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

10 September 2000

12 October 2000

23 October 2000

Harvard Forest
Hurricane Ivan: 15 Sept 04 approaching the Gulf Coast

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.

Credit line for all images: Provided by the SeaWiFS Project, NASA Goddard Space Flight Center, and ORBIMAGE
Electromagnetic radiation (EMR)
Electromagnetic radiation

- electric field (E)
- magnetic field (M)
- perpendicular and travel at velocity, \( c = (3 \times 10^8 \text{ ms}^{-1}) \)
Wave: terms

• All waves characterised by:
  • wavelength, \( \lambda \) (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)
THE ELECTROMAGNETIC SPECTRUM

increasing wavelength

non-ionizing

ionizing

increasing energy

wavelength

TYPE OF RADIATION

extremely low frequency

radio

microwaves

infrared

visible

ultra violet

X-rays

gamma rays

SOURCES

power lines

AM radio

FM radio

TV

microwave oven

radiant heat

arc welding

medical X-rays

radioactive sources

• We will see how energy is related to frequency, \( f \) (and hence inversely proportional to wavelength, \( \lambda \))

• When radiation passes from one medium to another, speed of light (c) and \( \lambda \) change, hence \( f \) stays the same
Electromagnetic spectrum

- 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

Near Polar Orbits

Geosynchronous Orbit
35,790 km

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

- classified by longitude of their subsatellite point

- GMS (Geostationary Meteorological Satellite)
  - Japan
  - 140E

- Insat
  - India
  - 74E

- Meteosat
  - Prime Meridian
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
Tropical Storm ZETA came on at the end of last year and is still hanging around this year. This system seems to be weakening, with maximum sustained winds of 55 knots. No Atlantic storm has ever formed into a hurricane in the month of January.
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

- **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.

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