

Lecture 1: Intro to satellite remote sensing

1. Types of platforms used for remote sensing: ground-based, airborne and spaceborne.

Ground-based platforms: ground, vehicles and/or towers => up to 50 m

Examples:

DOE ARM (Atmospheric radiation Program): <http://www.arm.gov/>

NASA AERONET (AErosol RobotiC NETwork): <http://aeronet.gsfc.nasa.gov/>

Airborne platforms: airplanes, helicopters, high-altitude aircrafts, balloons => up to 50 km

Examples:

NCAR, NOAA, and NASA research aircrafts, <http://www.eol.ucar.edu/raf/>

Spaceborne: rockets, satellites, shuttle => from about 100 km to 36000 km

Space shuttle: 250-300 km

Space station: 300-400 km

Low-level satellites: 700-1500 km

High-level satellites: about 36000 km

Examples:

NASA current and planned Earth's observing satellite missions:

<http://science.hq.nasa.gov/missions/earth.html>

NOAA weather satellites: <http://www.noaa.gov/satellites.html>

2. Passive and active remote sensing.

Passive sensors measure natural radiation emitted by the target material or/and radiation energy from other sources reflected from the target.

Two main natural sources of radiation: Sun and Earth's thermal emission

Examples:

Passive microwave radiometer that detects naturally emitted microwave energy.

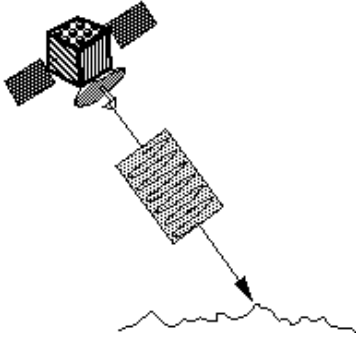
Radiometers that measure reflected (or backscattered) sun light from the atmosphere and ocean.

Active sensors transmit their own signal and measure the energy that is reflected (or scattered back) from the target material.

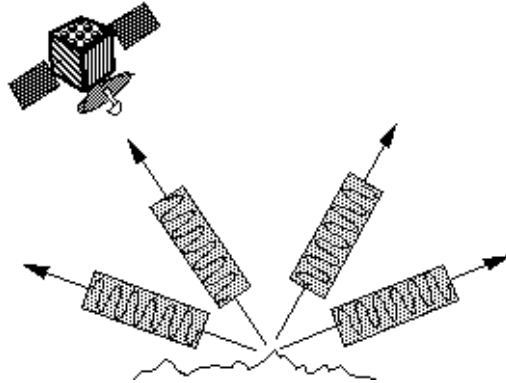
Examples:

Lidar (LIght Detection And Ranging)

Radar (RAdio Detection And Ranging)



Radar transmits a pulse and



measures reflected echo (backscatter)

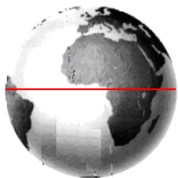
3. General characteristics: orbits, resolutions, types of satellite sensors, and viewing geometry.

➤ **Satellites orbits: low-level and high-level**

Low-level (700-1500 km) Earth observation satellites (called LEO) fall into three broad groups:

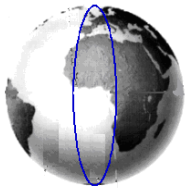
- i). Equatorial orbiting satellites
- ii). Polar orbiting satellite
- iii). Oblique orbiting (or near-polar) satellites

- LEO satellites are often on **sun-synchronous** orbits. **Sun-synchronous** means that the satellite remains fixed with respect to the Sun with the Earth rotating under the satellite (i.e., satellite passes over its target on the Earth at roughly the same local time).



Equatorial orbiting satellites, whose orbits are within the plane of the Equator

Example: TRMM



Polar orbiting satellites, whose orbits are in the plane of the Earth's polar axis

- Ascending pass is when the satellite travels from south to north, and descending when the satellite travels from north to south.
- Oblique orbiting satellites can be launched eastwards into direct (called prograde) orbit (so called because the movement of such satellites is in the same direction as the rotation of the Earth), or westwards into retrograde orbit.
- The inclination of an orbit is specified in terms of the angle between its ascending track and the Equator.
- Prograde orbits regress while retrograde orbits precess with respect to the planes of their initial orbits because the Earth is not a perfect sphere and it causes a gyroscopic influence on satellites in oblique orbits.

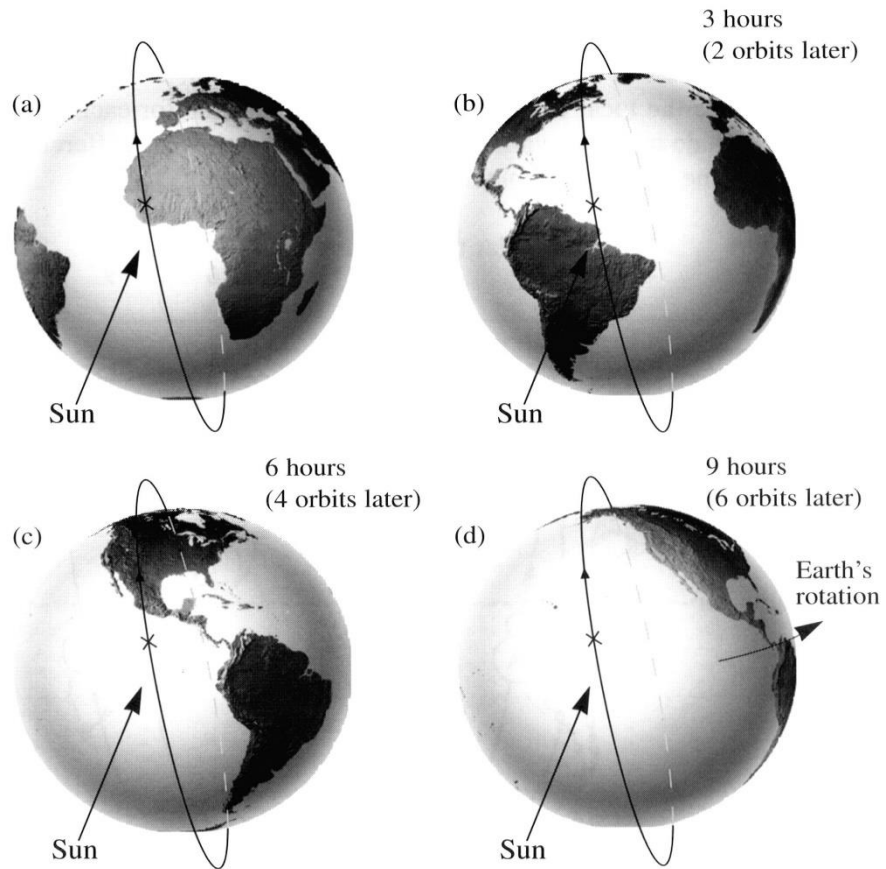


Figure 1.1 Oblique orbiting (near-polar orbiting) satellites: Sun-synchronous orbits (each 3 hours)

High-level (about 36000 km) satellites:

Geostationary satellites (often called weather satellites) are “fixed” above a given point on the Earth surface because their circular orbits above the equator have rotation period equals to the earth’s rotation period.

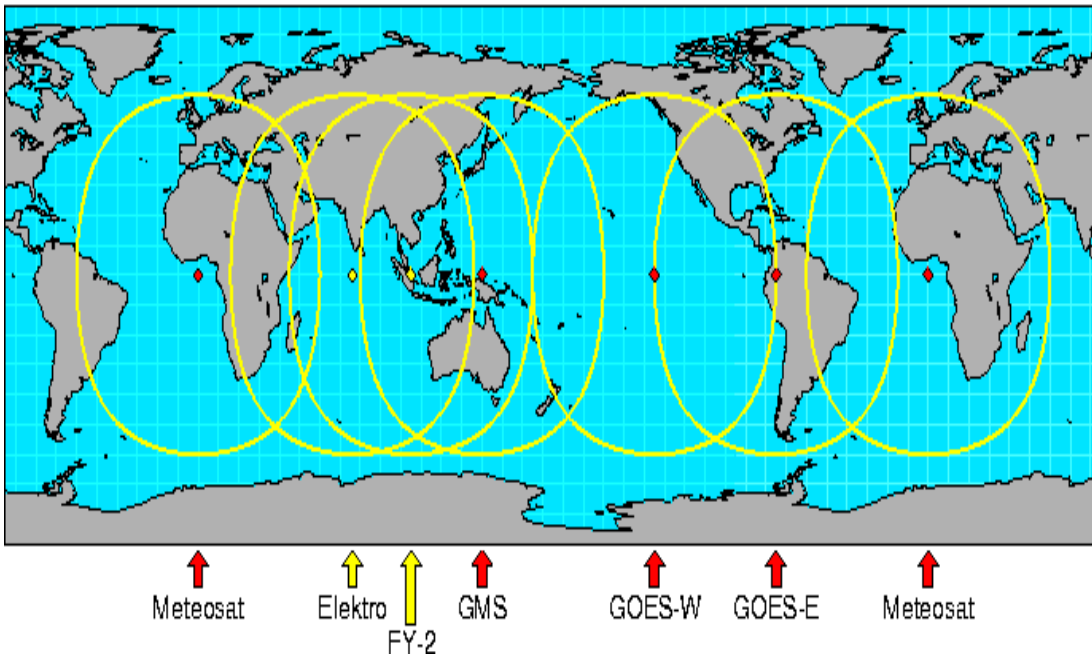


Figure 1.2 Example of geostationary satellite coverage.

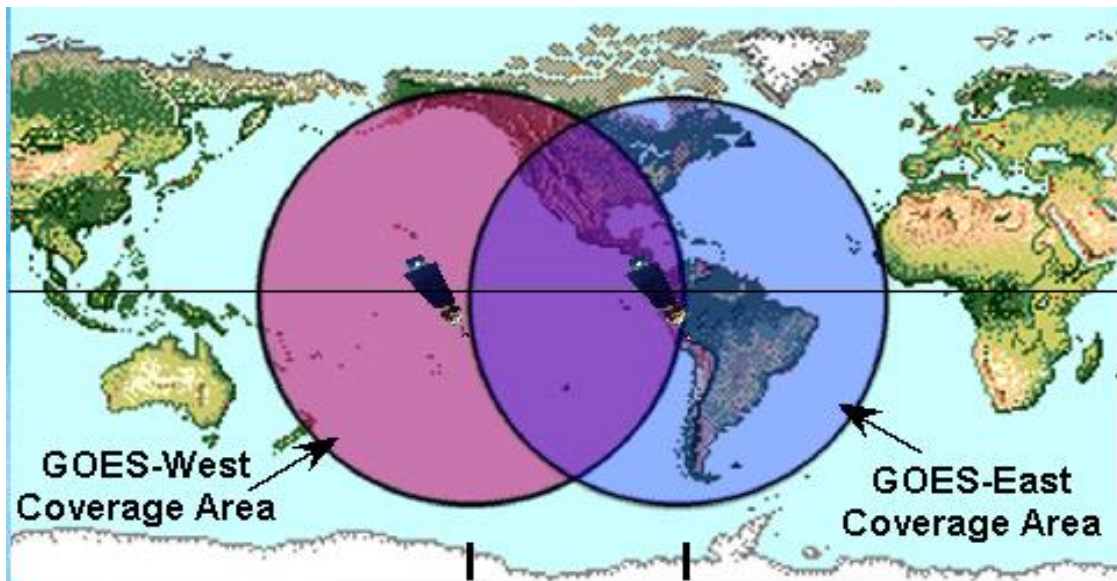
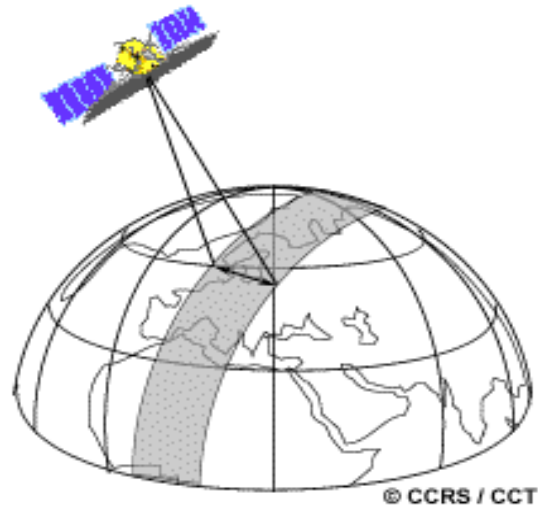


Figure 1.3 U.S. geostationary satellites: GOES

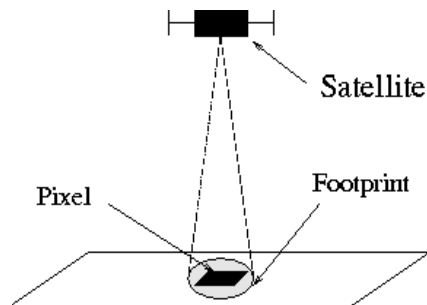
➤ *Resolutions: spatial, spectral, radiometric, and temporal*

Swath is the width of the track covered by a sensing system on the surface of the Earth. In general, swaths for spaceborne sensors vary between tens and hundreds of kilometers wide.



Spatial resolution is often defined as the ability to distinguish between two closely spaced objects on an image. No single definition for spatial resolution exists.

- Spatial resolution depends on the field of view (FOV), altitude and viewing angle of a sensor.



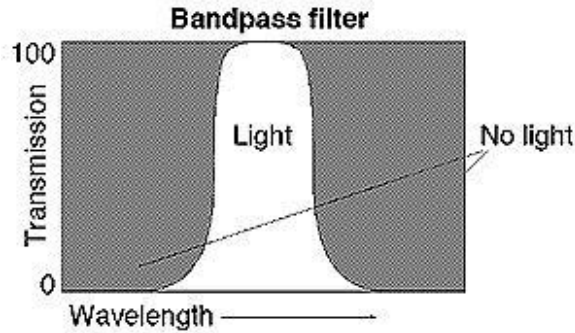
NOTE: small pixel => large spatial resolution

- The size of the pixel sets a lower limit on the spatial resolution.
- A measure of the size of the pixel is given by the instantaneous field of view

Instantaneous Field of View (IFOV) is the solid angle through which a detector is sensitive to radiation.

Spectral resolution refers to the dimension and number of wavelength regions (or bands) in the electromagnetic spectrum to which the sensor is sensitive.

- Based on the spectral resolution the sensors fall into the following broad groups: broad-band, narrow-band, spectral and hyperspectral sensors.



The narrower the bandwidth, the better the spectral resolution!

Examples:

Broad-band sensor: CERES (Clouds and the Earth's Radiant Energy System)

Three bands (channels): Solar region: 0.3 - 5.0 μm ; IR window: 8 - 12 μm ; and total: 0.3 to > 100 μm

Narrow-band sensor: MODIS (Moderate Resolution Imaging Spectroradiometer)

Table 1.1 MODIS spectral bands

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required SNR ³
Land/Cloud/Aerosols Boundaries	1	620 - 670	21.8	128
	2	841 - 876	24.7	201
Land/Cloud/Aerosols Properties	3	459 - 479	35.3	243
	4	545 - 565	29.0	228
	5	1230 - 1250	5.4	74
	6	1628 - 1652	7.3	275
	7	2105 - 2155	1.0	110
Ocean Color Phytoplankton Biogeochemistry	8	405 - 420	44.9	880
	9	438 - 448	41.9	838
	10	483 - 493	32.1	802

	11	526 - 536	27.9	754
	12	546 - 556	21.0	750
	13	662 - 672	9.5	910
	14	673 - 683	8.7	1087
	15	743 - 753	10.2	586
	16	862 - 877	6.2	516
Atmospheric Water Vapor	17	890 - 920	10.0	167
	18	931 - 941	3.6	57
	19	915 - 965	15.0	250
Surface/Cloud Temperature	20	3.660 - 3.840	0.45 (300K)	0.05
	21	3.929 - 3.989	2.38 (335K)	2.00
	22	3.929 - 3.989	0.67 (300K)	0.07
	23	4.020 - 4.080	0.79 (300K)	0.07
Atmospheric Temperature	24	4.433 - 4.498	0.17 (250K)	0.25
	25	4.482 - 4.549	0.59 (275K)	0.25
Cirrus Clouds Water Vapor	26	1.360 - 1.390	6.00	150(SNR)
	27	6.535 - 6.895	1.16 (240K)	0.25
	28	7.175 - 7.475	2.18 (250K)	0.25
Cloud Properties	29	8.400 - 8.700	9.58 (300K)	0.05
Ozone	30	9.580 - 9.880	3.69 (250K)	0.25
Surface/Cloud Temperature	31	10.780 - 11.280	9.55 (300K)	0.05
	32	11.770 - 12.270	8.94 (300K)	0.05
Cloud Top Altitude	33	13.185 - 13.485	4.52 (260K)	0.25

	34	13.485 - 13.785	3.76 (250K)	0.25
	35	13.785 - 14.085	3.11 (240K)	0.25
	36	14.085 - 14.385	2.08 (220K)	0.35
<p>* <i>Footnotes:</i> ¹ Bands 1 to 19 are in nm; Bands 20 to 36 are in μm ² Spectral Radiance values are ($\text{W}/\text{m}^2 \cdot \mu\text{m}\cdot\text{sr}$) ³ SNR = Signal-to-noise ratio ⁴ $NE(\Delta)T = \text{Noise-equivalent temperature difference}$</p>				

Radiometric resolution is a measure of the sensitivity of a sensor to differences in the intensity of the radiation measured the sensor.

- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in reflected or emitted energy.

Technical definition:

Radiometric resolution is a measure of how many grey levels are measured between pure black and pure white.

- The radiometric resolution is measured in bits: 1-bit system ($2^1 = 2$) measures only two radiation levels; 2-bit system measures ($2^2=4$) four levels, etc.

Temporal resolution is a measure of how often data are obtained for the same area (i.e., how often an area can be revisited).

- The temporal resolution varies from hours for some systems to about 20 days to others. High temporal resolution: daily or twice daily.

➤ Types of sensors.

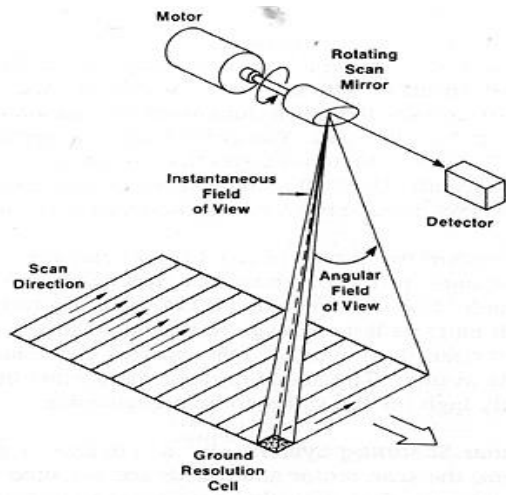
Classification based on energy source or generated product.

- Energy source: Passive (owns no energy source) or active (owns energy source in restricted spectral bands, like radar systems).

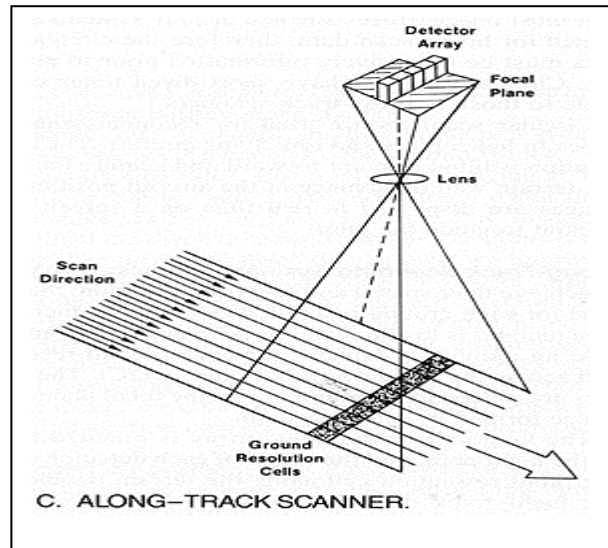
- Product:
 - No-imaging: Generates no images of the observed surface, used to collect precise spectral signature of objects.
 - Imaging: Generates images of the observed surface.
- Imaging systems are classified by:
 - Framing systems: acquisition of a whole image at the same time
 - Scanning systems: Scans lines to generate image

Scanning systems: cross-track scanners; spin scanners; along-track scanners side-scanning (or oblique scanners) (e.g., radar)

Examples:



A. CROSS-TRACK SCANNER.



C. ALONG-TRACK SCANNER.

Viewing geometry:

