

Satellite Remote Sensing: Data Processing and Applications

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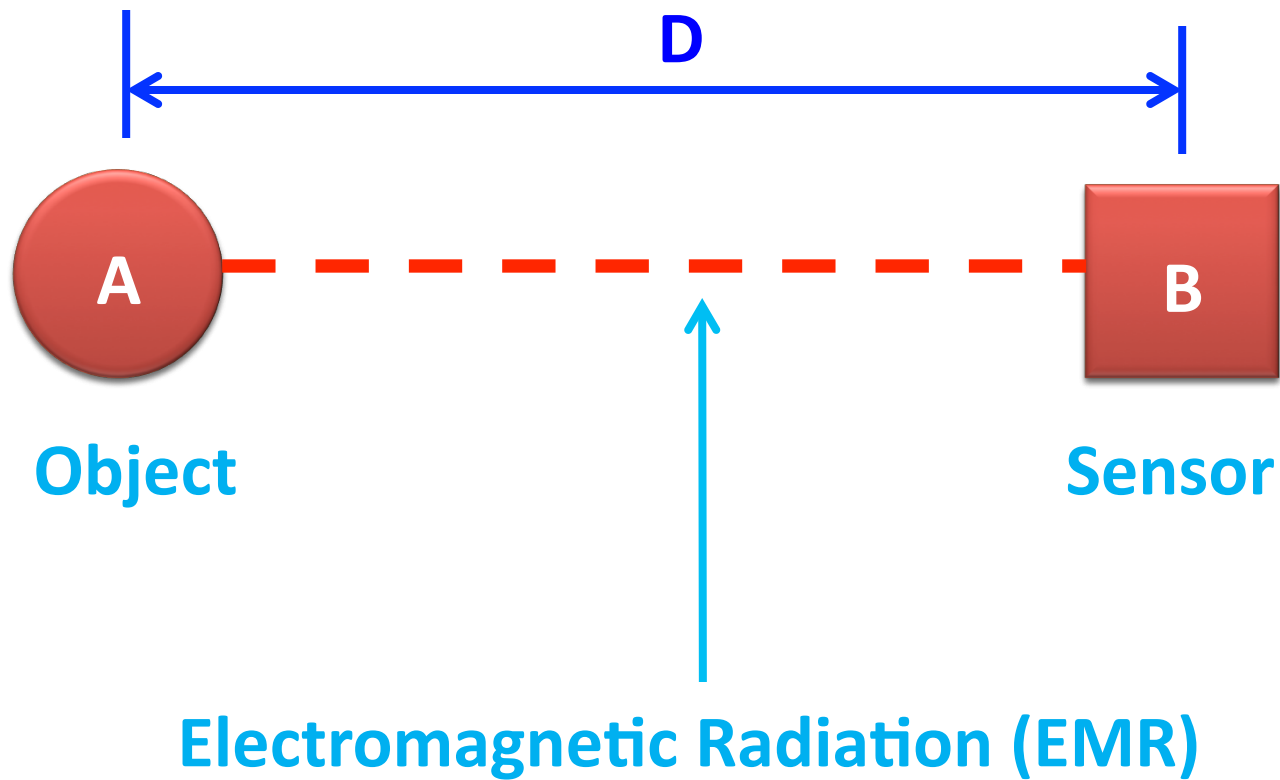
Outline

- Basics of remote sensing
- Environmental monitoring
- InSAR measurements

Basics of Remote Sensing

Remote Sensing

Remote Sensing



Remote Sensing

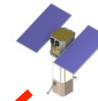
- **Remote sensing** is the acquisition of information about an object or phenomenon





In modern usage ...

Aerial sensors



Detecting, classifying,
measuring objects on Earth



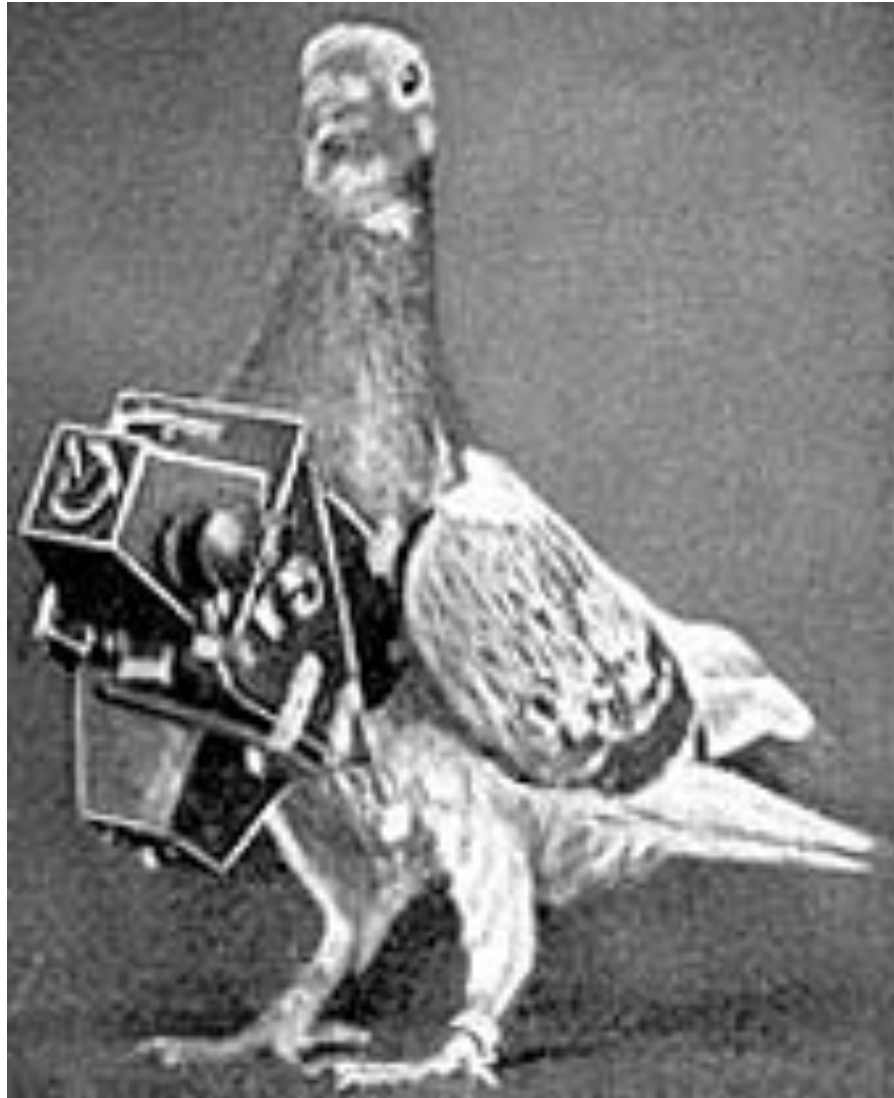
Solid Earth,
oceans,
atmosphere

Limitations of our Eyes as Sensors

- Sensitive to only the visible range of electromagnetic energy;
- Viewing perspectives dictated by the location of our bodies;
- Viewing distance limited
- Inability to form a lasting record of what we view.

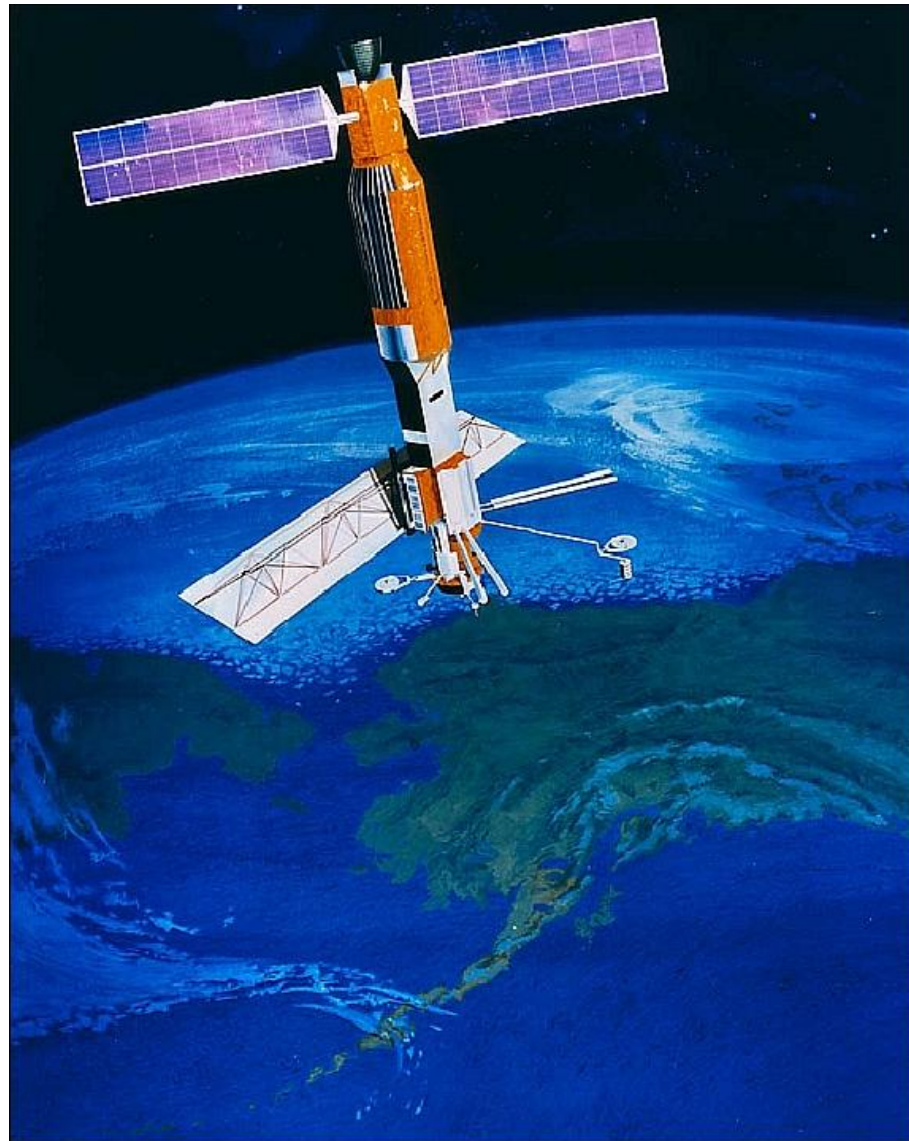
Humans have continuously sought to develop the technological means to increase our ability to see and record the physical properties of our environment.





Pigeonparadise.com

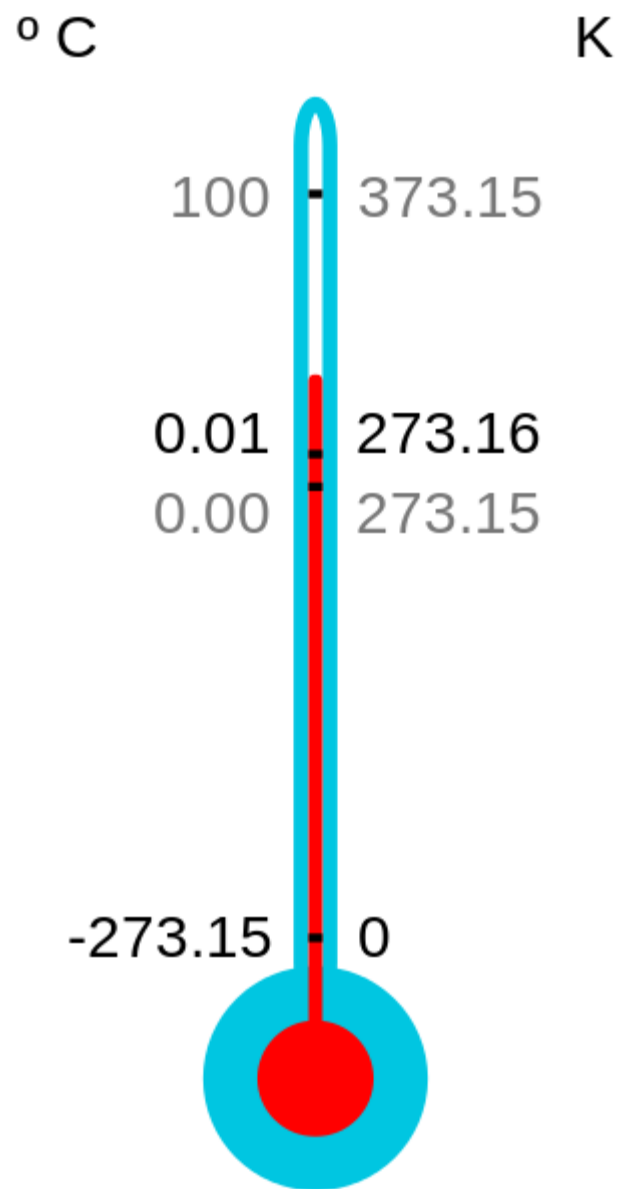
**Camera mounted on a bird for pictures
from behind enemy lines in WWII.**



SeaSat, the first ever civilian spaceborne imaging radar instrument (SAR) was launched in 1978.

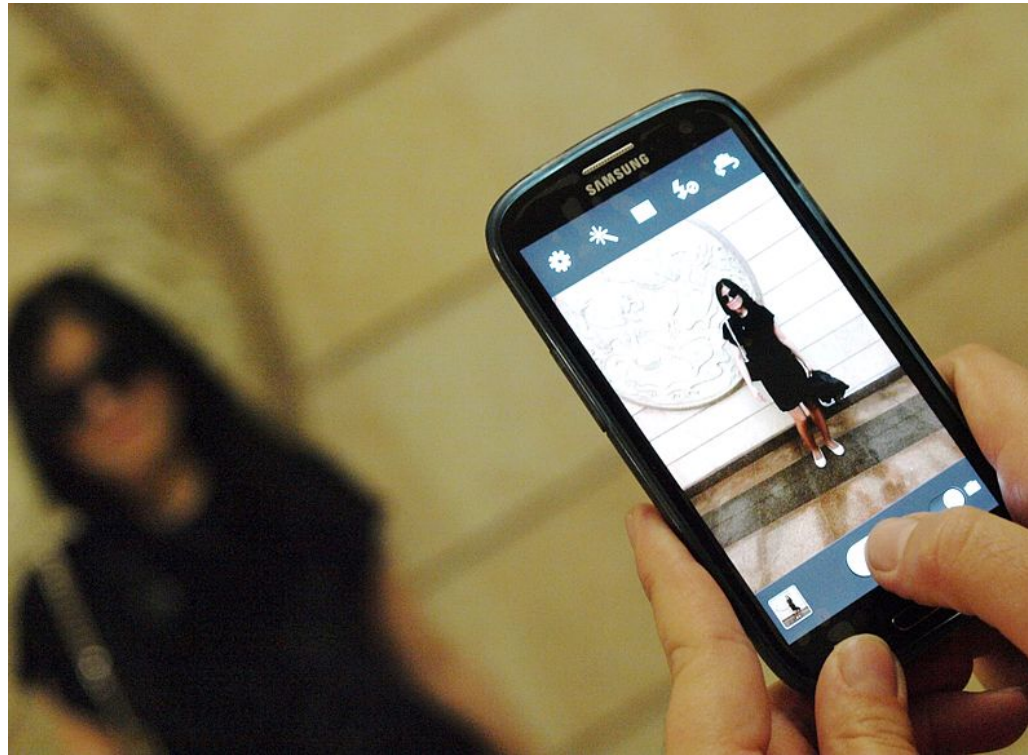
During its brief 110-day lifetime, SeaSat collected more information about the oceans than had been acquired in the previous 100 years of shipboard research.

Sensors and Platforms for Remote Sensing



Examples: Passive Sensor

Photography



Examples: Passive Sensor

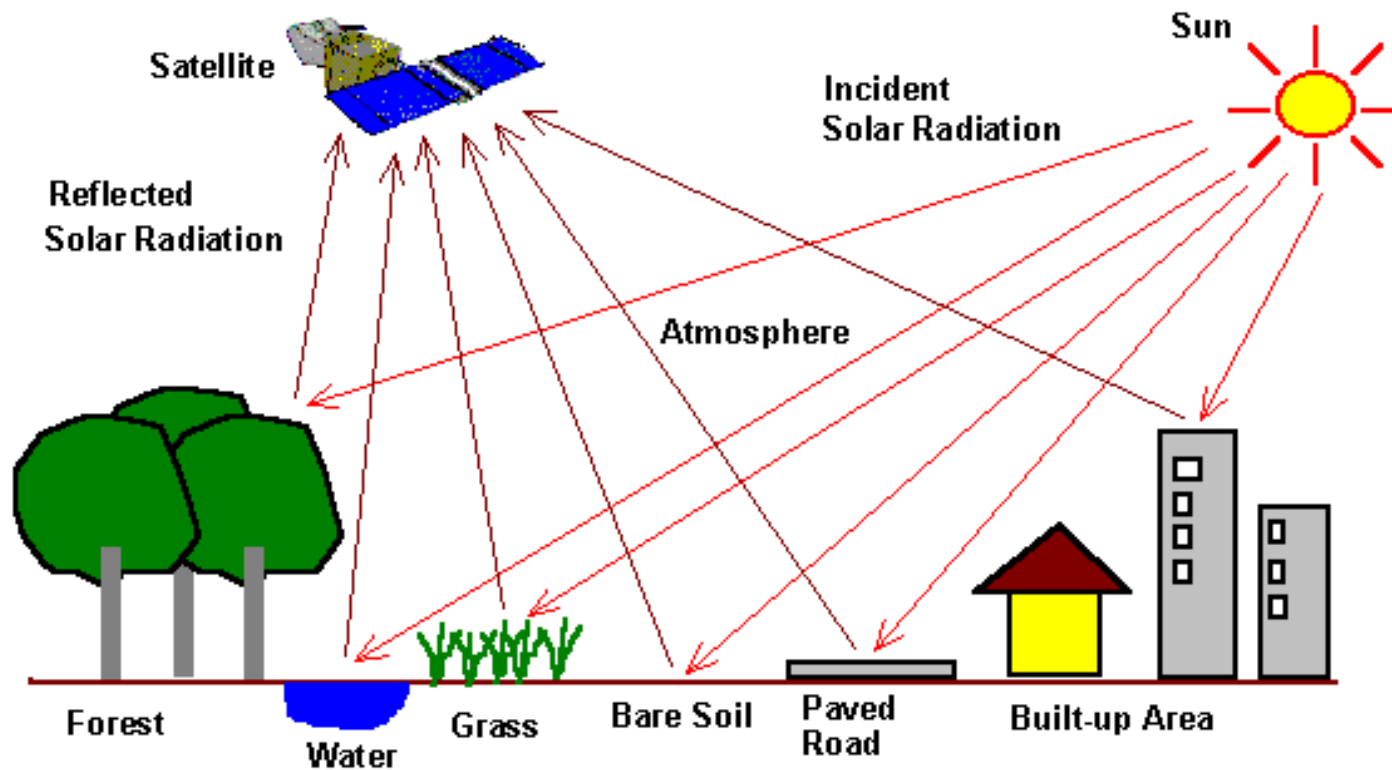
Infrared Sensor



Infrared (IR) is invisible radiant energy. Most of the thermal radiation emitted by objects near room temperature is infrared.

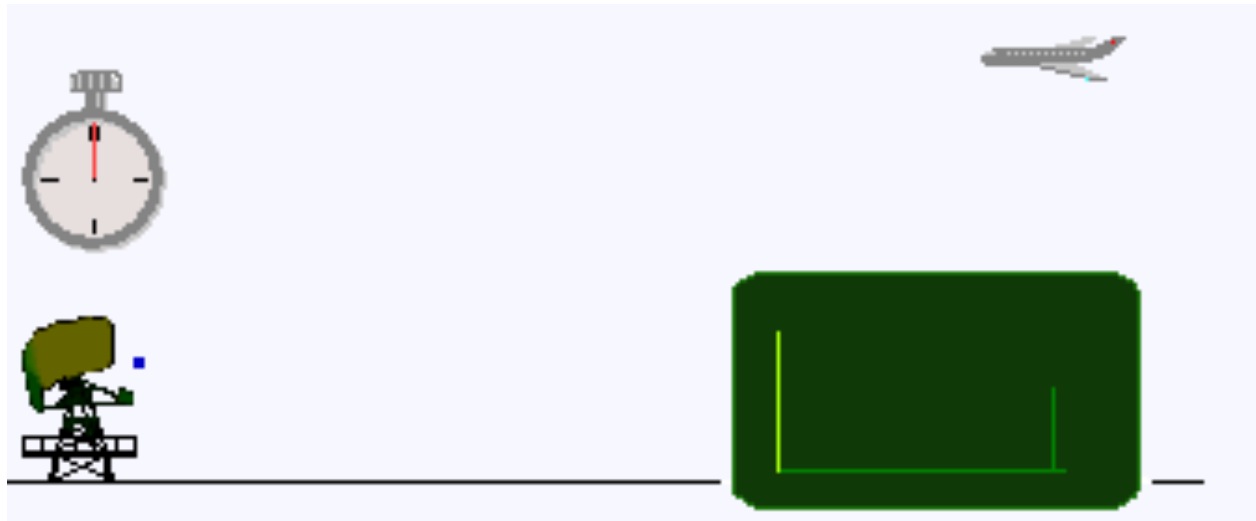
Examples: Passive Sensor

Optical Remote Sensing



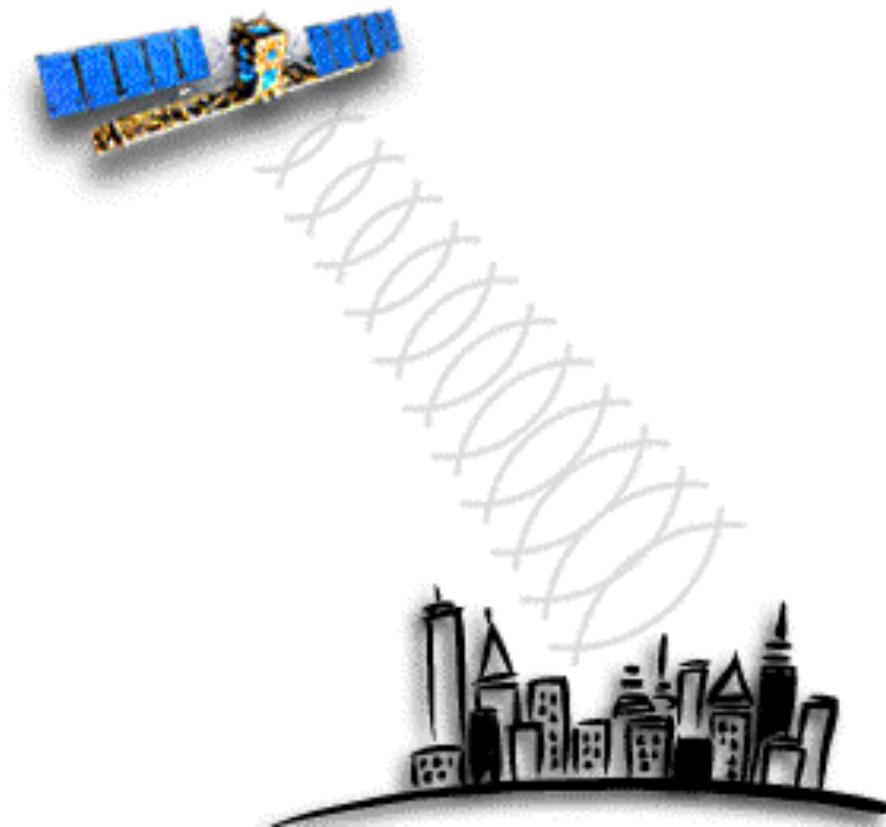
Examples: Active Sensor

Radar (RAdio Detection And Ranging)



Examples: Active Sensor

Radar (RAdio Detection And Ranging)



Examples: Active Sensor

LiDAR (Light Detection And Ranging)

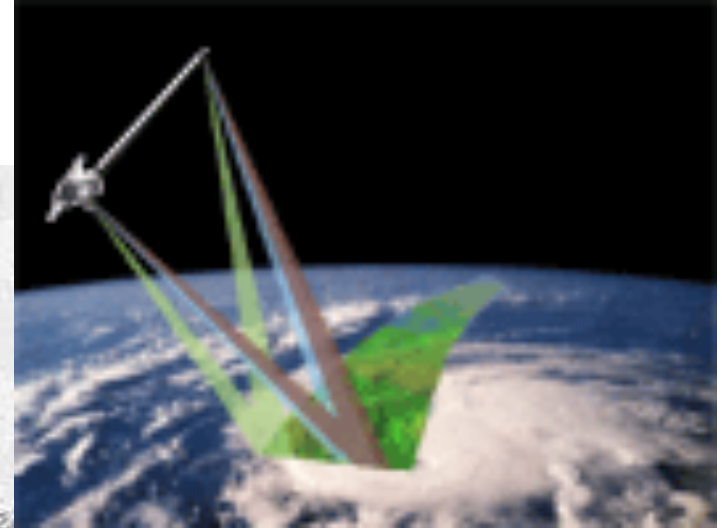


Examples: Active Sensor

LiDAR (Light Detection And Ranging)

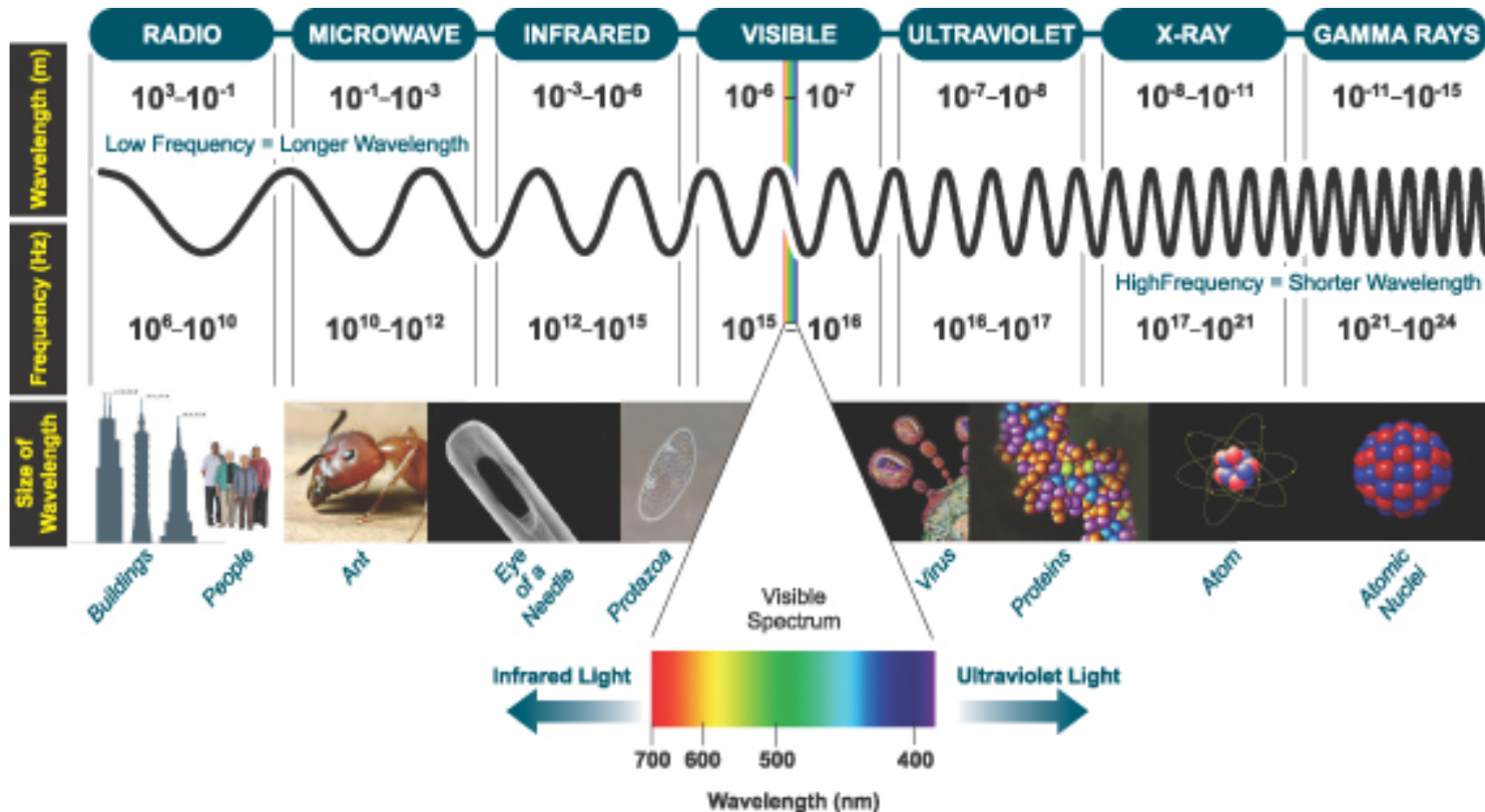


Remote Sensing Platforms



Electromagnetic Spectrum

Electromagnetic Spectrum



Environmental Remote Sensing

Reflected:

1. Visible wavelengths

2. Near/mid Infra-Red

Emitted:

3. Thermal infra-red (Heat)

4. Microwave radar (cloud-free)

Atmospheric Windows

- Some types of electromagnetic radiation easily pass through the atmosphere, while other types do not.
- The ability of the atmosphere to allow radiation to pass through it is referred to as its transmissivity, and varies with the wavelength/type of the radiation.
- The areas of the EM spectrum that are absorbed by atmospheric gases such as water vapor, carbon dioxide, and ozone are known as absorption bands.

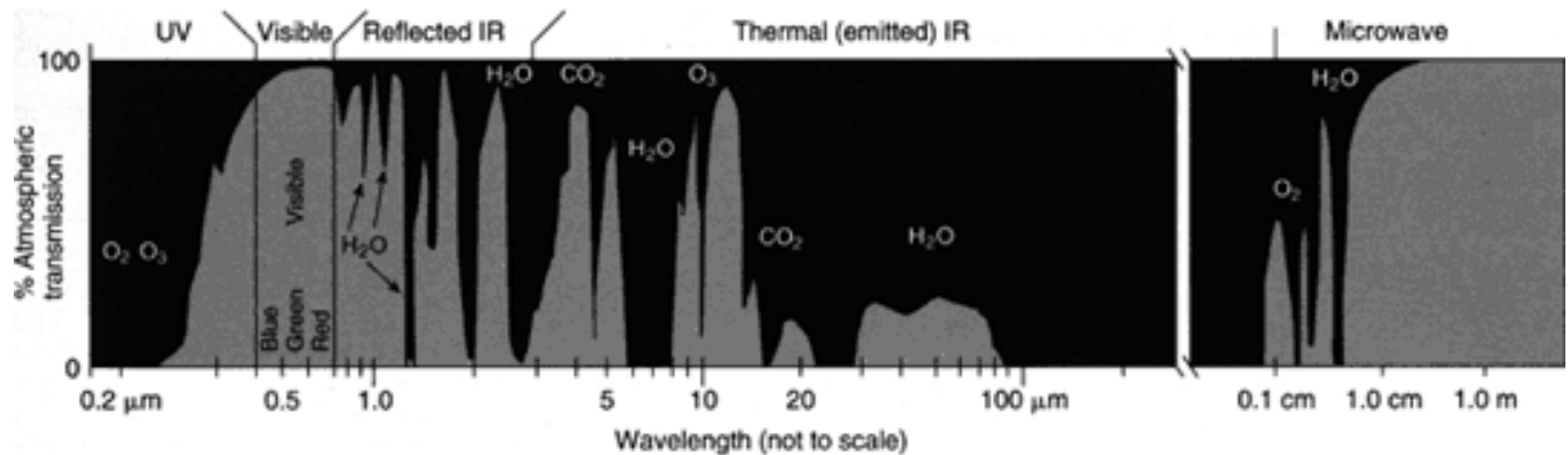


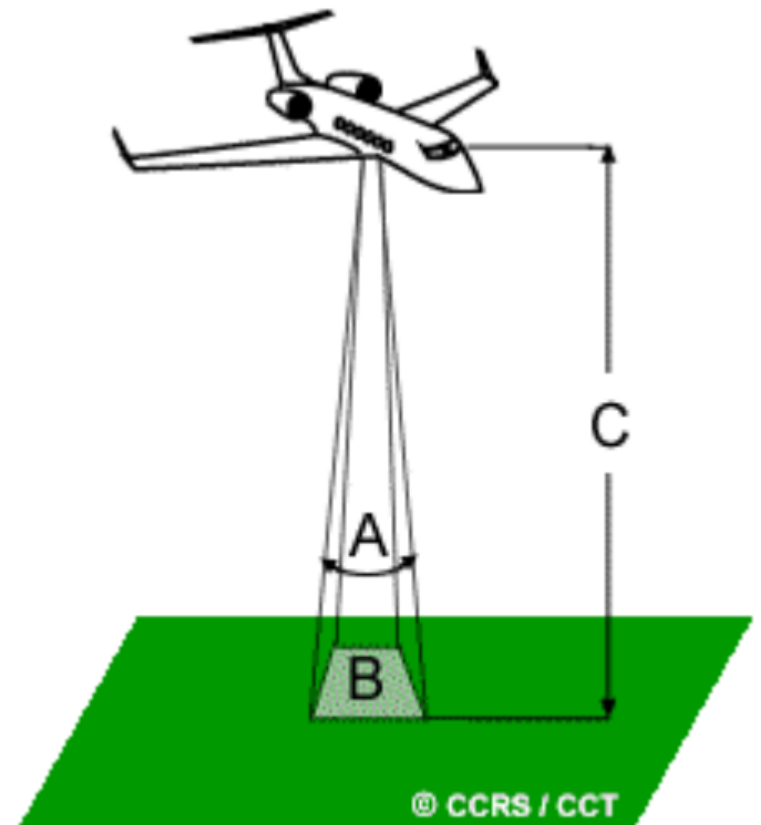
Diagram of atmospheric windows—wavelengths at which electromagnetic radiation will penetrate the Earth's atmosphere. Chemical notation (CO₂, O₃) indicates the gas responsible for blocking sunlight at a particular wavelength.

http://earthobservatory.nasa.gov/Features/RemoteSensing/remote_04.php

Remote Sensing Resolutions

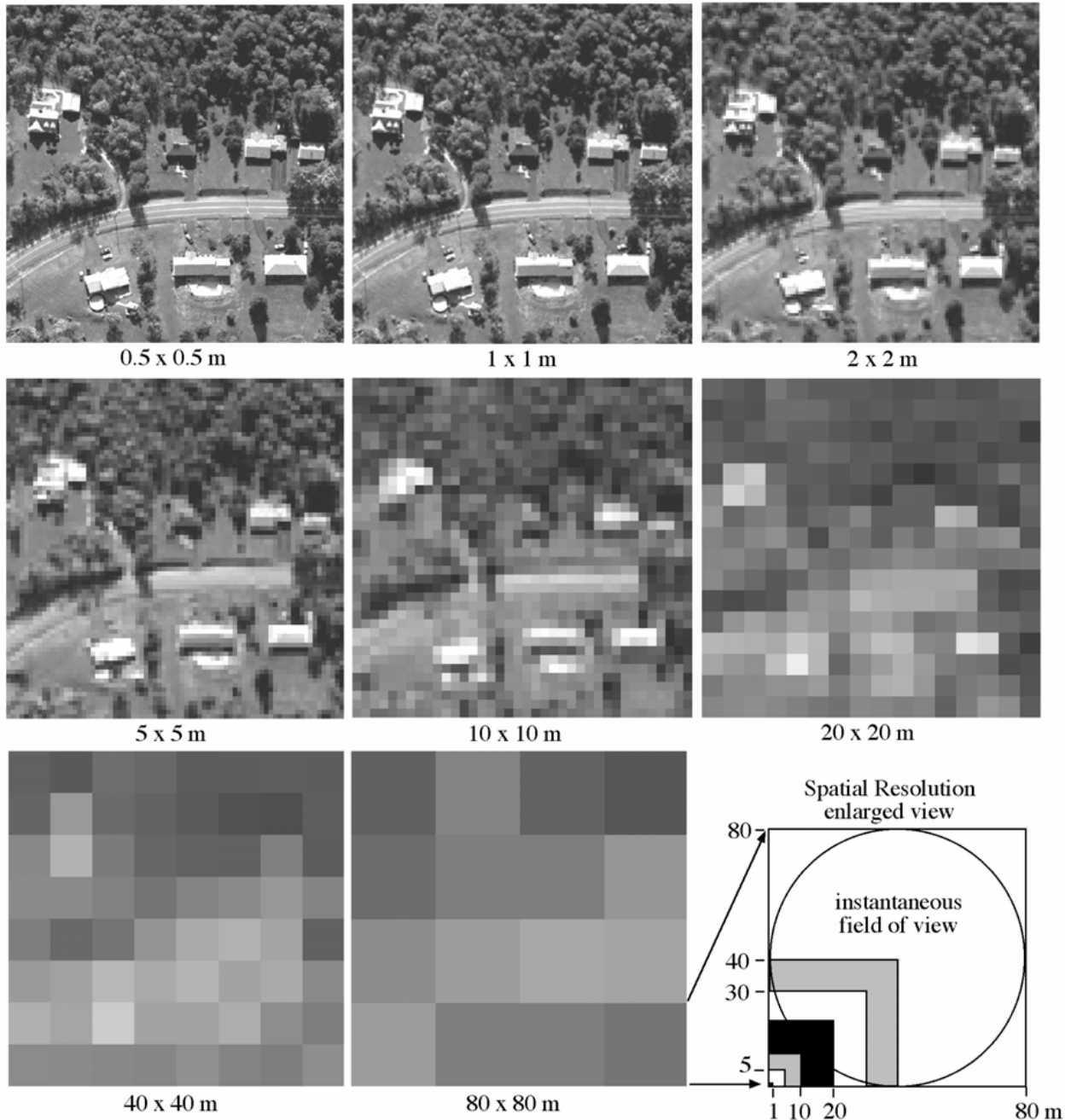
Spatial Resolution

- Spatial resolution depends on the angular cone of visibility (A) and the distance from the sensor to the ground (C).



Spatial Resolution

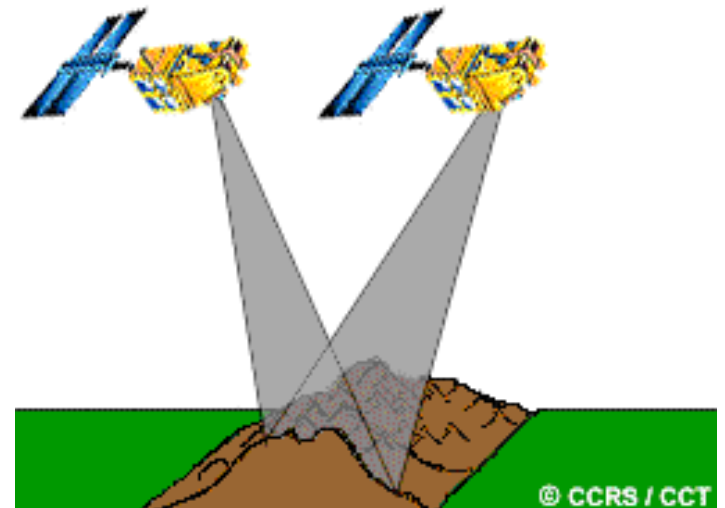
- Pixel: smallest unit of an image
 - Low resolution: 1 km -10 km (national) (GOES)
 - Medium resolution: 100 -500 m (regional) (MODIS)
 - High resolution: 10-100 m (Landsat)
 - Very high: 1 - 10 m (Local) (Ikonos, Quickbird, Geoeye)



(Jensen, 2000)

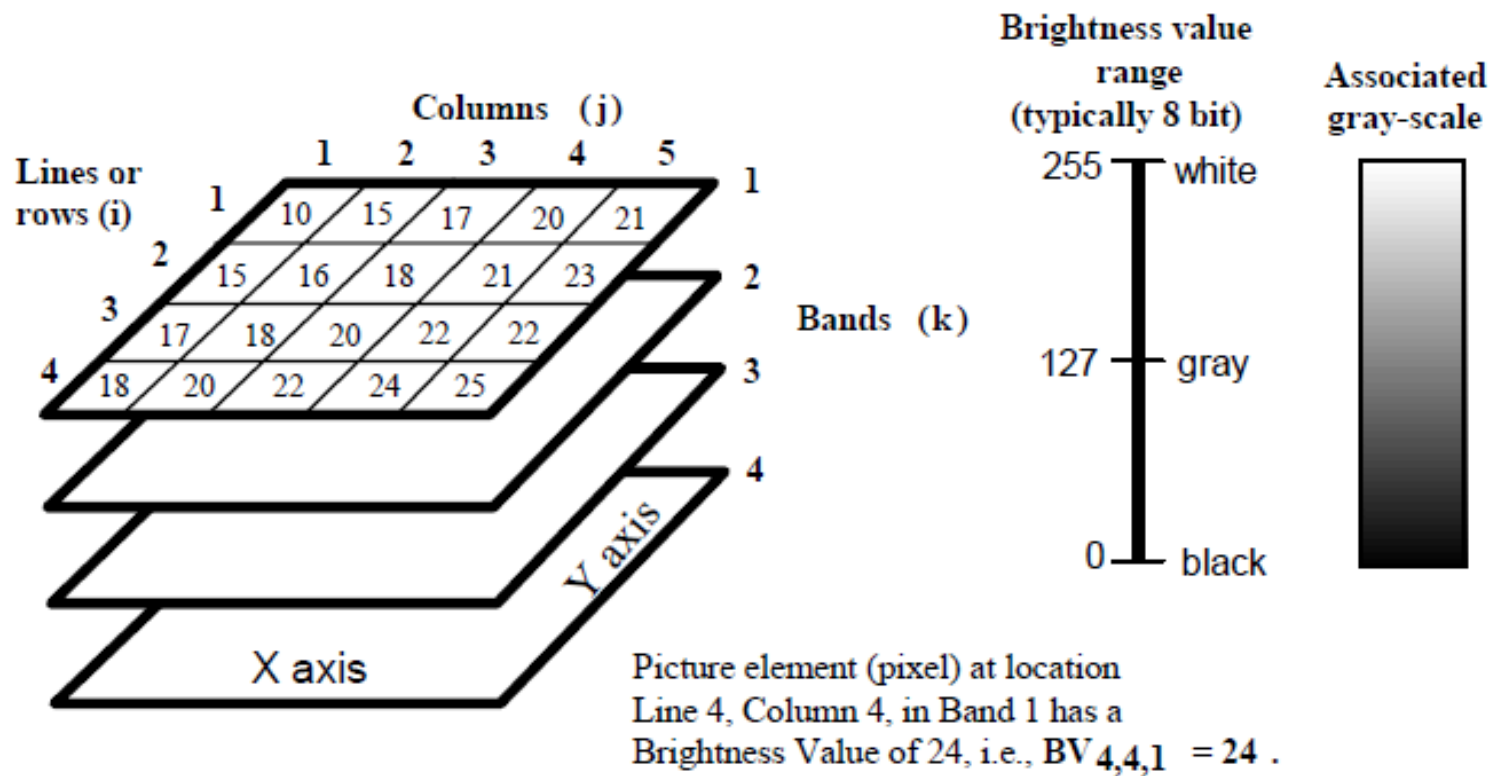
Temporal Resolution

- Temporal resolution is the revisit period, and is the length of time for a satellite to complete one entire orbit cycle, i.e. start and back to the exact same area at the same viewing angle.
- For example, Landsat needs 16 days, MODIS needs one day, NEXRAD needs 6 minutes.



Radiometric Resolution

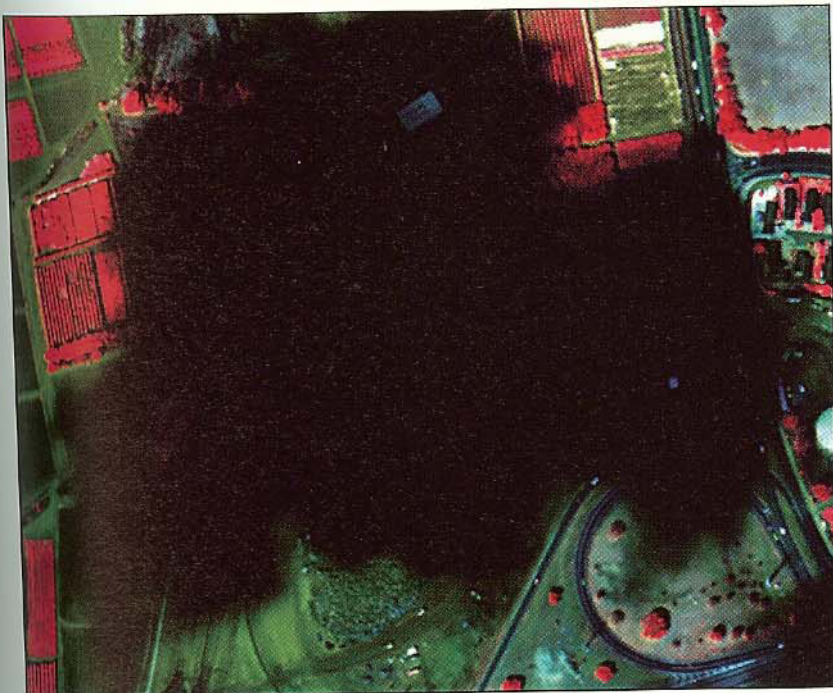
- Sensor's sensitivity to the magnitude of the electromagnetic energy,
- The finer the radiometric resolution of a sensor, the more sensitive it is to detecting small differences in energy



Jensen, 2000



Comparing a 2-bit image with an 8-bit image



a

Figure 4.19 IKONOS 11-bit data enables detail to be captured in areas within the cloud shadow. In the 8-bit image (a), there is no detail



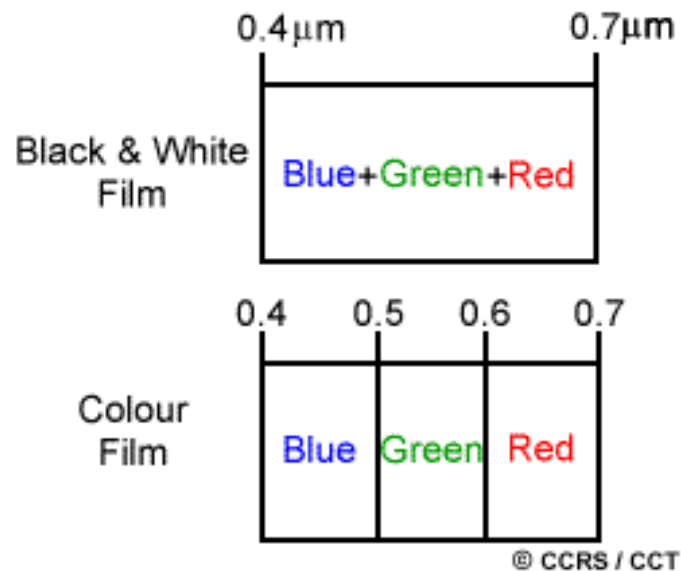
b

in the black cloud shadow area. Image (b) shows improved shadow detail after enhancement using the full 11 bits of data.

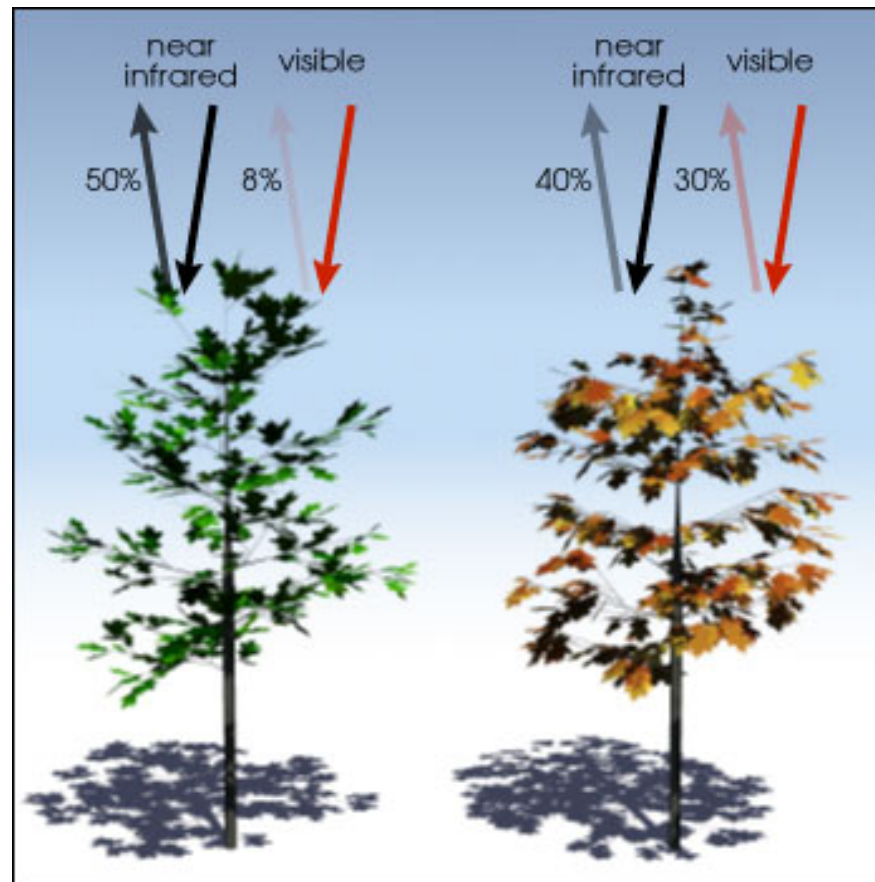
Source: Image courtesy of Space Imaging Corporation.

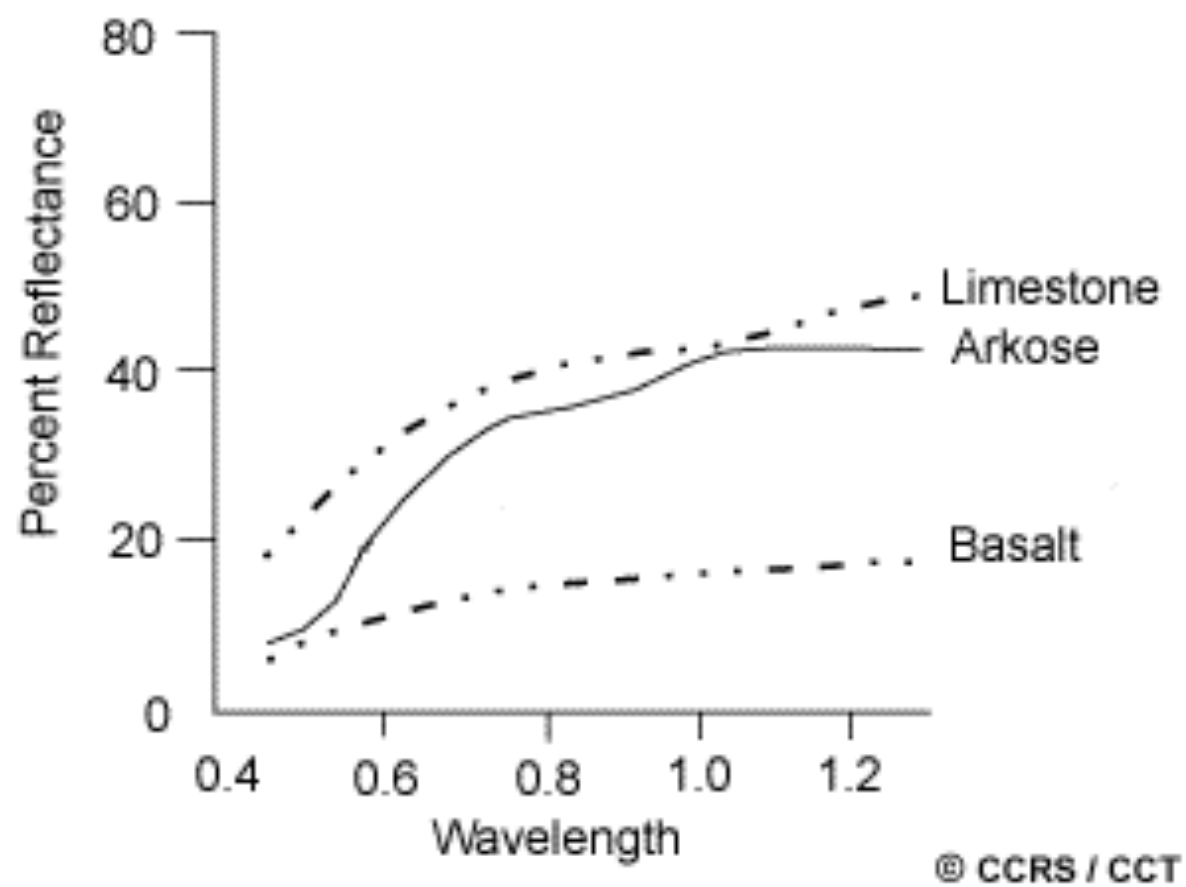
Spectral Resolution

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals
- The finer the spectral resolution, the narrower the wavelength range for a particular channel or band



- Different surface materials absorb and reflect energy of certain wavelengths of EMR differently
- One can distinguish one surface material from another by the differences in reflectance.





Panchromatic Imaging Systems

- The sensor is a single channel detector sensitive to radiation within a broad wavelength range.
- If the wavelength range coincide with the visible range, then the resulting image resembles a "black-and-white" photograph taken from space.
- The physical quantity being measured is the apparent brightness of the targets. The spectral information or "colour" of the targets is lost
- Examples: IKONOS PAN, SPOT HRV-PAN



Portion of a 1-meter resolution panchromatic image of Washington, DC produced by the Ikonos

https://www.e-education.psu.edu/natureofgeoinfo/c8_p11.html

Multispectral Imaging Systems

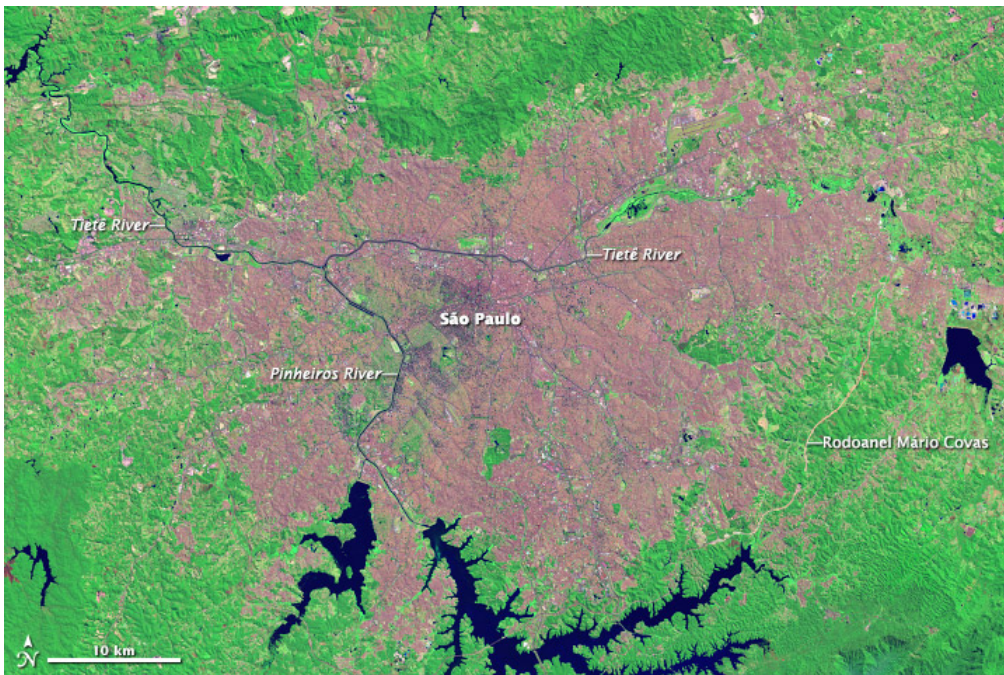
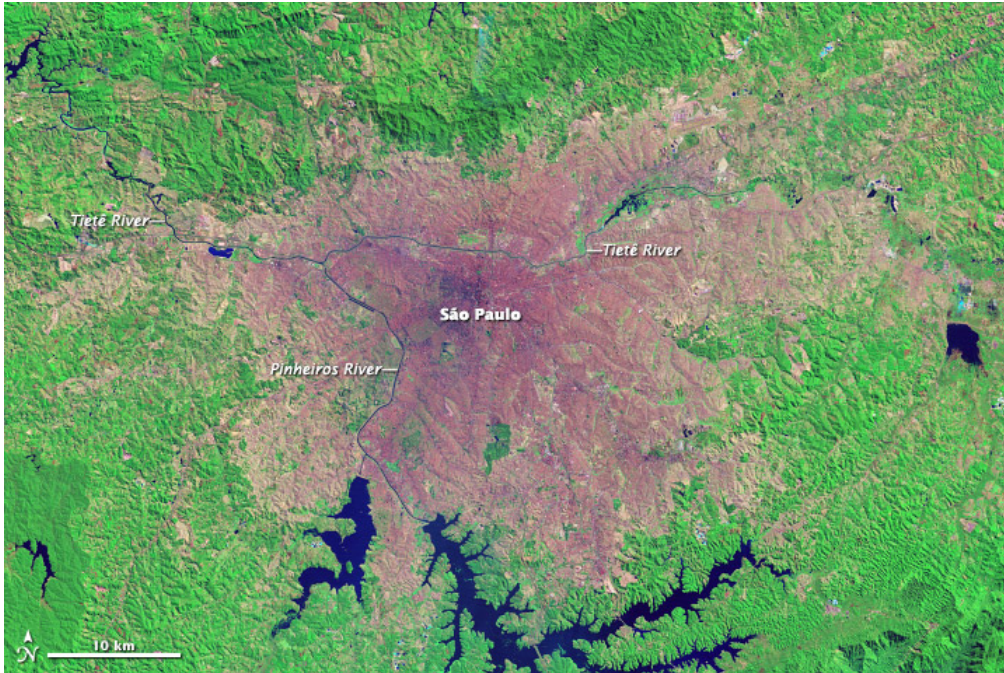
- The sensor is a multichannel detector with a few spectral bands.
- Each channel is sensitive to radiation within a narrow wavelength band.
- The resulting image is a multilayer image which contains both the brightness and spectral (colour) information of the targets being observed.
- Examples: LANDSAT MSS, LANDSAT TM, SPOT HRV-XS, IKONOS MS

LANDSAT 4,5 MSS Sensor Characteristics

	Band	Wavelength (μm)	Resolution (m)
Green	1	0.5 - 0.6	82
Red	2	0.6 - 0.7	82
Near IR	3	0.7 - 0.8	82
Near IR	4	0.8 - 1.1	82

LANDSAT 8

Band Number	μm	Resolution
1	0.433–0.453	30 m
2	0.450–0.515	30 m
3	0.525–0.600	30 m
4	0.630–0.680	30 m
5	0.845–0.885	30 m
6	1.560–1.660	30 m
7	2.100–2.300	30 m
8	0.500–0.680	15 m
9	1.360–1.390	30 m
10	10.6–11.2	100 m
11	11.5–12.5	100 m



The Landsat satellites captured this change in these two false-color images. Landsat 5 acquired the top image on August 6, 1986; the lower image is from Landsat 8 on September 1, 2013. In both images, urban areas range from tan in the suburbs to pink and purple in the most densely built areas. Plant-covered land is green, and exposed earth is tan (like the urban areas).

<http://landsat.visibleearth.nasa.gov/view.php?id=83987>

Superspectral Imaging Systems

- A superspectral imaging sensor has many more spectral channels (typically >10) than a multispectral sensor.
- The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor.
- Examples: MODIS, MERIS

Spectral Bands of MODIS

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

Primary Use	Band	Bandwidth ¹	Spectral Radiance ²	Required NE[delta]T(K) ⁴
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
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 = Noise-equivalent temperature difference Note: Performance goal is 30-40% better than required				



MODIS

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- SPECIFICATIONS

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SPECIFICATIONS

Orbit:	705 km, 10:30 a.m. descending node (Terra) or 1:30 p.m. ascending node (Aqua), sun-synchronous, near-polar, circular
Scan Rate:	20.3 rpm, cross track
Swath Dimensions:	2330 km (cross track) by 10 km (along track at nadir)
Telescope:	17.78 cm diam. off-axis, afocal (collimated), with intermediate field stop
Size:	1.0 x 1.6 x 1.0 m
Weight:	228.7 kg
Power:	162.5 W (single orbit average)
Data Rate:	10.6 Mbps (peak daytime); 6.1 Mbps (orbital average)
Quantization:	12 bits
Spatial Resolution:	250 m (bands 1-2) 500 m (bands 3-7) 1000 m (bands 8-36)
Design Life:	6 years

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Images

+ IMAGE GALLERY

+ IMAGES OF THE DAY

July 14, 2014

July 13, 2014

July 12, 2014

July 11, 2014

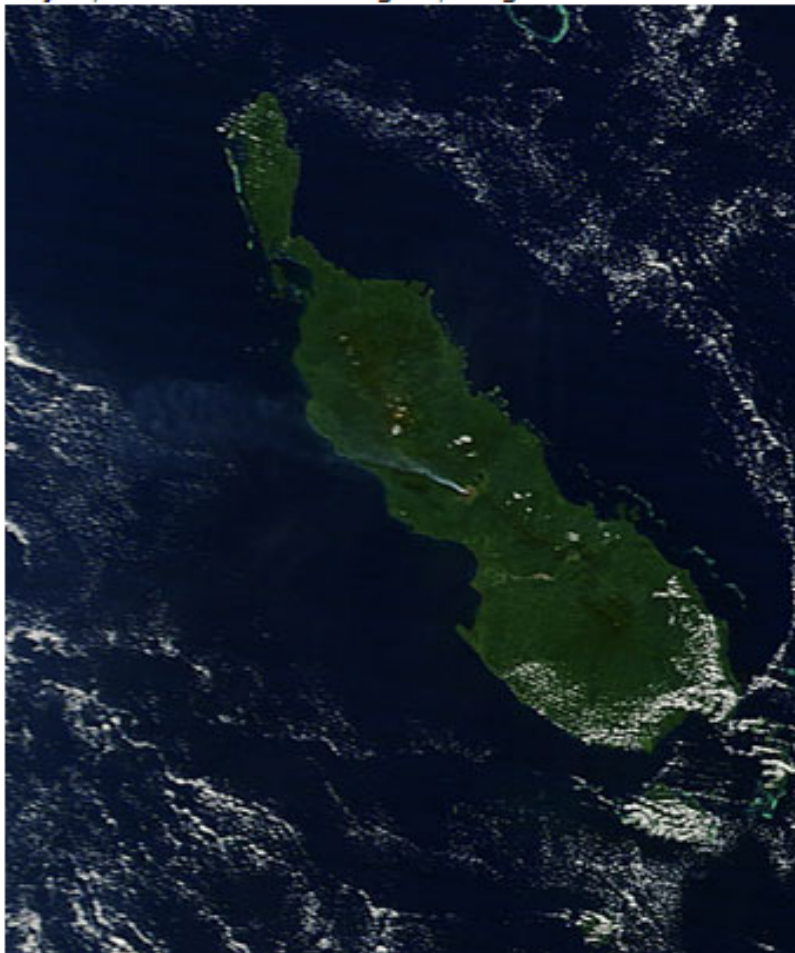
July 10, 2014

July 9, 2014

July 8, 2014

IMAGES OF THE DAY

July 14, 2014 - Plume from Bagana, Bougainville Island



Satellite: Terra

Date Acquired: 7/6/2014

Resolutions: 500m (67.9 KB)
250m (156.8 KB)

Bands Used: 1,4,3

Credit: Jeff Schmaltz
MODIS Land Rapid Response Team,
NASA GSFC

http://modis.gsfc.nasa.gov/gallery/individual.php?db_date=2014-07-14

Hyperspectral Imaging Systems

- A hyperspectral imaging system is also known as an "imaging spectrometer".
- It acquires images in about a hundred or more contiguous spectral bands.
- The precise spectral information contained in a hyperspectral image enables better characterisation and identification of targets.
- Hyperspectral images have potential applications in such fields as precision agriculture (e.g. monitoring the types, health, moisture status and maturity of crops), coastal management (e.g. monitoring of phytoplanktons, pollution, bathymetry changes).
- Example: Hyperion on EO1 satellite

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 resolution. The instrument can image a 7.5 km by 100 km land area per image, and provide detailed spectral mapping across all 220 channels with high radiometric accuracy.



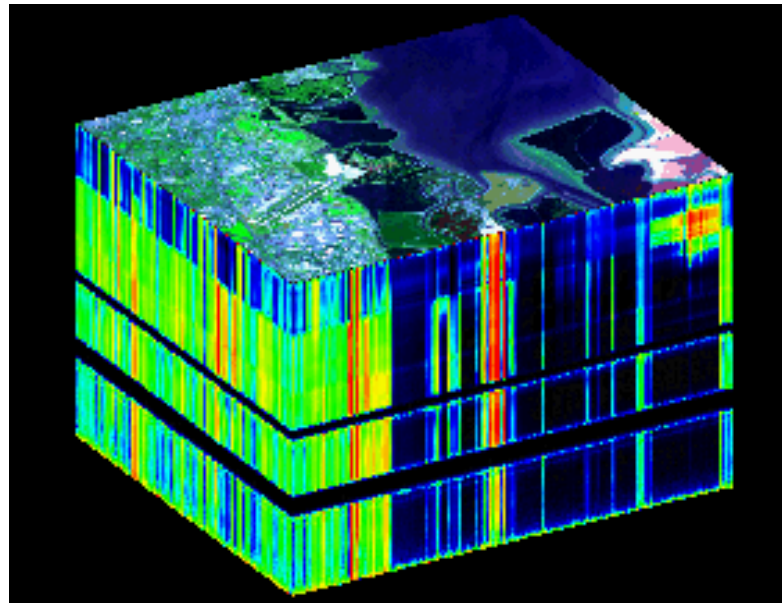
<http://earthobservatory.nasa.gov/Features/EO1Tenth/page3.php>

Hyperspectral Imaging Systems

- Applications of hyperspectral imagery:
 - **Atmosphere:** water vapor, cloud properties, aerosols
 - **Ecology:** chlorophyll, leaf water, cellulose, pigments, lignin
 - **Geology:** mineral and soil types
 - **Coastal Waters:** chlorophyll, phytoplankton, dissolved organic materials, suspended sediments
 - **Snow/Ice:** snow cover fraction, grainsize, melting
 - **Biomass Burning:** subpixel temperatures, smoke
 - **Commercial:** mineral exploration, agriculture and forest production

Hyperspectral Imaging Systems

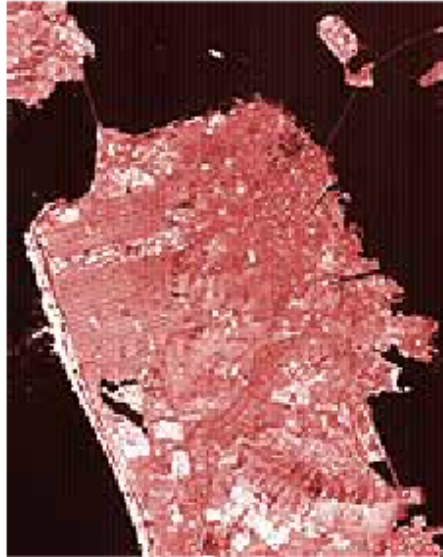
- Hyperspectral imagery is typically collected (and represented) as a data cube with spatial information collected in the X-Y plane, and spectral information represented in the Z-direction.



Spectral Signatures

- Images taken at different wavelengths (multispectral sensors) can be combined to make composite images by displaying the image for each wavelength as red, green, or blue in the final image.

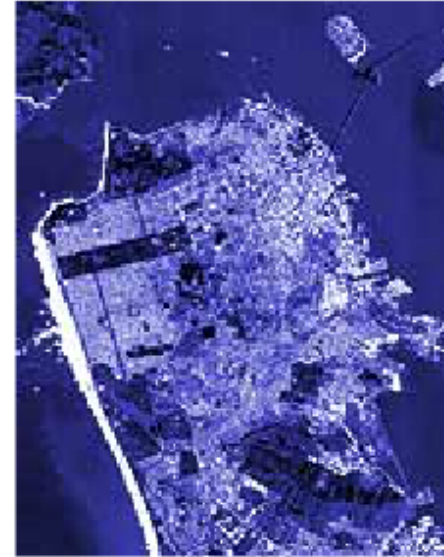
near infrared image
wavelength = 810 nm



visible light image
wavelength = 660 nm

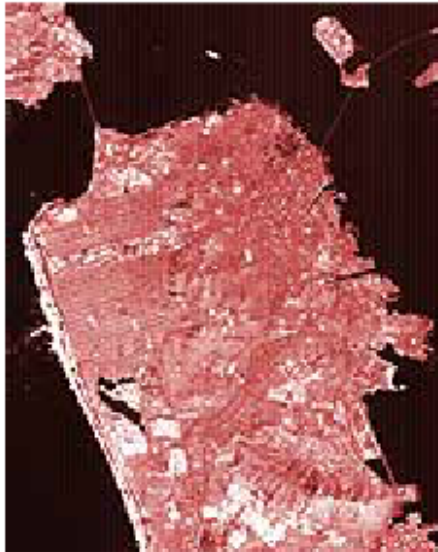


visible light image
wavelength = 560 nm

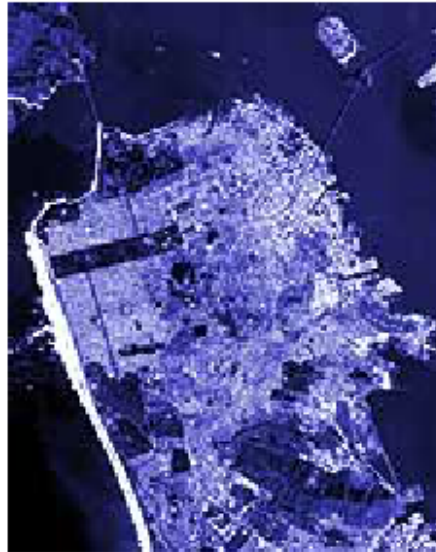


http://www.classzone.com/books/earth_science/terc/content/investigations/esu101/esu101page07.cfm

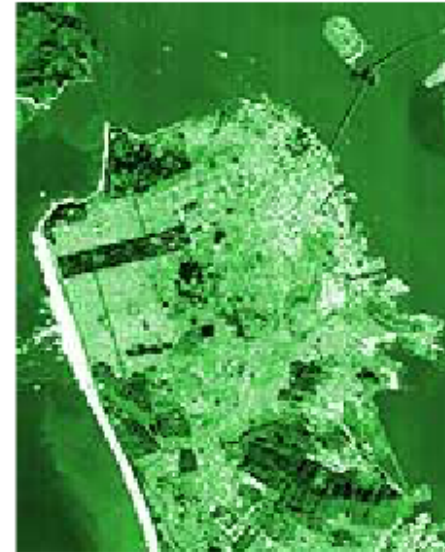
near infrared image
wavelength = 810 nm



visible light image
wavelength = 660 nm



visible light image
wavelength = 560 nm



http://www.classzone.com/books/earth_science/terc/content/investigations/esu101/esu101page07.cfm



Remote Sensing Satellites



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DATA

The MODIS Data section contains everything from ATBDs to Product Descriptions to tutorials on ordering MODIS data from the various DAACs. [Peruse the Data section today.](#)

[Registration now open](#) for the 2012 MODIS Science Team Meeting on May 7-9, 2012.

NEWS

The MODIS news section details all the developing news surrounding the MODIS project.

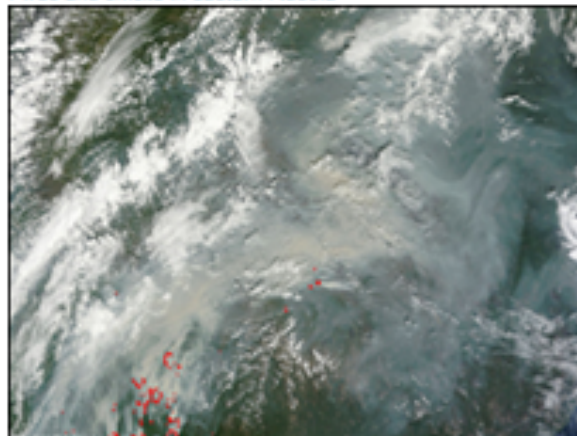
[May 2012 MODIS Science Team Meeting Presentations Available For Download](#)

[XML](#) [MODIS IOTD RSS Feed](#)

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IMAGES

[Fires and smoke in eastern Russia](#)



[Fires still burned in Eastern Russia in mid-July, 2012, consuming thousands of hectares of boreal forest...](#)

DISCIPLINES



Atmosphere



Land



Ocean



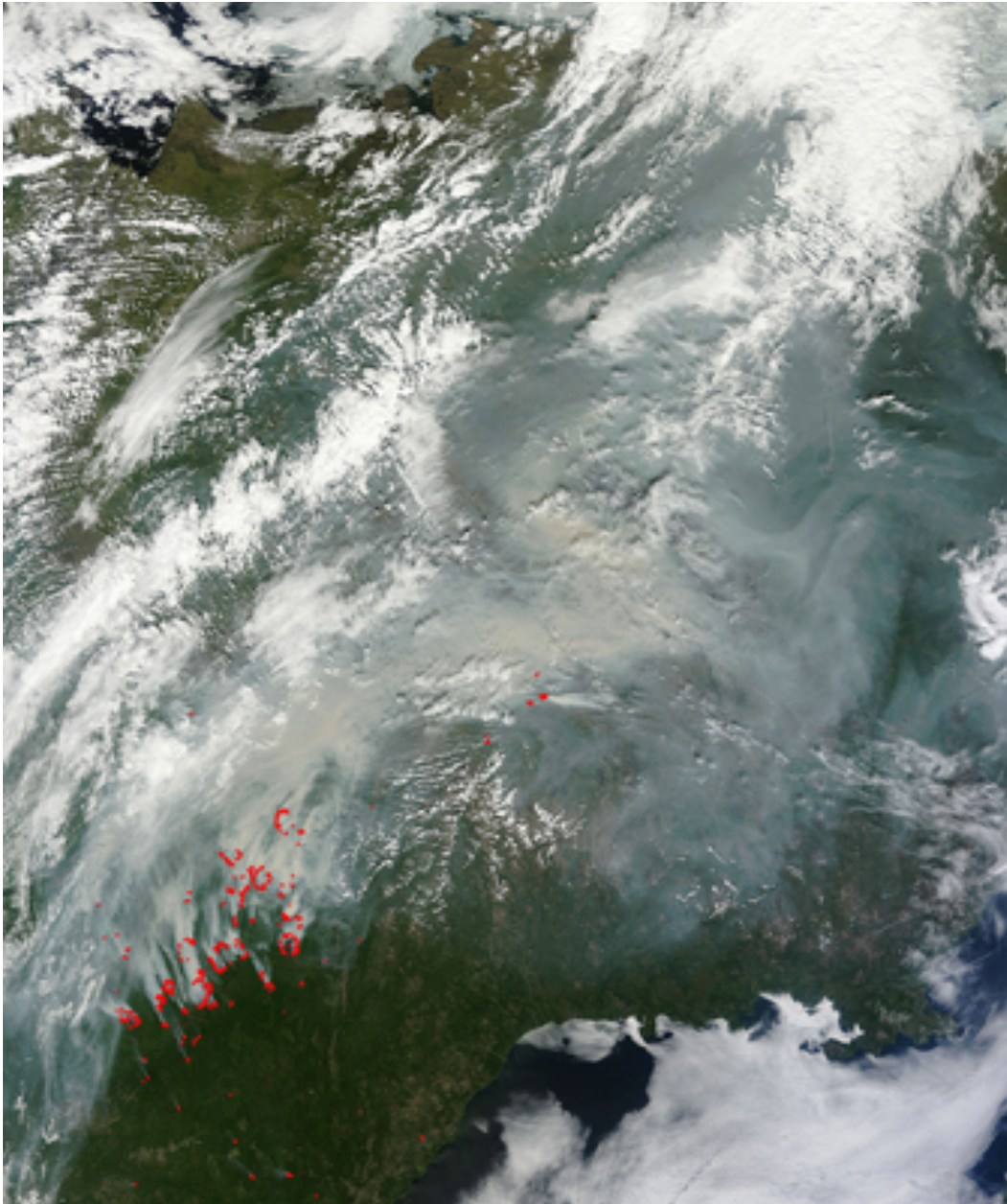
Calibration

MODIS

- MODIS = Moderate Resolution Imaging Spectroradiometer
- Aboard Terra and Aqua satellites, Terra passes from north to south across the equator in the morning, while Aqua passes south to north over the equator in the afternoon.
- Terra was launched on December 18, 1999, and Aqua was launched on May 4, 2002.

MODIS

- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days
- Acquiring data in 36 spectral bands, or groups of wavelengths



Fires in Eastern Russia in mid-July, 2012, consuming thousands of hectares of boreal forest.

The MODIS flying aboard the Terra satellite acquired this true-color image of the ongoing Russian wildfires on July 12, 2012 at 02:15 UTC .

The instrument's thermal sensors detected heat signatures in multiple locations, and these appear in red in the image. When combined with smoke, such signatures indicate active fires.



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landsat
data



so
what?



digital
media



landsat
data
continuity
mission

The Landsat Program

The Landsat Program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Since 1972, Landsat satellites have collected information about Earth from space. This science, known as remote sensing, has matured with the Landsat Program.

Landsat satellites have taken specialized digital photographs of Earth's continents and surrounding coastal regions for over three decades, enabling people to study many aspects of our planet and to evaluate the dynamic changes caused by both natural processes and human practices.

[:: learn more ::](#) [search site ::](#)



Tahiti, French Polynesia

Important News

Landsat & the Chesapeake

June 19 • Big changes are happening to the Chesapeake Bay
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Earth as Art contest ...

Landsat 5 update ...

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bio





Landsat

- Since the early 1970s, the Landsat program has collected spectral information from Earth's surface, creating a historical archive unmatched in quality, detail, coverage, and length.
- Landsat sensors have a moderate spatial-resolution. This is an important spatial resolution because it is coarse enough for global coverage, yet detailed enough to characterize human-scale processes such as urban growth.

Landsat 1

THE DETAILS

Launch Date: July 23, 1972
Status: expired, January 6, 1978
Sensors: RBV, MSS
Altitude: nominally 900 km
Inclination: 99.2°
Orbit: polar, sun-synchronous
Equatorial Crossing Time: nominally 9:42 AM mean local time (descending node)
Period of Revolution : 103 minutes; ~14 orbits/day
Repeat Coverage : 18 days

Landsat 7

THE DETAILS

Launch Date: April 15, 1999
Status: operational despite Scan Line Corrector (SLC) failure May 31, 2003
Sensors: ETM+
Altitude: 705 km
Inclination: 98.2°
Orbit: polar, sun-synchronous
Equatorial Crossing Time: nominally 10 AM (± 15 min.) local time (descending node)
Period of Revolution : 99 minutes; ~14.5 orbits/day
Repeat Coverage : 16 days

The Thematic Mapper

TM Bands

Band Number	μm	Resolution
1	0.45-0.52	30 m
2	0.52-0.60	30 m
3	0.63-0.69	30 m
4	0.76-0.90	30 m
5	1.55-1.75	30 m
6	10.4-12.5	120 m
7	2.08-2.35	30 m

TM TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**
Spatial Resolution: **30 m (120 m - thermal)**
Spectral Range: **0.45 - 12.5 μm**
Number of Bands: **7**
Temporal Resolution: **16 days**
Image Size: **185 km X 172 km**
Swath: **185 km**
Programmable: **yes**

The Multispectral Scanner System

MSS Bands

Band Number (L1-L3)	Band Number(L4-L5)	μm	Resolution*
4	~ 2 (0.52–0.60 μm)	0.5-0.6	68 m X 83 m
5	~ 3 (0.63–0.69 μm)	0.6-0.7	68 m X 83 m
6	~ 4 (0.76–0.90 μm)	0.7-0.8	68 m X 83 m
7	~ 4	0.8-1.1	68 m X 83 m
8	~ 6 (2.08–2.35 μm)	10.41-12.6	68 m X 83 m

MSS TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**

*Spatial Resolution: **68 m X 83 m (commonly resampled to 57 m, or 60 m)**

Spectral Range: **0.5 - 1.1 μm**

Number of Bands: **4, 5 (Landsat 3 only)**

Temporal Resolution: **18 days (L1-L3), 16 days (L4 & L5)**

Image Size: **185 km X 185 km**

Swath: **185 km**

Programmable: **no**

The Enhanced Thematic Mapper Plus

ETM+ Bands

Band Number	μm	Resolution
1	0.45-0.515	30 m
2	0.525-0.605	30 m
3	0.63-0.69	30 m
4	0.75-0.90	30 m
5	1.55-1.75	30 m
6	10.4-12.5	60 m
7	2.09-2.35	30 m
8	0.52-0.9	15 m

ETM+ TECHNICAL SPECIFICATIONS

Sensor type: **opto-mechanical**

Spatial Resolution: **30 m (60 m - thermal, 15-m pan)**

Spectral Range: **0.45 - 12.5 μm**

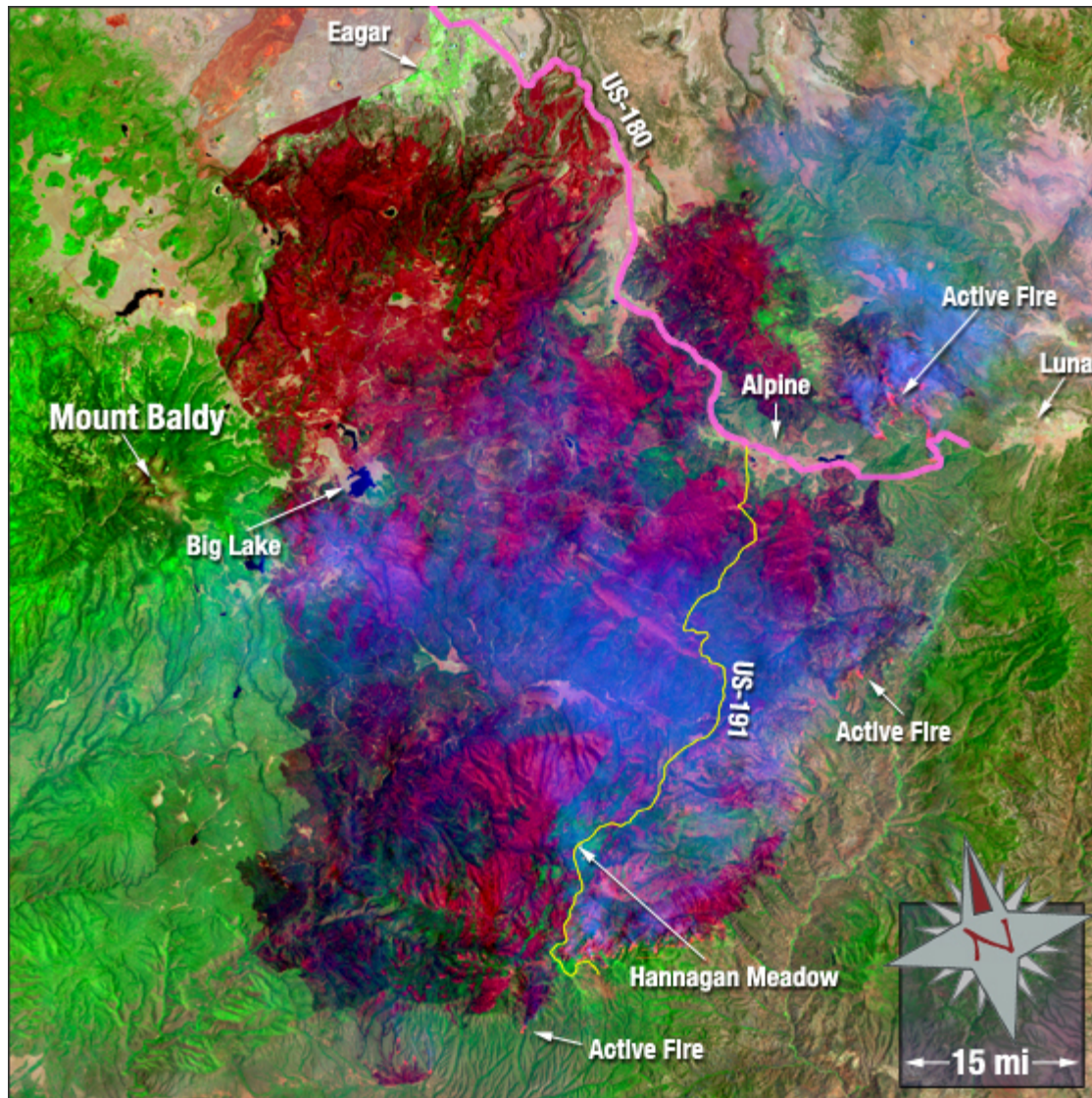
Number of Bands: **8**

Temporal Resolution: **16 days**

Image Size: **183 km X 170 km**

Swath: **183 km**

Programmable: **yes**



The Wallow fire began May 29, 2011 in the Bear Wallow Wilderness area located in eastern Arizona. High winds and low humidity combined to turn the the Wallow Fire into Arizona's largest wildfire to date by June 14, 2011 with over 733 square miles burned.



This Landsat 5 image was acquired August 7, 2011. This natural colored image was created using TM bands 3, 2 and 1. Vancouver falls on WRS-2 Path 47 Row 26.