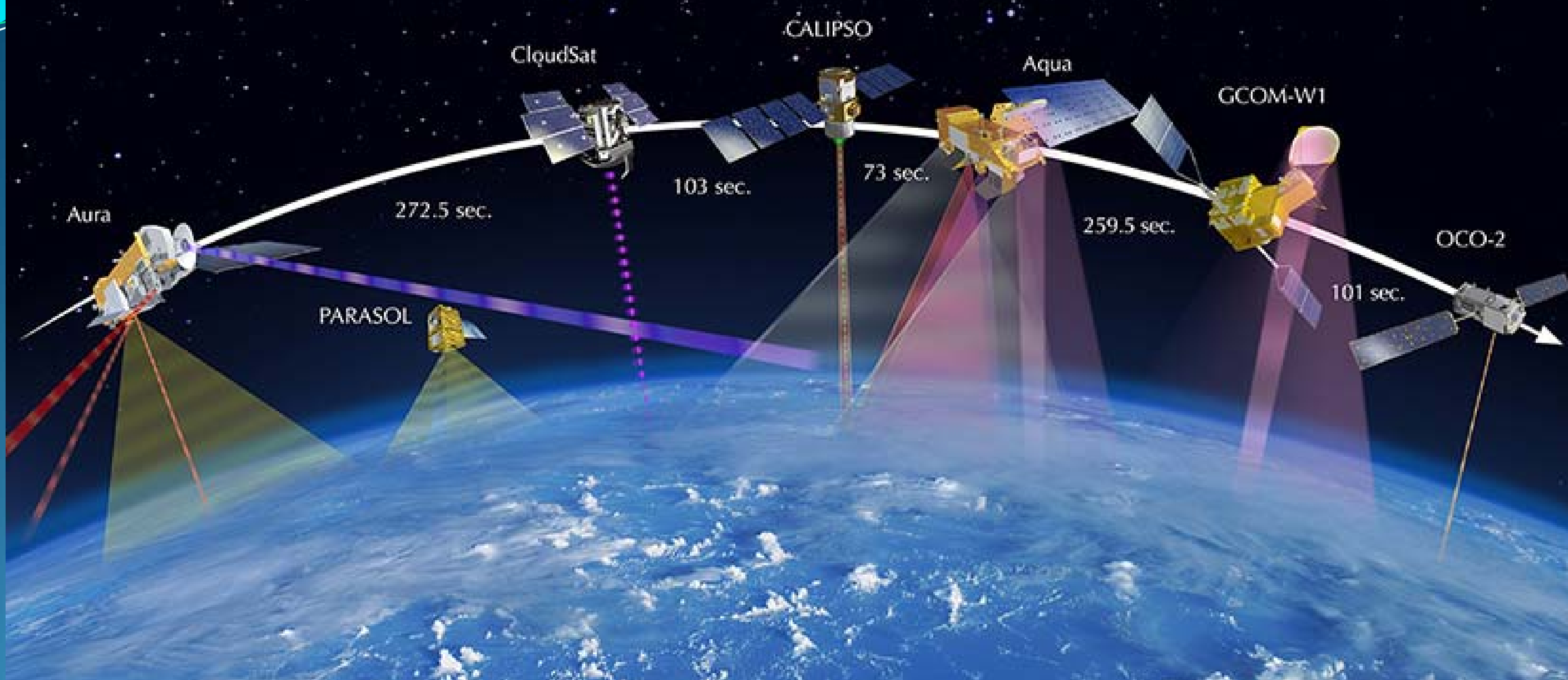
ATMO 611 – Satellite Data Applications



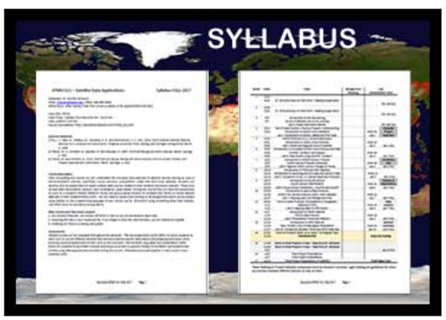
Course Introduction

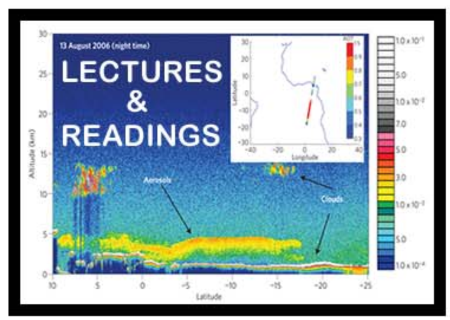
Lecture 1: History of Remote Sensing

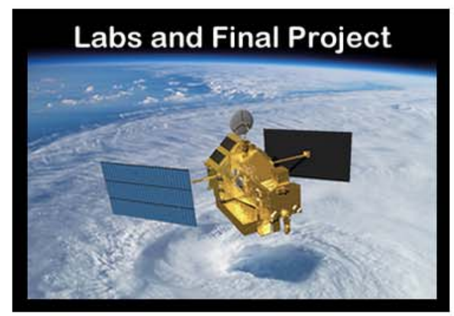
Jennifer D. S. Griswold

Class Website

- http://jenniferdsmallphd.com/ATMO_611.htm







SYLLABUS

Click on the links below to download the Course Syllabus in your preferred format.
WORD or PDF

LECTURES & READINGS

Click on the image above to go to the Lectures page to download lectures in PPT or PDF and the Readings in PDF.

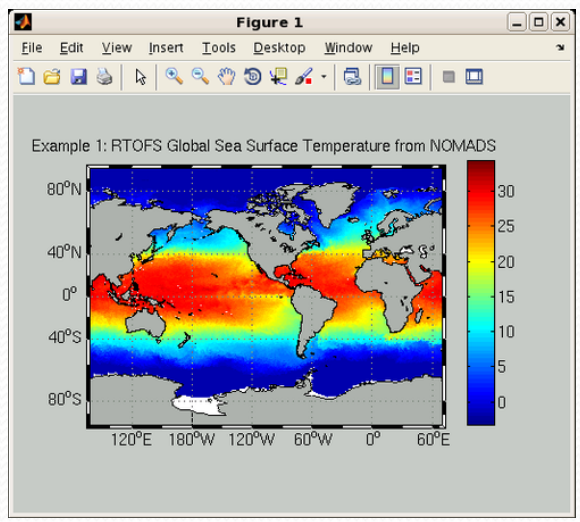
LABS & FINAL PROJECT

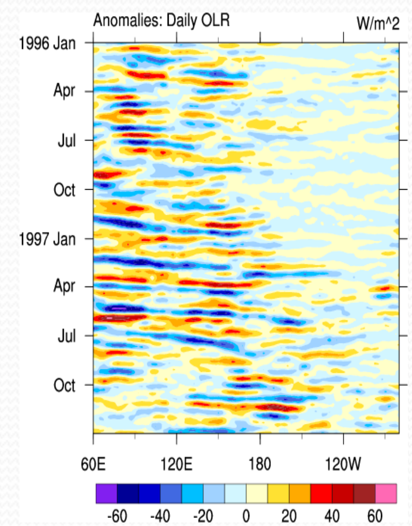
Click on the image above to go to the Lab Assignment and Final Project page to download the assignments.

Purpose of ATMO 611

- **Enable practical use of remote sensing data through**
  - Familiarization with various satellites and data products
  - Background theory and understanding of different satellites
  - Practical experience manipulating satellite data
  - Understand quality controls and data limitations

- **Use of MatLab to:**
  - Extract Data
  - Manipulate Data
  - Plot Data
  - Conduct Statisitical Tests





Syllabus - Course Expectations

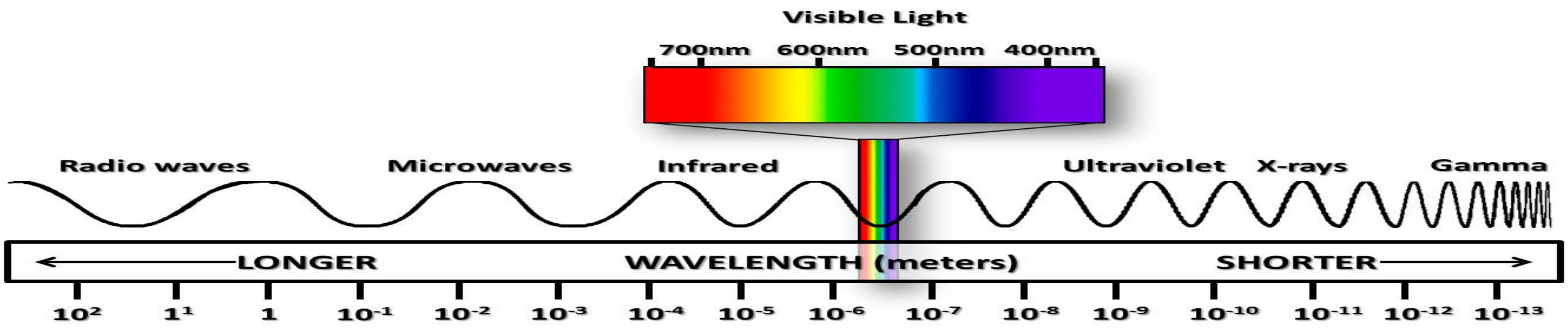
- **10 Laboratory Assignments**
  - Labs will be due ***one week*** after they are assigned.
- **One Semester Long Project**
  - Final Paper
  - Oral Presentation
- **No Exams**
- **Reading Material (PDFs)**
  - journal articles related to individual satellites or data sets to support your understanding of the data and to provide resources for your final projects.

What is Remote Sensing?

- **Remote Sensing**: remote sensing is science of
  - acquiring
  - processing
  - and interpreting

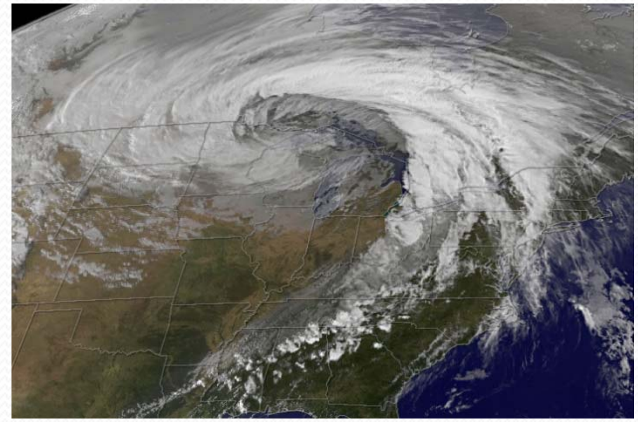
  images and related data that are obtained from ground-based, air-or space-borne instruments that record the interaction between matter (target) and electromagnetic radiation.

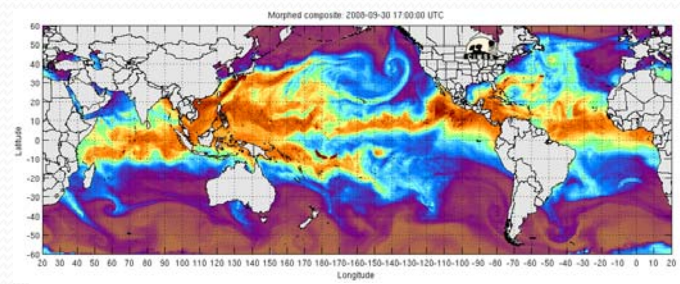
- **Current Remote Sensing**: using electromagnetic spectrum to image the land, ocean, and atmosphere.

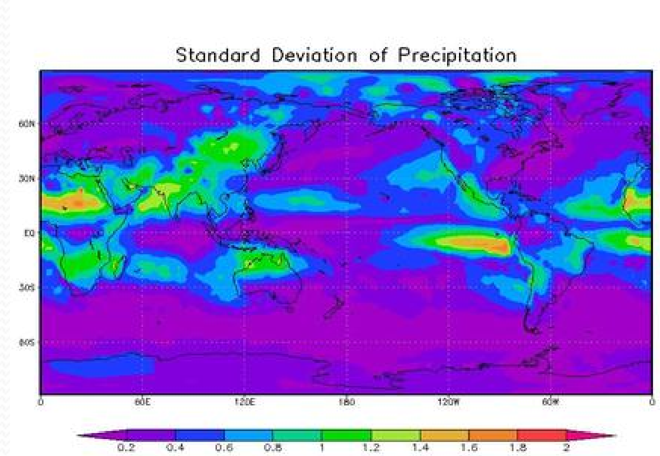


Why do we need/use Remote Sensing?

- **Source of spatial and temporal information**
  - land surface, oceans, atmosphere, ice
- **Monitor** and develop understanding of environment
- Information can be **accurate**, **timely**, **consistent** and **large** (spatial) scale
- Move to **quantitative** applications
  - data for climate (temperature, atmospheric gases, land surface, aerosols, clouds, precipitation….)
- Some '**Commercial**' applications
  - Weather, agricultural monitoring, resource management

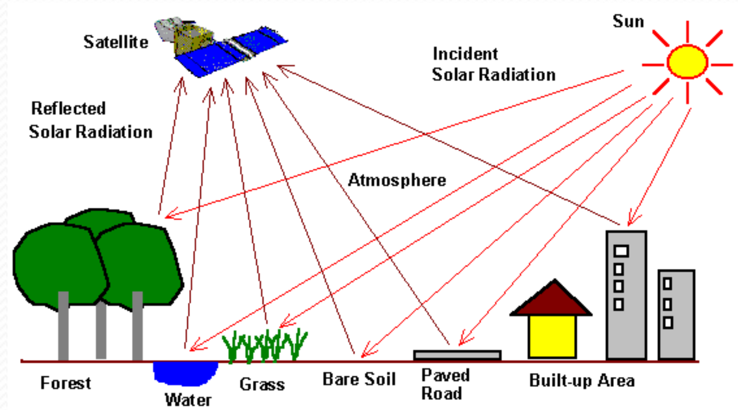


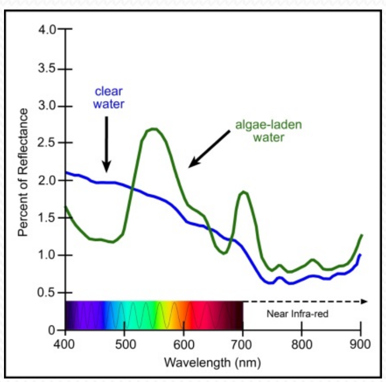




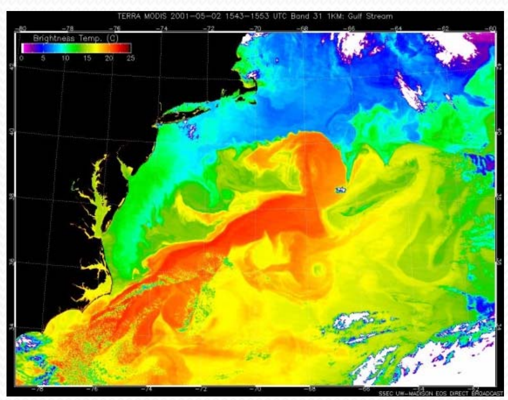
Issues with Remote Sensing

- **Remote sensing has various issues**
  - Can be expensive
  - Can be technically difficult
  - **NOT direct**
    - measure surrogate variables
      - reflectance (%)
      - brightness temperature ($Wm^{-2} \Rightarrow {}^{o}K$)
      - backscatter (dB)
    - **RELATE to other, more direct properties.**

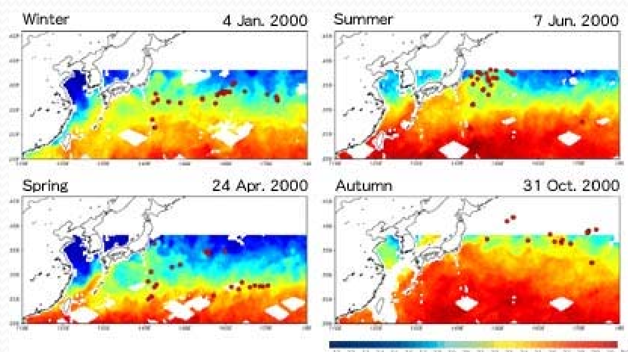




http://lms.seos-project.eu/learning_modules/marinepollution/marinepollution-c03-p05.html



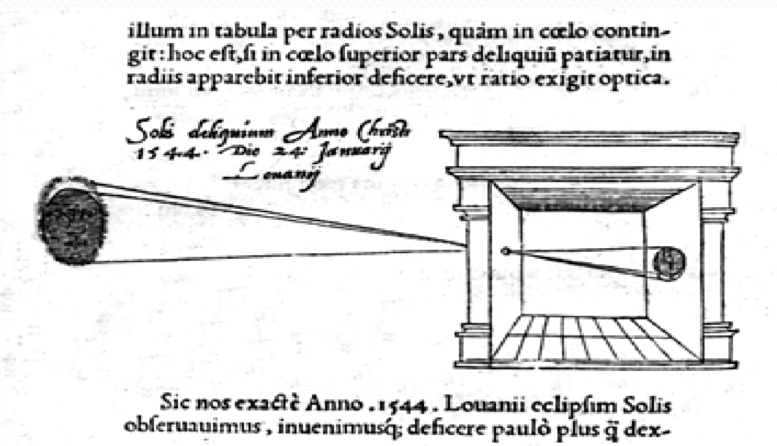
http://earthobservatory.nasa.gov/IOTD/view.php?id=1393



http://www.eorc.jaxa.jp/TRMM/channel/earth/agriculture_e.htm

Historical Perspective

- 1038 AD - **Al Hazen** an Arabian mathematician explained the principle of the ***camera obscura*** to observe sun eclipse.


illum in tabula per radios Solis, quàm in cœlo contin-
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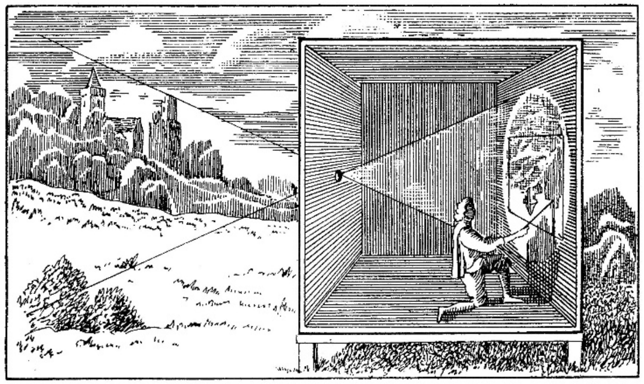
radiis apparebit inferior deficere, vt ratio exigit optica.

Sic nos exactè Anno .1544. Louanii eclipſim Solis
obſeruauimus, inuenimusq; deficere paulò plus q̃ dex-

Historical Perspective

- 1490 - **Leonardo da Vinci** describes in detail the principles underlying the *CAMERA OBSCURA* (literally *DARK ROOM*).



- 1550- **Gerolamo Cardano** put optics on a camera obscura for obtaining a better quality image.

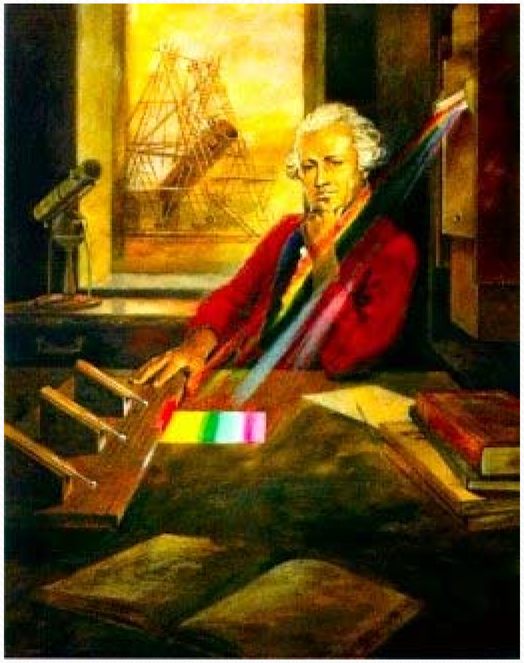
- 1608 – Description of first telescope (**Galileo** made his in 1609)

- 1614 - **Angelo Sala** discovers that silver salts darken when exposed to sunlight.

Historical Perspective

- 1666 - **Sir Isaac Newton**
  - experimenting with a prism, found that he could disperse light into a spectrum
  - utilizing a second prism, he found that he could re-combine the colors into white light.

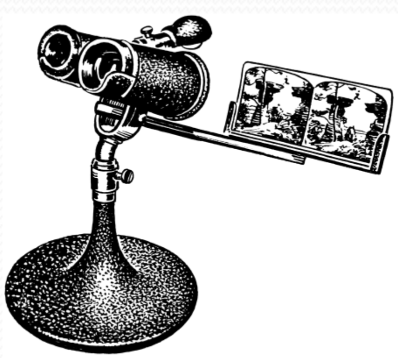
- 1800 - **Sir William Herschel**
  - measures the temperatures of light split with a prism into the spectrum of visible colors. He had discovered ***thermal infrared electromagnetic radiation.***

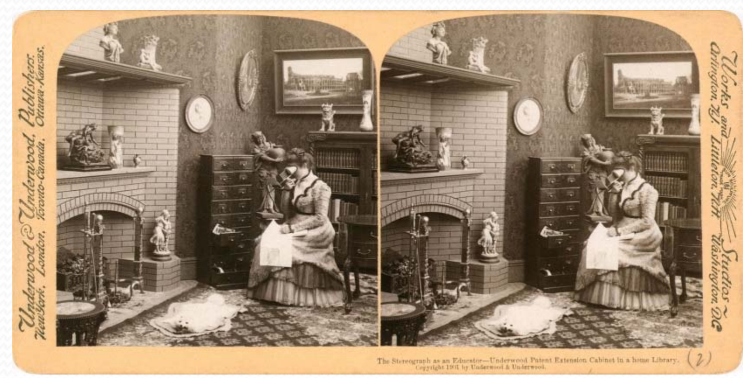


Historical Perspective

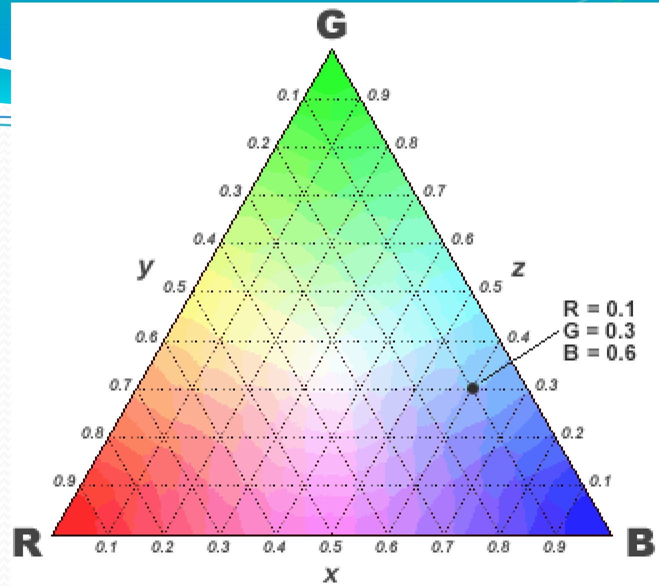
- 1827 - Niepce takes ***first picture*** of nature from a window view of the French countryside
  - camera obscura and an emulsion using bitumen of Judea, a resinous substance, and oil of lavender
  - it took 8 hours in bright sunlight to produce the image

- 1830s – Invention of the Stereoscope



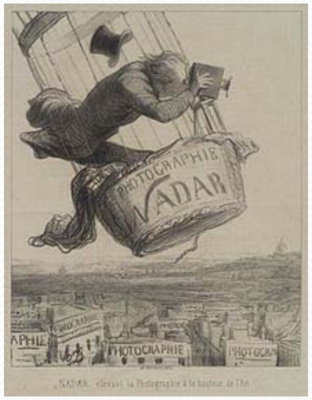


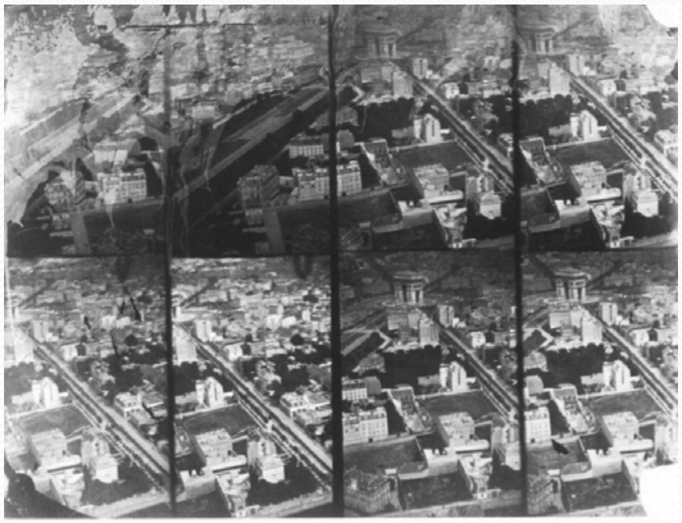
Historical Perspective



- 1855 - **John Clerk Maxwell** describes *color additive theory*.
  - The color additive theory describes how we perceive color and how they are created (true color images)

- 1858 - **Gasper Felix Tournachon** "*Nadar*"
  - takes the first aerial photograph from a captive balloon from an altitude of 1,200 feet over Paris.



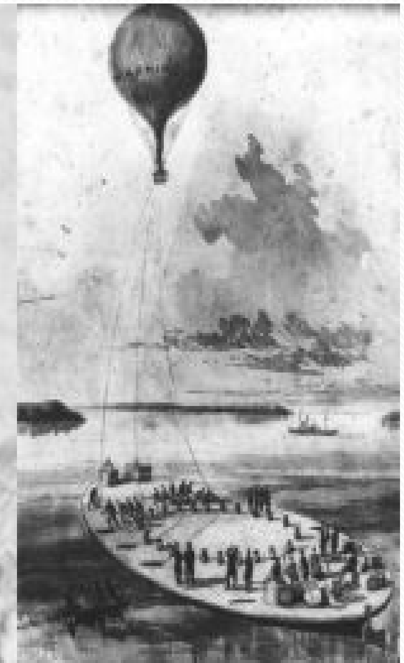


NADAR (GASPARD FÉLIX TOURNACHON). *The Arc de Triomphe and the Grand Boulevards, Paris, from a Balloon*. 1868.

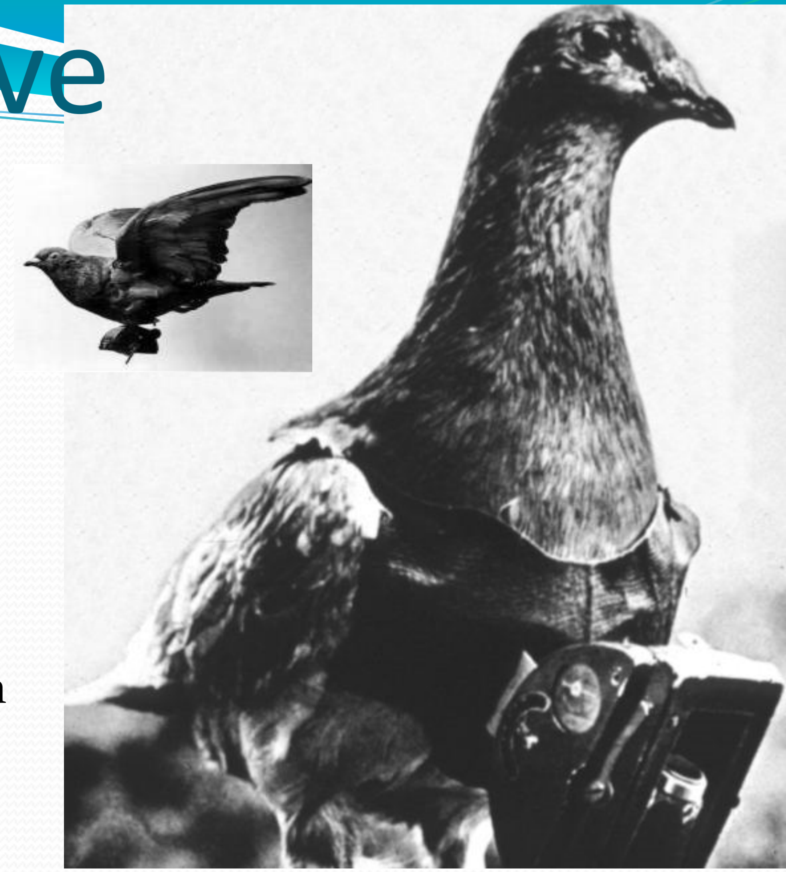
Historical Perspective

- 1860's - Aerial observations, and possible photography, for ***military purposes*** were acquired from balloons in the Civil War.

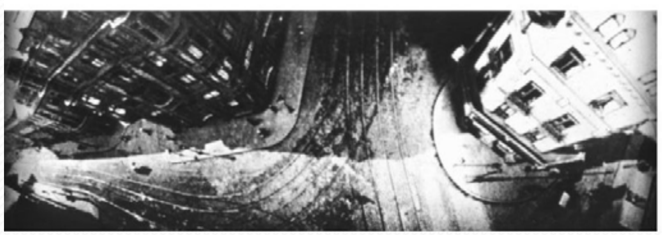
- 1862 – **US Army Balloon Corp** for aerial reconnaissance
  - Photos?
  - Maybe.



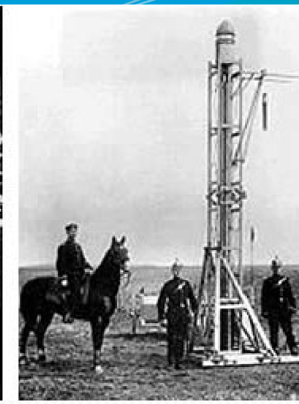
Historical Perspective



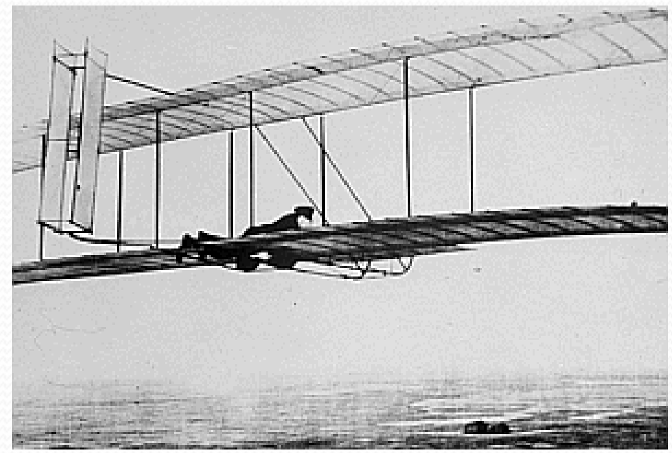
- 1903 - **The Bavarian Pigeon Corps** uses pigeons to transmit messages and take aerial photos.
  - **Pigeon photography** is an aerial photography technique invented in 1907 by the German apothecary Julius Neubronner, who also used pigeons to deliver medications.
  - A homing pigeon was fitted with an aluminum breast harness to which a lightweight time-delayed miniature camera could be attached.



Historical Perspective

- 1906 - **Albert Maul**, using a rocket propelled by compressed air, took an aerial photograph from a height of 2,600 feet, the camera was ejected and parachuted back to earth.



- 1908 – First photographs from an ***airplane***

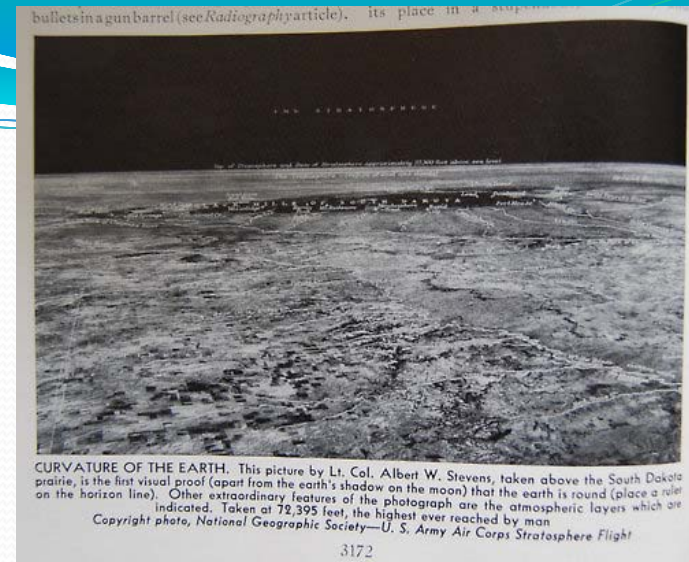

- 1914 - WWI provided a boost in the use of ***aerial photography***,
  - but after the war, enthusiasm waned

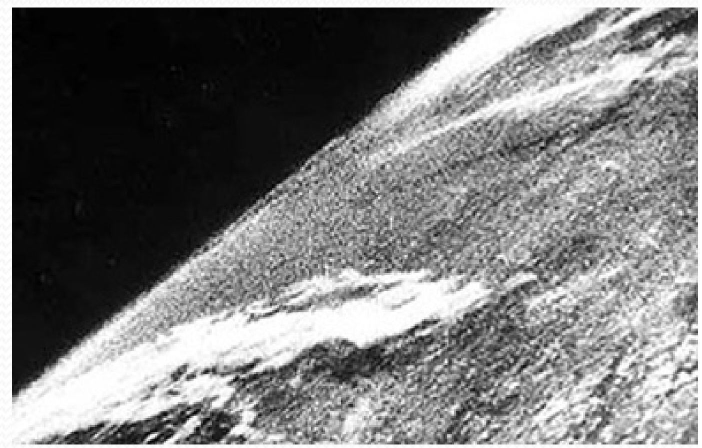
Historical Perspective

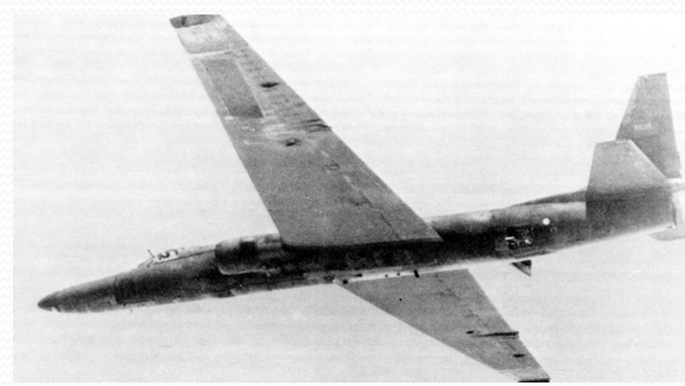
- 1936 - **Albert W. Stevens** takes the first photograph of the actual curvature of the earth - taken from a free balloon at an altitude of 72,000 feet.

- 1946 - First space photographs from **V-2 rockets**.

- 1956 - **U-2** high altitude aircraft takes first flight.
  - Max altitude 21300 meters at a speed of about Mach 0.75
  - about 800 kilometers per hour at its altitude

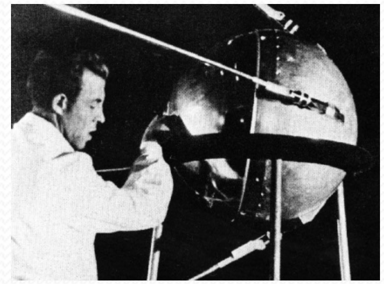


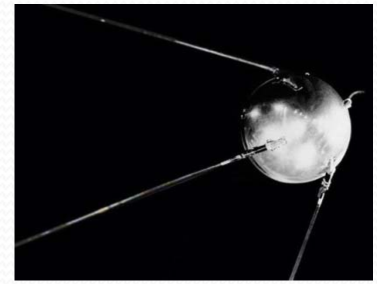




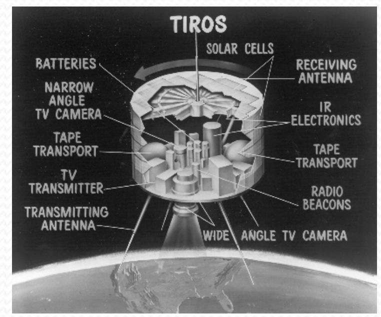
Historical Perspective

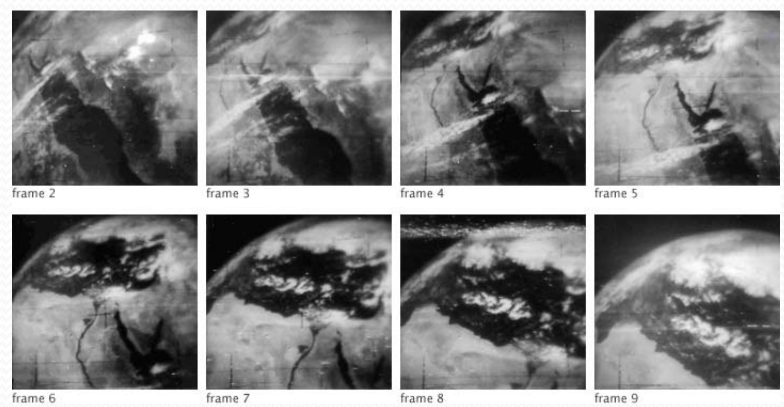
- 1957 – **Sputnik-1** is launched in Russia
  - *Unexpected*
  - Encouraged our government to make space exploration a priority.





- 1960 - **TIROS-1** launched by US as first meteorological satellite.
  - ***Television InfraRed Observation Satellite***
  - Two tiny television cameras (2lbs)
    - One camera captured a wide view of the Earth about 450 miles below, the other recorded a narrower, more detailed view.
  - ***Polar orbiter – with photos every 30 sec***
  - The TIROS program provided the first accurate weather forecasts based on data from space
  - ***The satellite has a long legacy***. TIROS-1 led to:
    - 9 more TIROS satellites
    - 7 Nimbus-series meteorological research satellites
    - 14 GOES
    - 19 NOAA Polar Orbiting Satellites
    - and many more meteorological satellites maintained by the Department of Defense and other nations.



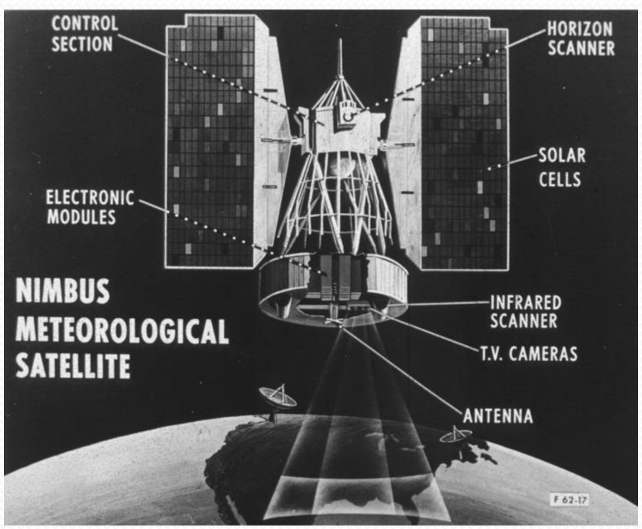


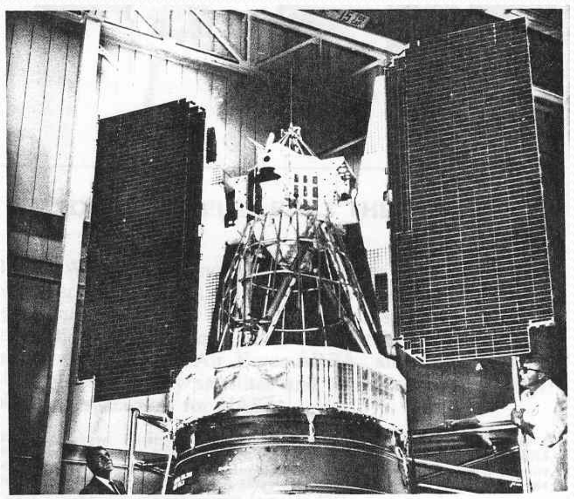
http://earthobservatory.nasa.gov/IOTD/view.php?id=43401

Historical Perspective

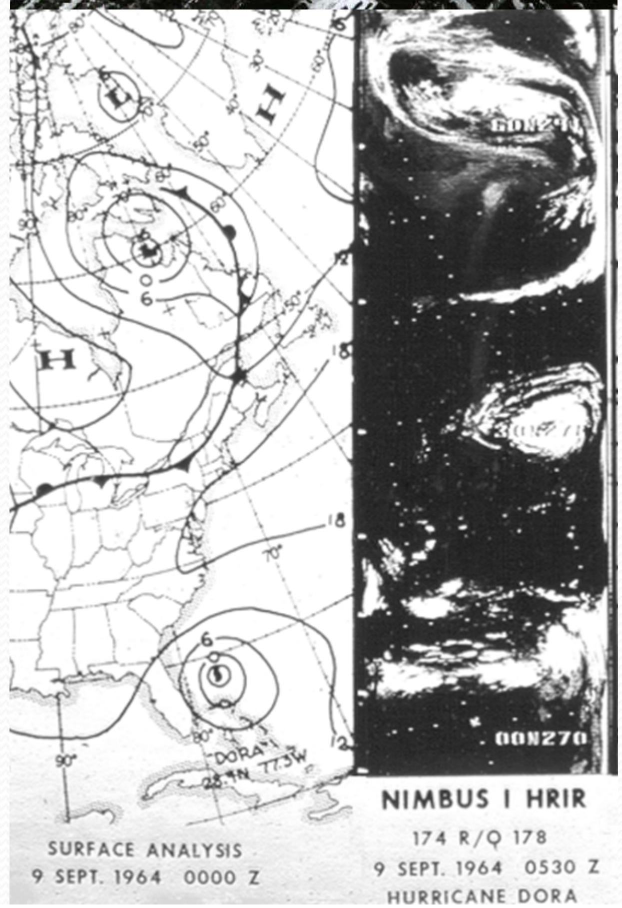
- 1960's - US begins collection of intelligence photography from Earth orbiting satellites, **CORONA**.

- 1964- Nimbus Weather Satellite Program begins with the Launch of **Nimbus-1.**



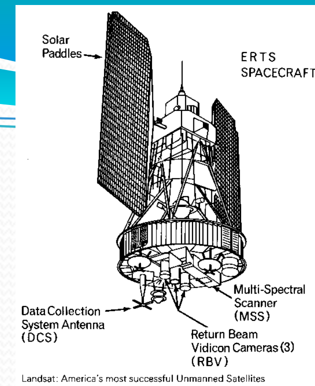


Nimbus 1 returned sharp cloud cover photos, plus night-time infrared pictures.

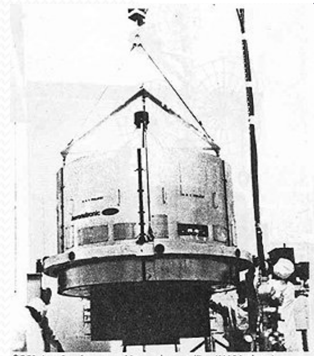


Historical Perspective

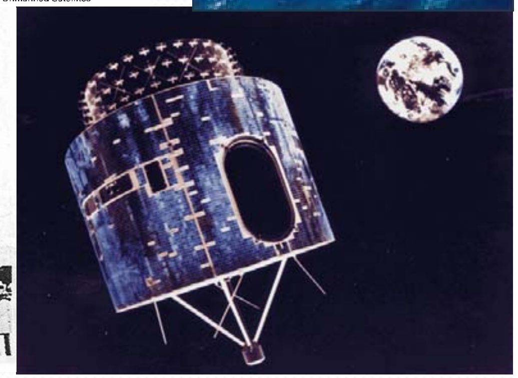
- 1972 - Launch of **ERTS-1** (the first Earth Resources Technology Satellite ,later renamed **Landsat 1**).



- 1975 - **Landsat 2**, **GOES**



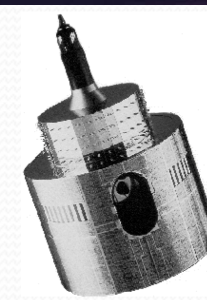
GOES-A — Synchronous orbit weather satellite. (NASA photo)



- 1977 - **Meteosat-1** the first in a long series of European weather satellites

METEOSAT-1

FIRST IMAGE: 9 DEC 1977 COPYRIGHT ESA

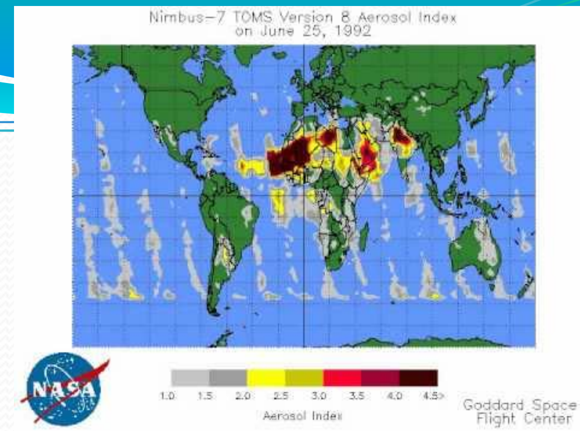


- 1978 - **Landsat 3**

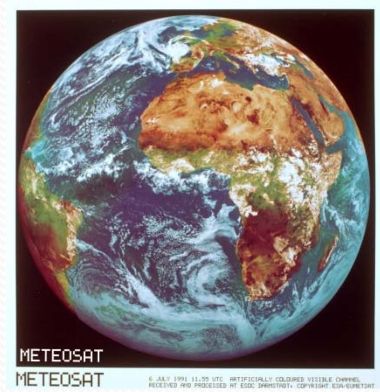
- 1978 - **Seasat**, the first civil Synthetic Aperture Radar (**SAR**) satellite.

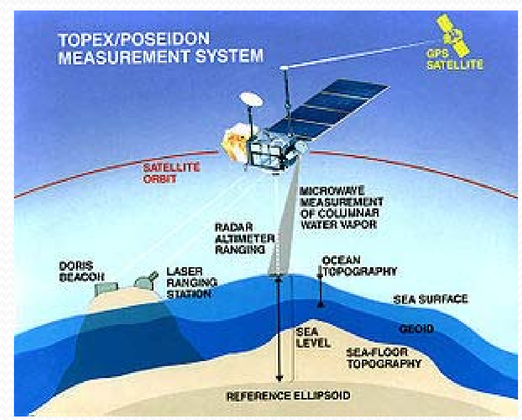
Historical Perspective

- 1978 - Launch of Nimbus-7 with Total Ozone Mapping Sensor (***TOMS***) and the Coastal Zone Color Scanner (***CZCS***),GOES-3.
- 1981 - **Space-Shuttle Imaging Radar (SIR-A), Meteosat-2**
- 1982 - **Landsat-4**
- 1984 - **SIR-B**
- 1984 - **Landsat-5**
- 1988 - **Meteosat 3**
- 1989 - **Meteosat-4**
- 1991 - **ERS (Euro Radar Satellite), Meteosat-5**
- 1992 - **JERS-1,Topex/Poseidon**.
- 1993 - **Meteosat-6**
- 1994 - **SIR-C/X-SAR** flys on the space shuttle.



We'll be using Nimbus-7 data in this class.

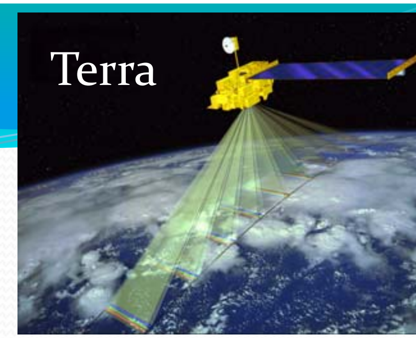


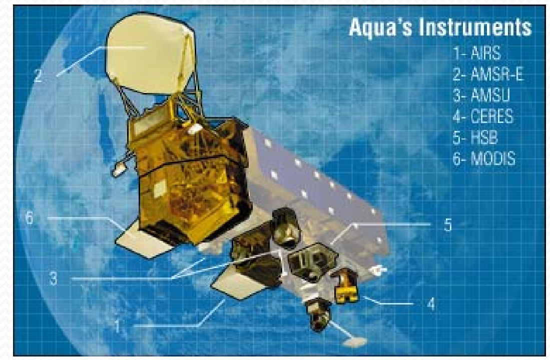


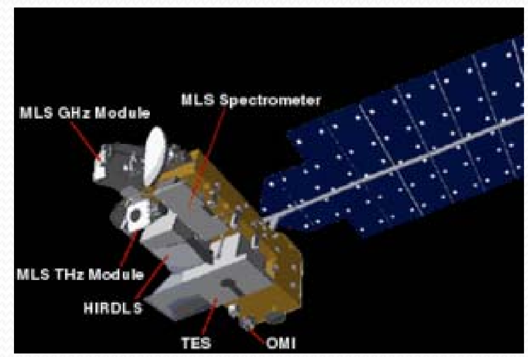
Historical Perspective

- 1995 - Launch of **ERS-2**, **Radarsat-1**
- 1997 - **Orbview-2** with **SeaWiFS**, **GOES-10**, **Meteorsat-7**
- 1998 - Launch of **JERS-1**
- 1999 - Launch of **Landsat 7**, **QuickSCAT**, **CBERS-1**, **Terra** (***MODIS***, ***ASTER***, ***CERES***, ***MISR***, ***MOPITT***)
- 2000 - **Jason-1**
- 2002 – **Aqua** (***MODIS***, ***CERES***, ***AIRS***), **ENVISAT**
- 2003 - Launch of **ICESat**
- 2004 – **Aura** (***HIRDLS***, ***OMI***, ***MLS***, ***TES***)
- 2006 – **CloudSat and CALIPSO**

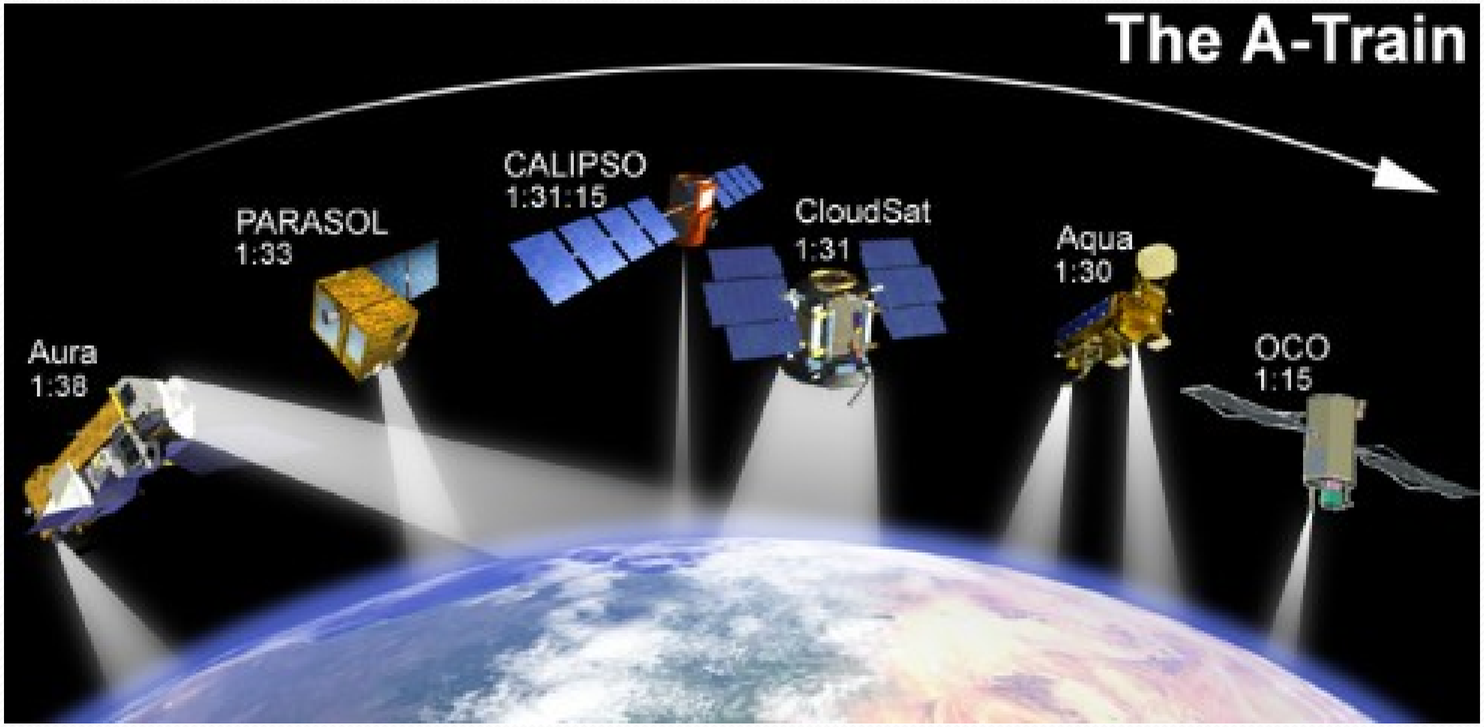
We'll be using data from Terra, Aqua, Aura, CloudSat and CALIPSO







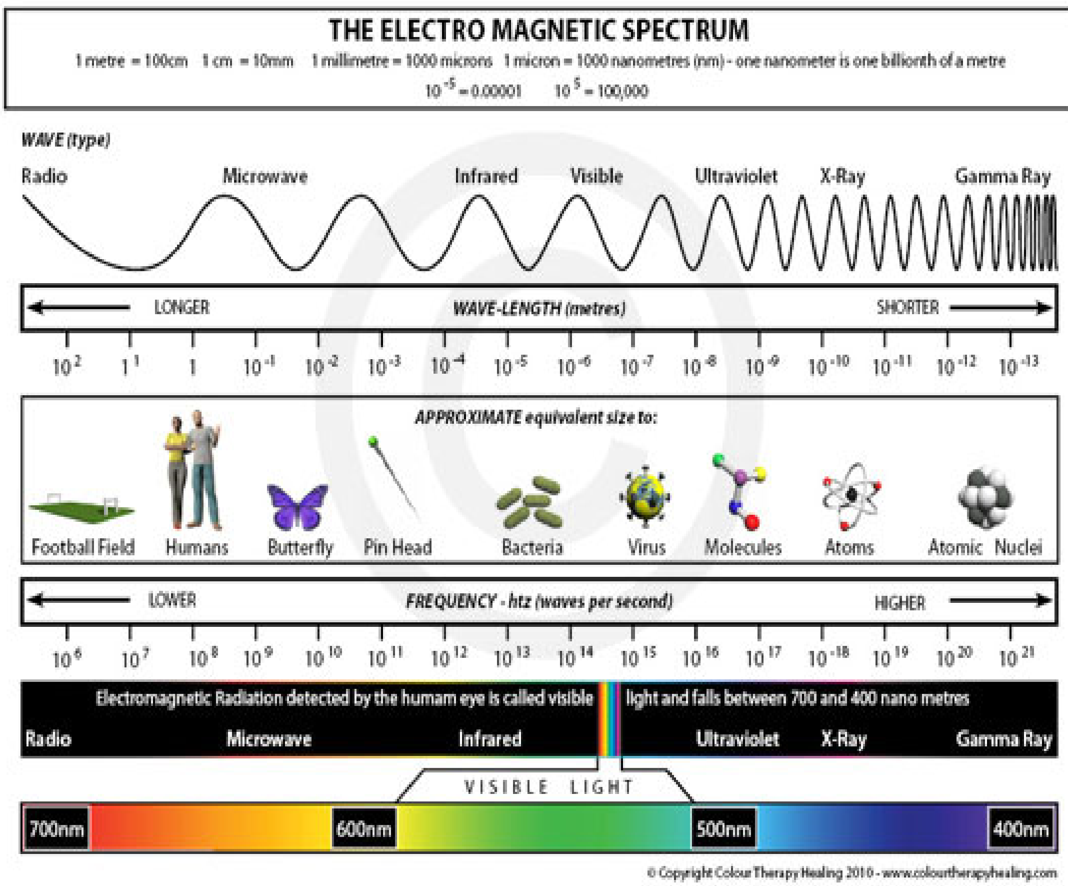
A-Train



- Earth observation satellites of varied nationality in sun-synchronous orbit at an altitude of 705 kilometers above the Earth.
- The orbit, at an inclination of 98.14°, crosses the equator each day at around 1:30 pm solar time, and crosses the equator again on the night side of the Earth, at around 1:30 am.
- "A" stands for "afternoon"

Electromagnetic Spectrum

- Wavelength (λ) is the length of one wave cycle, is measured in meters (m) or some factor of meters



- Velocity is the speed of light, $c=3 \times 10^8$ m/s

- Frequency (v) refers to the number of cycles of a wave passing a fixed point per unit of time.
  - Unlike c and λ changing as propagated through media of different densities, v remains constant.

$$c=\lambda v$$

where:

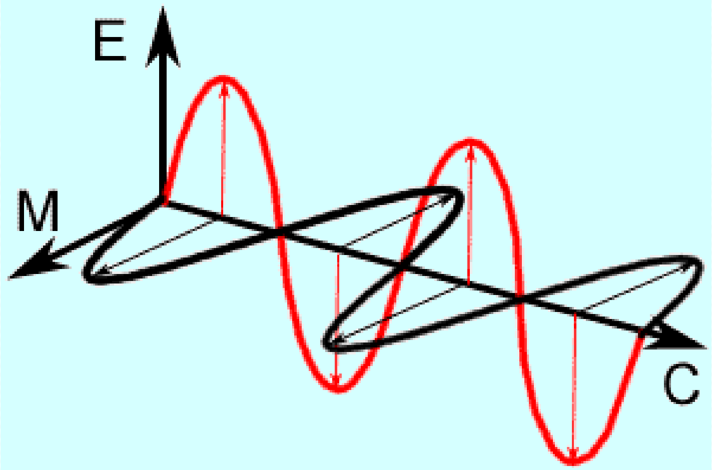
λ = wavelength (m)

v= frequency (cycles per second, Hz)

c =speed of light (3×10^8 m/s)

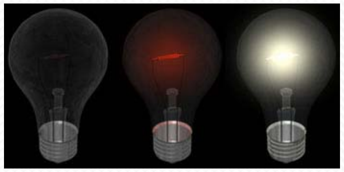
Electromagnetic Radiation (EMR)

- **James Clerk Maxwell** first formally postulated ***electromagnetic waves*** (Confirmed by Heinrich Hertz.
  - Maxwell derived a wave form of the electric and magnetic equations

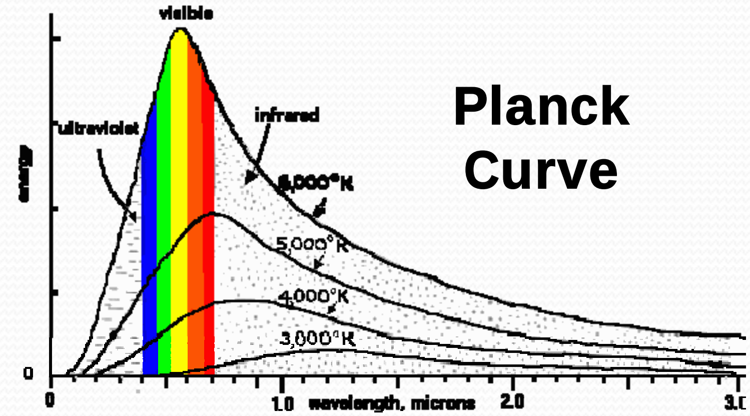


- 1884 – Relationship between temperature and radiant energy
  - deduced by J. Stefan in 1884 and theoretically explained by Boltzmann about the same time. It states:

$$\textbf{Total Energy} = \sigma T^4$$



- **Max Planck** - energy of the oscillators must be *quantized*,
  - the energies can not take any value but must change in steps, the size of each step, or quantum is proportional to the frequency of the oscillator and **equal to hν, where h is the Planck constant**.
  - The brightness distribution of a black body it is defined by its temperature.



Particle model of EMR

- Sir Isaac Newton (1704) was the first person stated that the light had not only wavelike characteristics but also light was a stream of particles, traveling in straight lines.

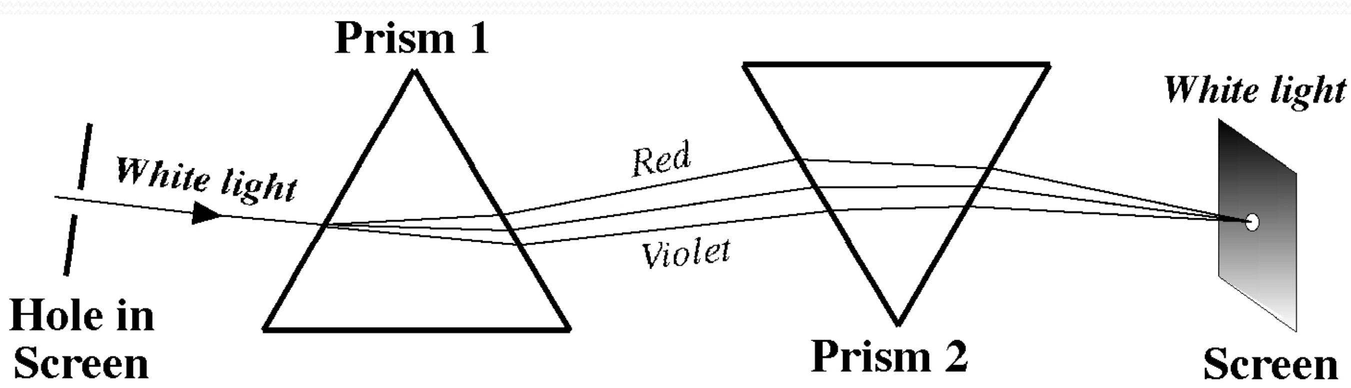
- Niels Bohr and Max Planck (20's) proposed the **quantum theory** of EMR:

  Energy content: Q (Joules) = hv (h is the Planck constant 6.626 x 10 −34 J s)

  λ= c/v=hc/Q or Q=hc/ λ

- The longer the wavelength, the lower its energy content, which is important in remote sensing because it suggests it is more difficult to detect longer wavelength energy

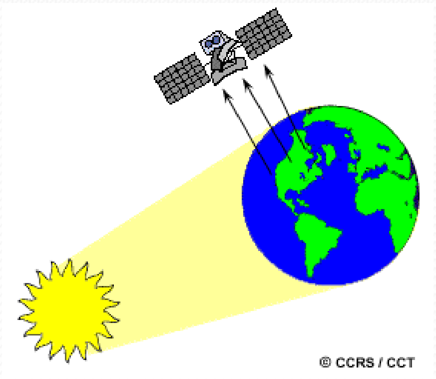
Newton's experiment in 1966



Remote Sensing Systems

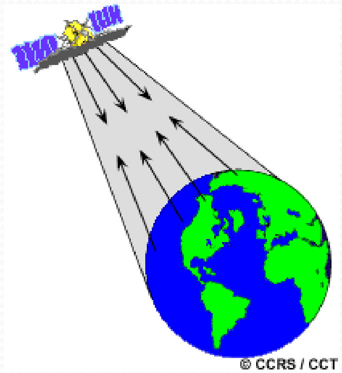
- Passive
  - Human eye
  - Camera
  - Radiometer

- Remote sensing systems which measure energy that is naturally available are called **passive sensors**.



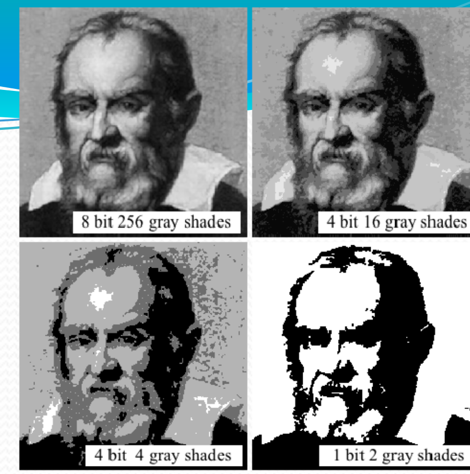
- Active
  - Radar
  - Sonar
  - Laser

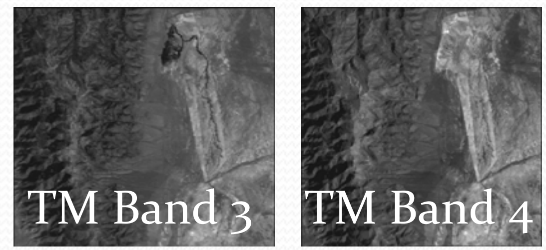
- **Active sensors**, on the other hand, provide their own energy source for illumination.

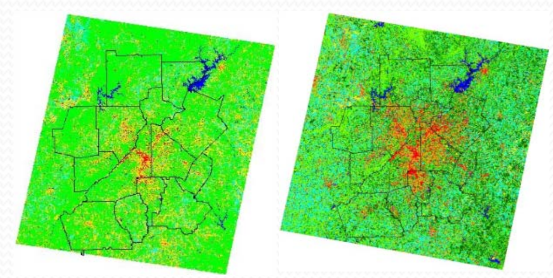


Four Properties

- Image depends on the wavelength response of the sensing instrument and the emission or reflection spectra of the target (the signal)
  - **Radiometric resolution**
  - **Spectral resolution**
- Image depends in the size of the objects that can be discerned
  - **Spatial Resolution**
- Knowledge of the changes in the target depends on how often the target is observed
  - **Temporal Resolution**



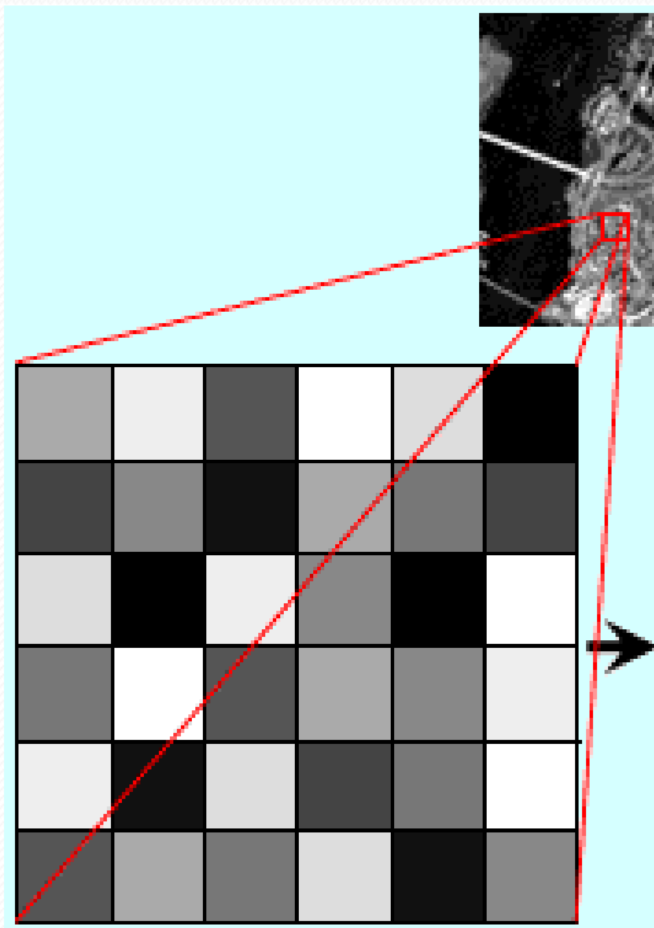




Atlanta, 1973 1987

Pixels

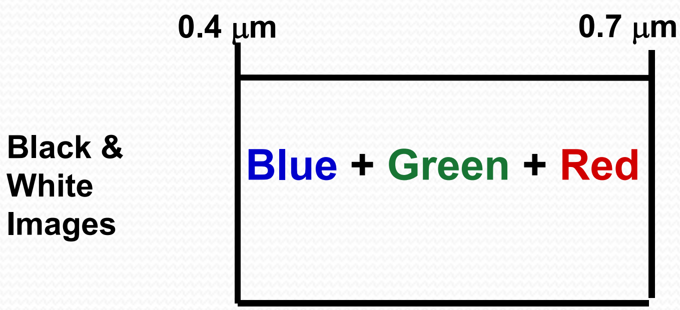
- Grid boxes are assigned number values for whatever variable you are looking at.



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Spectral Resolution

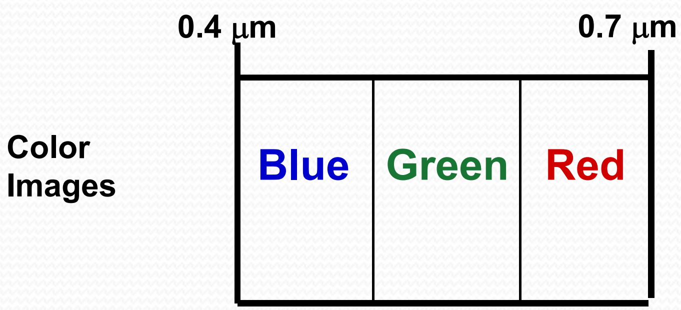
- **Example: Black and White Image**
  - Single sensing device
  - Intensity is the sum of intensity of all visible wavelengths



- **Can you tell the color of the platform top?**
- **The color of her Sash?**

Spectral Resolution

- **Example: Color Image**
  - Color images need at least three sensing devices, e.g. Red, Green, and Blue (RBG)

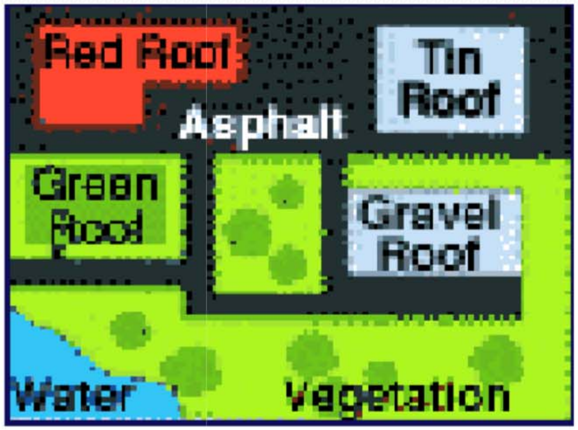


- **Using increased spectral resolution (three sensing wavelengths) adds information**

- **In this case by "sensing" RBG you can combine them to get full color rendition**

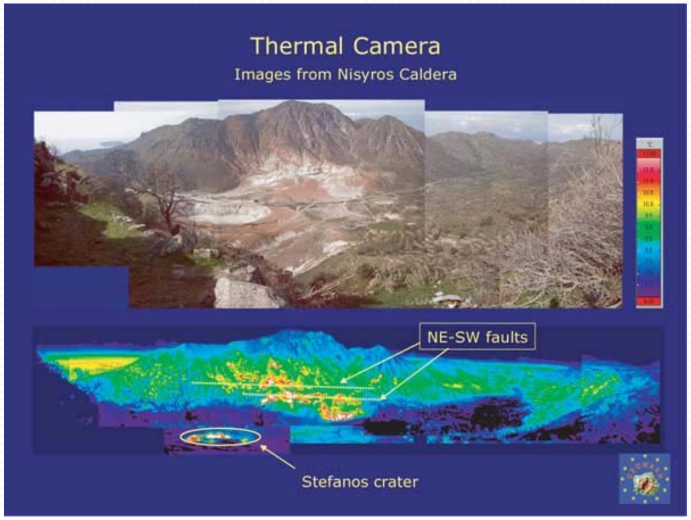
Spectral Resolution

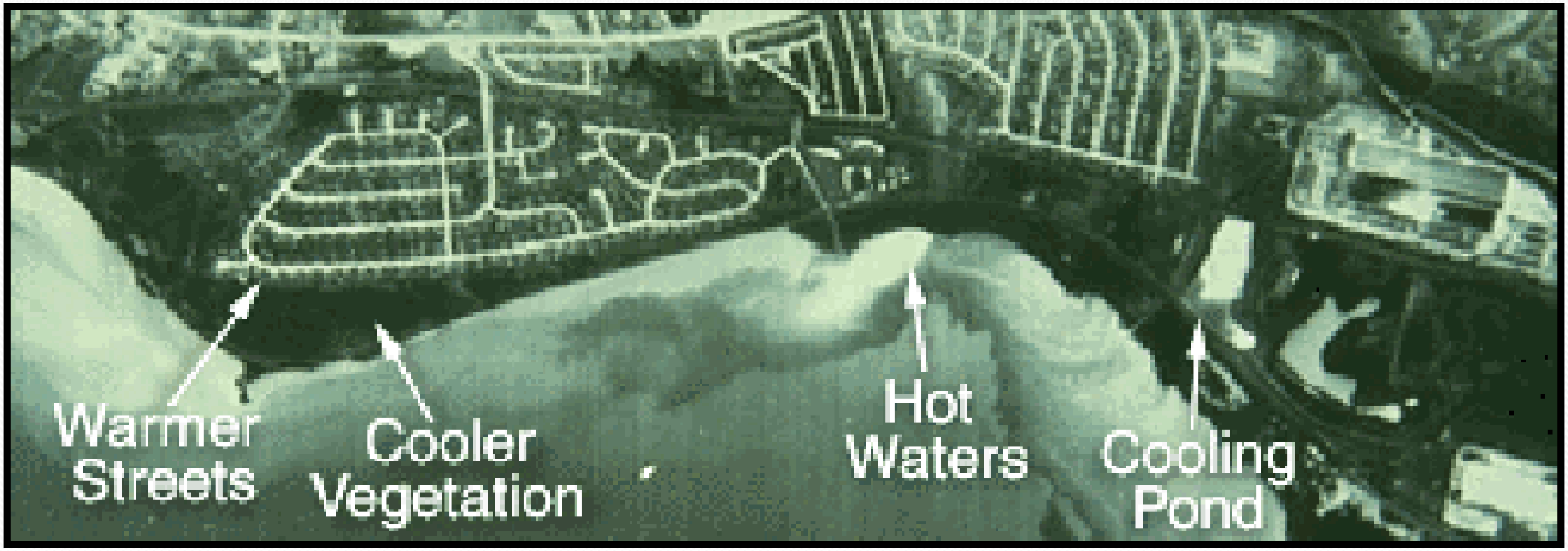
- What do you believe the image would look like if you used a **BLUE** only sensitive film?
- A **GREEN** only?
- A **RED** only?



Heat-Energy Transfer

- Thermal Infrared View
- Warmer Objects are Brighter

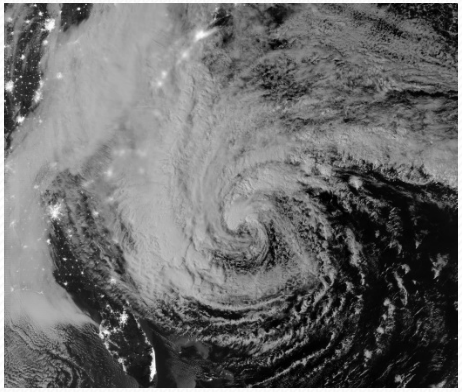




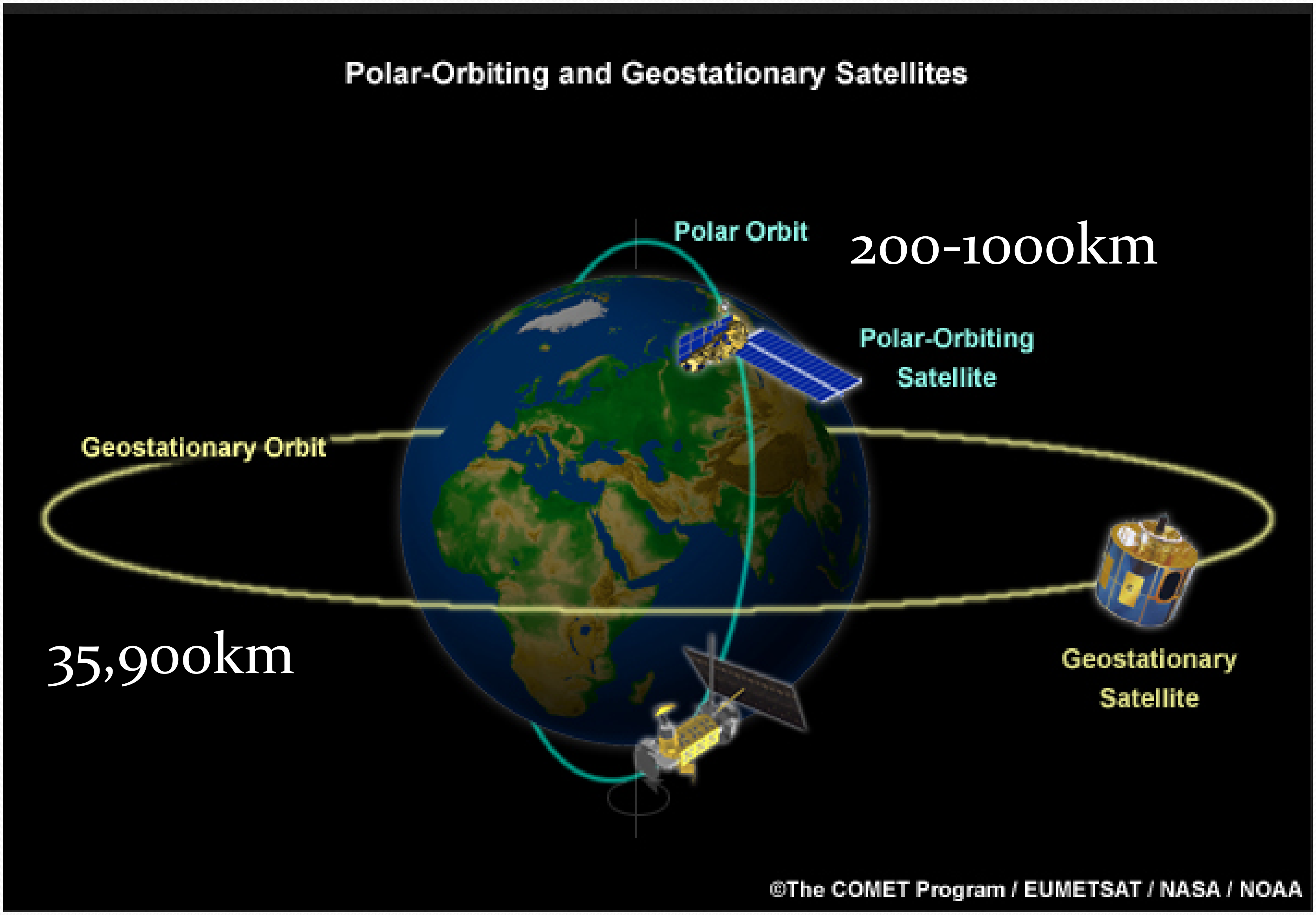
Example of Sampling Wavelengths

Band	Wavelength	Description	Characteristics and Notes
1	.45-.52	Visible Blue	Maximum water penetration; vegetation vs soil; deciduos vs. conifers
2	.52-.60	Visible Green	Plant vigor (reflectance peak for plants)
3	.63-.69	Visible Red	Chloropyll absorption; vegetation discrimination
4	.76-.90	Near Infrared	Reflected IR; biomass and shoreline mapping
5	1.55-1.75	Middle Infrared	Reflected IR; moisture content of soil and vegetation; cloud/smoke penetration; vegetation mapping
7	2.08-2.35	Middle Infrared	Reflected IR; mineral mapping
6	10.4-12.5	Thermal Infrared	Thermal IR; soil moisture; thermal mapping


Alaska, Near-IR

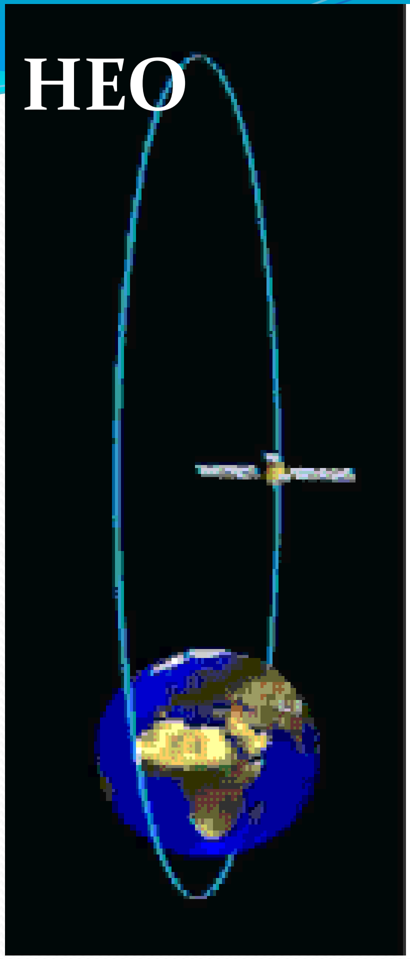

Superstorm Sandy

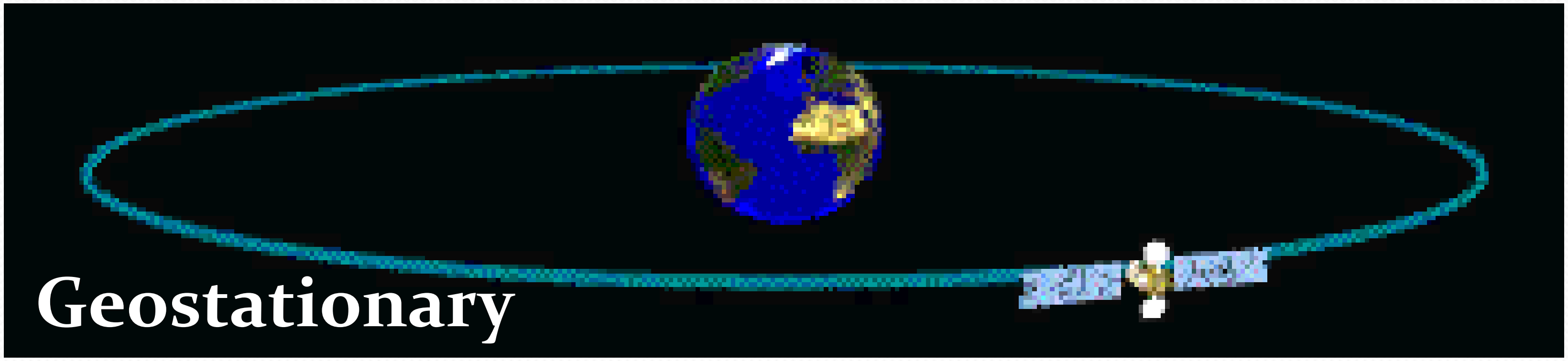
Data Acquisition – Satellite Orbits



Satellite Orbit Determines

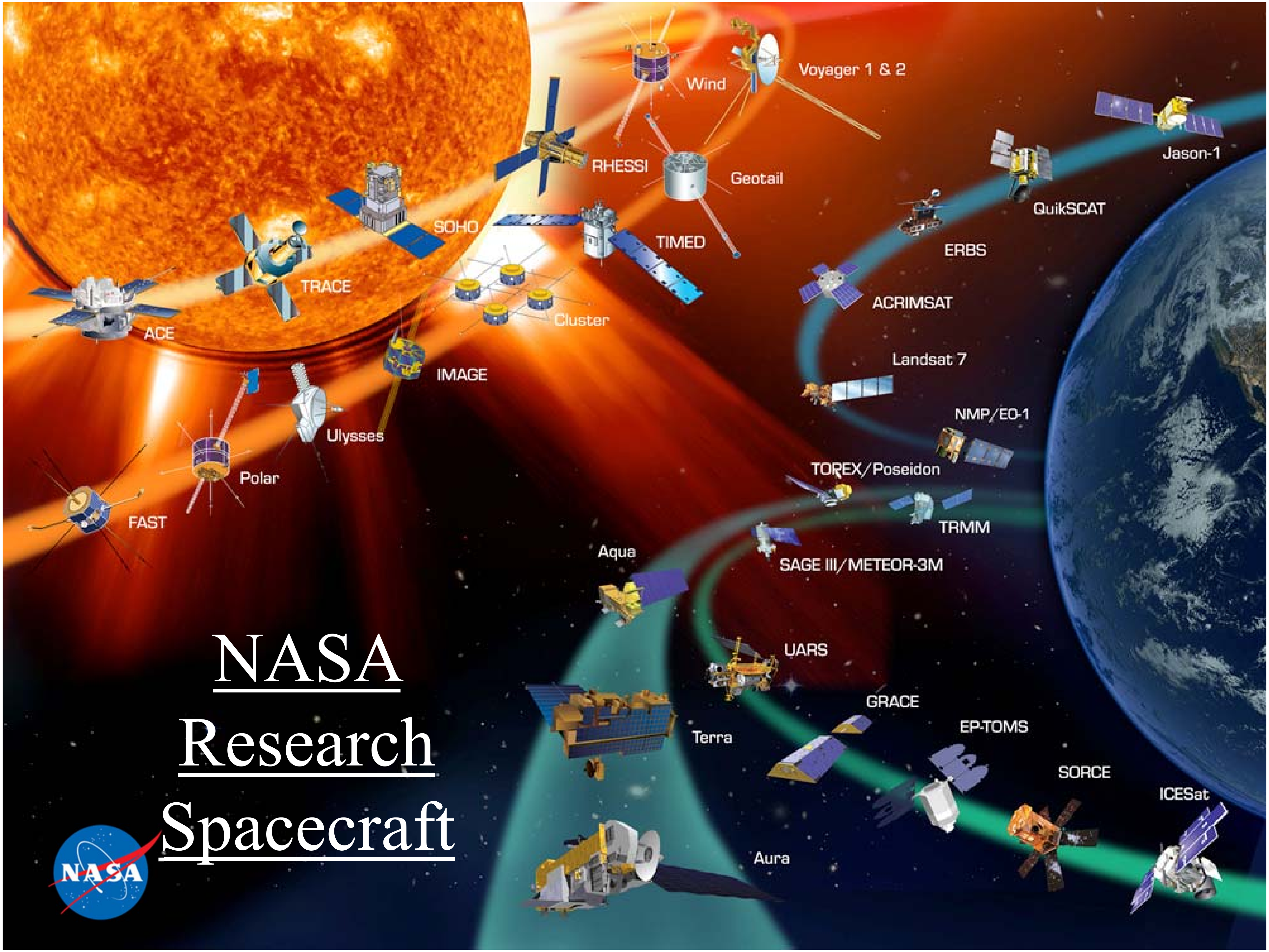
- What part of the globe can be viewed
- The size of the field of view.
- How often the satellite can revisit the same place
- The length of time the satellite is on the sunny side of the planet





Some (not all) Data Access Sites

- GLOVIS (USGS Global Visualisation Viewer)
  - http://glovis.usgs.gov/
  - All global Landsat data now available – hugely useful resource
  - Plus ASTER, MODIS (moderate/coarse resolution but global coverage)
- NASA Distributed Active Archive Centres – huge range of free NASA data:
  - http://nasadaacs.eos.nasa.gov/about.html (overview)
  - https://lpdaac.usgs.gov/ (land)
  - http://podaac.jpl.nasa.gov/ (oceans)
  - http://www.nsidc.org/daac/ (snow and ice)
- UK/NERC
  - NERC National Centre for Earth Observation (NCEO)
  - http://www.nceo.ac.uk
  - Earth Observation Data Centre
  - http://www.neodc.rl.ac.uk/ (UK/European focused, with ESA data, airborne, various campaign surveys etc. – may require registration)


NASA
Research
Spacecraft
Voyager 1 & 2
Wind
Jason-1
RHESSI
Geotail
QuikSCAT
SOHO
TIMED
ERBS
TRACE
ACRIMSAT
ACE
Cluster
Landsat 7
IMAGE
NMP/EO-1
Ulysses
TOPEX/Poseidon
Polar
FAST
TRMM
Aqua
SAGE III/METEOR-3M
UARS
GRACE
Terra
EP-TOMS
SORCE
ICESat
Aura
NASA