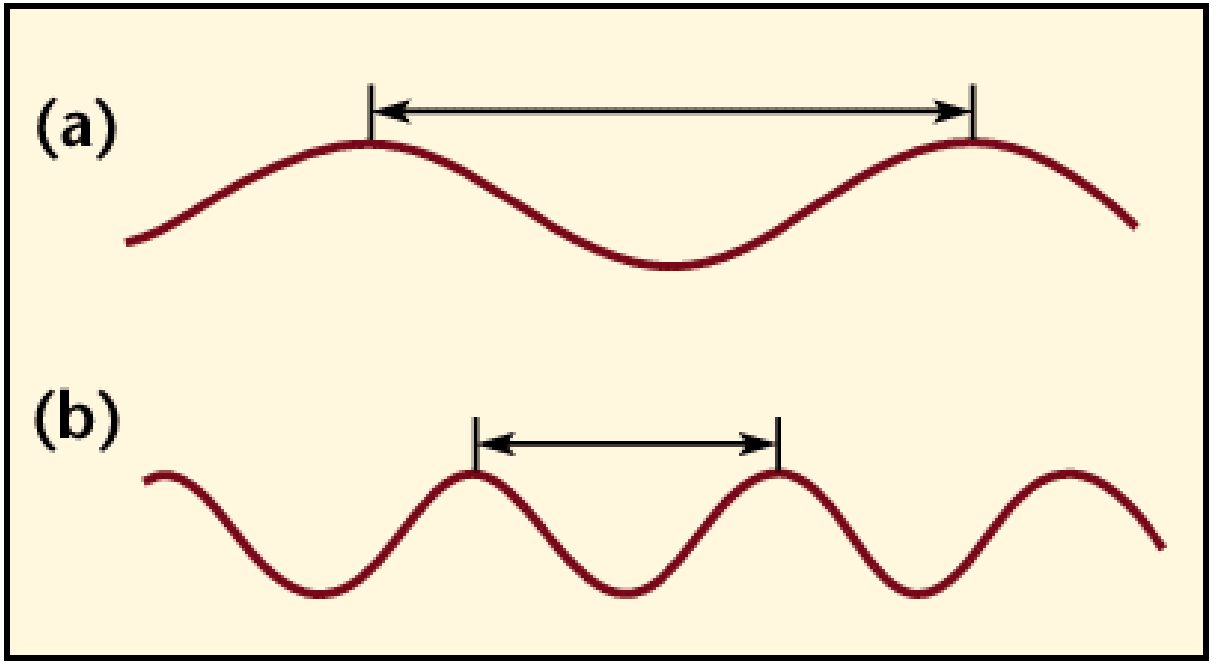
Satellites, Weather and Climate Module 1:
Introduction to the Electromagnetic Spectrum



SWAC

The UNIVERSITY of VERMONT

NSF

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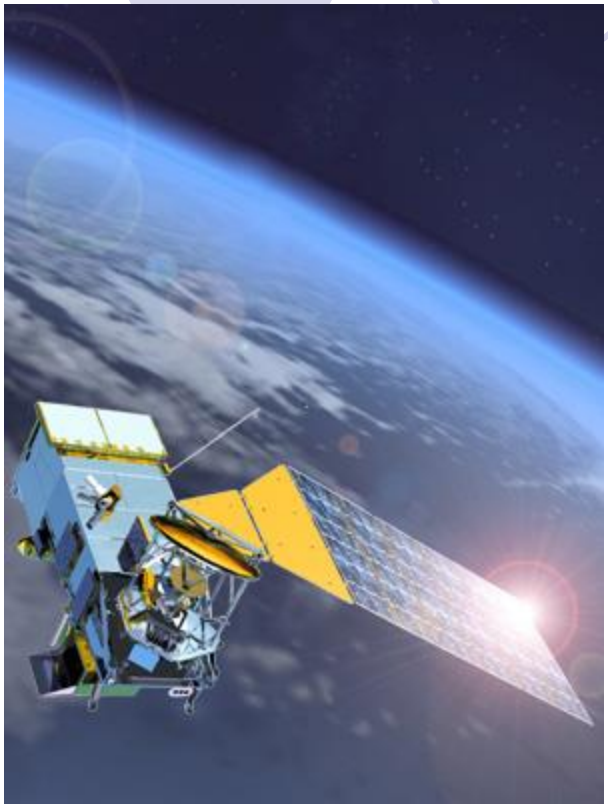
What is remote sensing?

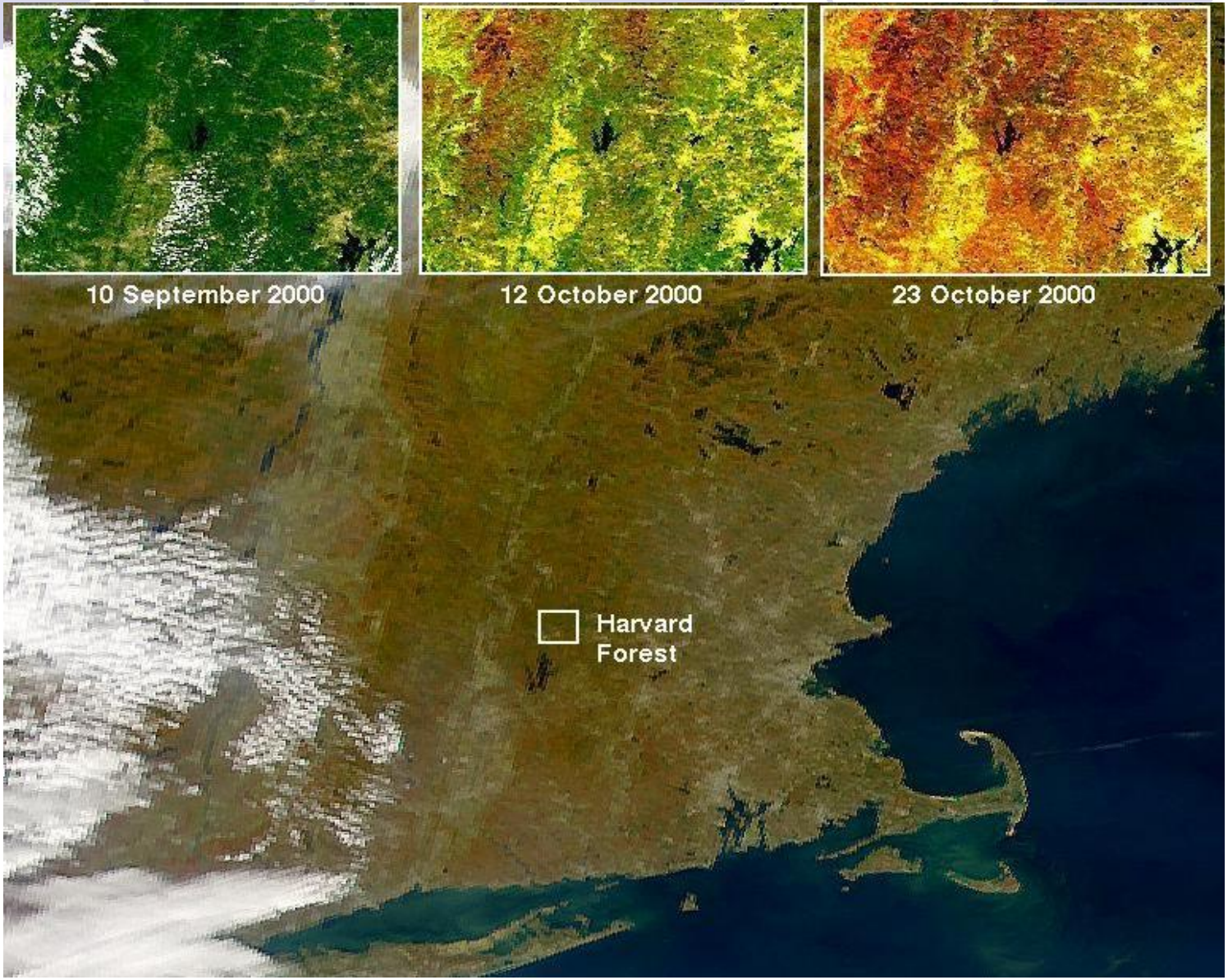


- = science & art of obtaining information through data analysis, such that the device is not in contact with object

Applications of RS data

- Earth resources
  - changes of previously mapped areas
  - water resources & land-use monitoring and management
  - geologic mapping
  - crop diseases
  - agricultural yield forecasting
- Weather
  - wind fields
  - temperature
  - humidity profiles
  - cloud heights
  - severe storm analysis

Seasonal Change at Harvard Forest



Hurricane Ivan: 15 Sept 04 approaching the Gulf Coast

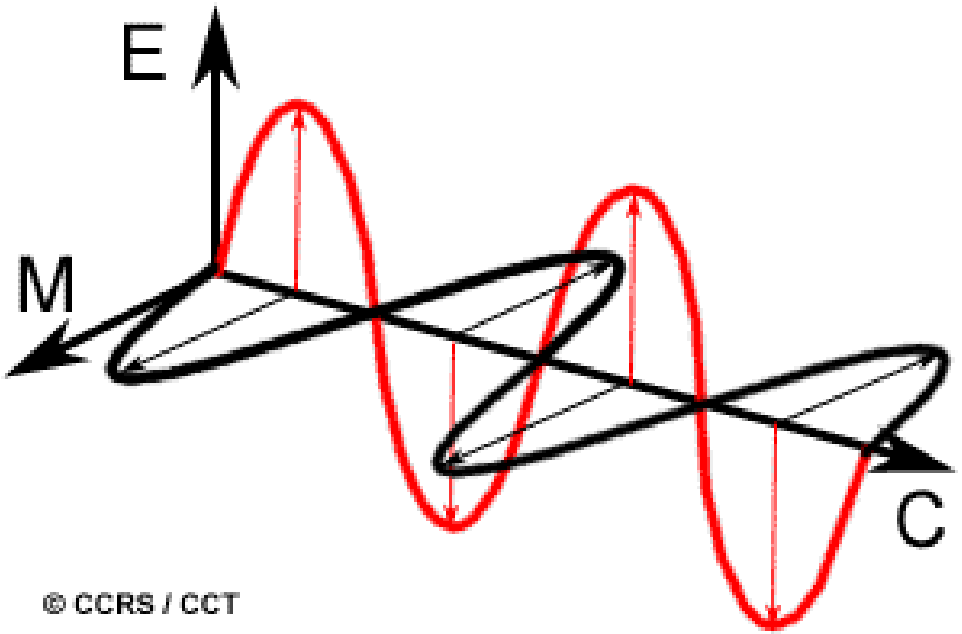
Gene Feldman, NASA GSFC, Laboratory for Hydrospheric Processes, SeaWiFS Project Office (gene.c.feldman@nasa.gov)

SeaWiFS view of Hurricane Ivan was collected at 1:50 PM Central Daylight Time as it approached the U.S. Gulf Coast. The forth tropical storm to hit Florida in only 6 weeks.

Electromagnetic radiation (EMR)

Electromagnetic radiation

- electric field (E)
- magnetic field (M)
- perpendicular and travel at velocity, c ($3x10^8$ ms^{-1})



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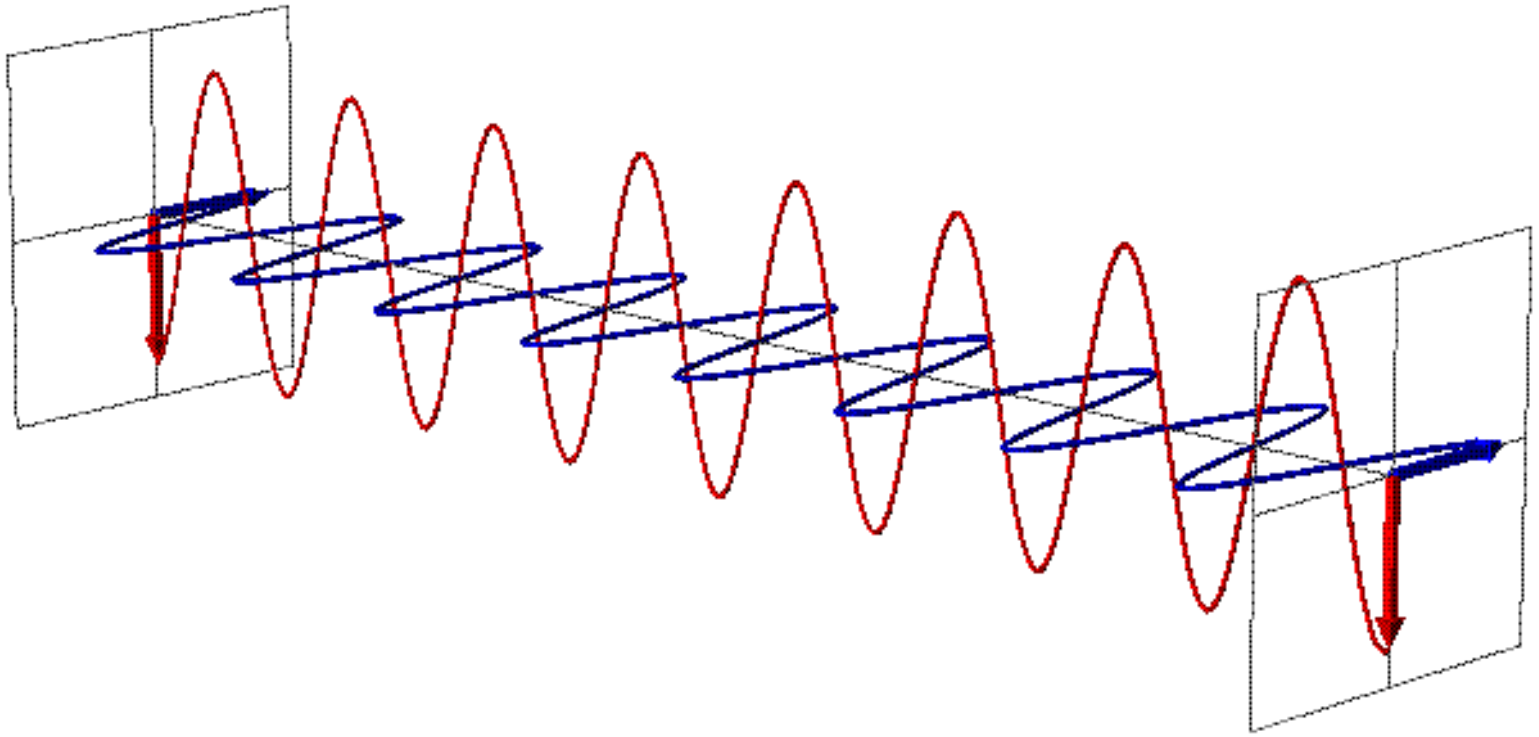
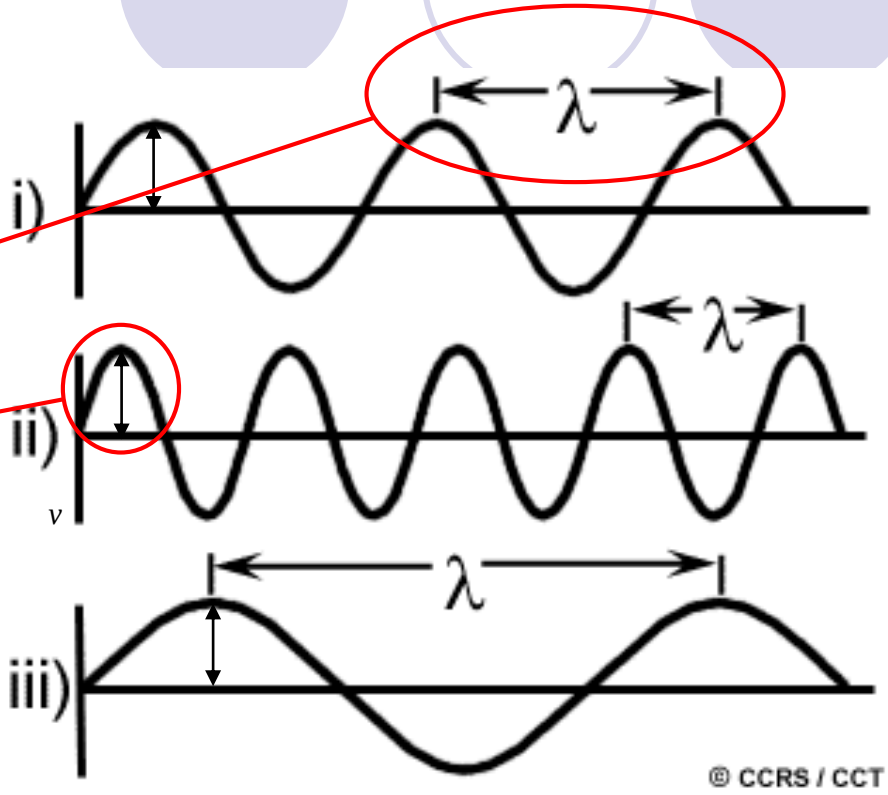


http://www.physchem.co.za/OB12-ele/radiation.htm

Wave: terms

- All waves characterised by:
  - wavelength, λ (m)
  - amplitude, a (m)
  - velocity, v (m/s)
  - frequency, f (s^{-1} or Hz)
  - sometimes period, T (time for one oscillation i.e. 1/f)



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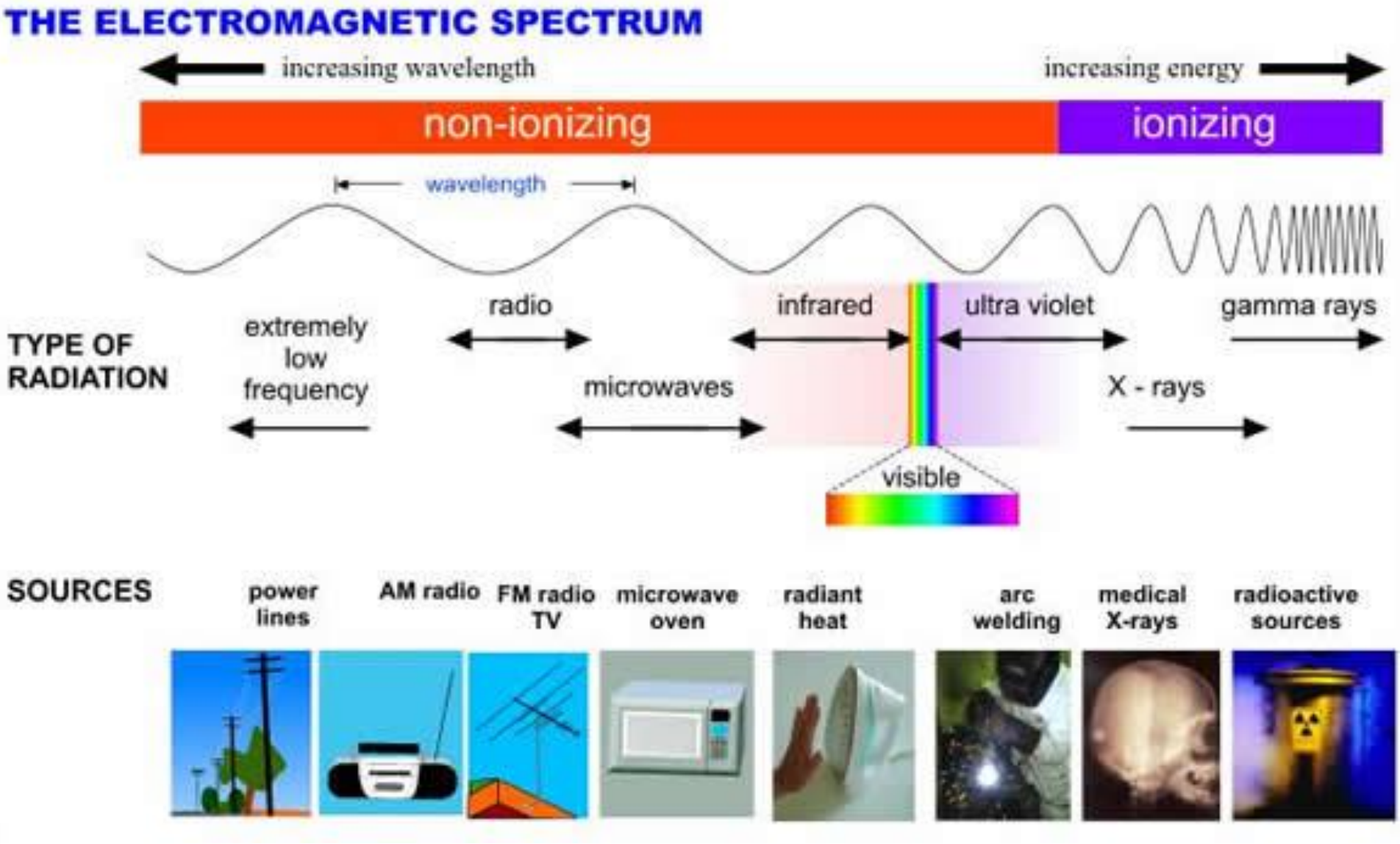
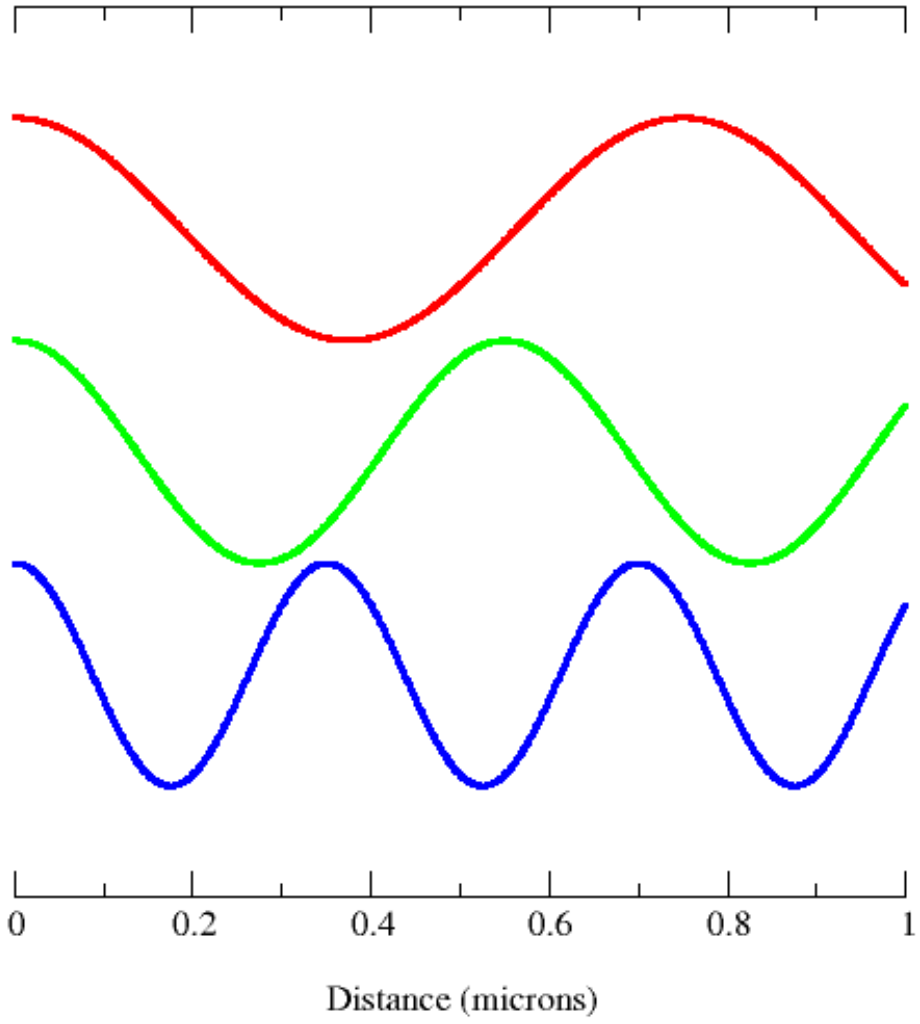
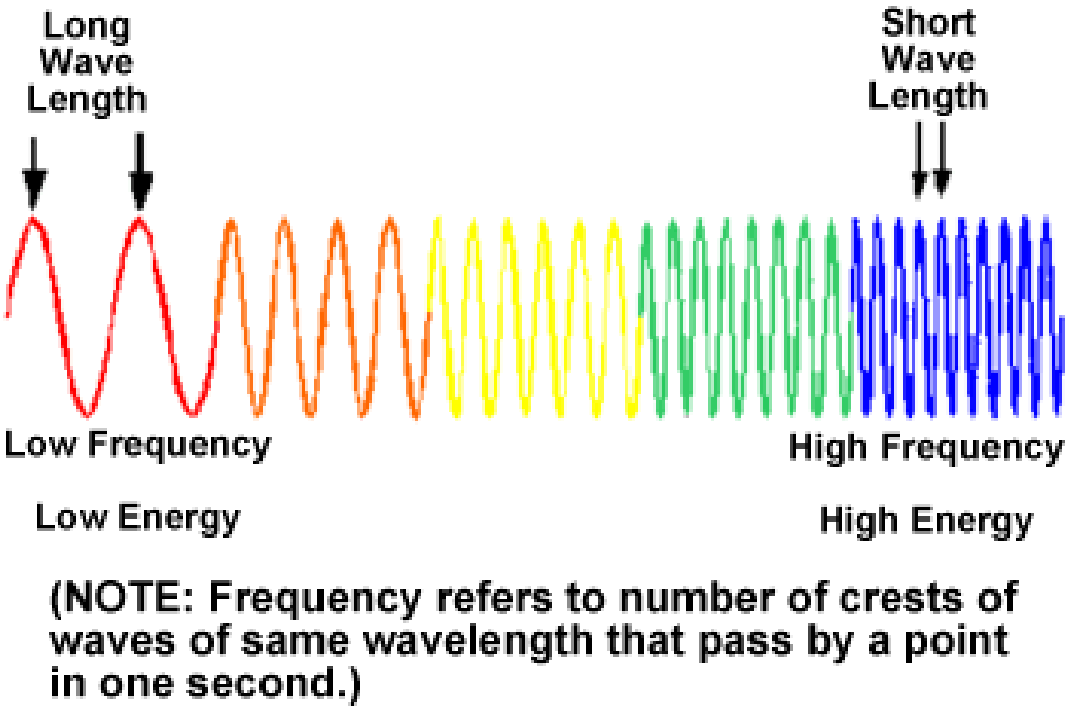


http://www.arpansa.gov.au/images/basics/emr.jpg



http://reference.findtarget.com/search/electromagnetic%20radiation/

EM Spectrum



- We will see how energy is related to frequency, f (and hence inversely proportional to wavelength, λ)
- When radiation passes from one medium to another, speed of light (c) and λ change, hence f stays the same

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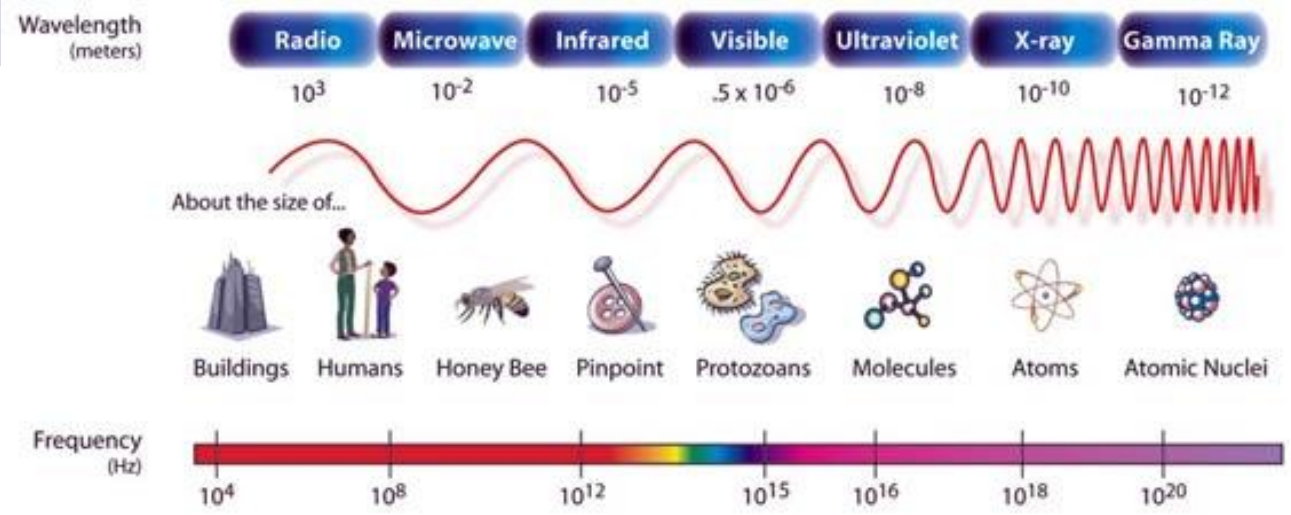
Electromagnetic spectrum



NASA: Echo the bat

- divided into different spectral bands (visible light, NIR, microwave)
- every object reflects or emits radiation = signature

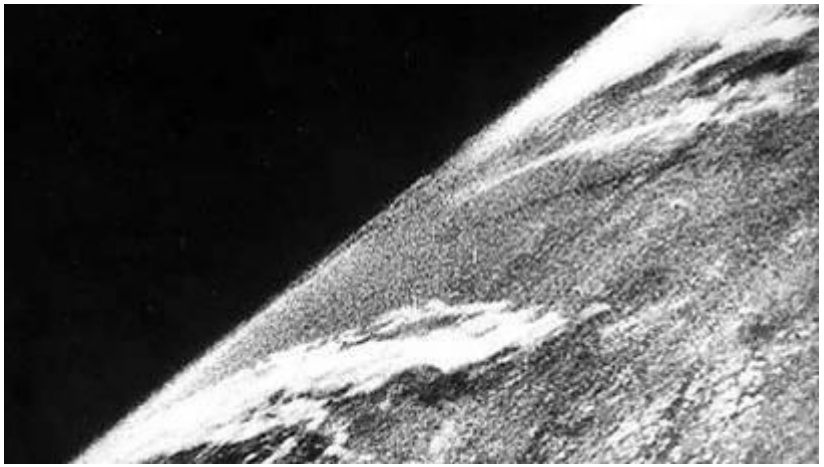
- signatures recorded by remote-sensing devices

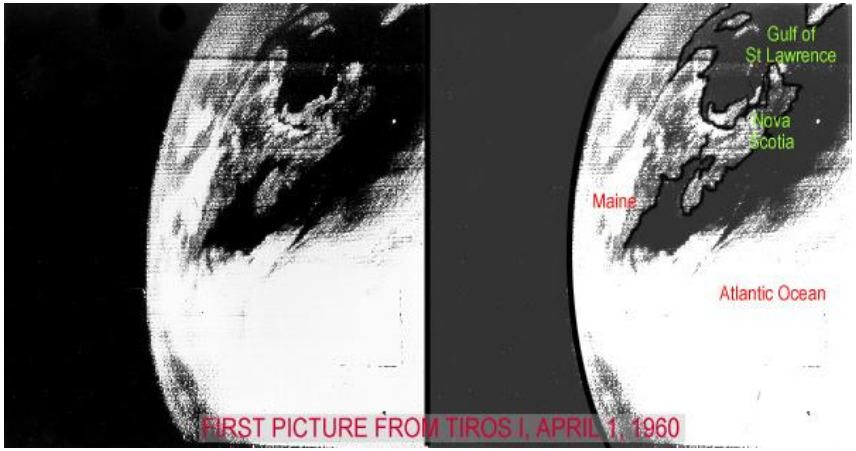
- use of different parts of spectrum
  - visible
  - infrared
  - microwave

Satellite images

history & terminology

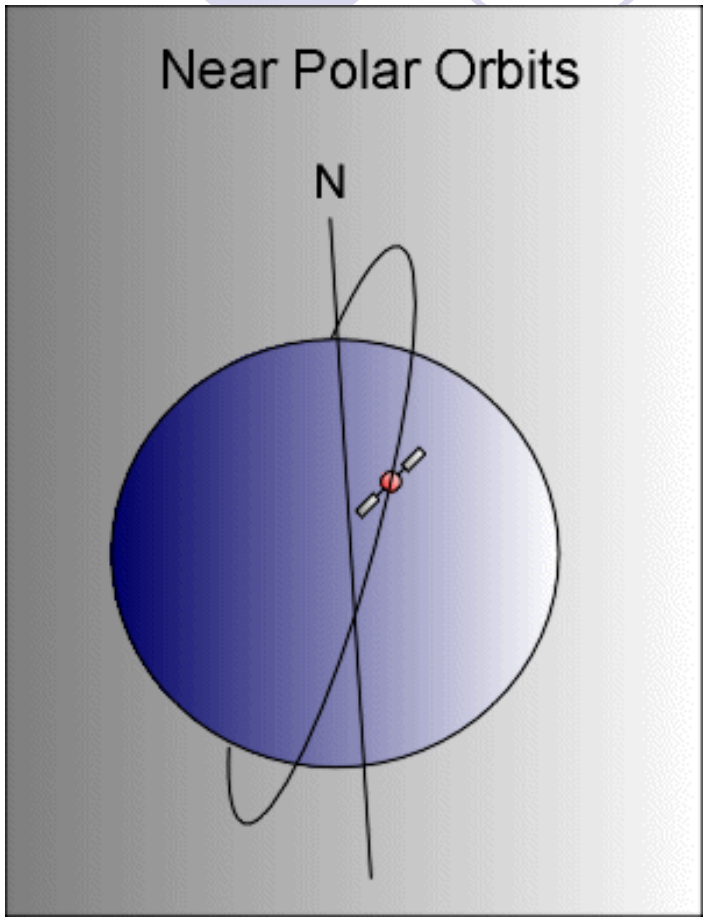
First picture transmitted by a weather satellite

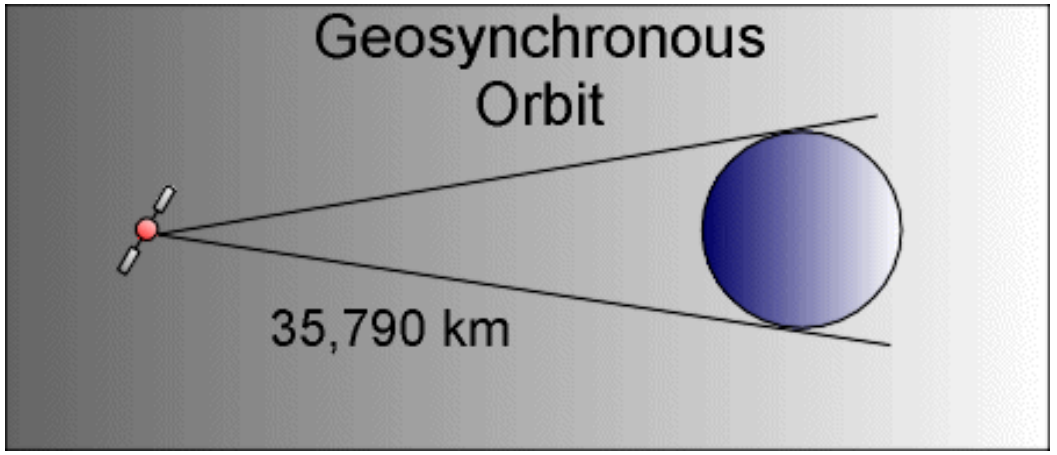




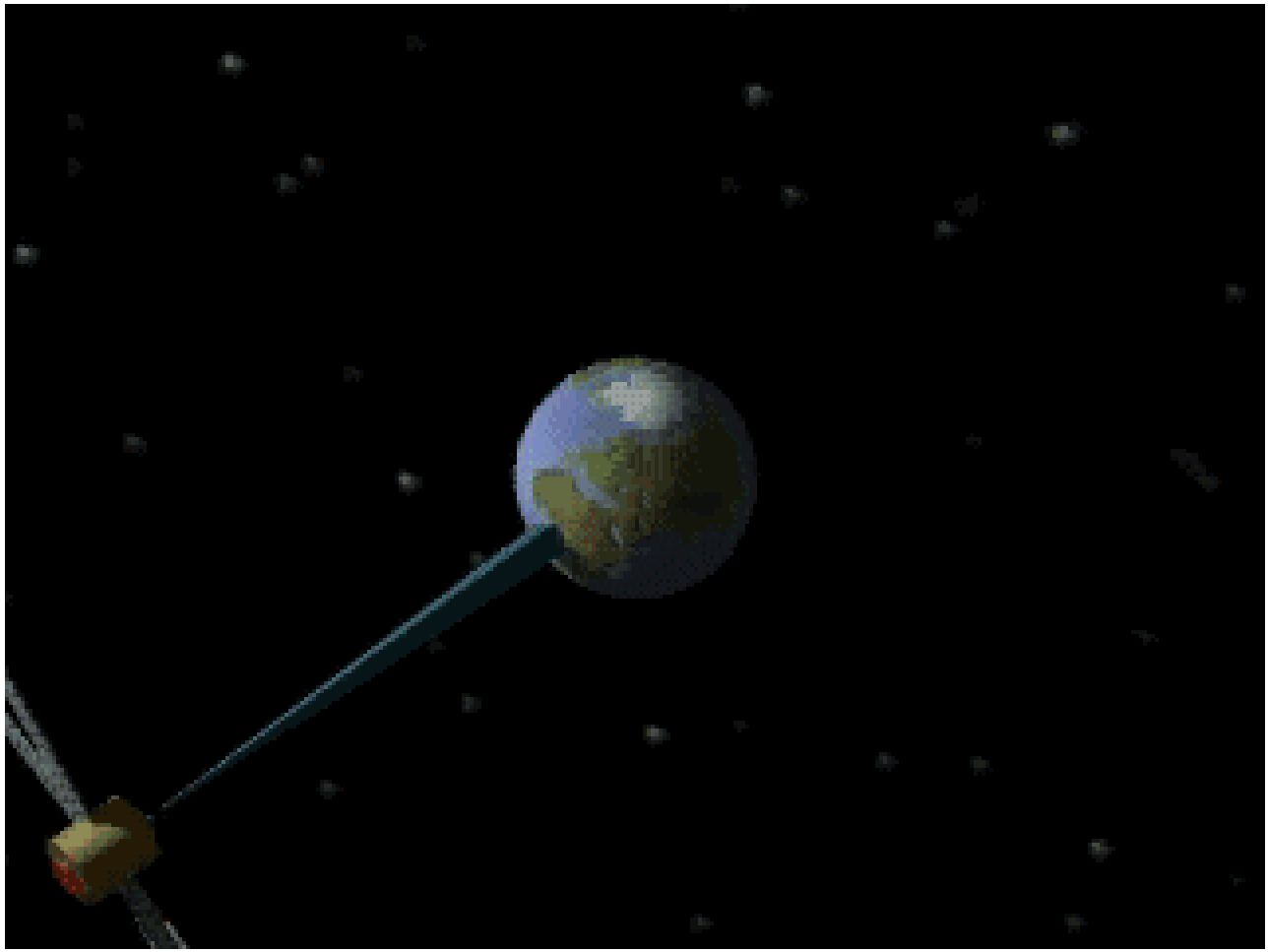
- First cloud picture from space, October, ***1946*** from V-2 rocket, altitude of 65 miles via 35 mm camera (top image).
- First weather satellite photo from ***TIROS-1, April 1, 1960 (bottom image).***
- ***TIROS Pictures available only during daytime***, between 48 deg N and S with poor ***resolution.***
- ***Early satellites were geared for research community***, but operational uses were evident.

Satellite Orbits



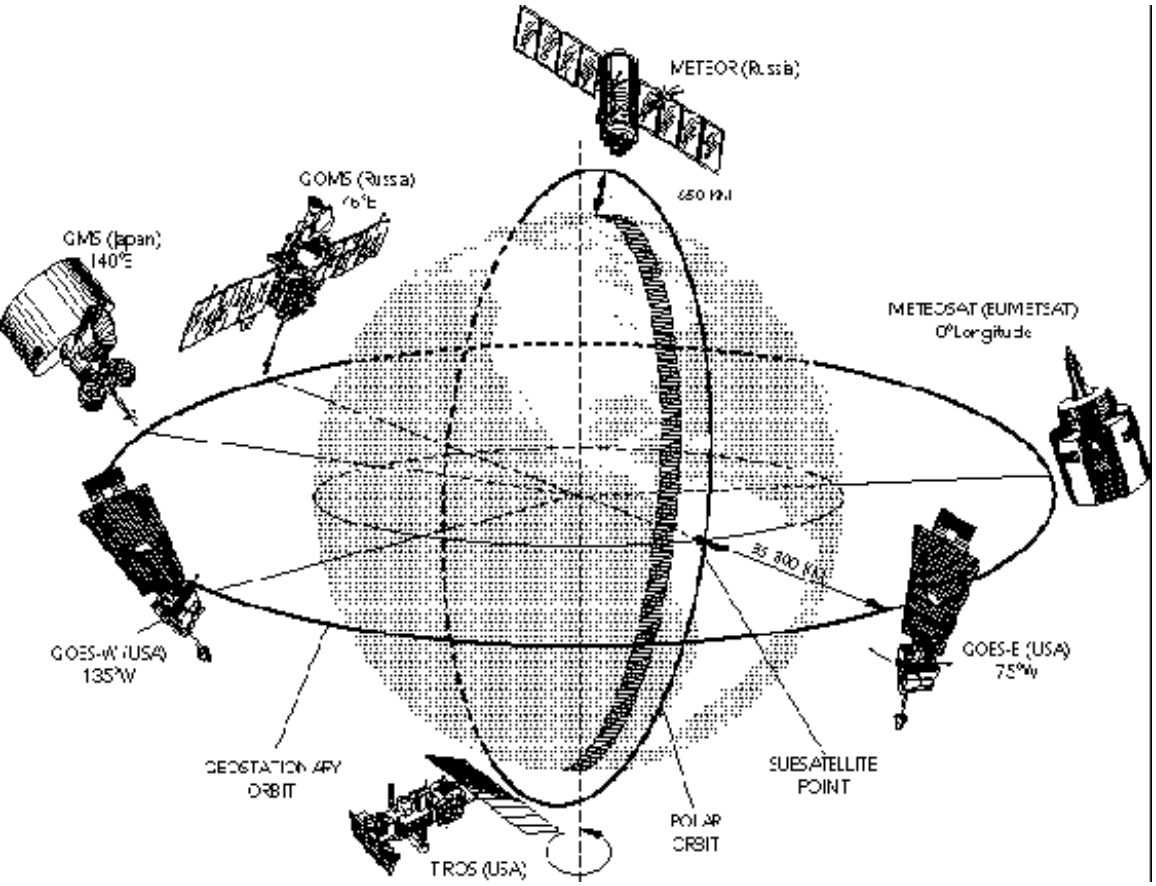


http://www.classzone.com/books/earth_science/terc/content/investigations/esu101/esu101page03.cfm?chapter_no=investigation



http://eoedu.belspo.be/en/guide/orbito.asp?section=2.4

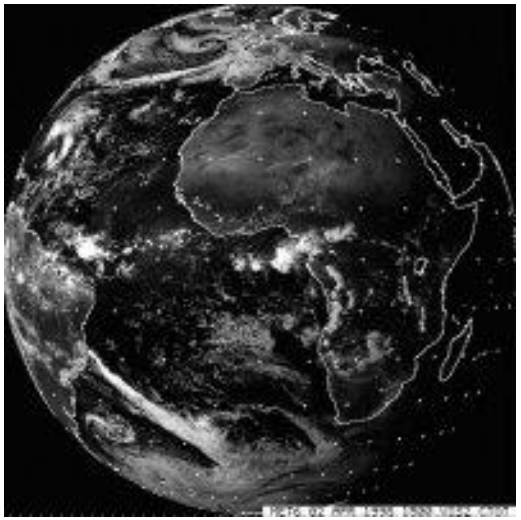
Geostationary satellites

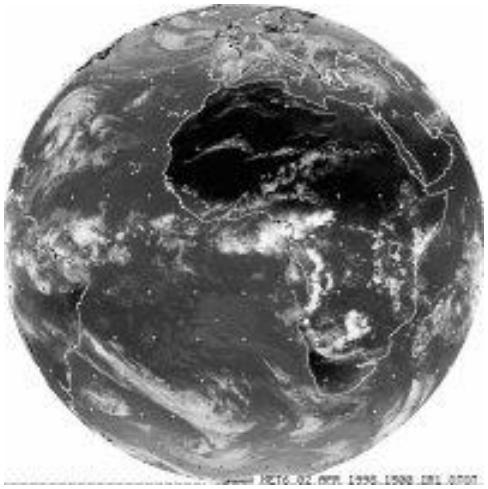


- classified by longitude of their subsatellite point
- GMS (Geostationary Meteorological Satellite)
  - Japan
  - 140E
- Insat
  - India
  - 74E
- Meteosat
  - Prime Meridian

METEOSAT

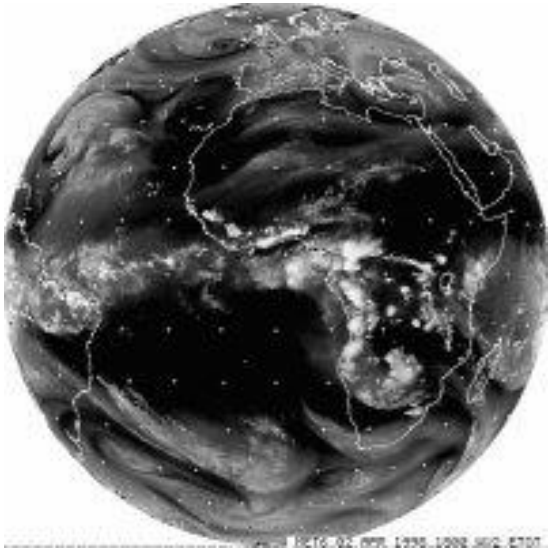
VIS

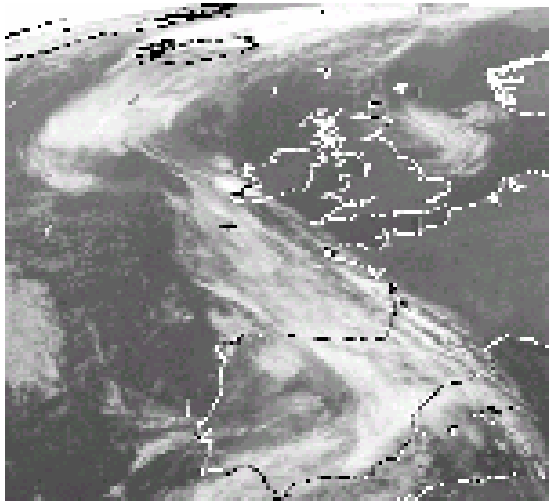




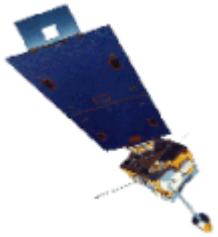
IR

WV





GOES – Geostationary Operational Environmental Satellite

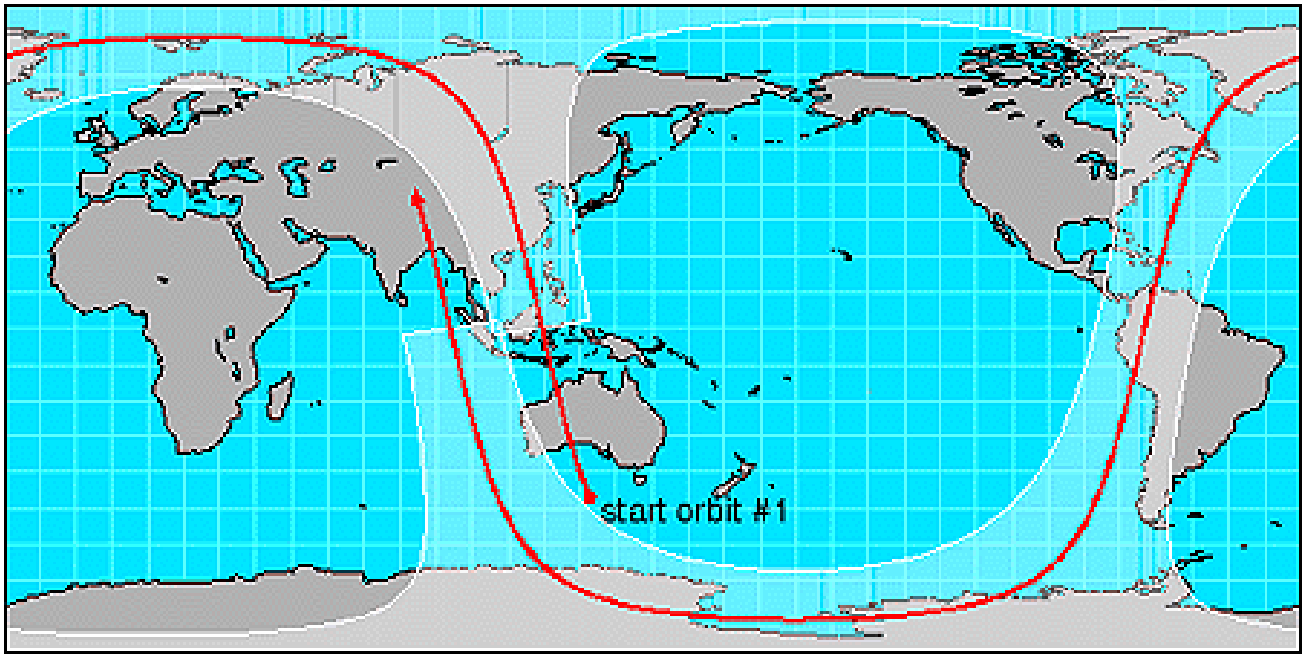


- geostationary orbit
- 75W, 135W

- 1-3 first series
- GOES 4 second generation

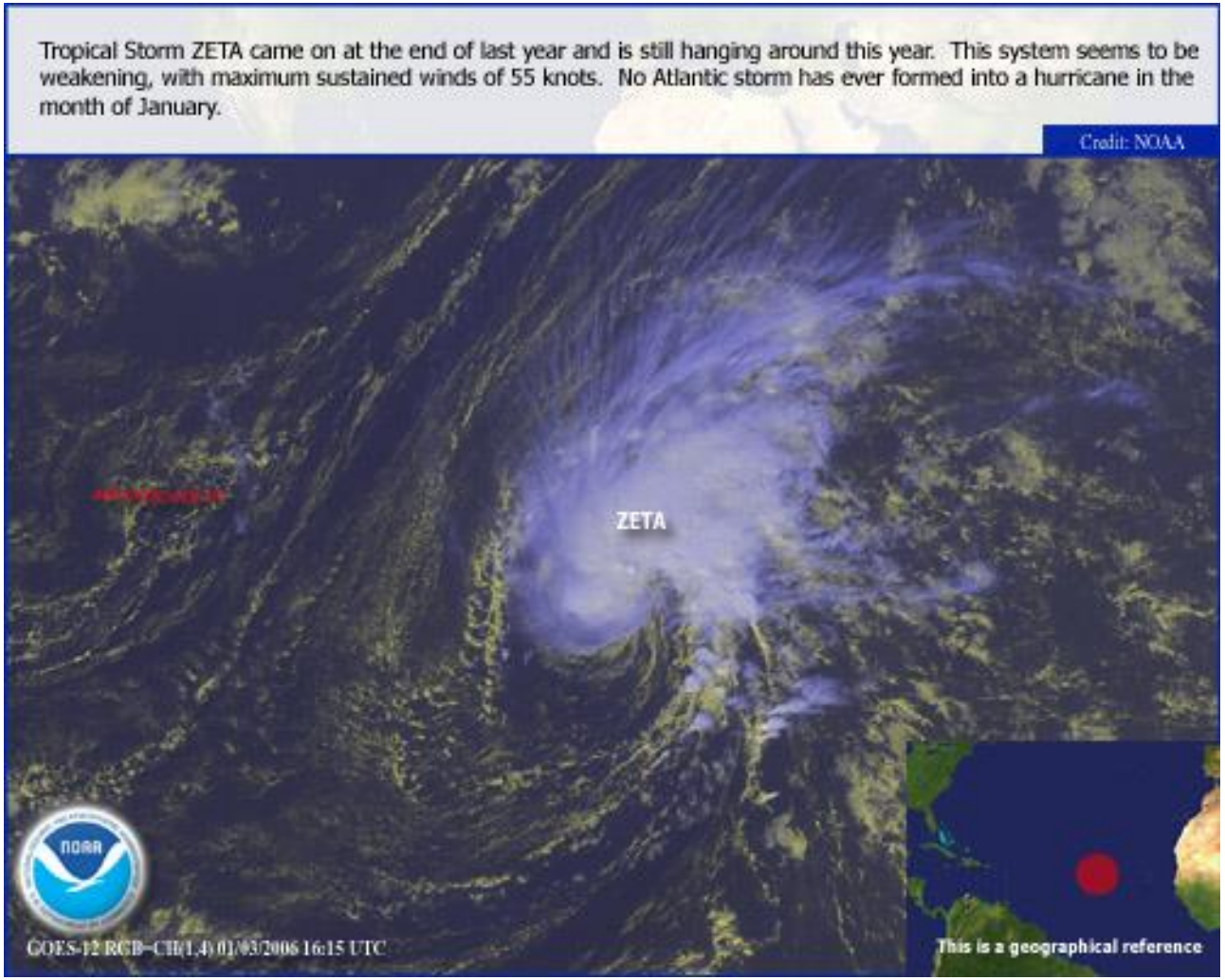
- 35,800 km (22,300 miles) altitude
- data every 30 minutes

Sunsynchronous orbits



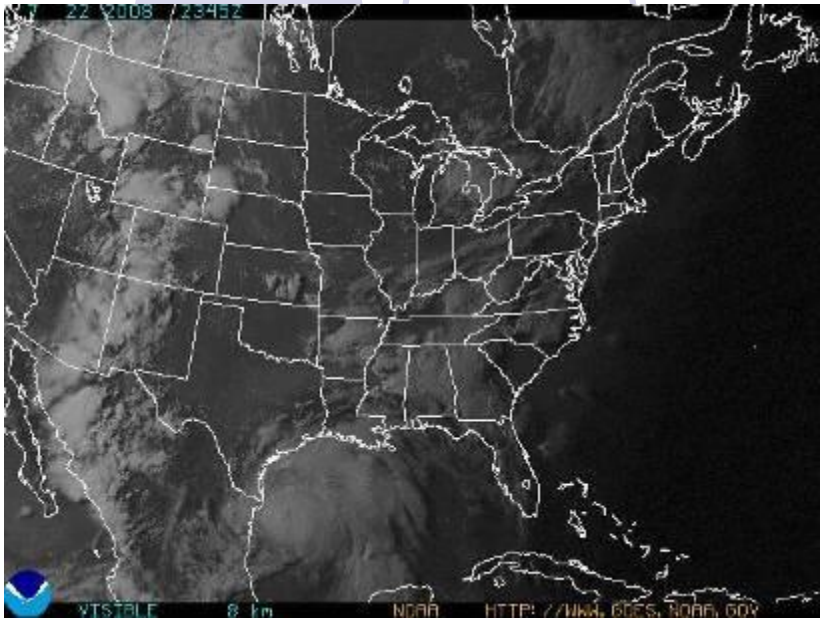
- satellite crosses the equator at the same local time every day
- orbit high latitudes - polar orbiters

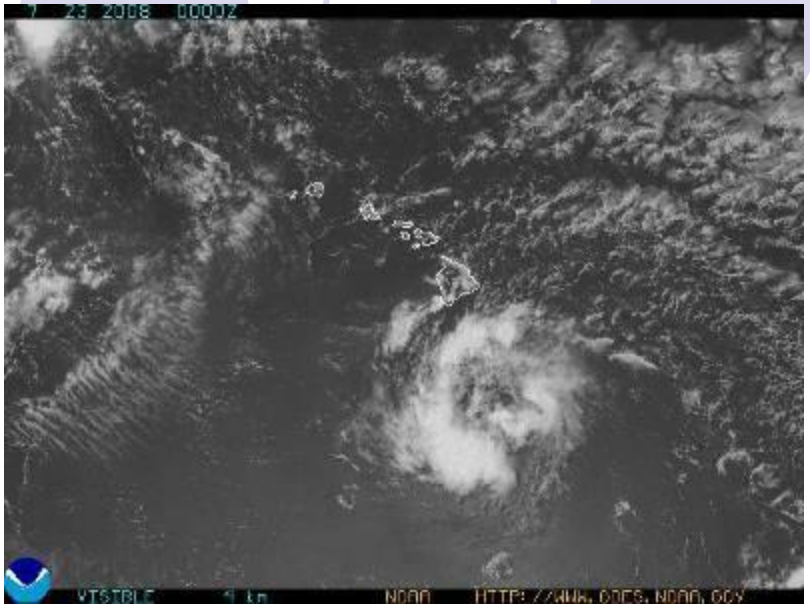
NOAA AVHRR – Tropical Storm Zeta in January 2006



GEOSTATIONARY IMAGERY

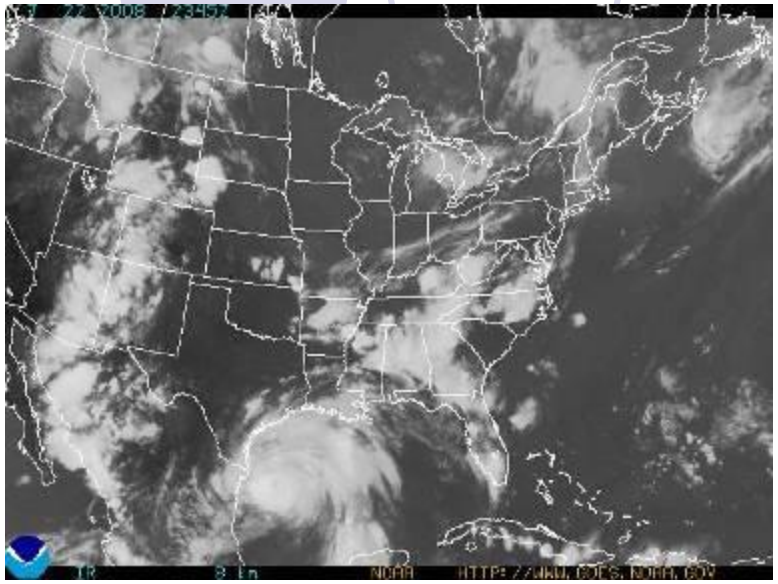
Visible satellite Imagery

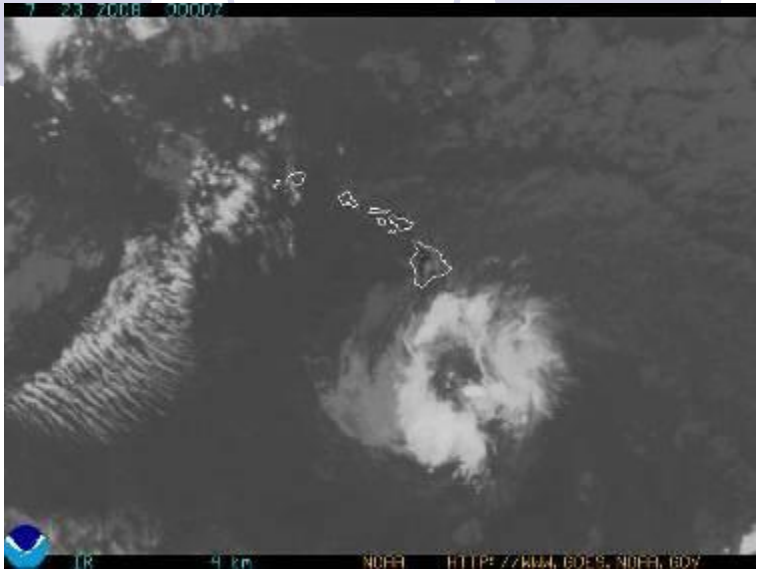




- represents sunlight scattered/reflected by objects such as clouds, land and water surfaces.
- visible images are only available during the day.
- generally, land areas are brighter than water.
- thick frontal clouds, as well as thunderstorms (western Mexico into Colorado and tropical system southeast of Texas) are bright.

Infrared Satellite Imagery





- IR picture is a display of the infrared radiation emitted by a surface and converted to temperature.
- cold objects are white (Thunderstorm convective cloud tops) and hot surfaces appear black (land areas).
- low clouds and fog are relatively warm and appear gray in IR satellite images.
- IR satellite images are available day and night ***(A bonus).***

A few satellite cloud imagery terms

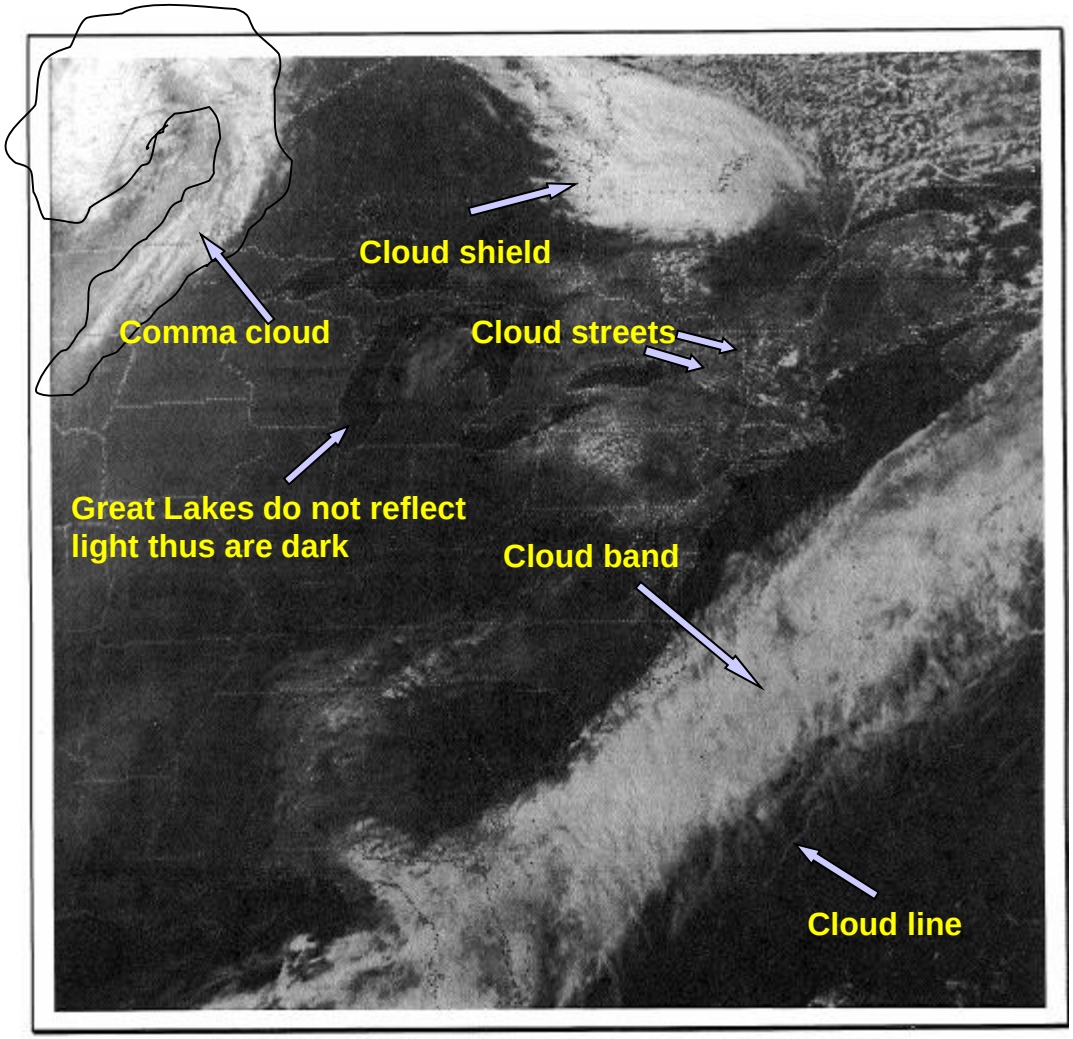
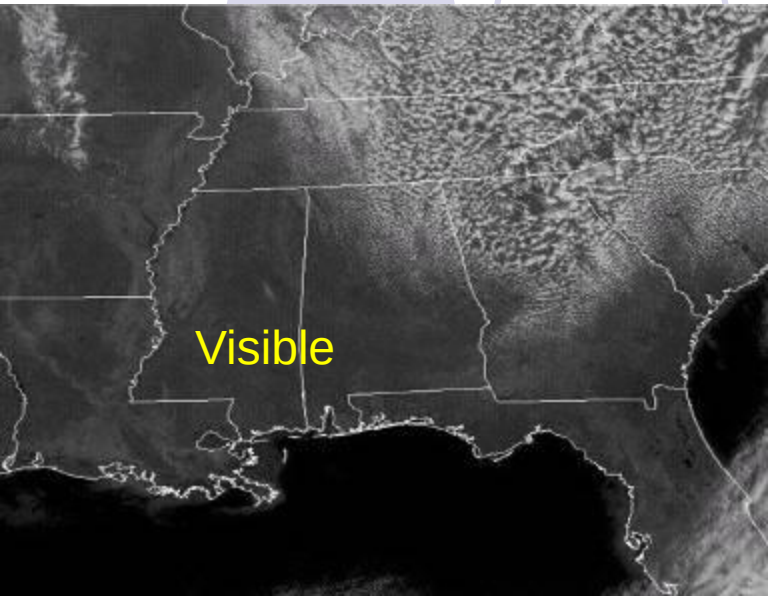
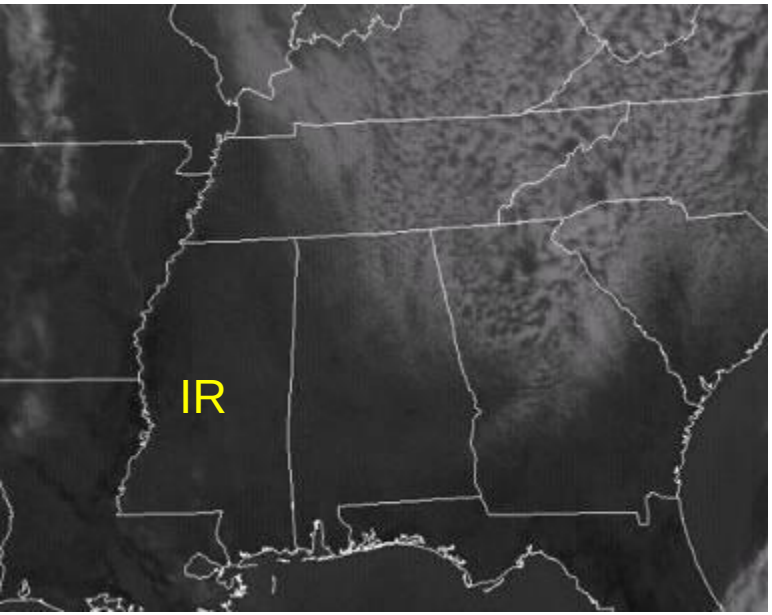


Figure 6.2. Examples of various large-scale cloud formations (GOES VIS, September 7, 1988)

- ***Comma clouds*** are generally associated with counter-clockwise flow of low pressure
- ***Cloud shield*** is a broad area of clouds not defined by a long axis
- ***Cloud streets*** line up with the low level winds
- ***Cloud bands*** (defined by long axis) are usually associated with multi-layered frontal clouds

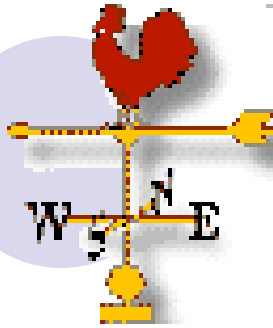
Visible (VIS) versus Infrared (IR) satellite imagery





- ***Visible images available during daylight*** hours (depend on reflectivity). ***IR available 24/7*** as they measure cloud temperature.
- ***Visible images have better resolution than IR***, showing cloud texture
- ***In visible, bright white clouds are thick or multi-layered clouds*** while thin clouds are medium grey. ***In IR, cold objects appear bright white*** and ***warm objects appear dark***
- ***Bright*** grey/white ***clouds on visible that are difficult to see on IR are*** close to the earth's surface (warm), such as ***fog or stratus***.
- ***Thunderstorms appear as bright white*** on visible (thick clouds) and IR (cold cloud tops)
- ***Cumulus and stratocumulus*** clouds have a ***lumpy*** texture as in picture to left. ***Stratus*** clouds have a ***flat dull grey*** texture.
- On ***visible images, the oceans and great lakes are generally black*** as to poor reflectivity (light absorbed) of water.

Clues to look for in satellite imagery



- ***Brightness***…in visible imagery, high brightness indicates thick clouds. In IR imagery bright clouds indicate cold high cloud tops.

- ***Cloud texture*** …convective clouds appear lumpy and may cast shadows on surrounding lower clouds. Clouds with a smooth appearance are layered type clouds, and may cast shadows from their edges onto lower clouds.

- ***Organization or structure*** …cellular or banded. Celluar clouds are usually convective while banded clouds are frequently associated with fronts.