OVERVIEW OF REMOTE SENSING

(David Sandwell, Copyright, 2007)

Definition

Remote sensing is an incredibly broad subject ranging from photographic imaging to nuclear magnetic resonance imaging to seismic tomography to multibeam sonars to synthetic aperture radars . . . In this class we'll limit the scope to:

- satellite (or aircraft) remote sensing of the Earth (mostly);
- information carried by electromagnetic waves; and
- no discussion of atmospheric sounding.

When you look through the textbook by Rees [2001], you will not find detailed discussion of applications of remote sensing. Instead the focus is on the physical principles of remote sensing. Studying all the applications in a 10-week course would be impossible. Moreover, the methods and applications change frequently so details learned today will be obsolete tomorrow. It is more important to learn the fundamental principles and learn the details later as needed. For the graduate-level course, the students select a scientific problem that can be addressed using one or more remote sensing tools. Then they can become experts on the particular application with scientific guidance from a researcher at SIO. Over the years I have collected perhaps 100 term papers from SIO graduate students. The topics are **very** diverse. For example a student prepared a term paper on the correlation of offshore bird census information (from ship observations) with ocean surface temperature measured by satellite. My area of expertise uses the tools satellite geodesy to measure the properties of the solid earth. This includes measuring micro variations in the pull of gravity over the oceans using radar altimetry and measuring crustal deformation using synthetic aperture radar interferometry. Each year new remote sensing instrumentation is being developed. This technology development is driven by scientific questions and practical needs.

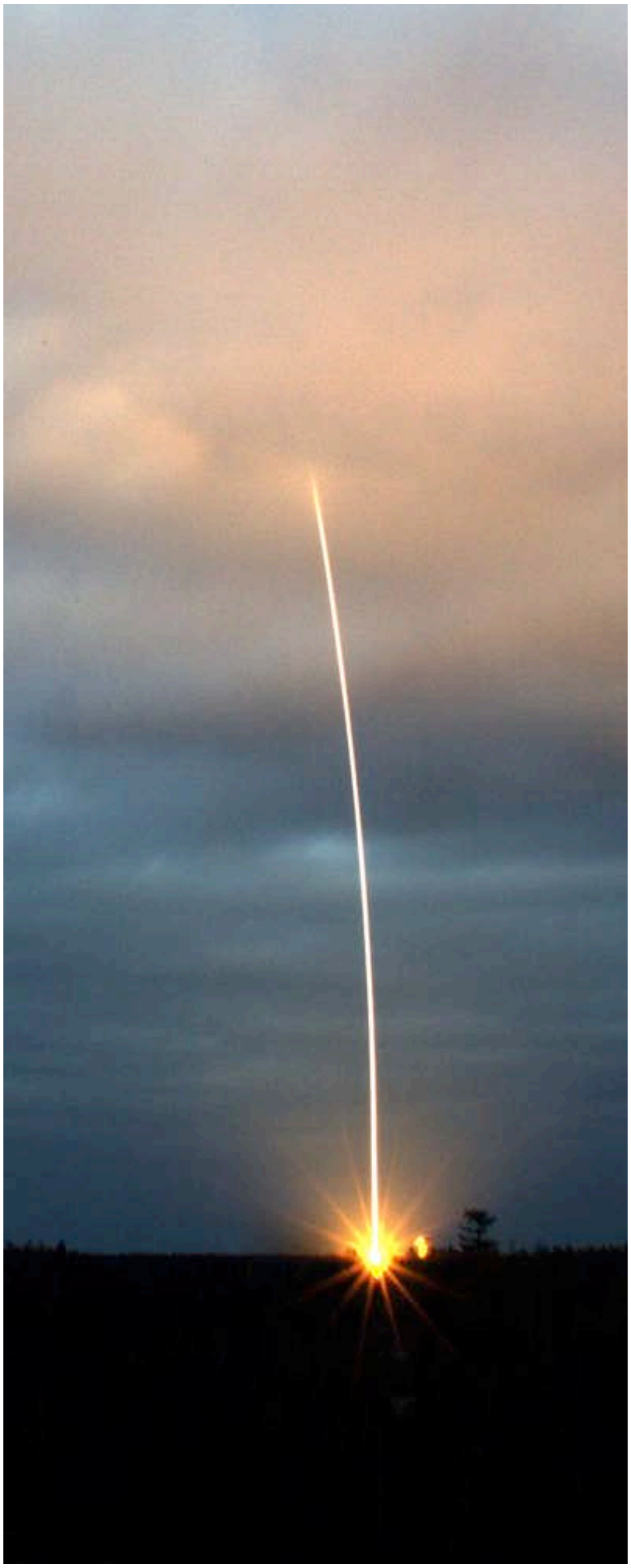
I hope that you can get the following out of this course:

- a brief review of some basic physics;
- a broad understanding of the methods and limitations of remote sensing systems;
- an introduction to image processing and display methods;
- an overview of a few of the systems being deployed today; and
- finally, throught the term project (graduate students only), I hope you can obtain a detailed understanding of a particular remote sensing system and how it addresses a scientific issue.

Most of the information gathered by remote sensing satellites could be obtained by other means. For example if one wanted to measure sea surface temperature (SST) across the Gulf Stream between New York and Bermuda, one could make the measurement from a ship or aircraft that commonly traverse that route. However, if one wanted to measure SST across the Antatctic Circumpolar Current then a satellite is the more appropriate platform. The main advantages of satellite remote sensing are:

- global data set of uniform quality;
- rapid data acquisition after the satellite is designed, built, and launched;
- no need to obtain permission from other countries;
- can revisit a site on a regular basis for a long period of time; and
- spacacraft provide very stable platforms.

Of course the main disadvantages are the high cost of a satellite system, the many years it takes to develop and launch the system, and the possibility of a launch failure or system failure.



CryoSat Mission lost due to launch failure

8 October 2005

ESA PR 44-2005. Today at 21.00 CEST Mr Yuri Bakhvalov, First Deputy Director General of the Khrunichev Space Centre on behalf of the Russian State Commission officially confirmed that the launch of CryoSat ended in a failure due to an anomaly in the launch sequence and expressed his regret to ESA and all partners involved.

Preliminary analysis of the telemetry data indicates that the first stage performed nominally. The second stage performed nominally until main engine cut-off was to occur. Due to a missing command from the onboard flight control system the main engine continued to operate until depletion of the remaining fuel.
As a consequence, the separation of the second stage from upper stage did not occur. Thus, the combined stack of the two stages and the CryoSat satellite fell into the nominal drop zone north of Greenland close to the North Pole into high seas with no consequences to populated areas.

Space is a risky business, it always has been, it doesn't always go perfectly Prof Duncan Wingham, Cryosat chief scientist

"It is a very sad event for many scientists around Europe and also for the teams involved in industry which built the satellite," he said.

http://www.esa.int/esaCP/SEMR3Q5Y3EE_index_0.html

Applications of Remote Sensing

Meterology - profiling of atmospheric temperature, pressure, water vapor, and wind velocity.

Oceanography - measuring sea surface temperature, mapping ocean currents, and wave energy spectra.

Glaciology - measuring ice cap volumes, ice stream velocity, and sea ice distribution.

Geology - geomorphology, identification of rock type, mapping faults and structure.

Geodesy - measuring the figure of the earth and its gravity field.

Topography and cartography - improving digital elevation models

Agriculture, forestry, and botany - monitoring the biomass of land vegetation, monitoring the health of crops, mapping soil moisture, forecasting crop yields.

Hydrology - assessing water resources from snow, rainfall and underground aquifers.

Disaster warning and assessment - monitoring of floods and landslides, monitoring volcanic activity, assessing damage zones from natural disasters.

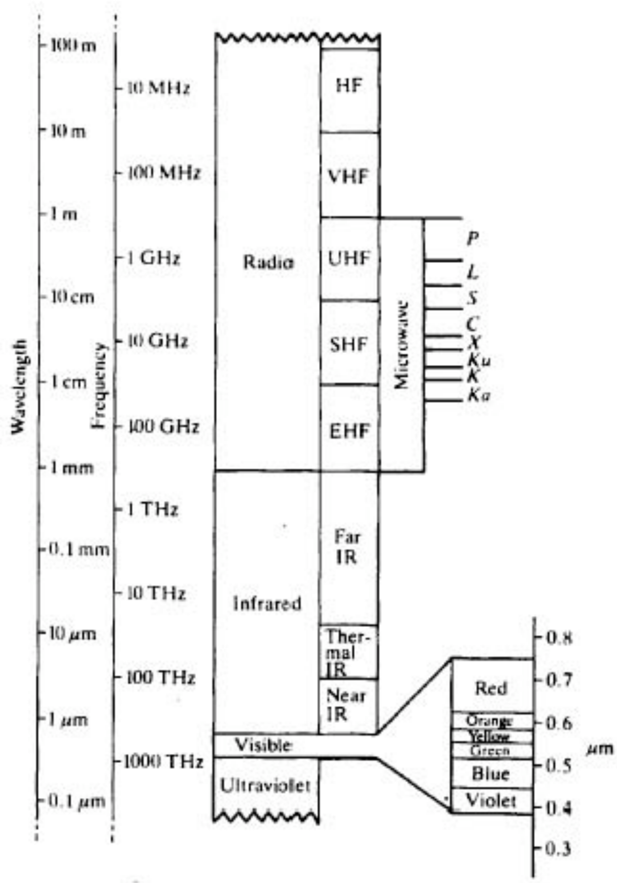
Planning applications - mapping ecological zones, monitoring deforestation, monitoring urban land use.

Oil and mineral exploration - locating natural oil seeps and slicks, mapping geological structures, monitoring oil field subsidence.

Military - developing precise maps for planning, monitoring military infrastructure, monitoring ship and troop movements . . . (This is where most of the US funding for remote sensing goes.)

Electomagnetic Spectrum

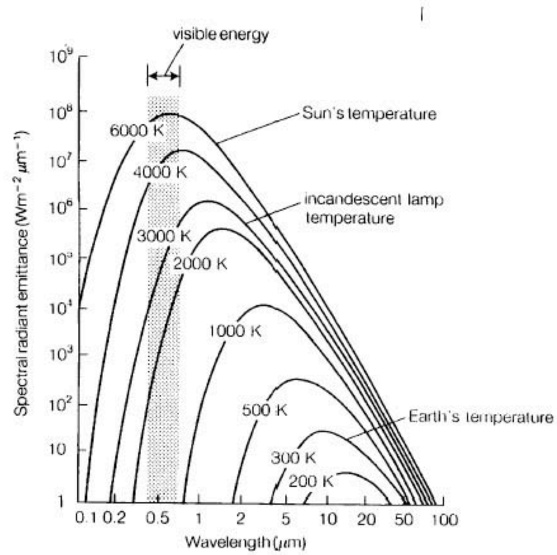
Before starting the course it is useful to review the relevant part of the electromagnetic spectrum. This figure from Rees [2001] shows a wavelength range from ultraviolet through the visible spectrum through infrared to microwave and longer radio waves. Of course, the visible spectrum is subdivided by color (hue). Next lecture we'll discuss how our eyes and brain process visible light. The other major subdivision occurs in the microwave part of this spectrum. As we'll see next, this is a very important part of the spectrum for remote sensing and the electrical engineers have provide cryptic labels that we should all learn (Ka, K, Ku, X, C, S, L, and P).



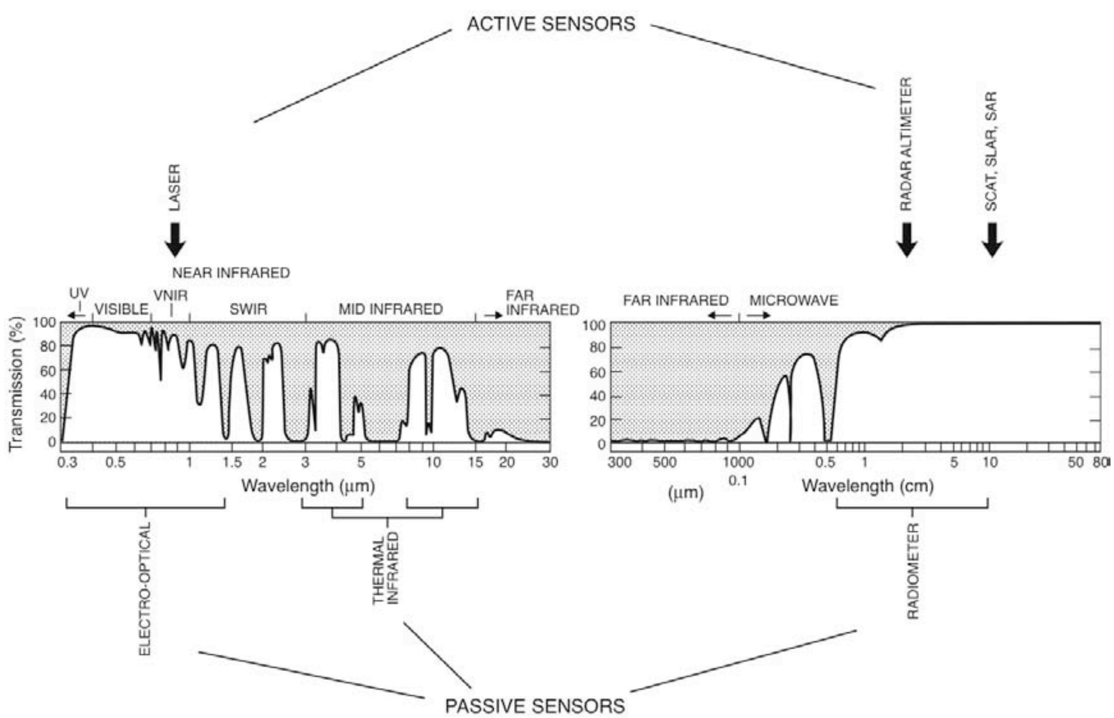
Constraints

There are three practical constraints on satellite remote sensing of the Earth.

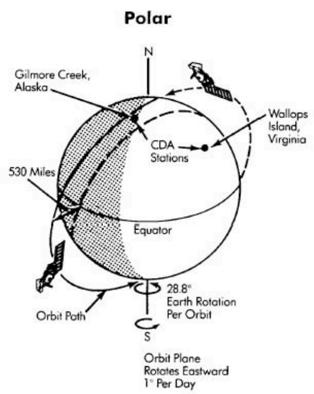
1) There needs to be a source of radiation. Passive remote sensing systems rely thermal emissions from the Sun (mostly visible) which reflect off the surface of the Earth as well as direct thermal emissions from the Earth (thermal IR). Active systems can operate in the visible (laser), IR (laser) and microwave (radar).



2) The EM waves must be able to penetrate through the ionosphere and atmosphere. For the Earth there are three main windows in the visible, thermal infrared (IR) and the microwave region.



3) There needs to be a platform in space to collect the EM signals, digitize them, and transmit the data back to Earth. The satellite must be in orbit around the earth so the inward force of gravity must be equal to the outward centrifugal force. A variety of orbits are possible as will be discussed in the next lecture. One can tune the orbit and platform characteristics to vary altitude and speed, revist time, phase of the orbit plane with respect to solar illumination or lunar/solar tides, and platform orientation (yaw, pitch and roll).



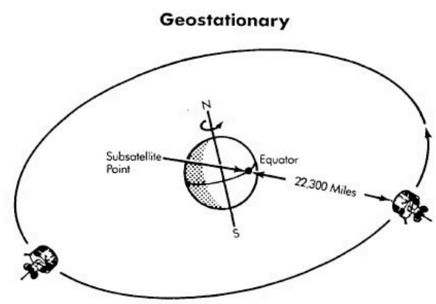


Figure 4. Opposite and above: polar and geostationary orbits for NOAA satellites. Note that the polar orbit rotates one degree per day; this is to make it synchronous with the sun. The geostationary satellite stays continuously above one spot on Earth.

HOW REMOTE SENSING WORKS

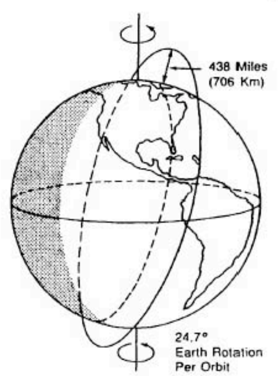


Figure 5. Details of the sun-synchronous polar orbit used by the Landsat satellites.

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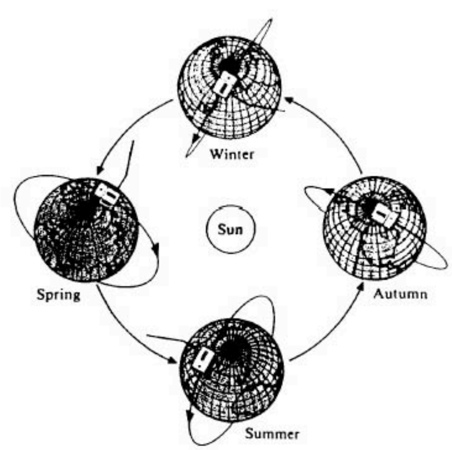

Figure 6. A sun-synchronous orbit. The plane of the orbit is always the same in relation to the sun, regardless of the season of the year.

References

Rees, W. G., *Physical Principles of Remote Sensing, Second Edition*, Cambridge University Press, Cambridge, UK, 343 pp., 2001.

Baker, D. J., *Planet Earth: The View From Space*, Harvard University Press, Cambridge, Massachusetts, 191 pp., 1990.