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

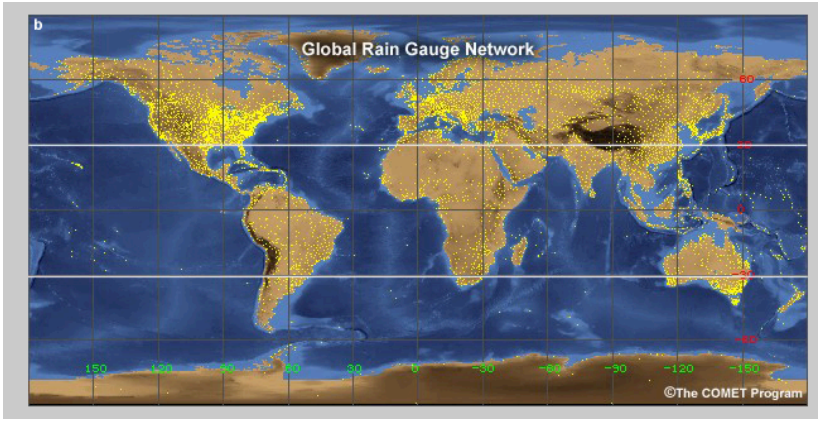
- Advantages of Satellite Remote Sensing
- Basics of Satellite Remote Sensing
- Types of Satellite Sensors
- Satellite Remote Sensing Attributes
- Remote Sensing Data Processing Levels

Advantages of Satellite Remote Sensing

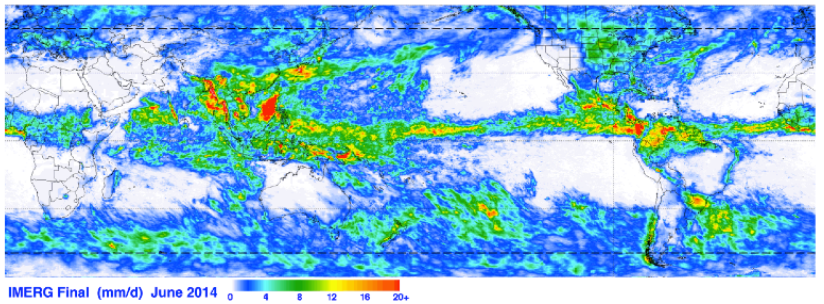
Remote Sensing Augments Surface Observations

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

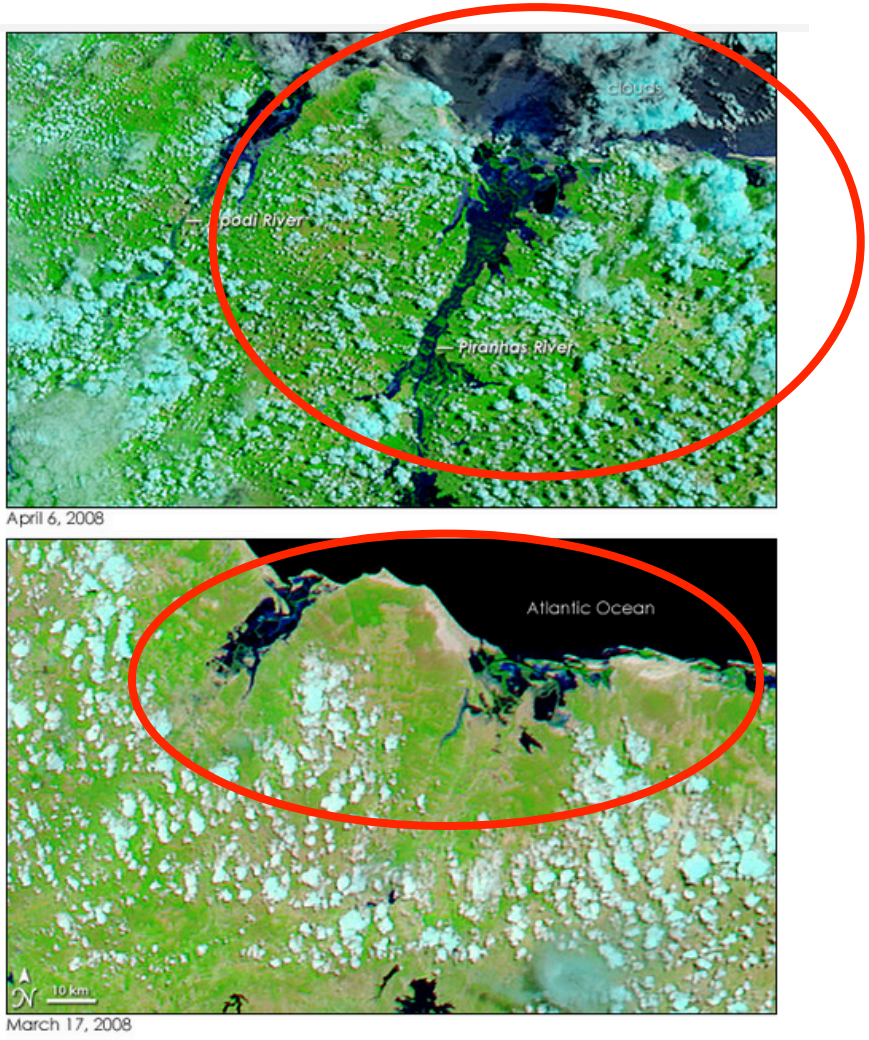
Non-uniform Coverage
of Surface Measurements



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?

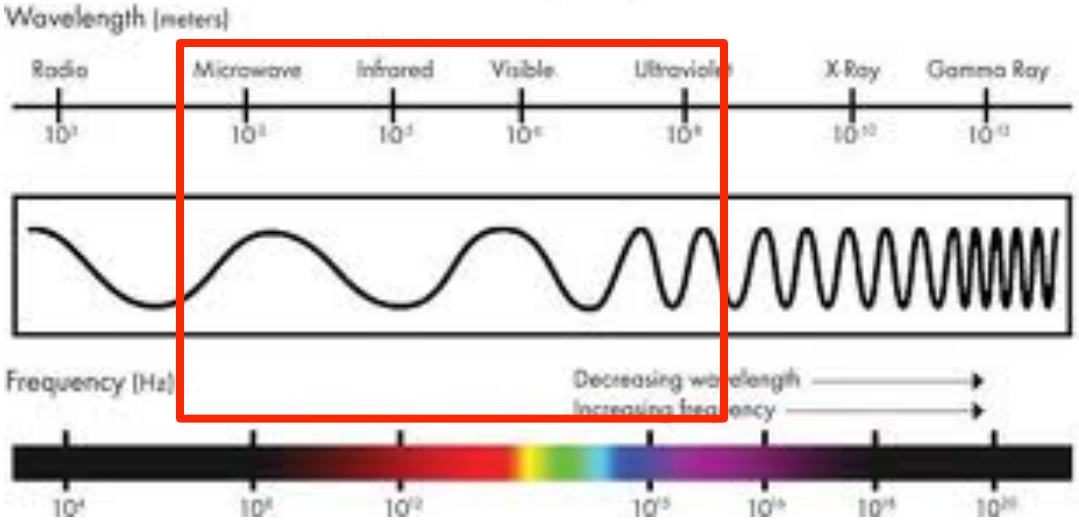
Measuring properties of the earth-atmosphere system from space

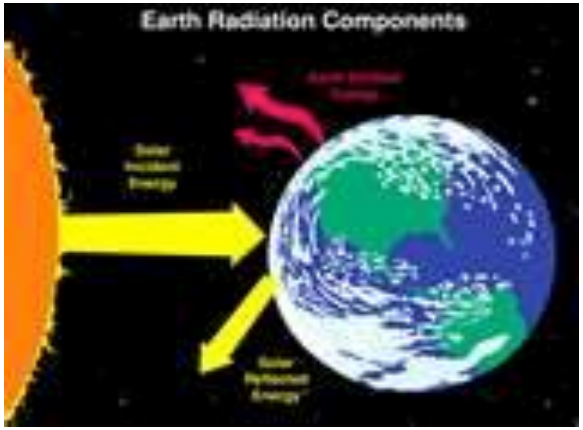
Earth-Ocean-Land-Atmosphere System :

- 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

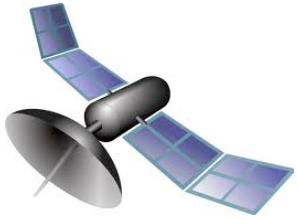


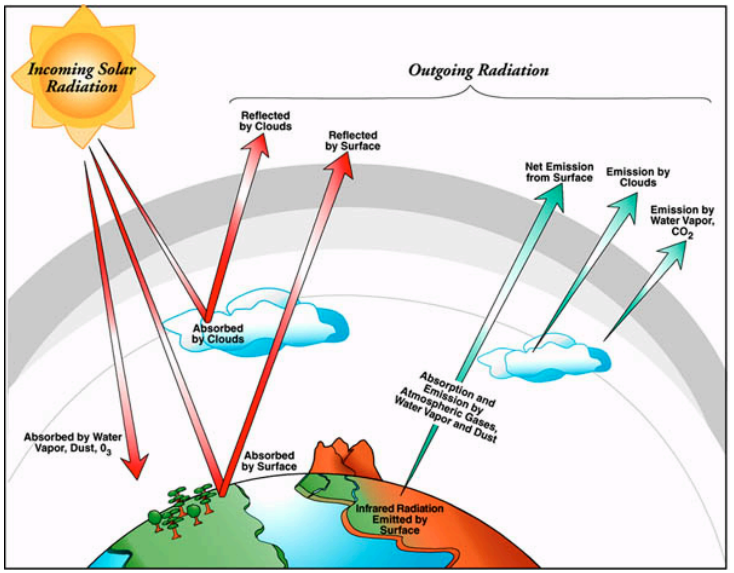


Measuring Properties of the Earth-Atmosphere System from Space

- 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

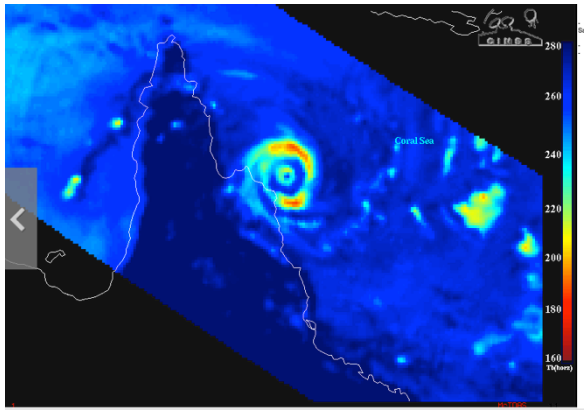
Passive remote sensors

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

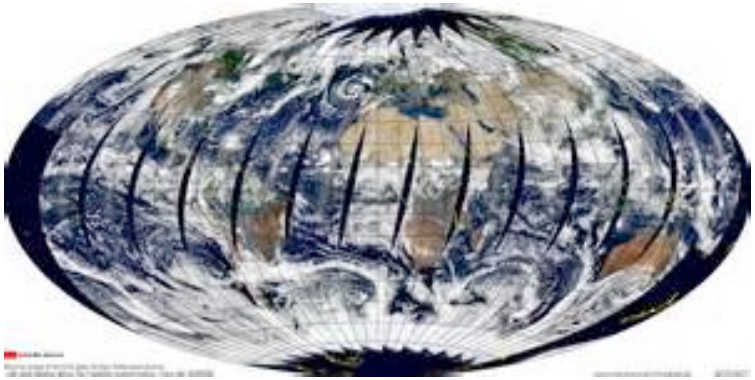
Radiant energy is converted to
bio-geophysical quantities
such as temperature,
precipitation, soil moisture,
chlorophyll-a

Examples: TRMM Microwave
Imager, MODIS, AIRS

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



MODIS Reflectance Image
earthobservatory.nasa.gov

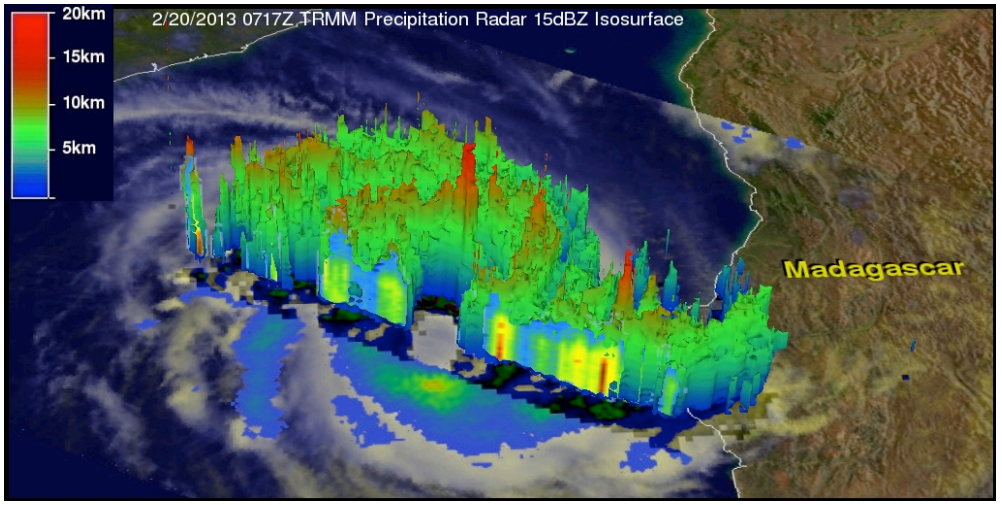


Satellite Sensors

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

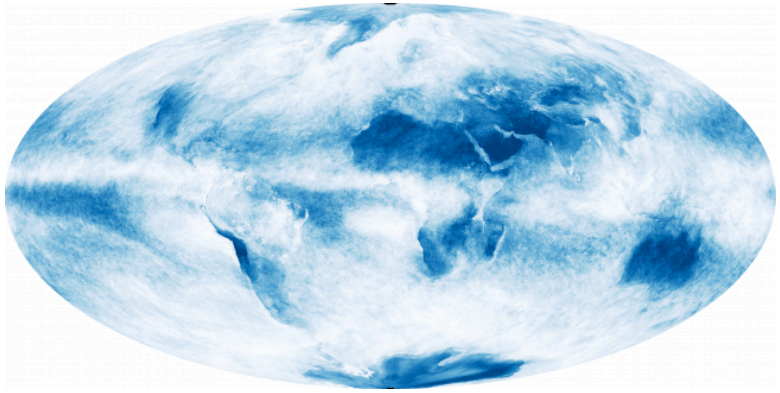
Examples: Radar, LIDAR



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



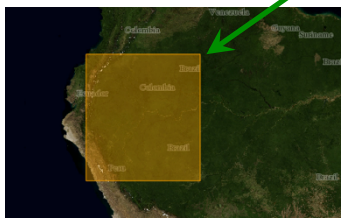
Imagers: Create Images

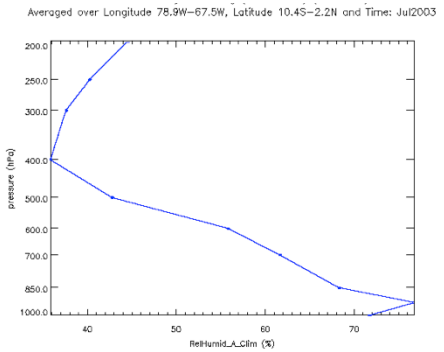
Examples: MODIS, TMI

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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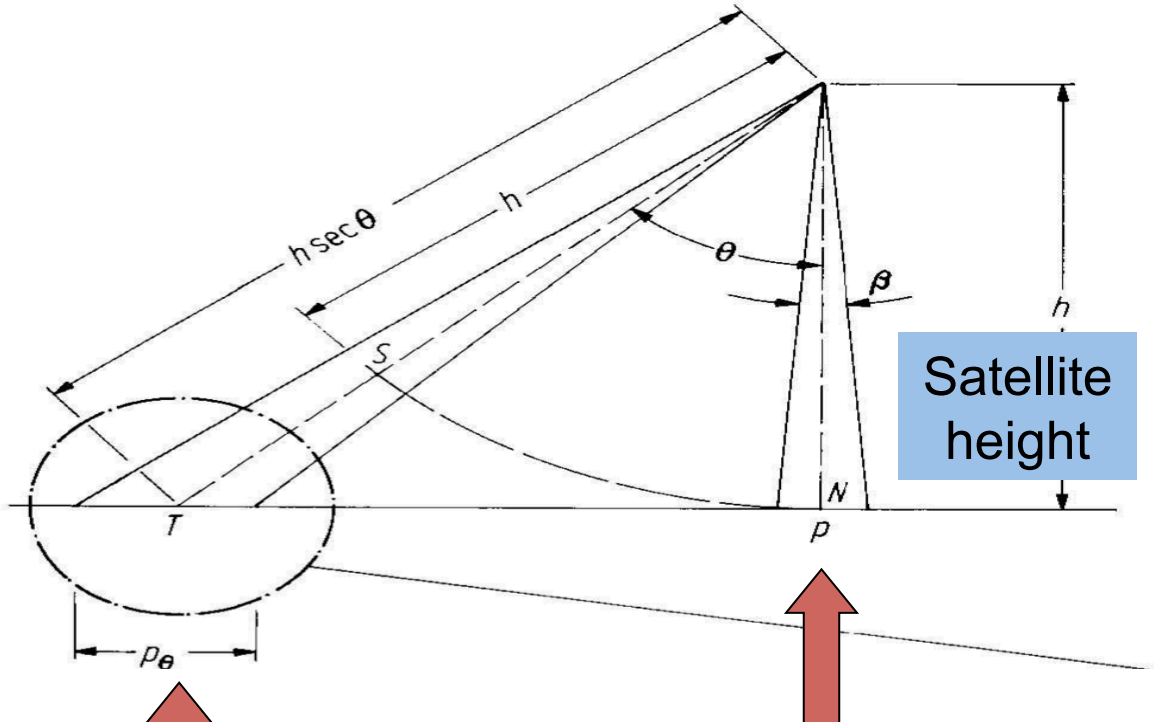
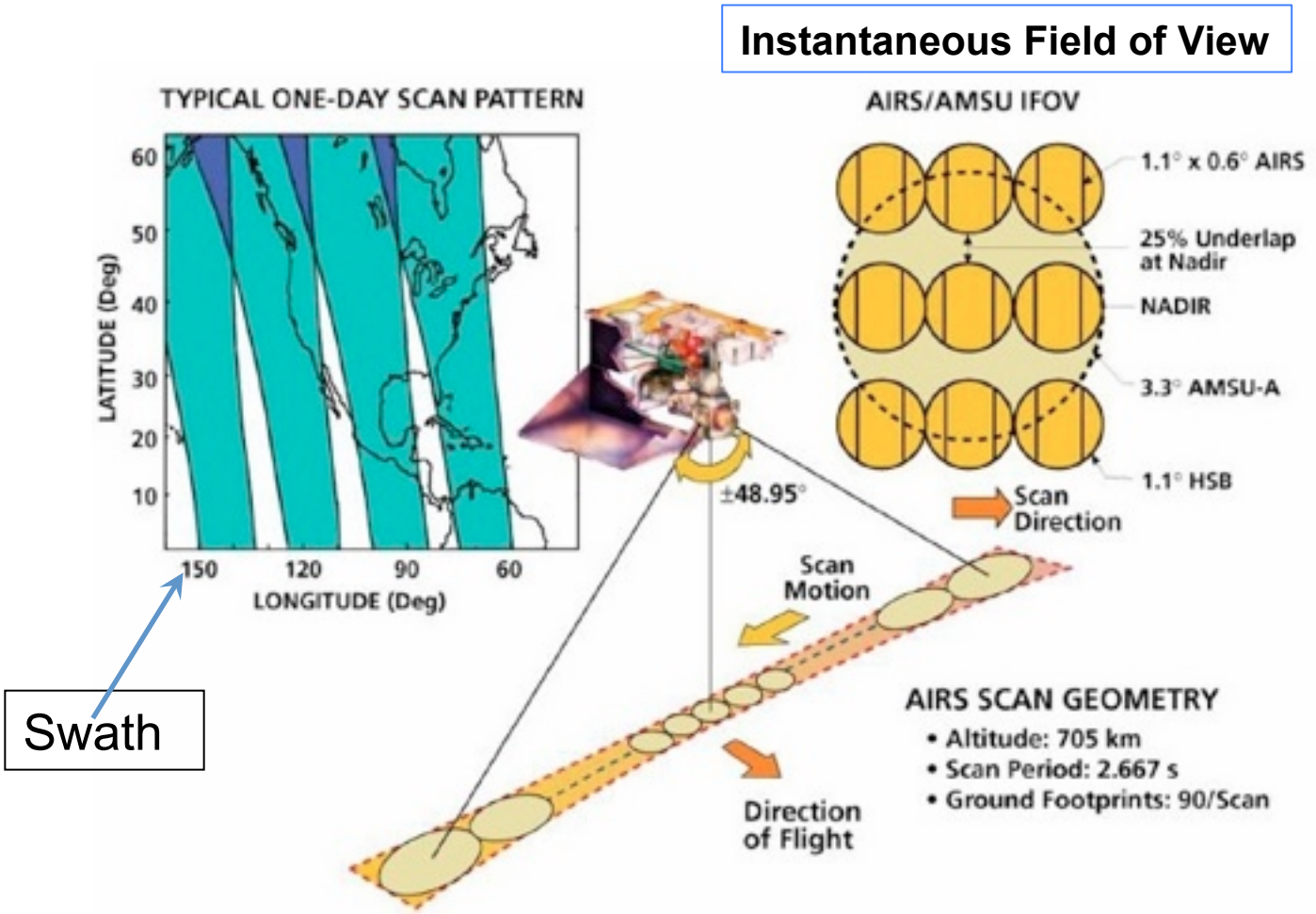
Spatial Resolution

- 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

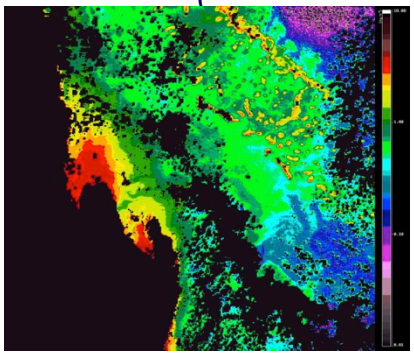
Varies with satellite/sensor

Landsat-7 Image of Niger River Delta

Spatial resolution: 30 m

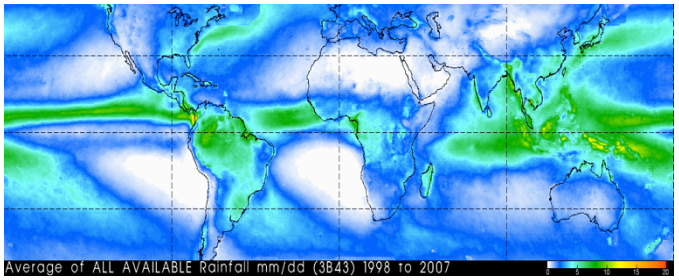
Chlorophyll from Terra/MODIS:

Spatial resolution: 1 km

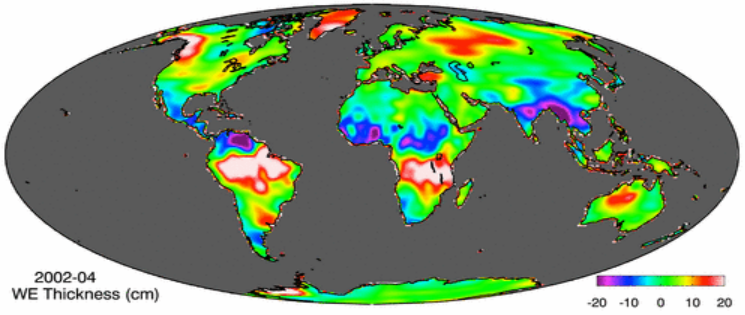


TRMM and Multi-satellite Rain Rate

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

Depend on the satellite orbit configuration and sensor design

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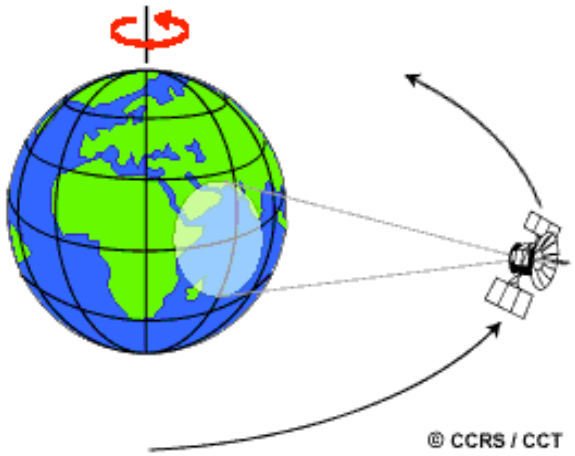
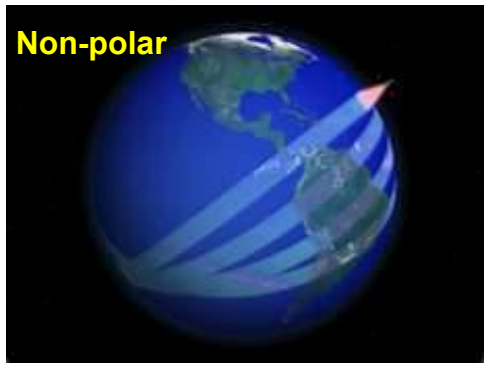
Types of Satellite Orbits

Geostationary orbit

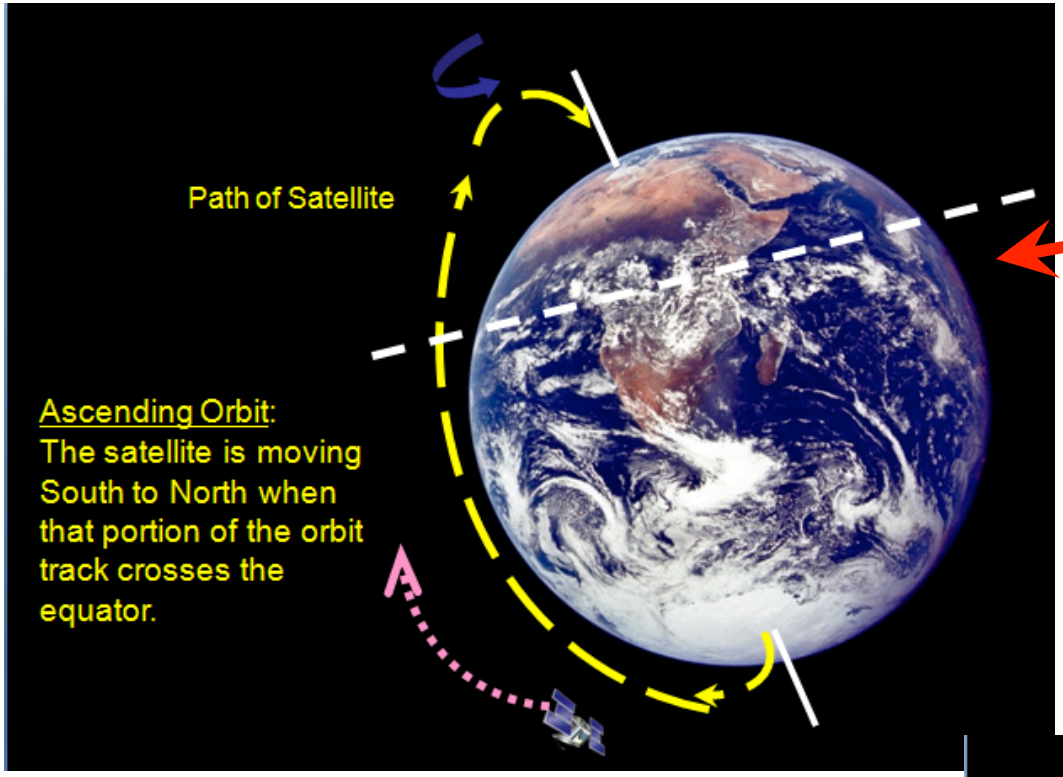


Satellite is ~36,000 km above earth the equator. Same rotation period as earth's. Appears 'fixed' in space.

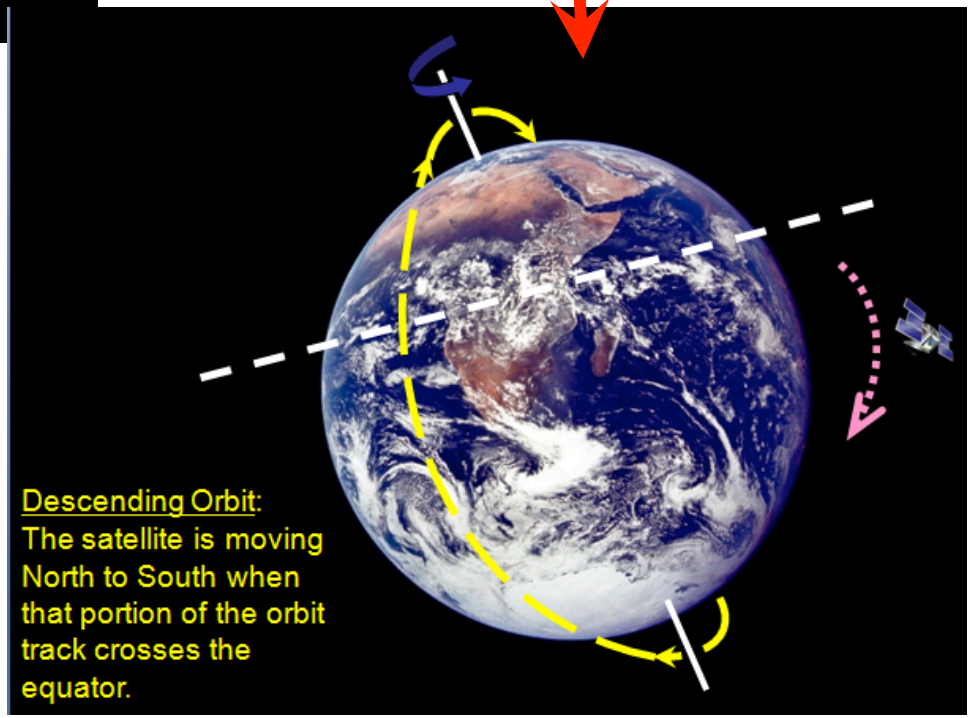
Low Earth Orbit (LEO)



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

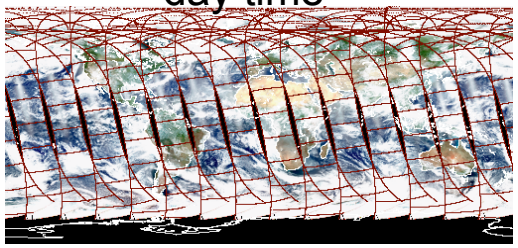
Spatial Coverage and Temporal Resolution of Satellite Measurements

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

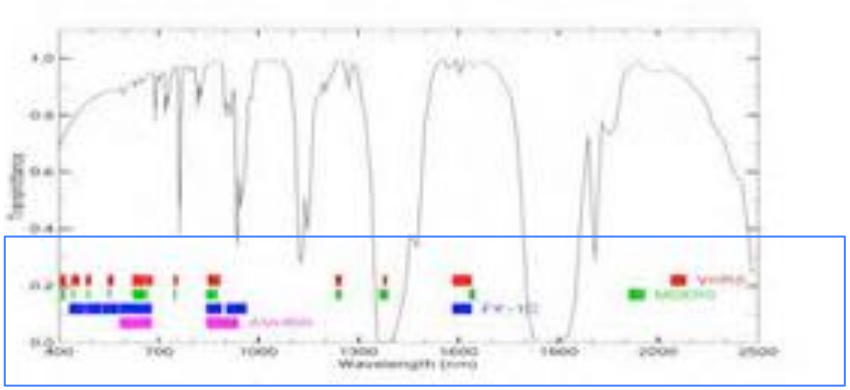
Spectral and Radiometric Resolutions

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