



ARSET

Applied Remote Sensing Training

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# Introduction to Satellite Remote Sensing for Air Quality Applications

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*Webinar Session 1 – July 6, 2016*

**Training Overview and Introduction to  
Satellite Remote Sensing**



# Outline

- ✓ **Introduction to ARSET**
- ✓ **Tour of the ARSET webpage**
- ✓ **Training overview**
- ✓ **Fundamentals of Satellite Remote Sensing**

Today's Instructor: **Pawan Gupta**  
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<http://arset.gsfc.nasa.gov/people/pawan-gupta-0>



# NASA Applied Sciences: Capacity Building

National and international activities to engage and train users applying NASA Earth Science satellites and modeling data in their decision making activities.



## ARSET

Increasing the utilization of NASA Earth science and model data through online webinars and hands-on trainings.

Register to participate in courses or review past recorded webinars  
[arset.gsfc.nasa.gov/webinars](https://arset.gsfc.nasa.gov/webinars)

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Dual workforce/decision-maker capacity building through collaborative applied sciences projects.

Apply to participate in a DEVELOP project  
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Explore example DEVELOP projects  
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## SERVIR

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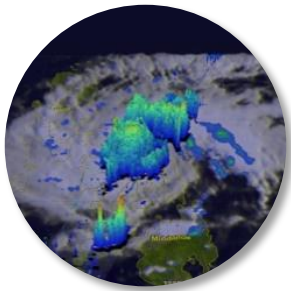
# Applied Remote Sensing Training Program (ARSET)

<http://arset.gsfc.nasa.gov>

Provide online and on-site trainings tailored to:

- policy makers
- regulatory agencies
- applied environmental professionals

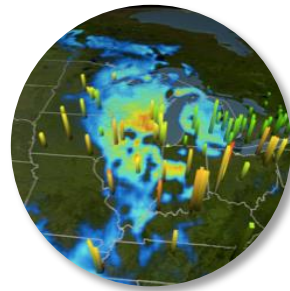
to increase the use of NASA Earth Science models & data for environmental applications:



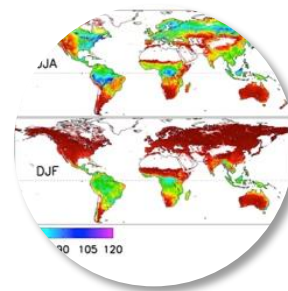
Disasters



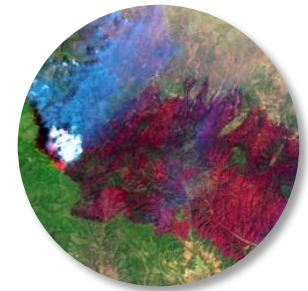
Ecoforecasting



Health &  
Air Quality



Water  
Resources



Wildfires

# ARSET Trainings

A gradual learning approach

## Basic Trainings

- Webinars & Workshops
  - Assumes no prior RS knowledge
- Examples: Fundamentals of Remote Sensing; Introduction to Remote Sensing*

## Advanced Trainings

- Webinars & Workshops
  - Requires basic training
  - Focuses on specific applications
- Example: Satellite Remote Sensing of Particulate Matter Air Quality*

**Upcoming  
ARSET AQ  
Training at**

**17th IUAPPA World Clean Air Congress and  
9th CAA Better Air Quality Conference**

29 August – 2 September 2016 | Busan, S. Korea

# ARSET Contact Information

*(Any individual or organization can contact us for more advanced training in the area of satellite remote sensing and its applications. ARSET provides trainings to public, private and non-profit organizations around the world.)*

- **Overall program information**
  - Ana Prados ([aprados@umbc.edu](mailto:aprados@umbc.edu))
- **Training Request**
  - Brock Blevins ([brockbl1@umbc.edu](mailto:brockbl1@umbc.edu))
- **Air Quality**
  - Pawan Gupta ([pawan.gupta@nasa.gov](mailto:pawan.gupta@nasa.gov))



## ARSET

Applied Remote Sensing Training

<http://arset.gsfc.nasa.gov>

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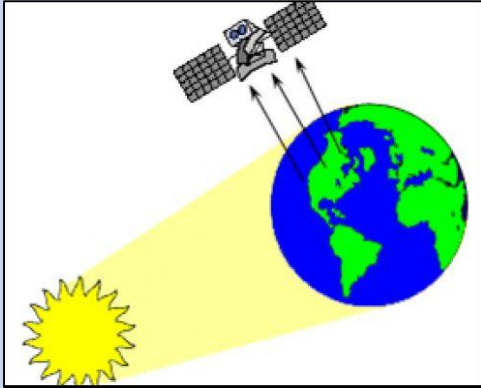
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## Brief tour of the ARSET page

<http://arset.gsfc.nasa.gov>

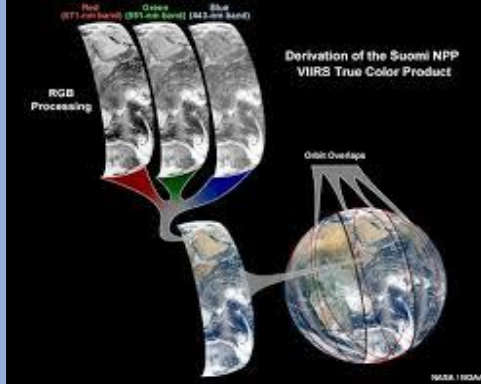
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# 5 Weeks Webinar Series: Agenda



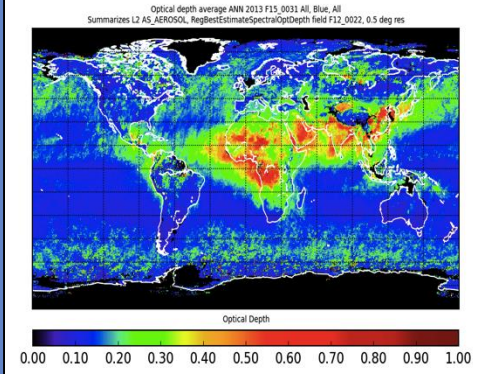
A diagram illustrating the fundamental process of remote sensing. A yellow sun on the left emits a beam of light towards a satellite in orbit above a globe. The satellite has three arrows pointing towards the Earth, representing the collection of data. The globe is colored with a gradient from blue to green to red, representing different levels of data or environmental conditions.

**Week 1: Fundamental of Remote Sensing**



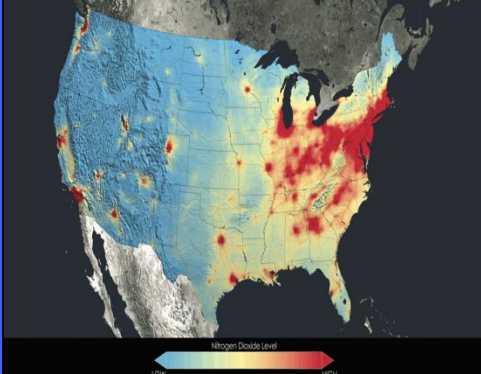
A diagram showing the derivation of the Suomi NPP VIIRS True Color Product. It features three satellite orbits labeled 'Red (413nm band)', 'Green (555nm band)', and 'Blue (443nm band)'. The orbits are shown overlapping, with the text 'Derivation of the Suomi NPP VIIRS True Color Product' and 'RGB Processing' indicating the process. A globe is shown with 'Orbit Overlaps' and the NASA/NOAA logo.

**Week 2: Satellite Imagery**



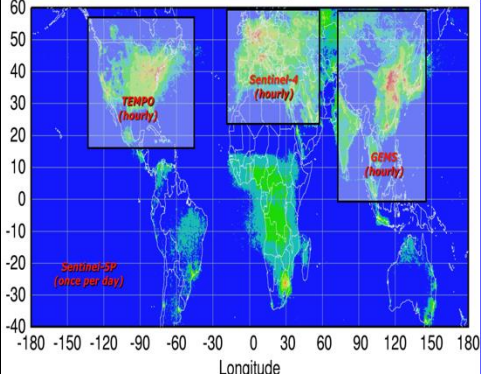
A global map showing aerosol data. The map is color-coded by optical depth, with a legend at the bottom ranging from 0.00 (blue) to 1.00 (red). The map shows high concentrations of aerosols in the mid-latitude regions, particularly over the North Atlantic and the Indian Ocean. The text 'Optical depth average ANN 2013 F15\_0031 All, Blue, All Summarizes L2 AS\_AEROSOL\_RegBestEstimateSpectraOptDepth field F12\_0022, 0.5 deg res' is visible at the top.

**Week 3: Aerosol Data**



A map of the United States showing trace gas data. The map is color-coded by Nitrogen Dioxide Level, with a legend at the bottom ranging from LOW (blue) to HIGH (red). The map shows high concentrations of Nitrogen Dioxide in the eastern United States, particularly in the Northeast and the Southeast.

**Week 4: Trace Gas Data**



A map showing future capabilities for satellite data. The map is color-coded by data type, with a legend at the bottom ranging from LOW (blue) to HIGH (red). The map shows high concentrations of data in the mid-latitude regions, particularly over the North Atlantic and the Indian Ocean. The text 'TEMPO (hourly)', 'Sentinel-1 (hourly)', 'GEMS (hourly)', and 'Sentinel-5P (once per day)' is visible on the map.

**Week 5: Future Capabilities**





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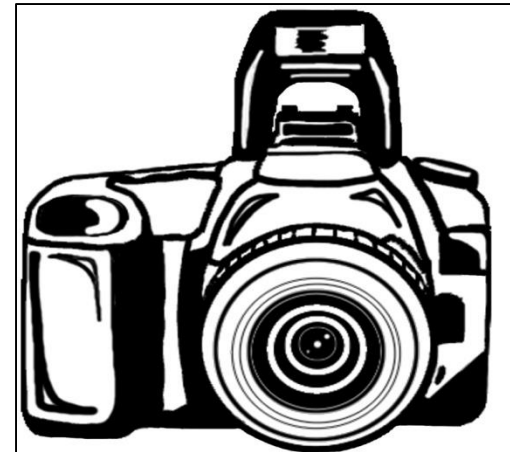
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# Fundamentals of Satellite Remote Sensing

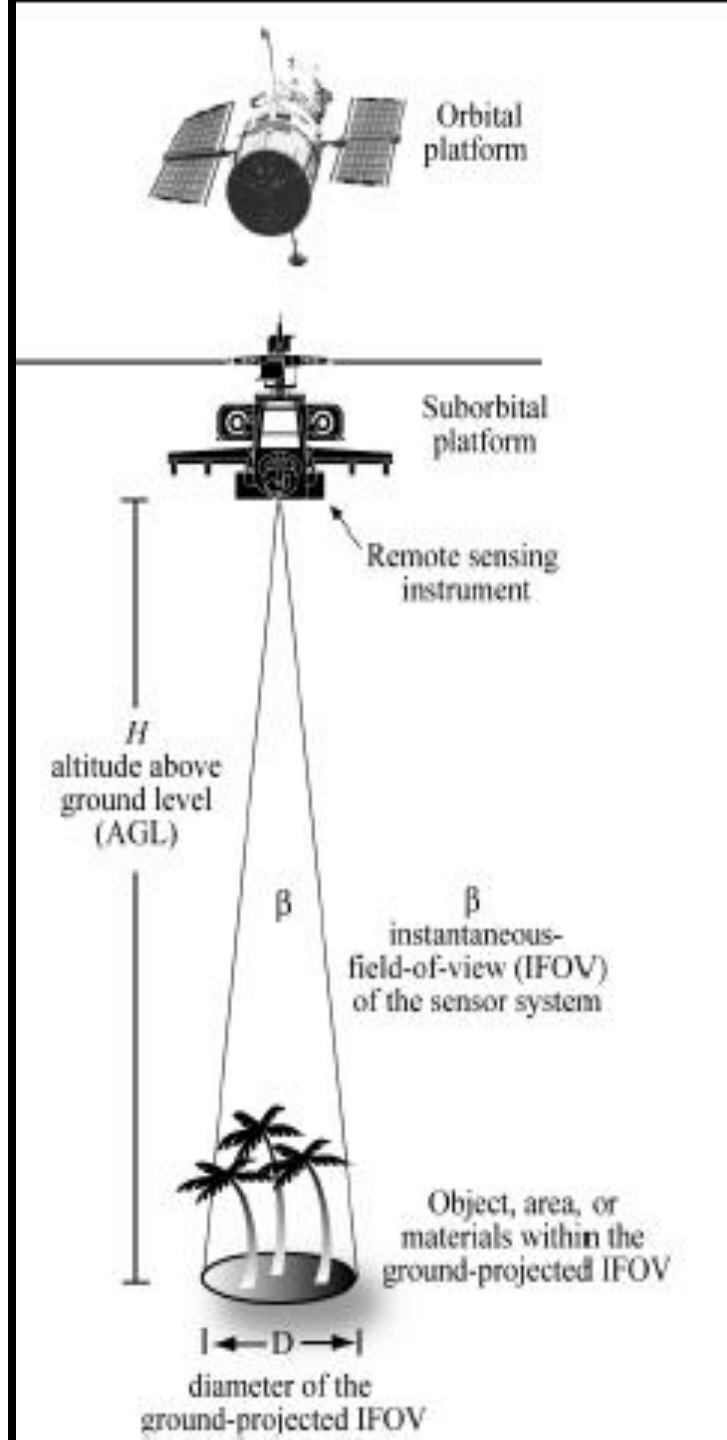
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# What is Remote Sensing ?

**Collecting information about an object without being in direct physical contact with it.**



# Remote Sensing ...

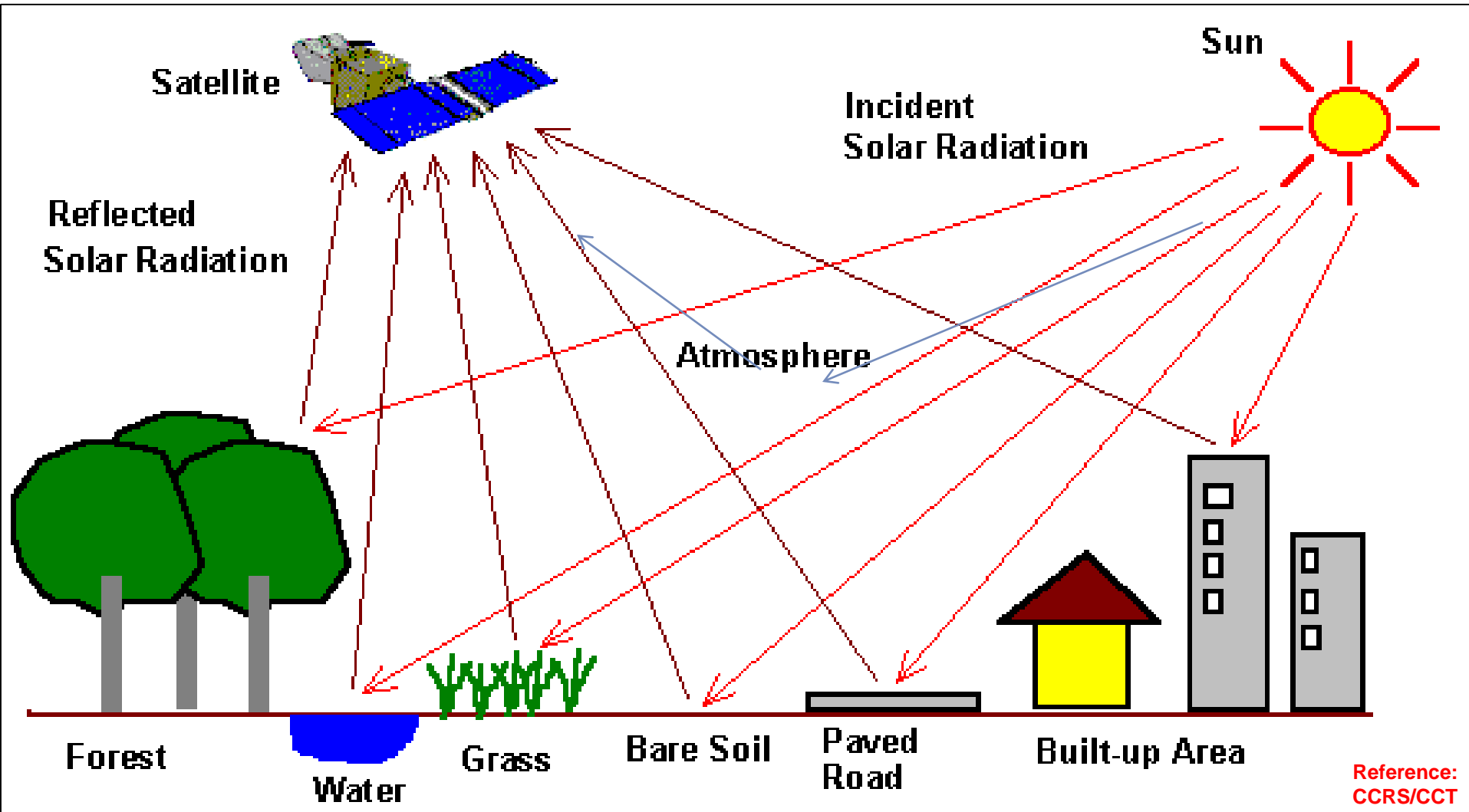


# Remote Sensing: Platforms



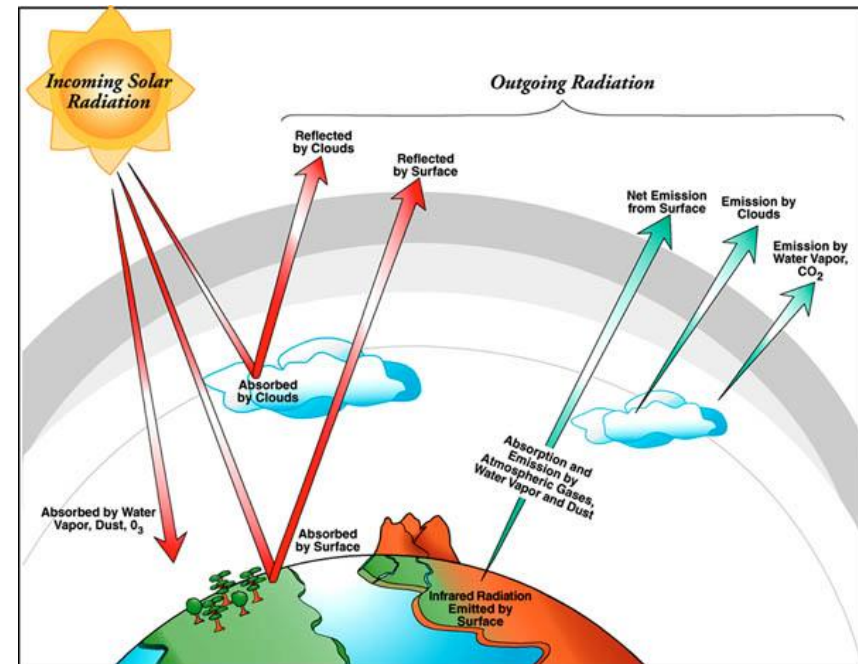
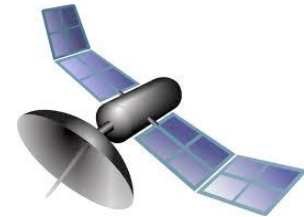
- **The platform depends on the end application**
- **What information do you want?**
- **How much detail do you need?**
- **What type of detail?**
- **How frequently do you need the data?**

# What do satellites measure ?



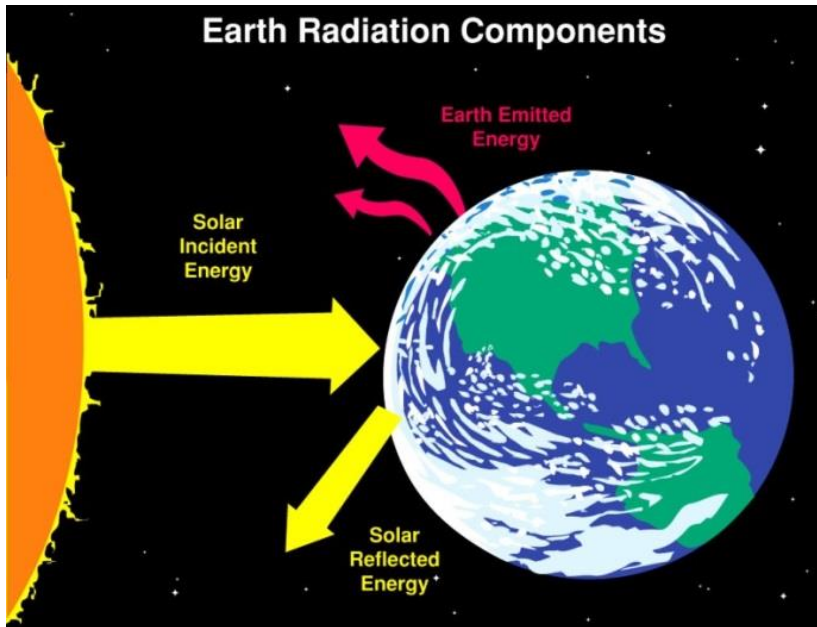
# Measuring Properties of the Earth-Atmosphere System from Space

- ❑ The intensity of reflected and emitted radiation to space is influenced by the surface and atmospheric conditions.
- ❑ Thus, satellite measurements contain information about the surface and atmospheric conditions.

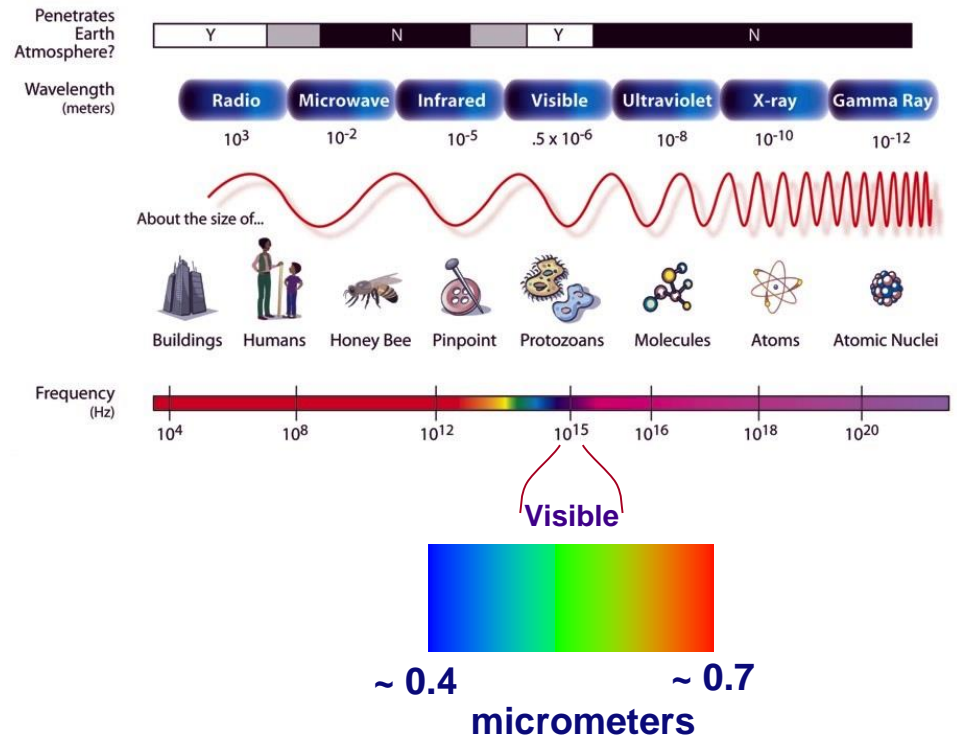


# Electromagnetic Radiation

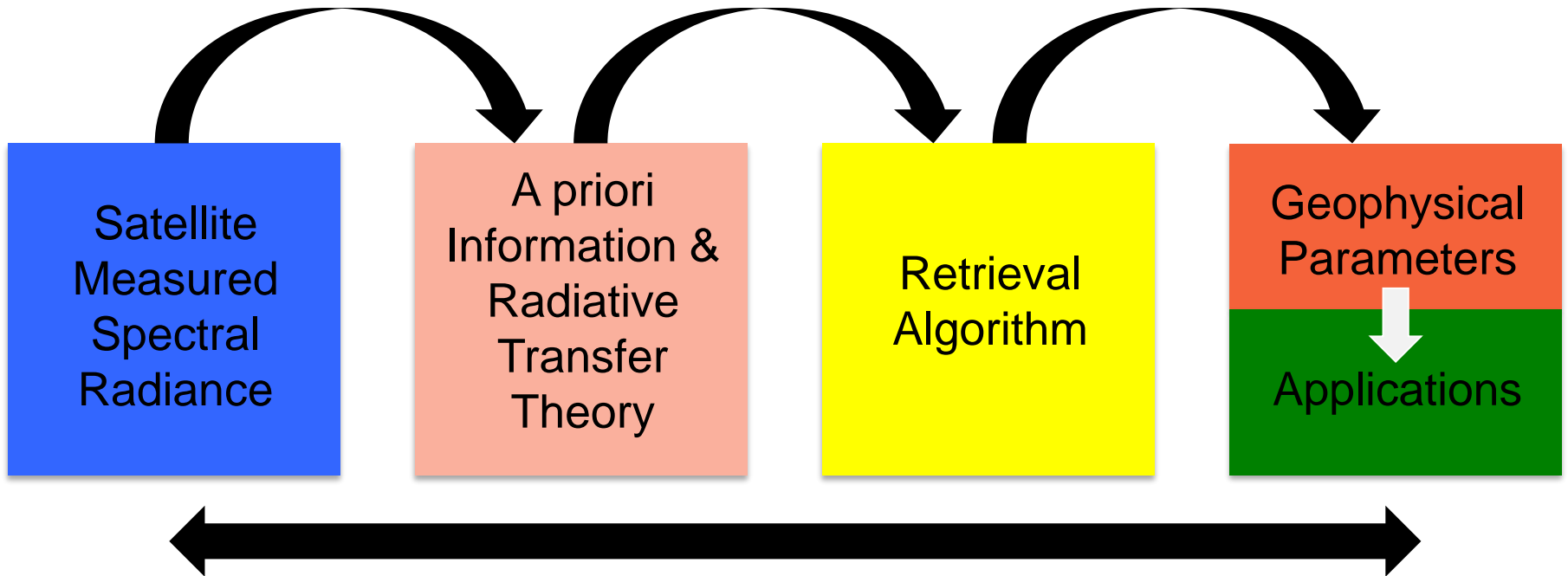
- Earth-Ocean-Land-Atmosphere System
  - Reflects solar radiation back into space
  - Emits infrared and microwave radiation into space



## THE ELECTROMAGNETIC SPECTRUM



# The Remote Sensing Process







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# Satellites, Sensors, and Orbits

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# 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:

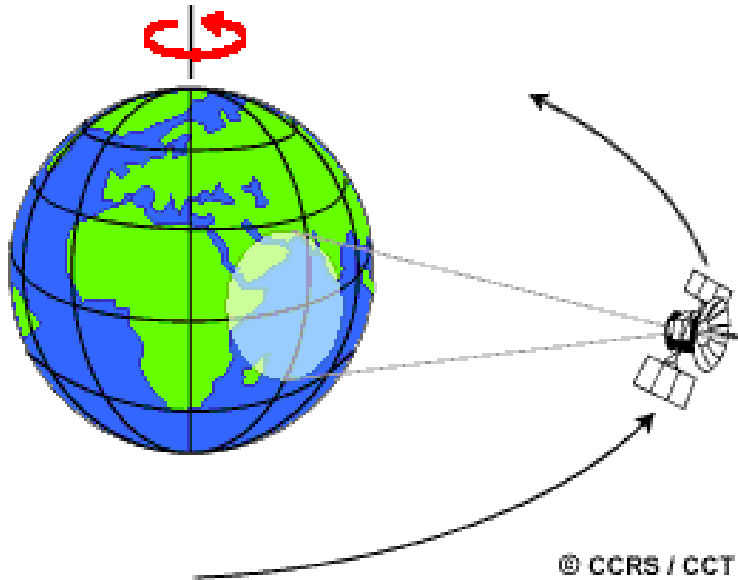
- OMI
- TES
- HIRDLS
- MLS

# Characterizing Satellites and Sensors

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

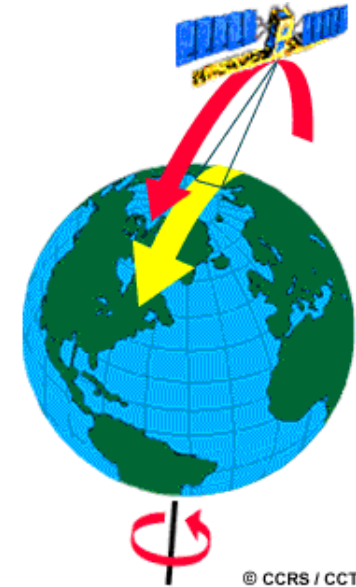
# Common types of orbits

## Geostationary



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

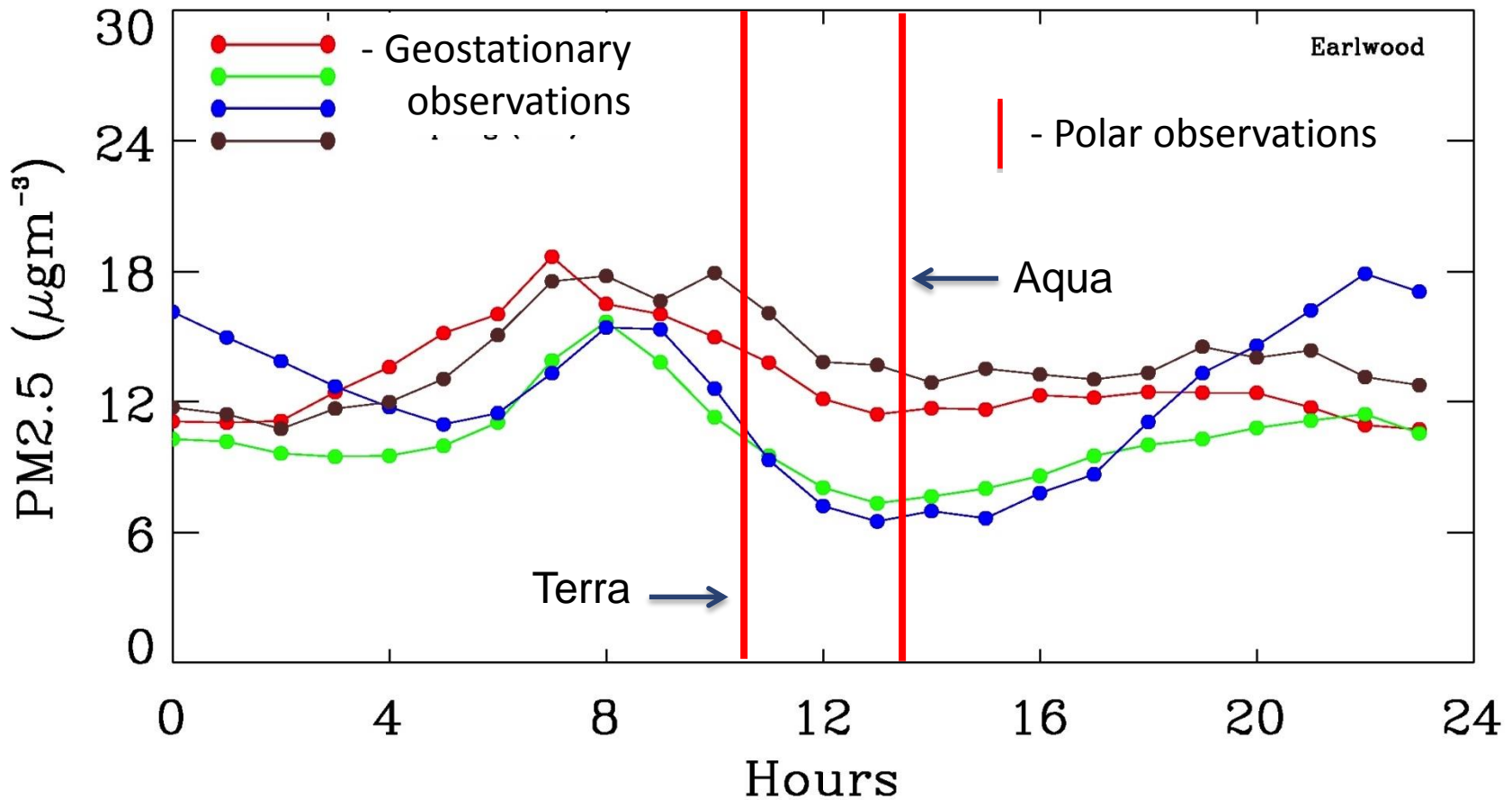
## Polar



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

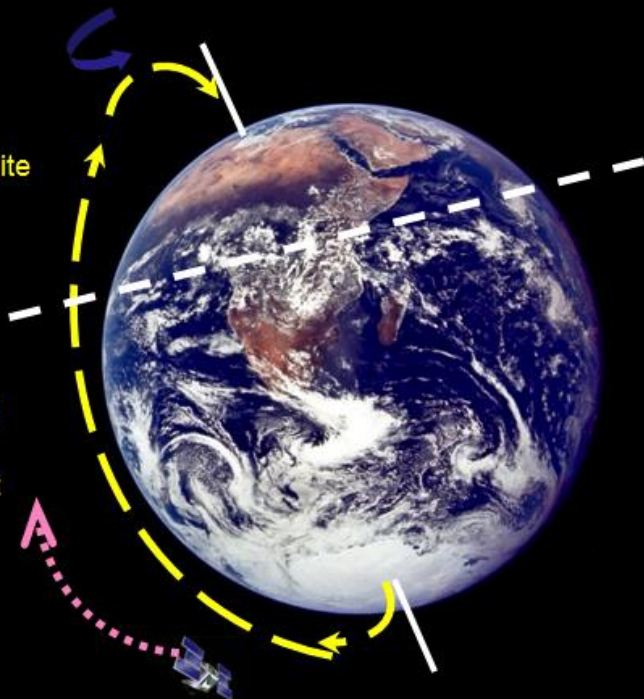


Geostationary satellites – Future satellites - TEMPO, GEMS, Sentinel-4

# Ascending vs Descending

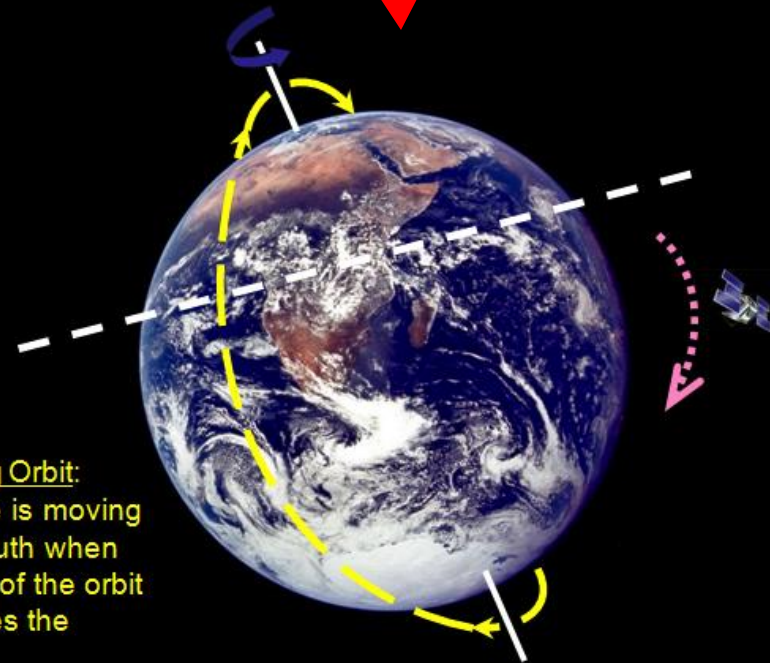
Path of Satellite

Ascending Orbit:  
The satellite is moving South to North when that portion of the orbit track crosses the equator.

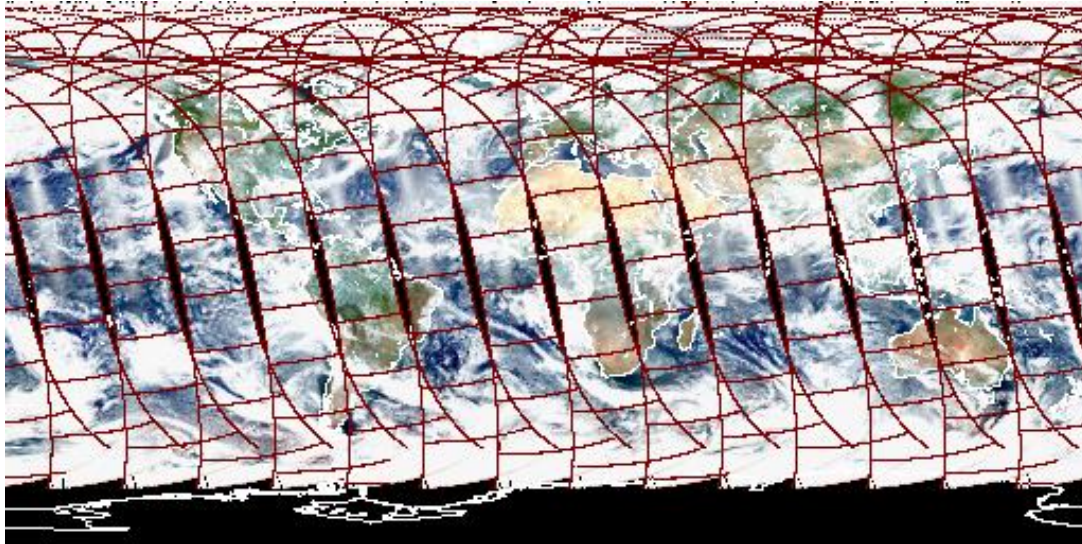


## Polar Orbits

Descending Orbit:  
The satellite is moving North to South when that portion of the orbit track crosses the equator.



# MODIS-Aqua (“ascending” orbit)

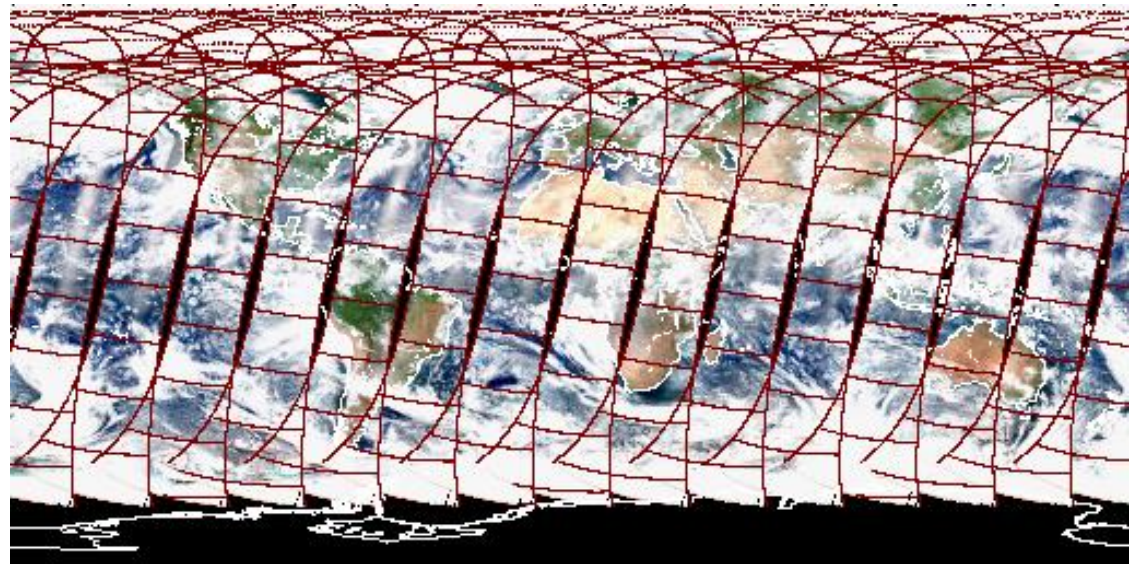


Approximately  
1:30 PM local  
overpass time  
**Afternoon  
Satellite**

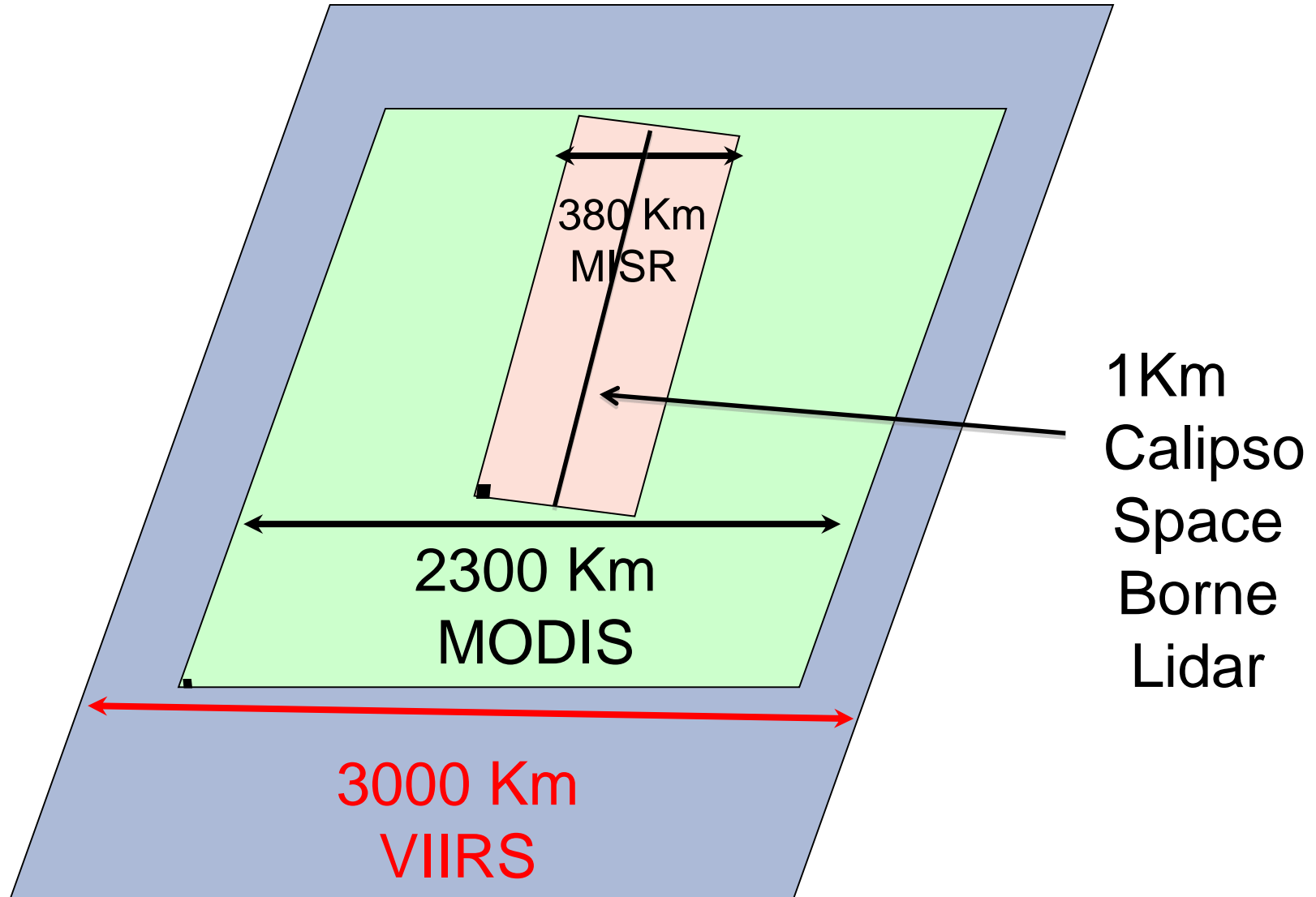
# MODIS-Terra (“descending”)

Approximately  
10:30 AM local  
overpass time

**Morning  
Satellite**

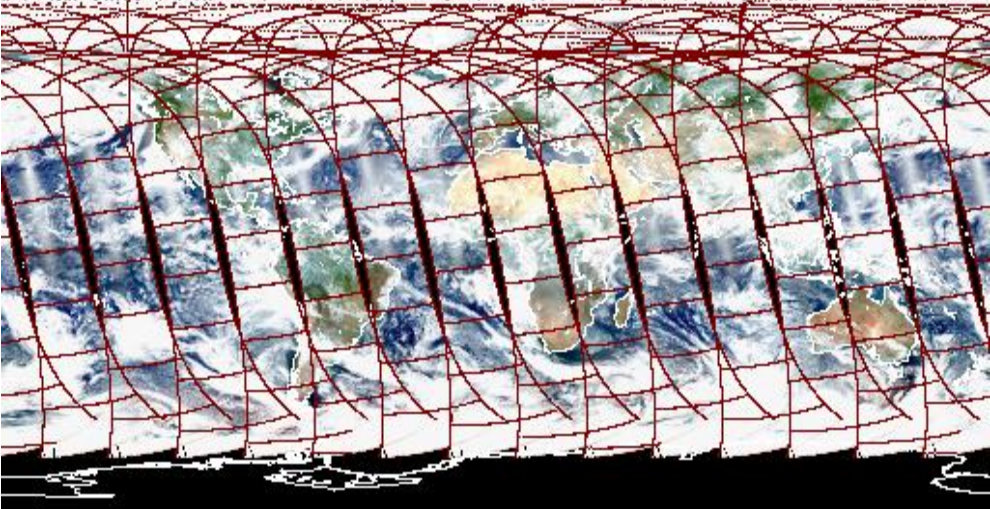


# Satellite Coverage

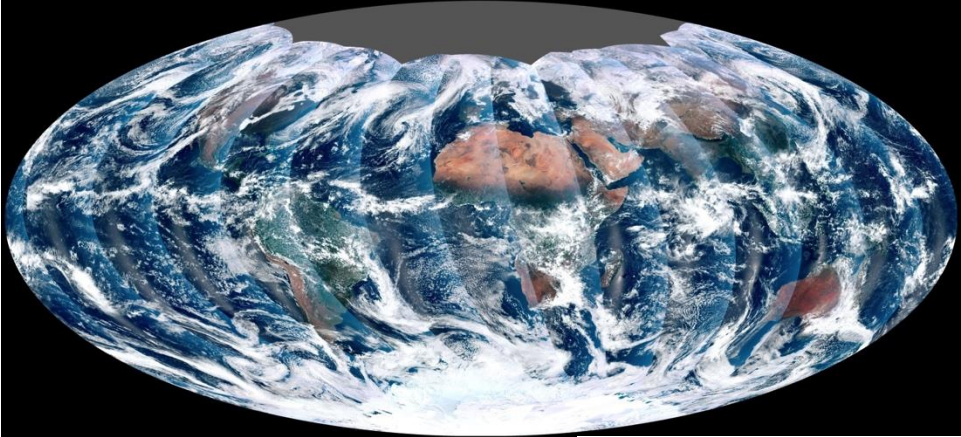




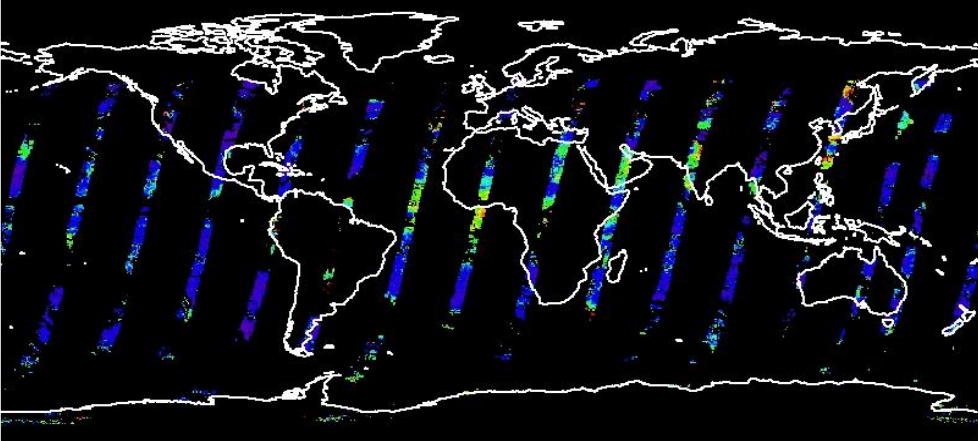
# Satellite Coverage



**MODIS**



**VIIRS**



**MISR**

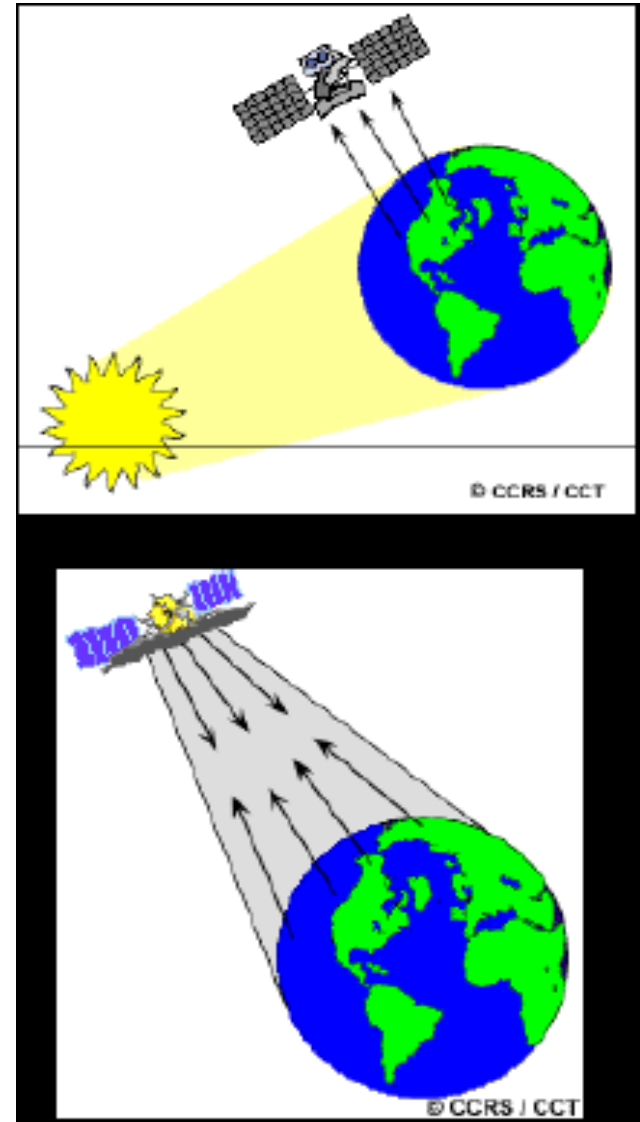
# Remote Sensing: Active and Passive Sensors

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

**MODIS, MISR, OMI, VIIRS**

**Active Sensors:** The sensor emits radiation that is directed toward the target to be investigated. The radiation reflected from that target is detected and measured by the sensor.

**CALIPSO**



The background is a satellite image showing a coastline with various shades of blue, green, and brown. A semi-transparent white rectangular box is centered over the image, containing the word 'Resolution' in a bold, black, sans-serif font. Below the text is a solid black horizontal line.

# Resolution

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# Remote Sensing – Types of Resolution

- **Spatial resolution**

The smallest spatial measurement.

- **Temporal resolution**

Frequency of measurement.

- **Spectral resolution**

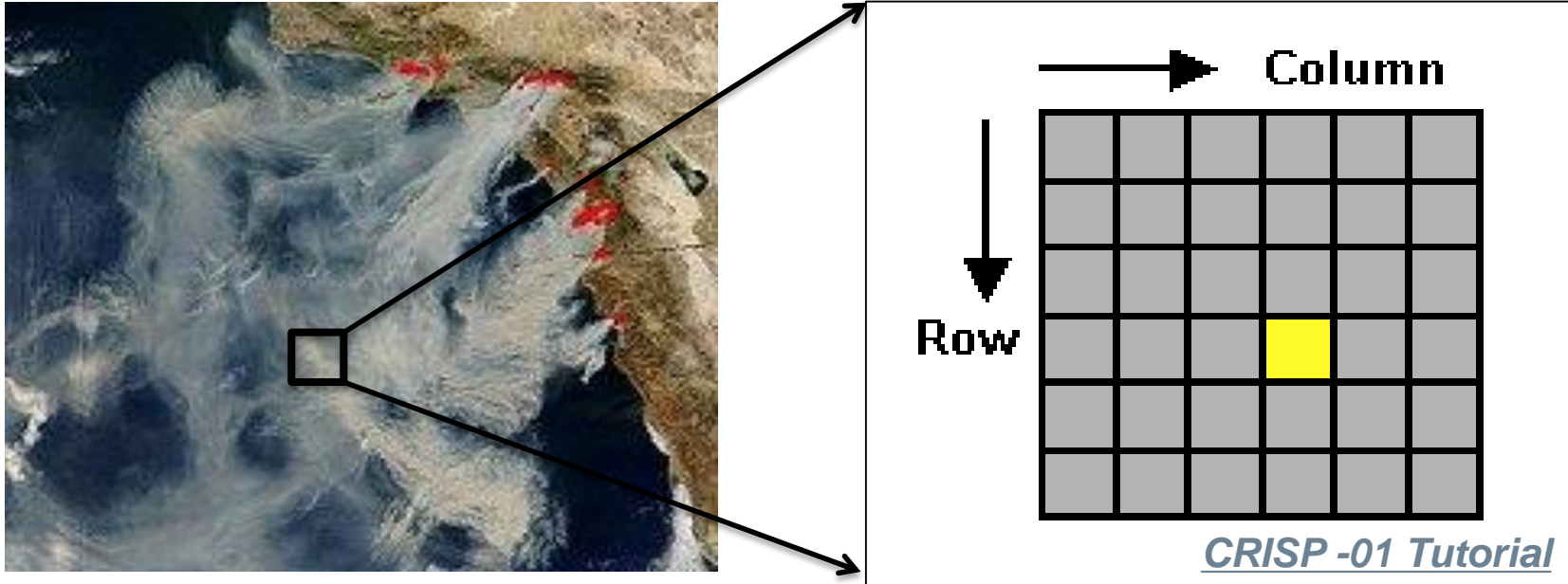
The number of independent channels.

- **Radiometric resolution**

The sensitivity of the detectors.

**Depends on the satellite orbit configuration and sensor design. Resolutions are different for different sensors**

# Pixel - the smallest unit of an image



- ✓ A digital image is comprised of a two dimensional array of individual picture elements – called pixels – arranged in columns and rows.
- ✓ Each pixel represents an area on the Earth's surface.
- ✓ A pixel has an intensity value and a location address in the two dimensional image.
- ✓ Spatial resolution is defined by the size of pixel

# Why is spatial resolution important ?



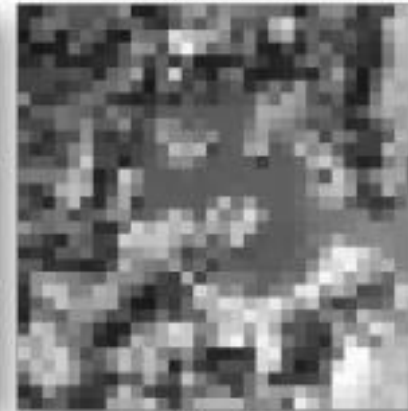
a. 0.5 x 0.5 m.

b. 1 x 1 m.

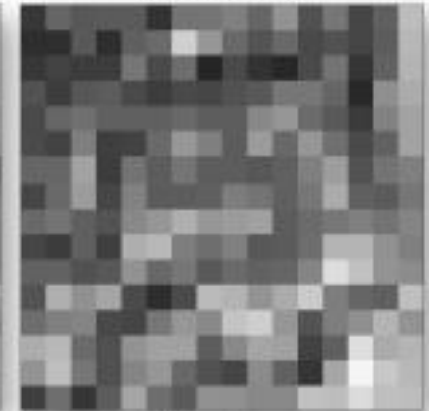
c. 2.5 x 2.5 m.



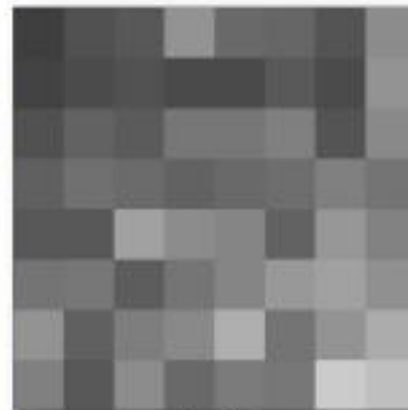
d. 5 x 5 m.



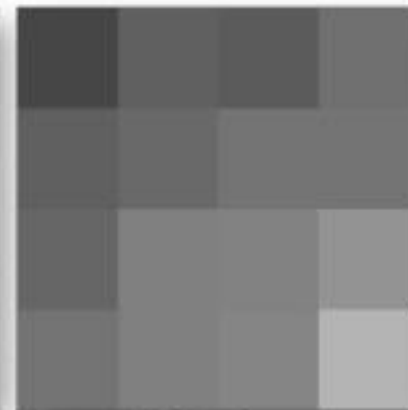
e. 10 x 10 m.



f. 20 x 20 m.

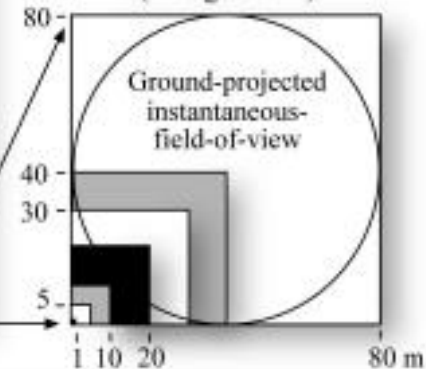


g. 40 x 40 m.



h. 80 x 80 m.

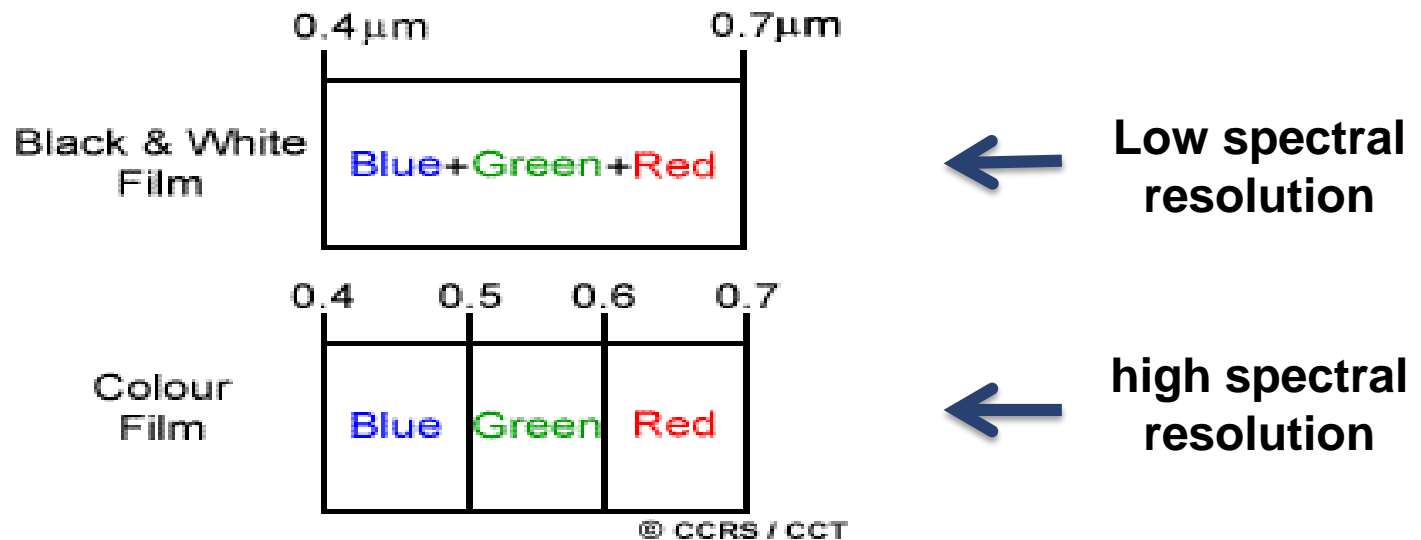
**Nominal Spatial Resolution  
(enlarged view)**



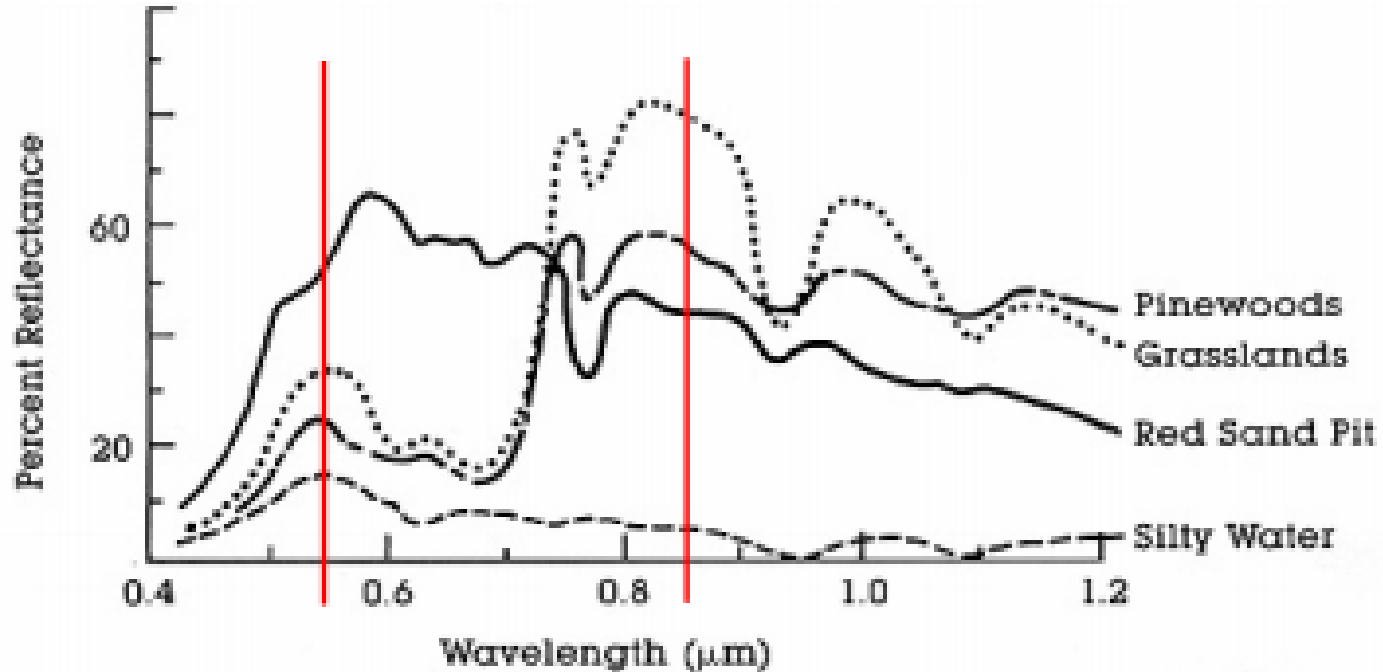
- MODIS
  - 250 m to 1 km
- MISR
  - 275 m to 1.1 km
- OMI
  - 13x24 km
- VIIRS
  - 375 m

# 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 – low spectral resolution**
- **hyperspectral sensors - OMI, AIRS – high spectral resolution**




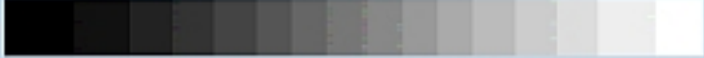
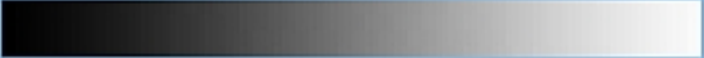
# Why is spectral resolution important ?





# Radiometric Resolution

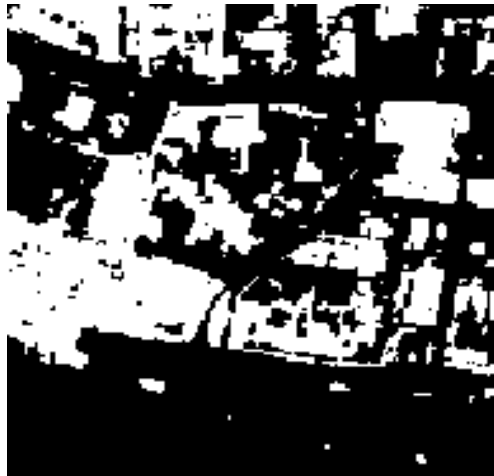
- Imagery data are represented by positive digital numbers that vary from 0 to (one less than) a selected power of 2.
- The maximum number of brightness levels available depends on the number of bits used in representing the energy recorded.
- The larger this number, the higher the radiometric resolution, and the sharper the imagery

| Bits | Werteumfang         | Grauwerte   |
|------|---------------------|---|
| 1Bit | $2^1 = 2$ (0-1)     | 0  1     |
| 4Bit | $2^4 = 16$ (0-15)   | 0  15    |
| 8Bit | $2^8 = 256$ (0-255) | 0  255 |

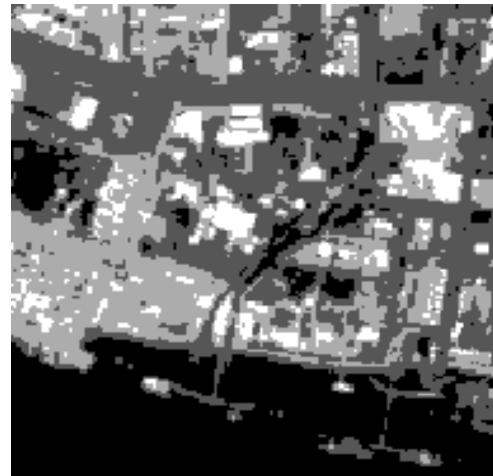
- ❑ 12 bit sensor (MODIS, MISR) –  $2^{12}$  or 4096 levels
- ❑ 10 bit sensor (AVHRR) –  $2^{10}$  or 1024 levels
- ❑ 8 bit sensor (Landsat 7 TM) –  $2^8$  or 256 levels (0-255)

# Radiometric Resolution

2 - levels



4 - levels



8 - levels



16 - levels

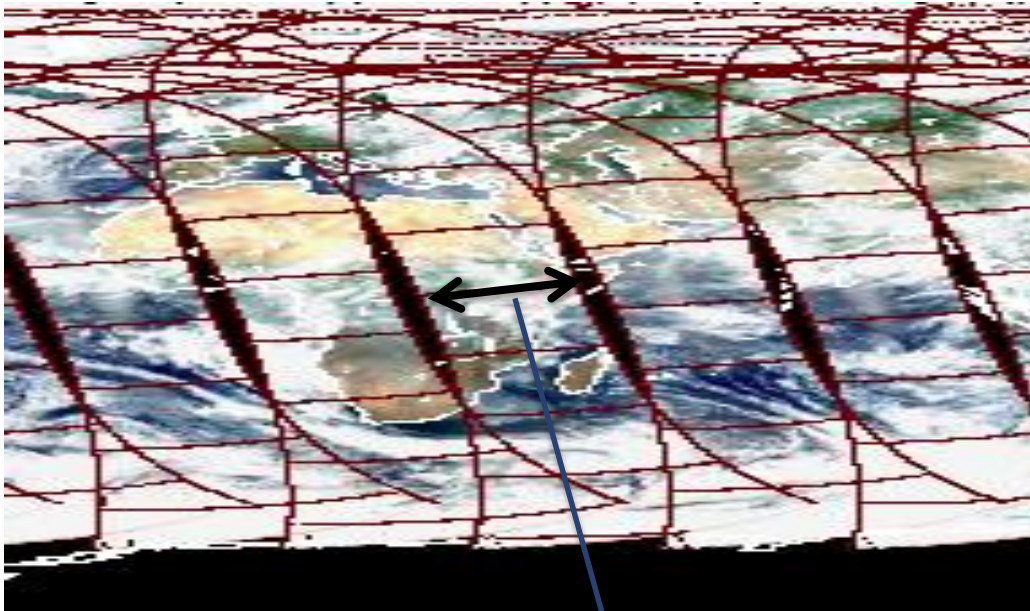


(MODIS  
4096 levels)

**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 the same area on the earth
- It mostly depends on swath width of the satellite – larger the swath – higher the temporal resolution



**Swath width**

**MODIS**

-1-2 days

**OMI**

-1-2 days

**MISR**

-6-8 days

**VIIRS**

- 1 day

**Geostationary**

-10 min to 1 hour

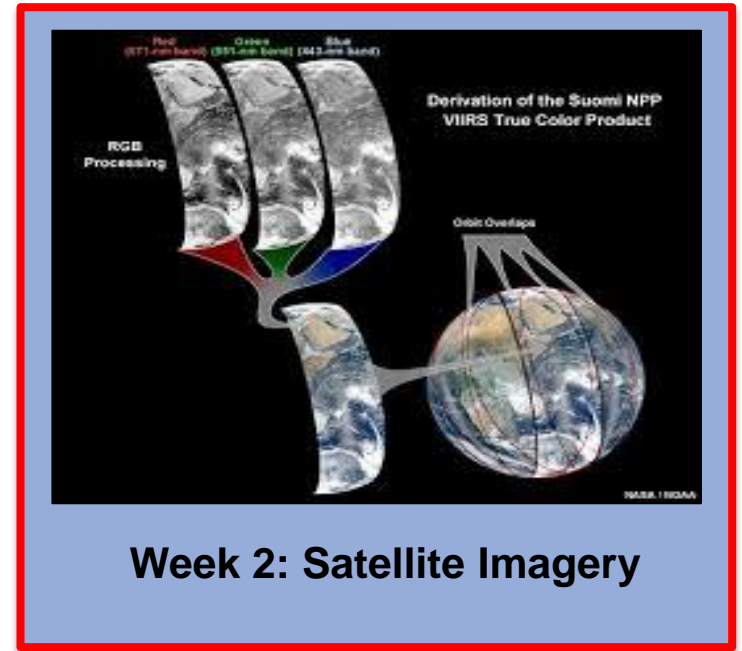


## **Remote Sensing Tradeoff**

**It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolutions at the same time**

# Next Week

- Visible satellite imagery and air quality applications
- Image information content, feature identification, and image archives
- Near Real-Time Image Access Exercise



# References and Further Reading

- Natural Resources Canada

<http://www.nrcan.gc.ca/earth-sciences/geomatics/satellite-imagery-air-photos/satellite-imagery-products/educational-resources/9309>

- Center for Remote Imaging, Sensing and Processing

<http://www.crisp.nus.edu.sg/~research/tutorial/image.htm>

- Earth Observatory

[http://earthobservatory.nasa.gov/Features/RemoteSensing/remote\\_06.php](http://earthobservatory.nasa.gov/Features/RemoteSensing/remote_06.php)

- EOS-Goddard

<http://fas.org/irp/imint/docs/rst/Front/tofc.html>

- Spectral Resolution

[http://web.pdx.edu/~jduh/courses/Archive/geog481w07/Students/Cody\\_Spectral\\_Resolution.pdf](http://web.pdx.edu/~jduh/courses/Archive/geog481w07/Students/Cody_Spectral_Resolution.pdf)

A satellite-style map of the Pacific Northwest coast of the United States, showing the coastline from the Columbia River down to the San Francisco Bay area. The map features a semi-transparent grey overlay in the center. The text "NO ASSIGNMENTS" is written in large, bold, black capital letters across the middle of the overlay. A thin black horizontal line is positioned directly below the text.

**NO ASSIGNMENTS**

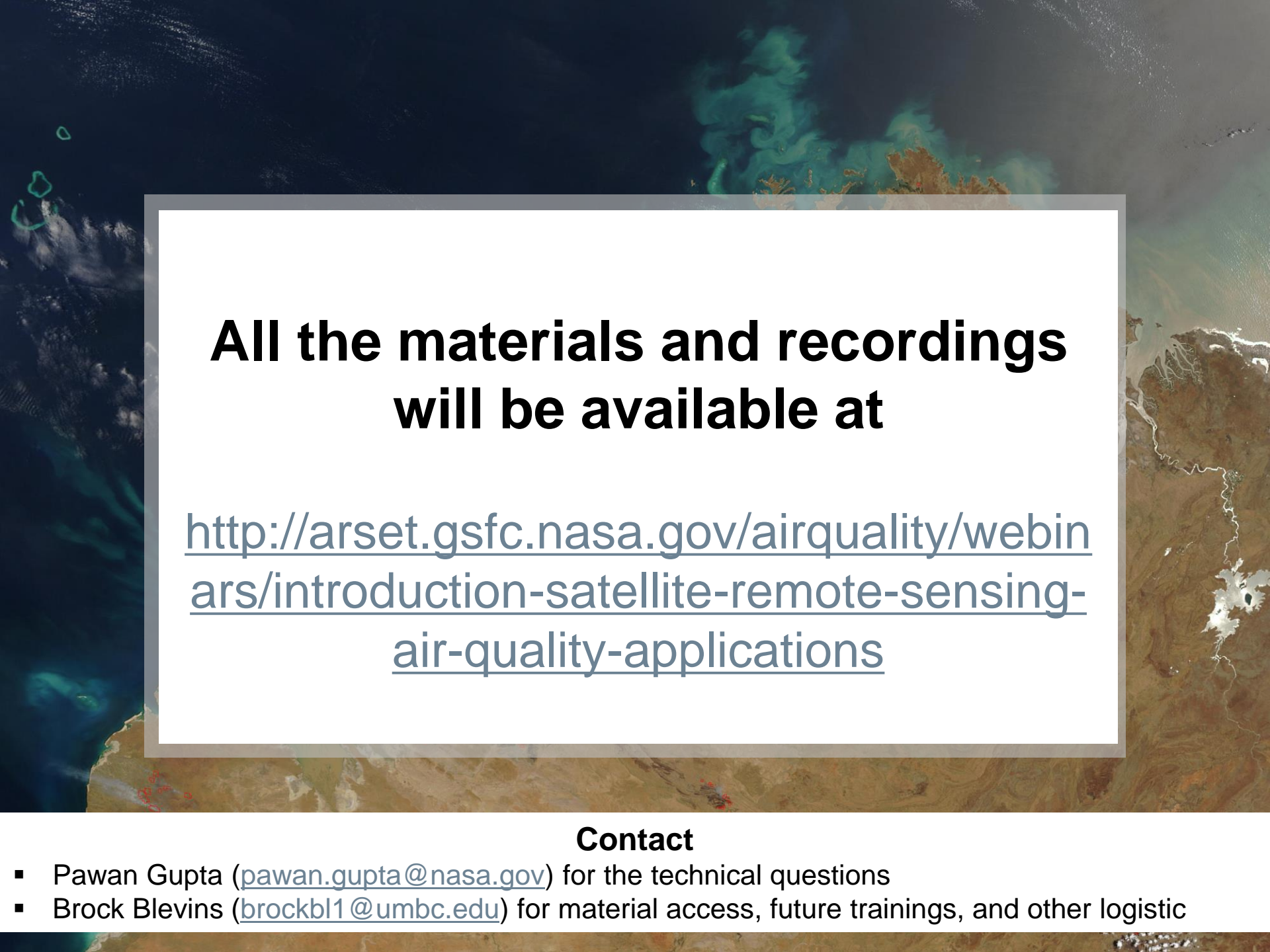
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An aerial satellite photograph of a coastal region, likely the Gulf of Mexico. The image shows a mix of dark blue ocean water, lighter turquoise shallow waters, and brownish-tan landmasses. A semi-transparent grey rectangular box is overlaid on the center of the image, containing text. The text is in a bold, black, sans-serif font. Below the text, a solid black horizontal line is drawn across the width of the text area.

**Attending all sessions (live or recording) required for the certificate**

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A satellite image of Earth showing a coastline and ocean. The image is used as a background for the slide.

**All the materials and recordings  
will be available at**

<http://arset.gsfc.nasa.gov/airquality/webinars/introduction-satellite-remote-sensing-air-quality-applications>

### **Contact**

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