# Fundamentals of Remote Sensing

# Objective

To provide a basic understanding of satellite remote sensing and related attributes required for using remote sensing data for environmental applications

# Outline

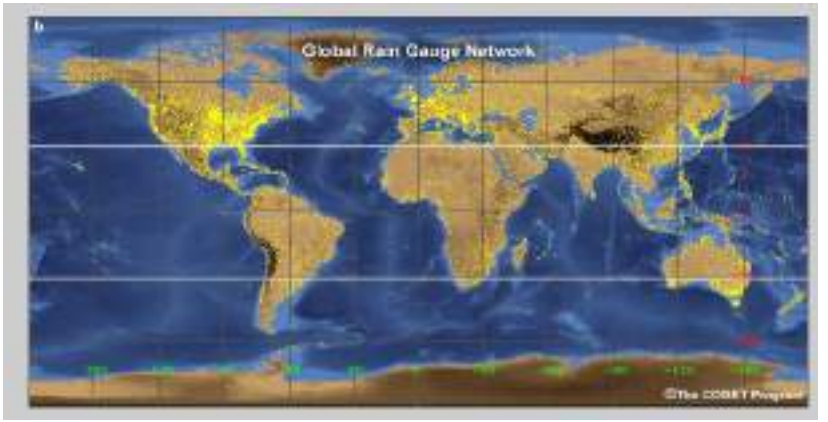
- Advantages of Satellite Remote Sensing
- Basics of Satellite Remote Sensing
- Types of Satellite Sensors
- Satellite Remote Sensing Attributes
- Remote Sensing Data Processing Levels

# Advantages of Satellite Remote Sensing

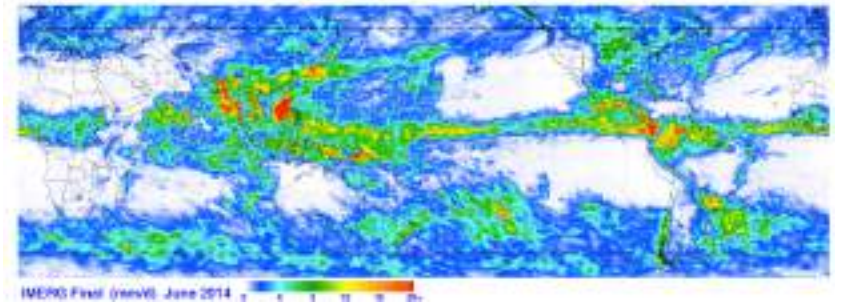
# Remote Sensing Augments Surface Observations

- Provides information where surface-based measurements are not available and augments existing measurements
- Provides global/near-global coverage with consistent observations

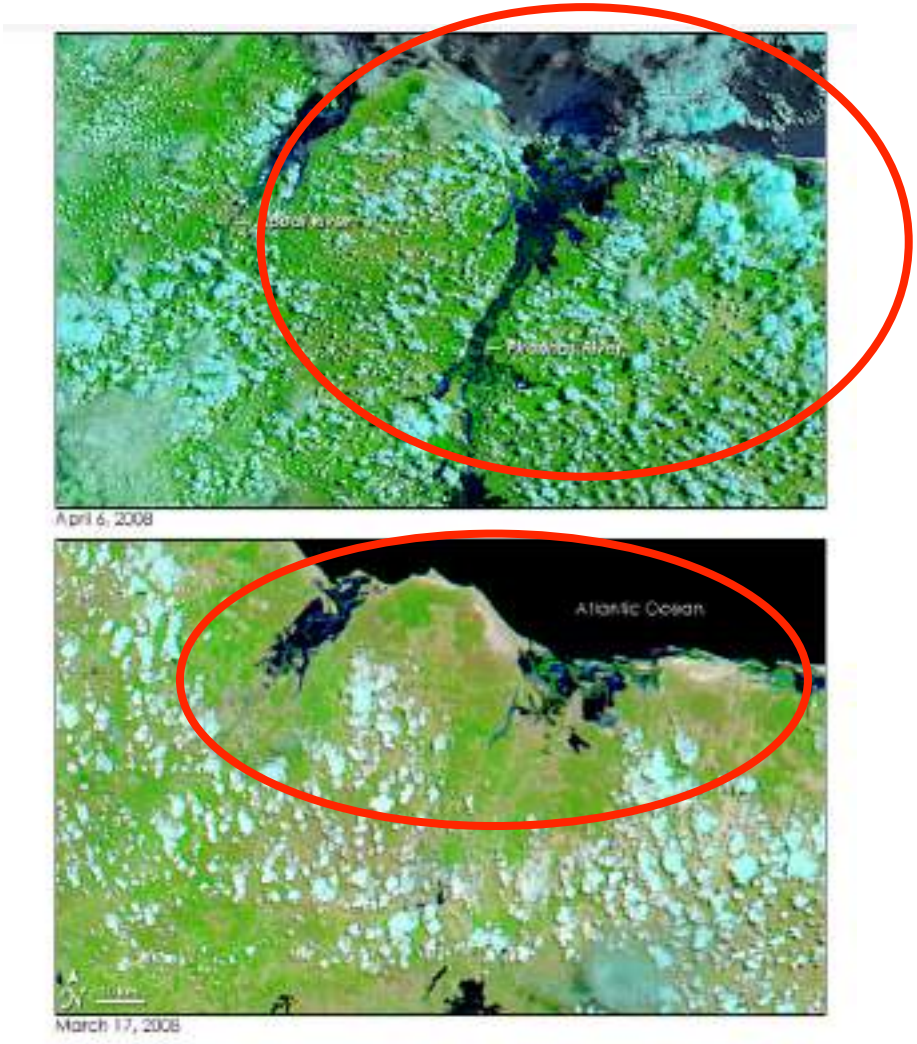
Non-uniform Coverage
of Surface Measurements




Continuous Coverage
From TRMM Multi-satellite Precipitation



# Remote Sensing observations continuous, large-scale coverage compared to point measurements




**From NASA Earth Observatory**

http://earthobservatory.nasa.gov/IOTD/view.php?id=8641

These images are from the Moderate Resolution Imaging Spectroradiometer (MODIS) sensors on NASA's Terra and Aqua satellites.

The images show flooding conditions in Piranhas and the Apodi Rivers in Brazil. The rivers are much wider on April 6, 2008 (upper image) than on March 17, 2008 (lower image).

# Basics of Satellite Remote Sensing

# What is Remote Sensing?

Measurement of a quantity associated with an object by a device not in direct contact with the object

- Platform depends on application
- What information?  how much detail?
- How frequent?

# What is Satellite Remote Sensing?

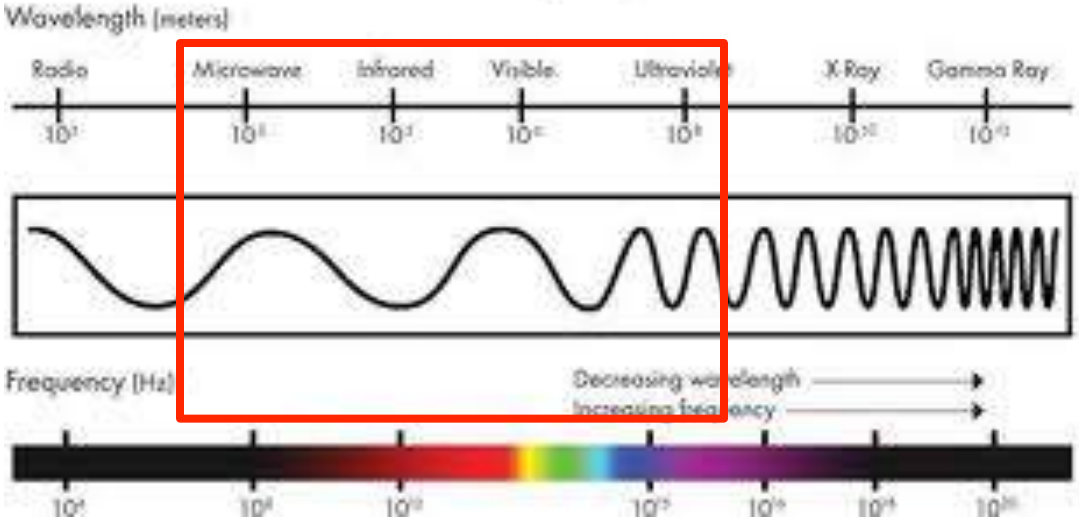
Measuring properties of the earth-atmosphere system from space

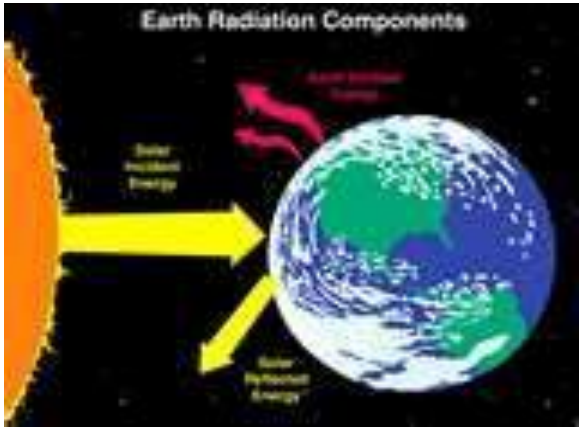
Earth-Ocean-Land-Atmosphere System :

- reflects solar radiation back to space
- emits infrared radiation and microwave radiation to space

- Satellites carry **instruments or sensors which measure electromagnetic radiation** coming from the earth-atmosphere system

The Electromagnetic Spectrum

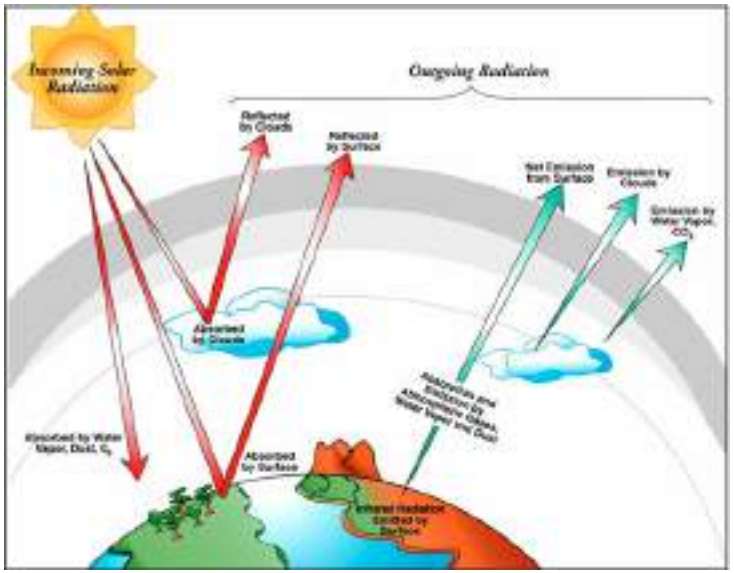


# Measuring Properties of the Earth-Atmosphere System from Space

- The intensity of **reflected** and **emitted radiation** to space is influenced by surface and atmospheric conditions

- Thus, satellite measurements contain information about surface and atmospheric conditions



# Types of Satellite Sensors

# Satellite Sensors

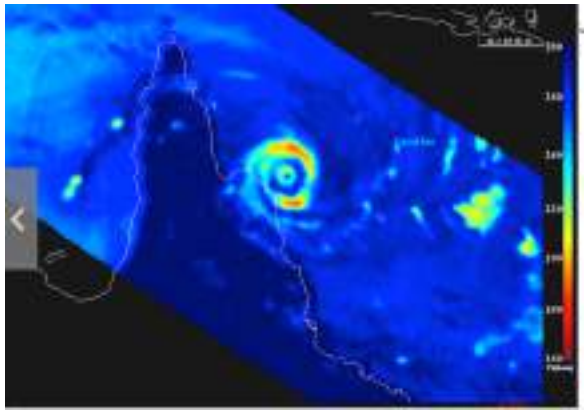
## Passive remote sensors

measure radiant energy reflected or emitted by the earth-atmosphere System

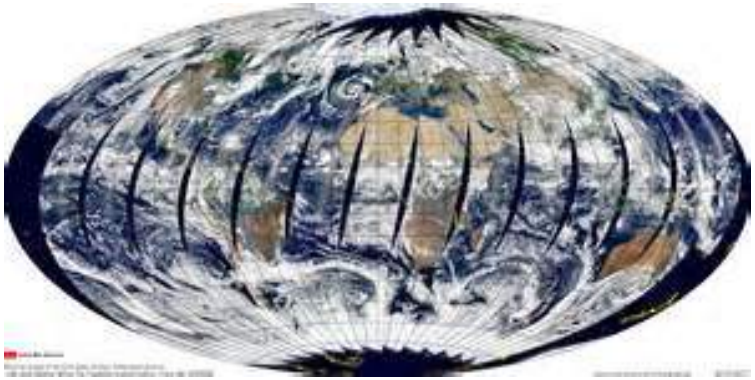
Radiant energy is converted to bio-geophysical quantities such as temperature, precipitation, soil moisture, chlorophyll-a

Examples: TRMM Microwave Imager, MODIS, AIRS

TRMM TMI 85 GHz Microwave Image
cimss.ssec.wisc.edu



MODIS Reflectance Image
earthobservatory.nasa.gov

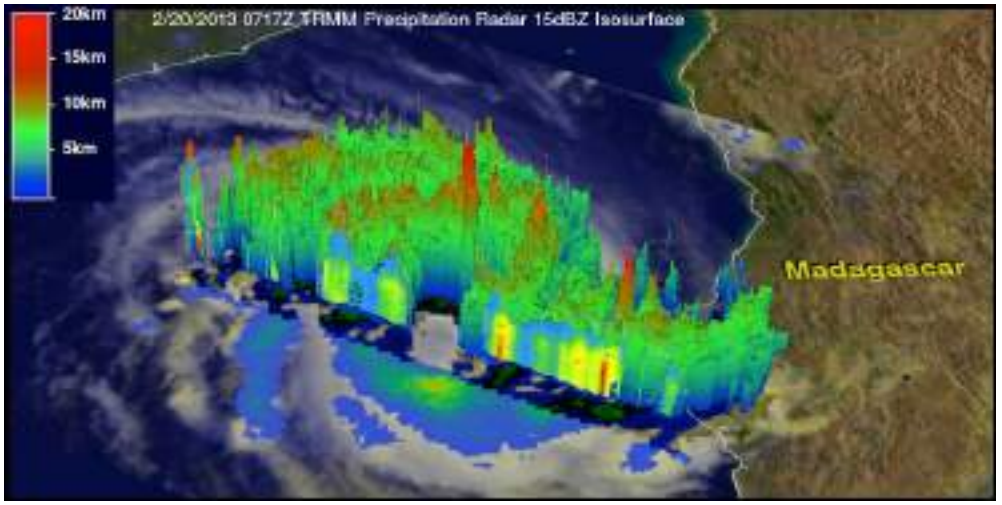


# Satellite Sensors

**Active remote sensors**
'throw' beams of radiation on the earth-atmosphere system and measure 'back-scattered' radiation

The back-scattered radiation is converted to geophysical quantities

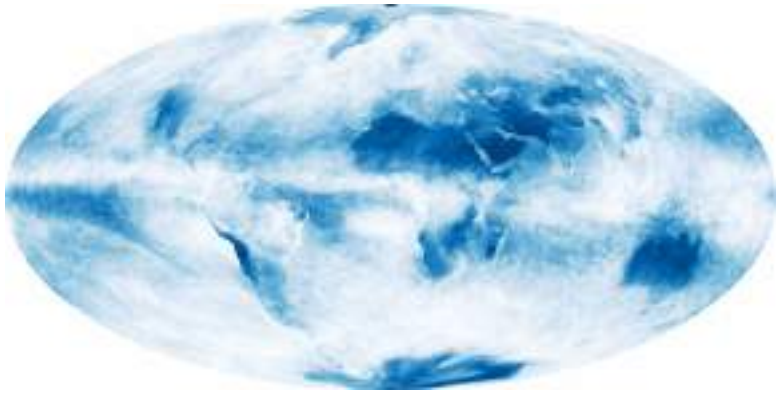
Examples: Radar, LIDAR




The 3-D image was derived from a TRMM Precipitation Radar (PR) slice through tropical storm Haruna's center pmm.nasa.gov

# Satellite Sensors

**Cloud Image from MODIS**



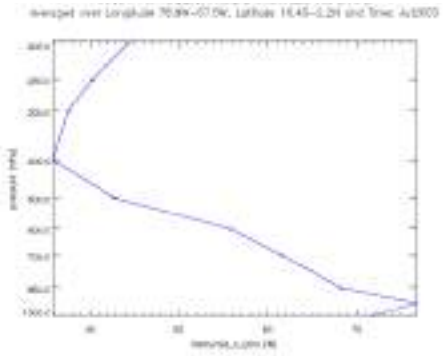
**Imagers:** Create Images

Examples: MODIS, TMI

**Sounders:** Provide vertical profiles

Examples: AIRS

**Regional Relative Humidity Profile from AIRS**



# Satellite Remote Sensing Attributes

# Spatial and Temporal Resolutions of Satellite Measurements

## Depend on the satellite orbital configuration and sensor design

- **Spatial Resolution:**

  Determined by its pixel size -- pixel is the smallest unit measured by a sensor

- **Spatial Coverage:**

  The geographical area covered by a satellite

- **Temporal resolution:**

  How frequently a satellite observes the same area of the earth

- **Temporal Coverage:**

  Time span or life-time of a satellite for which measurements are available

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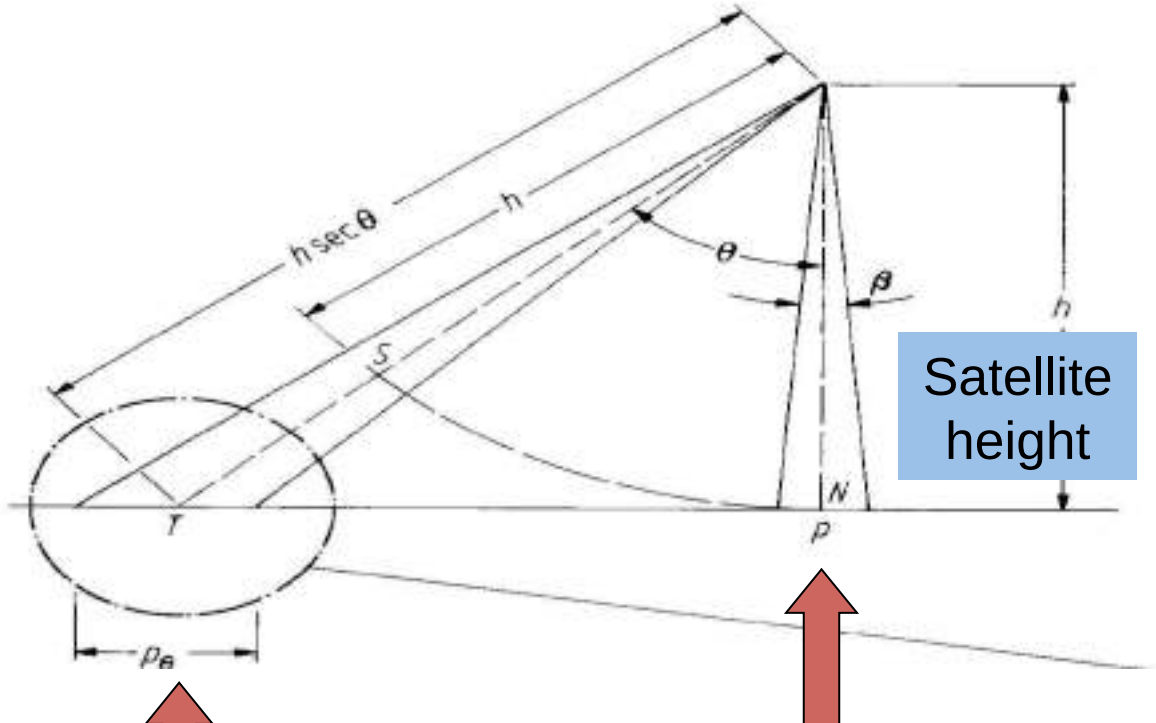
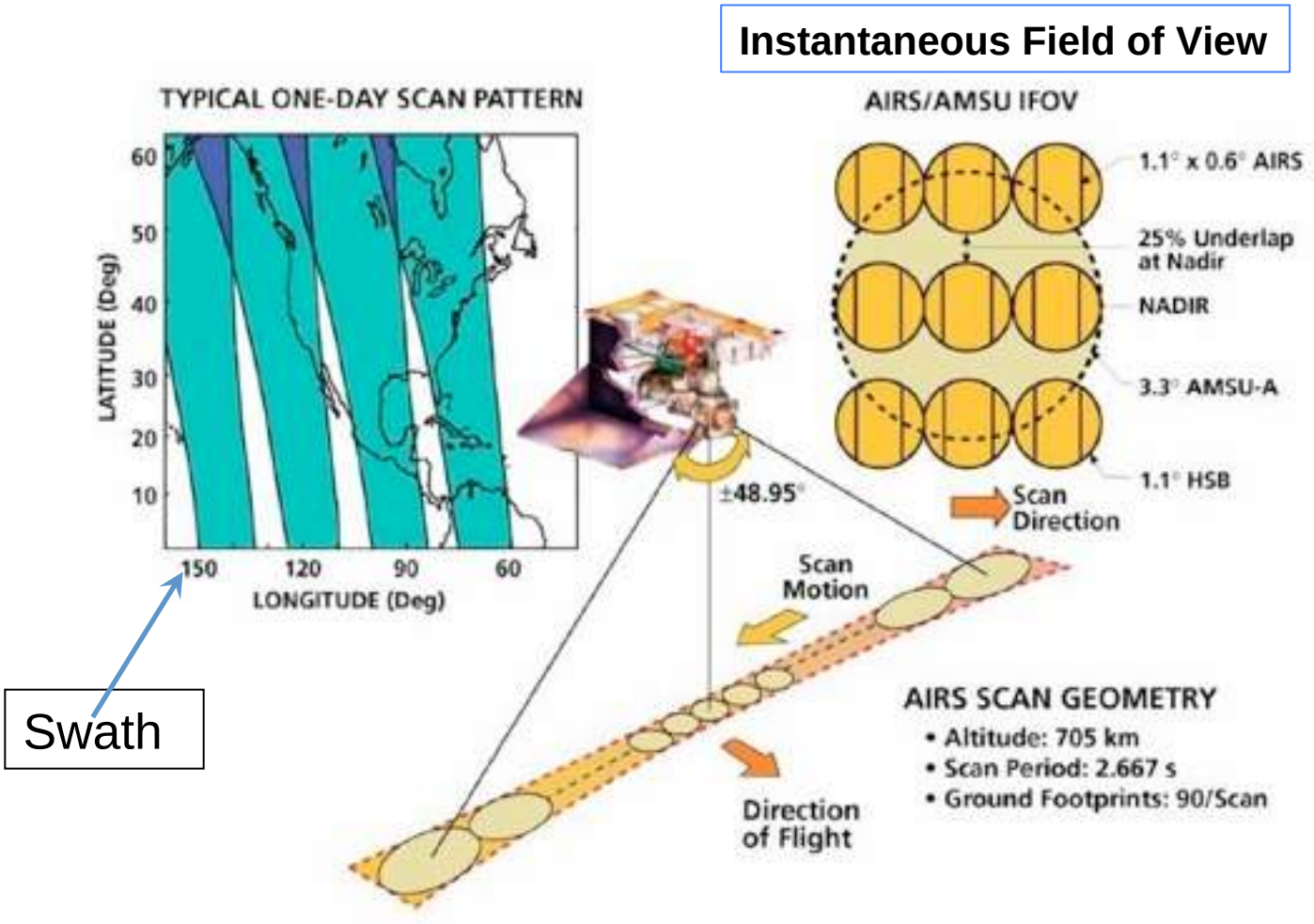
# Spatial Resolution

- A simple definition is the pixel size - smallest size - that satellite images cover
- Satellite images are organized in rows and columns called raster imagery and each pixel has a certain spatial size



# Spatial resolution

## Example (AIRS -- Atmospheric Infrared Sounder)



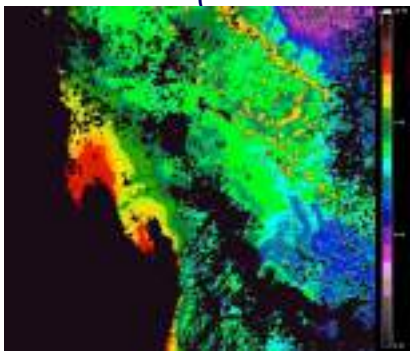

AIRS is flying aboard NASA's Aqua satellite

# Spatial Resolution

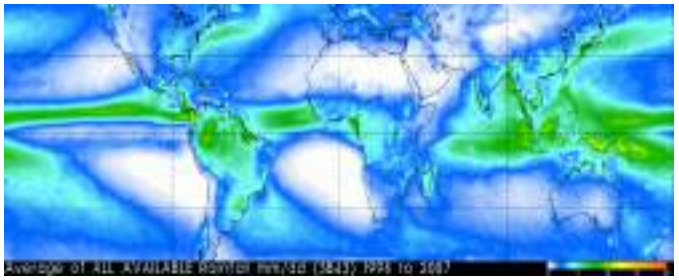
## Varies with satellite/sensor

**Landsat-7 Image of Niger River Delta**
Spatial resolution: 30 m

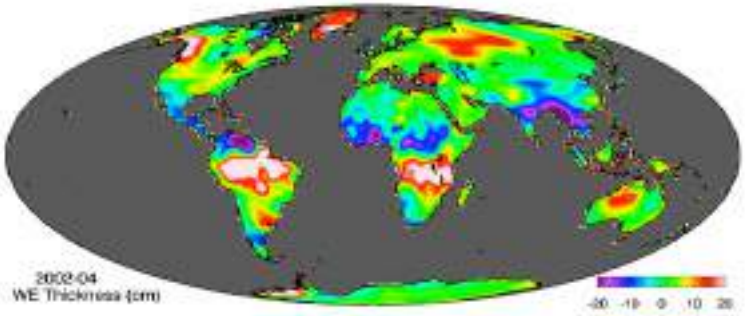
**Chlorophyll from Terra/MODIS:**
Spatial resolution: 1 km



**TRMM and Multi-satellite Rain Rate**
Spatial resolution: 25 km



**Terrestrial Water Storage Variations from GRACE:** Spatial resolution: ~100 km or coarser **(**Courtesy: Matt Rodell, NASA-GSFC)



# Spatial Coverage and Temporal Resolution of Satellite Measurements

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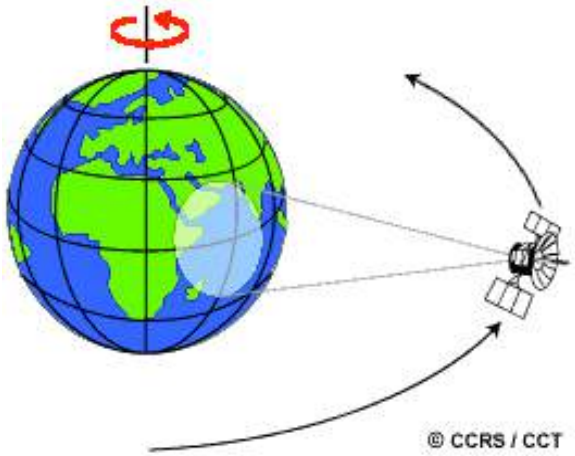
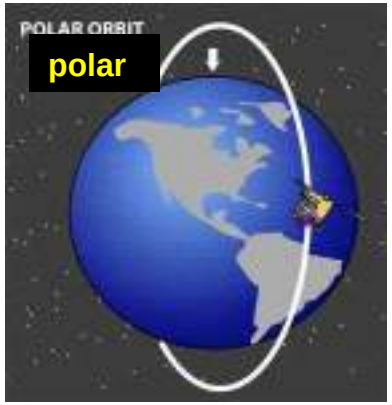
# Types of Satellite Orbits

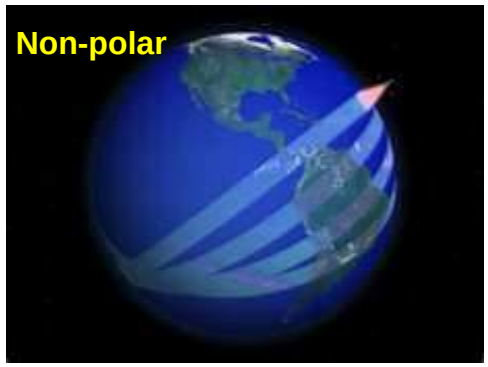
## Geostationary orbit



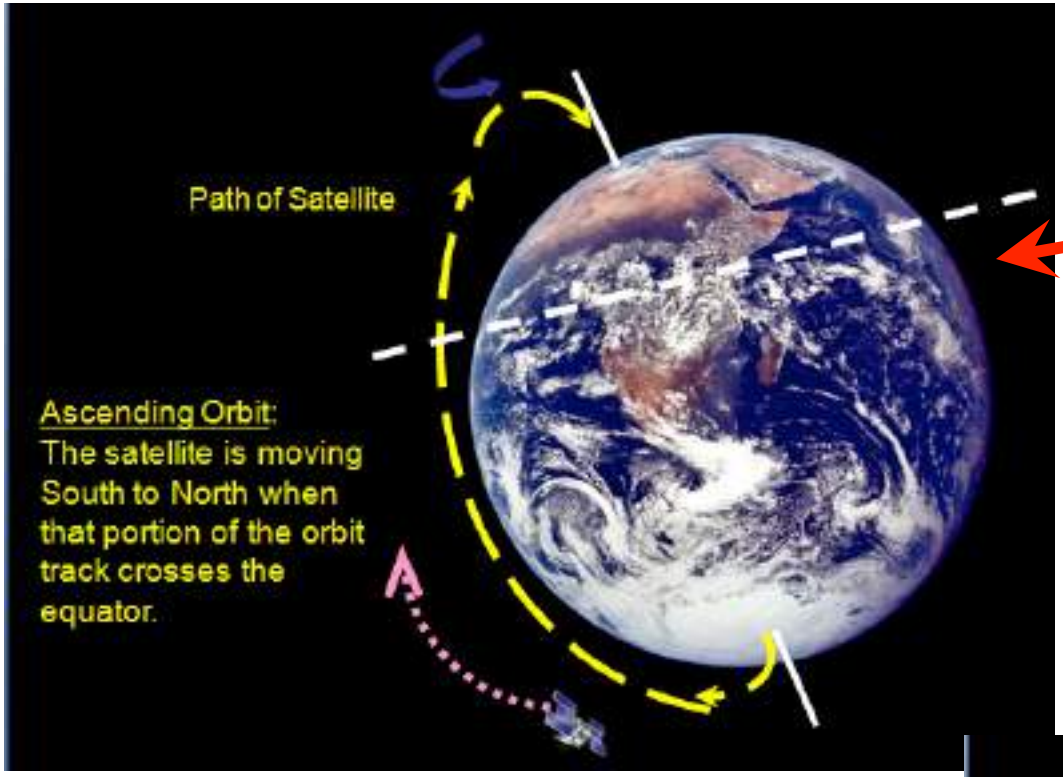

Satellite is ~36,000 km above earth the equator. Same rotation period as earth's. Appears 'fixed' in space.

## Low Earth Orbit (LEO)

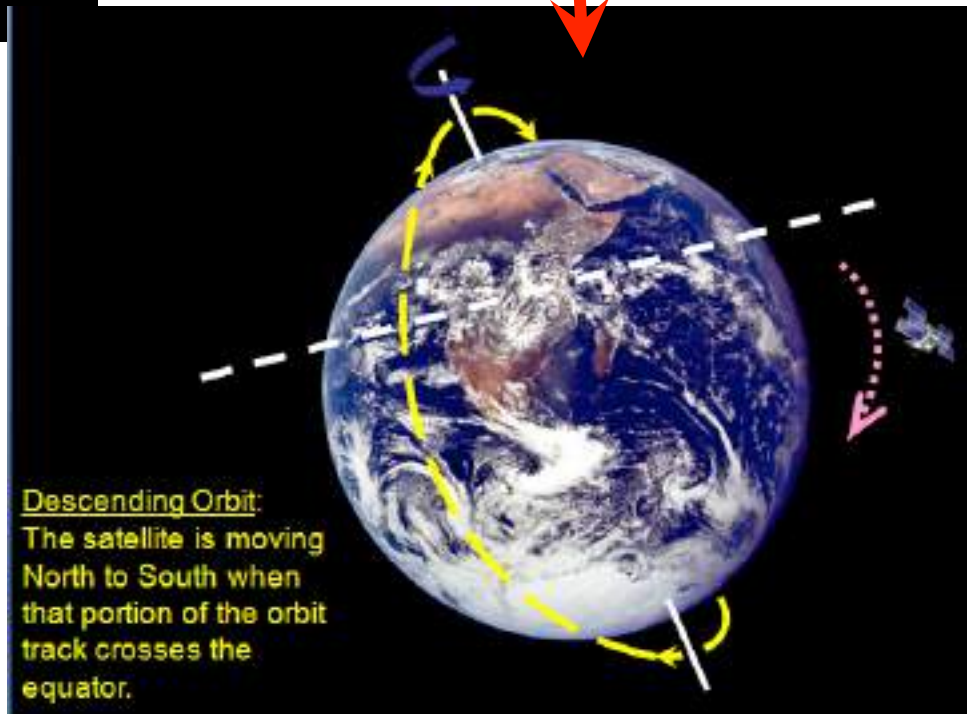



Circular orbit constantly moving relative to the Earth at 160-2000 km. Can be in Polar or non-polar orbit




# Ascending vs Descending




## Polar Orbits

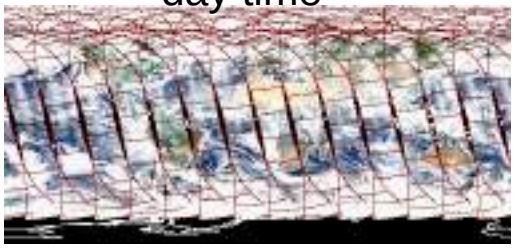
# Spatial Coverage and Temporal Resolution of Satellite Measurements

**Polar orbiting satellites:** global coverage - but one to two or fewer measurements per day per sensor. Orbital gaps present. Larger the Swath size, higher the temporal resolution.

**Non-Polar orbiting satellites:** Less than one per day. Non-global coverage. Orbital gaps present. Larger the Swath size, higher the temporal resolution.

**Geostationary satellites:** multiple observations per day, but limited spatial coverage, more than one satellite needed for global coverage.

Aqua ("ascending" orbit) day time



TRMM Image

GOES Image

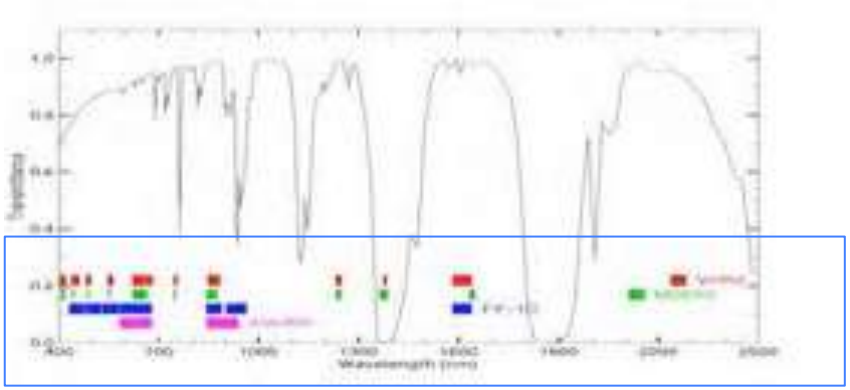
# Spectral and Radiometric Resolutions

## Spectral Resolution:

The number and width of spectral channels. More and finer spectral channels enable remote sensing of different parts of the atmosphere

## Radiometric Resolution:

Remote sensing measurements represented as a series of digital numbers – the larger this number, the higher the radiometric resolution, and the sharper the imagery



Spectral Bands and Resolution for various sensors
cimss.ssec.wisc.edu

# Remote Sensing Data Processing Levels

# Remote Sensing Data Processing Levels

**Level 0** Raw Instrument Data

**Level 1** Geolocated and Calibrated

**Level 2** Geophysical Data Product Derived from L1 Data

**Focus of this training**

**Level 3** Composites Of Level 2 Data Products

**Level 4** Model-derived Data Product

**Less Processing**

**Orbital Data**

- More user control
- Highest spatial/temporal resolution
- Harder to use

**More Processing**

**Gridded Data Products**

- Less user control
- Lower spatial/temporal resolution but gridded and may be available at multiple spatial/temporal resolutions
- More web-tools available for analysis/access
- Easier to use

# Remote Sensing Data and Products

GPM/TRMM Satellite Images or L1 Data are either in the form of brightness temperatures or radar reflectivity

**Algorithms**

L2 and L3 Precipitation Products are derived from L1 Data

The Precipitation Products are used in various applications

Any information can be referred to as ‘Data’ and often ‘Data’ and ‘Data Products’ are used synonymously

# Remote Sensing Data Formats

- **Text/ASCII**

  pros: easy to read and examine the data right away (can be read with tools such as excel and GIS software)

  cons: large data files, not always available.

- **Binary – HDF, NetCDF, OpenDAP**

  pros: takes less space, more information (metadata, SDS)

  cons: need specific tools or code to read the data

- **KML or KMZ (zipped KML)**

  pros - easy 2D and 3D visualization of the data through free tools such as Google Earth. Data files are smaller in size and easier to download

- **Shapefiles/Geotiff**

  GIS Applications. May or may not work with open source

**Next Presentation will be on:**

Introduction to NASA Remote Sensing Missions and Earth System Models, and Data Access Tools Relevant for Monitoring Climate Variability and Flooding