NASA Earth Science
Applied Sciences Program

Applications to Decision Making: Thematic Areas

Agricultural Efficiency

Air Quality

Climate

Disaster Management

Ecological Forecasting

Public Health

Water Resources

Weather

Applied Remote Sensing Training Program (ARSET) (part of NASA Applied Sciences)

GOAL:

Increase utilization of NASA observational and model data for decision-support

Online and hands-on courses:

- **Who:** policy makers, environmental managers, modelers and other professionals in the public and private sectors.

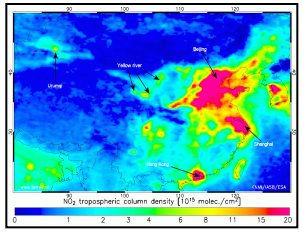
  Where: U.S and internationally
- **When**: throughout the year. Check websites.
- Do NOT require prior remote- sensing background.
- Presentations and hands-on guided computer exercises on how to access, interpret and use NASA satellite images for decision-support.

NASA Training for California Air Resources Board, Sacramento

Applied Remote Sensing Training Program (ARSET)

Health (Air Quality)

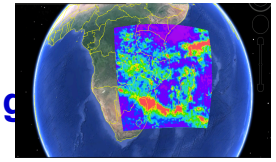
Nitrogen Dioxide over China



- 2008 – present
- 26 Trainings
- +700 end-users
- Analysis of dust, fires and urban air pollution.
- Long range transport of pollutants
- Satellite and regional air quality model inter-comparisons.
- Support for air quality forecasting and exceptional event analysis

Water Resources and Flood Monitoring

Satellite derived precipitation



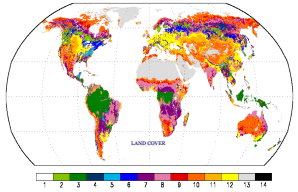
- April 2011 – present
- 6 Trainings
- +300 end-users
- Flood/Drought monitoring
- Severe weather and precipitation
- Watershed management
- Climate impacts on water resources
- Snow/ice monitoring
- Evapotranspiration (ET), ground water, soil moisture, and runoff.

Inundation mapping

Land Use/Change and Ecology

- Beginning in 2014
- Webinars and in-person courses
- Topics to be informed by ongoing end-user needs assessment
- GIS applications
- Land use/change and vegetation indices
- Fire products

Land Cover



Gradual Learning Approach

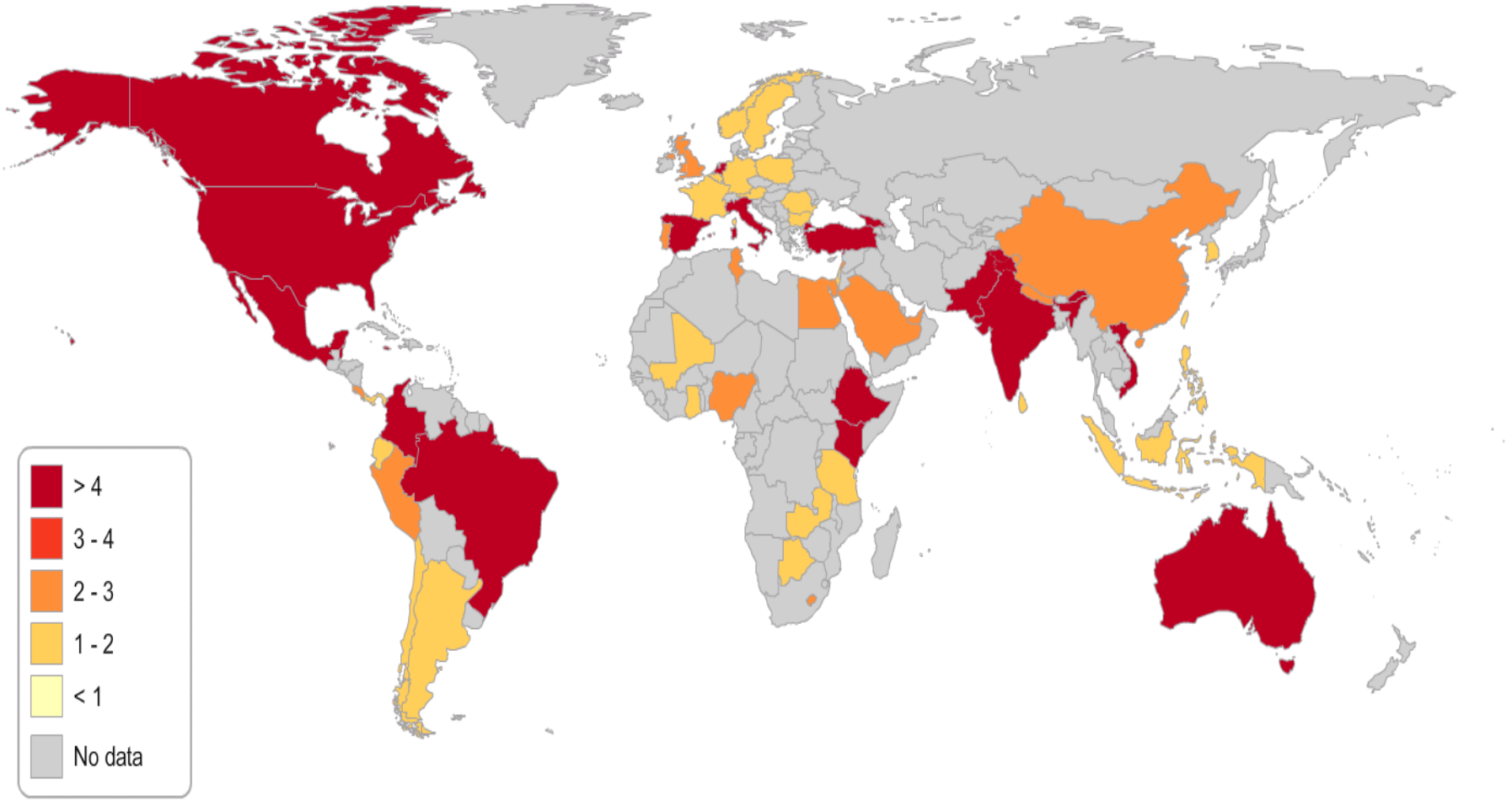
Basic Courses
Webinars
Hands-on
Assumes no prior knowledge of RS

Advanced Courses
Hands-on
Webinar course generally required
Focused on a specific application/ problem: for example dust or smoke monitoring in a specific country or region

ARSET: 2009 – 2013

+1000 End-users Reached

Number of participating organizations per country: Air Quality, Water Resources, Flood Monitoring.



http://airquality.gsfc.nasa.gov/

Publicly available Modules

Case Studies

NOTE:

New ARSET website coming soon

Sign up to the **listserve** for new website information and URL, and for program updates

https://lists.nasa.gov/mailman/listinfo/arset

ARSET Contact Information

- Overall program information

  Ana Prados: aprados@umbc.edu

- Interest in future ARSET activities

  Pawan Gupta: pawan.gupta@nasa.gov

Fundamentals of Satellite Remote Sensing Instruments and Applications

Introduction to Remote Sensing and Air Quality Applications for the Indian Sub-Continent and Surrounding Regions

ARSET

Applied Remote SEnsing Training

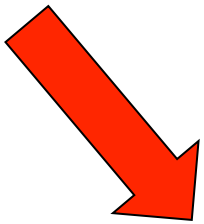
A project of NASA Applied Sciences

Outline

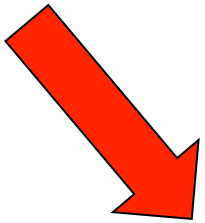
- What you should expect from this course.
- Why use remote sensing?
- Advantages and Limitations of Remote Sensing
- Sensors and Satellites
- Satellite Capabilities, Satellite Products and their Application to Remote Sensing

What should you expect from this webinar series?

Satellite Measurements



Satellite Products



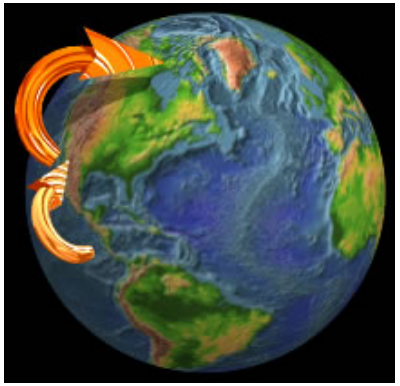
Air Quality Applications

What should you not expect as a result of this webinar series ?

- The capability to perform research using satellite remote sensing data.

- A complete knowledge of all of the satellite products and web tools which can be used for air quality applications.

Some Things We Want to Know About Aerosols and Trace Gasses



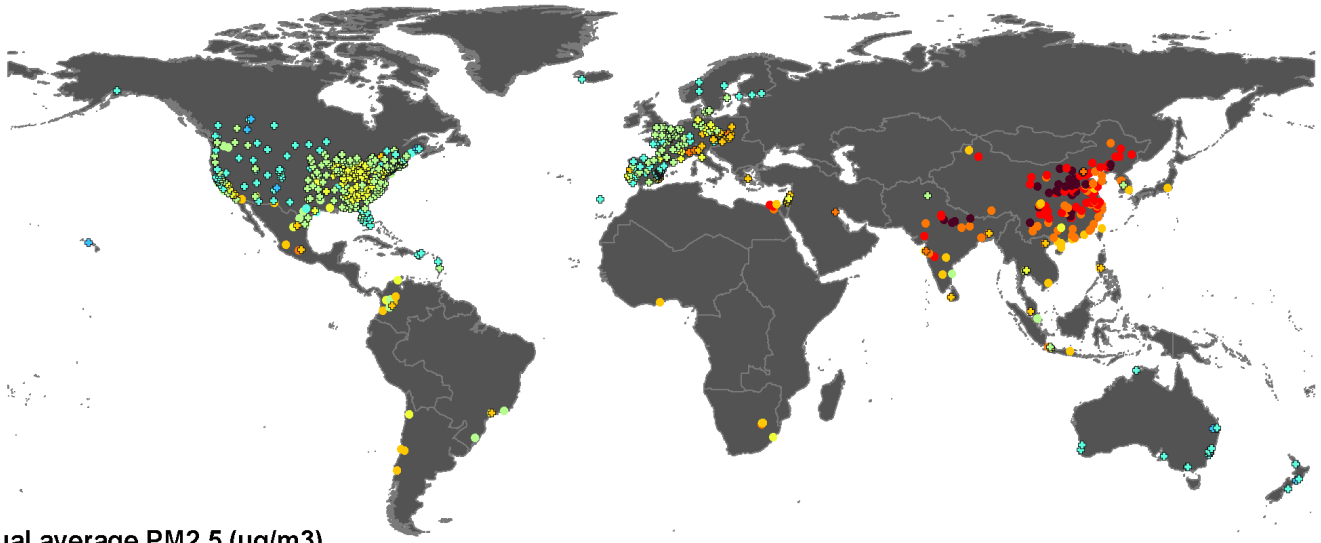
Sources and sinks

Concentrations at the ground

<u>Human exposure estimates</u>

- Acute exposure
- Long term records
- Air quality forecasts

Global Status of PM2.5 Monitoring Networks



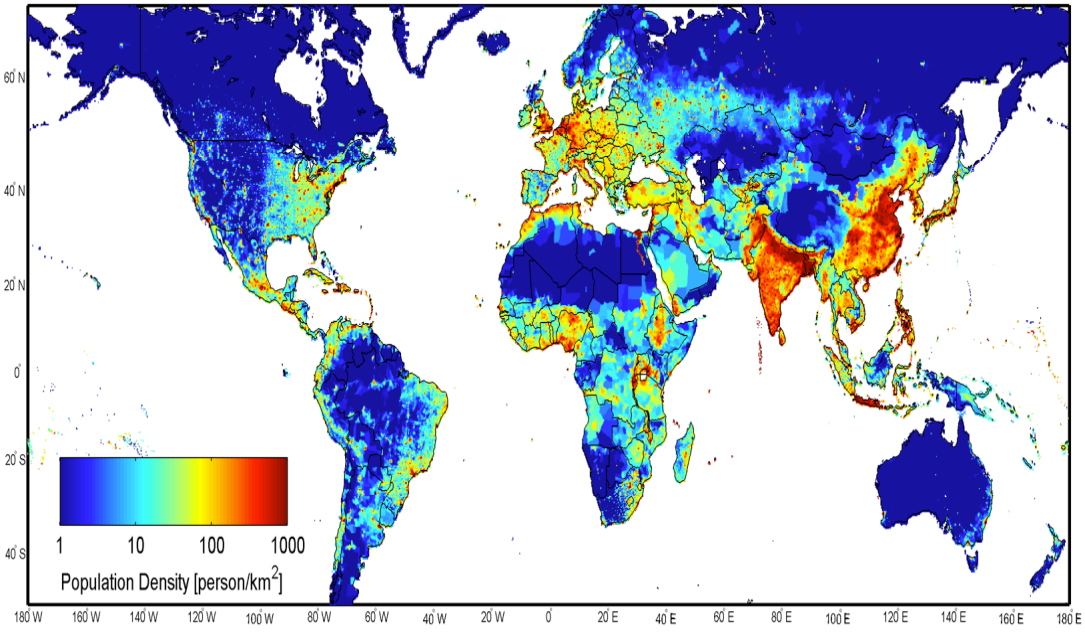
Annual average PM2.5 (µg/m3)

Measured

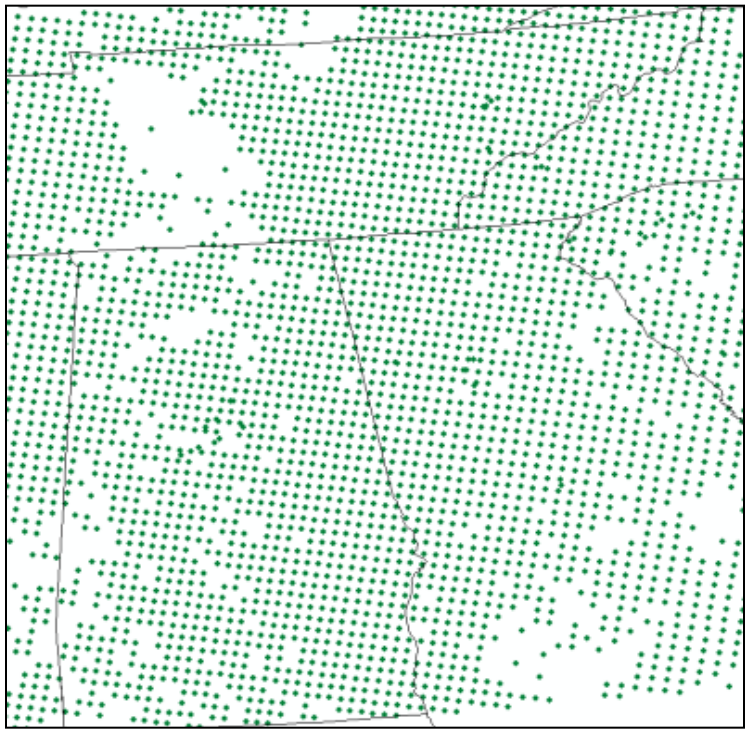
Not Measured

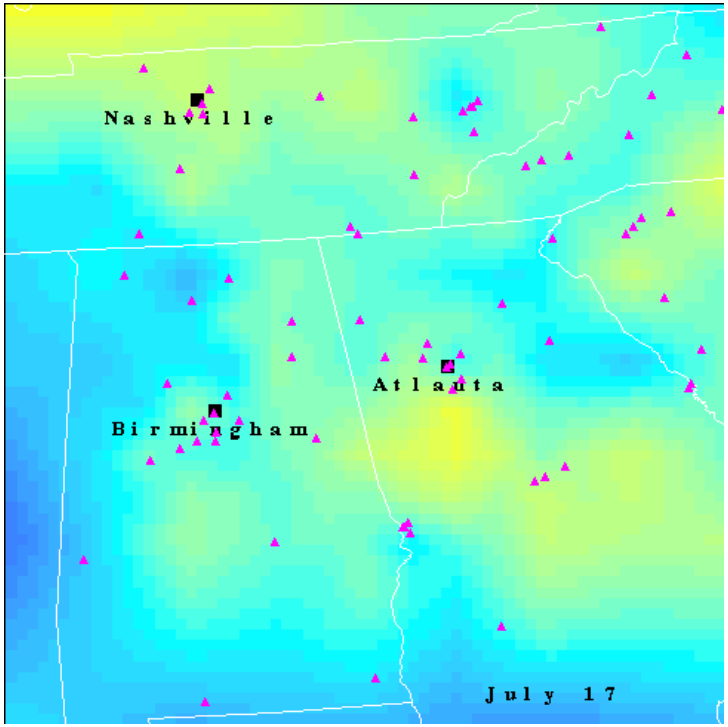
0 - 1 | 1 - 2 | 2 - 5 | 5 - 10 | 10 - 15 | 15 - 20 | 20 - 40 | 40 - 60 | 60 - 80 | 80 - 130

Brauer M, Ammann M, Burnett R et al.
GBD 2010 Outdoor Air Pollution Expert Group
2011 Submitted –under review



Why Use Remote Sensing Data?
Spatial Coverage



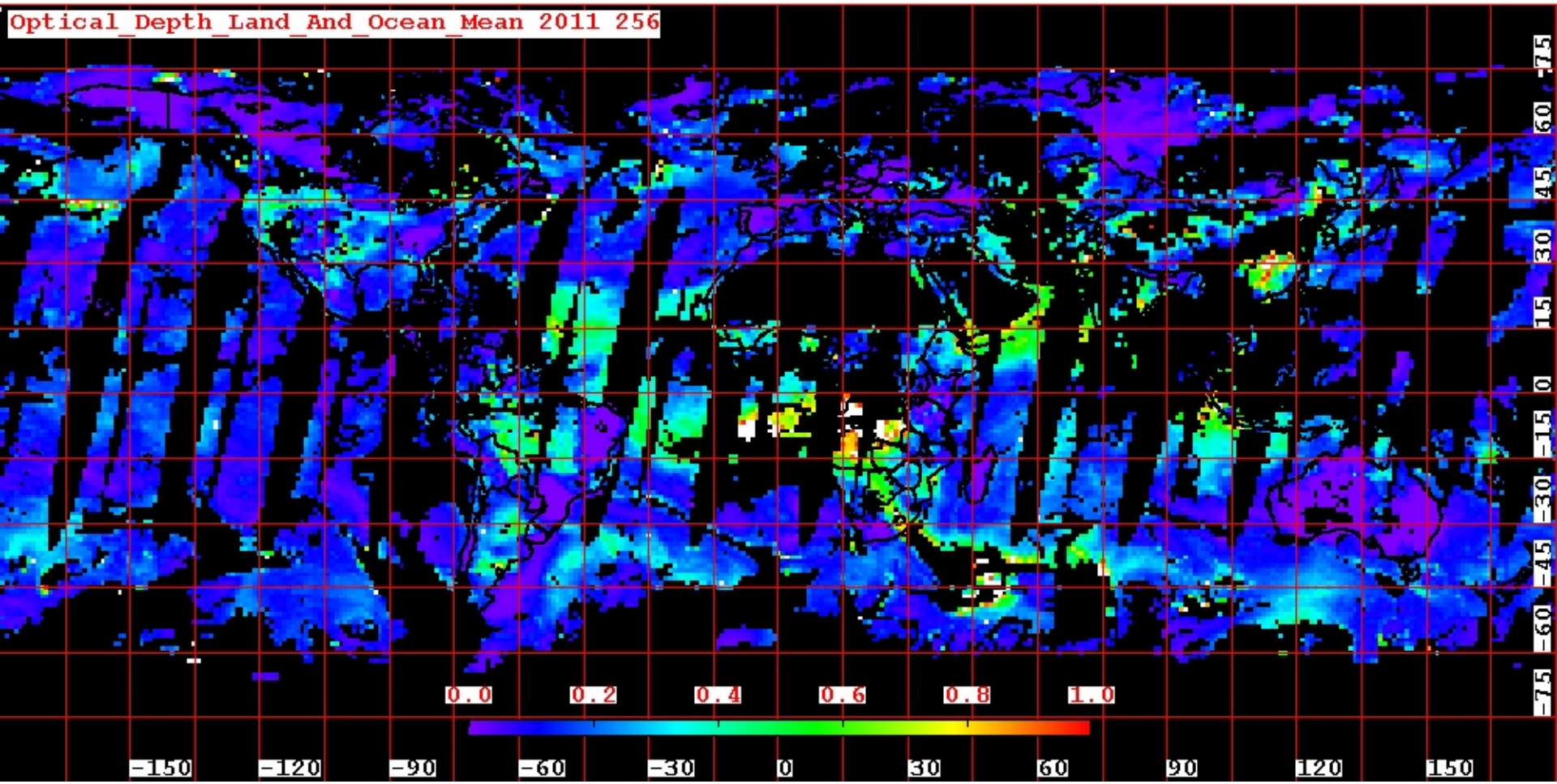


- Satellite (MODIS) Retrieval Locations
White Areas – No Data
(Most likely due to clouds)

– Ground Monitors

Spatial Coverage

MODIS One Day Aerosol Product Coverage

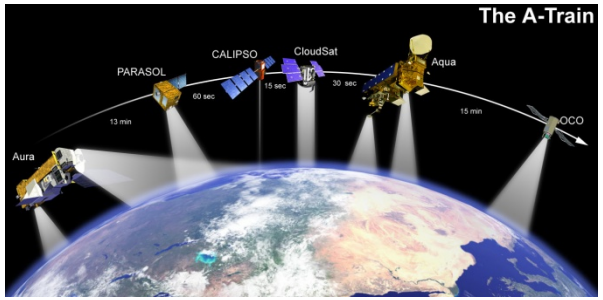


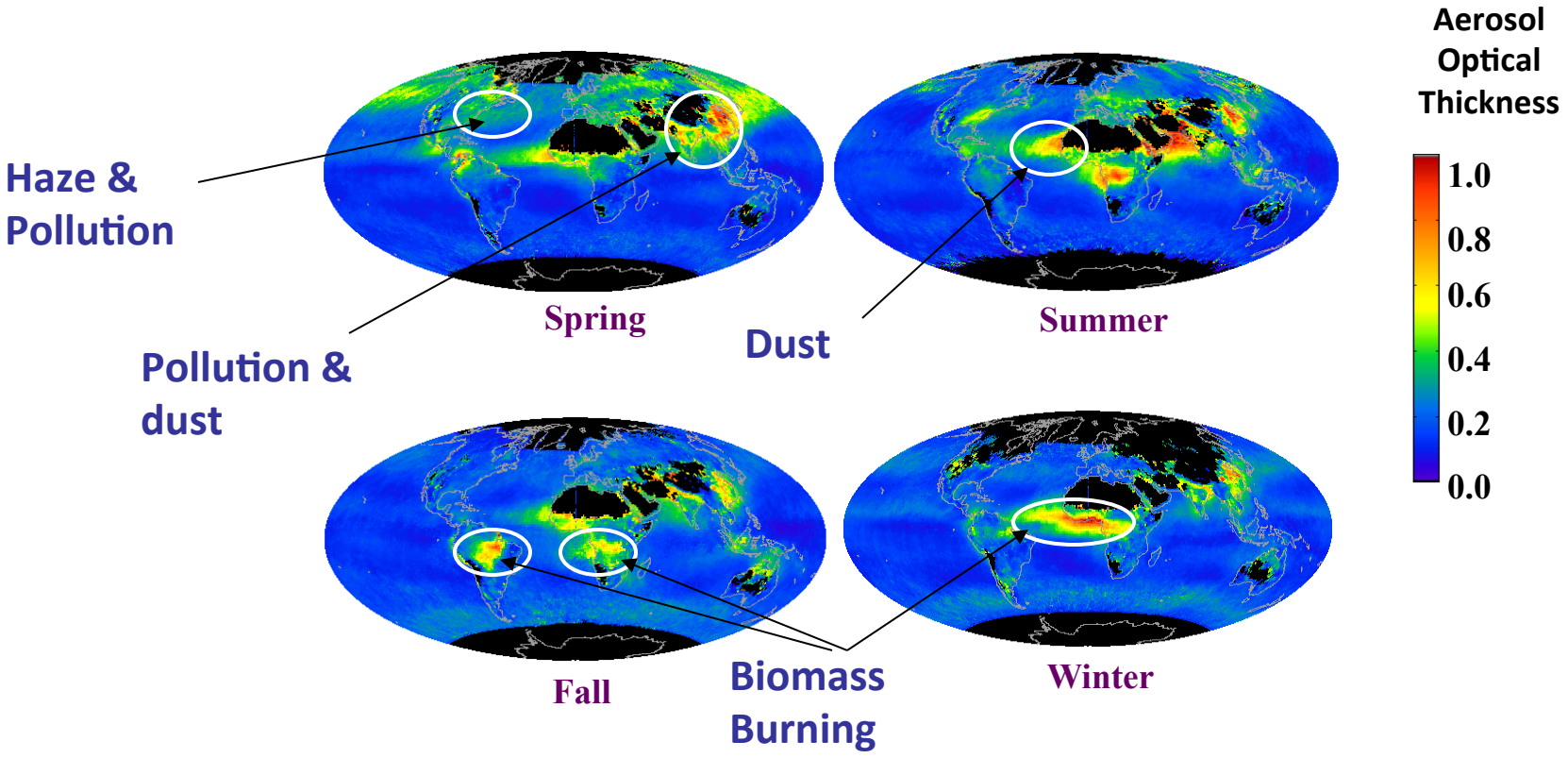
Satellite Products for Air Quality Applications

- **Particulate Pollution** (dust, haze, smoke)
  - Qualitative: Visual imagery
  - Quantitative*: Atmospheric Column Products

- **Fire Products**: Fire locations or 'hot spots'
  Fire radiative power
- **Trace Gases**
  - Quantitative*: Column Products
  - Vertical profiles: mostly mid-troposphere
  - Some layer products

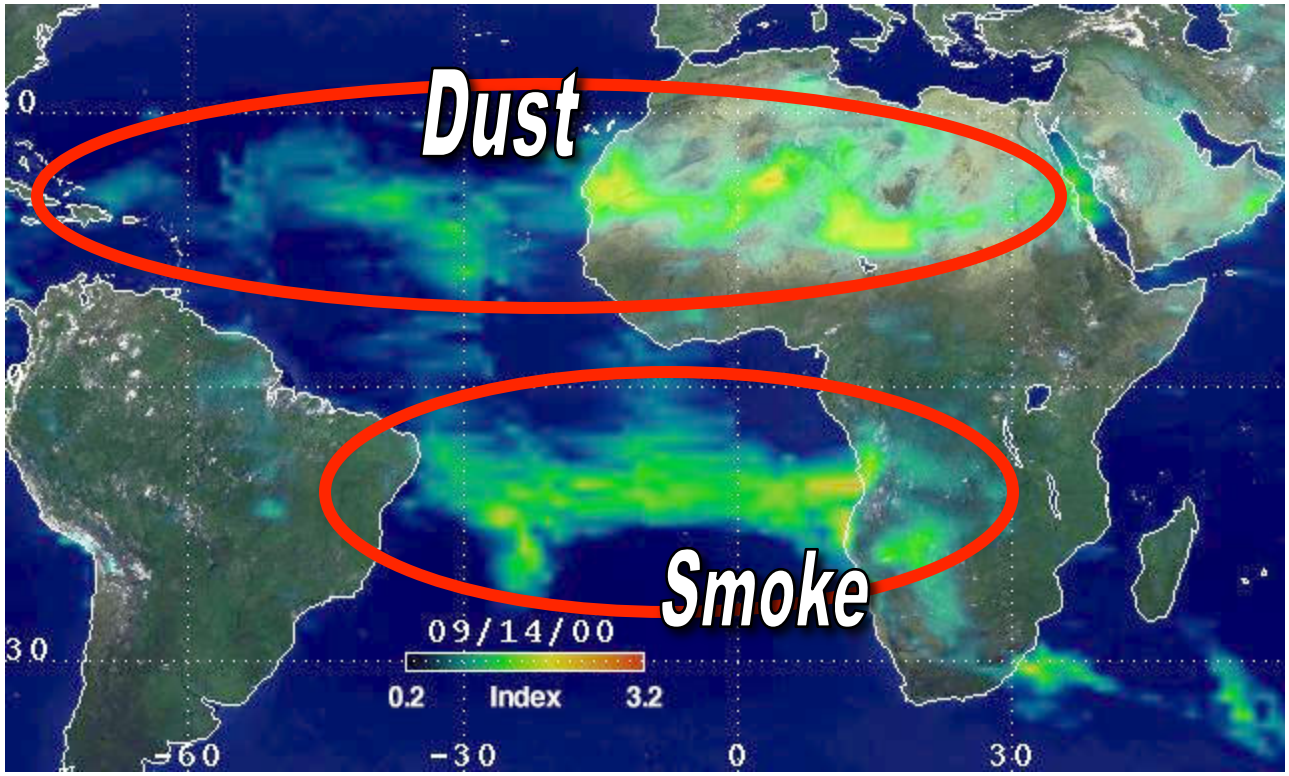
Some kinds of aerosol data available from satellite.





Several satellites provide state-of-art aerosol measurements over global region on daily basis

Global Coverage Helps Us to Estimate Transport and Source Regions



Aerosols Transported Across the Atlantic

Earth Satellite Observations

Advantages

Air Quality/Pollution

- Provides coverage where there are no ground monitors
- Synoptic and trans-boundary view (time and space)
- Visual context
- Qualitative assessments and indications of long range transport
- **Adds value when combined with surface monitors and models**

Earth Satellite Observations

Limitations

1. Temporal Coverage

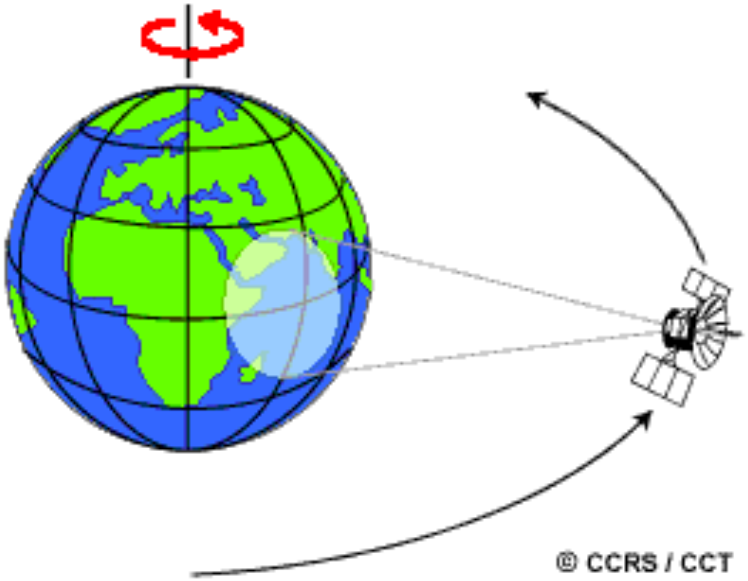
2. Vertical Resolution of Pollutants

3. Lack of Near Surface Sensitivity

4. Lack of specific identification of pollutant type

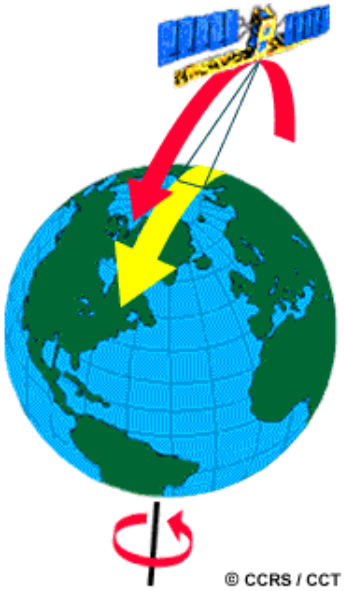
Common types of orbits

Geostationary



Geostationary orbit
An orbit that has the same Earth's rotational period
Appears 'fixed' above earth Satellite on equator at ~36,000km

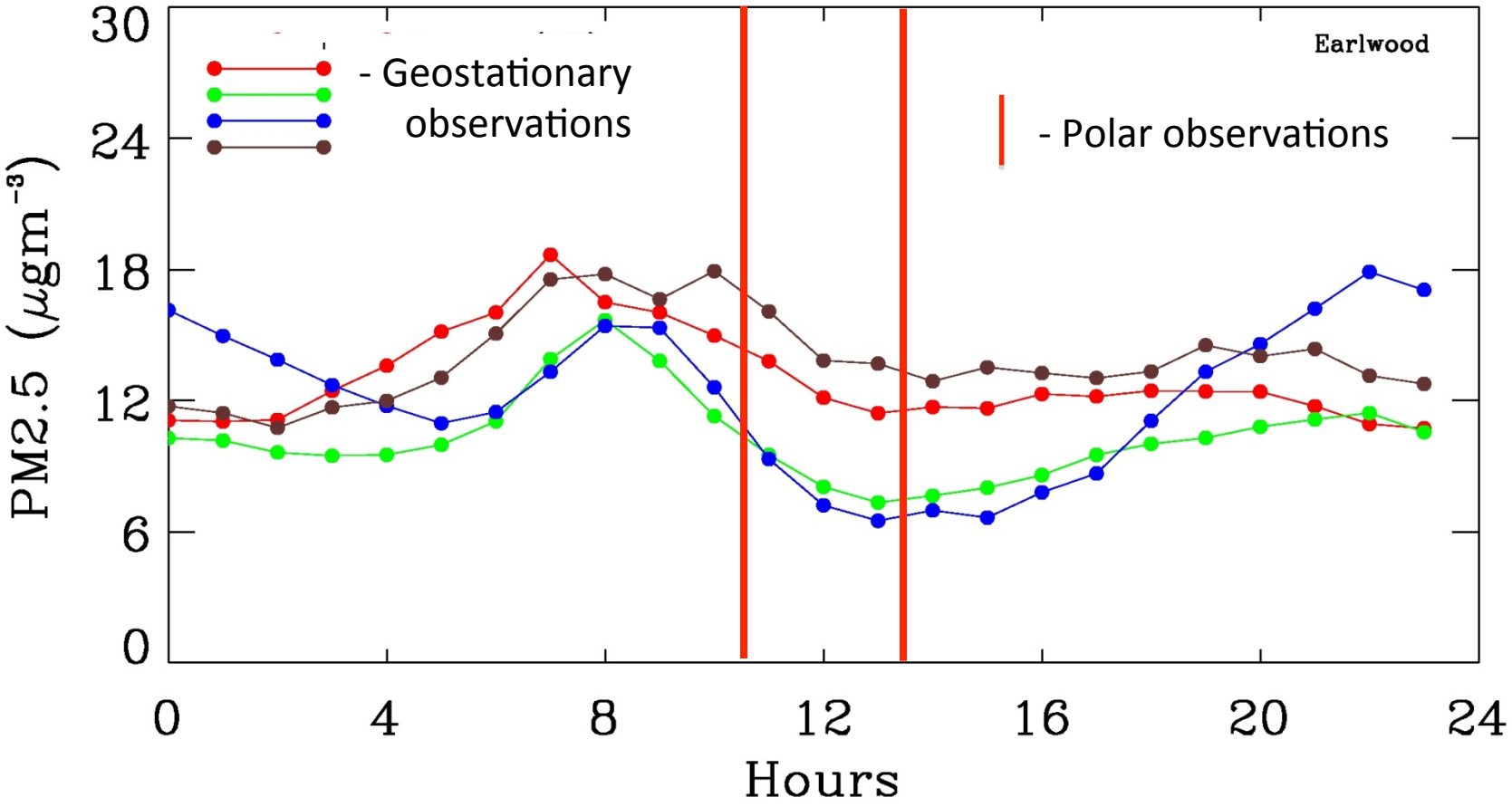
Polar



Polar orbiting orbit fixed circular orbit above the earth, ~600-1000km in sun synchronous orbit with orbital pass at about same **local solar time** each day

Observation Frequency

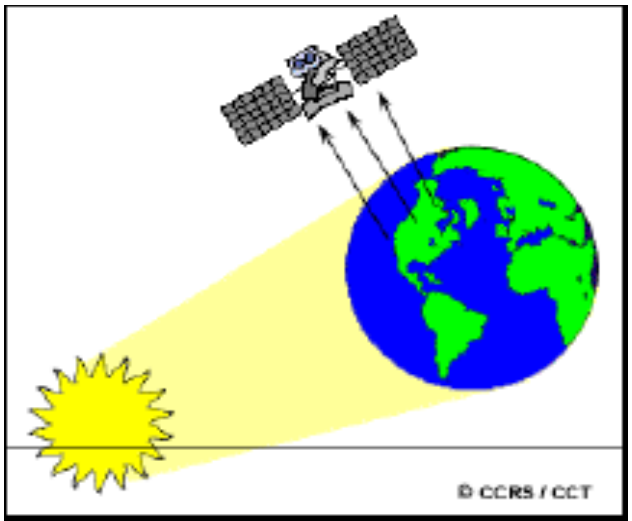
Polar orbiting satellites – 1 - 2 observations per day per sensor



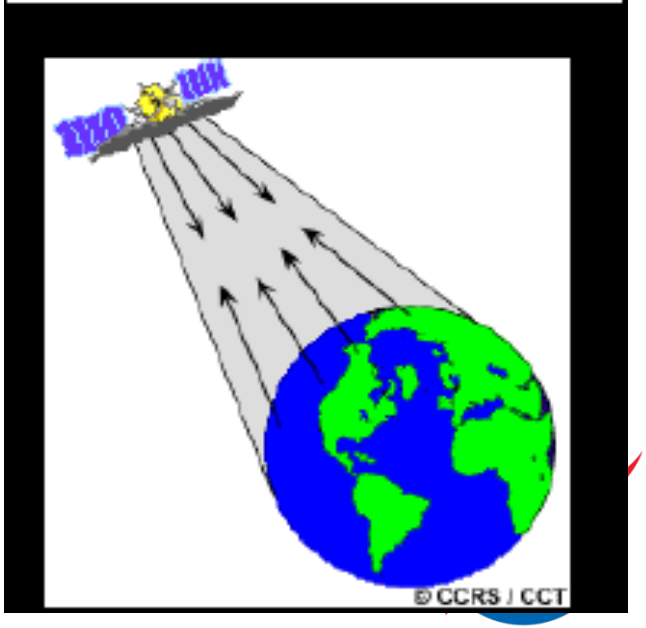
Geostationary satellites – product quality is lacking in many locations

Remote Sensing …Sensors

Passive Sensors: Remote sensing systems which measure energy that is naturally available are called passive sensors.



Active Sensors: 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.



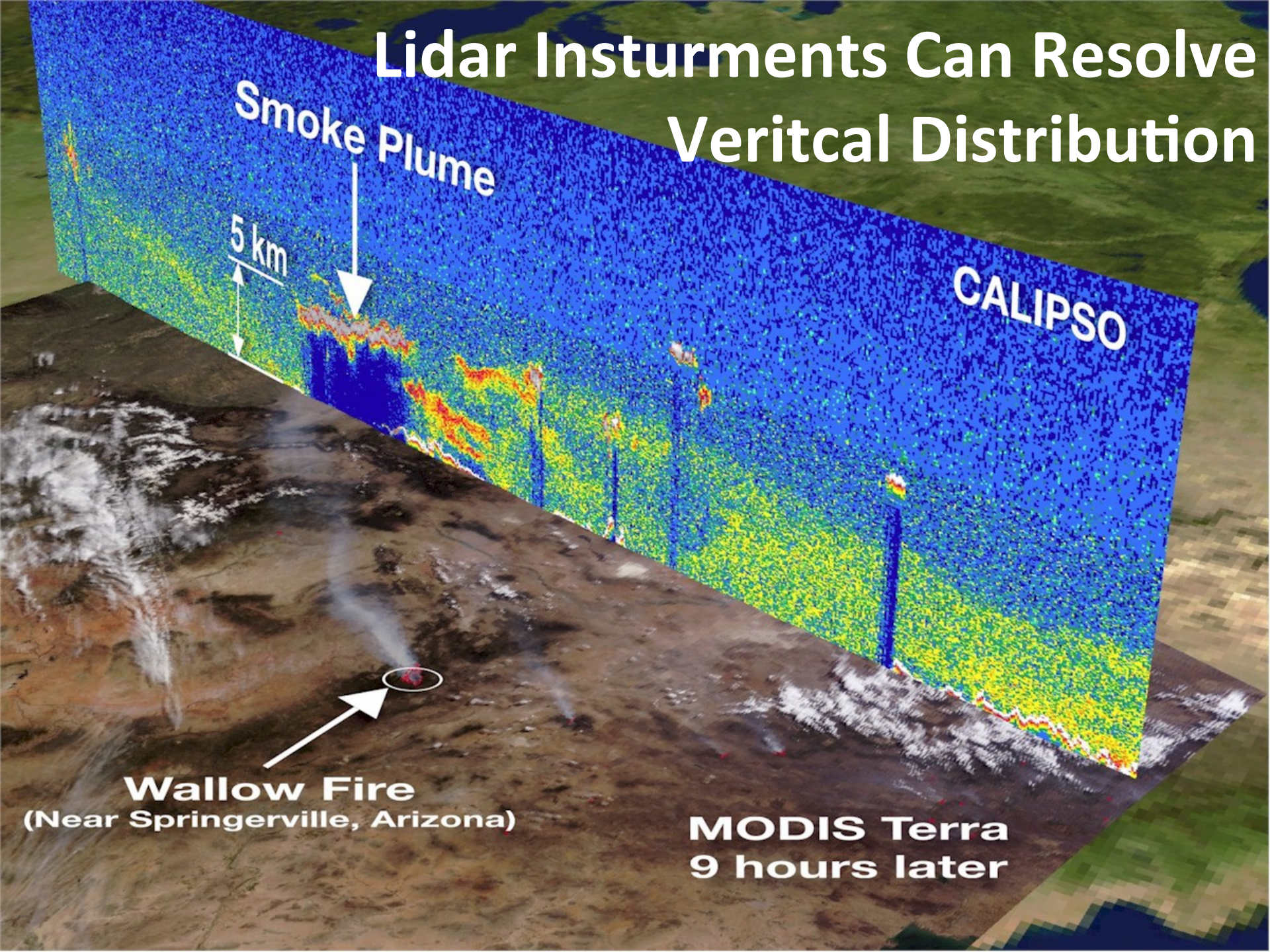
Limitations of Satellite Data

Almost all satellite sensors are passive sensors.

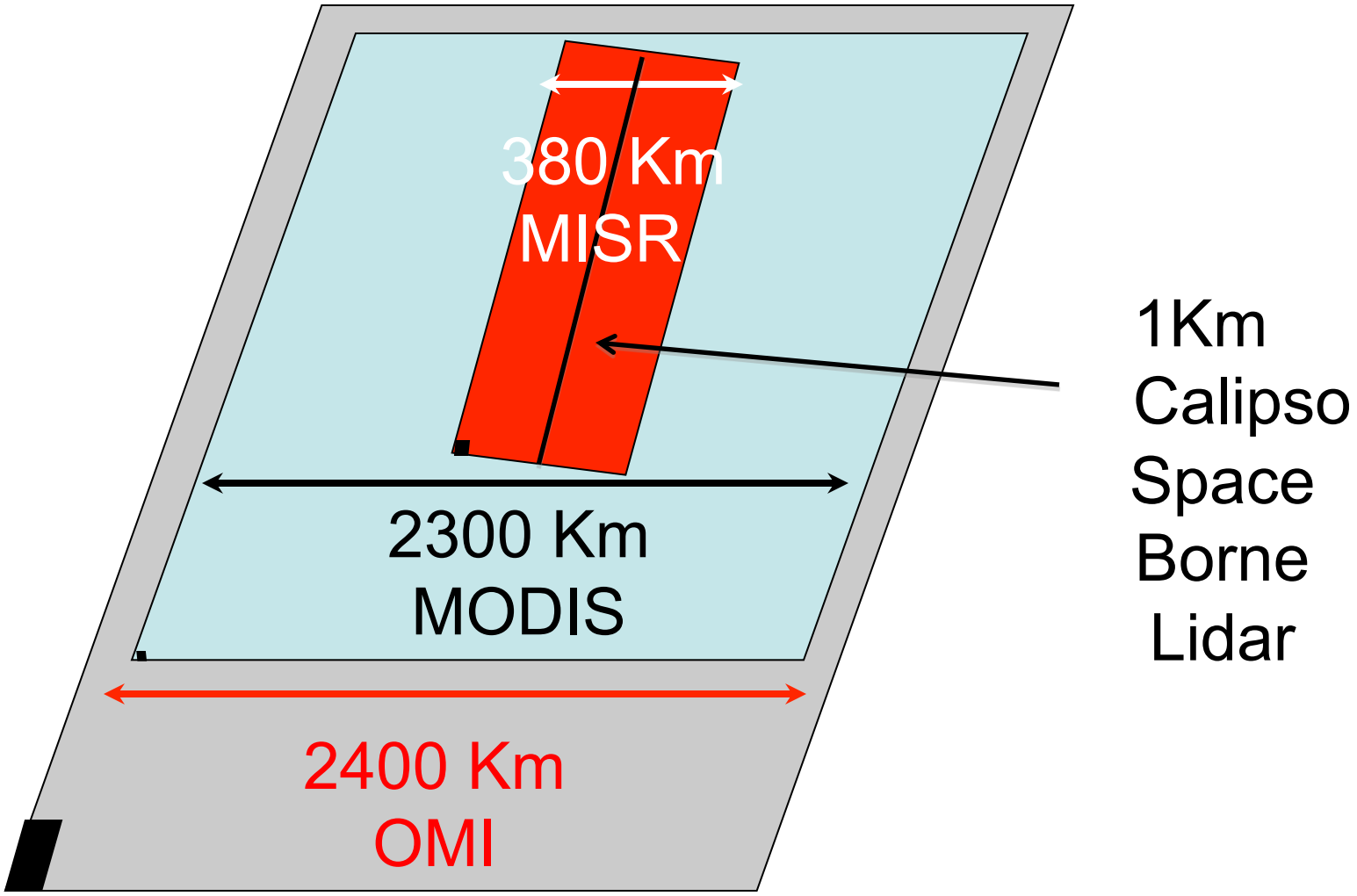
Passive sensors measure the entire column.

Column measurements may or may not reflect what is happening at ground level.

This is true whether we are measuring aerosols or trace gasses.


Lidar Insturments Can Resolve
Veritcal Distribution
Smoke Plume
5 km
CALIPSO
Wallow Fire
(Near Springerville, Arizona)
MODIS Terra
9 hours later

Principal Satellites in Air Quality Remote Sensing



Satellites Vs Sensors

Earth-observing satellite remote sensing instruments are named according to

1) the satellite (also called platform)

2) the instrument (also called sensor)

Aqua Satellite

Six Instruments:

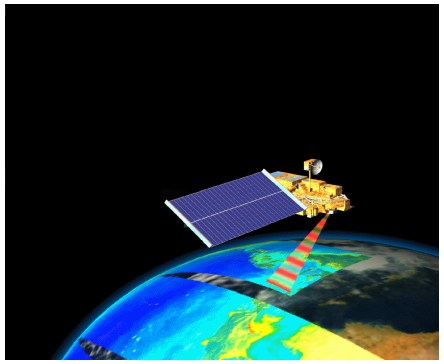
- MODIS
- CERES
- AIRS
- AMSU-A
- AMSR-E
- HSB

Aura Satellite

Four Instruments:

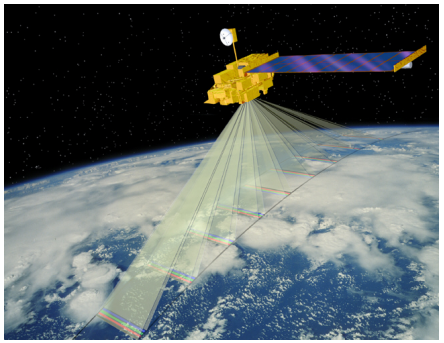
- OMI
- TES
- HIRDLS
- MLS

Primary Sensors - AEROSOLS



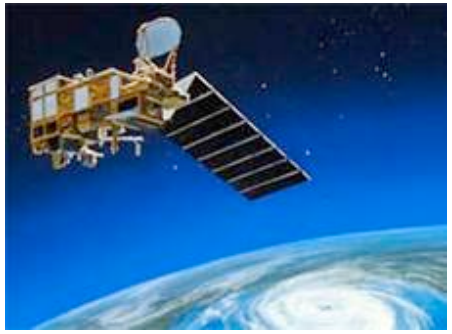
MODIS
MODerate resolution **I**maging **S**pectro**R**adiometer

Measures total column aerosol
AOD - Aerosol Optical Depth



MISR
Multi-angle **I**maging **S**pectro**R**adiometer

AOD
Particle Type



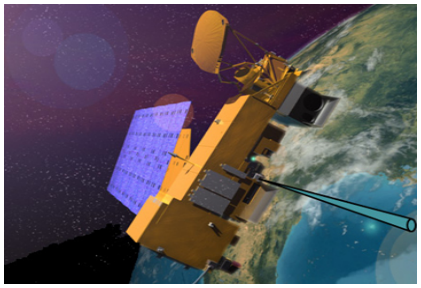
VIIRS
Visible **I**nfrared **I**maging **R**adiometer **S**uite

AOD
Particle Type

Primary Sensors – Trace Gases

OMI

Ozone **M**onitoring **I**nstrument



AIRS

Atmosphere **I**nfrared **S**ounder

Instrument Capabilities – for Air Quality

Imagers

MODIS – Terra and Aqua
250m-1 KM Resolution

MISR
275m- 1.1 KM Resolution

VIIRS
6 KM Resolution

Radiometers

OMI –
13 x 24 KM Resolution

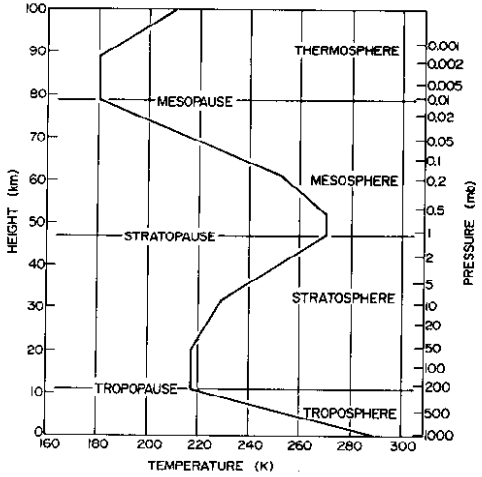
GOME-2
40 x 80 KM Resolution

SCIAMACHY
30 x 60 KM Resolution

Imagers & Sounders

Imagers create images – MODIS, MISR

Active and passive sounders can provide vertical profiles –
Cloud Profiling Radar (CLOUDSAT)
SAR (Synthetic Aperture RADAR)
Atmospheric Infrared Sounder (AIRS)

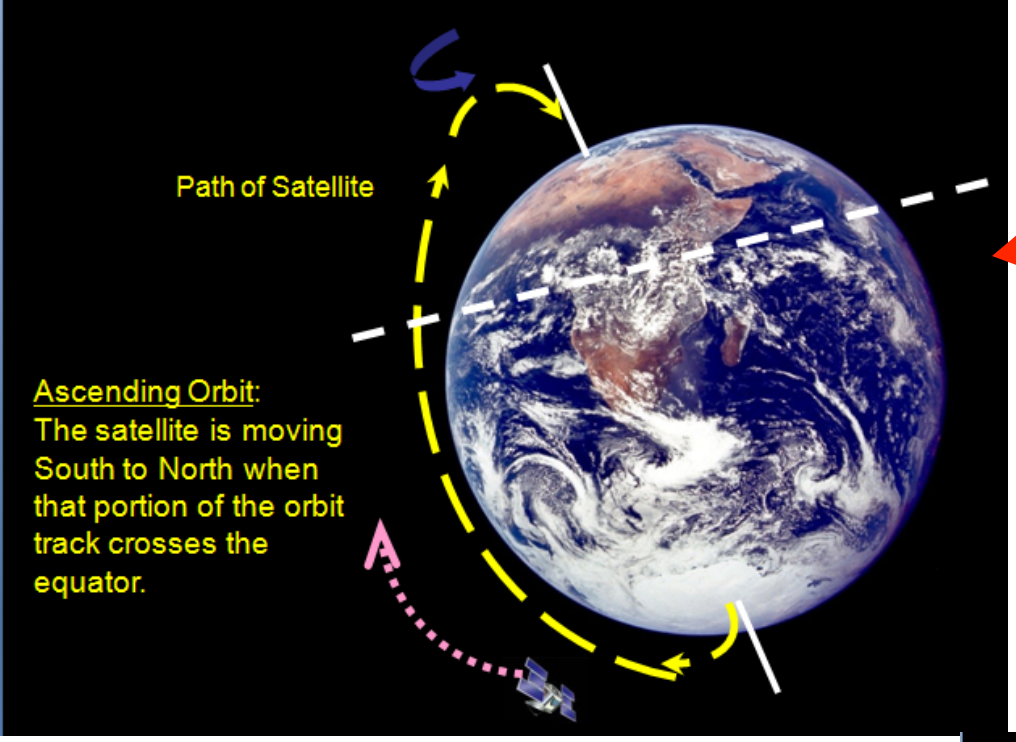


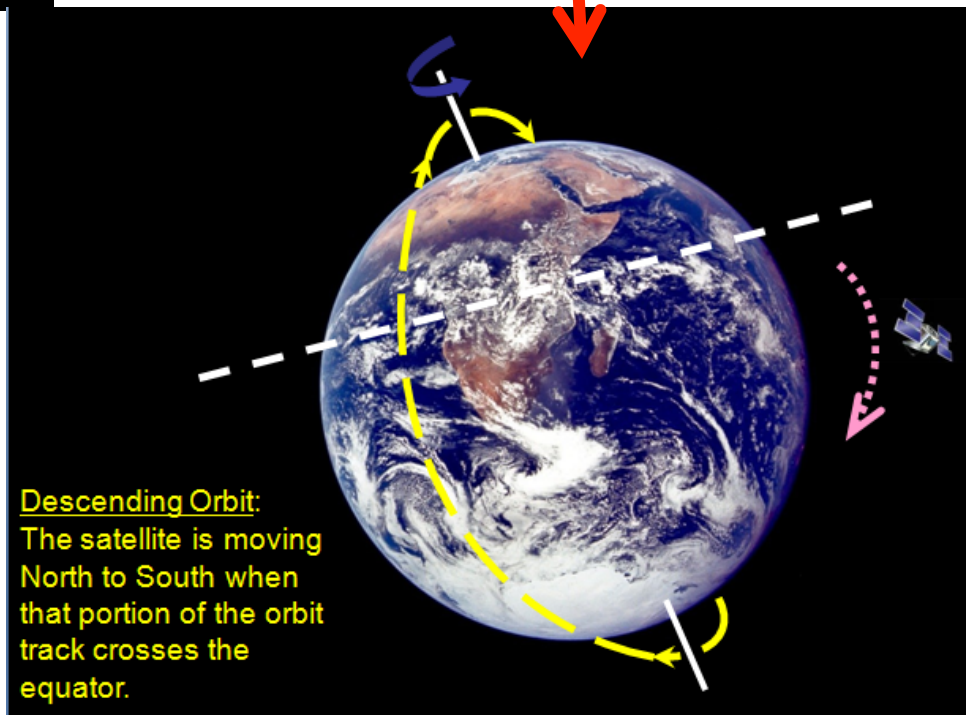
Satellite/Sensor Classifications

Some of the ways satellites/sensor can be classified

- **Orbits**
  - Polar vs Geostationary
- **Energy source**
  - Passive vs Active …
- **Solar spectrum**
  - Visible, UV, IR, Microwave …
- **Measurement Technique**
  - Scanning, non-scanning, imager, sounders …
- **Resolution (spatial, temporal, spectral, radiometric)**
  - Low vs high (any of the kind)
- **Applications**
  - Weather, Ocean colors, Land mapping, Atmospheric Physics, Atmospheric Chemistry, Air quality, radiation budget, water cycle, coastal management …

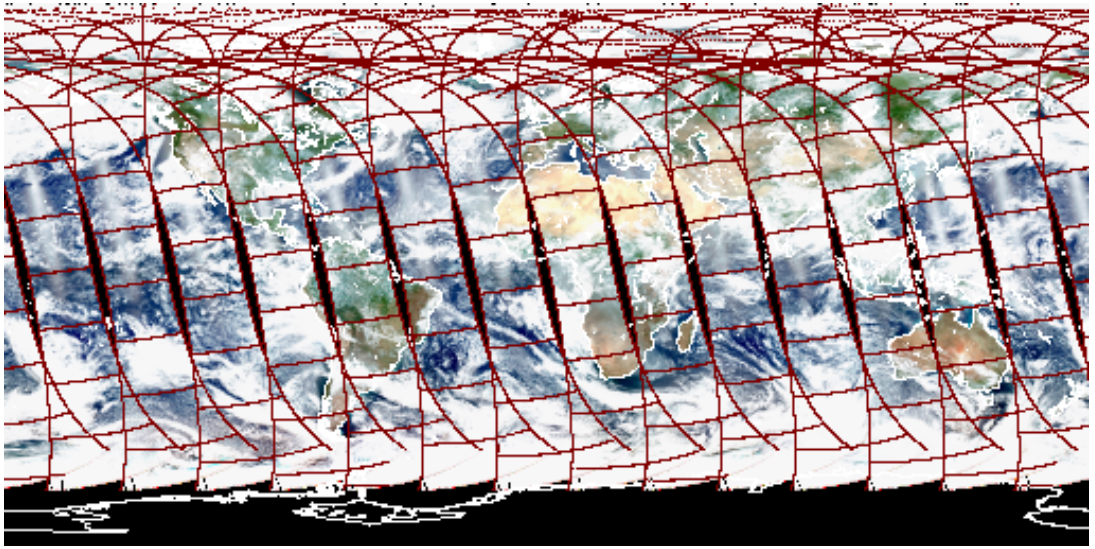
Ascending vs Descending





Polar Orbits

MODIS-Aqua ("ascending" orbit)



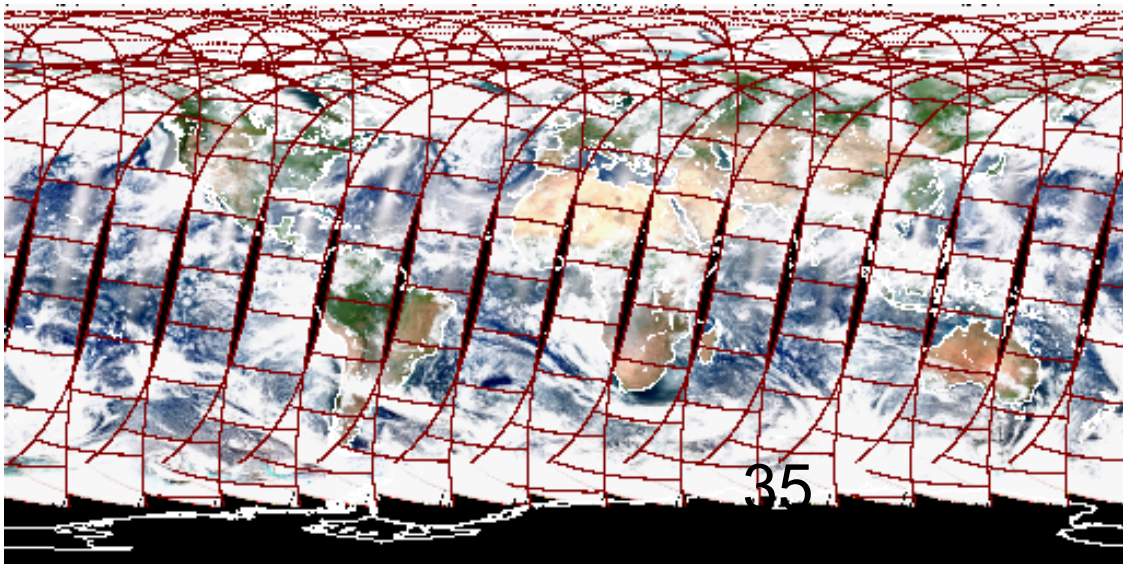
Approximately 1:30 PM local overpass time

Afternoon Satellite

MODIS-Terra ("descending")

Approximately 10:30 AM local overpass time

Morning Satellite



Pause for Questions

- **Important Note:**

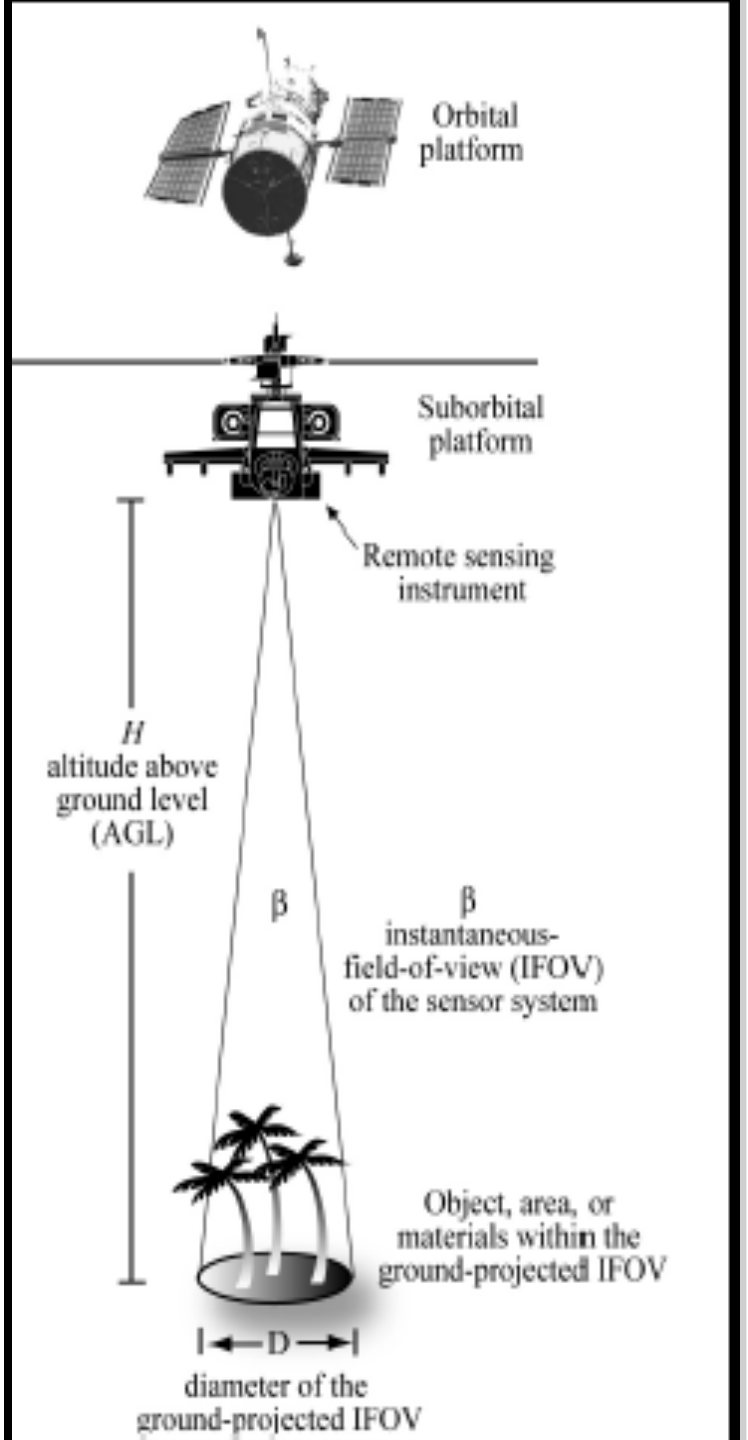
Passive instruments measure reflected/ emitted radiance at the top-of-atmosphere.

All other information is derived from this and some ancillary data.

The Remote Sensing Process and Sensor Measurements

Remote Sensing …

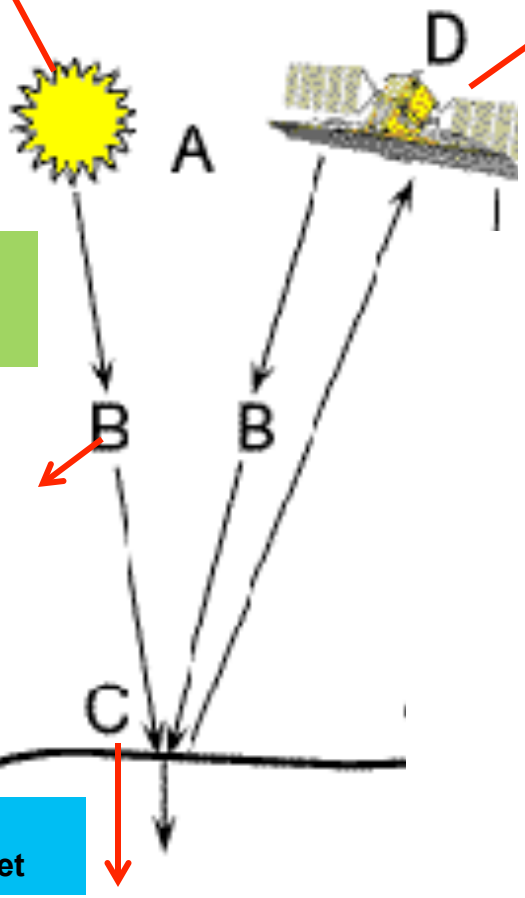
Remote sensing instrument measures reflected or emitted radiation



Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor



(B)
Radiation and the Atmosphere

(C)
Interaction with the Target

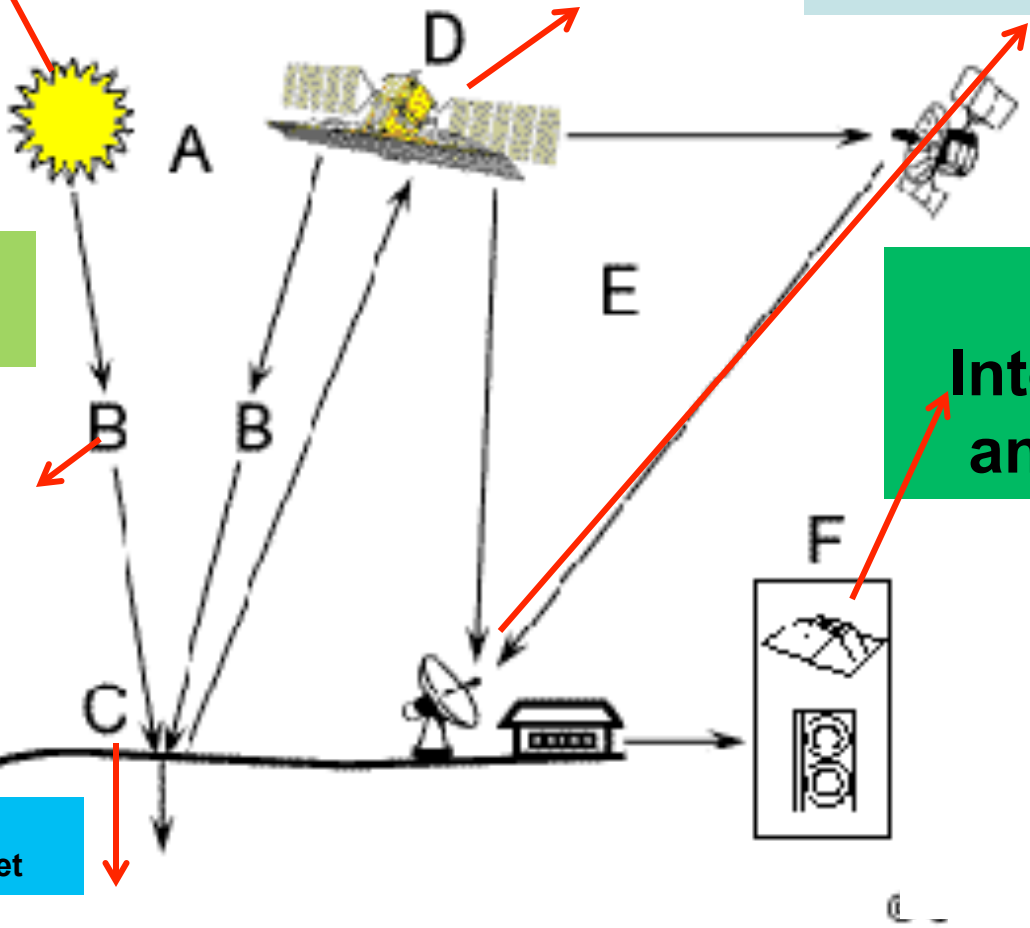
Reference:
CCRS/CCT

Remote Sensing Process

(A)
Energy Source or Illumination

(D)
Recording of Energy by the Sensor

(E)
Transmission, Reception, and Processing



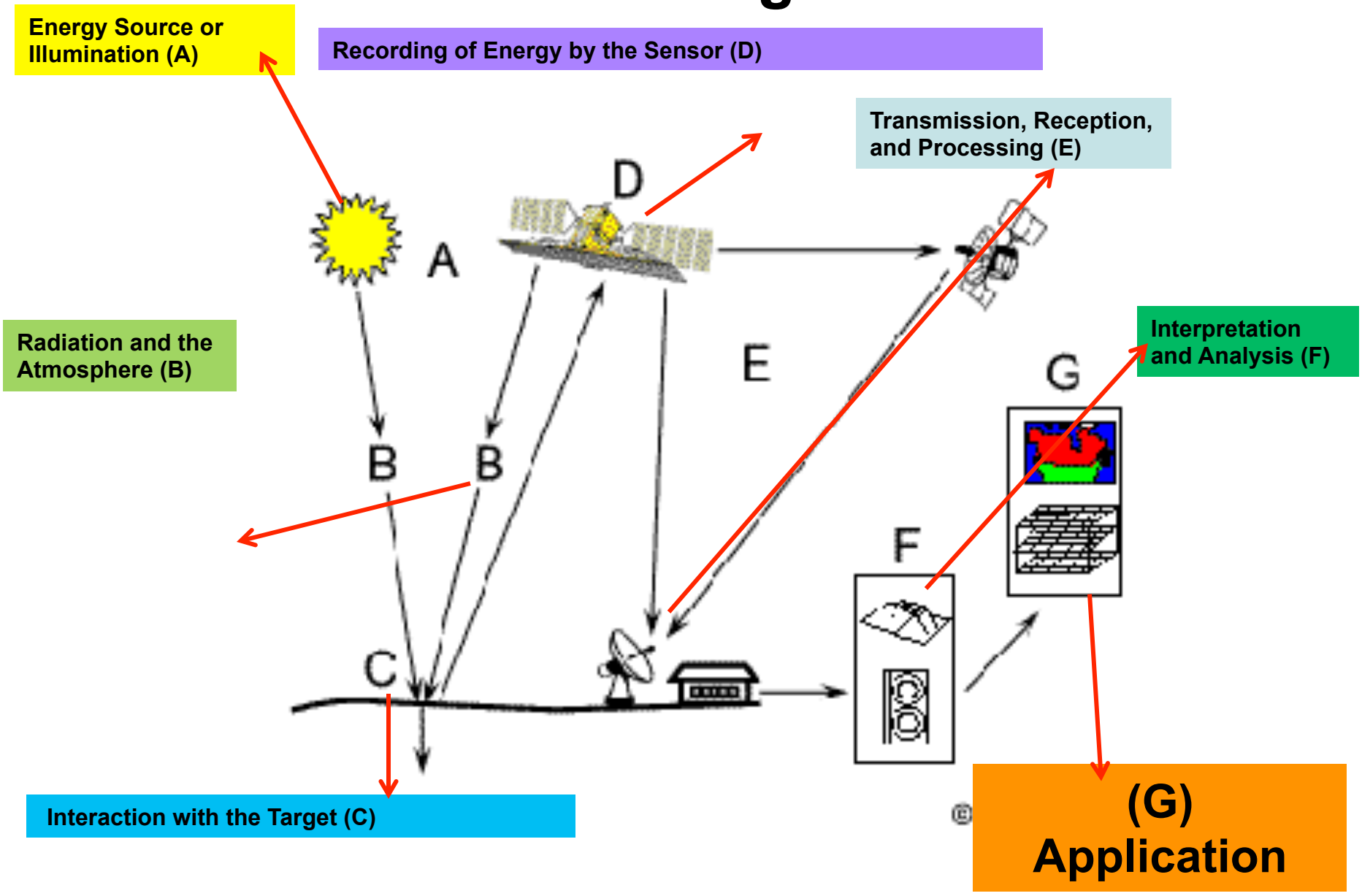
(B)
Radiation and the Atmosphere

(F)
Interpretation and Analysis

(C)
Interaction with the Target

Reference:
CCRS/CCT

Remote Sensing Process



Reference: CCRS/CCT

Remote Sensing – Resolutions

- **Spatial resolution**

  The smallest spatial measurement.

- **Temporal resolution**

  Frequency of measurement.

- **Spectral resolution**

  The number of independent channels.

- **Radiometric resolution**

  The sensitivity of the detectors.

Pixel

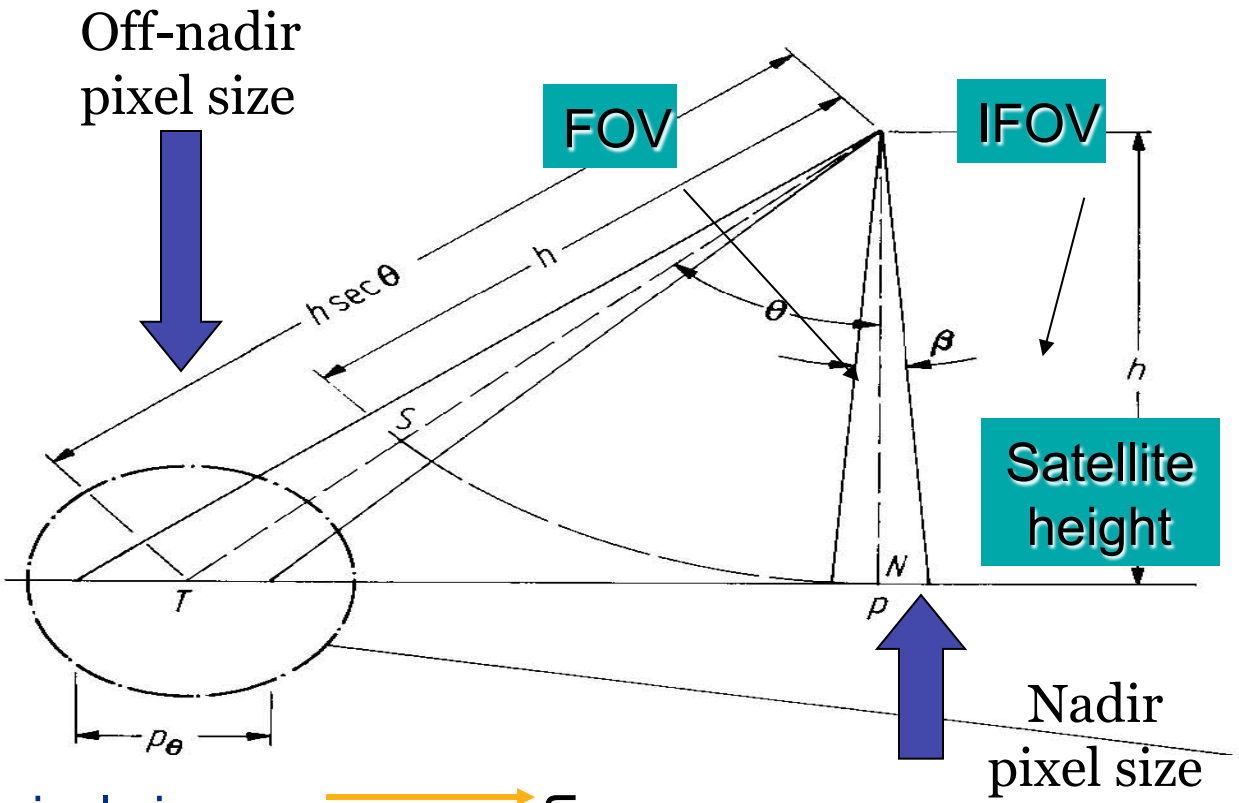
pixels - the **smallest units of an image**.

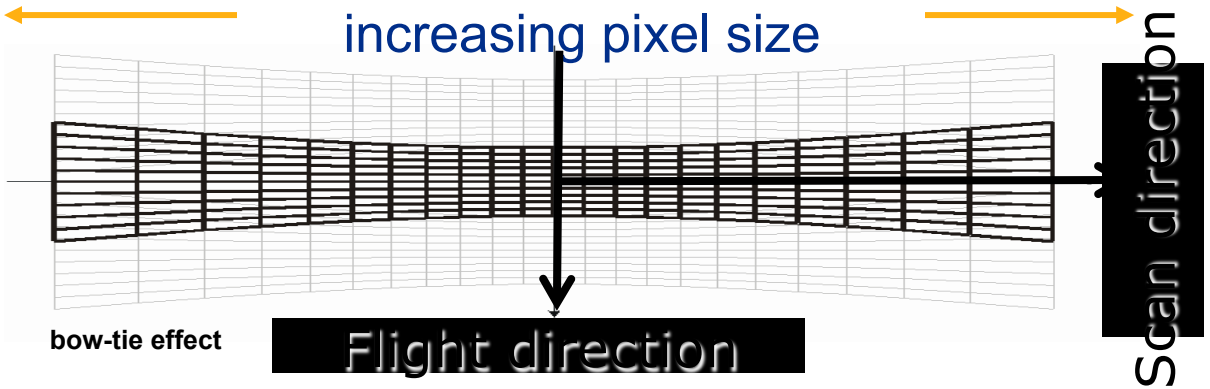
Image pixels are normally square (but not necessary) and represent a certain area on an image/Earth.

Spatial Resolution

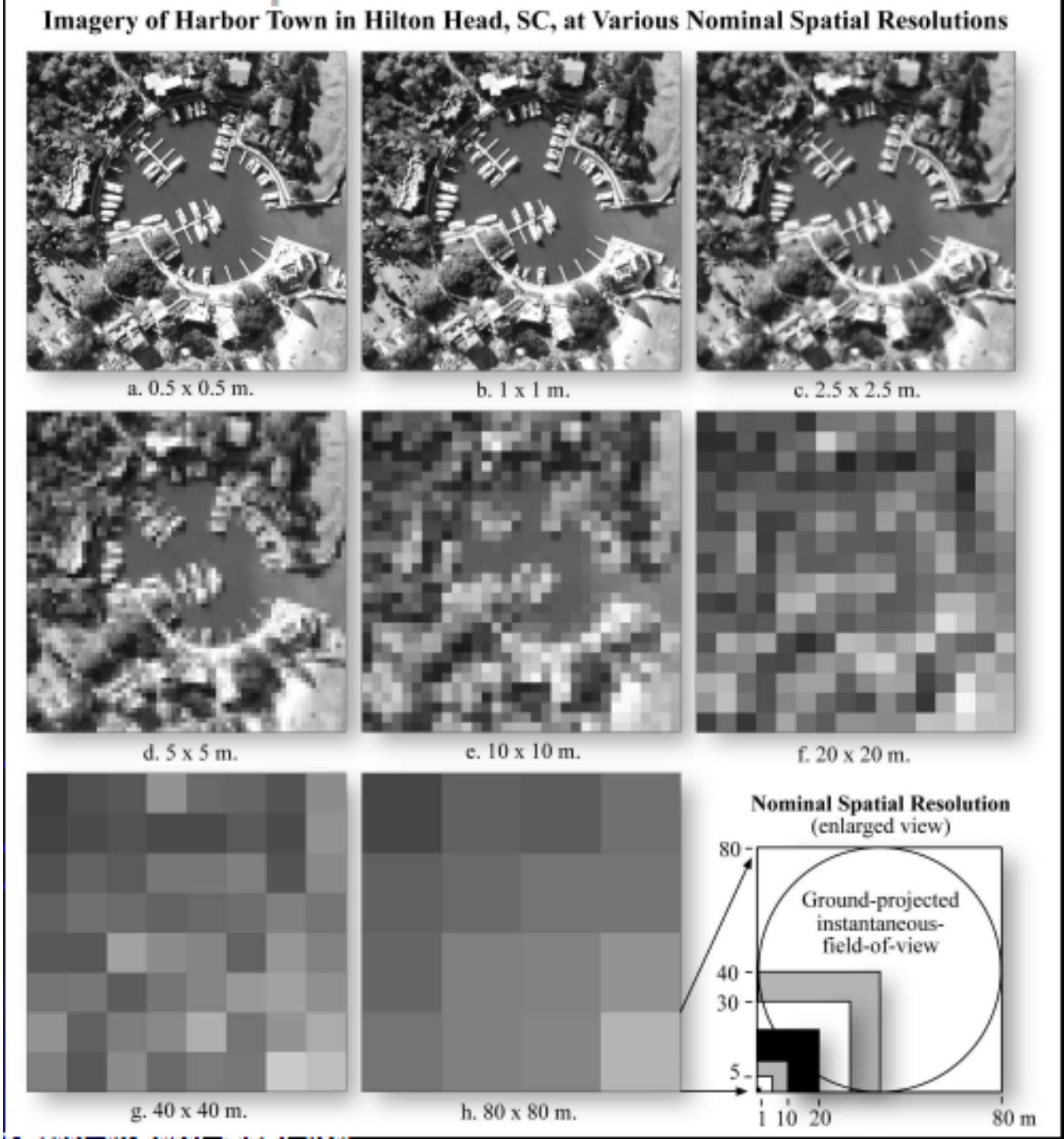
- Spatial Resolution :
  The highest magnification of the sensor at the ground surface

- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.



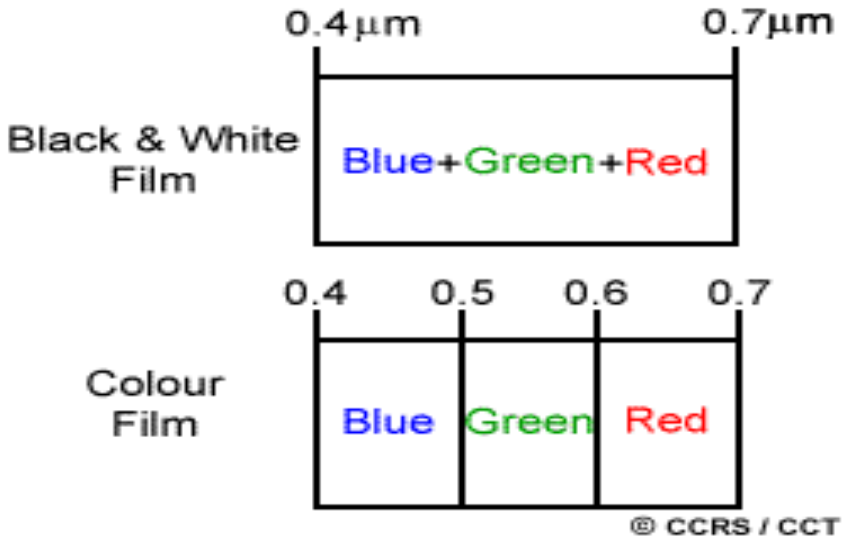


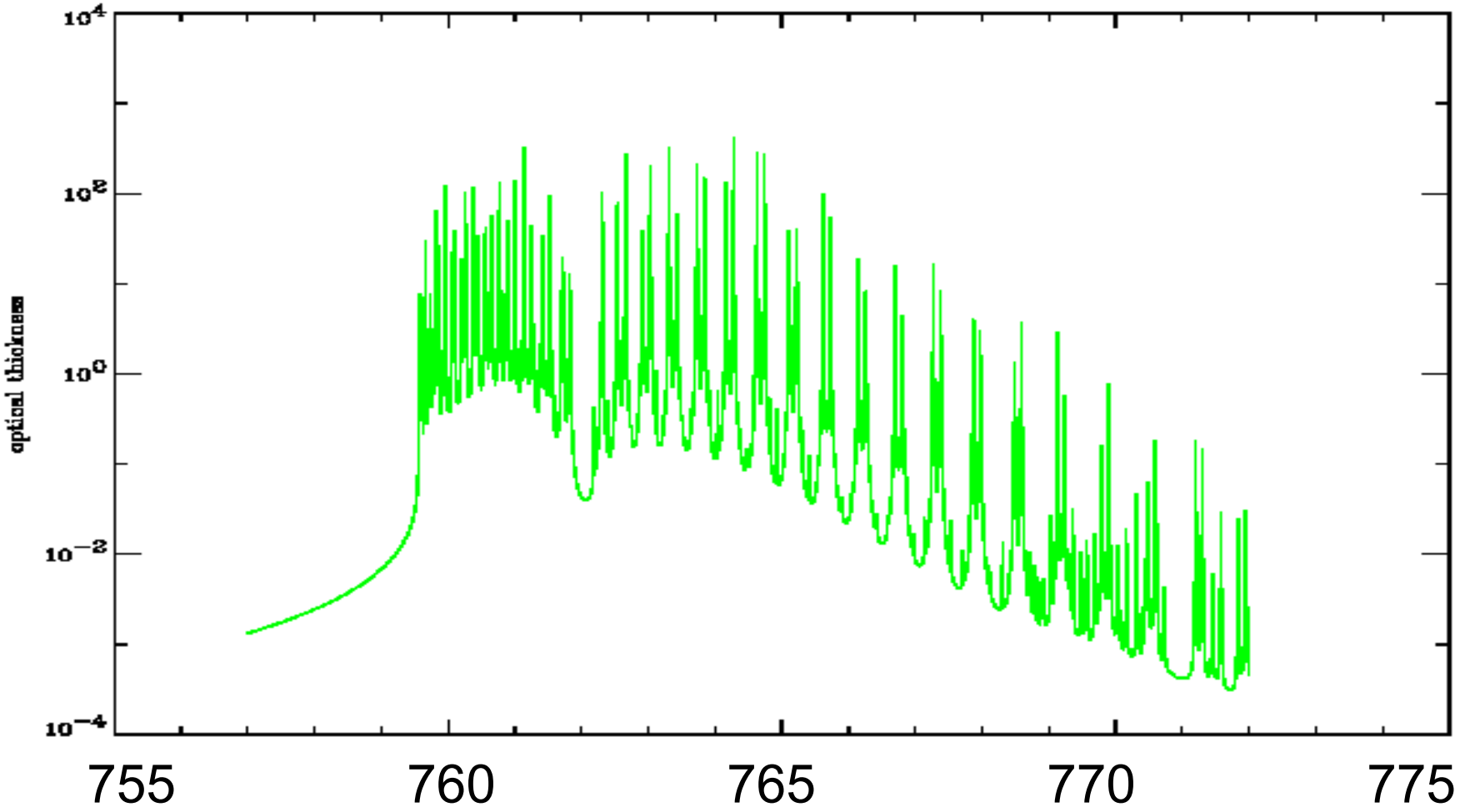
Why is spatial resolution important ?



Spectral Resolution

- Spectral resolution describes the ability of a sensor to define fine wavelength intervals. The finer the spectral resolution, the narrower the wavelength range for a particular channel or band.
- **multi-spectral sensors - MODIS**
- **hyper spectral sensors - OMI, AIRS**





In order to capture information contained in a narrow spectral region – hyper spectral instruments such as OMI, or AIRS are required

Radiometric Resolution

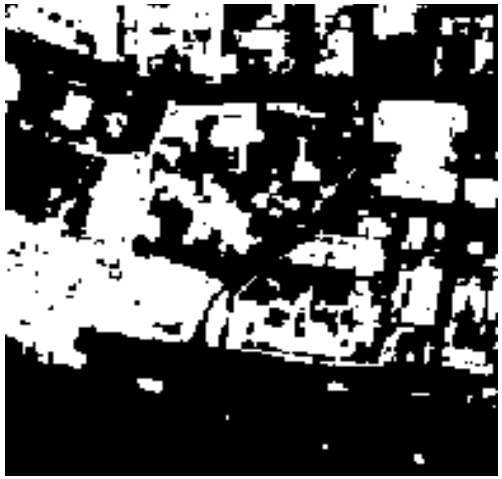
•Imagery data are represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2.

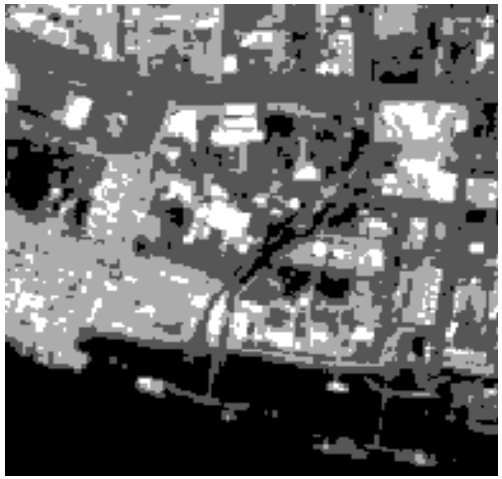
•The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded.

- **12 bit sensor (MODIS, MISR) – 2^{12} or 4096 levels**
- **10 bit sensor (AVHRR) – 2^{10} or 1024 levels**
- **8 bit sensor (Landsat TM) – 2^8 or 256 levels (0-255)**
- **6 bit sensor (Landsat MSS) – 2^6 or 64 levels (0-63)**

Radiometric Resolution

2 - levels





4 - levels

8 - levels

16 - levels

In classifying a scene, different classes are more precisely identified if radiometric precision is high.

Temporal Resolution

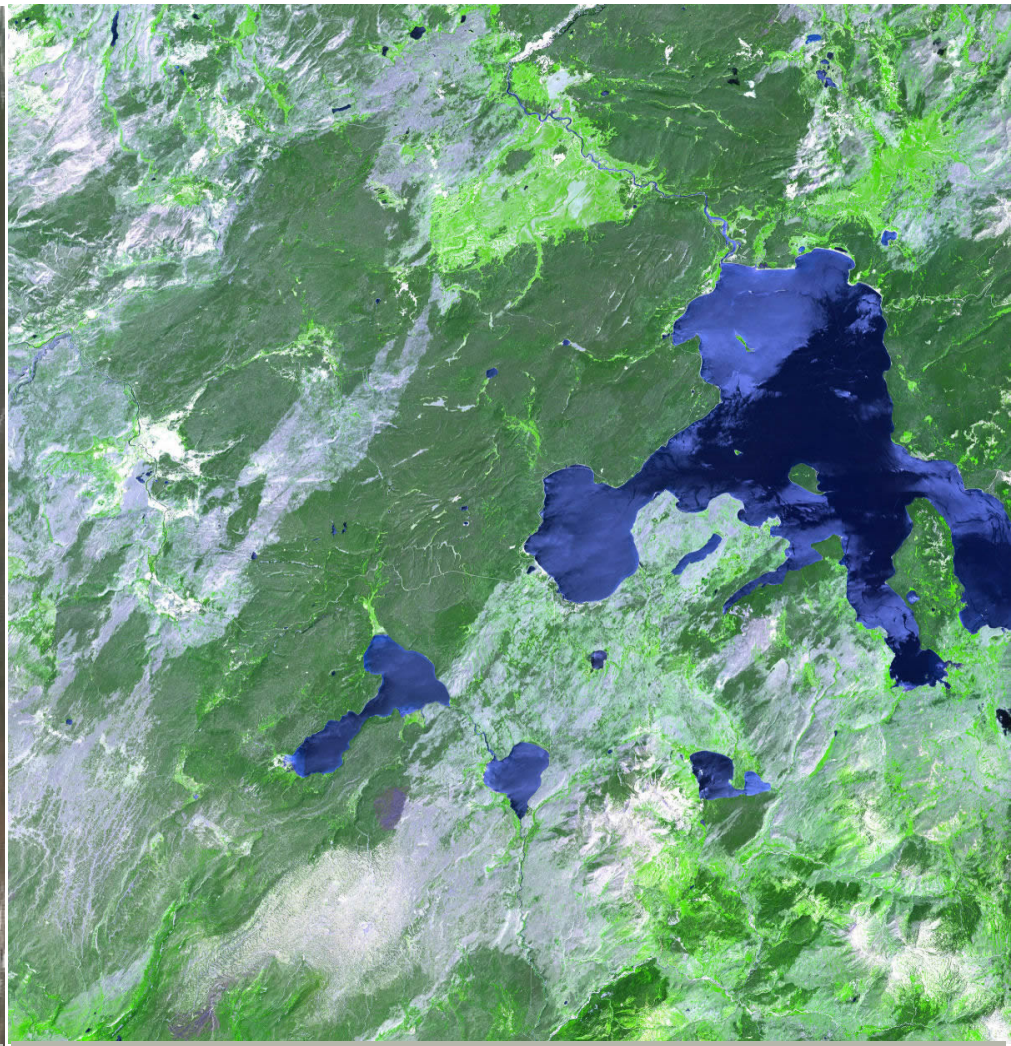
- How frequently a satellite can provide observation of same area on the earth
- It mostly depends on swath width of the satellite – larger the swath – higher the temporal resolution

- **MODIS – 1-2 days – 16 day repeat cycle**
- **OMI – 1-2 days**
- **MISR – 6-8 days**
- **Geostationary – 15 min to 1 hour**

  (but limited to one specific area of the globe)

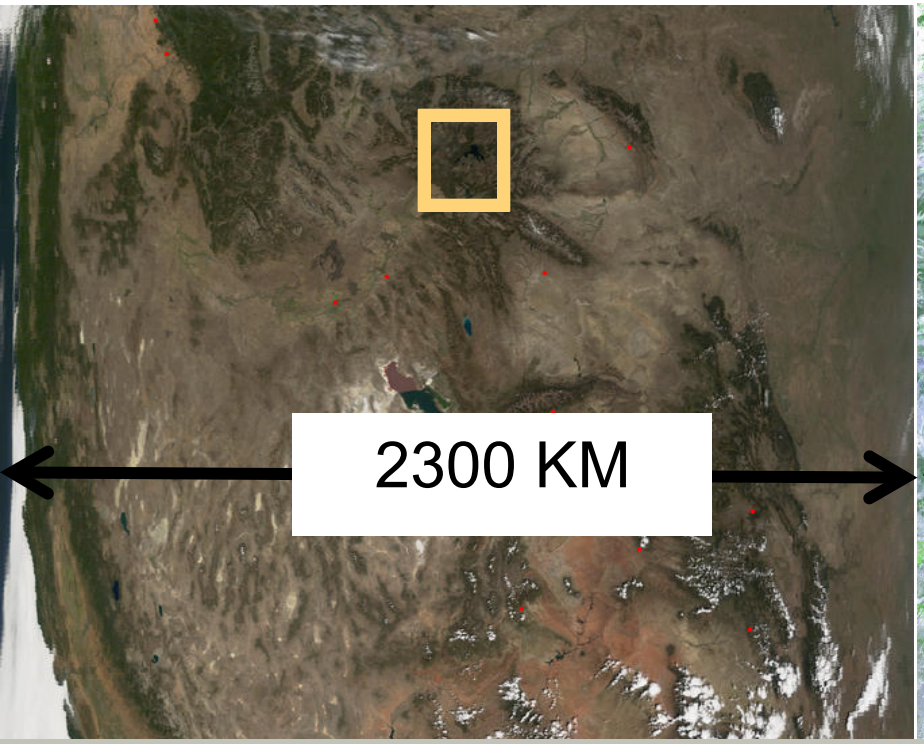
Remote Sensing – Trade offs

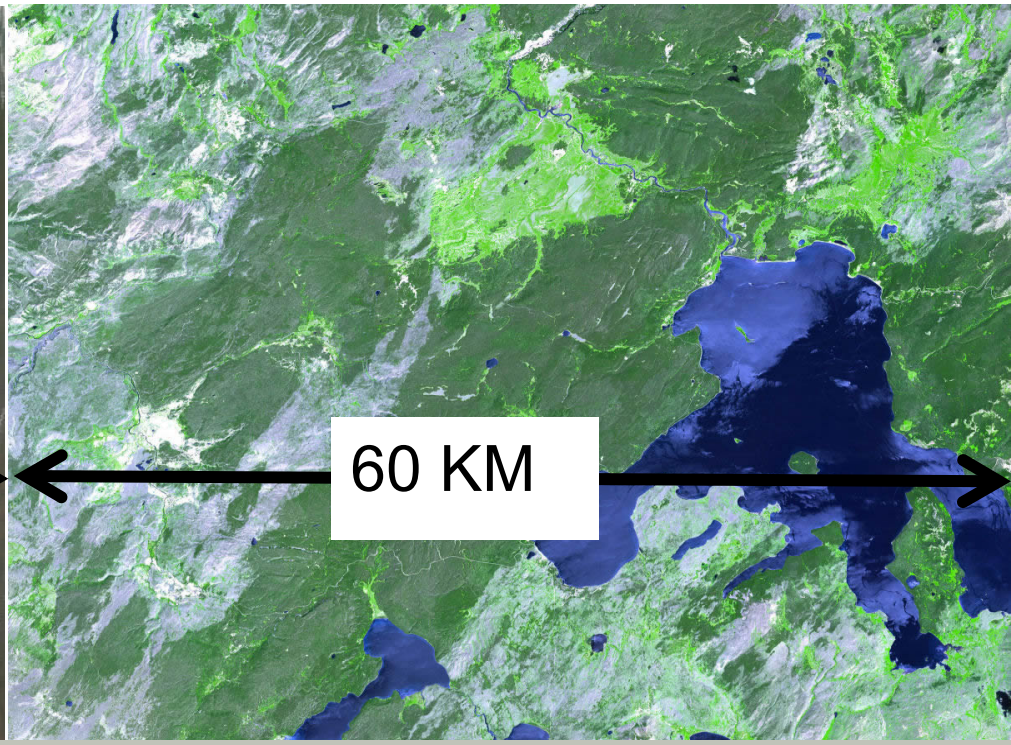
MODIS 500 Meter
True color image



Aster Image
15 M Resolution

Remote Sensing – Trade offs





•The different resolutions are the limiting factor for the utilization of the remote sensing data for different applications. Trade off is because of technical constraints.

•Larger swath is associated with low spatial resolution and vice versa

•Therefore, often satellites designs are applications oriented

Trade Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolutions at the same time
- MODIS, OMI and several other sensors can obtain global coverage every one – two days because of their wide swath width
- Higher resolution polar orbiting satellites may take 8 – 16 days for global coverage or may never provide full coverage of the globe.
- Geostationary satellites obtain much more frequent observations but at lower resolution due to the much greater orbital distance.

Factors which change with each instrument

- Calibration accuracy
- Quality Assurance
- Data formats
- Product Resolutions
- Level of data products
- Current release of the data and data history

Geophysical Products

Images

Cloud Fraction

Aerosol Optical Depth – Particulate Matter

Total Column Trace Gas Amount

Trace Gas Layer Concentrations

Land Cover Type

Vegetation Index

Assignment Week - 1

https://docs.google.com/forms/d/1FSSnjDVodhTNcZ94A_uz-5FeFUcPtNkDYEVauryZQBI/viewform