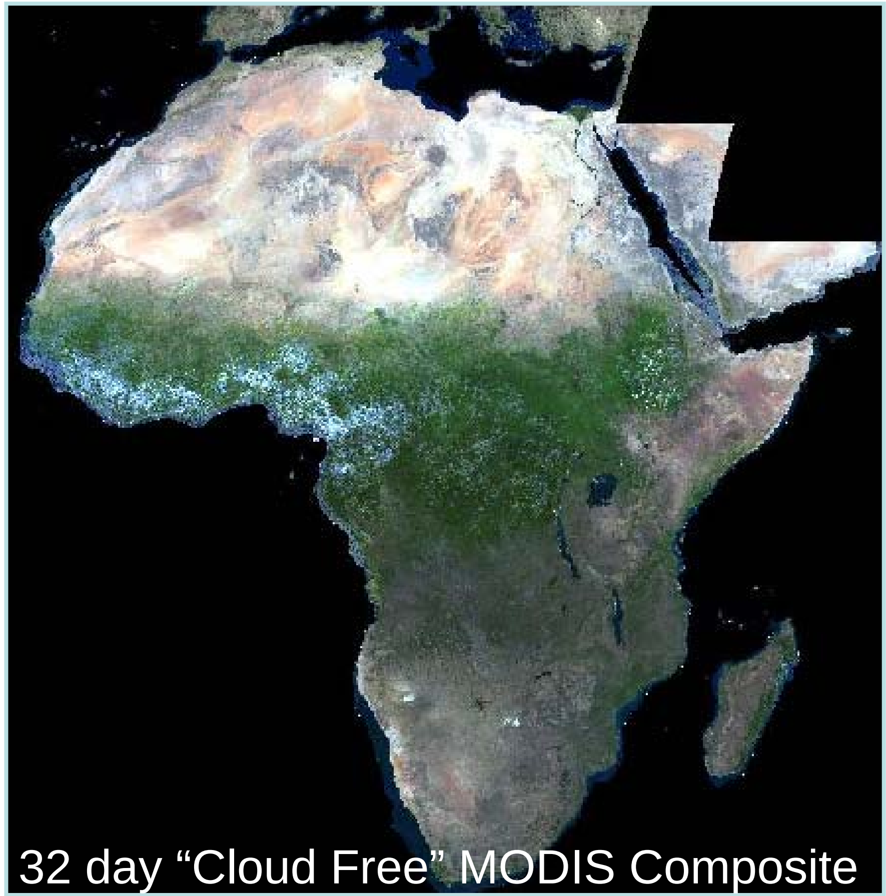
Remote Sensing Lecture 1.
Introduction to Remote Sensing



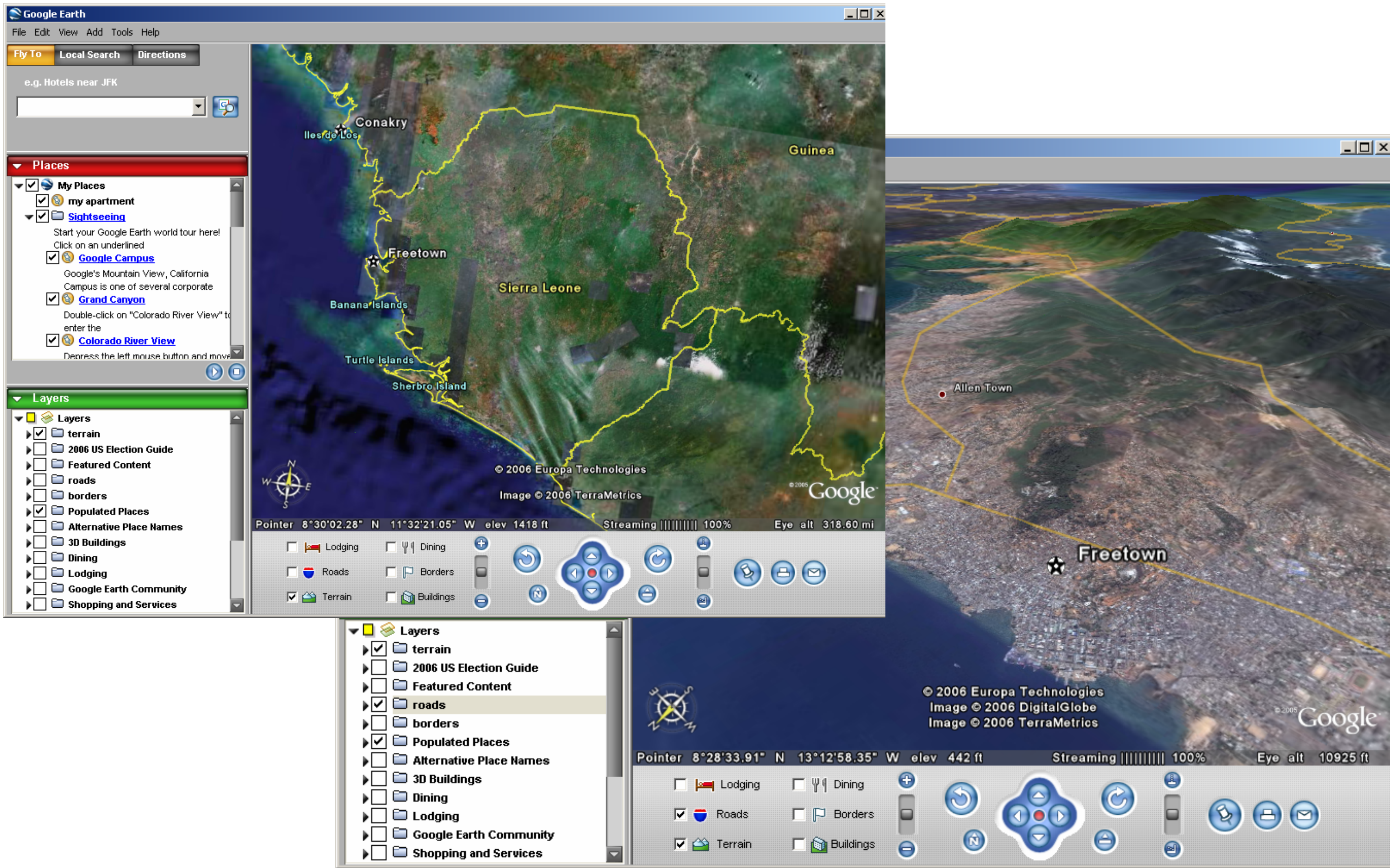
Data Conversion/Entry (GIS, Databases)
November 6 – 10, 2006
Freetown, Sierra Leone

Lecture Outline

- Definition of Remote Sensing
- Additional sources of Remote Sensing Learning Materials/labs
- Passive verses Active Sensors
- Satellite Orbits
- Sensors
  - Landsat MSS
  - Landsat TM/ETM
  - Terra/Aqua MODIS
- The Electromagnetic Spectrum

GOOGLE EARTH

http://earth.google.com/



***A* Definition of Remote Sensing**

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

Source:

Lillesand, T. M. and R. W. Kiefer, 1994. "***Remote Sensin and Image Interpretation***", John Wiley & Sons.

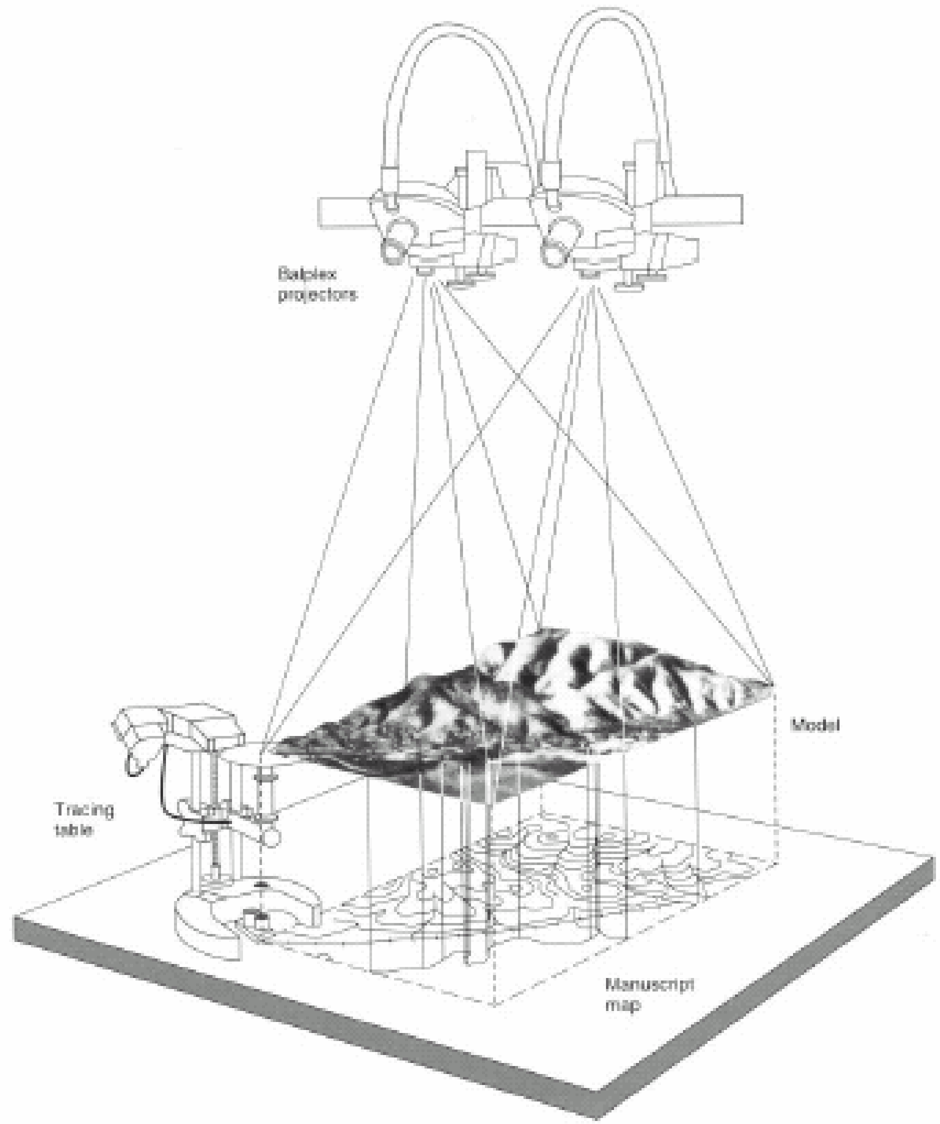
Is your camera a remote sensor?

Introductory Remote Sensing Online Courses

Remote Sensing Tutorials
http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/tutorials_e.html
(It is recommended you download this course as a reference)

The Remote Sensing Tutorial
http://rst.gsfc.nasa.gov/

Photogrammetry: 2-D → 3-D

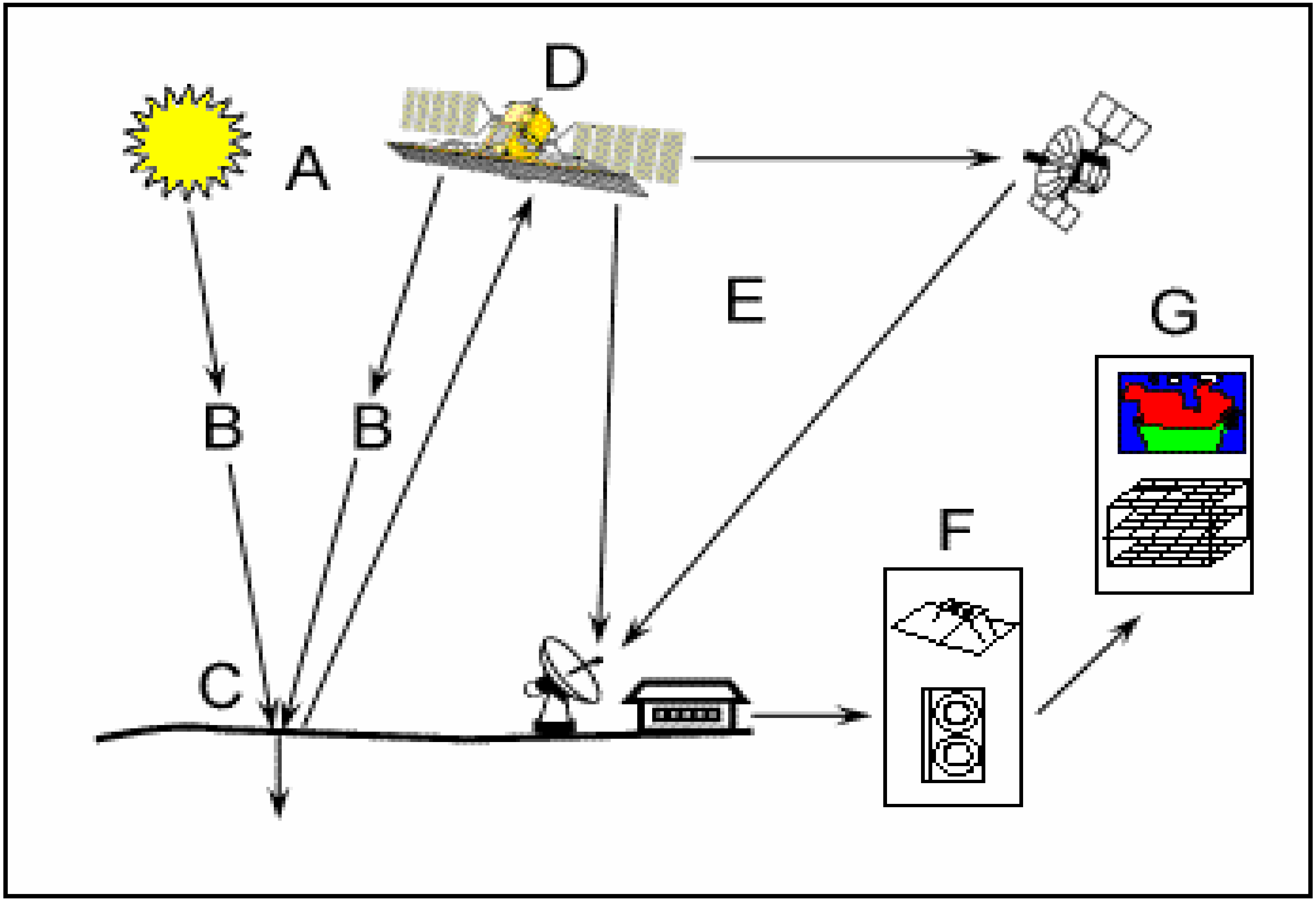


Face Recognition Software Utilizing 3-D Photogrammetry Methods

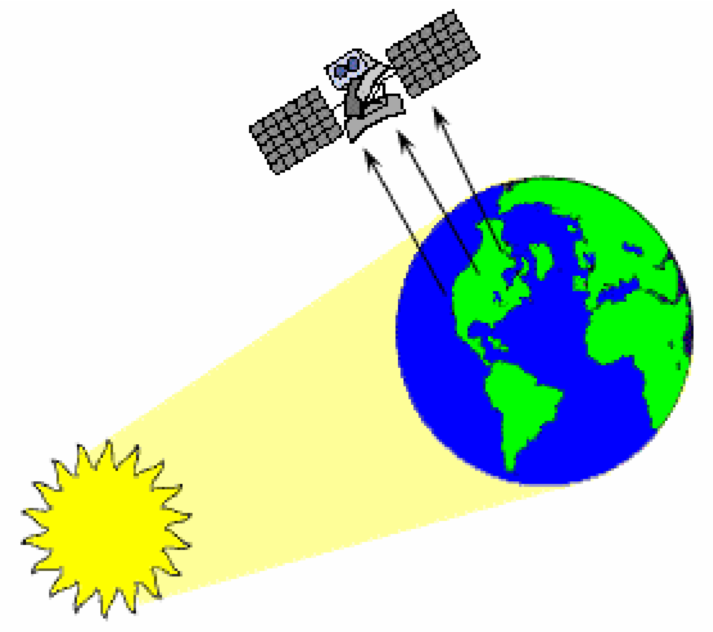
Left Image

Right Image

Remote Sensing Satellite Data Capture Process



PASSIVE versus ACTIVE SENSORS



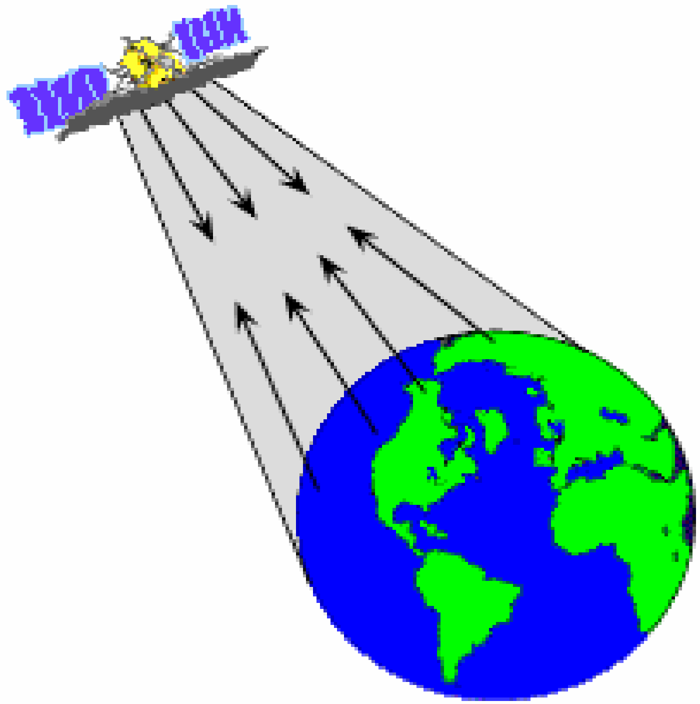
- **Passive sensors** can only be used to detect energy when the naturally occurring energy is available.

- For all **reflected energy**, this can only take place during the time when the **sun** is illuminating the Earth.

- Energy that is naturally **emitted** can be detected day or night.

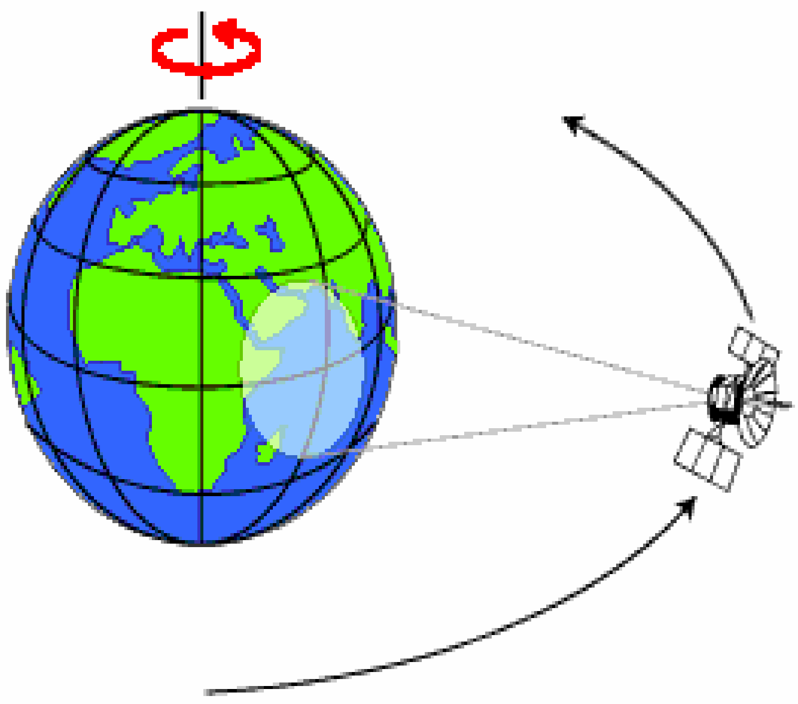
http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

PASSIVE versus ACTIVE SENSORS



- **Active Sensors** provide **their own energy source for illumination**. The sensor emits radiation which is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.
- Advantages for active sensors include the ability to obtain measurements anytime, regardless of the time of day or season.

GEOSTATIONARY ORBITS



Satellites at **very high altitudes** (approximately 36,000 km), which view the same portion of the Earth's surface at all times have **geostationary orbits**.

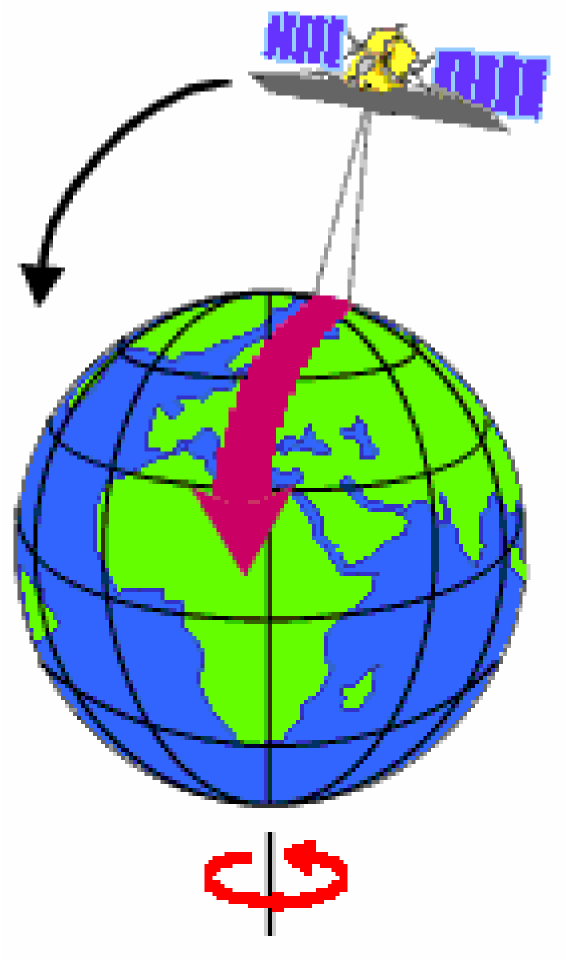
Geostationary satellites revolve at speeds which **match the rotation of the Earth** so they seem **stationary**, relative to the Earth's surface.

This allows the satellites to observe and collect information **continuously over specific areas**.

Weather and **communications satellites** commonly have these types of orbits.

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

NEAR-POLAR ORBITS

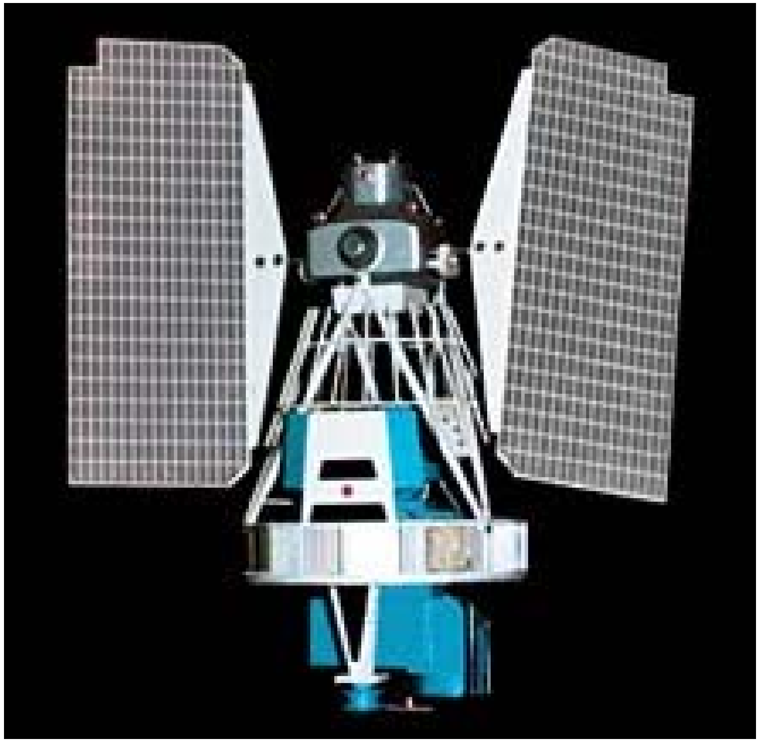


Many remote sensing platforms are designed to follow an orbit which, in conjunction with the Earth's rotation, allows them to cover most of the Earth's surface over a certain period of time.

These are **near-polar orbits**, so named for the inclination of the orbit relative to a line running between the North and South poles.

EARTH OBSERVATION SATELLITES

Landsat



The first satellite designed specifically to monitor the Earth's surface, **Landsat-1**, was launched by NASA in **1972**. Initially referred to as **ERTS-1**, (Earth Resources Technology Satellite), Landsat was designed as an ***experiment!*** to test the feasibility of collecting multi-spectral Earth observation data from an unmanned satellite platform. Since that time, this highly successful program has collected an abundance of data from around the world from several Landsat satellites.

Originally managed by **NASA**, responsibility for the Landsat program was transferred to **NOAA in 1983**. In 1985, the program became commercialized, providing data to civilian and application users.

Landsat Program Summary

System	Launch	End of Service	Imaging systems	Resolution (m)	Altitude (Km)
Landsat 1	7/23/72	1/6/78	RBV, MSS	80, 80	918
Landsat 2	1/22/75	2/25/82	RBV, MSS	80, 80	918
Landsat 3	3/5/78	3/31/83	RBV, MSS	30, 80	918
Landsat 4	7/16/82		MSS, TM	80, 30	705
Landsat 5	3/1/84		MSS, TM	80, 30	705
Landsat 6	10/5/93	10/5/93	ETM	15, 30	705
Landsat 7	4/15/99		ETM	15, 30	705

CHARACTERISTICS OF LANDSAT SENSORS

Instrument	Band	Spectral Range (μm)	IFOV (m)	Dynamic Range (bits)
MSS	4	0.5 - 0.6 (green)	79 x 79	7
	5	0.6 - 0.7 (red)	79 x 79	7
	6	0.7 - 0.8 (near IR)	79 x 79	7
	7	0.8 - 1.1 (near IR)	79 x 79	7
TM	1	0.45 - 0.52 (blue)	30 x 30	8
	2	0.52 - 0.60 (green)	30 x 30	8
	3	0.63 - 0.69 (red)	30 x 30	8
	4	0.76 - 0.90 (near IR)	30 x 30	8
	5	1.55 - 1.75 (mid IR)	30 x 30	8
	7	2.08 - 2.35 (mid IR)	30 x 30	8
	6	10.4 - 12.5 (thermal)	120 x 120	8
ETM*	8	0.52 to 0.90	15	8
	6	10.4 - 12.5 (thermal)	60 x 60	8

* ETM (Enhanced TM is similar to TM but with an increased resolution on the thermal Band 6 and the inclusion of a Panchromatic Band 8 at 15 metres.

Landsat Thematic Mapper (TM) Spectral bands

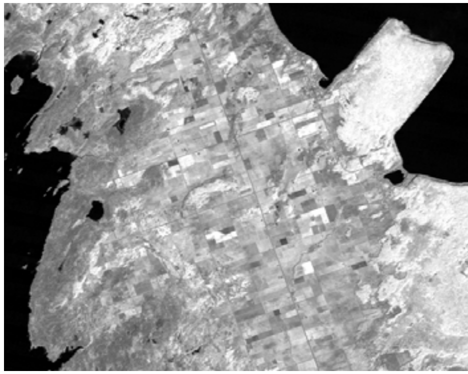
Band	Wavelength (μm)	General Characteristics
1	0.45 - 0.52	**Blue-green**: penetrates water. Useful for bathymetric mapping in shallow water, for soil-vegetation differentiation and for distinguishing forest types.
2	0.52 - 0.60	**Green**: matches green reflectance peak of vegetation. Useful for assessing plant health.
3	0.63 - 0.69	**Red**: matches a chlorophyll absorption band that is important for discriminating vegetation types.
4	0.76 - 0.90	**Reflected infrared**: ideal for detecting reflectance peaks of healthy green vegetation and for mapping water bodies and shorelines. Useful for determining vegetation types, vigor, biomass content and soil moisture.
5	1.55 - 1.75	**Reflected infrared**: indicates moisture content of soil and vegetation. Penetrates thin clouds. Useful for discriminating between rock and mineral types.
6	10.40 - 12.50	**Thermal infrared**: useful for thermal mapping, soil moisture discrimination vegetation stress analysis.
7	2.08 - 2.35	**Reflected infrared**: useful for discrimination of rock and mineral types. Sensitive to vegetation moisture content.

THE SEVEN BANDS OF LANDSAT THEMATIC MAPPER

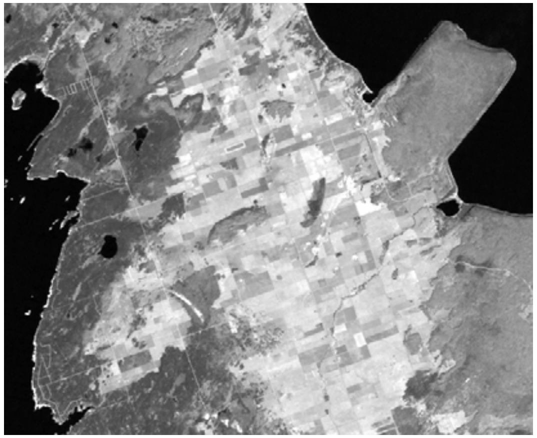
BAND 1 - blue
0.45 - 0.52 μm

BAND 2 - green
0.52 - 0.60 μm

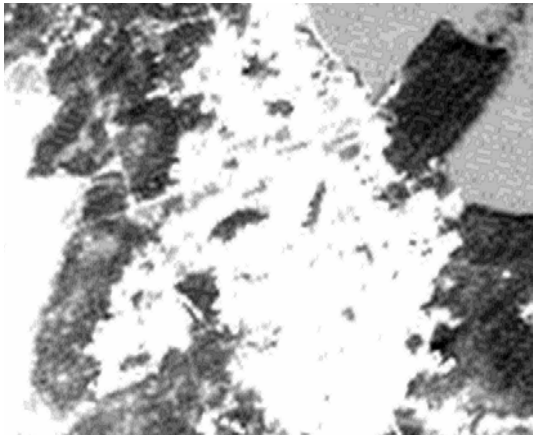
BAND3 - red
0.63 - 0.69 μm



BAND4
near infrared
0.76 - 0.90 μm



BAND 5
short-wave infrared
1.55 - 1.76 μm



BAND 6 (res: 120 m)
thermal infrared
10.5 - 11.5 μm

BAND7
short-wave infrared
2.08 - 2.35 μm

MODIS - Moderate Resolution Imaging Spectroradiometer

Continuing from NOAA’s AVHRR Sensors

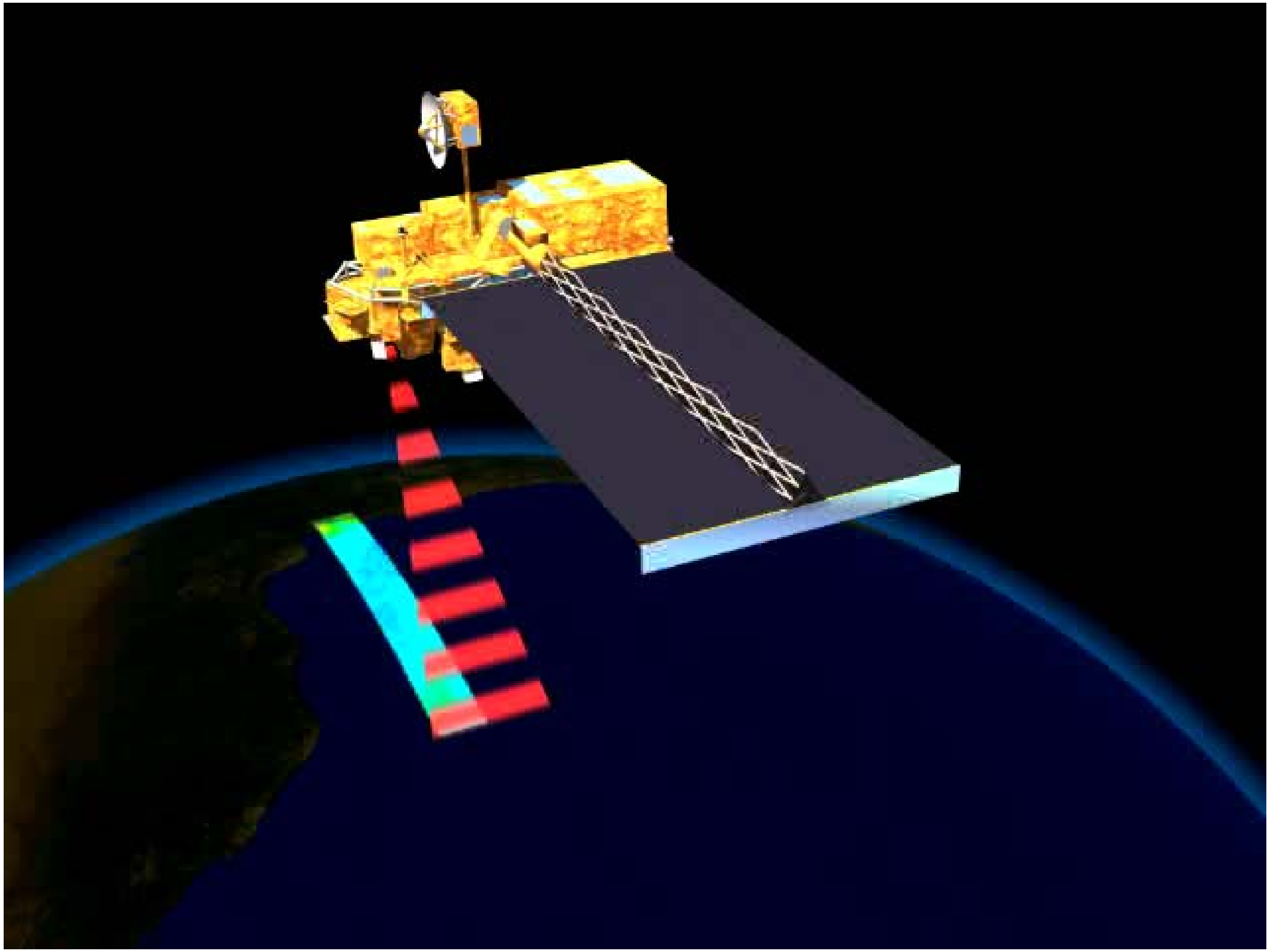
- MODIS is a key instrument aboard the Terra (EOS AM) (Launched Feb. 2000) and Aqua (EOS PM) (Launched May 2002) satellites.
- Terra's orbit around the Earth is timed so that it passes from north to south across the equator in the morning.
- Aqua’s orbit around the Earth is timed so that it passes from south to north over the equator in the afternoon.

MODIS - Moderate Resolution Imaging Spectroradiometer

Continuing from NOAA's AVHRR Sensors

- Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 to 2 days.
- MODIS is acquiring data in 36 spectral bands, or groups of wavelengths.
- These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere.
- MODIS is playing a vital role in the development of validated, global, interactive earth system models.

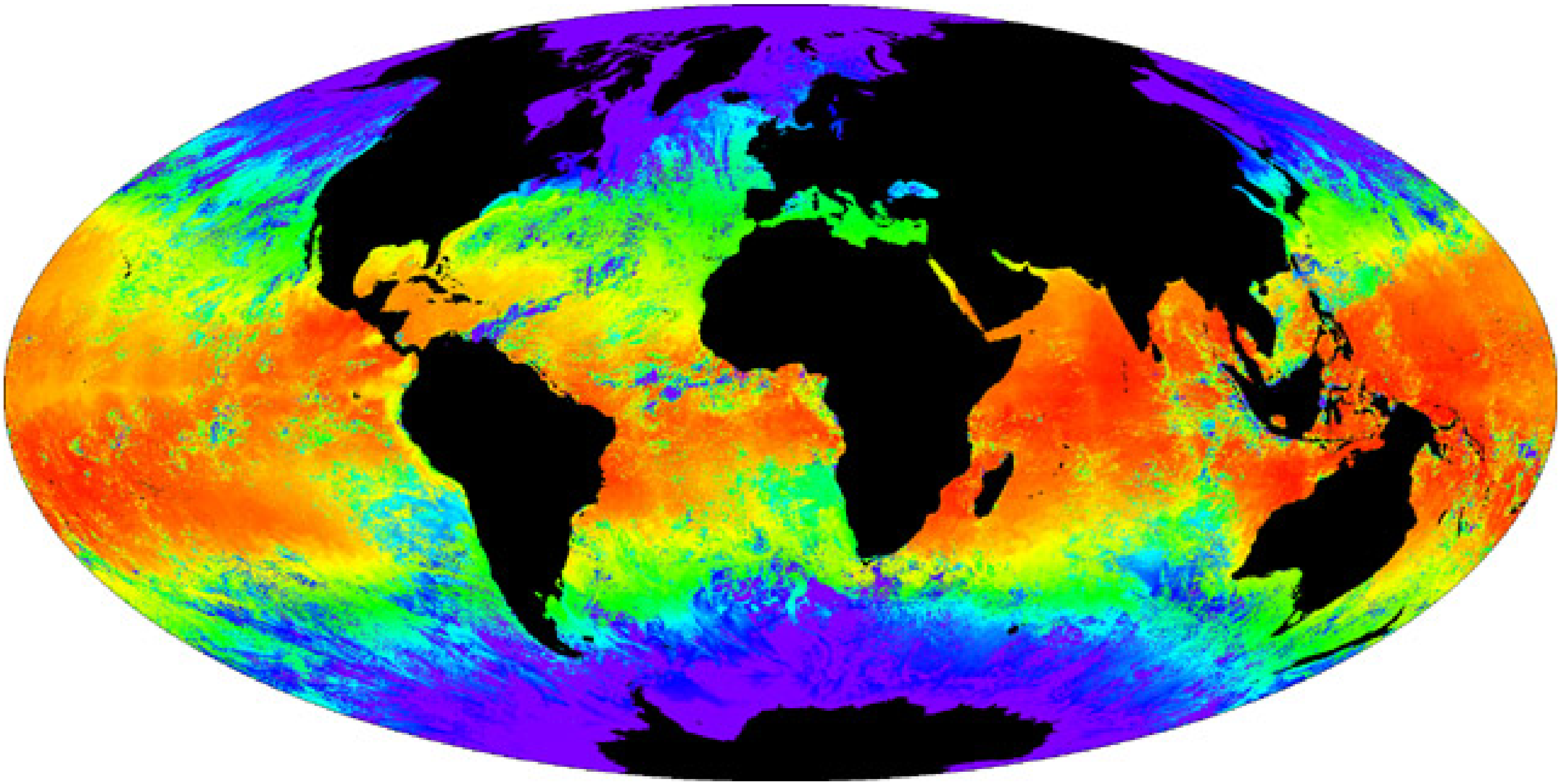
The MODIS Scanning Swath (2330 Kilometres)



A trick question: Is this MODIS on the Terra Satellite or Aqua Satellite?

Global Composite MODIS Imagery

Global Sea Surface Temperature – From MODIS



MODIS Technical 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)**
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**

The First 7 MODIS Bands
Note this suite is very similar to Landsat TM Bands

Band	Wavelength (nm)	Description
1	620-670	Red
2	841-876	Near-infrared
3	459-479	Blue
4	545-565	Green
5	1230-1250	Short wave infrared
6	1628-1652	Short wave infrared (similar to Landsat band 5)
7	2105-2155	Short wave infrared (similar to Landsat band 7)

Also be aware there are another 29 Bands available
http://modis.gsfc.nasa.gov/about/specifications.php

An example of how MODIS data are operationally Used for Global Environmental Applications

The Global Land Cover Mapping Facility

University of Maryland
Department of Geography

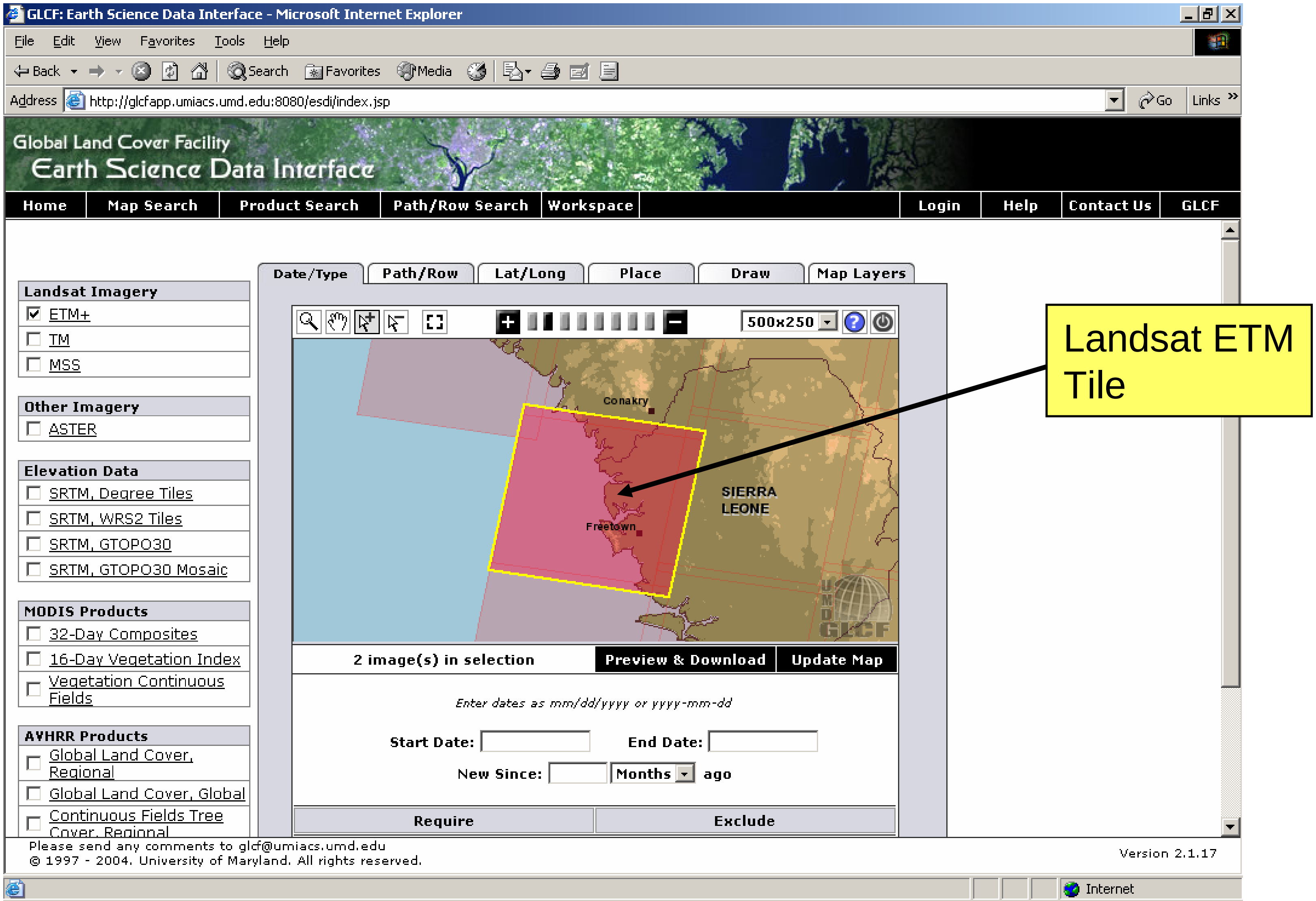
National Aeronautics and
Space Administration

The GLCF develops and distributes remotely sensed satellite data and products that explain land cover from the local to global scales. Primary data and products available at the GLCF are free to anyone via FTP. http://glcf.umiacs.umd.edu/aboutUs/

GLC Searchable, Downloadable Index of OrthoCorrected Imagery

Landsat (MSS, TM, ETM), ASTER, MODIS, AVHRR Land Cover Products

http://glcfapp.umiacs.umd.edu:8080/esdi/index.jsp

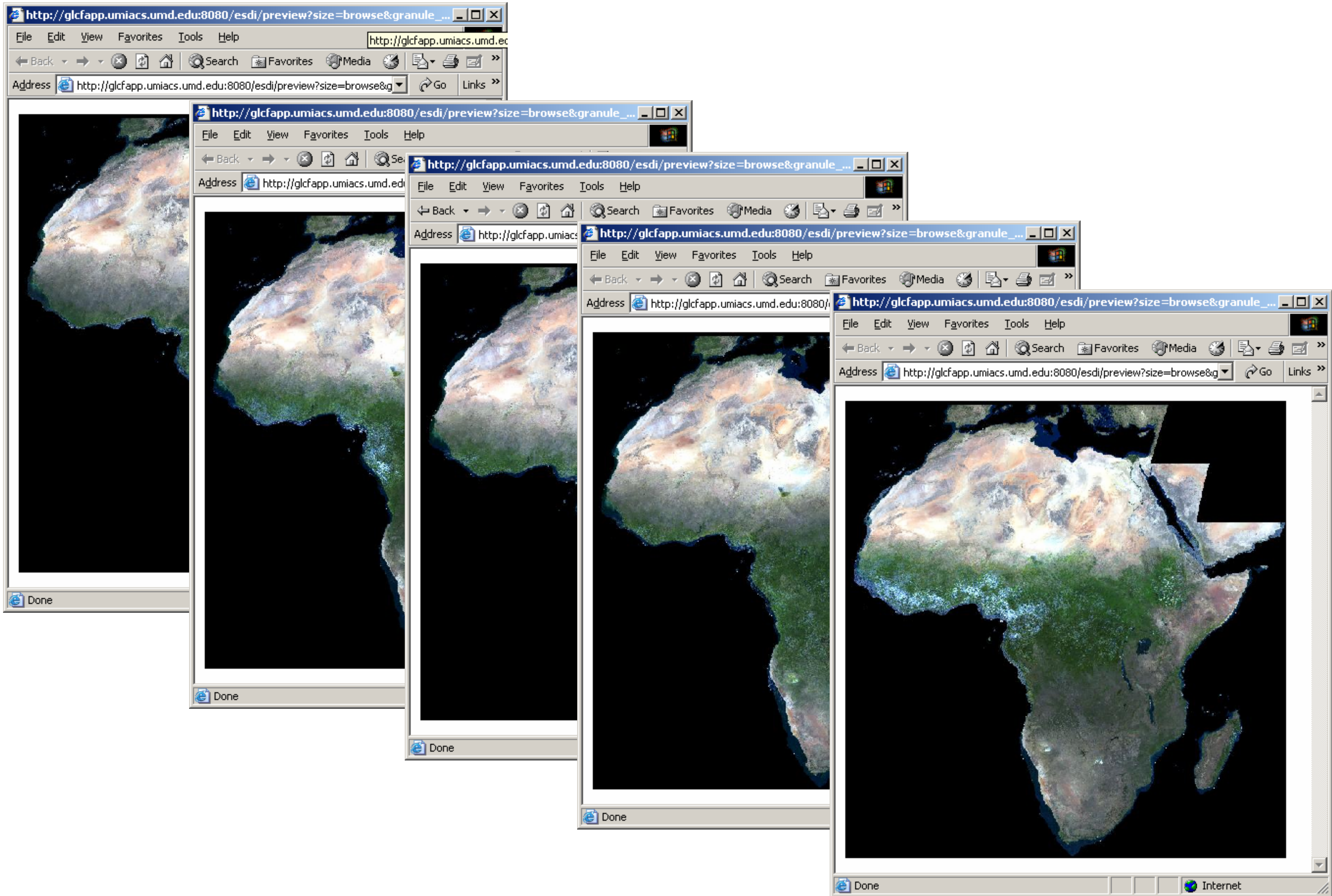


MODIS 500M 32-day Composites – Produced by GLC

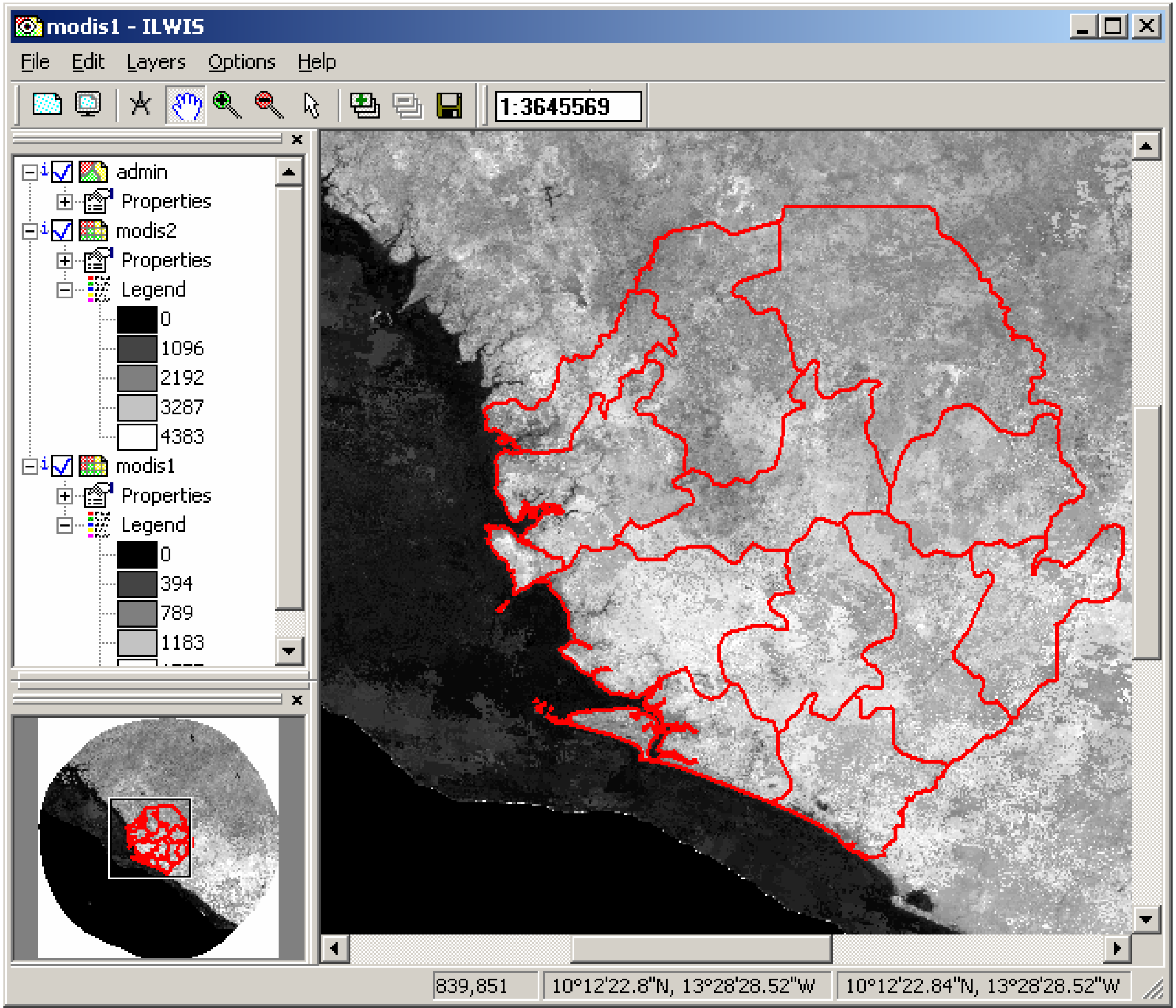
- 500m 32-day composites since Nov. 2000

Julian Day	Calendar Day
001-032	Jan.1-Feb.1
033-064	Feb.2-Mar.5
065-096	Mar.6-Apr.6
097-128	Apr.7-May 8
129-160	May 9-Jun.9
161-192	Jun.10-Jul.11
193-224	Jul.12-Aug.12
225-256	Aug.13-Sep.13
257-288	Sep.14-Oct.15
289-320	Oct.16-Nov.16
321-360	Nov.17-Dec.26
361-365	Dec.27-31

Time Series of 32 Day "Cloud-Free" MODIS Composite Images for Africa



Satellite Imagery from the Terra Satellite MODIS Instrument - For Sierra Leone



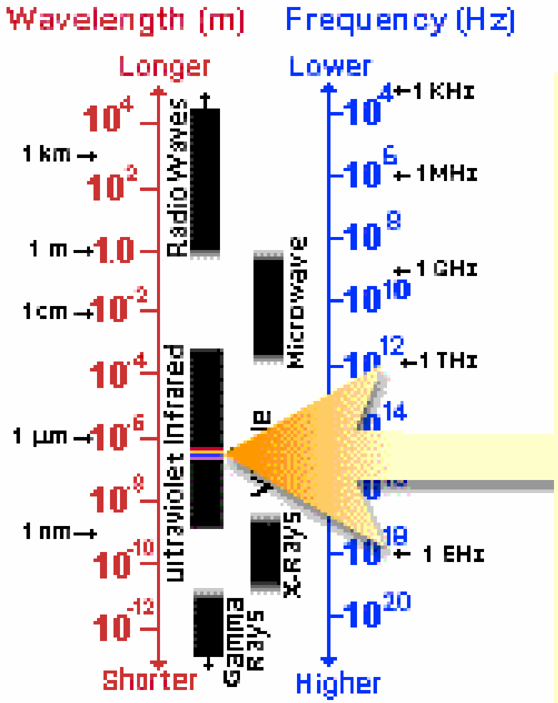
For more Information
Visit the Official MODIS Web Sites

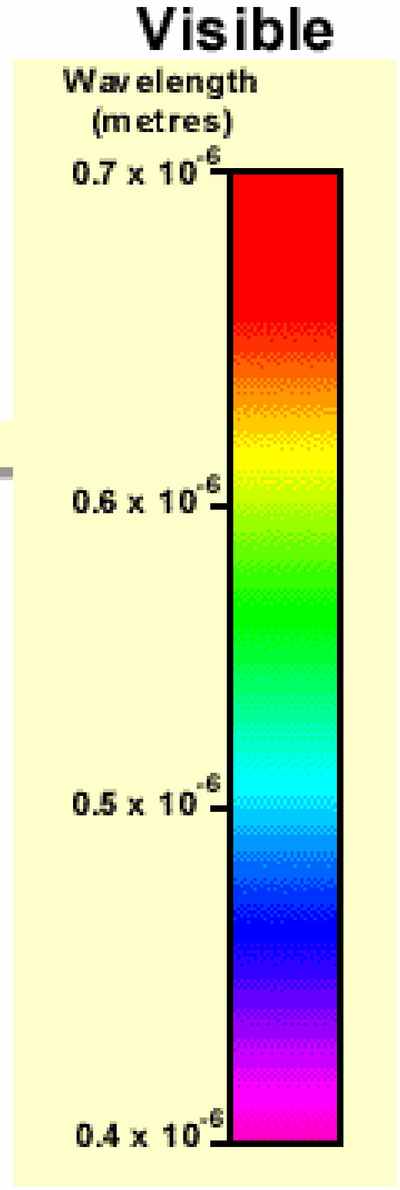
http://aqua.nasa.gov/

http://terra.nasa.gov/

http://modis.gsfc.nasa.gov/

The Electromagnetic Spectrum





RED

GREEN

BLUE

Violet: 0.4 - 0.446 µm
Blue: 0.446 - 0.500 µm
Green: 0.500 - 0.578 µm
Yellow: 0.578 - 0.592 µm
Orange: 0.592 - 0.620 µm
Red: 0.620 - 0.7 µm

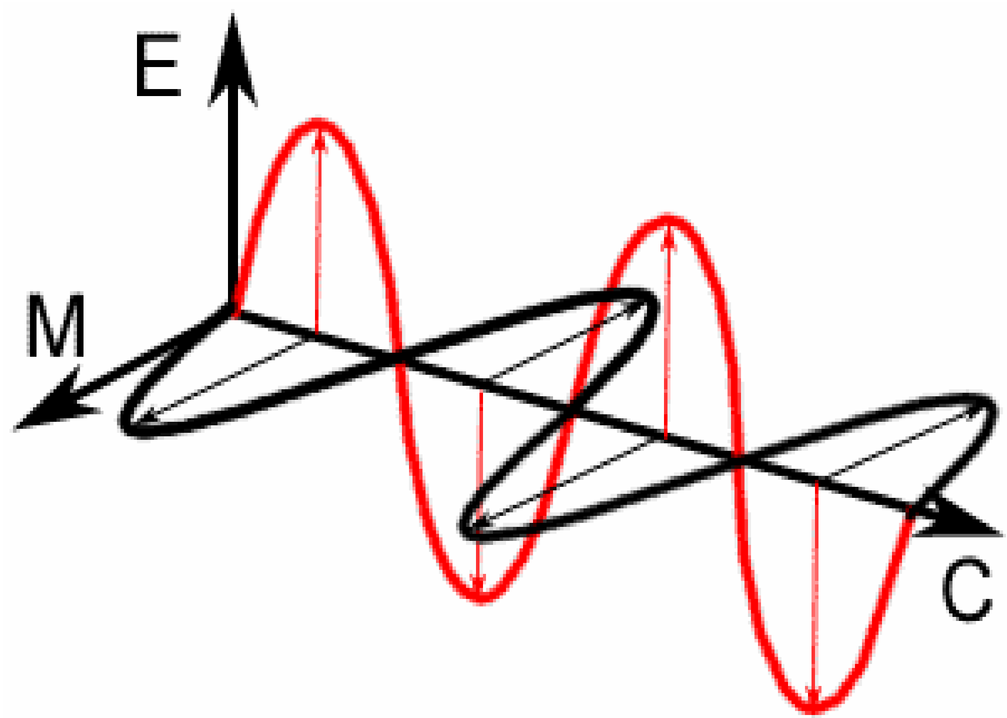
Remote Sensing and the Electromagnetic Energy

- Remote Sensing methods employ ***electromagnetic energy*** to detect and measure target characteristics.

- ***Electromagnetic energy*** refers to all energy that moves with the velocity of light in a harmonic wave pattern (such as light, heat, radio waves).

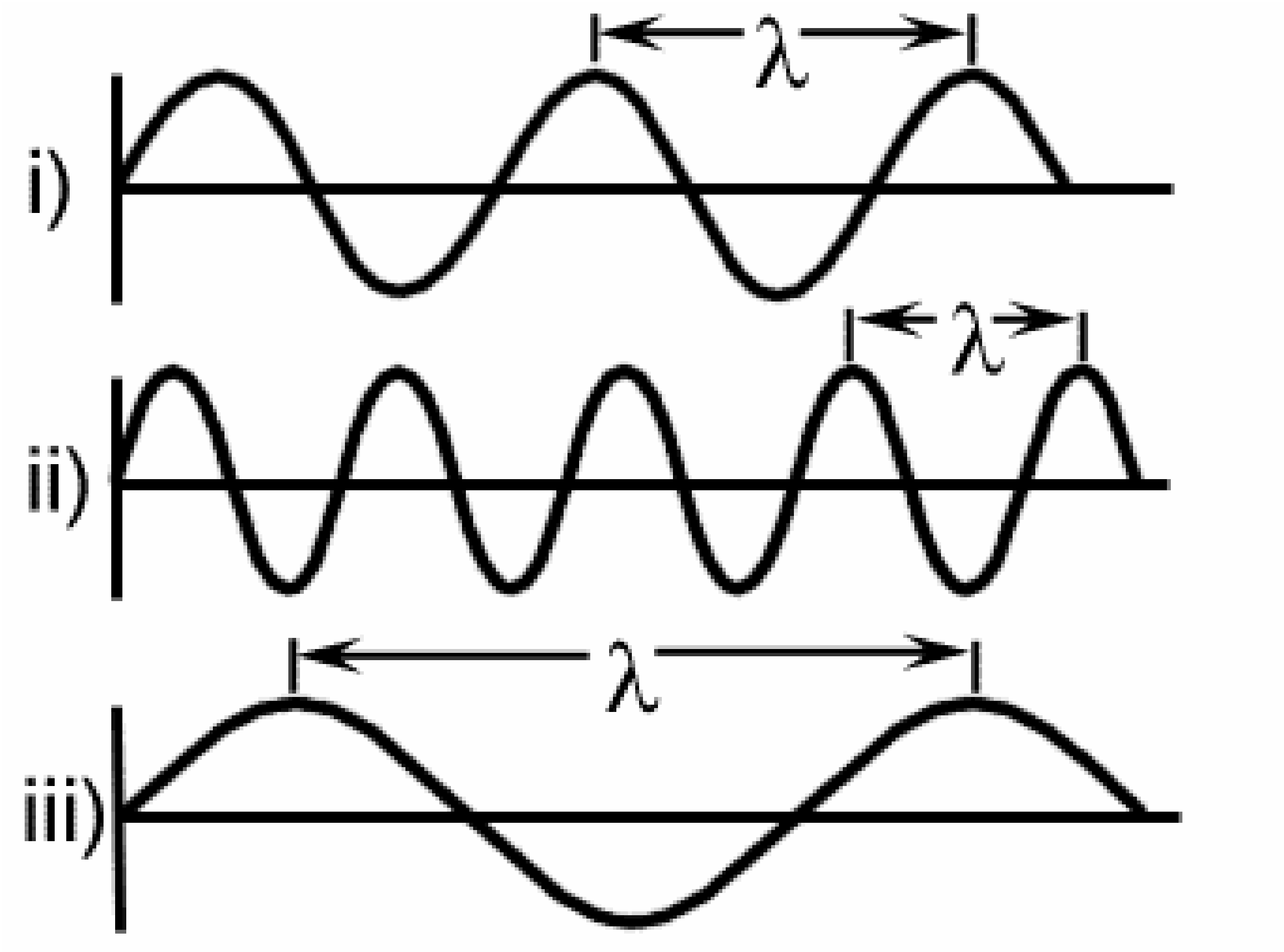
- Understanding the characteristics of electromagnetic radiation in terms of their ***wavelength*** and ***frequency*** is crucial to understanding the information to be extracted from remote sensing data.

Electromagnetic Energy



Electromagnetic radiation consists of an **electrical field** (**E**) which varies in magnitude in a direction perpendicular to the **direction** in which the radiation is traveling (**C**), and a **magnetic field** (**M**) oriented at right angles to the electrical field. Both these fields travel at the **speed of light** (***c***).

WAVELENGTH AND FREQUENCY



WAVELENGTH AND FREQUENCY

- The **wavelength** is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ) and is measured in **metres** (m) or some fraction of metres, such as **nanometres** (nm), **micrometres** (μm) or centimetres (cm).

- **Frequency** (ν) refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in **hertz** (Hz), equivalent to **one cycle per second**, and various multiples of hertz.

WAVELENGTH AND FREQUENCY

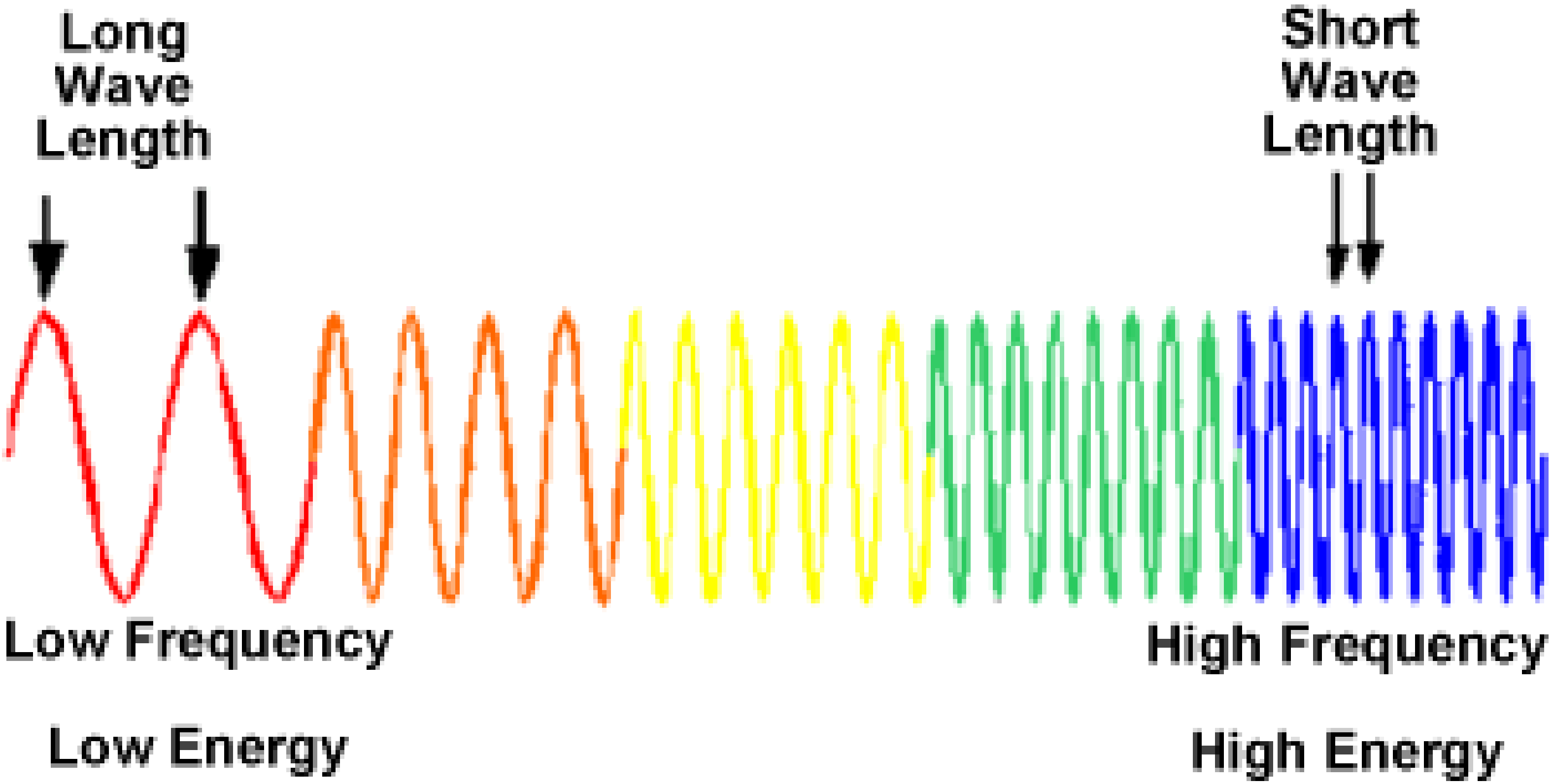
Wavelength and frequency are inversely related to each other:

- the shorter the wavelength, the higher the frequency.
- the longer the wavelength, the lower the frequency.

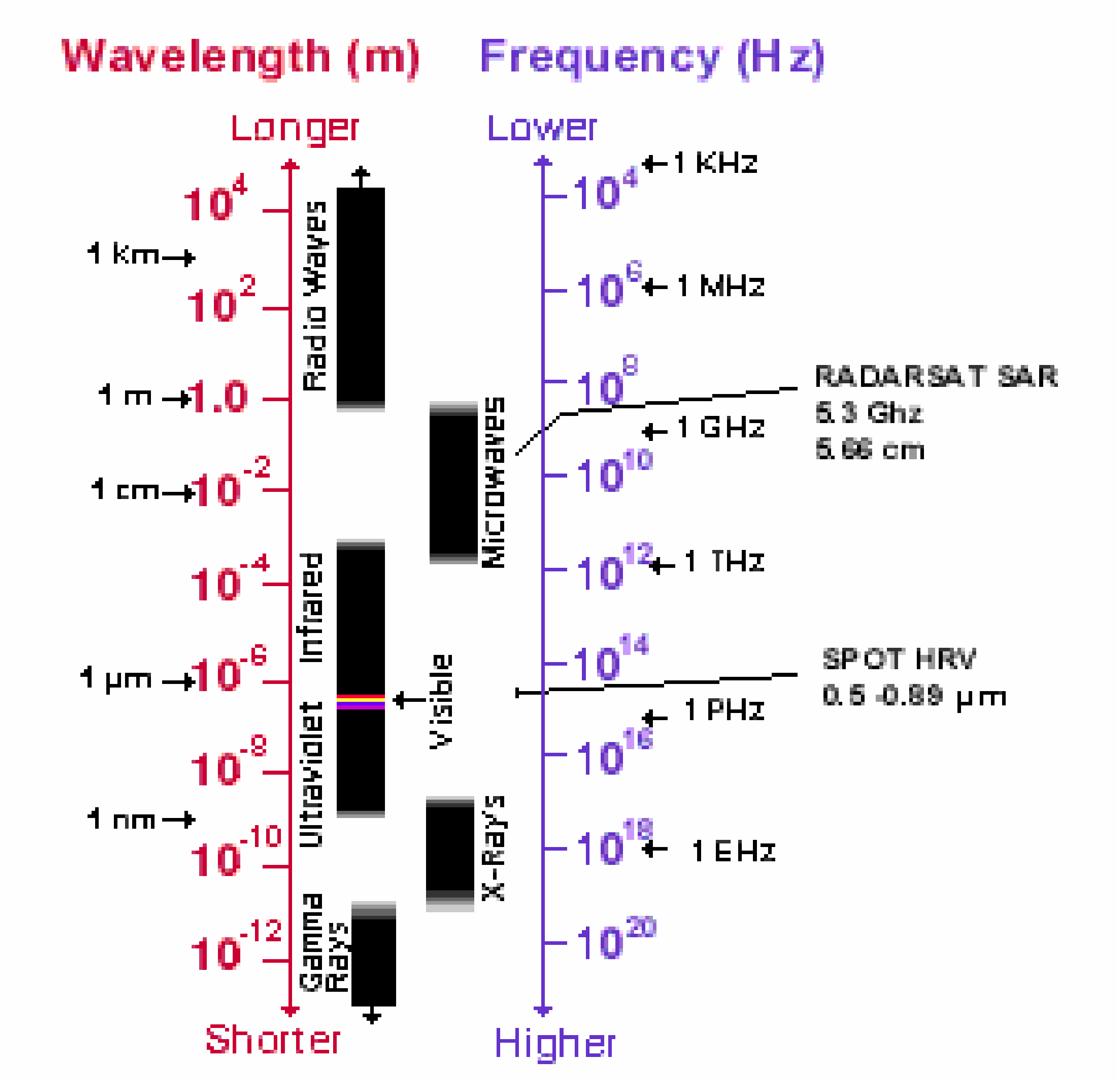
$$\mathbf{c = \lambda\nu} \text{ where:}$$

λ = wavelength (m)
ν = frequency (cycles per second, Hz)
c = speed of light ($3 * 10^8$ m/s)

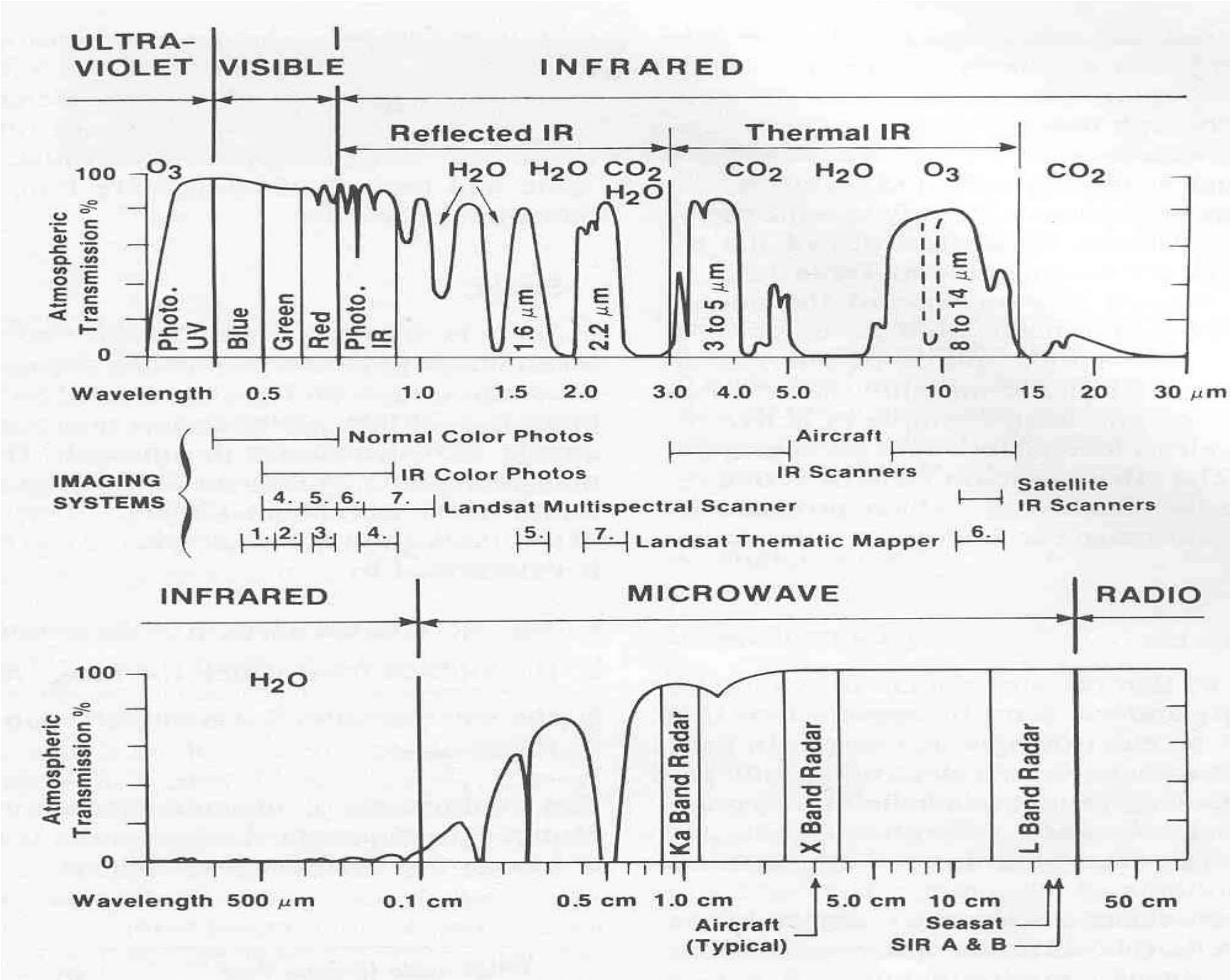
WAVELENGTH AND FREQUENCY



The Electromagnetic Spectrum



The Electromagnetic Spectrum



Electromagnetic Spectrum and Imaging Systems

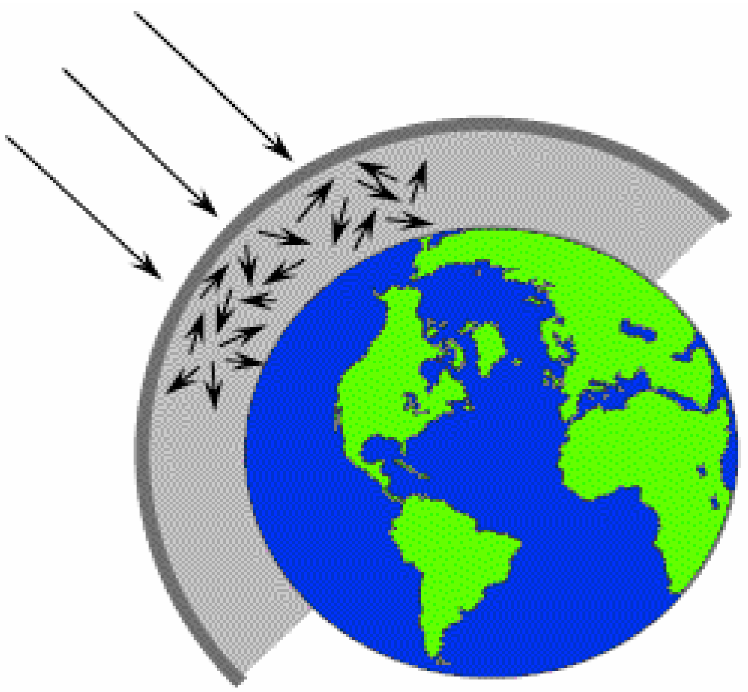
- Wavelength regions with high transmission are called ***atmospheric windows*** and are routinely employed to acquire remote sensing images.

- The major remote sensing regions are ***visible***, ***infrared*** and ***microwave***.

- Low transmission values correspond to wavelengths that are absorbed by the atmosphere (***absorption bands***).

- These wavelengths can not be used effectively to acquire remote sensing images.

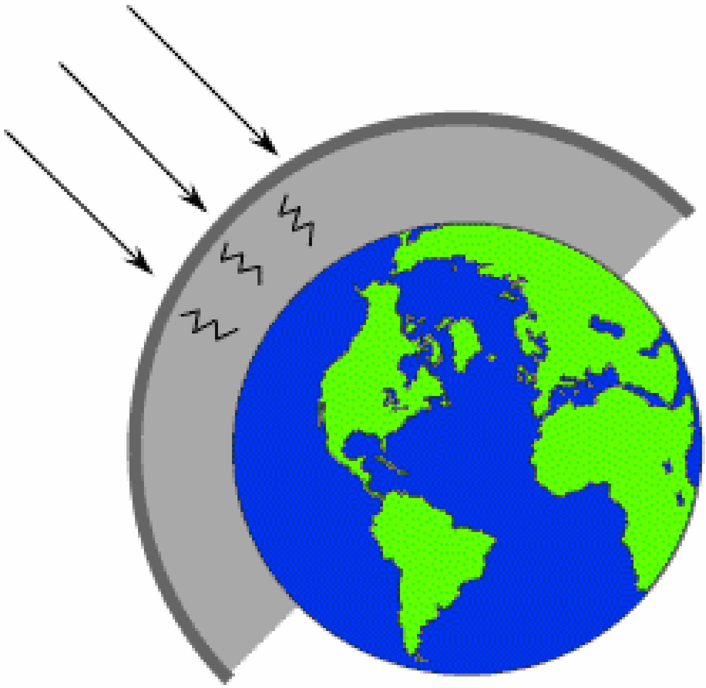
ATMOSPHERIC SCATTERING AND ABSORPTION



Scattering occurs when particles or large gas molecules present in the atmosphere interact with and cause the electromagnetic radiation to be redirected from its original path. How much scattering takes place depends on several factors including the wavelength of the radiation, the abundance of particles or gases, and the distance the radiation travels through the atmosphere.

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

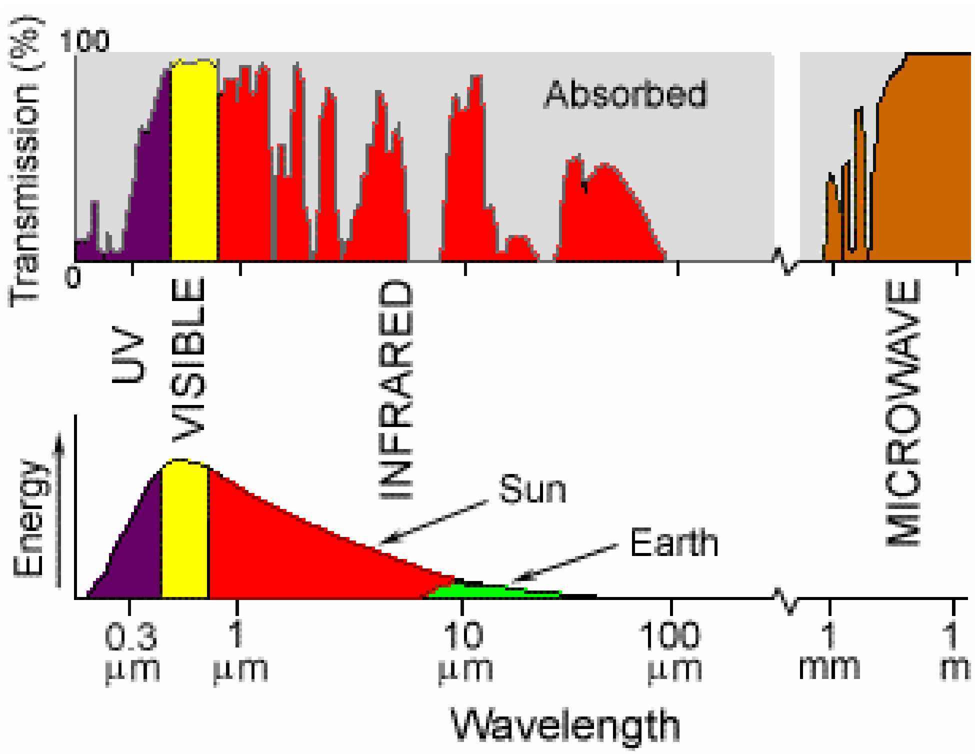
ATMOSPHERIC SCATTERING AND ABSORPTION



<u>Absorption</u> is the other main mechanism at work when electromagnetic radiation interacts with the atmosphere. In contrast to scattering, this phenomenon causes molecules in the atmosphere to absorb energy at various wavelengths. **Ozone, Carbon Dioxide**, and **Water Vapour** are the three main atmospheric constituents which absorb radiation.

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

ATMOSPHERIC WINDOWS



Because these gases absorb electromagnetic energy in very specific regions of the spectrum, they influence where (in the spectrum) we can "look" for remote sensing purposes.

Those areas of the spectrum which are not severely influenced by atmospheric absorption and thus, are useful to remote sensors, are called **atmospheric windows**.

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

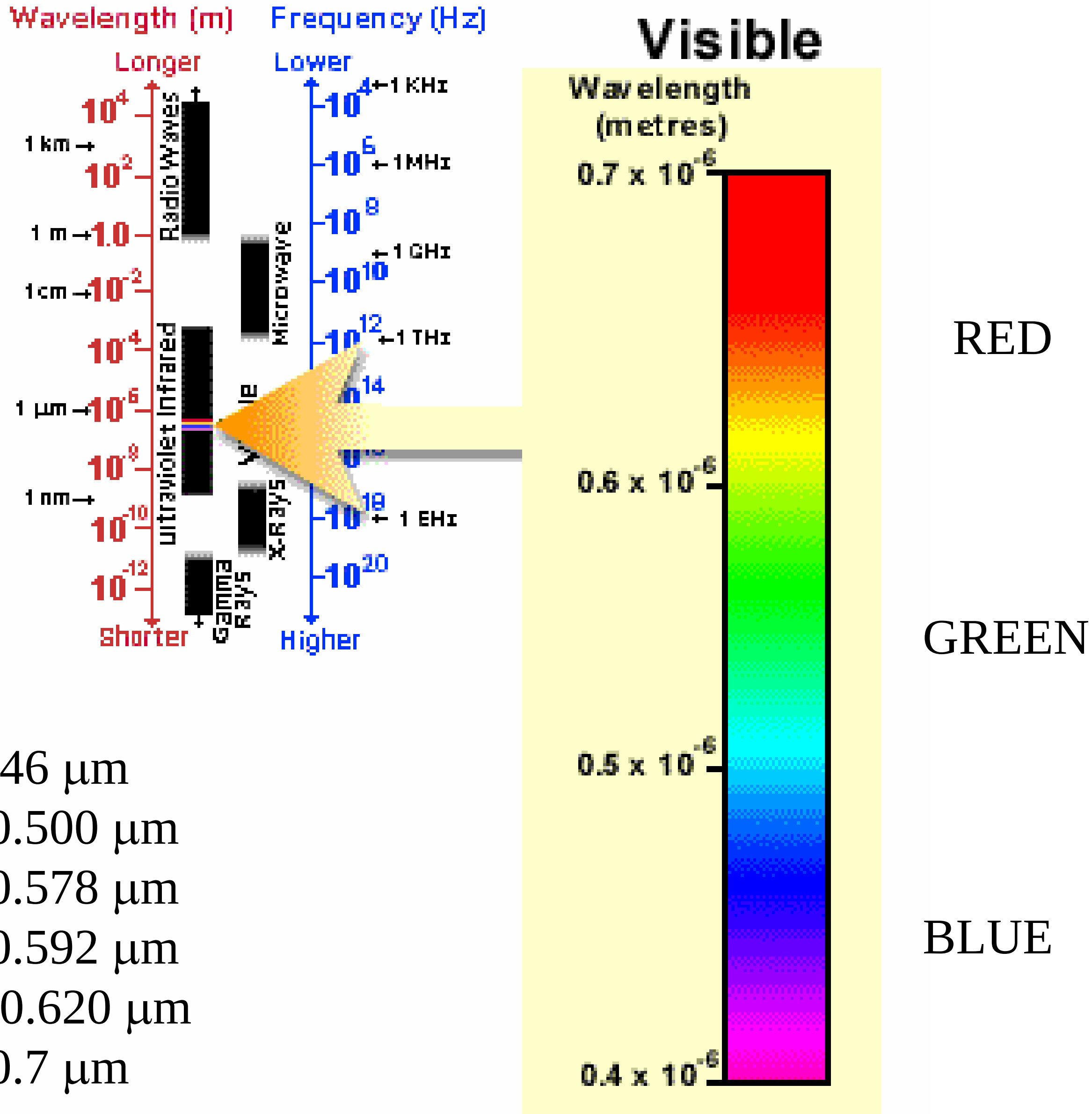
The Visible Region

- The ***visible region*** is a very small portion of the spectrum and covers a wavelength range from approximately 0.4 to 0.7 μm.

- This region is further subdivided in three segments (or ***bands***):

0.4-0.5 μm (blue)
0.5-0.6 μm (green)
0.6-0.7 μm (red).

The Electromagnetic Spectrum: the Visible Region



Violet: 0.4 - 0.446 µm
Blue: 0.446 - 0.500 µm
Green: 0.500 - 0.578 µm
Yellow: 0.578 - 0.592 µm
Orange: 0.592 - 0.620 µm
Red: 0.620 - 0.7 µm

Source: CCRS Remote Tutorial *http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html*

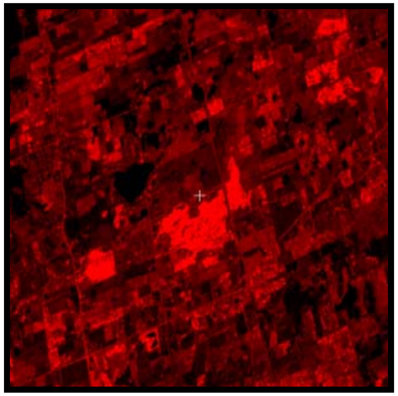
The Visible Region

- It is important to recognize how small the visible portion is relative to the rest of the spectrum.

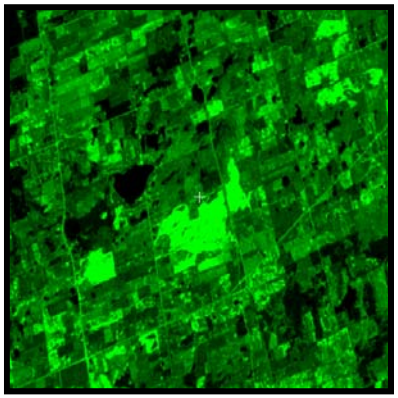
- There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by remote sensing instruments.

- The visible region is the only portion of the spectrum that we can associate with the concept of colours.

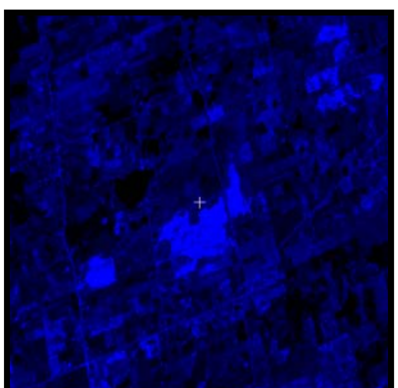
GENERATING TRUE COLOUR COMPOSITES LANDSAT BANDS 3, 2 and 1



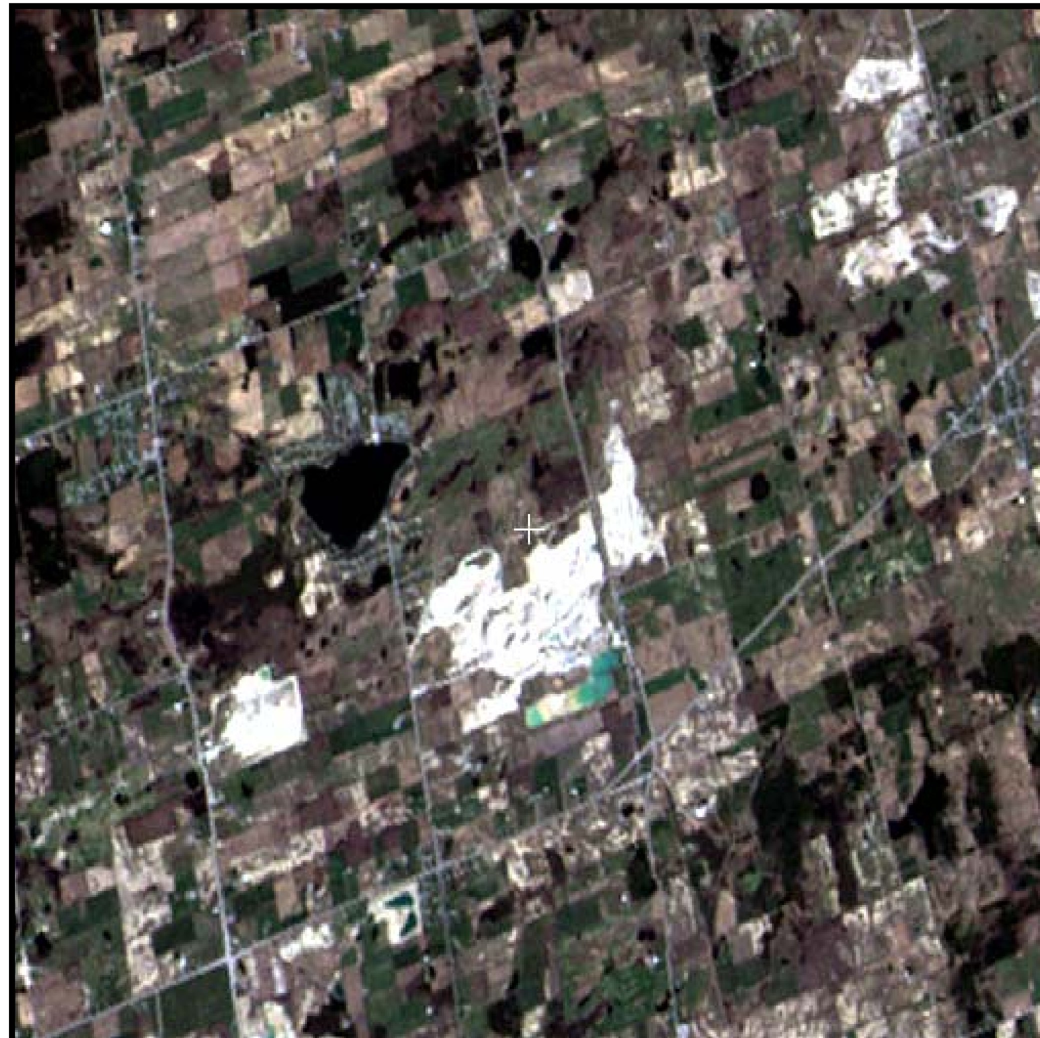
R: Band 3 (RED)



G: Band 2 (GREEN)



B: Band 1 (BLUE)



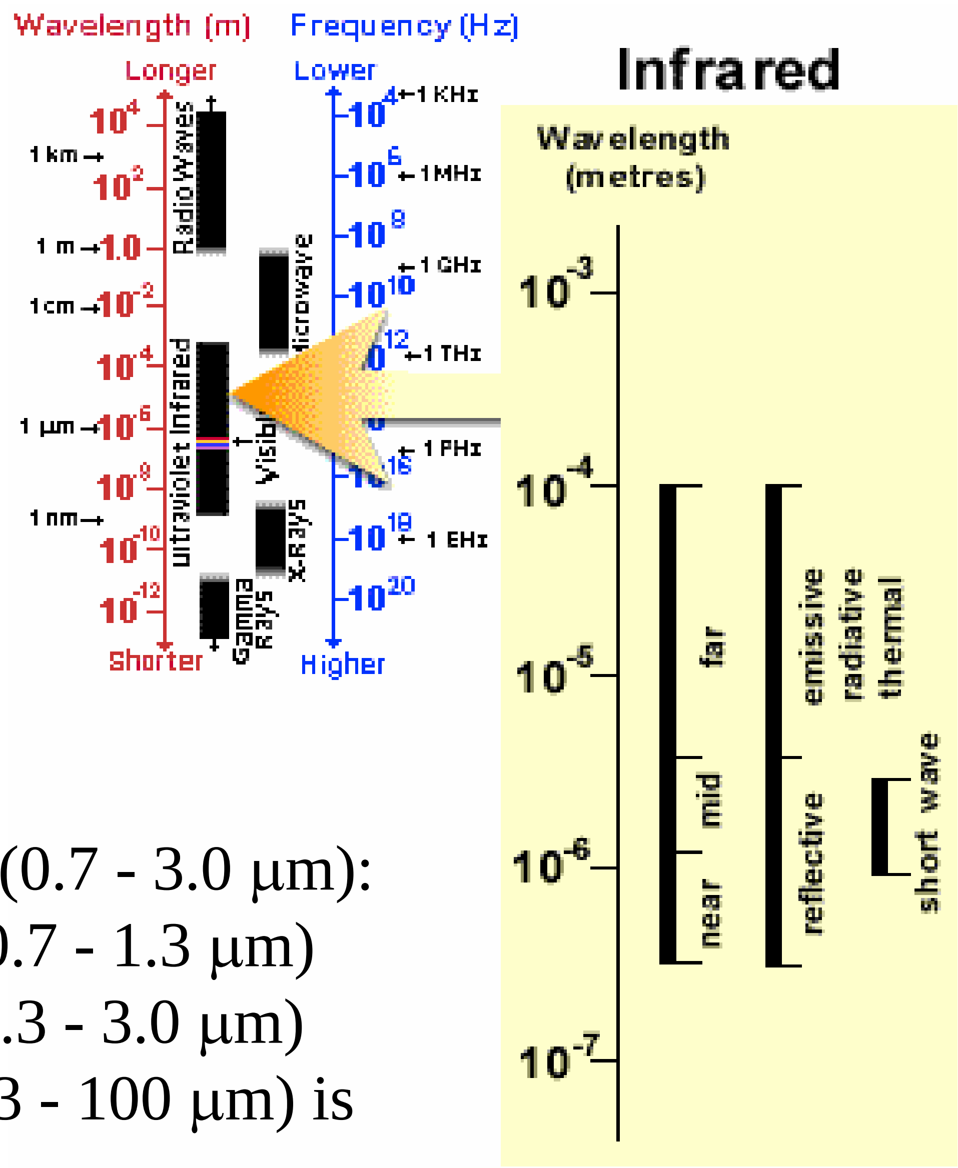
The Infrared Region (IR)

- The ***infrared region*** covers the wavelength range from approximately 0.7 μm to 100 μm (more than 100 times as wide as the visible portion).

- This region can be divided into two categories based on their radiation properties:

  - ***reflected IR*** (wavelengths from approximately 0.7 to 3.0 μm),
  - ***thermal IR*** (wavelengths from approximately 3.0 to 100 μm).

The Electromagnetic Spectrum: the Infrared Region



<u>Note</u>:

Reflected Infrared (0.7 - 3.0 µm):

- near-IR (0.7 - 1.3 µm)
- mid-IR (1.3 - 3.0 µm)

Thermal Infrared (3 - 100 µm) is also called far-IR.

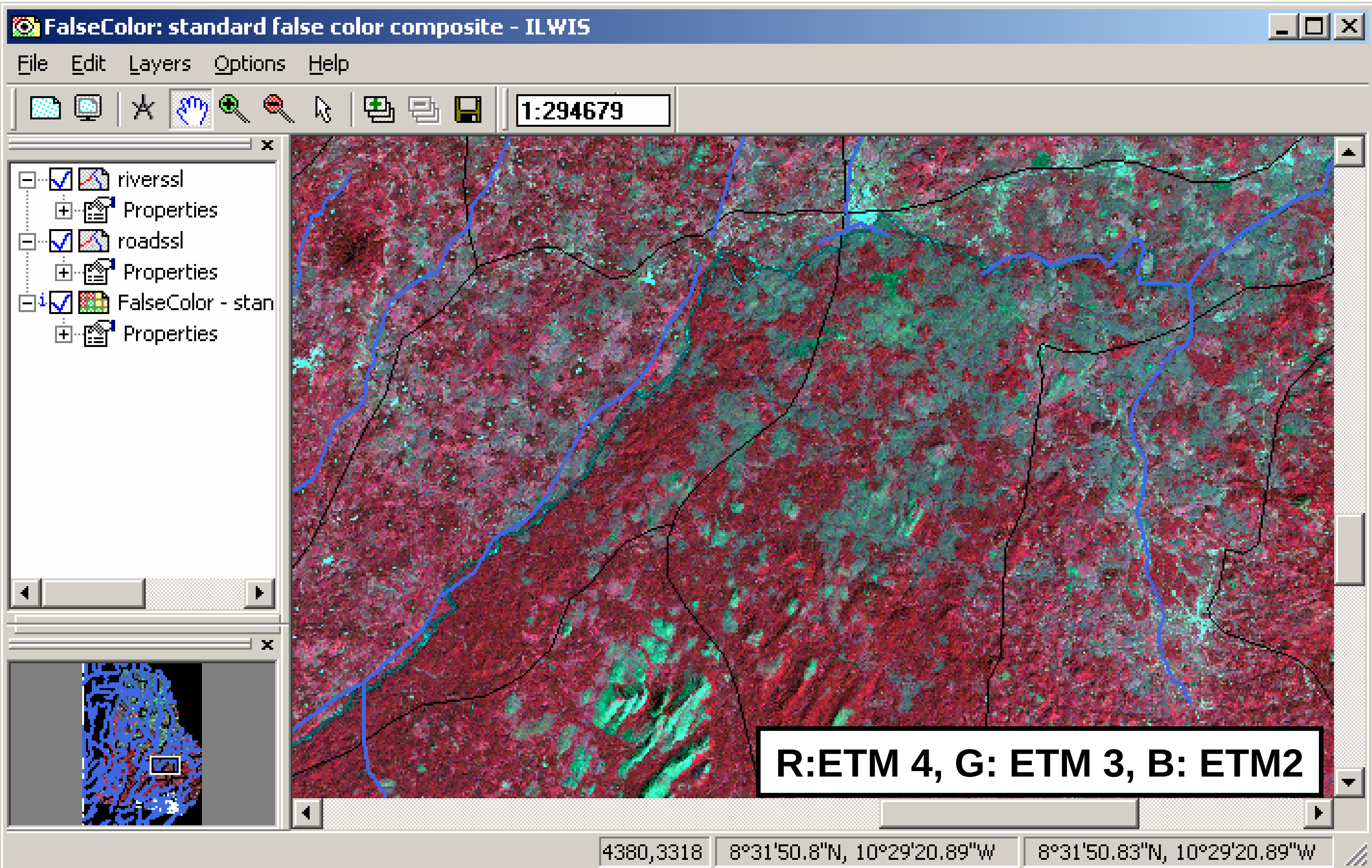
http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

Reflected and Thermal Infrared

- Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion.

- The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat.

Generating “False Colour” Composites using Landsat Satellite ETM Imagery for Sierra Leone



MSS Band 4 (Reflected Near-Infrared) for Sierra Leone
Note the Crisp Delineation of Land/Water

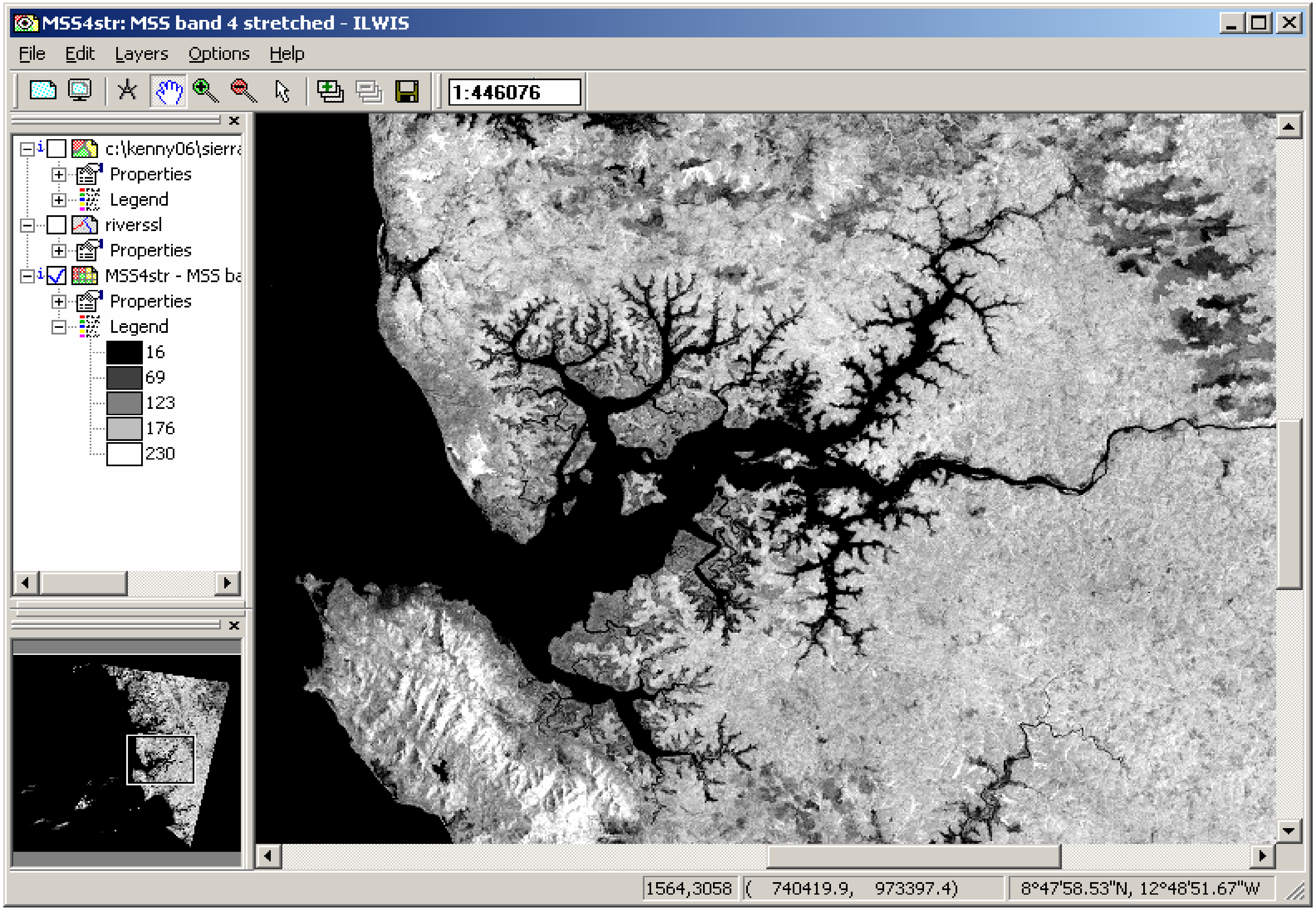
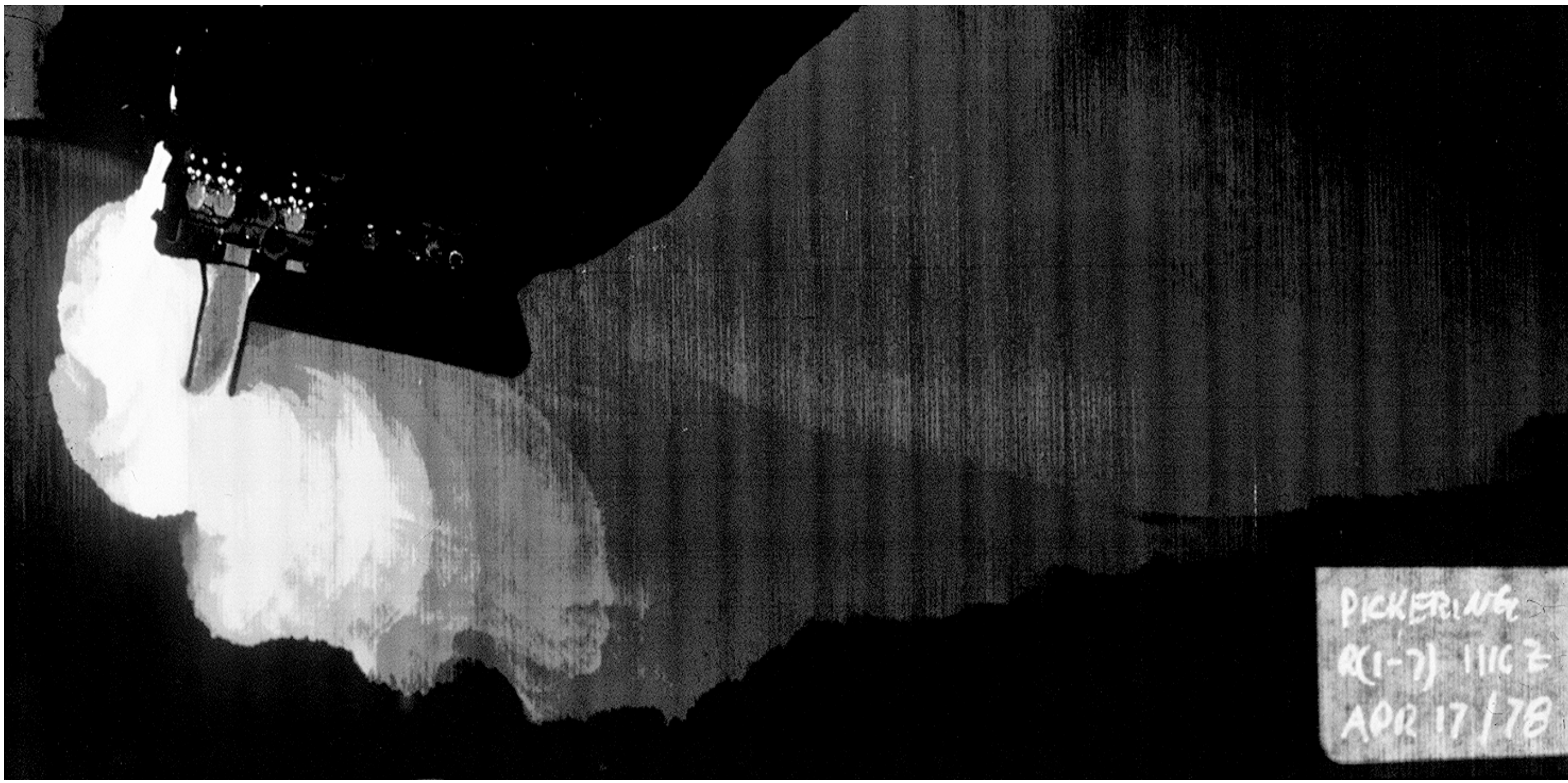
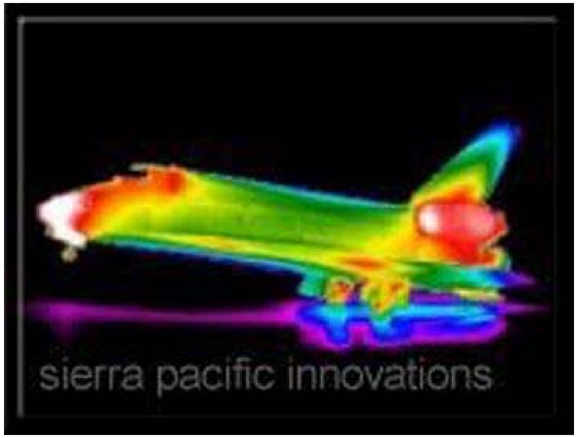


Image Acquired March 1, 1976

Monitoring Emitted Thermal Infrared Energy
THERMAL PLUME GERATED BY NUCLEAR POWER STATION



GROUND BASED THERMAL INFRARED IMAGES
Can you identify these images?



http://rst.gsfc.nasa.gov/Sect9/Sect9_9.html

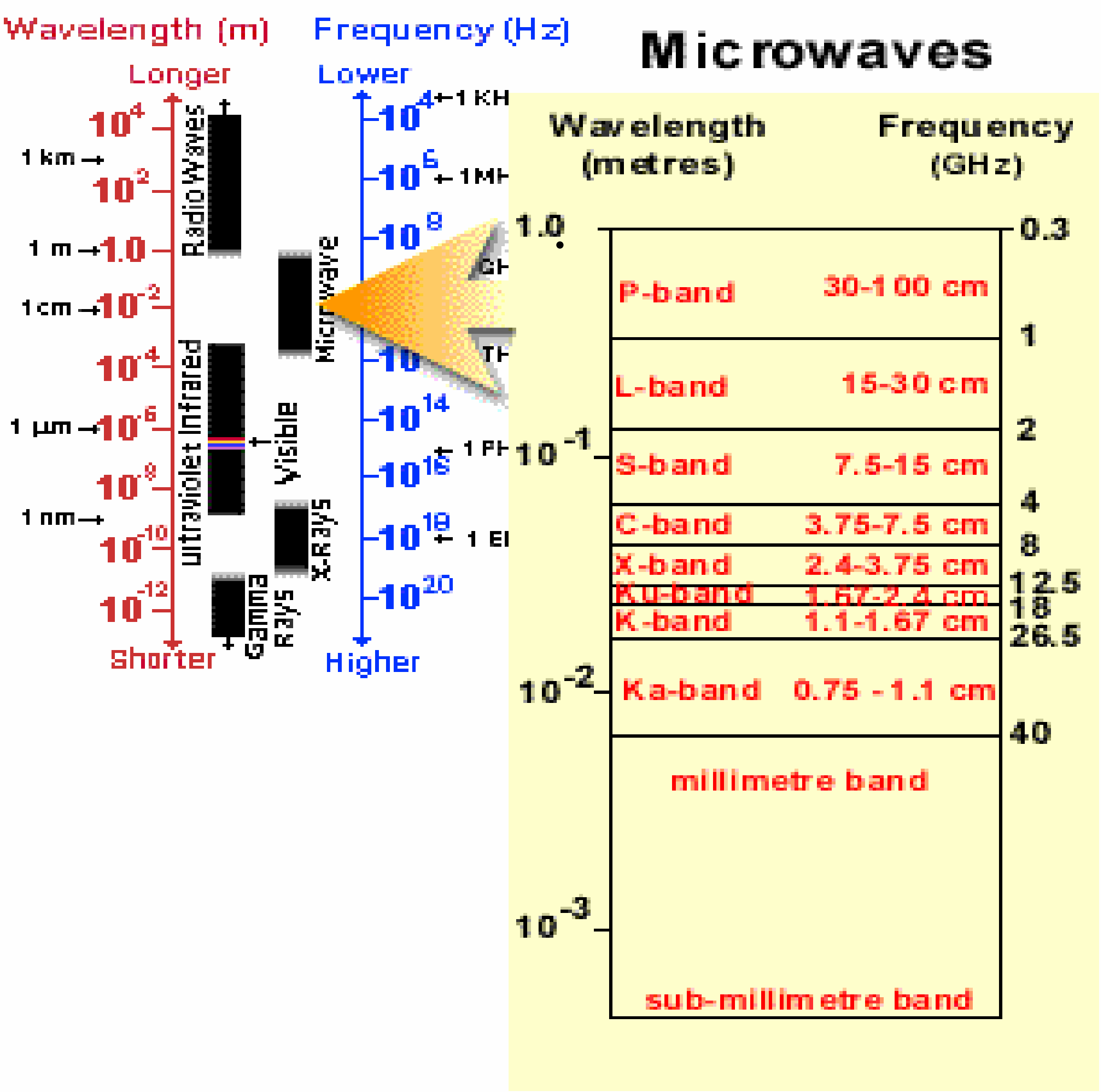
The Microwave Region

- The microwave region covers a wavelength range from about 0.1 to 30 cm: these are the longest wavelengths used for terrestrial remote sensing.

- These wavelengths can penetrate clouds, fog and rain.

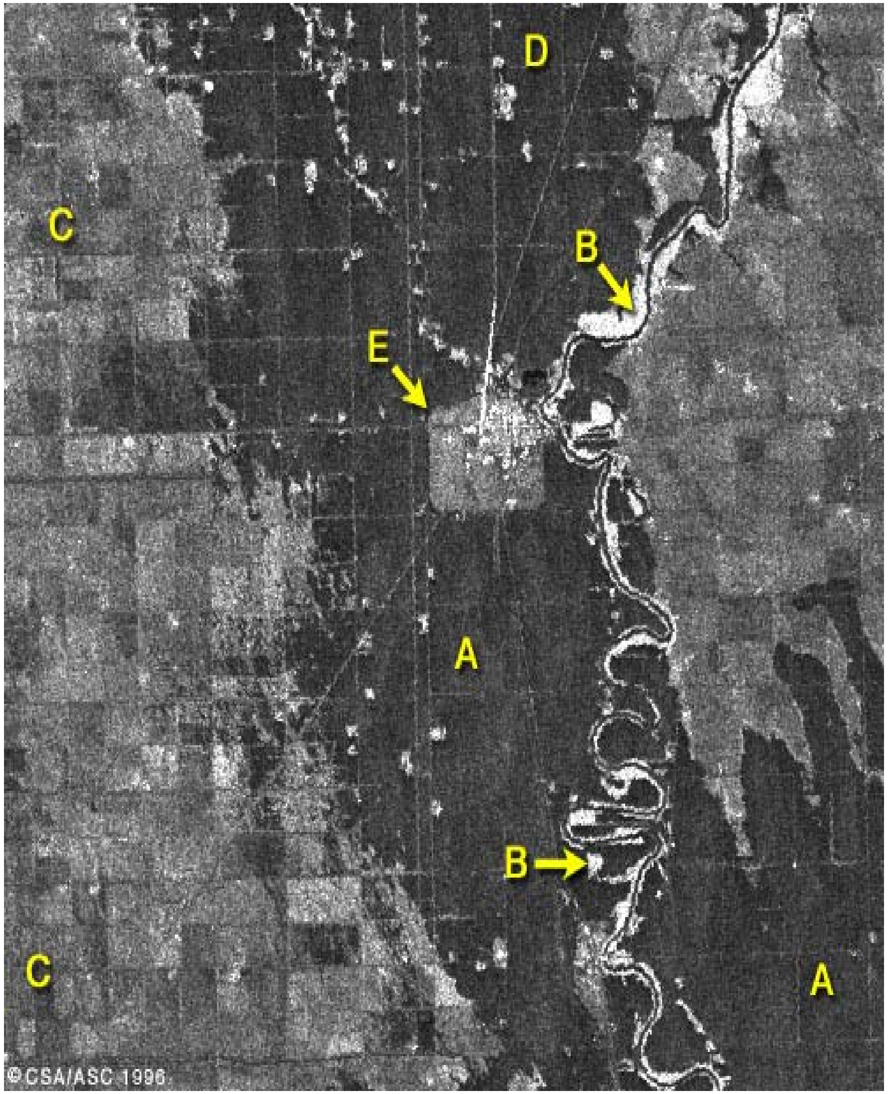
- ***Radar*** systems operate primarily in the microwave region of the electromagnetic spectrum.

The Electromagnetic Spectrum: the Microwave Region



http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

FLOOD MONITORING – Using Satellite Radar Imagery



This RADARSAT image was acquired during the Red River Flood in Manitoba. The all weather capability of RADAR allows it to penetrate both cloud and haze.

http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/radarsat/images/man/rman03i.jpg

Spectral Properties of Objects

- Every Earth surface feature will interact with the incident radiation in its own unique way, according to its spectral characteristics.

- Many features of interest can be identified , mapped and studied from satellite images on the basis of their spectral response.

- Thus, to utilize remote sensing effectively in any given application, one must know and understand the spectral characteristics of the particular features under investigation.

Spectral Reflectance Curves

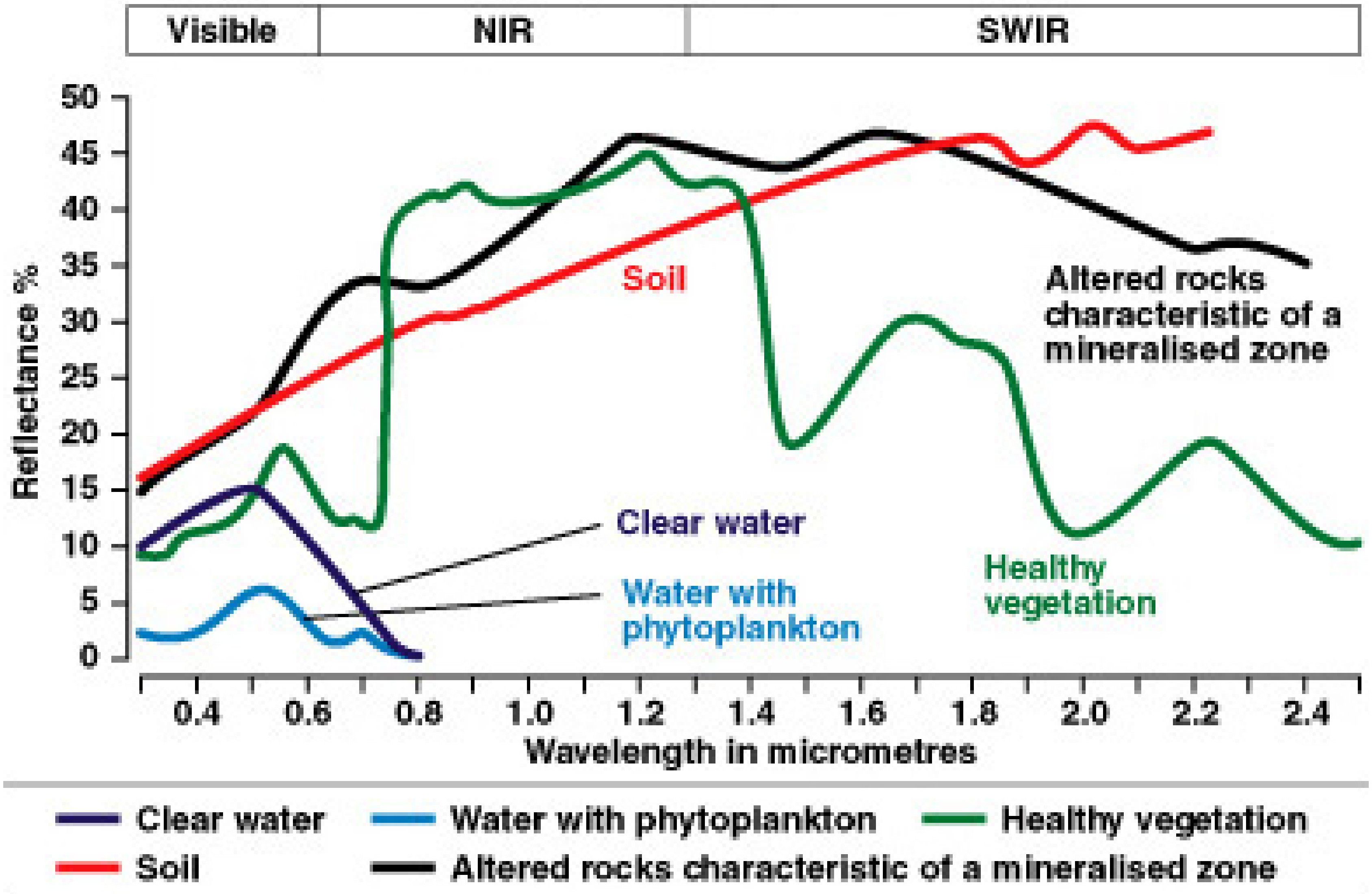
- The spectral reflectance characteristics of objects can be measured and represented graphically as ***spectral reflectance curves.***

- Every feature displays a unique ***spectral reflectance curve*** which may change over time: e.g. crops change their spectral response pattern as they mature.

- ***Spectral reflectance curves*** are measured by instruments called ***spectrometers*** that record the energy reflected from materials as a function of wavelength.

- The spectral reflectance curves characteristics of each feature type (such as vegetation, soil, minerals, water, etc.) are also called ***spectral signatures***.

Generalized Spectral Reflectance Curves of Surface Materials



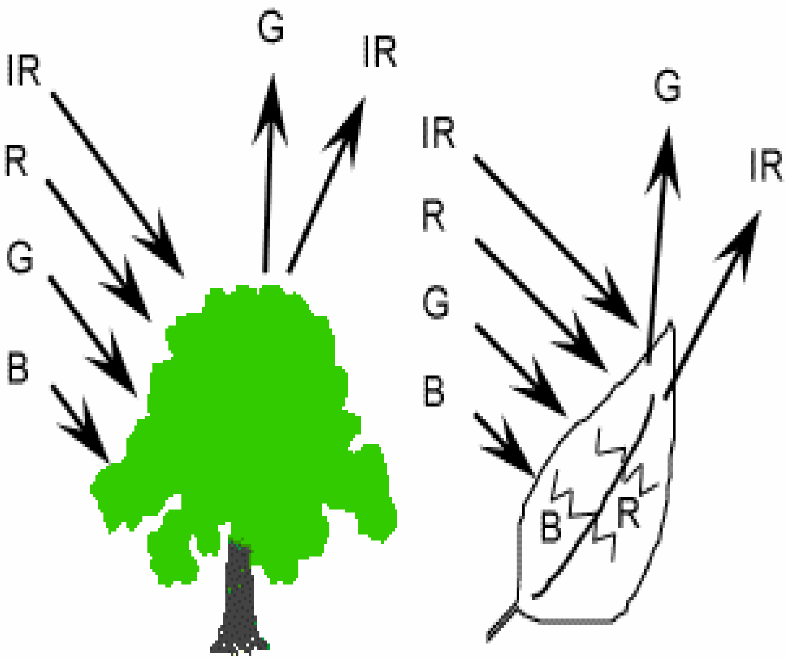
- **Note how distinctive the curves are for each feature.**

Spectral Properties of Objects

- Note that the ***spectral differences*** between types are a function of wavelength: e.g. water and vegetation reflect nearly equally in visible ***wavelengths***, yet these features are almost always separable in near-infrared wavelengths.

- ***Temporal*** and ***spatial effects*** can affect the spectral response patterns of objects and have to be evaluated in image interpretation.

Visible Interaction with Leaves

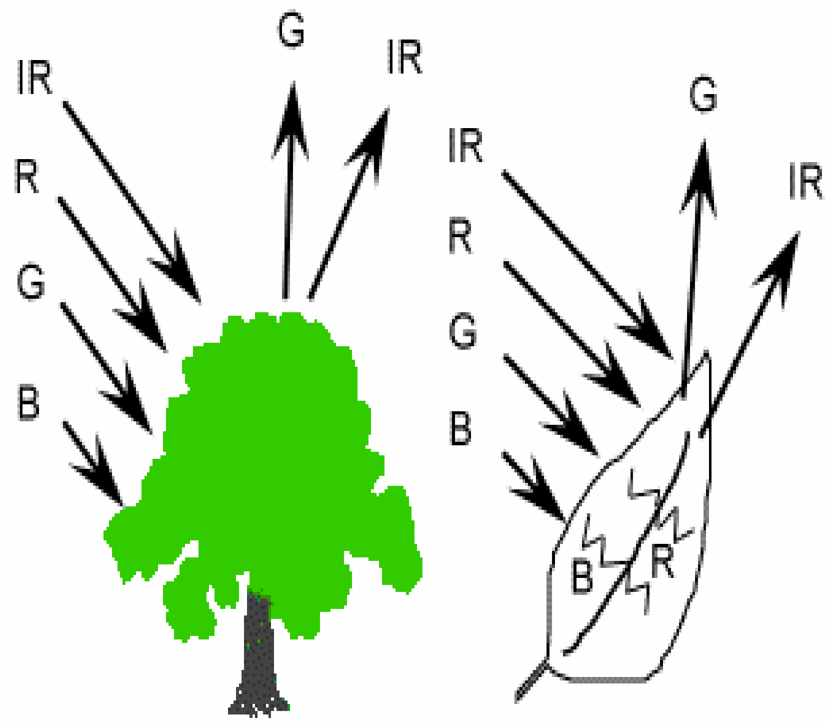


http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

A chemical compound in leaves called **chlorophyll** strongly absorbs radiation in the red and blue wavelengths but reflects green wavelengths. Hence, our eyes perceive healthy vegetation as green (e.g. in the summer, when chlorophyll content is at its maximum). In autumn, there is less chlorophyll in the leaves, so there is less absorption and proportionately more reflection of the red wavelengths, making the leaves appear red or yellow.

The same can happen if the plant is subject to some form of stress that interrupts its normal growth and productivity.

Infrared Interaction with Leaves

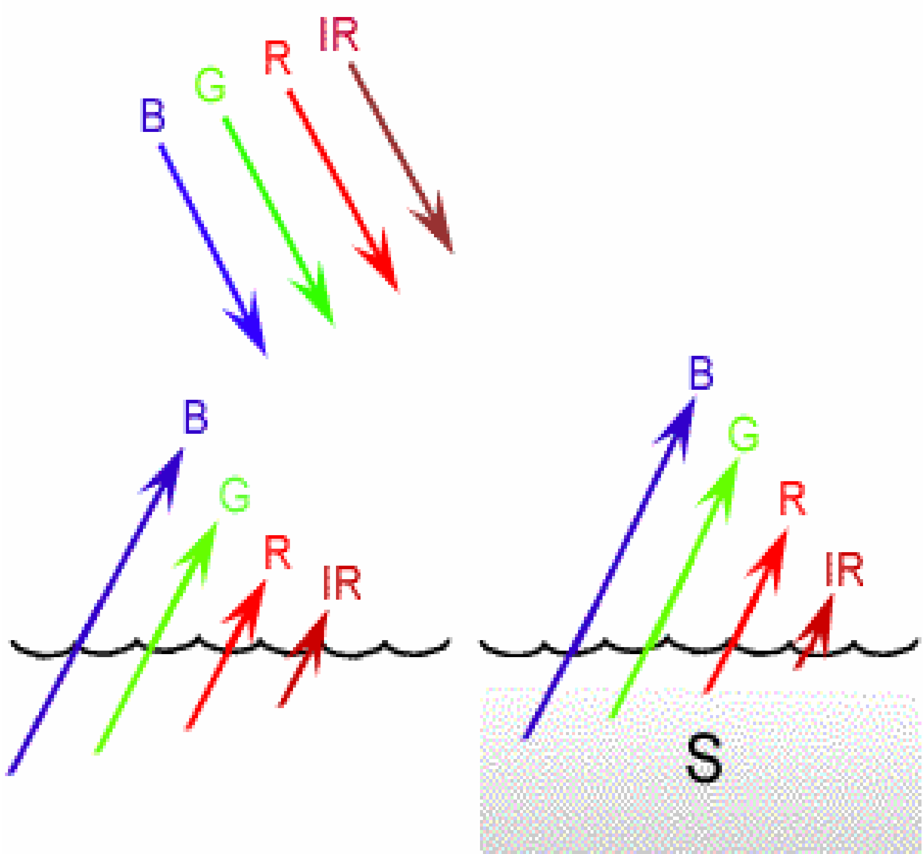


The reflectance of healthy vegetation increases dramatically in the near-infrared portion of the spectrum (at about 0.7 μm).
This is primarily due to the internal structure of plant leaves.

If our eyes were sensitive to near-infrared, green vegetation would appear extremely bright to us at these wavelengths.

Leave reflectance measurements and monitoring in the near-IR range permit scientists to detect vegetation stress and to discriminate between species.

Visible Interaction with Water

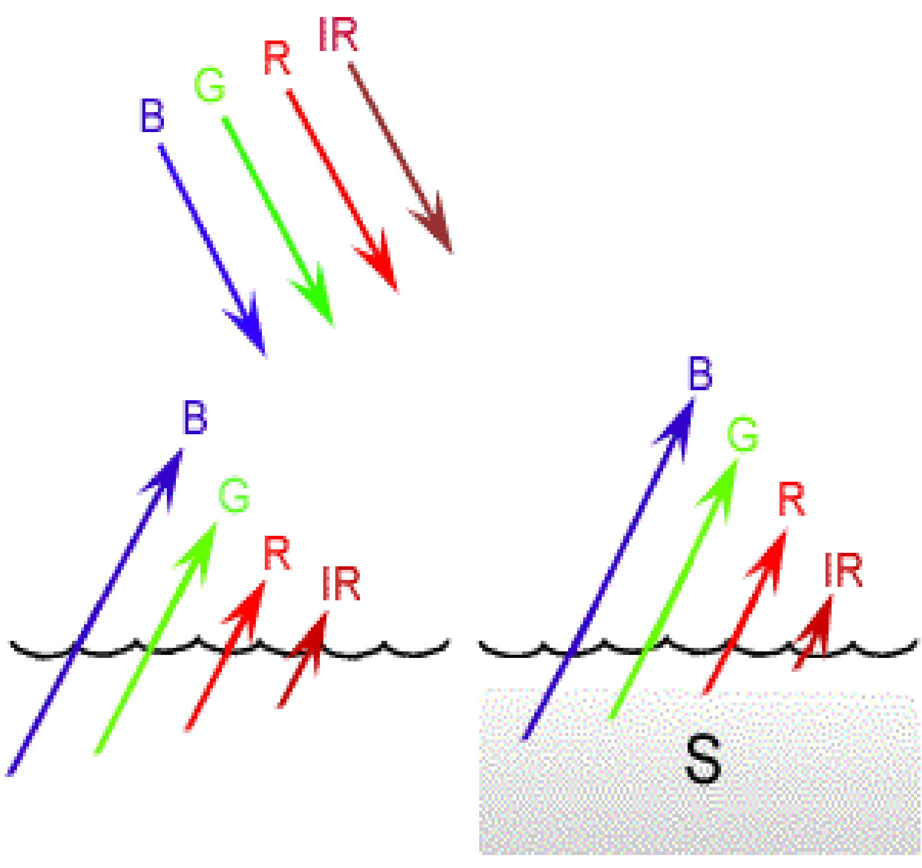


Longer visible wavelengths (red) are absorbed more by water than shorter visible wavelengths (blue and green).

Thus water typically looks blue or blue-green due to stronger reflectance at these shorter wavelengths and darker if viewed at red wavelengths.

http://www.ccrs.nrcan.gc.ca/ccrs/eduref/tutorial/tutore.html

Infrared Interaction with Water



Water absorbs completely the near-infrared radiation and has a uniform dark signature at these wavelengths.

Locating and delineating water bodies (such as lakes and streams) with remote sensing data are done most easily in the near-infrared wavelengths.

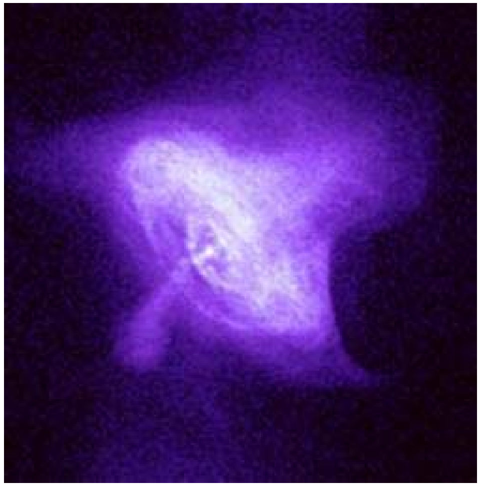
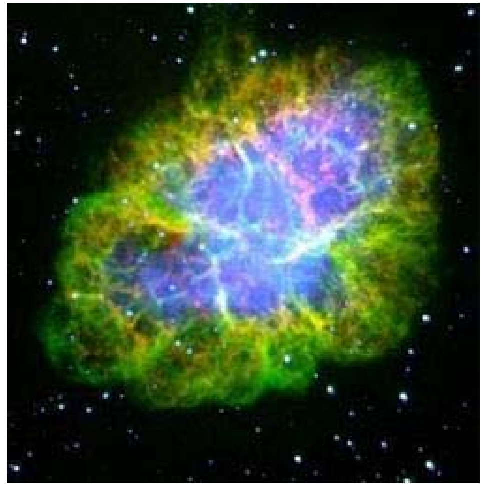
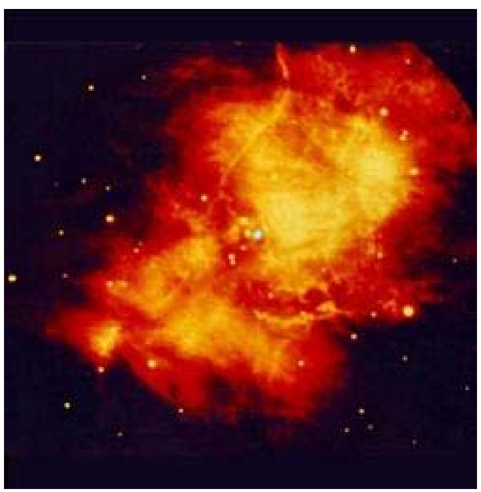
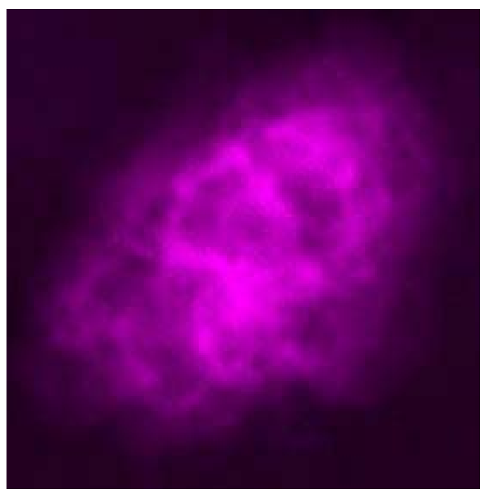
Visible and Infrared Interaction with Water

- Reflectance of water changes with chlorophyll and suspended sediment concentration.

- Chlorophyll in algae absorbs more of the blue wavelengths and reflects the green, making the water appear more green in colour when algae is present: these changes have been used to monitor the presence and estimate the concentration of algae using remote sensing data.

- Large quantities of suspended sediment in the upper layers of the water body can also be detected with remote sensing as they increase the visible reflectance of the water that will appear brighter in the images.

PLANETARY MULTISPECTRAL REMOTE SENSING

The following views are of astronomical bodies viewed through telescopes (some on space platforms) equipped with different multispectral sensing devices. These are four views of the nearby Crab Nebula, which is now in a state of chaotic expansion after a supernova explosion first sighted in 1054 A.D. by Chinese astronomers. The upper left illustration shows the Nebula in the high energy x-ray region; the upper right is a visual image; the lower left was acquired from the infrared region; and the lower right is a long wavelength radio telescope image.

http://rst.gsfc.nasa.gov/