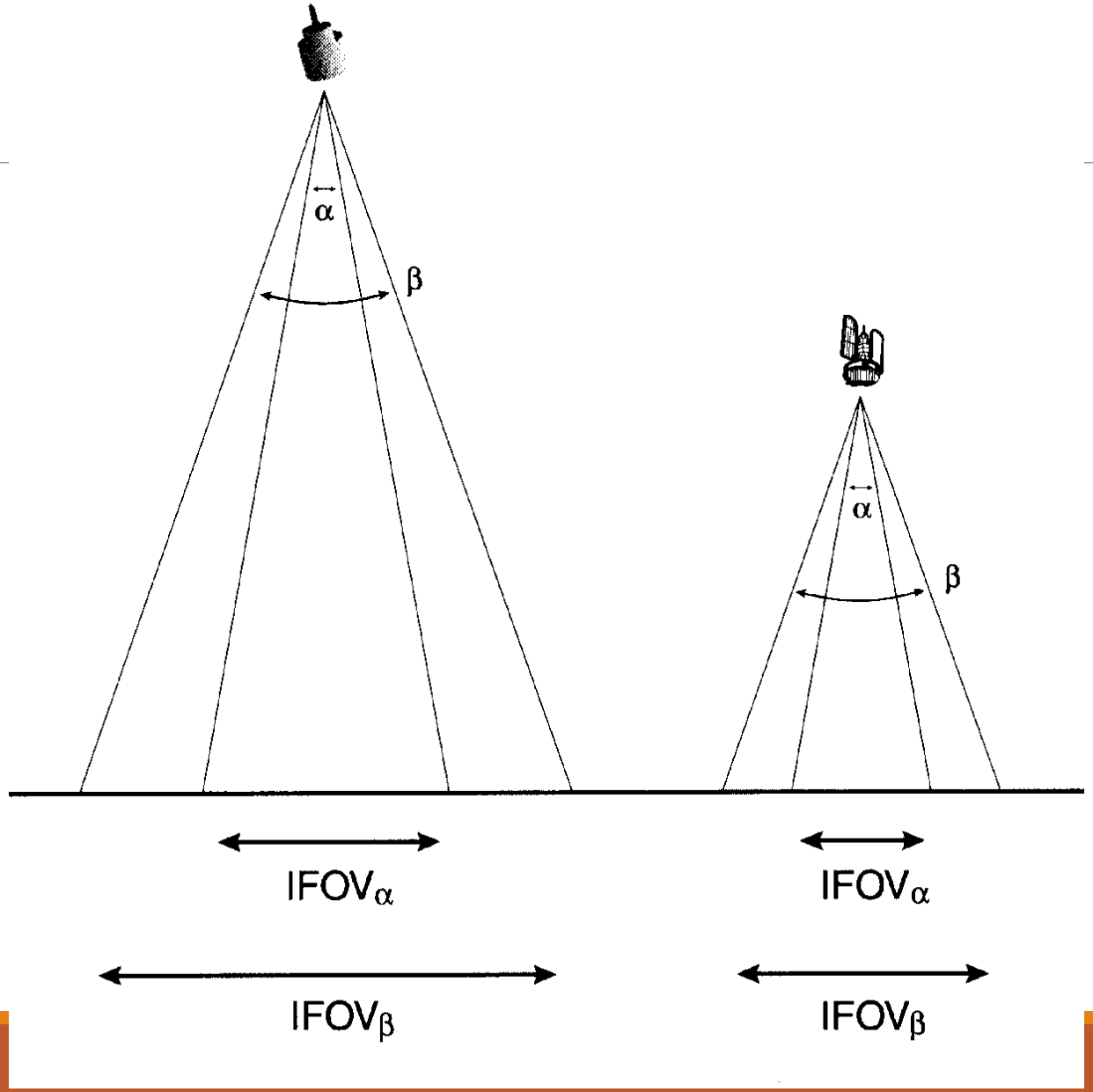
Temporal Resolution

Spatial Resolution

• This is a measure of the area or size of the smallest dimensions on the earth's surface over which an independent measurement can be made (pixel) by the sensor

•Expressed by the size of the pixel on the ground (ie., size of ground resolution cell) in m

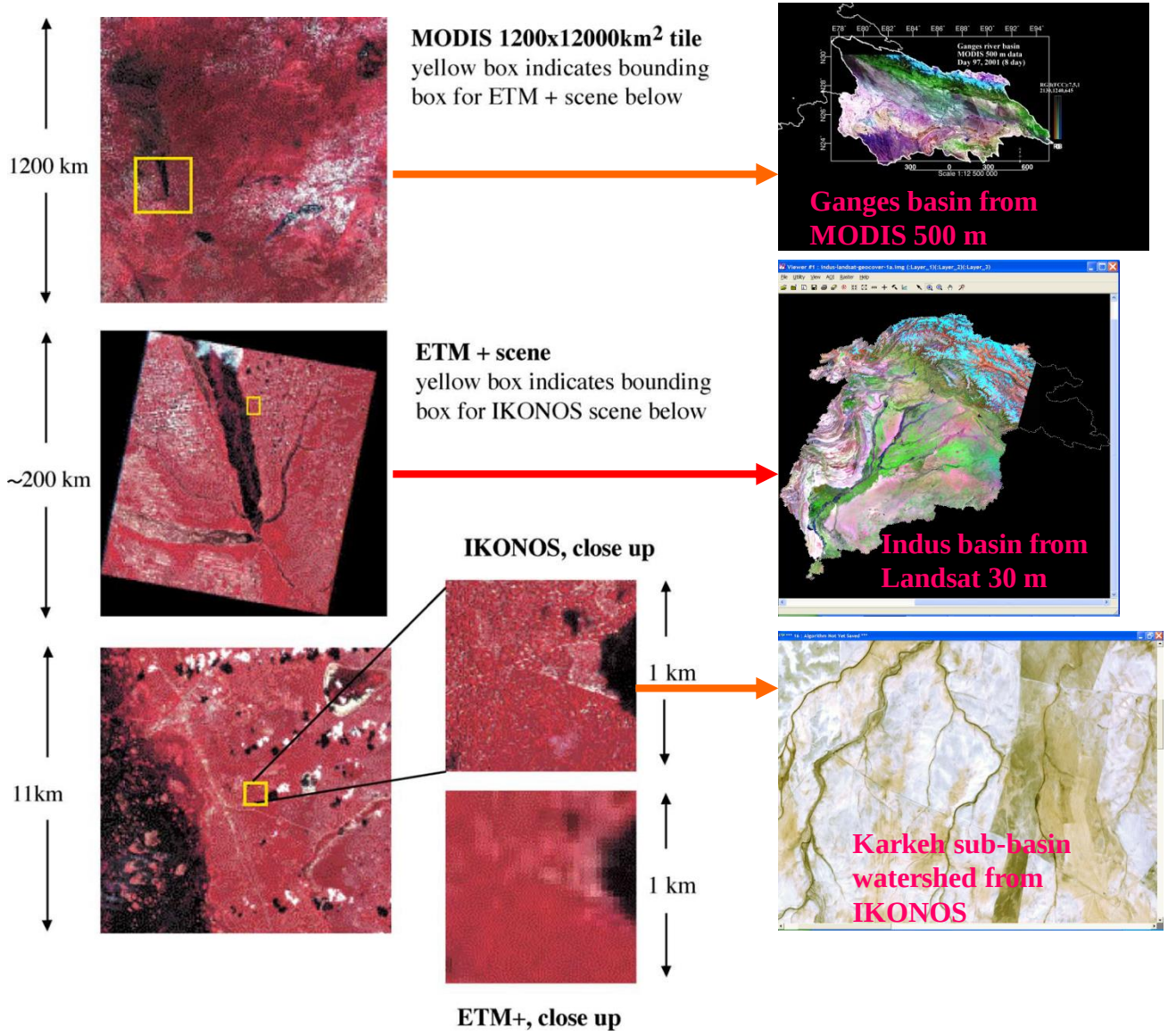
Spatial Resolution



Coarse Spatial Resolution

Fine Spatial Resolution

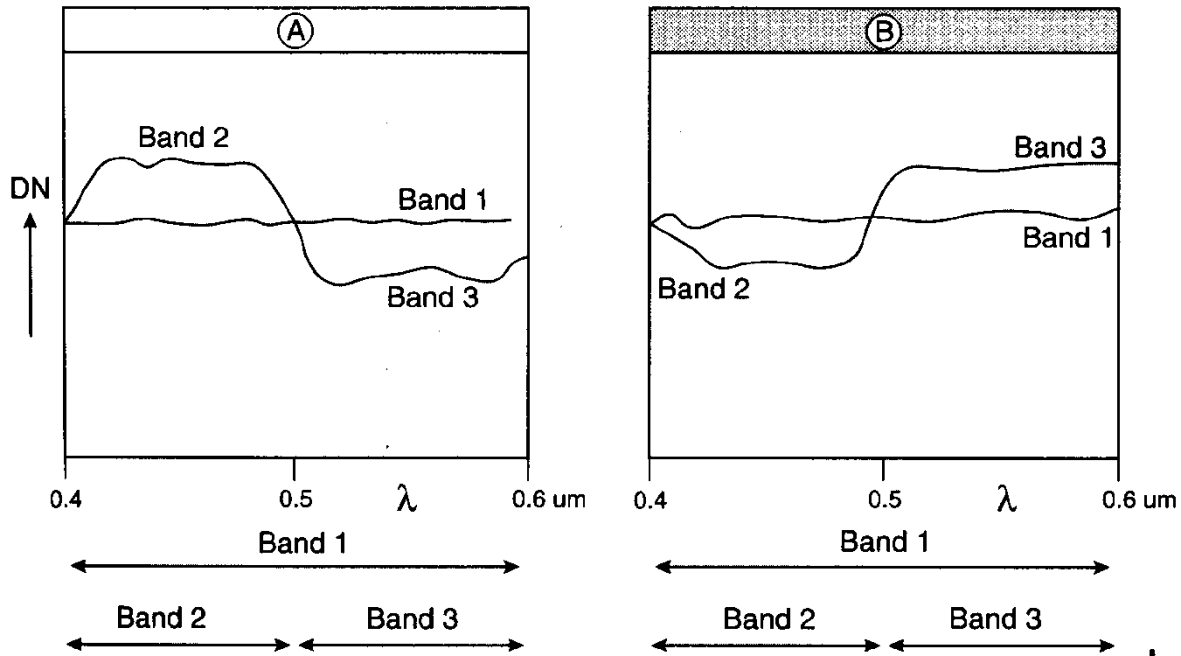
Data in a wide range of Pixel Resolutions (or scales), Radiometry, Bandwidths, and time-scales



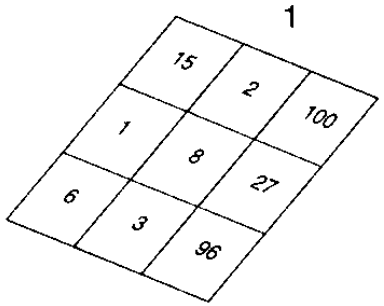
False color composite image (red = 850 nm, blue = 650 nm, blue = 555 nm) of MODIS, ETM+ and IKONOS imagery (Left image Courtesy: Morisette, 2002).

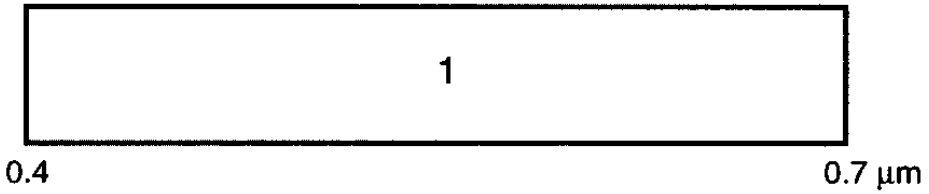
Spectral Resolution

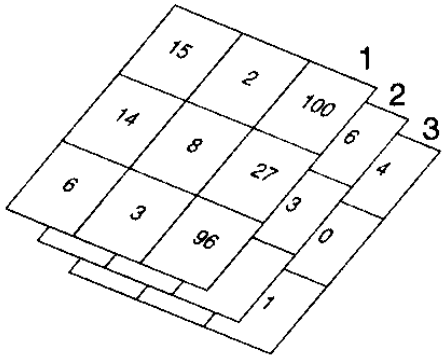
- The spectral resolution of a sensor characterizes the ability of the sensor to resolve the energy received in a spectral bandwidth to characterise different constituents of earth surface
- Spectral resolution is defined as the spectral band width of the filter and the sensitiveness of the detector
- Two different surfaces (A and B) are indistinguishable on a single band but can be differentiated in 2 bands

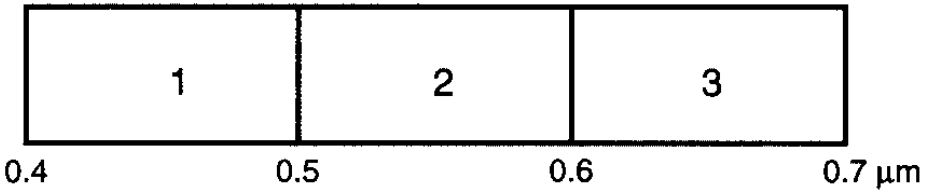


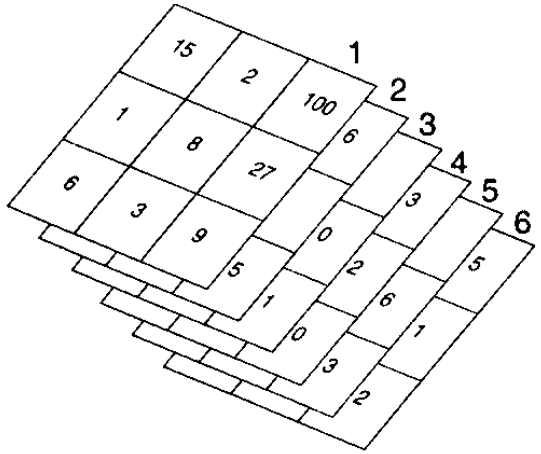
Spectral Resolutio

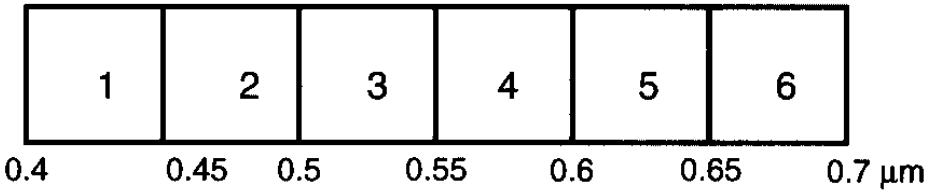






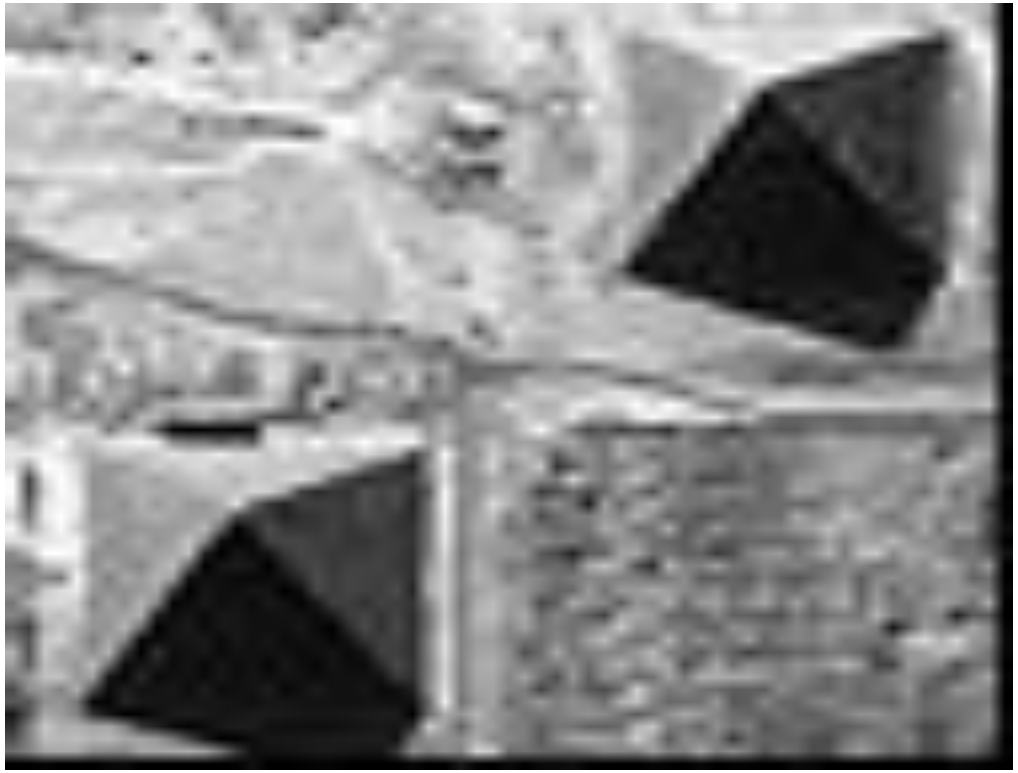






Spectral Resolution

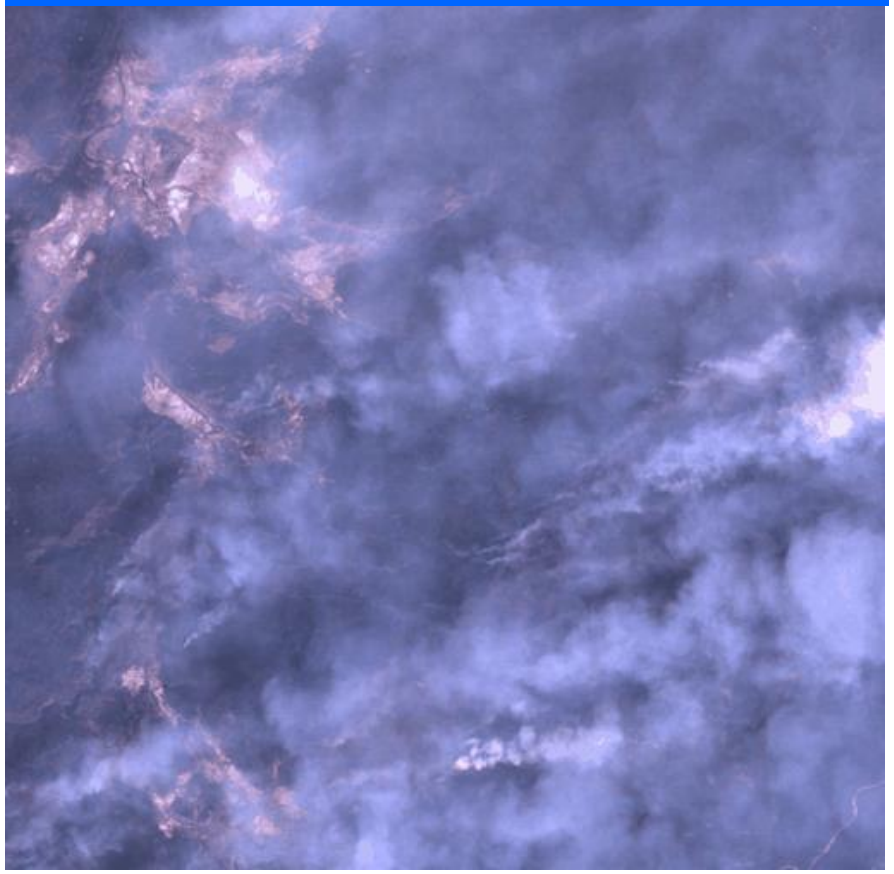
Pan Image (Course)



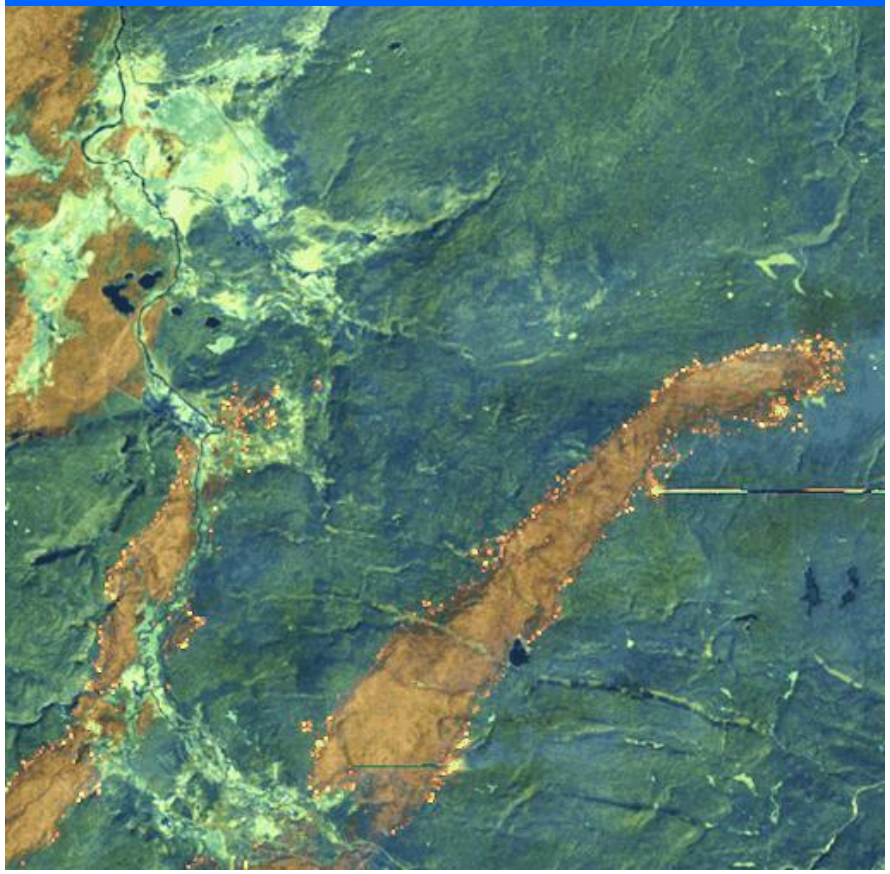
Landsat TM RGB=543 (Fine)

Forest Fire (Yellowstone NP)

Yellowstone NP, TCC (TM 321)



Yellowstone NP, FCC (TM 754)



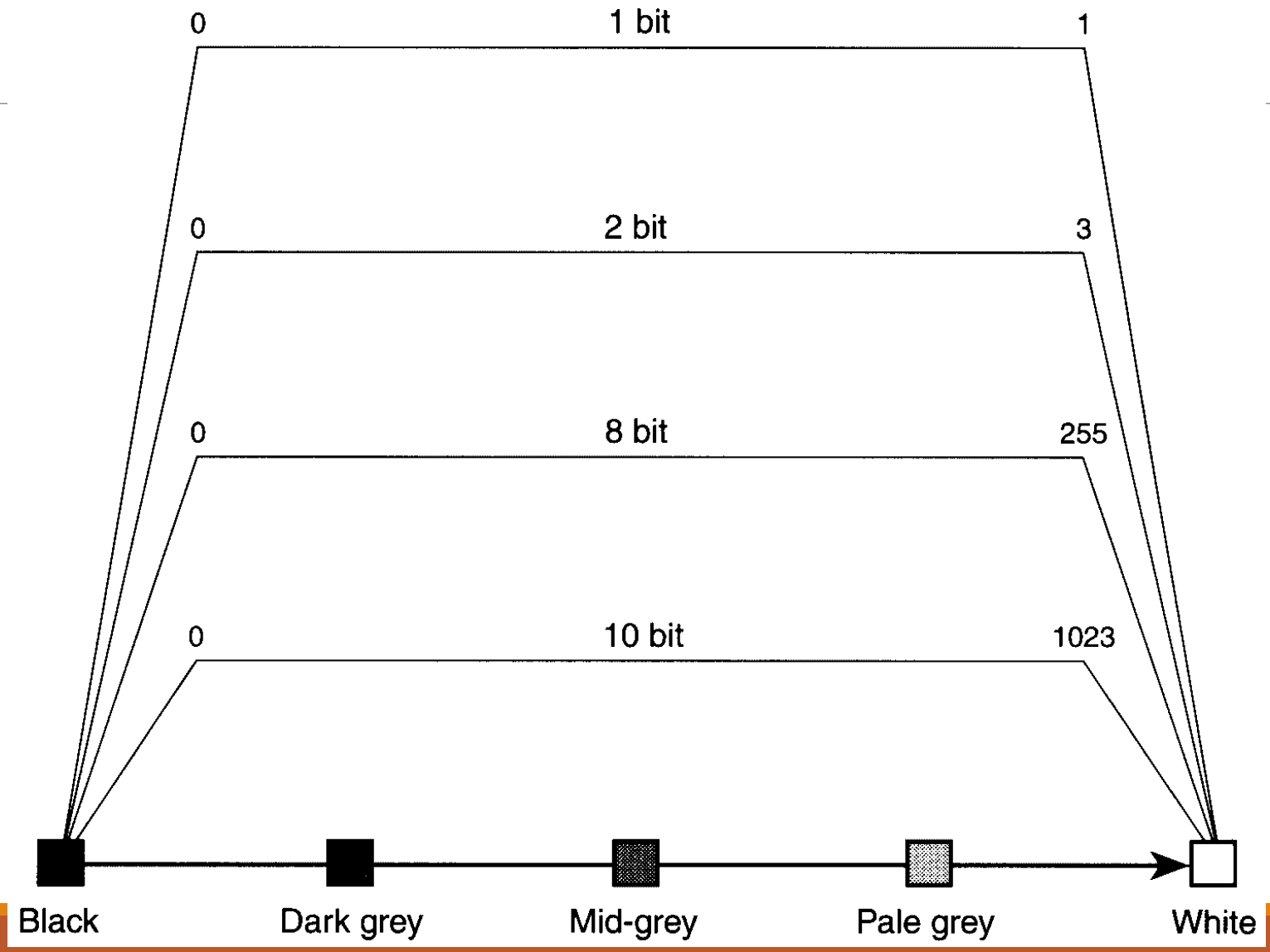
Radiometric Resolution

- Radiometric resolution of a sensor is a measure of how many grey levels are measured between pure black (no reflectance) to pure white.

- Is measured in bits — Examples
  - 1 bit (2^1) – 2 levels
  - 7 bits (2^7) – 128 levels — IRS 1A & 1B
  - 8 bits (2^8) – 256 levels — Ladnsat TM
  - 11 bits (2^{11}) – 2048 levels — NOAA – AVHRR

- In a 8 bit system, black is measured as 0 and white is measured as 255.
- For comparison across bands, all the bands should have same radiometric resolution.

Radiometric Resolution



Radiometric Resolution

2 Bit Data (Coarse)

8 Bit Data (Fine)

Temporal Resolution

- Temporal resolution of a RS system is a measure of how often data are obtained for the same area
  - Applicable to satellite RS only

- Temporal resolution varies from less than one hour to approximately 30 days.

Importance of Temporal Resolution

- Change in Land Use/ Land Cover
- Temporal Variation
- Monitoring of a Dynamic Event
  - Cyclone
  - Flood
  - Volcano
  - Earthquake

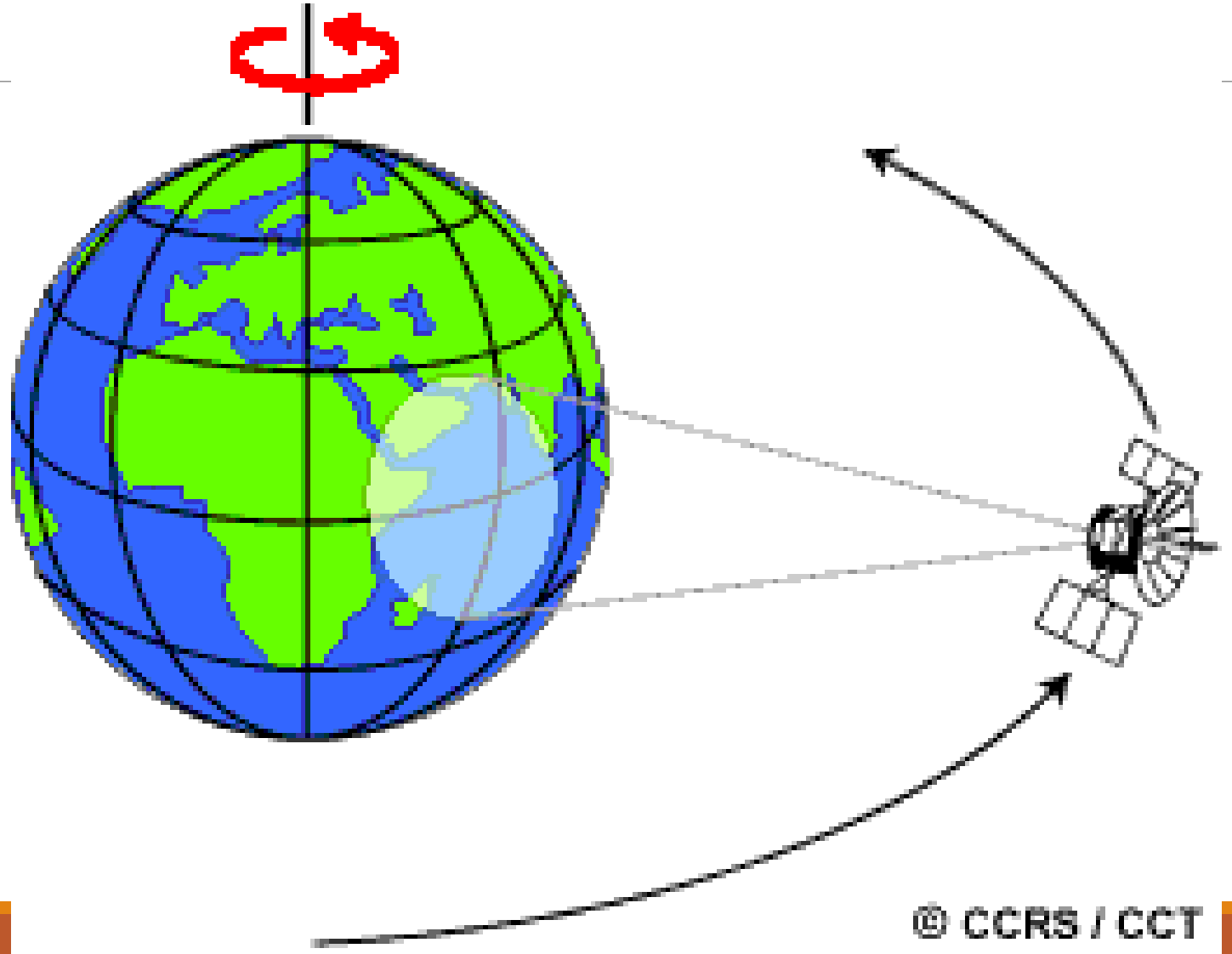
Satellite Orbits

Geostationary & Polar Orbiting Satellites

Geostationary or Geosynchronous Satellites are used for communication & meteorological purposes

- Satellite is stationary with respect to a point on equator
- Satellite must be geosynchronous i.e., orbital period should be 24 hrs.
- Placed in high altitude of 36,000 km
- It must be on equatorial plane
  - Heavily inclined orbit – 180^{o}
- Sense of direction must be the same as sense of rotation of earth on its axis i.e., West to East
- Can yield a large area coverage of 45% to 50% of the total globe (Foot Print)

Geo-stationary Orbit

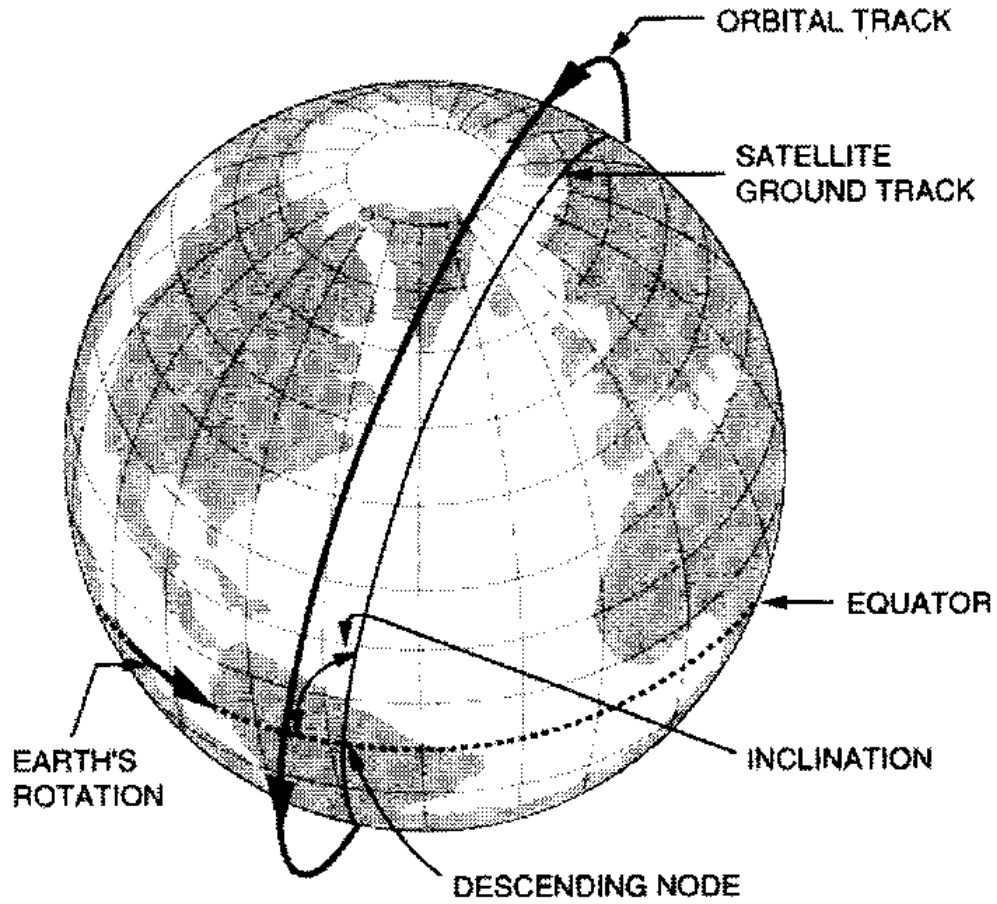


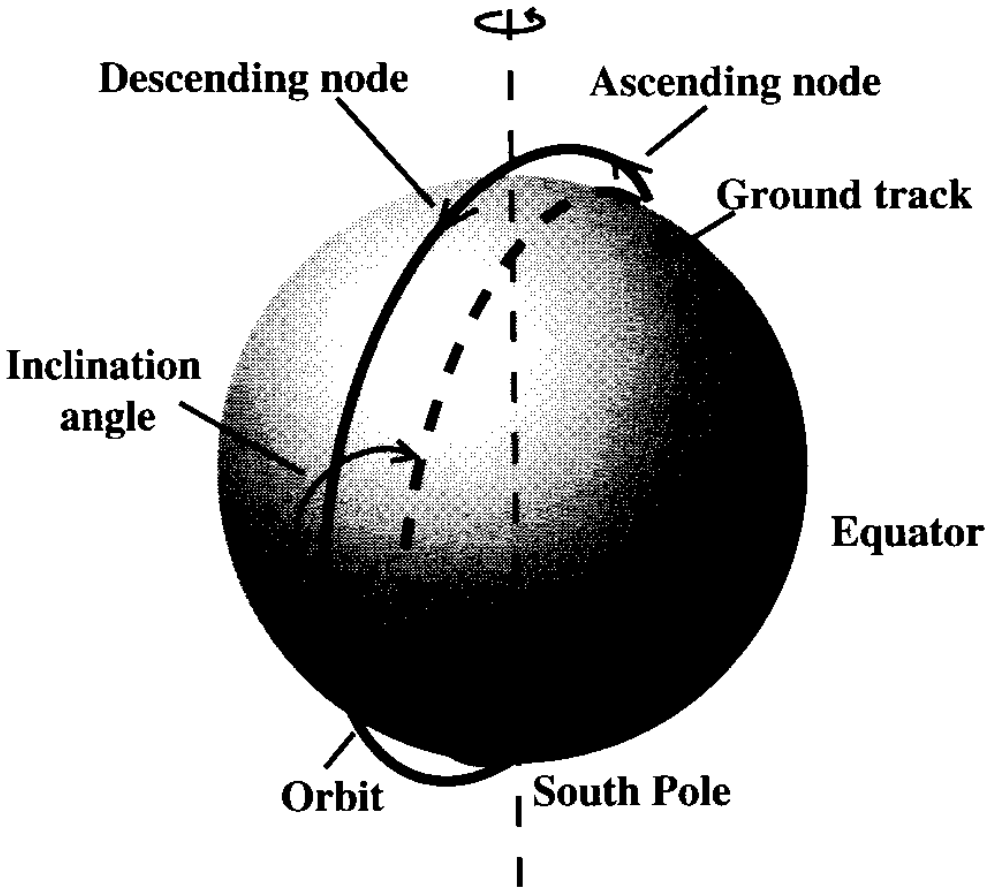
Polar Orbits

Polar orbit is to take the advantage of earth's rotation on its axis so that the newer segments (or sections) of earth will be under view of the satellite, provided the orbital period is smaller than the rotational period of earth (24 hrs)

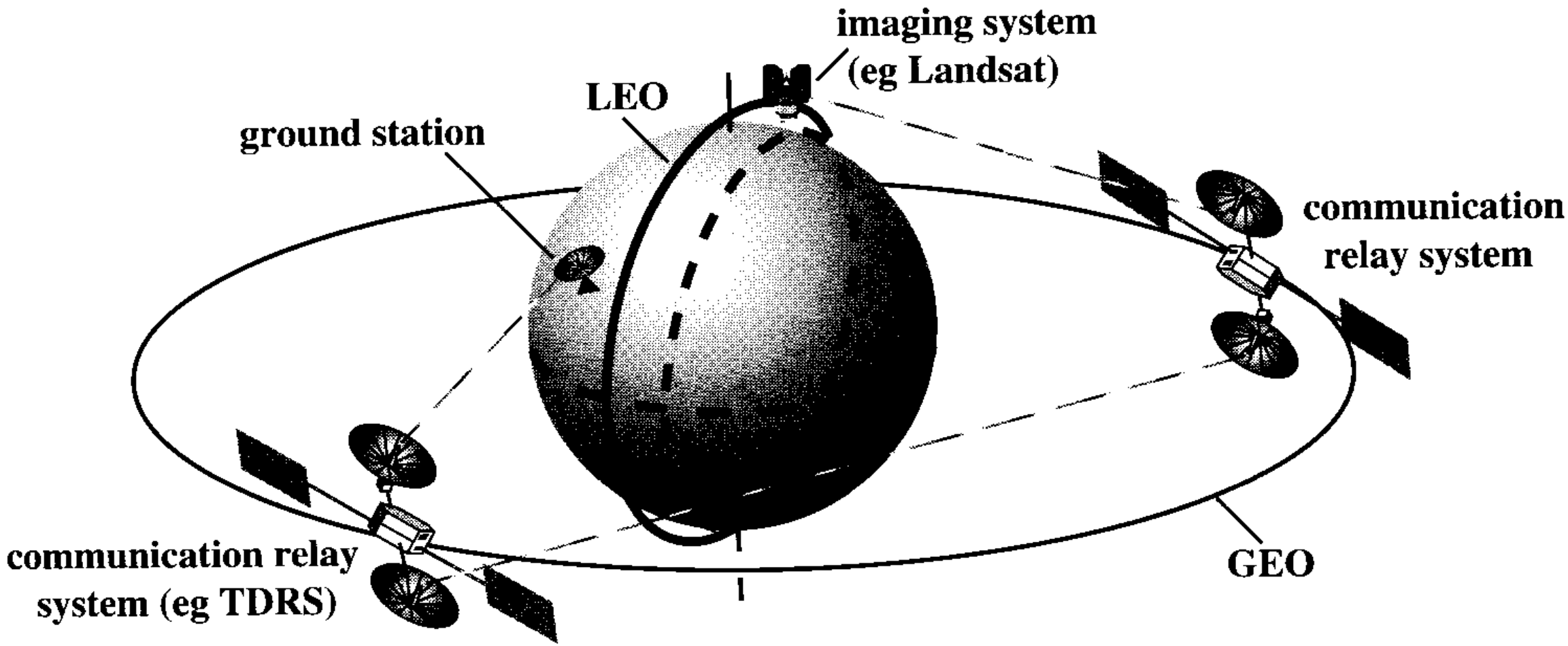
- Typically RS satellite period will be 103 mts.

Polar Orbiting Satellites

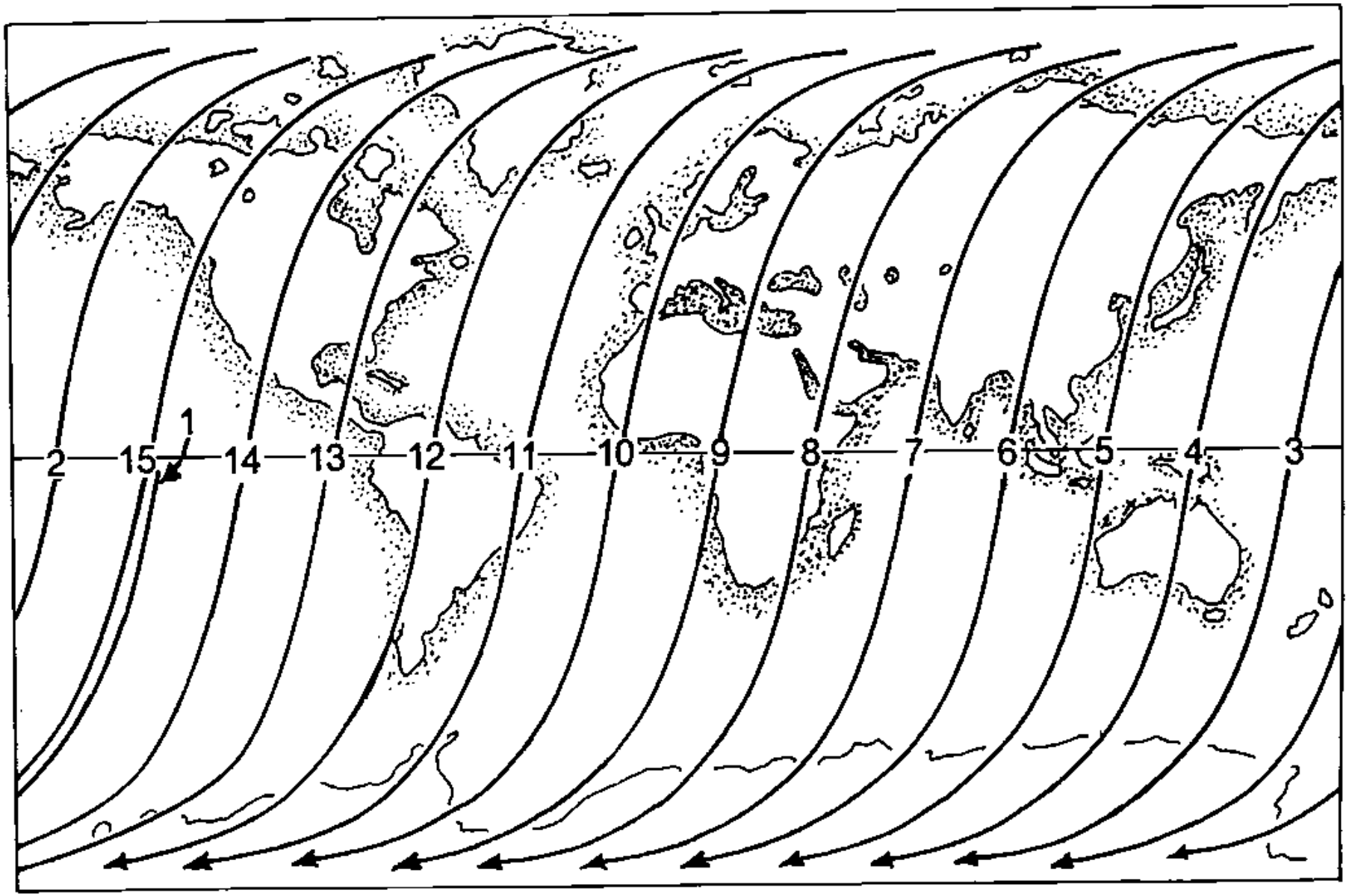




Geostationary & Polar Orbiting Satellites



Coverage Cycle of Landsat 1, 2 & 3 (14 Orbits per day)Incremental shift – 18 days revisiting



Landsat – TM Sensor Characteristics

Band	Resolution	Spectral definition	Some applications[a]
1	30 m	Blue-green, 0.45–0.52 μm	Penetration of clear water; bathymetry; mapping of coastal waters; chlorophyll absorption; distinction between coniferous and deciduous vegetation
2	30 m	Green, 0.52–0.60 μm	Records green radiation reflected from healthy vegetation; assesses plant vigor; reflectance from turbid water
3	30 m	Red, 0.63–0.69 μm	Chlorophyll absorption important for plant-type discrimination
4	30 m	Near infrared, 0.76–0.90 μm	Indicator of plant cell structure; biomass; plant vigor; complete absorption by water facilitates delineation of shorelines
5	30 m	Mid-infrared, 1.55–1.75 μm	Indicative of vegetation moisture content; soil moisture mapping; differentiating snow from clouds; penetration of thin clouds
6	120 m	Far infrared, 10.4–12.5 μm	Vegetation stress analysis; soil moisture discrimination; thermal mapping; relative brightness temperature; soil moisture; plant heat stress
7	30 m	Mid-infrared, 2.08–2.35 μm	Discrimination of rock types; alteration zones for hydrothermal mapping; hydroxyl ion absorption

[a]Sample applications listed here; these are not the only applications.

Revisit - 16 days; Swath – 185 km

IRS Program

IRS 1A - 1988; IRS 1B – 1991

IRS 1C - 1995; IRS 1D - 1997

Pan – 0.5-0.75 μm; 5.8 m;

Swath: 70 km – 90 km; Revisit: 5 days

WiFS; OBTR (24 mts or 62 GB)

Spectral Characteristics of LISS I & LISS II (IRS 1A & 1B)

Band	Spectral limits	Resolution	
		LISS-I	LISS-II
1	Blue-green 0.45–0.52 μm	72.5 m	36.25 m
2	Green 0.52–0.59 μm	72.5 m	36.25 m
3	Red 0.62–0.68 μm	72.5 m	36.25 m
4	Near infrared 0.77–0.86 μm	72.5 m	36.25 m

Spectral Characteristics of LISS III (IRS 1C & 1D)

Band	Spectral limits	Resolution
1[a]	Blue —	
2	Green 0.52–0.59 μm	23 m
3	Red 0.62–0.68 μm	23 m
4	Near infrared 0.77–0.86 μm	23 m
5	Mid-infrared 1.55–1.70 μm	70 m

[a]Band 1 is not included in this instrument, although the numbering system from earlier satellites is maintained to provide continuity.

Revisit - 22 days; Swath – 148.48 km for LISS I and 74.24 km LISS II

SPOT

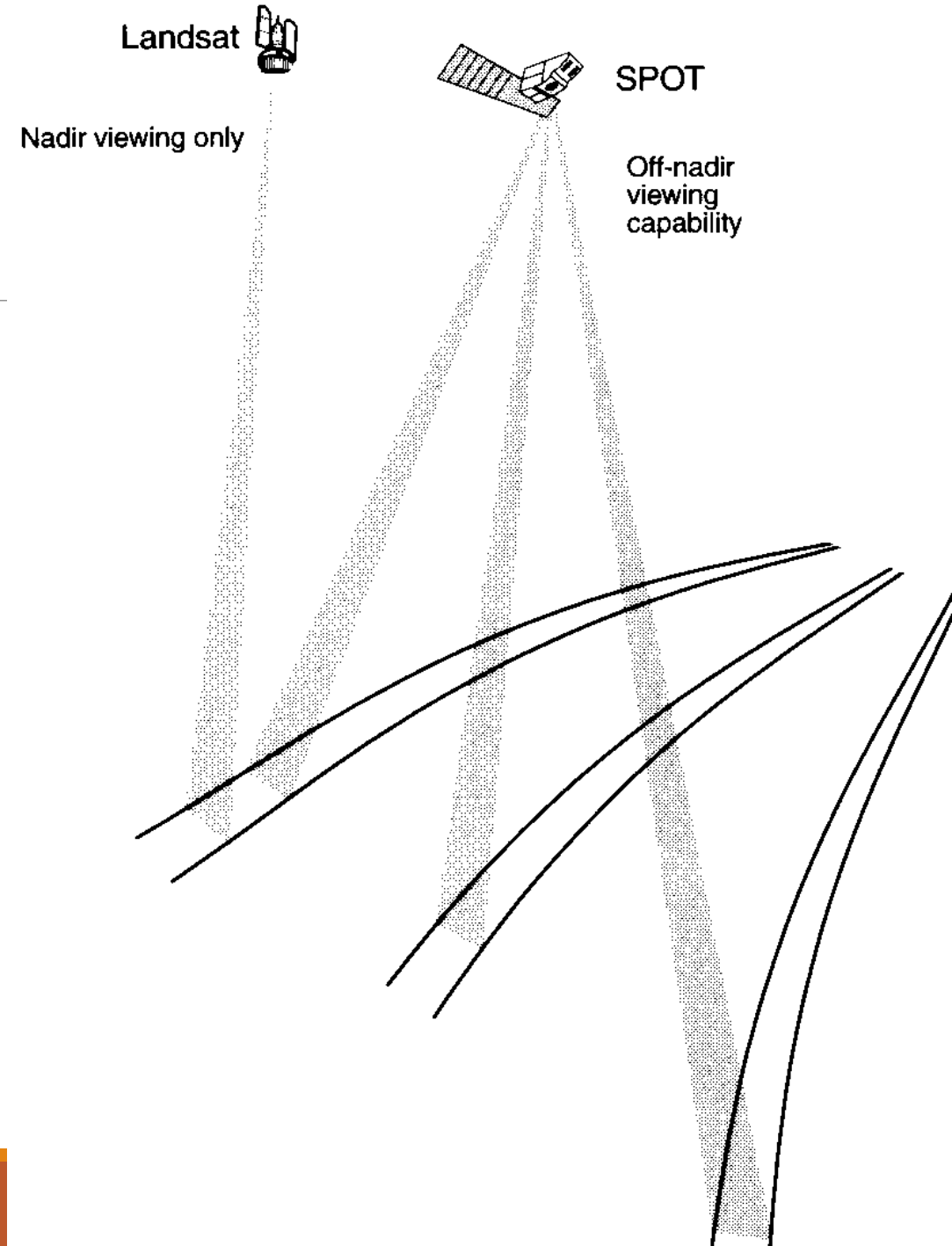
Satellite Probatoire d'Observation de la Terre

Multispectral mode (XS)

Band 1	0.50–0.59 μm (green)
Band 2	0.61–0.68 μm (red)
Band 3	0.79–0.89 μm (near infrared)
Band 4 (SPOT 4 only)	1.58–1.75 μm (near infrared)

Panchromatic mode (P)

0.51–0.73 μm (SPOT 1, 2 and 3)
0.61–0.68 μm (SPOT 4)



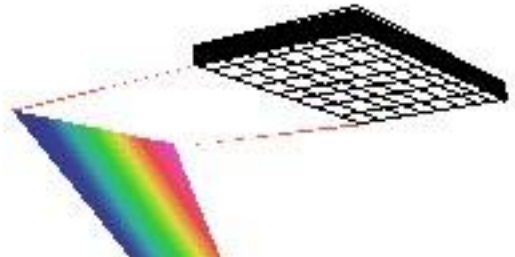
Hyperspectral Imaging

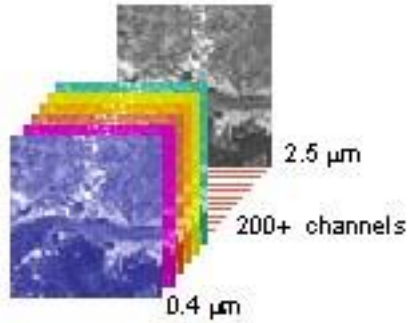
Hyperspectral imaging has wide ranging applications in mining, geology, forestry, agriculture, and environmental management. Detailed classification of land assets through the Hyperion will enable more accurate remote mineral exploration, better predictions of crop yield, and assessments, and better containment mapping.

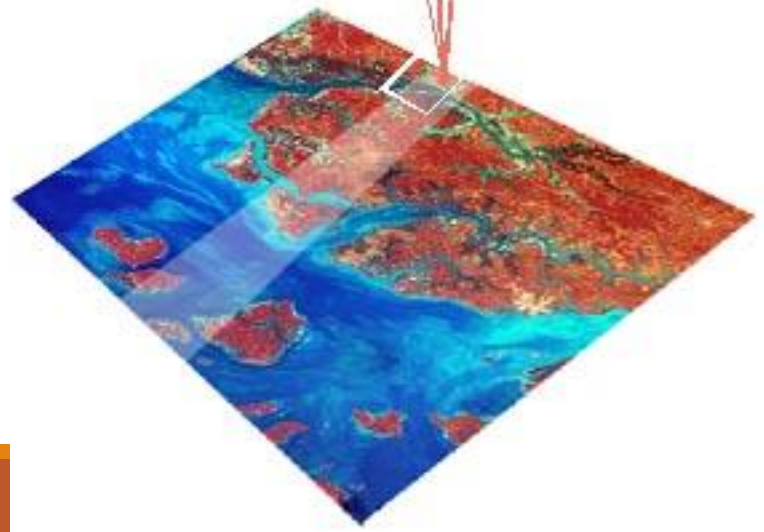
NASA EO-1 Hyperion

- Hyperion capabilities provide resolution of surface properties into hundreds of spectral bands versus less than ten multispectral bands flown on traditional RS Satellites
- Through the large number of spectral bands, complex land eco-systems shall be imaged and accurately classified
- The Hyperion provides a high resolution hyperspectral imager capable of resolving 220 spectral bands (from 0.4 to 2.5 µm) with a 30 meter spatial resolution and 10 nm spectral resolution. The instrument images a 7.5 km by 100 km land area per image and provides detailed spectral mapping across all 220 channels with high radiometric accuracy.

Hyperspectral Imaging







Eo1 -Hyperion

High resolution hyper spectral imagery with 220 spectral bands

Band	Wavelength (µm)	Bandwidth (µm)	Resolution (m)	Swath Width (km)	Revisit time (days)
Band (Hyper)	0.4 to 2.5	0.01	30	7.5 (100	3-5

Moderate Resolution Imaging Spectroradiometer

ODIS Revisit time – 2 d

Band	Wavelength (µm)	Resolution (m)	Swath Width (km)	Band	Wavelength (µm)	Resolution (m)	Swath Width (km)
Band 1 (VIS)	0.62 to 0.67	250	2330 (10)	Band 19 (NIR)	0.915 to 0.965	1000	2330 (10)
Band 2 (NIR)	0.841 to 0.876	250	2330 (10)	Band 20 (MWIR)	3.66 to 3.84	1000	2330 (10)
Band 3 (VIS)	0.459 to 0.479	500	2330 (10)	Band 21 (MWIR)	3.929 to 3.989	1000	2330 (10)
Band 4 (VIS)	0.545 to 0.565	500	2330 (10)	Band 22 (MWIR)	3.929 to 3.989	1000	2330 (10)
Band 5 (NIR)	1.23 to 1.25	500	2330 (10)	Band 23 (MWIR)	4.02 to 4.08	1000	2330 (10)
Band 6 (SWIR)	1.628 to 1.652	500	2330 (10)	Band 24 (MWIR)	4.433 to 4.498	1000	2330 (10)
Band 7 (SWIR)	2.105 to 2.155	500	2330 (10)	Band 25 (MWIR)	4.482 to 4.549	1000	2330 (10)
Band 8 (VIS)	0.405 to 0.42	1000	2330 (10)	Band 26 (SWIR)	1.36 to 1.39	1000	2330 (10)
Band 9 (VIS)	0.438 to 0.448	1000	2330 (10)	Band 27 (TIR)	6.535 to 6.895	1000	2330 (10)
Band 10 (VIS)	0.483 to 0.493	1000	2330 (10)	Band 28 (TIR)	7.175 to 7.475	1000	2330 (10)
Band 11 (VIS)	0.526 to 0.536	1000	2330 (10)	Band 29 (TIR)	8.4 to 8.7	1000	2330 (10)
Band 12 (VIS)	0.546 to 0.556	1000	2330 (10)	Band 30 (TIR)	9.58 to 9.88	1000	2330 (10)
Band 13 (VIS)	0.662 to 0.672	1000	2330 (10)	Band 31 (TIR)	10.78 to 11.28	1000	2330 (10)
Band 14 (VIS)	0.673 to 0.683	1000	2330 (10)	Band 32 (TIR)	11.77 to 12.27	1000	2330 (10)
Band 15 (VIS)	0.743 to 0.753	1000	2330 (10)	Band 33 (TIR)	13.185 to 13.485	1000	2330 (10)
Band 16 (NIR)	0.862 to 0.877	1000	2330 (10)	Band 34 (TIR)	13.485 to 13.785	1000	2330 (10)
Band 17 (NIR)	0.89 to 0.92	1000	2330 (10)	Band 35 (TIR)	13.785 to 14.085	1000	2330 (10)
Band 18 (NIR)	0.931 to 0.941	1000	2330 (10)	Band 36 (TIR)	14.085 to 14.385	1000	2330 (10)

MODIS data examples

Fine Spatial Resolution Systems

- *Band 1:* 0.45–0.52 μm (blue)
- *Band 2:* 0.52–0.60 μm (green)
- *Band 3:* 0.63–0.69 μm (red)
- *Band 4:* 0.76–0.90 μm (near infrared)

April 1999; IFOV – 1 m; 0.45-0.90 μm

Swath – 11 km (Nadir); Revisit: 1.5 – 3 days

IKONOS

October 2001

IFOV – 61 cm (Pan) & 2.44 m (MSS)

Swath – 16.5 km (Nadir); Revisit: < 3 days

QuickBird

- *Band 1:* 0.45–0.52. μm (blue)
- *Band 2:* 0.52–0.60 μm (green)
- *Band 3:* 0.63–0.69 μm (red)
- *Band 4:* 0.76–0.890 μm (near infrared)
- *Band 5:* 0.76–0.890 μm (panchromatic)

Examples of Quick bir images

Color Composites - Data

Landsat TM

Average Orbital Height: 700 km (440 Miles)
Spatial Resolution: 30 m, except band 6 which is 90 m
Records Data in 7 Wavelength Intervals (bands)

1. Visible Blue (0.45 to 0.52 microns)
2. Visible Green (0.52 to 0.60 microns)
3. Visible Red (0.63 to 0.69 microns)
4. Near Infrared (0.76 to 0.90 microns)
5. Mid Infrared (1.55 to 1.75 microns)
6. Thermal Infrared (10.4 to 12.5 microns)
7. Mid Infrared (2.08 to 2.35 microns)

Bands 1,2,3,4,5, and 7 record reflected energy
Band 6 records emitted thermal (heat) energy
Satellite Images of the Keweenaw Peninsula, USA

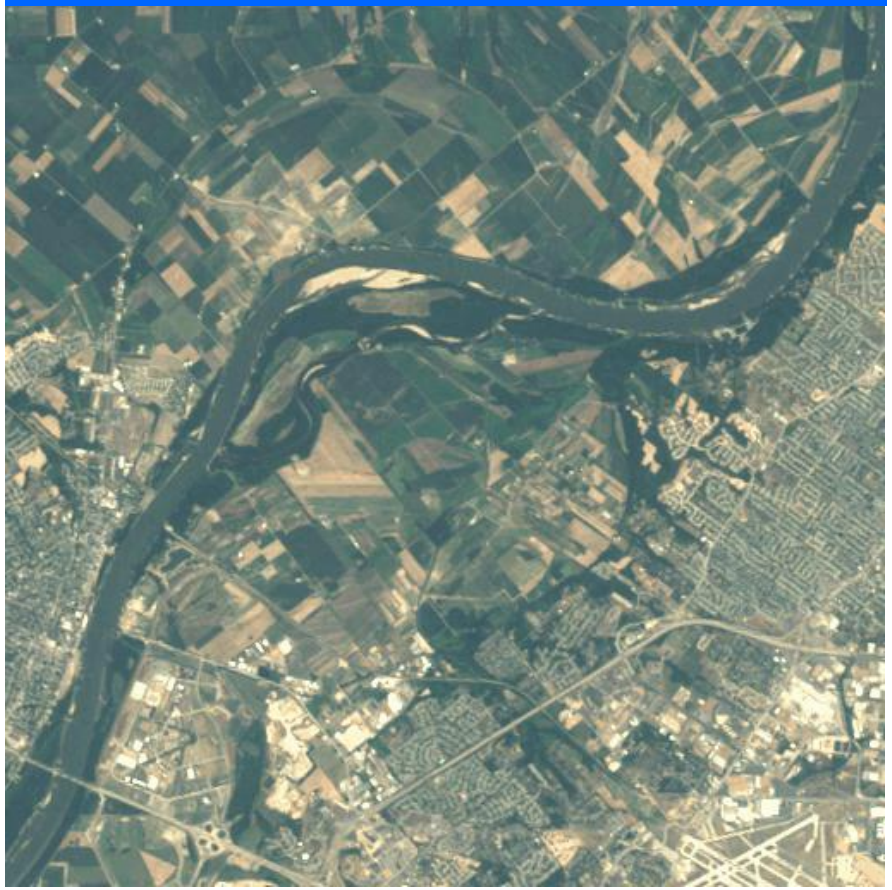
Photographic RS

False Colour

- **True Colour Composite (TCC)**
  - **Red band – Red; Green band – Green; Blue band – Blue**
- **False Colour Composite (FCC)**
  - **Any other combination of colours**
  - **E.g., Blue band – Red; Red band – Green; Green band – Blue**
  - **E.g., Blue band – Red; Red band – Green; NIR band – Blue**
- **Standard False Colour Composite (FCC)**
  - **E.g., NIR band – Red; Red band – Green; Green band – Blue**
  - **In IRS: Band 4 – Red; Band 3 – Green; Band 2 – Blue**

Monitoring Mississippi Flood

Non Flood Year (1988), TM 321

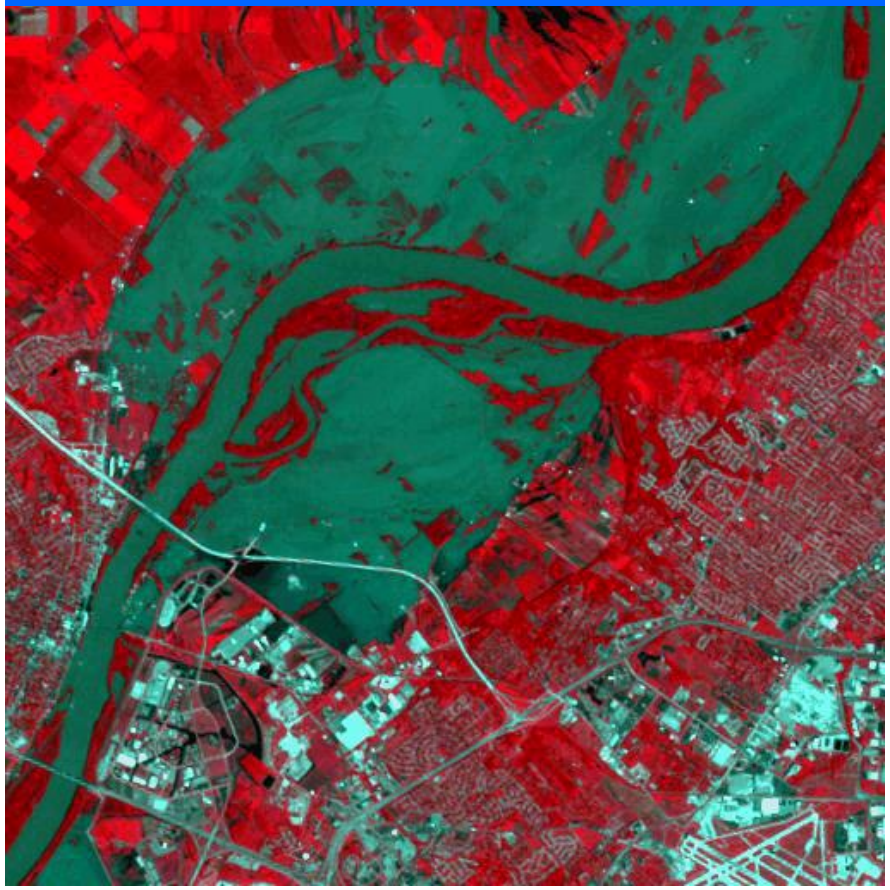


Flood Year (1993), TM 321

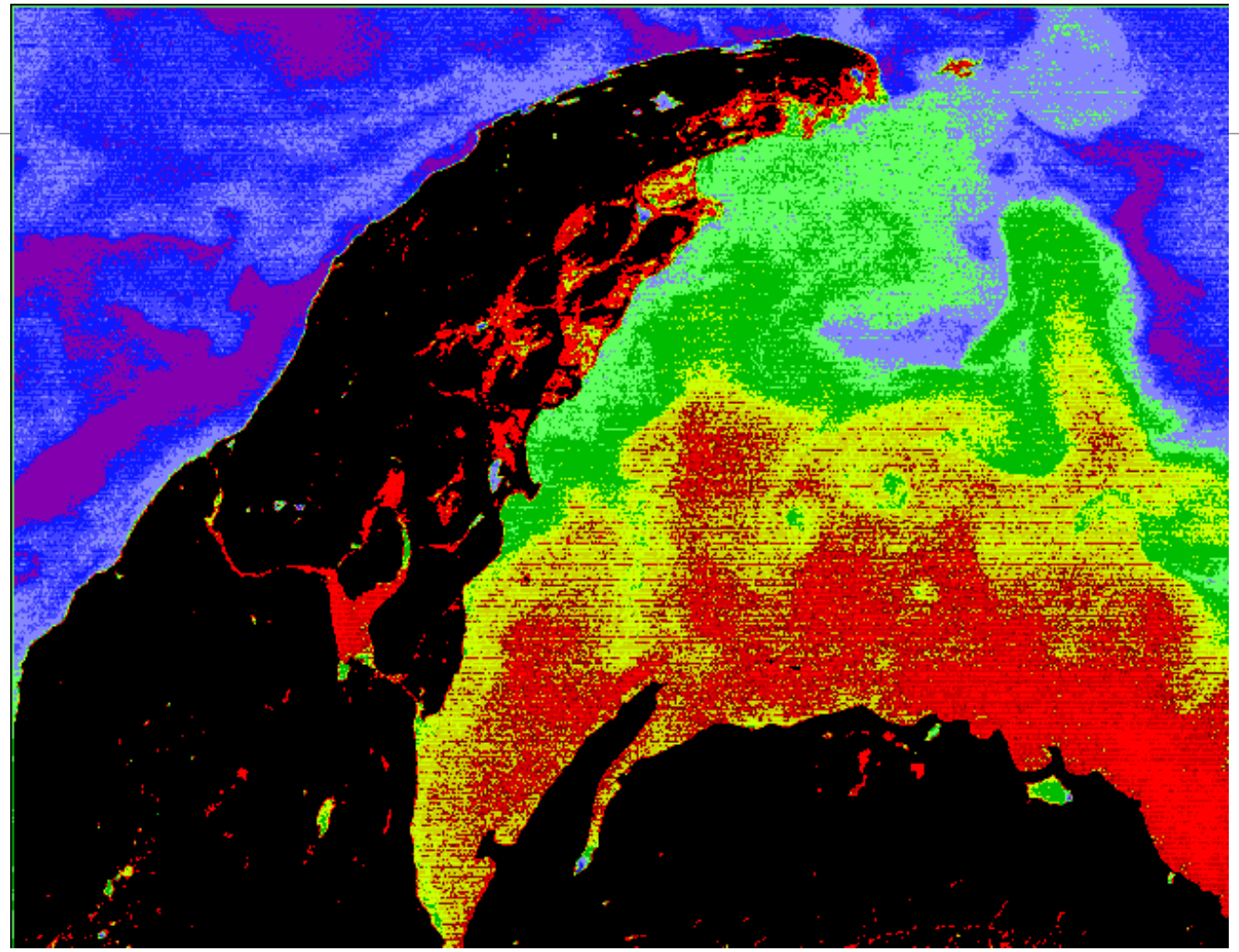
Monitoring Mississippi Flood

Non Flood Year (1988), TM 432

Flood Year (1993), TM 432



Temperature Image



Reference Material

Dr. T.V. Ramachandra, Principles of remote sensing in environmental Management, IISc

Dr. Nagesh Kumar, Notes of Priniciples of remote sensing in water resources, IISc

Landsat.org

Tutorials, CCRS, Canada

ITC, netherlands