Remote Sensing Introduction

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1

Outline

- EMR Spectrum
- Energy Interactions with Earth Surface
- Remote Sensing Images
- Satellites & Orbits

2

Remote Sensing

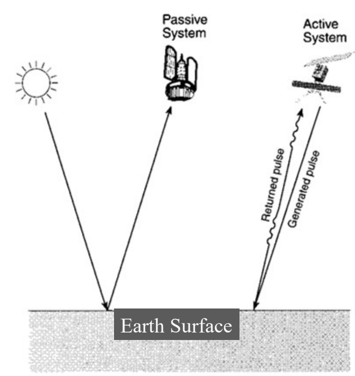
Remote Sensing is the science and art of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in physical contact with the object, area or phenomenon under investigation.

Examples

1. Eyes are living examples (EMR distribution)
2. Sonar (like bats): Acoustic wave distribution
3. Gravity Meter: Gravity force distribution

3

Passive and Active Remote Sensing



4

[redacted]emote Sensing

[redacted]ATA ACQUISITION

DATA ANALYSIS

Sensing System | Data Products | Interp-retation | Infor-mation | Users

Passive RS
Active RS

Satellite
High Altitude Arial
Low Altitude Arial
Ground Level

Reference Data
Pictorial
Numerical/ Digital

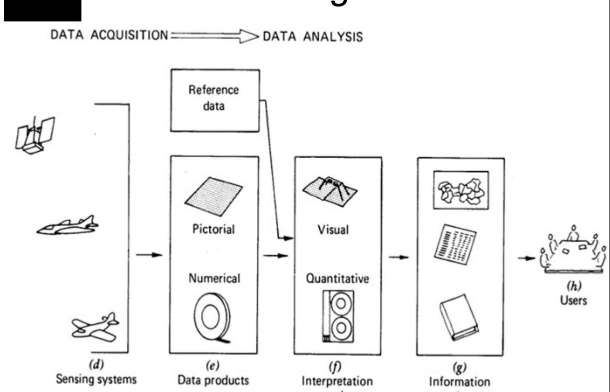
Visual
Digital

Maps/ Photos
Numerical
Reports

End Users

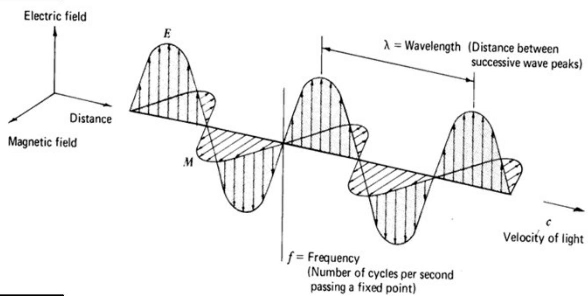
5

[redacted]emote Sensing



6

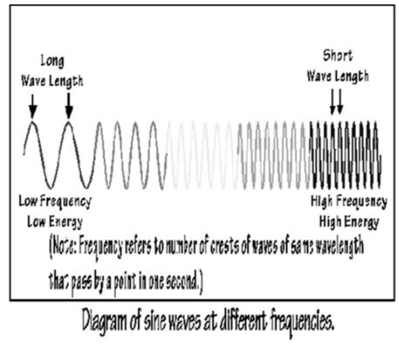
[redacted]lectromagnetic Wave



[redacted]inusoidal Electric Wave (E)	$\lambda = c/f$
[redacted]agnetic Wave (M)	λ is wave length (μm)
	f is Frequency
[redacted]ight angels to the source	c is Celerity (3×10^8 m/s)

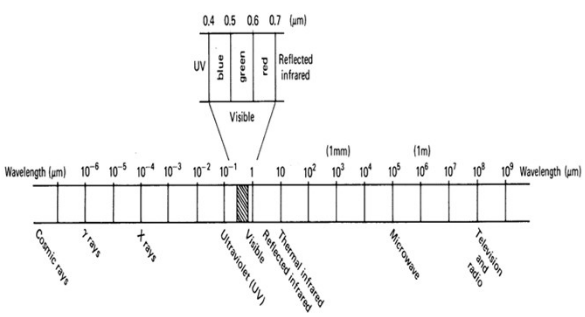
7

EMR



8

[redacted]MR Spectrum

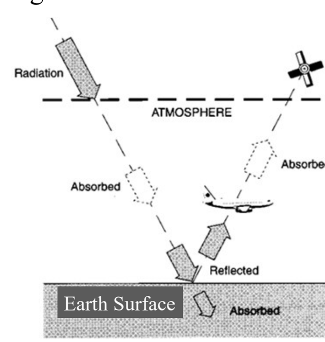


[redacted]

9

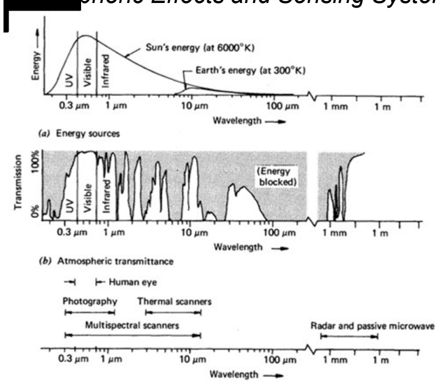
Energy Interactions in the Atmosphere

- All radiation detected by sensors passes through some distance of the atmosphere



10

[redacted]al characteristics of Energy sources, [redacted]pheric Effects and Sensing Systems



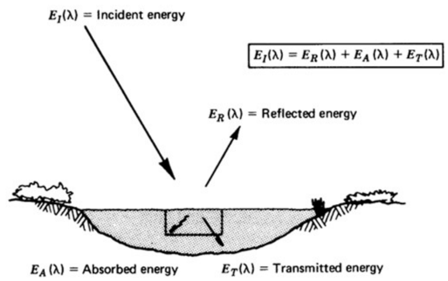
Wavelength is in logarithmic scale

11

Energy Interactions with Earth Surface

12

Energy Interactions with Earth Surface Features

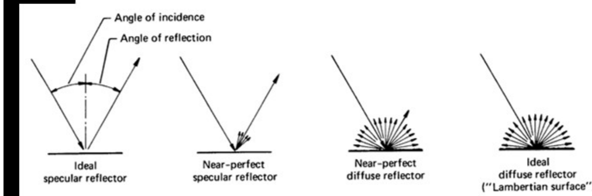


$$E_R(\lambda) = E_I(\lambda) - [E_A(\lambda) + E_T(\lambda)]$$

- Proportions of energy reflected, absorbed and transmitted will vary for different earth features
- Even within a given feature type these proportions will vary at different wavelengths

13

Specular Versus Diffuse Reflectance



- Diffuse reflections contain spectral information on the "color" of the reflecting surface, whereas specular reflections do not

Hence, in remote sensing, we are most often interested in measuring the diffuse reflectance properties of terrain features.

Spectral Reflectance - Albedo

$$R_\lambda = \frac{E_R(\lambda)}{E_I(\lambda)} = \frac{\text{Energy of wavelength } \lambda \text{ reflected from the object}}{\text{Energy of wavelength } \lambda \text{ incident upon the object}}$$

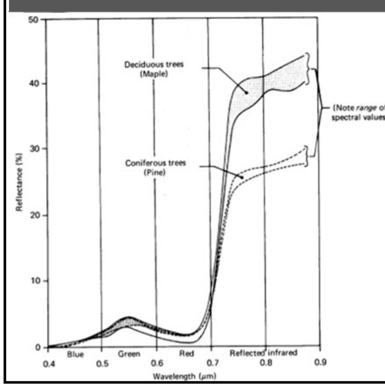
14

Albedo of various surface features

Surface Type	Albedo (%)
Grass	25
Concrete	20
Water	5–70
Fresh snow	80
Forest	5–10
Thick cloud	75
Dark soil	5–10

15

Generalised Spectral Reflectance Envelopes for Deciduous (Broad-leaved) and Coniferous (Needle-bearing leaves) Trees

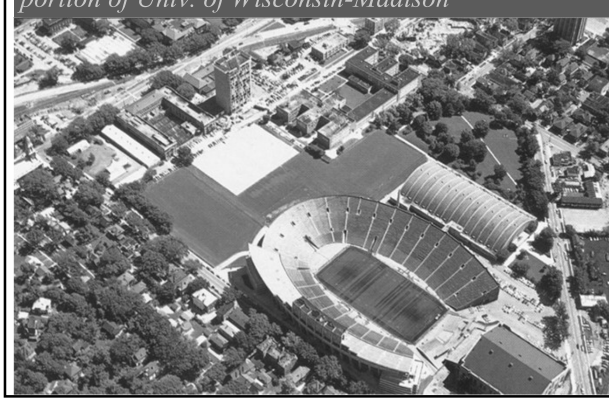


Spectral reflectance curve for each type overlap in most of the visible portion

However, in NIR they are quite different and distinguishable

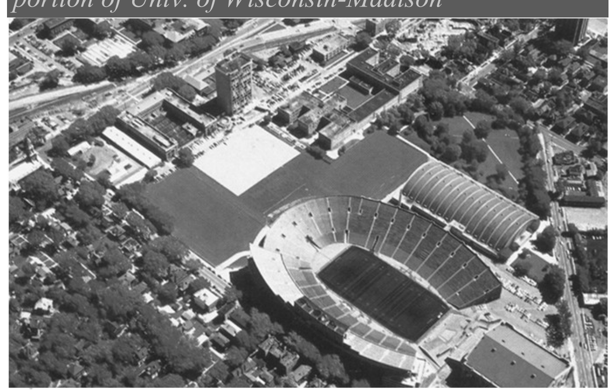
16

Oblique normal color aerial photograph showing portion of Univ. of Wisconsin-Madison



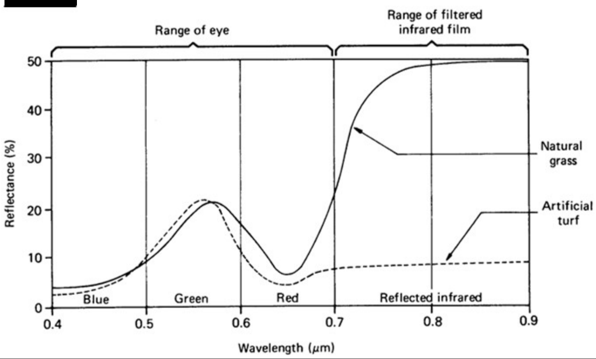
17

Oblique color infrared aerial photograph showing portion of Univ. of Wisconsin-Madison



18

Spectral Reflectance Curves for Natural Grass and Artificial Turf



19

Visible versus Infrared Photos

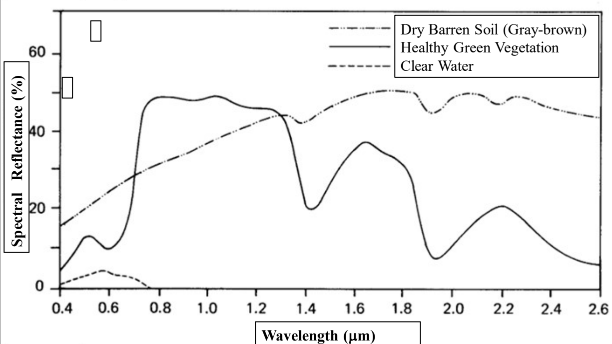
Visible Portion (Panchromatic)

Near Infrared

Football field has Artificial Turf

20

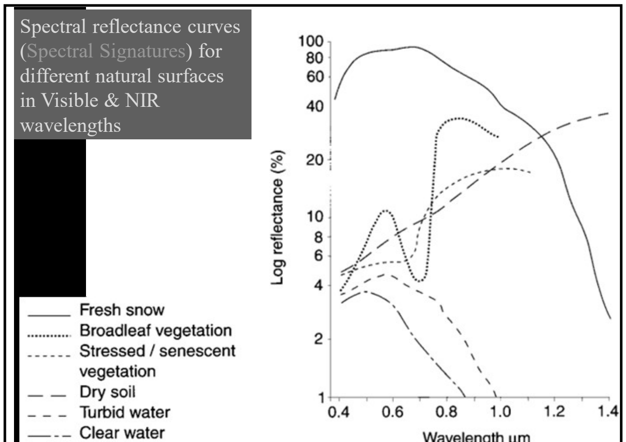
Typical Spectral Reflectance curves for Vegetation, Soil and Water



Lines in the figure represent ***average*** reflectance curves

21

Spectral reflectance curves (Spectral Signatures) for different natural surfaces in Visible & NIR wavelengths



22

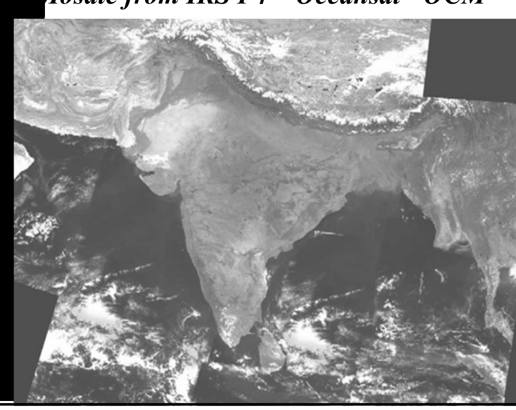
Advantages of Remote Sensing

- Ability to view large parts of the globe at different scales (Synoptic View)
- Capability to monitor regions which may be very remote or where access is denied
- Ability to analyse different surfaces at wavelengths not detectable to the human visual system
- Ability to obtain imagery of an area at regular intervals over many years in order that changes in the landscape can be evaluated
- Capability to see human-induced effects on our planet

- Disadvantages
  - Certain skill level is required to interpret the imagery
  - Interpretation based solely on remotely sensed data should be treated with caution unless supported by ground verification data.

23

Synoptic Coverage
Mosaic from IRS P4 – Oceansat - OCM



24

Remote Sensing Images

25

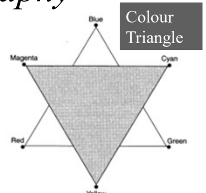
Types of Remote Sensing Images

- Based on recording of remote sensed data
  - Photographic
  - Digital
- Photographic RS – Restricted to Aerial RS
  - Panchromatic
  - Photographic Infrared
  - Natural Colour
  - Multispectral
  - False Colour

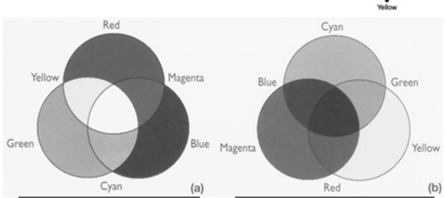
26

[redacted]ural Colour Photography

- Primary Additive Colours
  - Red, Green and Blue (RGB)
- Complementary Colours
  - Cyan, Magenta and Yellow
- Colour Triangle



Colour Triangle



Colour Additive Process

Colour Subtractive Process

27

Photographic RS (Contd..)

- Multispectral
  - Involves simultaneously obtaining images on the same scene at different wavelengths
  - Four: Blue, Green, Red and NIR parts of EMR
  - Multispectral imaging allows the examination of single band images
  - Natural and False colour composites can be produced
- False Colour
  - True colour composite (TCC):

28

Photographic RS (Contd..)

- 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

29

Color Composites - Data

Landsat TM

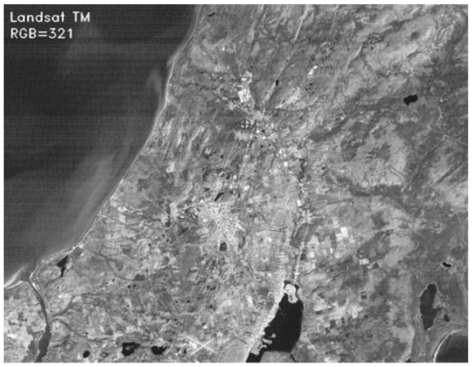
Average Orbital Height: 700 km (440 Miles)
Spatial Resolution: 30 m, except band 6 which is 90 m
Records Data in 7 Wavelength Intervals (bands)

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

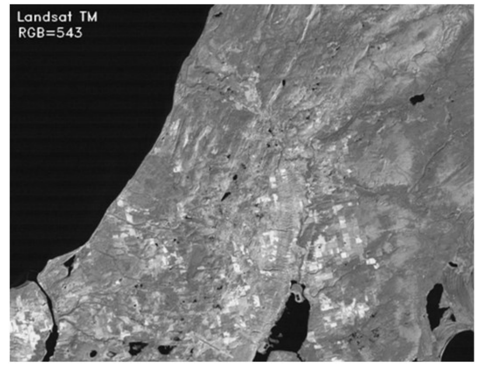
30

Band 321 (TCC)



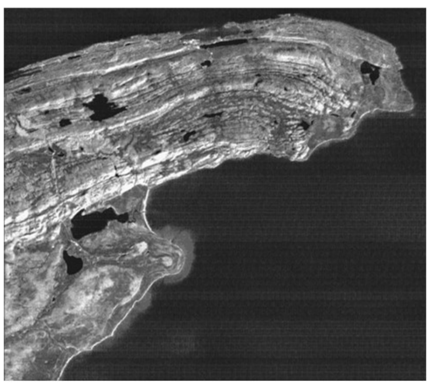
31

FCC (Band 543)



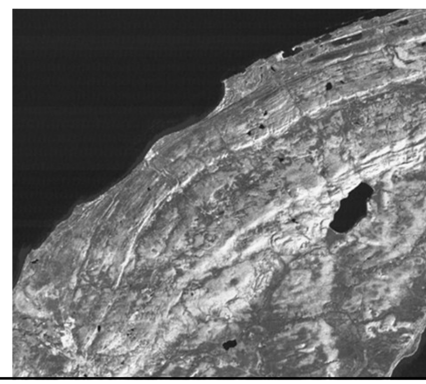
32

Band 321 (TCC)



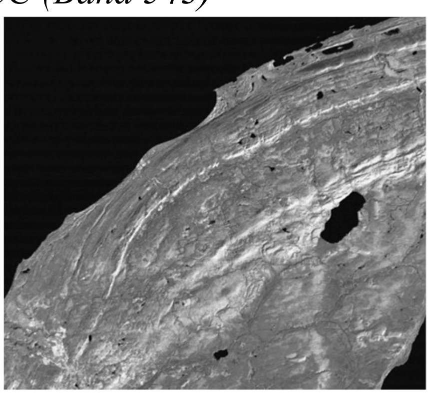
33

Standard FCC (Bands 432)



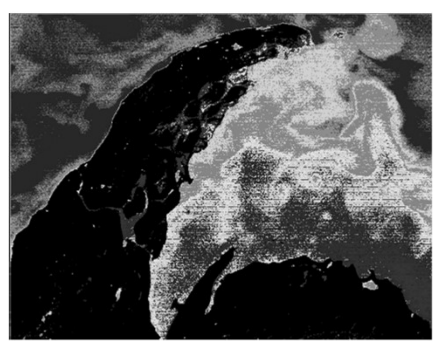
34

FCC (Band 543)



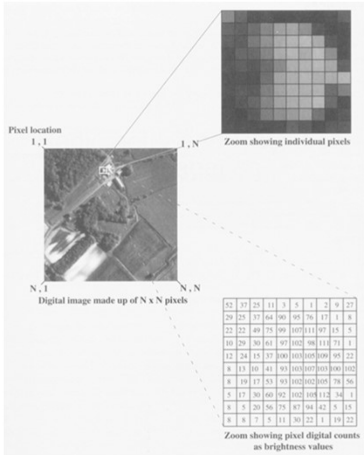
35

Temperature Image



36

Digital Image



37

Scale of an Image

- Scale of an image relates distances on the ground measured in any given units to distances measured in the same units.
- A scale of 1:50,000 means that, if two features are separated by 1 mm on an image, then the two features on the ground are 50,000 mm apart
  - Actual unit does not affect the calculation
- Scale of 1:1 million and 1: 10 million are common for satellite images

- Problem
  - Two buildings which are 360 m apart are separated by 36 mm on image A and 18 mm on image B. Calculate the scale of image A and image B and state which of the two images has larger scale.

Image A: 36/360,000 = 1: 10,000

Image B: 18/360,000 = 1: 20,000

Image A is at a larger scale

38

Satellites & Orbits

39

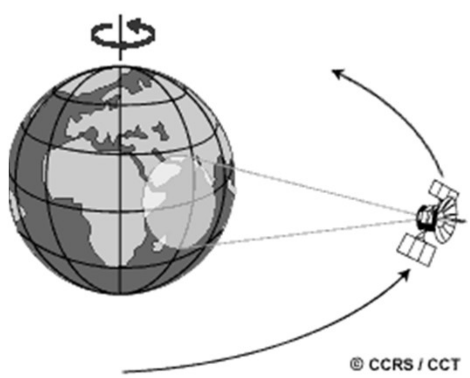
Satellite Orbits

- 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°
  - 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)

40

Geo-stationary Orbit



41

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.

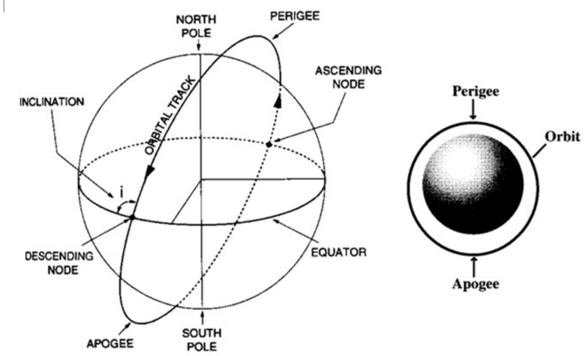
42

Satellite Orbits

- Orbit will be elliptical or near circular
- Time taken by a satellite to complete one revolution in its orbit around the earth is called the Orbital period.
- Apogee and Perigee
- Angle of inclination of orbital plane with respect to equator is measured clockwise (typically 99^{o} for RS Satellite)
- Nadir is the point of interception on the surface of the earth of the radial line between the center of the earth and the satellite
  - This is the point of shortest distance from the satellite
  - The circle on the surface of the earth described by the nadir point as the satellite revolves is called the ground track
- Any point just opposite to the nadir, above the satellite is called zenith.

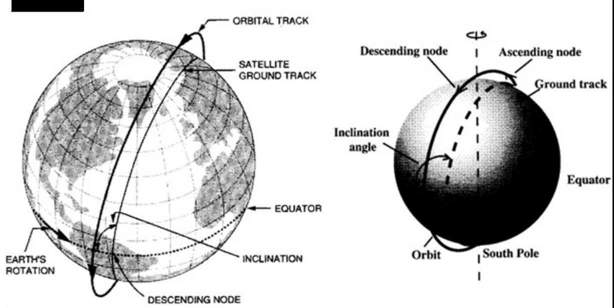
43

Polar Orbit



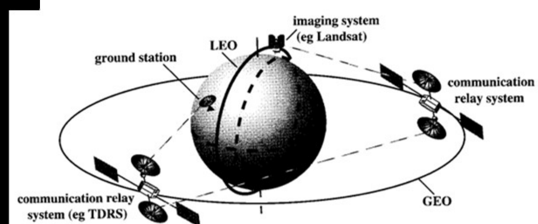
44

Polar Orbiting Satellites



45

Geostationary & Polar Orbiting Satellites



46

Swath

47

RS Satellite

- RS Satellite is placed in Near polar, Near circular, inclined, medium period and sun synchronous orbit
  - Near Polar – for global coverage
  - Near circular – for uniform swath
  - Inclined – for differences in gravitational pull
  - medium period – for global coverage
  - Sun synchronous – for constant angle between the aspects of incident sun and viewing by the satellite

48

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

49

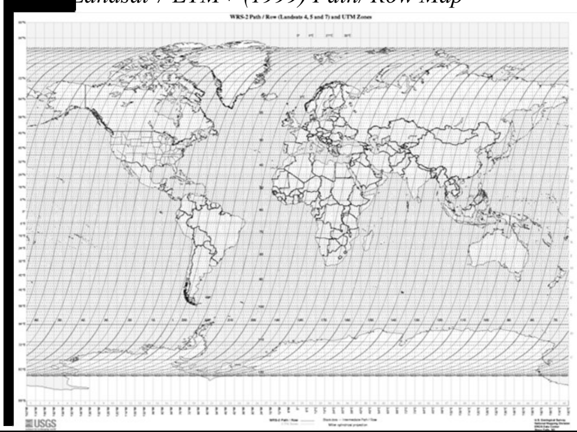
Landsat 7 (1999) – ETM+ Sensor Characteristics

Band	Spectral range	Ground resolution
1	0.450–0.515 µm	30 m
2	0.525–0.605 µm	30 m
3	0.630–0.690 µm	30 m
4	0.75–0.90 µm	30 m
5	1.55–1.75 µm	30 m
6	10.4–12.5 µm	60 m
7	2.09–2.35 µm	30 m
Pan	0.52–0.90 µm	15 m

Revisit - 16 days; Swath – 185 km

50

Landsat 7 ETM+ (1999) Path/ Row Map



51

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	Resolution 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

52