WELCOME TO NASA APPLIED REMOTE SENSING TRAINING (ARSET)

WEBINAR SESSION 1

FUNDAMENTALS OF REMOTE SENSING

Applied Remote SEnsing Training (ARSET)

NASA Applied Sciences Capacity Building Program

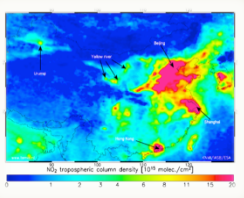
- **GOAL**: Increase utilization of NASA observational and model data for decision-support through training activities for environmental professionals.
- **Online Trainings**: Live and recorded, 4-6 weeks in length. Include demos on data access
- **In person Trainings**: In a computer lab, 2- 4 days. Large focus on data access
- **Train the Trainers**: Courses and training manuals for those interested in conducting their own remote sensing training.
- **Application Areas:** water resources, disasters, health/air quality, and land management
- http://arset.gsfc.nasa.gov

Accomplishments (2008 – 2015)

- 53 trainings completed
- 4000+ participants worldwide
- 1400+ organizations
- 130+ countries

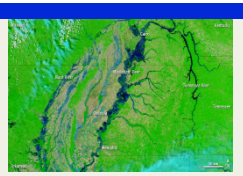
ARSET: Training Focus Areas

Health (Air Quality)



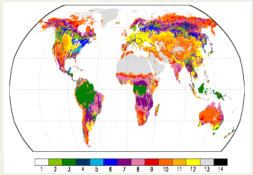
- Analysis of dust, fires and urban air pollution.
- Long range transport of pollutants
- Satellite and regional air quality model inter-comparisons.
- Support for air quality forecasting and exceptional event analysis

Water Resources and Flood Monitoring



- 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.

Land Management



- GIS Applications
- Conservation
- Vegetation indices
- Wildfire Applications

Train the Trainers

Courses and guidance on how to design and develop, *YOUR OWN* online and/or computer based remote sensing training

- How to develop effective presentations

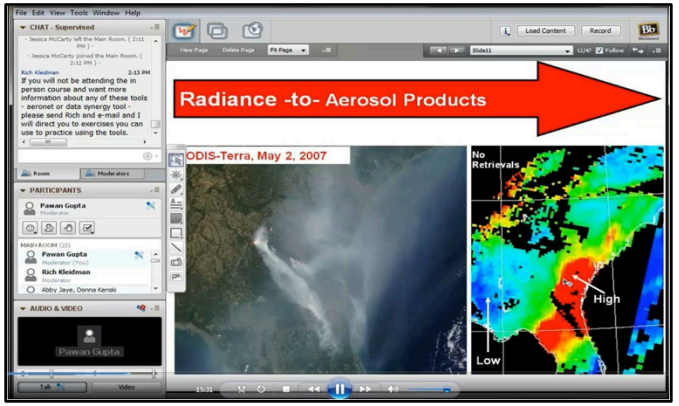
and exercises.

ARSET: Gradual Learning Approach

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

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

Online Training



In-Person Training

Outline

- Fundamentals of Remote Sensing
- Satellites and Sensors
  - Types
  - Resolution
- Advantages/Disadvantages of Remote Sensing
- Satellite Data Processing Levels
- Observations to Applications

*This training may be a pre-requisite for future in-depth training in the Water Resources, Land Management, and Wildfire focus areas.

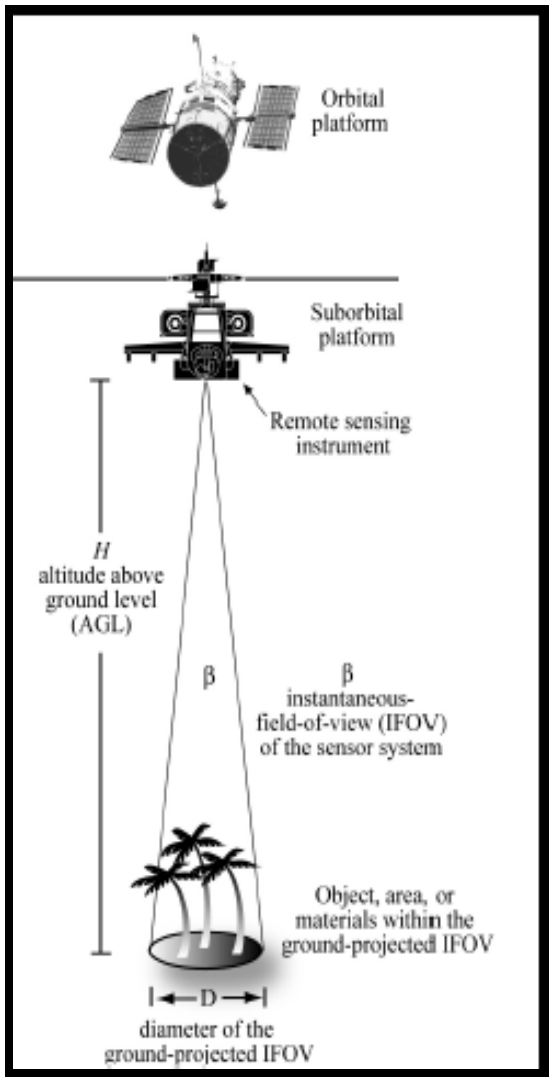
Fundamentals of Remote Sensing

What is Remote Sensing?

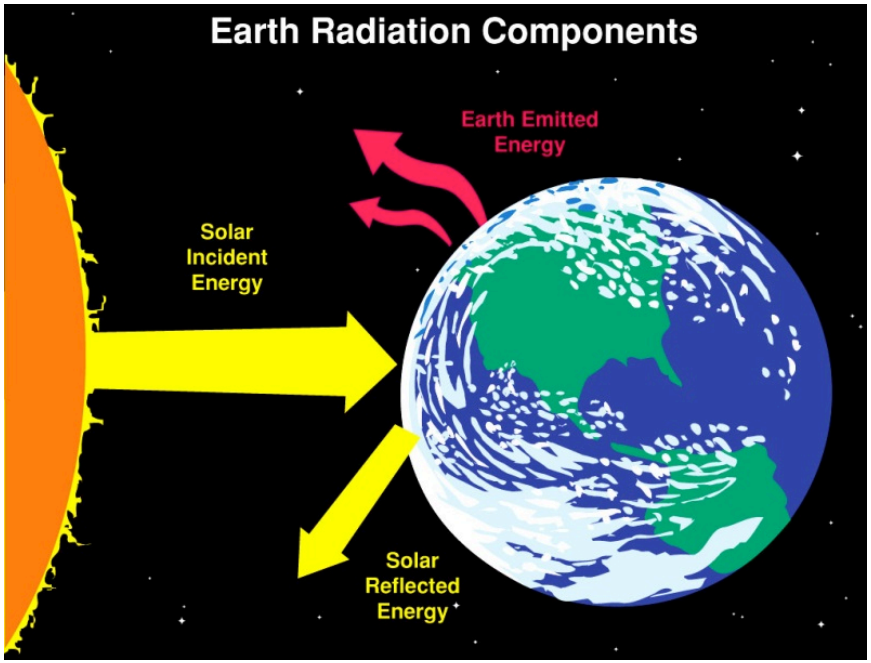
Measurement of a quantity associated with an object by a device not in direct contact with the object

- The most useful platform depends on the application.
- What information? How much detail?
- How frequent?

Satellite Remote Sensing



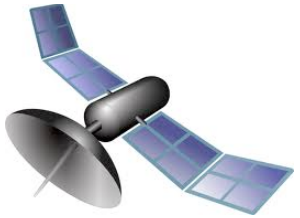
Satellites carry instruments or sensors which measure electromagnetic radiation coming from the earth-atmosphere system

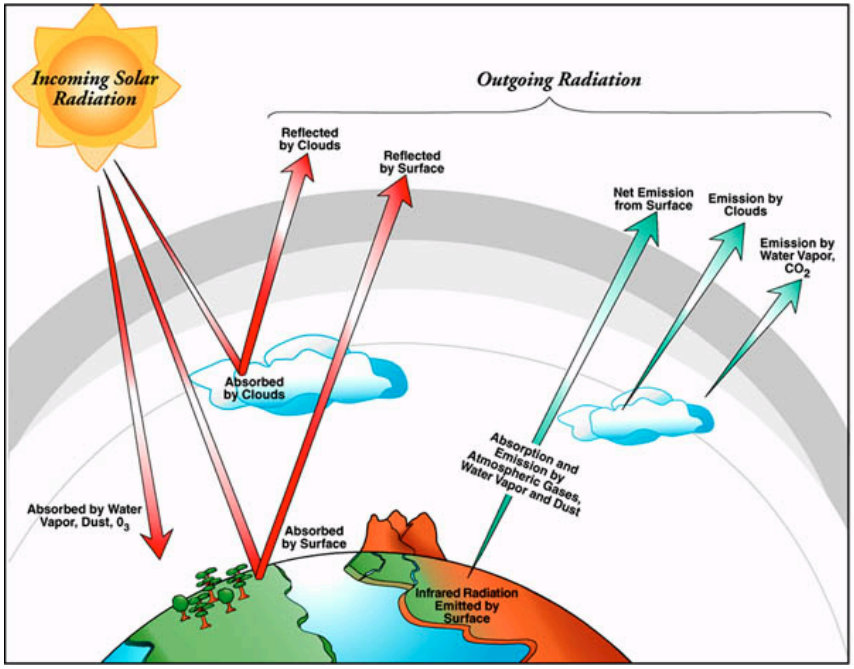


Measuring Properties of the Earth-Atmosphere System from Space

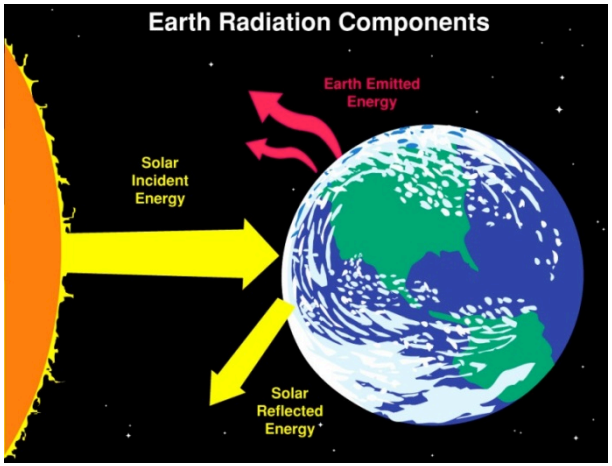
- The intensity of reflected and emitted radiation to space is influenced by the surface and atmospheric conditions.

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



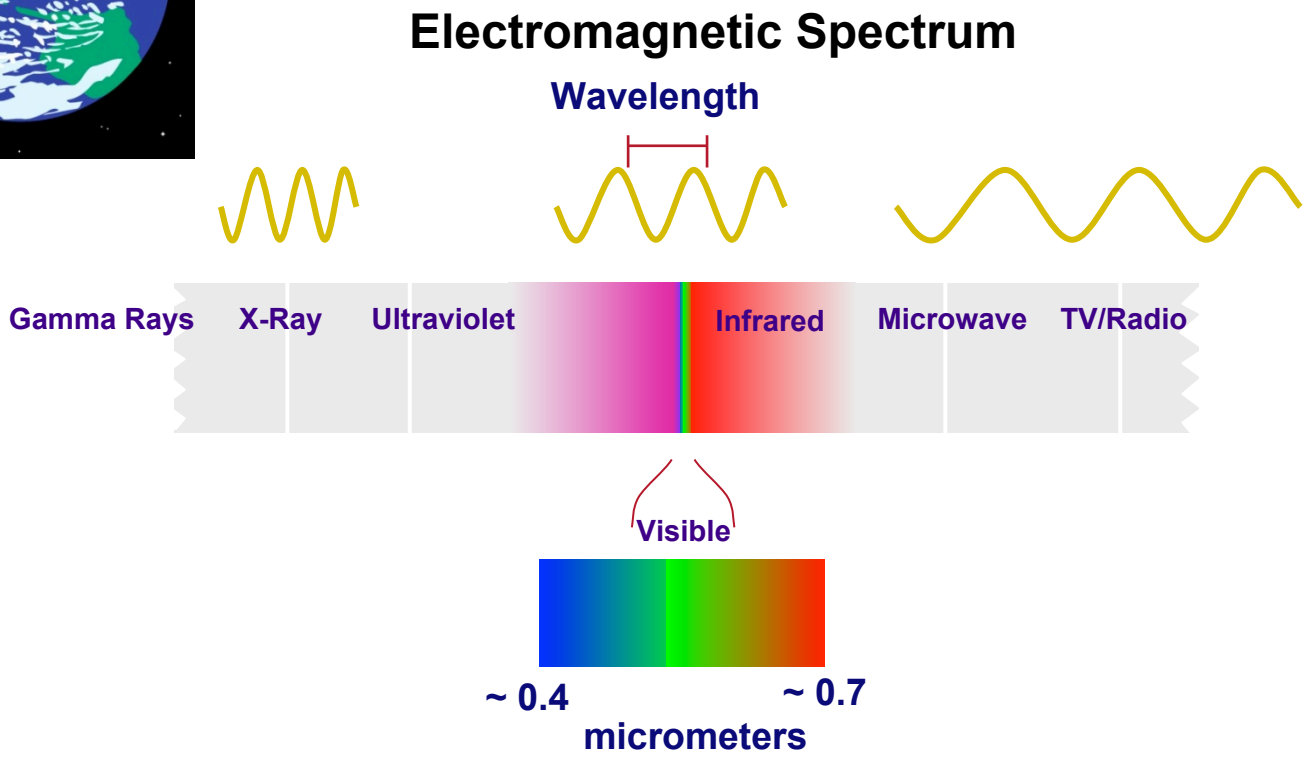


Electromagnetic Radiation

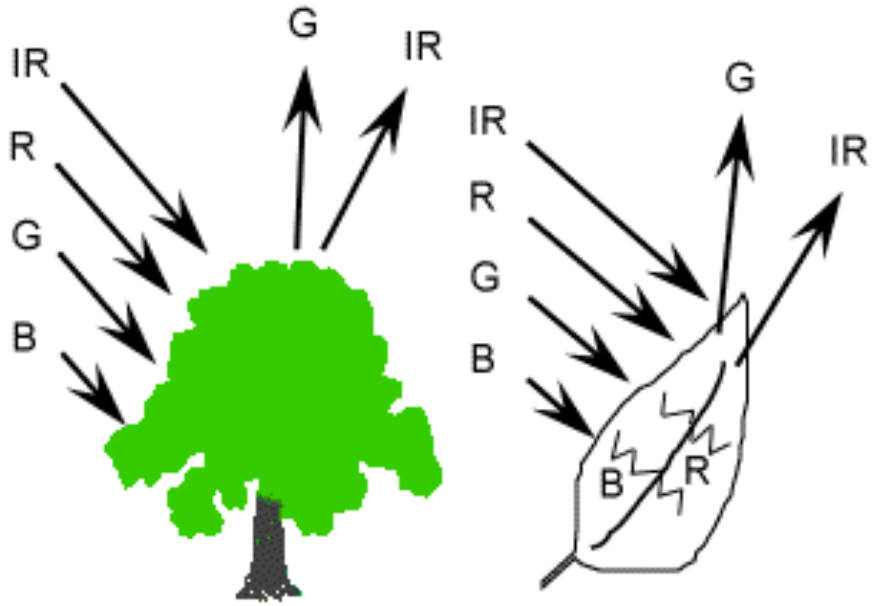


Earth-Ocean-Land-Atmosphere System :

- Reflects solar radiation back to space
- Emits Infrared and Microwave radiation to space



Interaction with Earth Surface: Vegetation



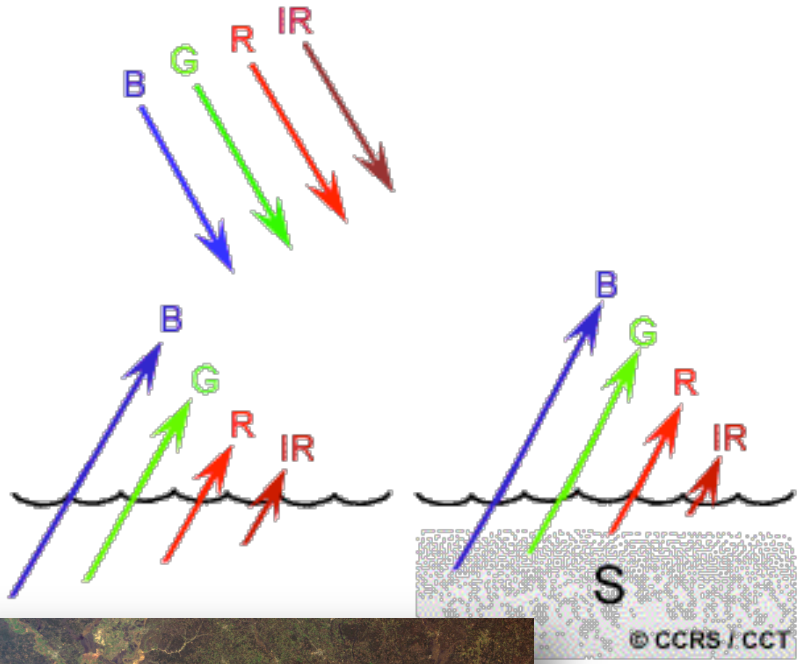
Example: Healthy, green vegetation absorbs Blue and Red wavelengths and reflects Green and Infrared

Since we cannot see infrared radiation, we see healthy vegetation as green

Interaction with Earth's Surface: Water

Longer visible wavelengths (G and R) and near-IR radiation is absorbed more by water than shorter visible wavelengths (B). So water usually looks blue or blue-green.

Sediment (S) present in the upper layers of the water will result in more reflectance and brighter appearance of the water.

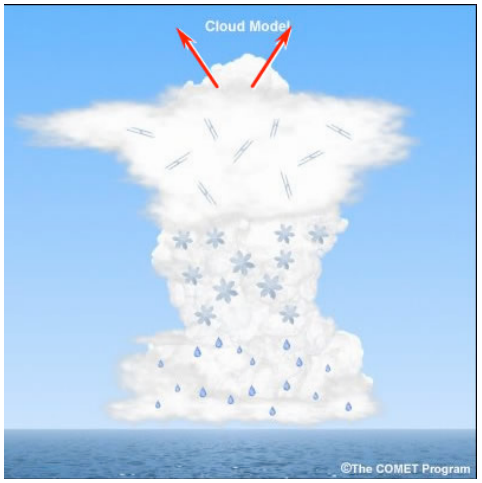


Mississippi River sediment plume

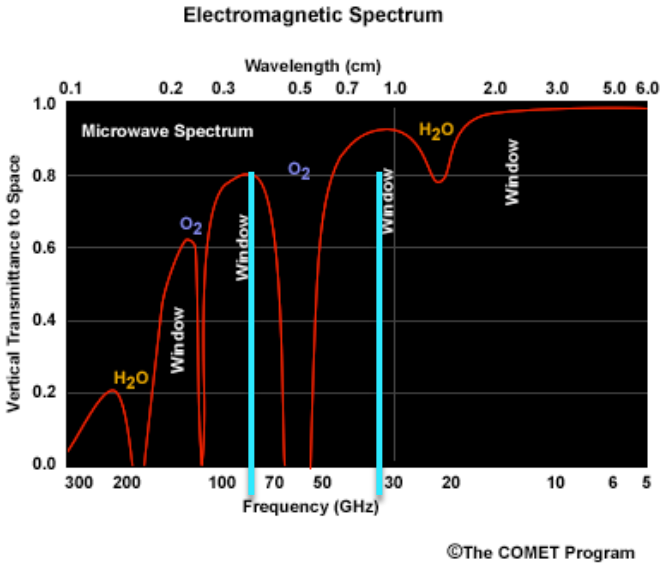
Source: earthobservatory.nasa.gov

Interaction with Earth's Atmosphere: Precipitation

- Clouds reflect visible solar radiation and emit Infrared radiation to space and provide indirect measure of precipitation

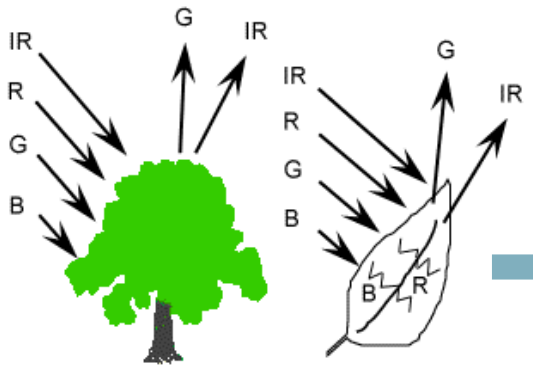


- Microwave frequencies are used to observe precipitation as at 37 GHz radiation is emitted to space by raindrops and at 85 GHz it is scattered to space by ice particles from above the freezing level

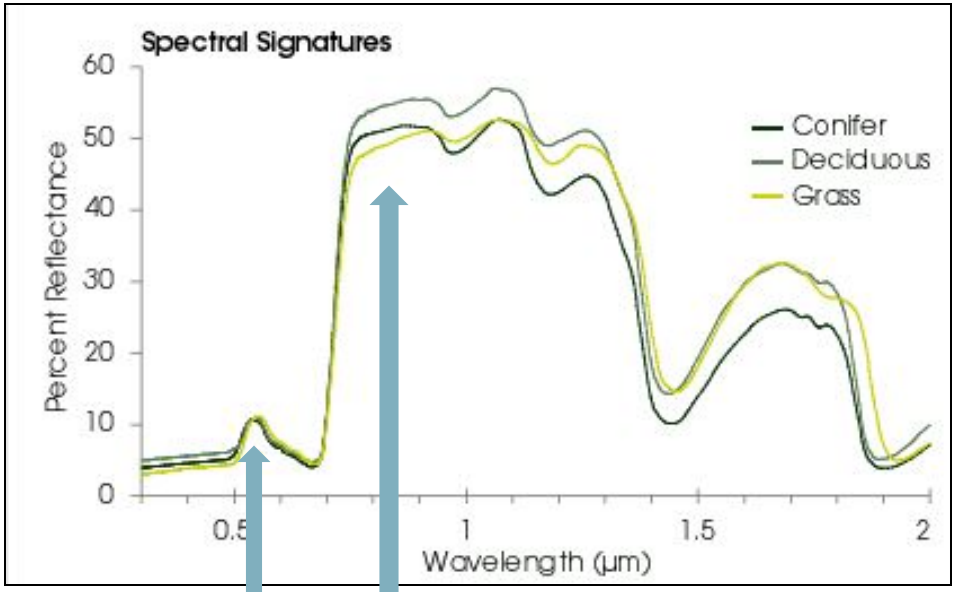


Spectral Signatures

- Every kind of surface has it's own spectral signature
- Going back to the healthy vegetation example….

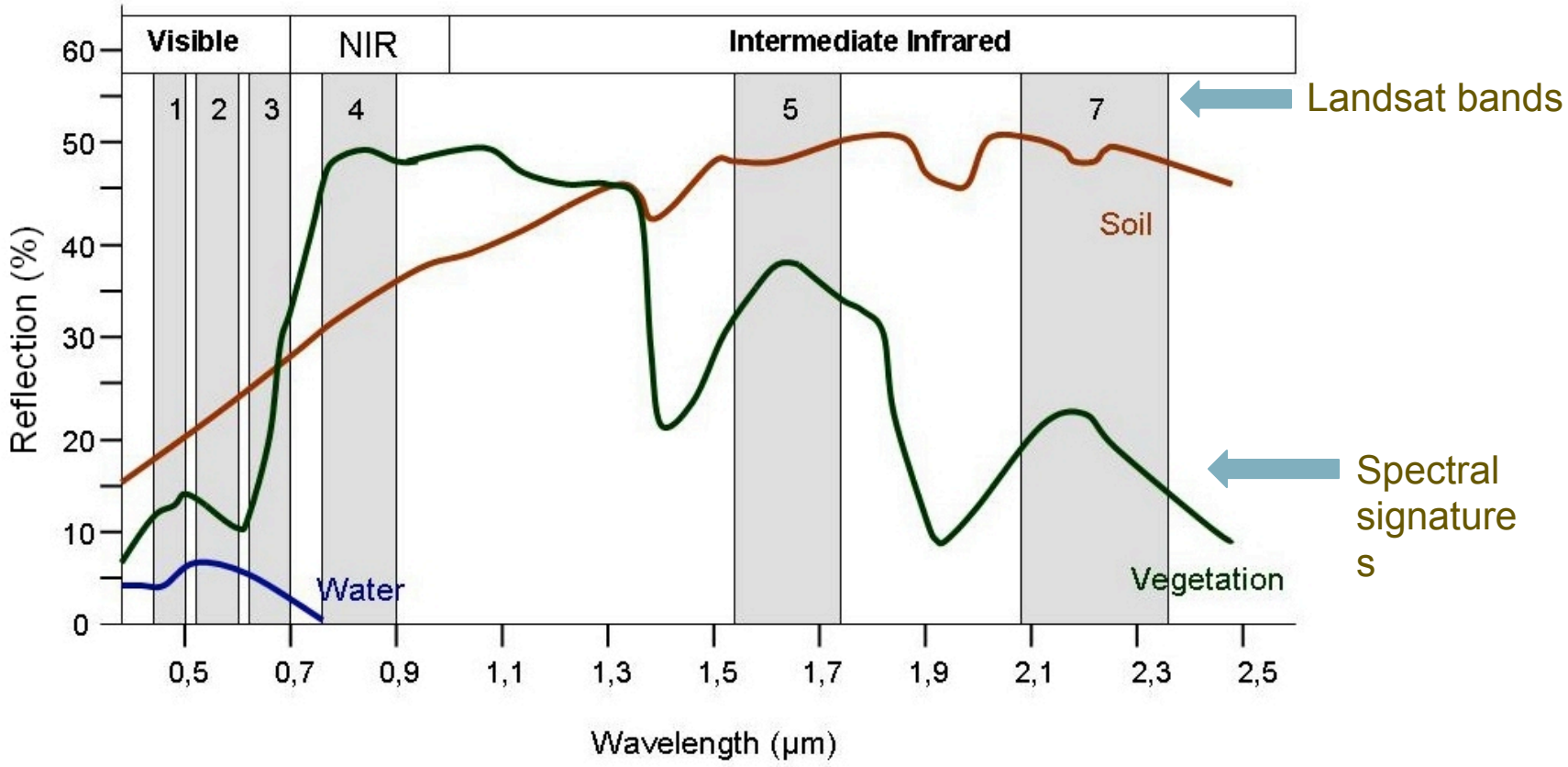


Spectral Signature

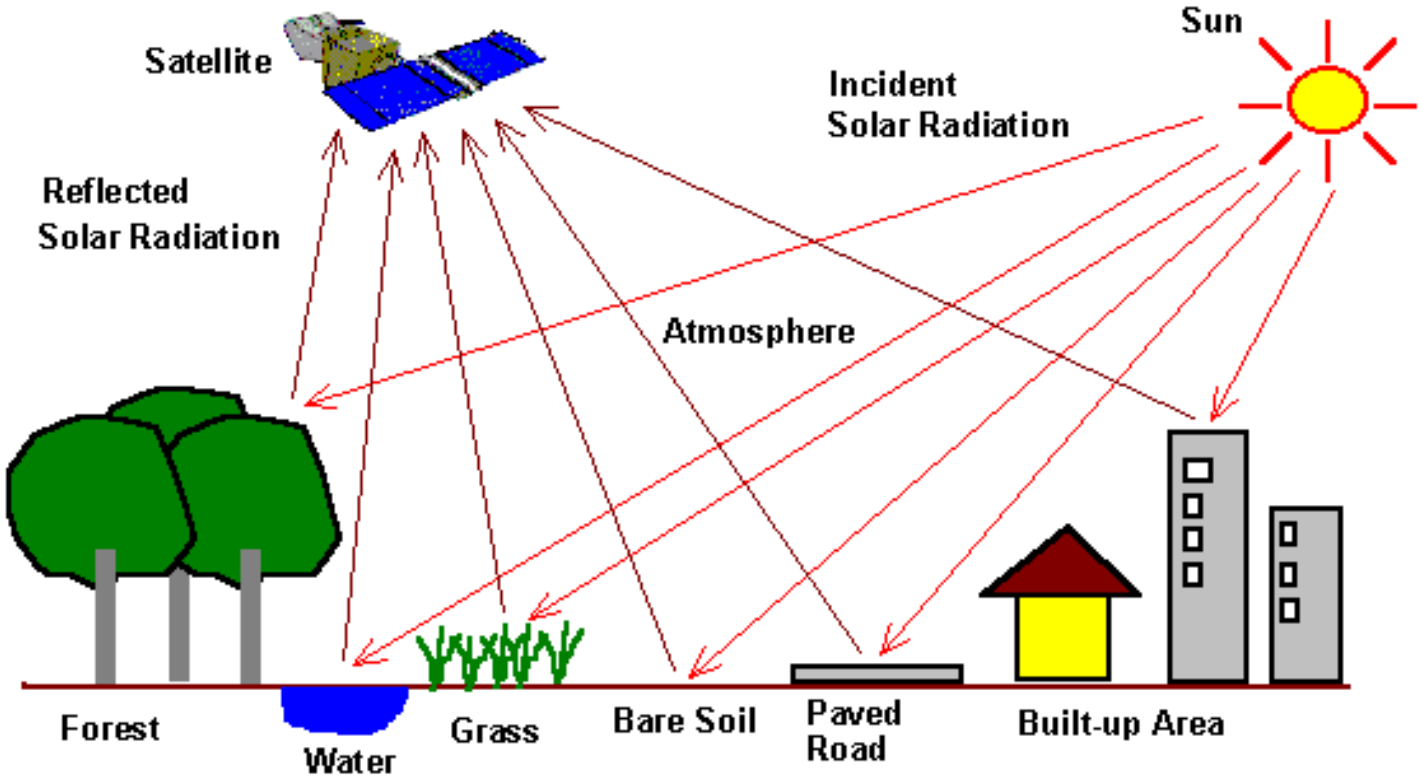


Spectral Signatures in Imagery

- Remotely sensed imagery acquires information in different wavelengths, representing different parts of the Electromagnetic Spectrum



How Satellites Collect Data



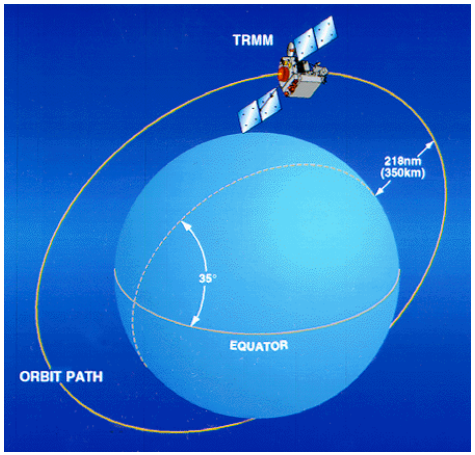
Satellites and Sensors

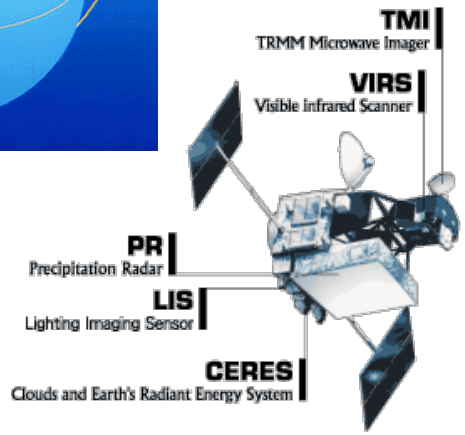
Satellite Remote Sensing Observations: What to Know

- Instruments/sensors and types
- Types of satellite orbits around the Earth
- Spatial and temporal coverage

These affect the spatial resolution, the temporal resolution

- Geophysical quantities derived from the measurements
- Quality and accuracy of the retrieved quantity
  - Applications and usage
  - Availability, access, format





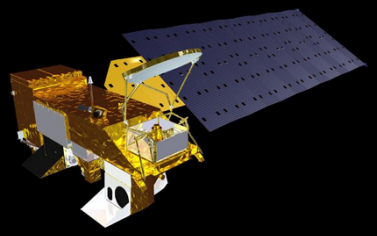
Satellite and Sensor Characteristics

- Satellite vs. Sensors
- Satellite Orbits
- Spectral Resolution
- Spatial Resolution
- Temporal Resolution
- Radiometric Resolution

Satellites vs. Sensors

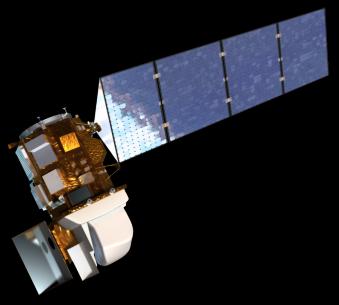
- Earth-observing satellite remote sensing instruments are named according to:
  - The satellite (also called platform)
  - The instrument (also called sensor)

Aqua Satellite



Six Instruments:
MODIS
CERES
AIRS
AMSU-A
AMSR-E
HSB

Landsat 8



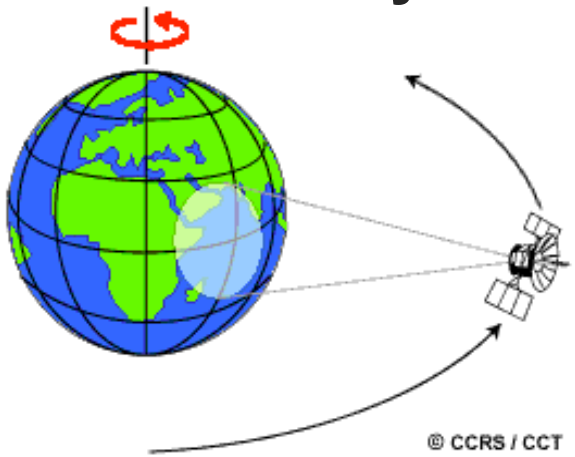
Two Instruments:
OLI
TIRS

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 …

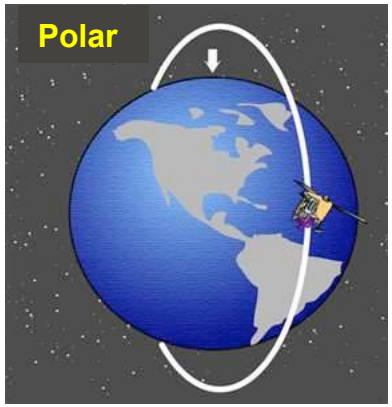
Types of Satellite Orbits

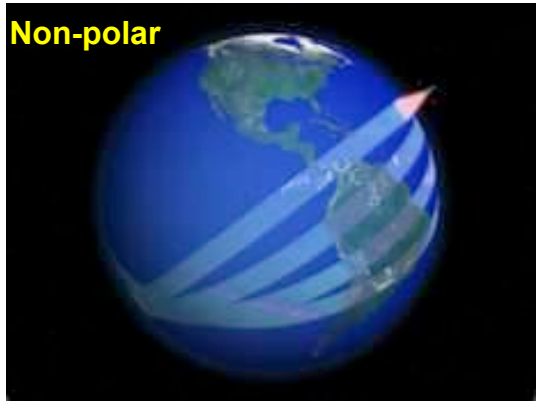
Geostationary orbit



- Satellite is at ~36,000 km above earth at equator. Same rotation period as earth's. Appears 'fixed' in space.
  - Frequent measurements
  - Limited spatial coverage
- Examples:
  - Weather or communications satellites

Low Earth Orbit (LEO)



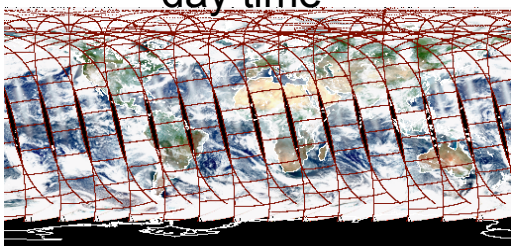


- Circular orbit constantly moving relative to the Earth at 160-2000 km. Can be in Polar or non-polar orbit
  - Less frequent measurements
  - Large (global) spatial coverage
- Polar orbit examples: Landsat or Terra satellites

Orbits: Spatial Coverage and Temporal Resolution

- **Polar orbiting**
  - Global coverage
  - Varied measurement frequency (1per day to 1 per month)
  - Larger swath size means higher temporal resolution
  - Sometimes orbital gaps
- **Non-polar orbiting**
  - Non-global coverage
  - Varied measurement frequency (less than 1 per day)
  - Larger swath size means higher temporal resolution
- **Geostationary**
  - Limited spatial coverage – more than one satellite needed for global coverage
  - Multiple observations per day

Aqua (“ascending” orbit) day time

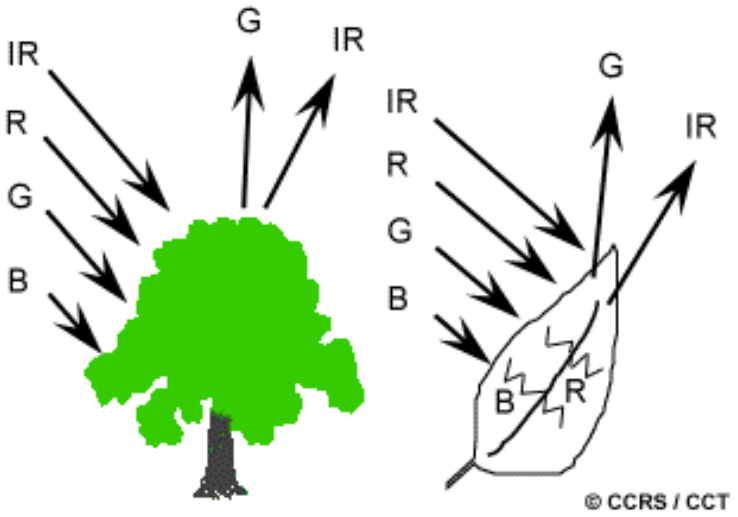


TRMM Image

GOES Image

Satellite Sensors: Passive

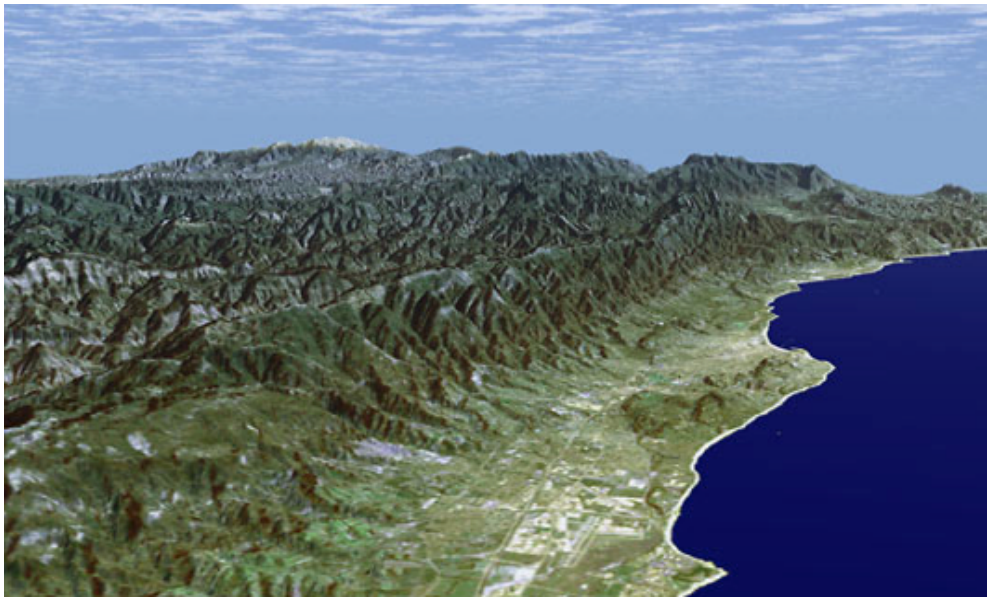
- **Passive** remote sensors measure radiant energy reflected or emitted by the Earth-atmosphere system
  - Radiant energy is converted to bio-geophysical quantities such as temperature, precipitation, soil moisture, chlorophyll-a
  - Examples: Landsat, MODIS, TRMM Microwave Imager, MODIS, AIRS



Landsat image of San Francisco Bay Area

Satellite Sensors: Active

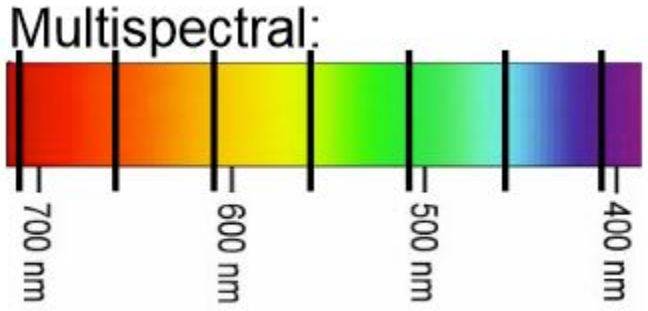
- **Active** remote sensors send beams of radiation on the earth-atmosphere system and measure 'back-scattered' radiation
  - The back-scattered radiation is converted to geophysical quantities
- Advantages:
  - Can be used day or night
  - Can penetrate cloud cover
- Disadvantages:
  - Challenging to process
  - Some available only from aircraft
- Examples: Radar, LIDAR



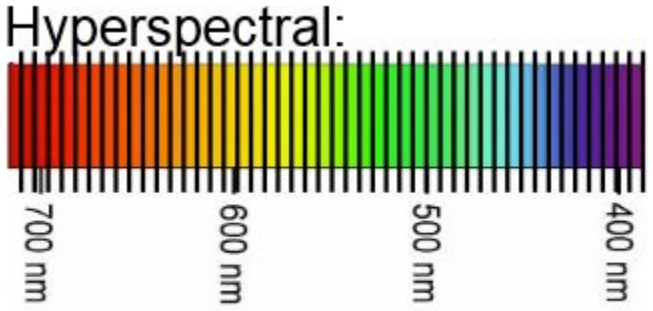
This perspective view of the Santa Barbara region was generated using data from the Shuttle Radar Topography Mission (SRTM) and an enhanced Landsat satellite image in February 2000.

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. More and finer spectral channels enable remote sensing of different parts of the Earth's surface



Example: Landsat (7-11 bands)
MODIS (36 bands)



Example: AVIRIS (256 bands)

Spatial and Temporal Resolution

Depends on the satellite orbit configuration and sensor design

- **Spatial Resolution:**
  - Decided by its pixel size -- pixel is the smallest unit measured by a sensor
- **Temporal Resolution:**
  - How frequently a satellite observes the same area of the earth

Spatial Resolution

- Spatial resolution refers to the detail discernable in an image by a pixel

Sensor	Spatial Resolution
DigitalGlobe (and others)	<1-4 m
Landsat	30 m
MODIS	250 m-1km
Global Precipitation Mission (GPM) Dual Frequency Radar	5 km

Spatial Resolution

1 meter | 10 meter | 30 meter

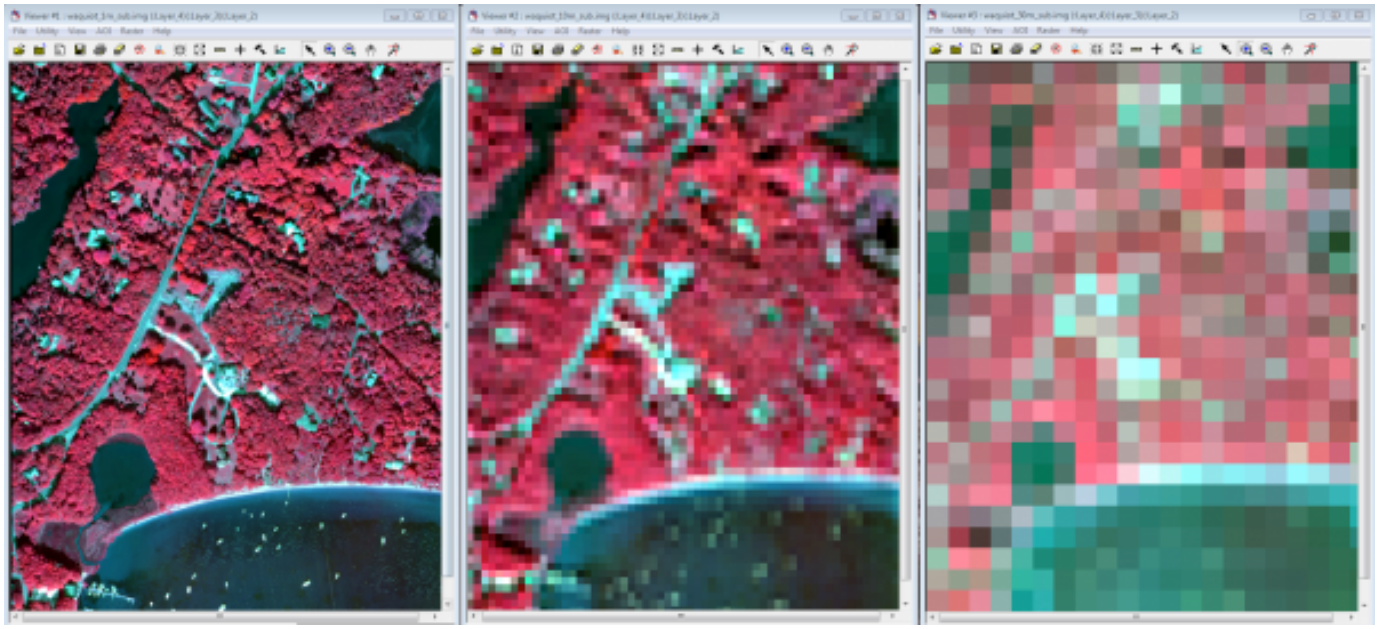


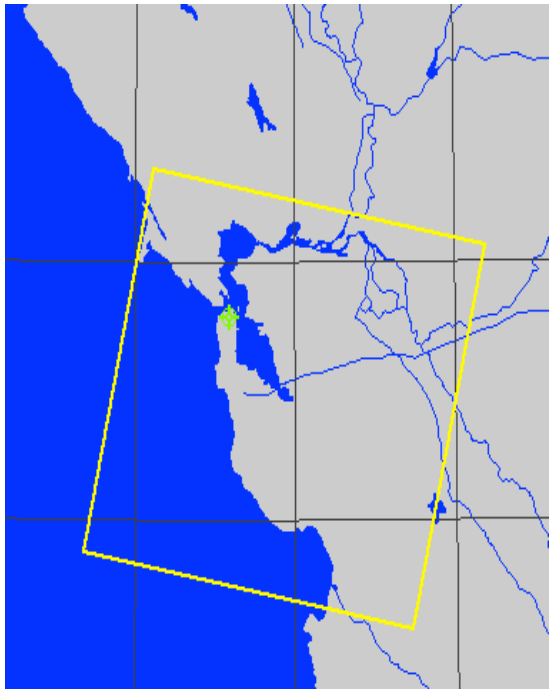
Image courtesy of www.csc.noaa.gov

- BUT….there is a tradeoff between spatial resolution and spatial extent!

Spatial Resolution vs. Extent

- Generally, the higher the spatial resolution the less area is covered by a single image

MODIS (250m -1 km)

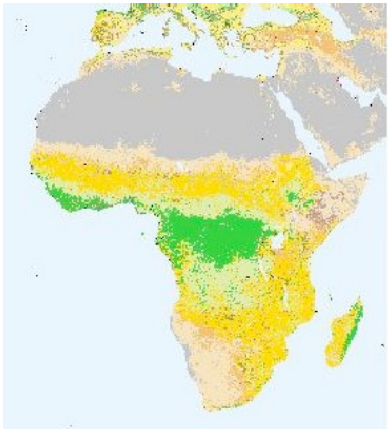


Landsat (30 m)

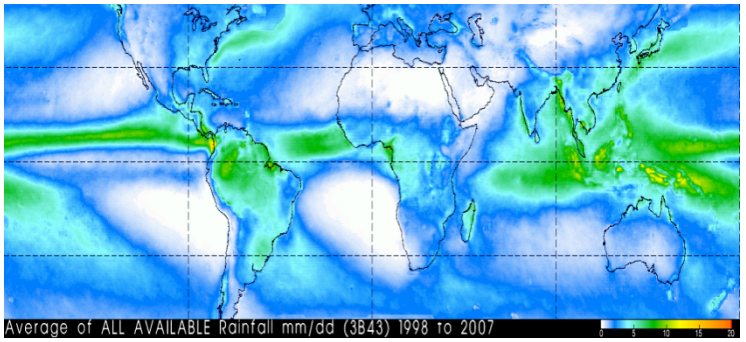
NASA Satellite Measurements with Different Spatial Resolutions

Landsat Image of Philadelphia
Spatial resolution: 30 m

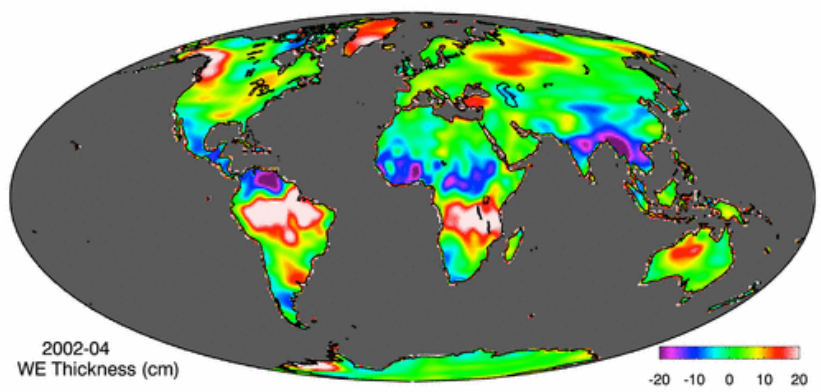
Land Cover from Terra/MODIS:
Spatial resolution: 1 km²
(From: http://gislab.jhsph.edu/)



Rain Rate from TRMM
Spatial resolution: 25 km²



Terrestrial Water Storage Variations from GRACE: Spatial resolution: 150,000 km² or coarser (Courtesy: Matt Rodell, NASA-GSFC)



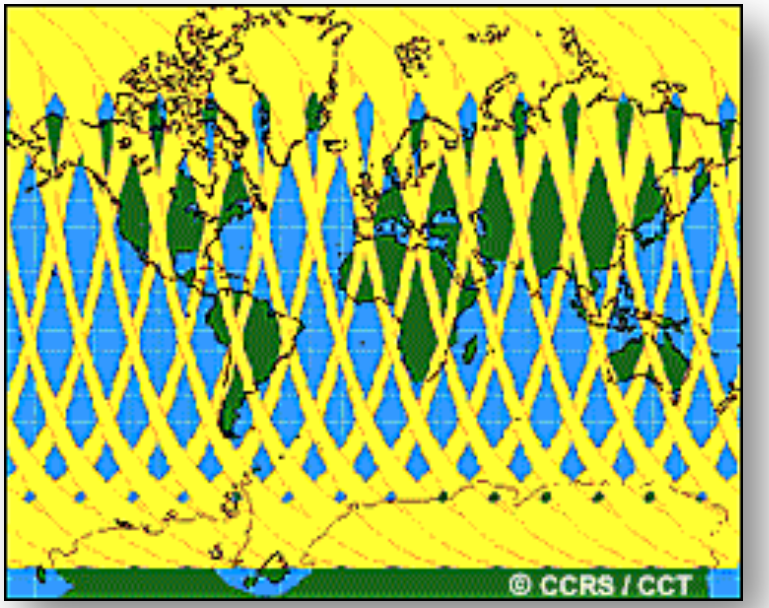
Temporal Resolution

- The time it takes for a satellite to complete one orbit cycle; also called “revisit time”
- Depends on satellite/sensor capabilities, swath overlap and latitude

Sensor	Revisit time
Landsat	16-days
MODIS	2-days
Commercial (OrbView)	1-2 days

Temporal Resolution

- Some satellites may have greater temporal resolution:
  - Some satellites are able to point their sensors
  - Some satellites have increasing overlap at higher latitudes so may have a greater repeat time



This examples shows a satellite path (in yellow) where areas at high latitudes will be imaged more frequently than the equatorial zone due to the increasing overlap in adjacent swaths as the orbit paths come closer together near the poles

Radiometric Resolution

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

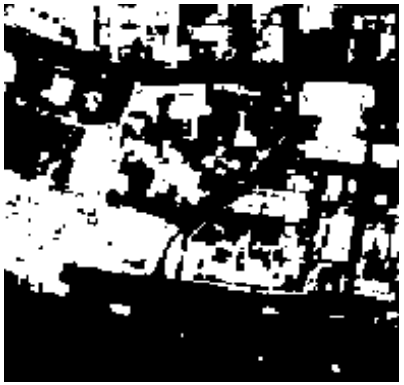
- The larger this number, the higher the radiometric resolution, and the sharper the imagery

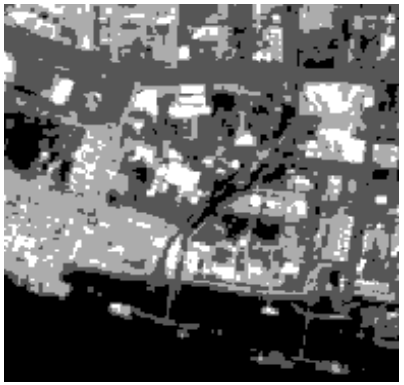
- Represented by positive digital numbers which vary from 0 to (one less than) a selected power of 2.

  - 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

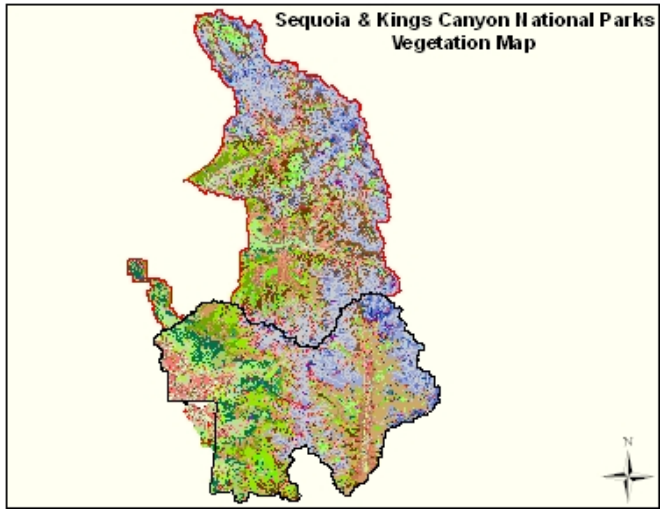
16 - levels

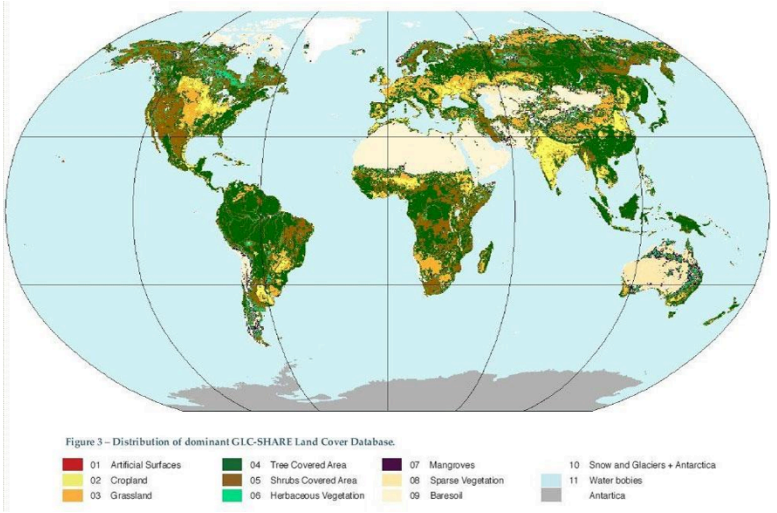
In classifying a scene, different classes are more precisely identified if radiometric precision is high.

Advantages and Disadvantages of Remote Sensing Observations

Remote Sensing Observations

- Provide information where there are no ground-based measurements
- Provide globally consistent observations
- Disadvantages:
  - Does not provide high level of detail at the ground level
  - Cannot detect landcover under canopy
  - Cannot detect much under water

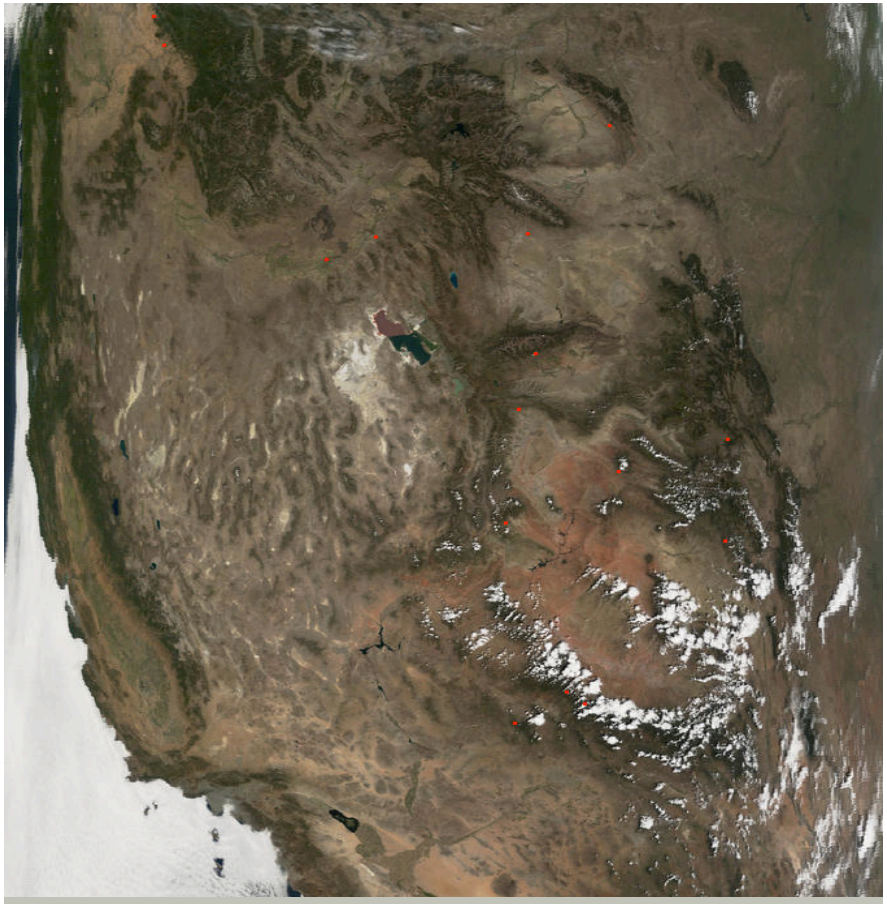




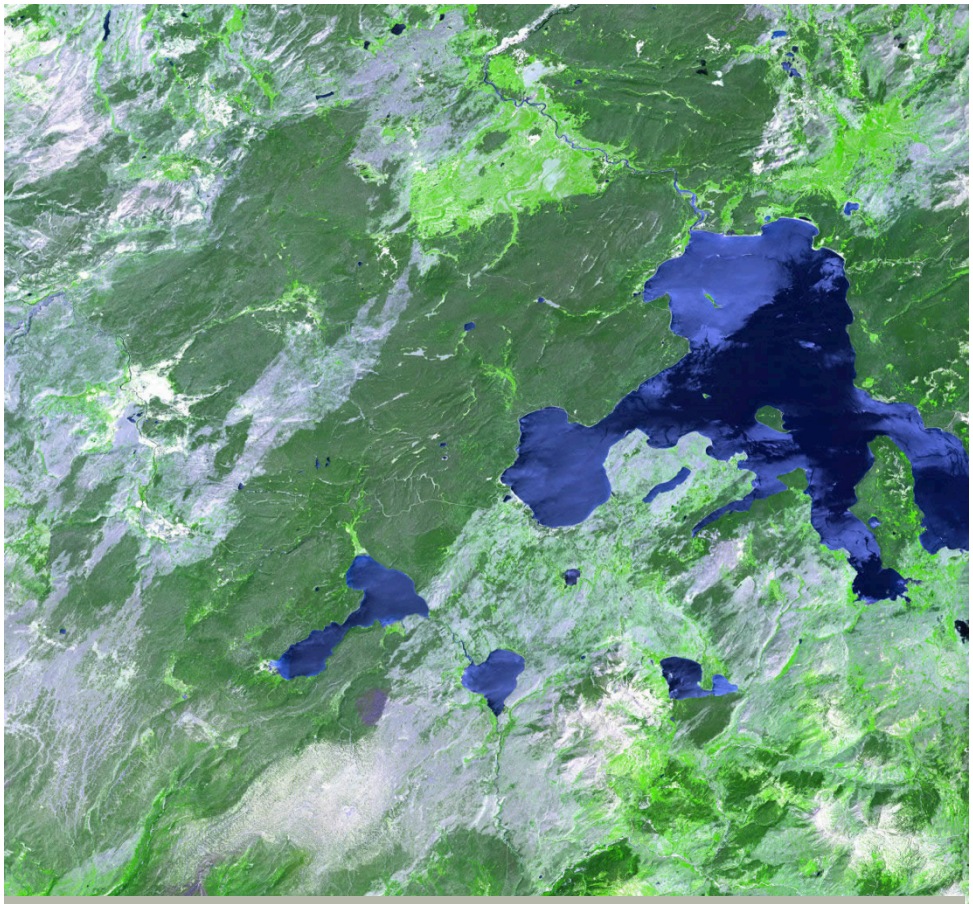
Remote Sensing Observations: Trade-Offs

- It is very difficult to obtain extremely high spectral, spatial, temporal and radiometric resolution at the same time
  - Several sensors can obtain global coverage every one – two days because of their wide swath width
  - Higher spatial resolution polar/non-polar orbiting satellites may take 8 – 16 days to attain global coverage
  - Geostationary satellites obtain much more frequent observations but at lower resolution due to the much greater orbital distance and only over a fraction of the earth
- Large amount of data with varying formats
- Data applications may require additional processing, visualization and other tools

Remote Sensing Observations: Trade-Offs

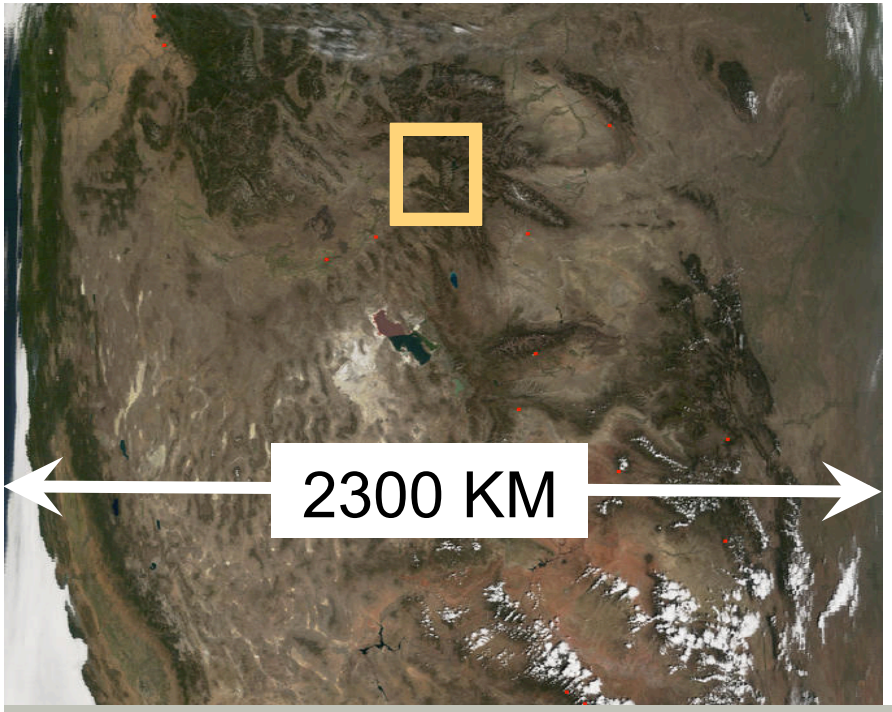


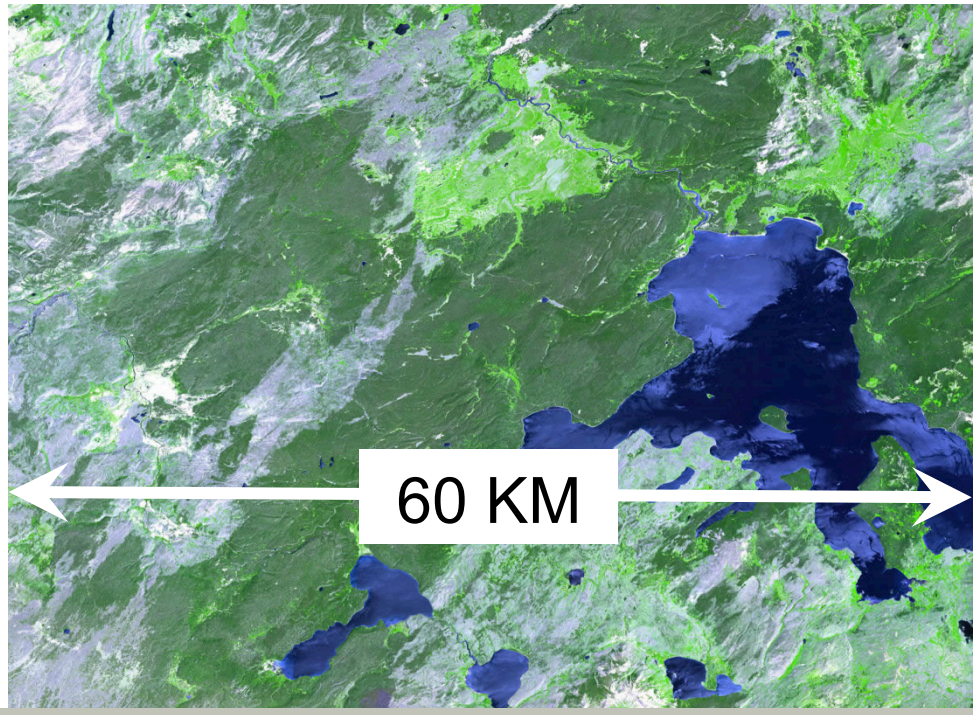
MODIS 500 Meter
True color image



Aster Image
15 M Resolution

Remote Sensing Observations: Trade-Offs



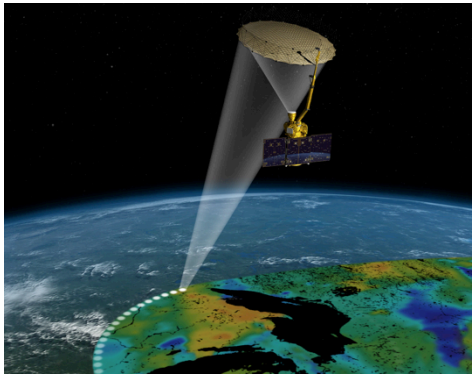
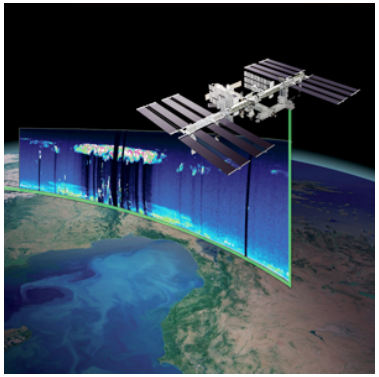
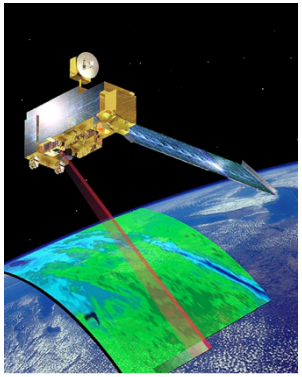
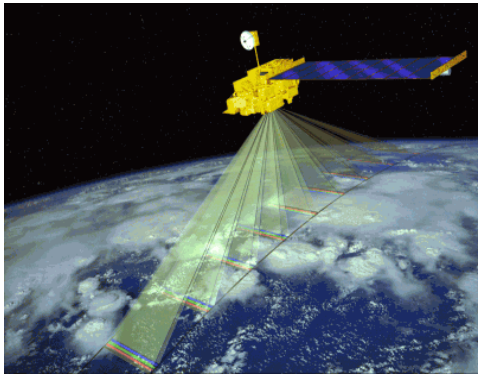


- The different resolutions are the limiting factor for the utilization of the remote sensing data for different applications. Trade off is because of technical constraints.
- Larger swath is associated with low spatial resolution and vice versa.
- Therefore, often satellites designs are applications oriented

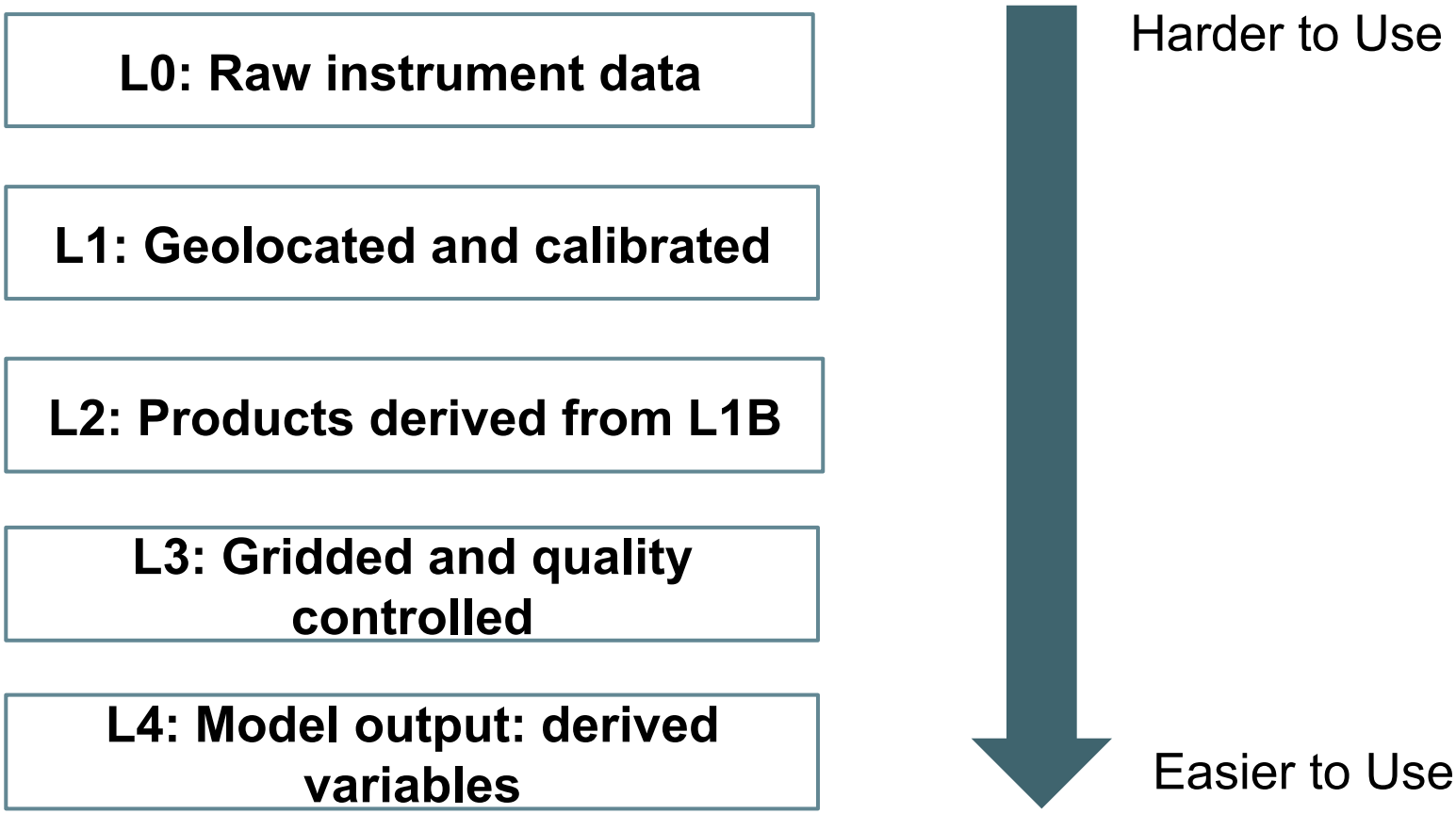
Satellite Data Processing Levels

Levels of Data Processing and Spatial Resolution

- **Level 1 and Level 2** data products have the highest spatial and temporal resolution.
- **Level 3 and 4 products** are derived products with equal or lower spatial and temporal resolution than Level 2 products.

Data Processing Levels



Data Processing Levels: Examples

Landsat	MODIS
Level 1T – Standard Terrain Corrected	**Level 2** – derived geophysical variables
Level 1Gt – Systematic Terrain Correction	**Level 2G** – level 2 data mapped on a uniform space-time grid scale
Level 1G – Systematic Correction	**Level 3** – gridded variables in derived spatial and/or temporal resolutions
	Level 4 – model output or results from analyses of lower level data

Landsat: Use level 1 imagery that includes spectral characteristics
MODIS: Use level 2, 3, or 4 products

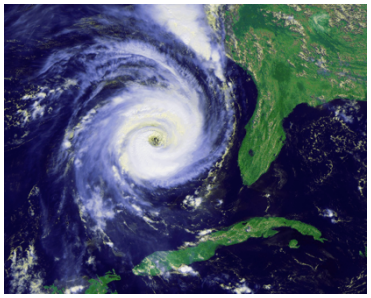
For more information on Landsat data processing levels:
http://landsat.usgs.gov/Landsat_Processing_details.php

For more information on MODIS Land Products processing levels:
http://lpdaac.usgs.gov/products/modis_products_table/modis_overview

Observations to Applications

Observations to Applications

Satellite Measurements



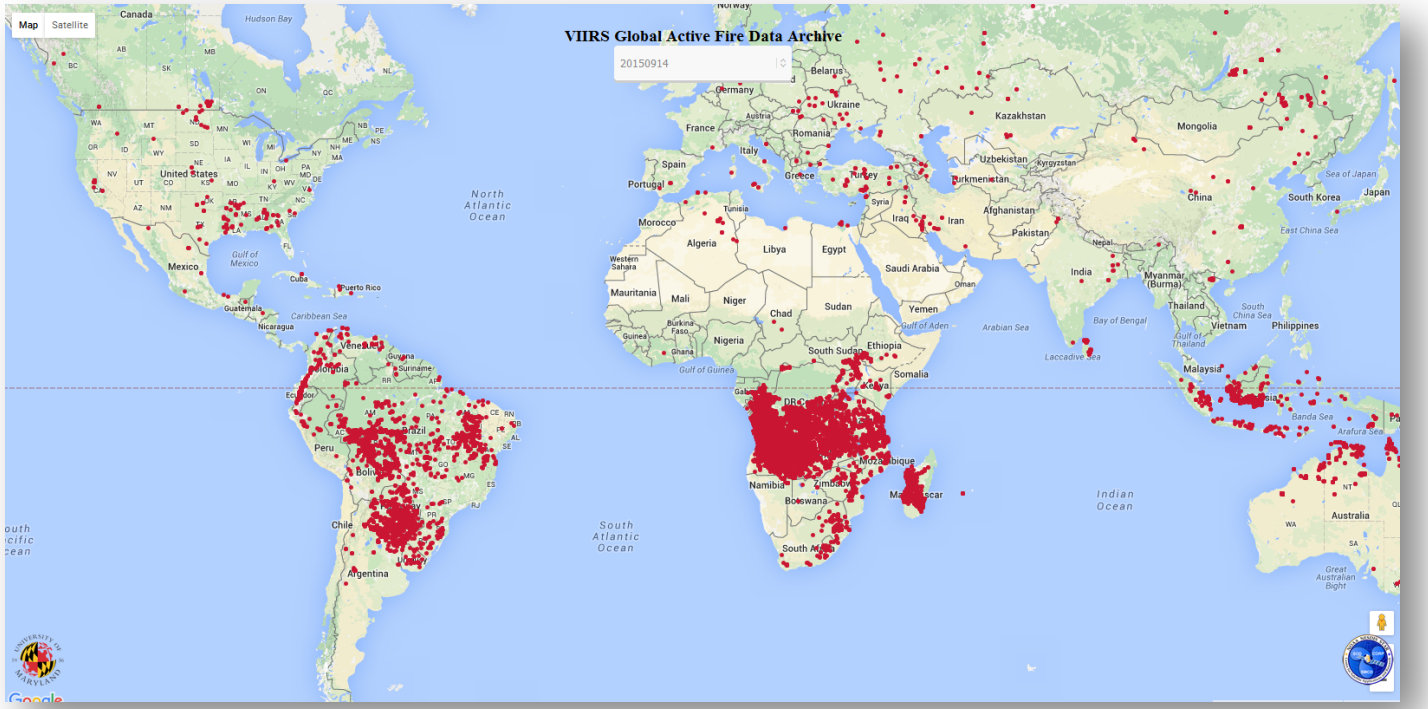
Satellite Products

Environmental Applications

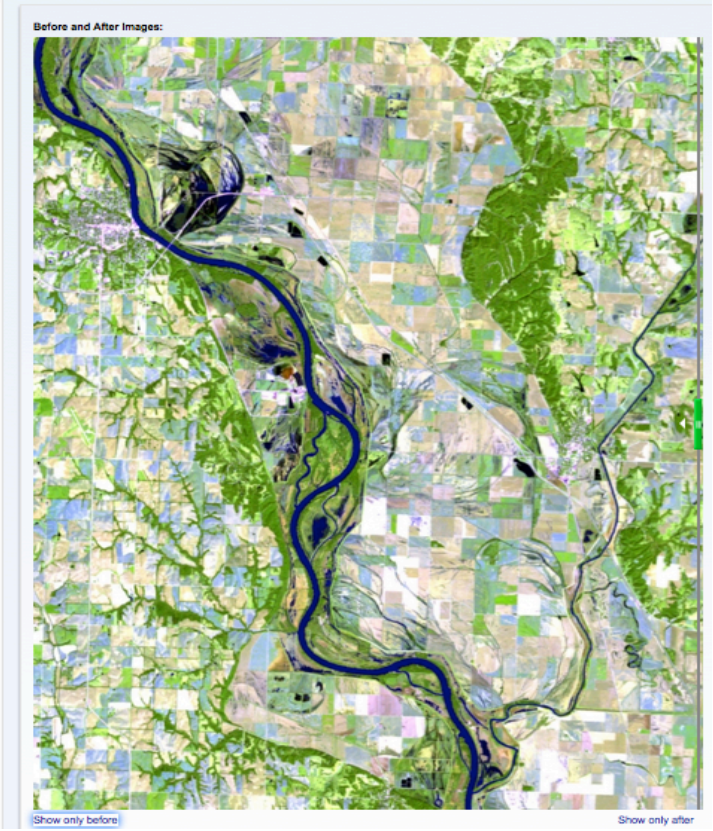
Examples of Data Applications

- NASA satellite images, remote sensing and modeling data, along with other sources of data, are used directly or in statistical or physical modeling tools for a variety of applications.

VIIRS Global Active Fires
September 2015



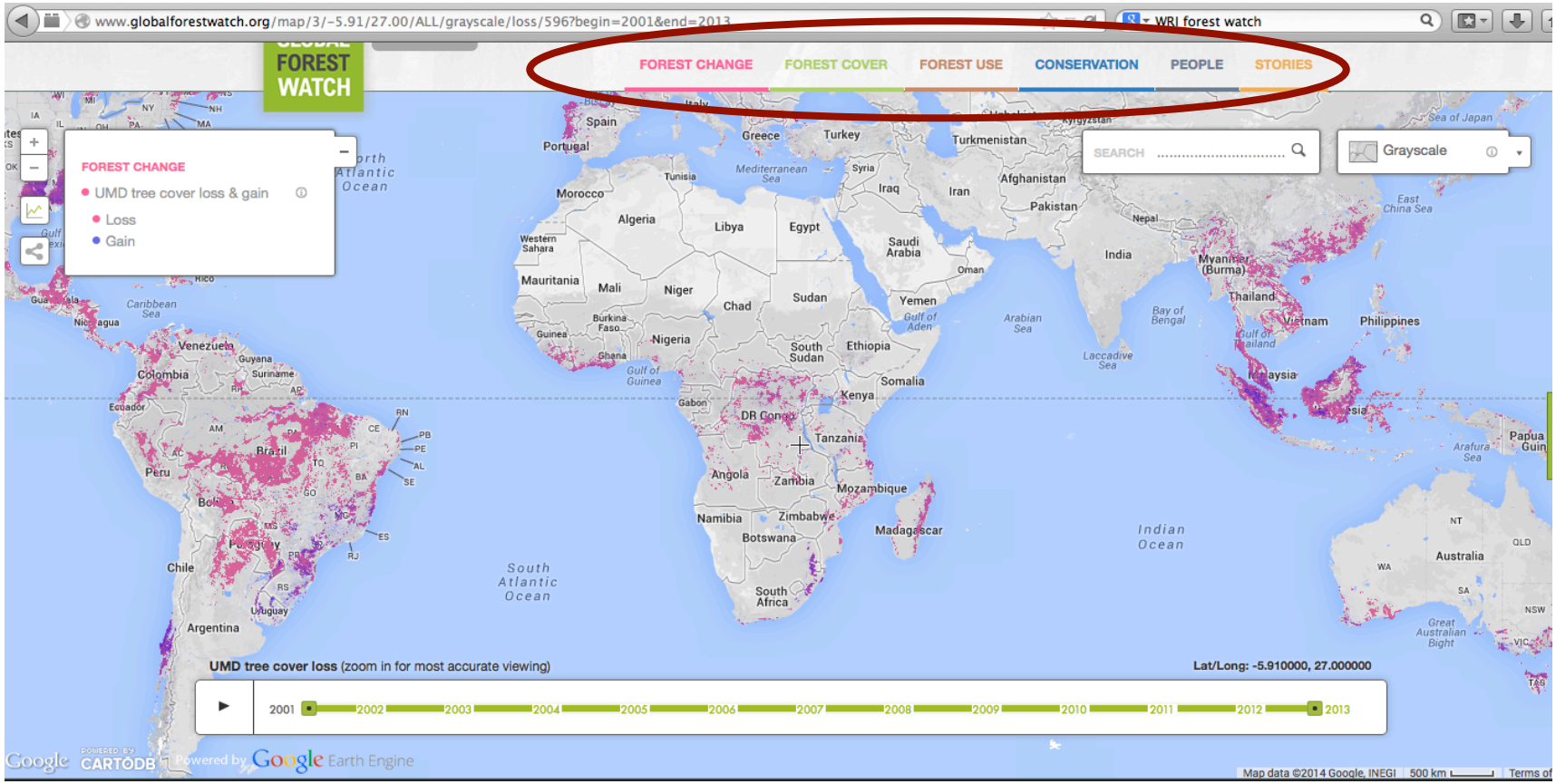
Examples of Data Applications: Flood Mapping



Heavy rains and snow pack resulted in record releases from dams in Montana and the Dakotas, and near-record flooding along parts of the Missouri River. The left image, acquired on Sept. 24, 2010, was taken by the Thematic Mapper sensor aboard Landsat 5. The right image, acquired on Aug. 2, 2011, was taken by the Enhanced Thematic Mapper Plus on Landsat 7.

Image Credit: U.S. Department of the Interior/USGS, NASA

Examples of Data Applications: Deforestation



NASA Landsat and MODIS data are used to map loss/gain of forests around the world

Examples of Data Applications: Drought Monitoring

NLDAS Drought Monitor

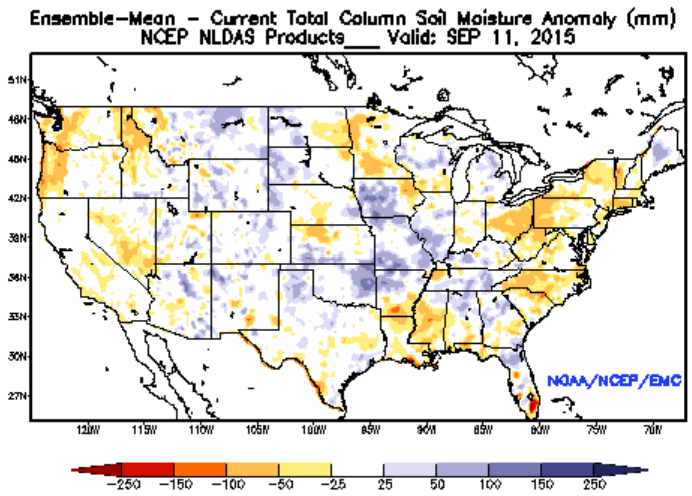
Soil Moisture

NOTE: This page is best viewed with a screen resolution of at least 1024x768

DISCLAIMER: Any data provided on this server should be used for research or educational purposes only. This data should NOT be relied on for any operational use as data gaps can occur due to hardware failure and/or model upgrading procedures.

Ensemble Mean LSM OUTPUT:

Current Total Column Soil Moisture Anomaly



The North American Land Data Assimilation System uses satellite observations and model output to create land-surface model datasets.

Webinar Session 2: Information

- This concludes Session 1 of the “Fundamentals of Remote Sensing” ARSET webinar.
- Two Session 2 webinars will be offered focusing on the topic areas of:
  - Land Management and Wildfire Applications
  - Water Resources
- Please take the Session 2 training more appropriate for your needs. You are also welcome to take both.

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