National Aeronautics and
Space Administration

ARSET

Applied Remote Sensing Training

http://arset.gsfc.nasa.gov

@NASAARSET

Introduction to Remote Sensing

CONSERVATION
INTERNATIONAL

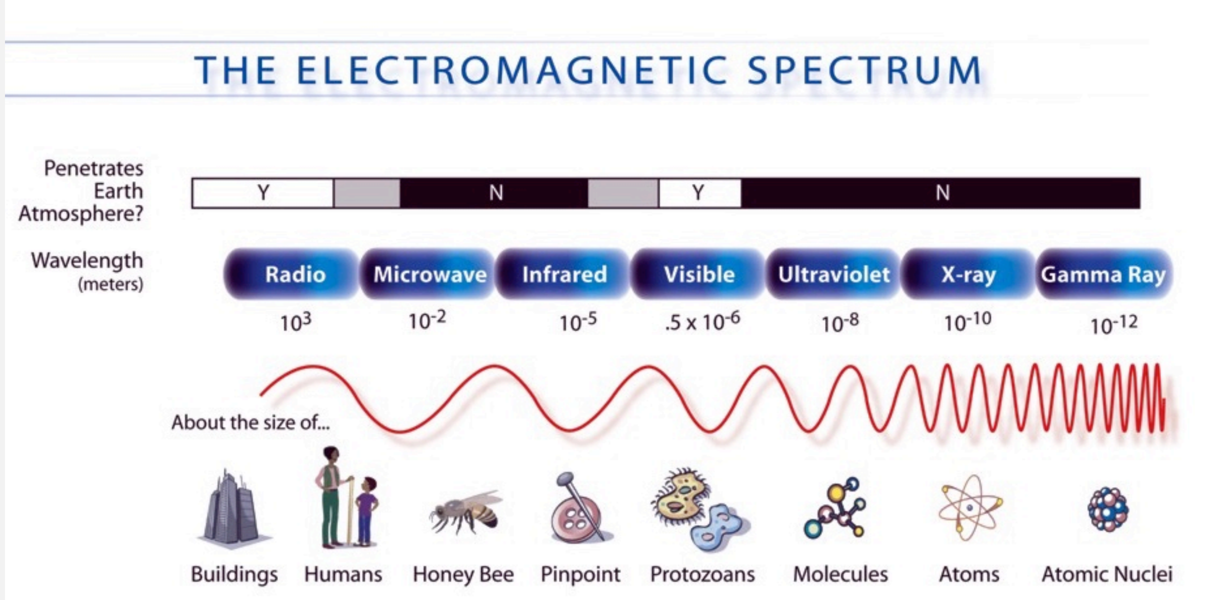
What is Remote Sensing?

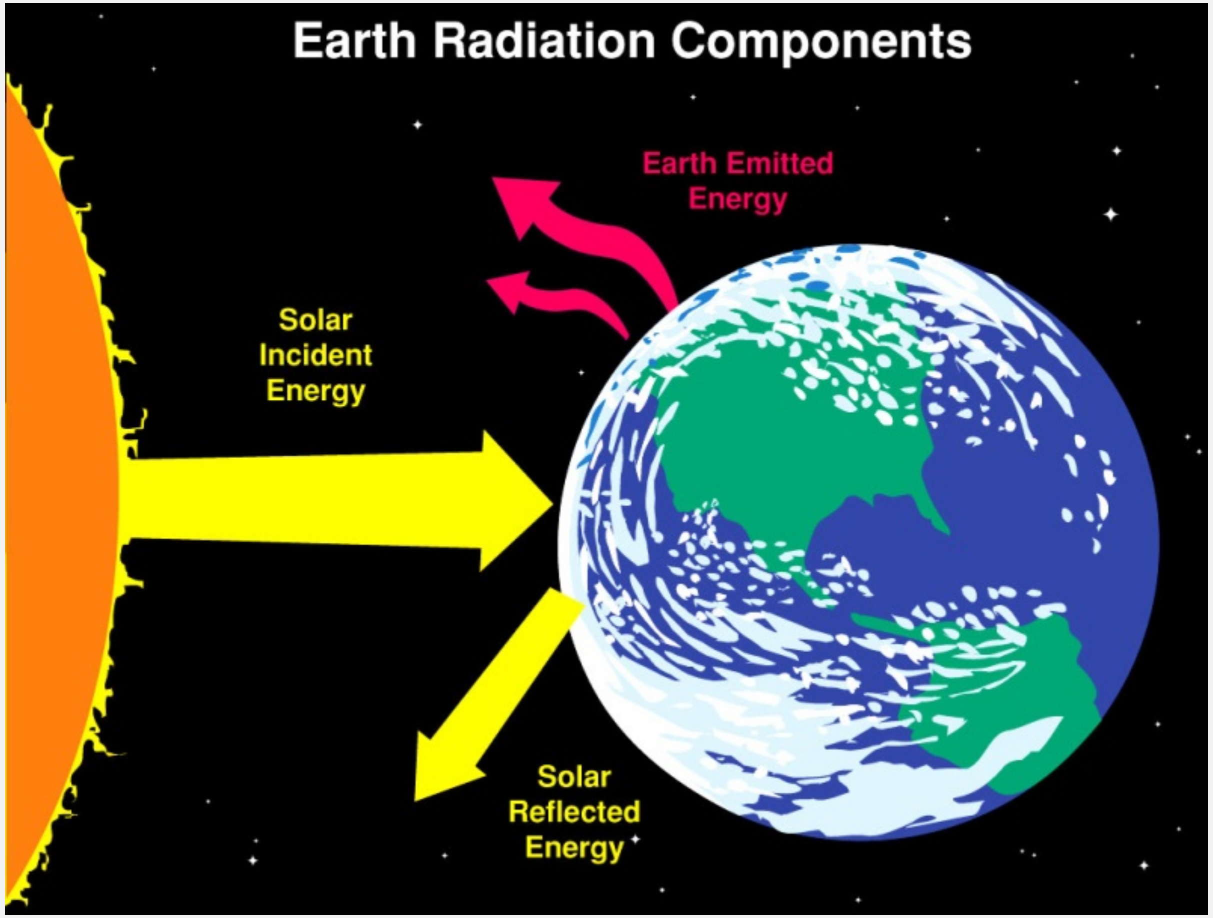
Remote Sensing

- Measurement of a quantity associated with an object by a device not in direct contact
- Usually involves “sensors” that can be ground-based, air-based or satellite-based
- The most useful platform depends on the application
- What information? How much detail?
- How frequent?

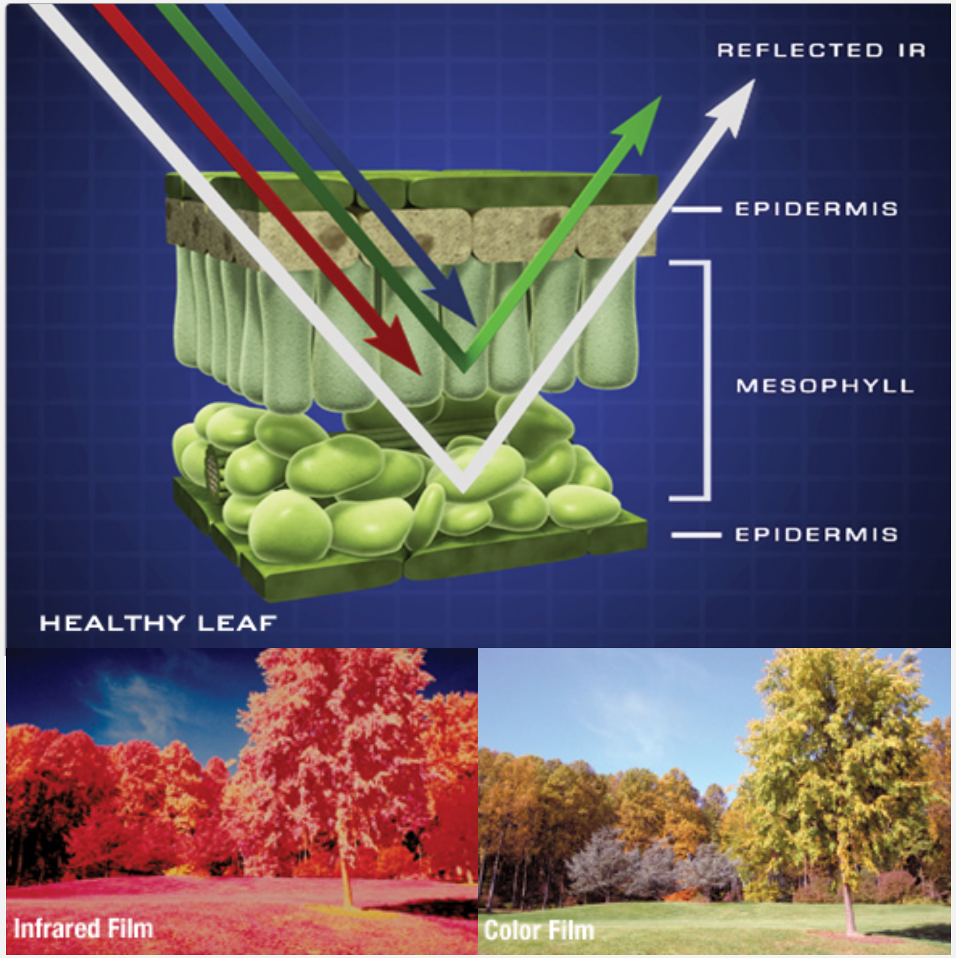
Electromagnetic Spectrum

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





Interaction with Earth's Surface: Vegetation



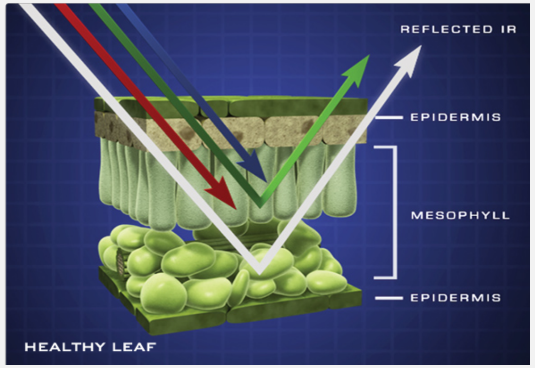
- Example: Healthy, green vegetation <u>absorbs</u> Blue and Red wavelengths (used by chlorophyll for photosynthesis) and <u>reflects</u> Green and Infrared
- Since we cannot see infrared radiation, we see healthy vegetation as green
- The amount of reflected energy is dependent on the health of the vegetation, water content, and phenological stage

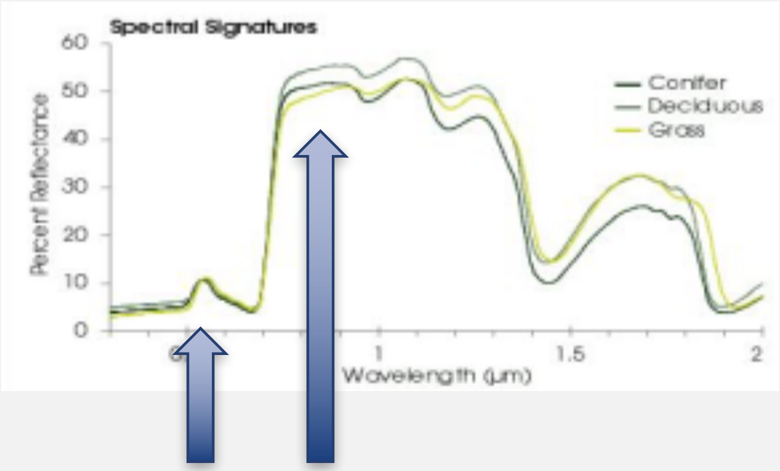
*Image Credits: NASA/Jeff Carns & Ginger Butcher

Satellites & Sensors

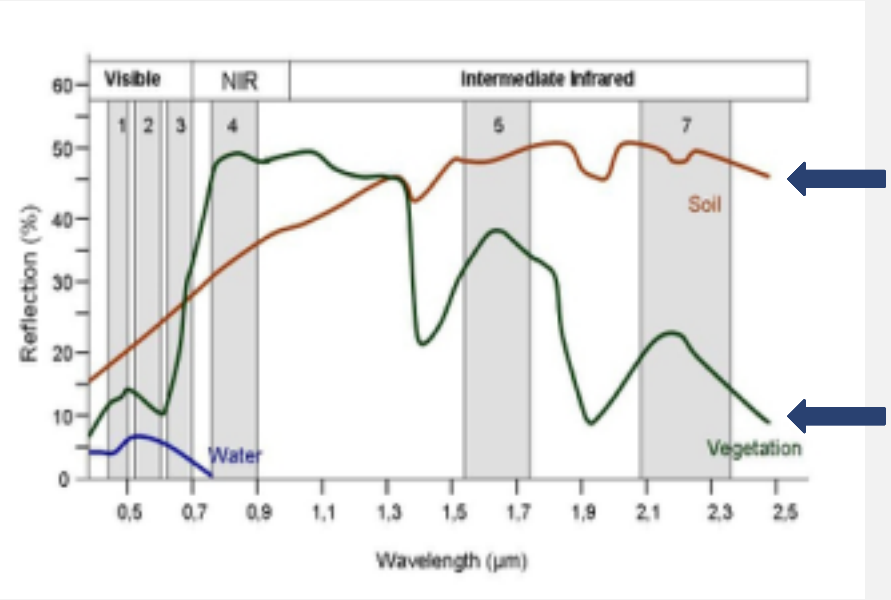
Space-based Remote Sensing

- Data acquired by satellites used in Earth monitoring is termed “remotely sensed imagery”
- Examples include Landsat and MODIS
- Remotely sensed imagery acquires information in different wavelengths, representing different parts of the Electromagnetic Spectrum
- Every kind of surface has its own spectral signature





Green Near-Infrared



Landsat bands

Spectral signatures

How Satellites Collect Data

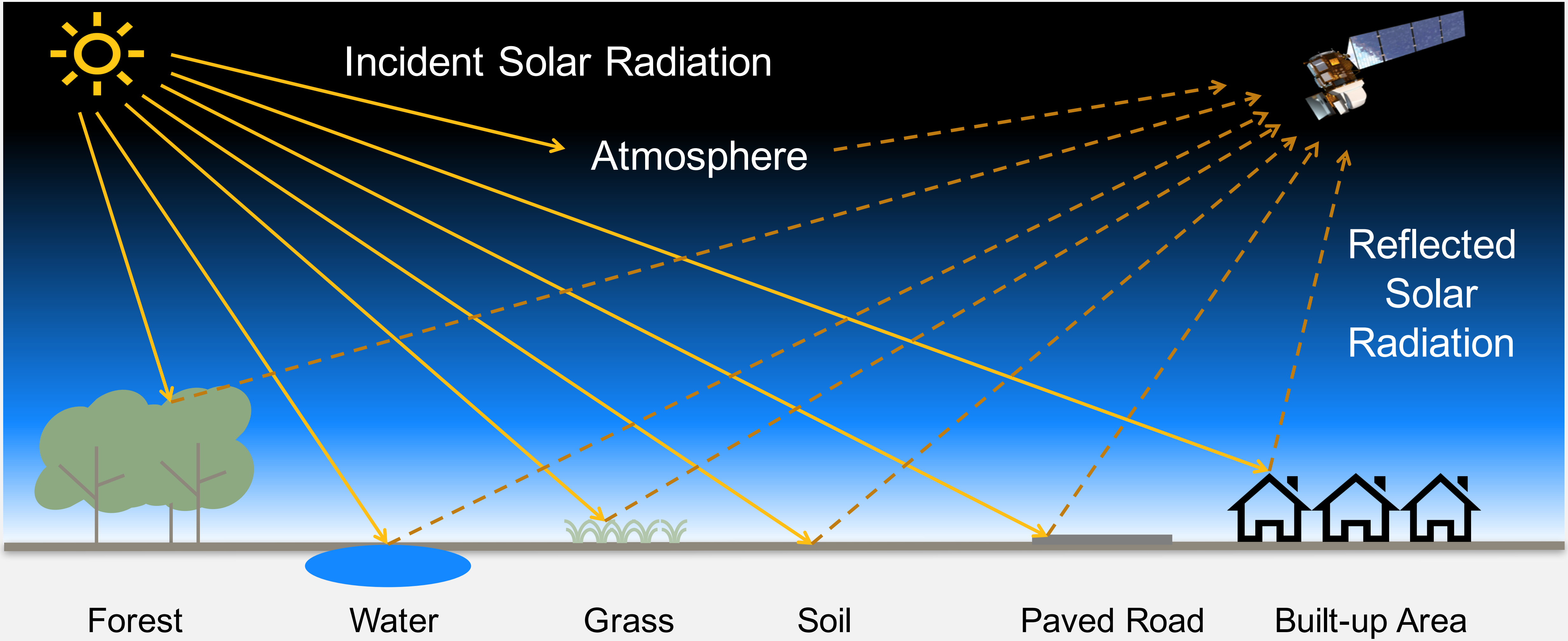
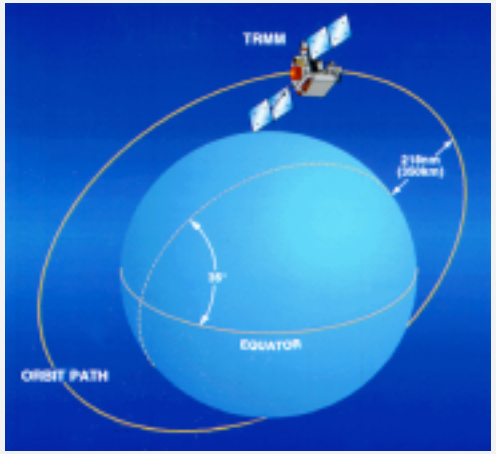
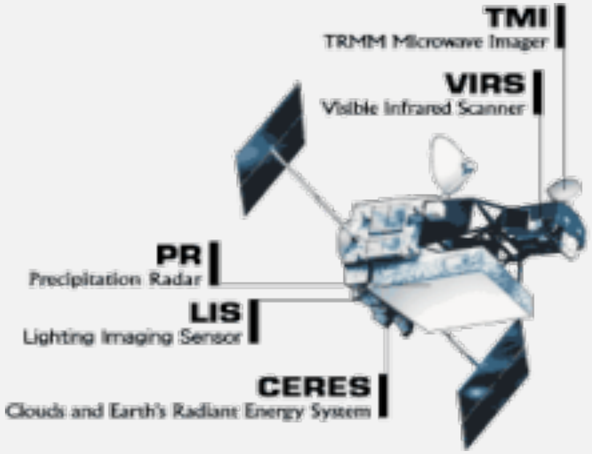


*Image recreated from Natural Resources Canada image

Satellite Remote Sensing Observations: What to Know

- Instruments, sensors, and types
- Types of satellite orbits around the earth
- Spatial and temporal coverage
- Geophysical quantities derived from the measurements
- Quality and accuracy of the retrieved quantity
  - Applications and usage
  - Availability, access, and format





Satellite Remote Sensing Observations: What to Know

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Affect spatial and temporal resolution

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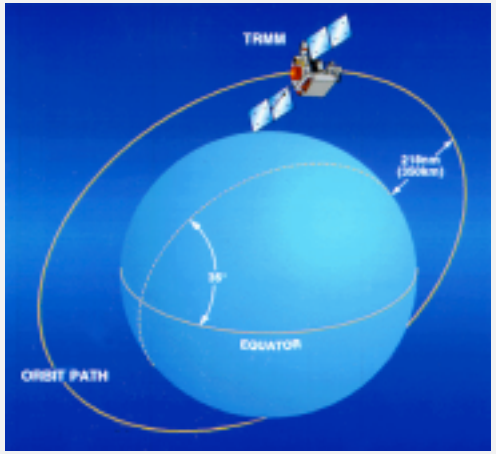
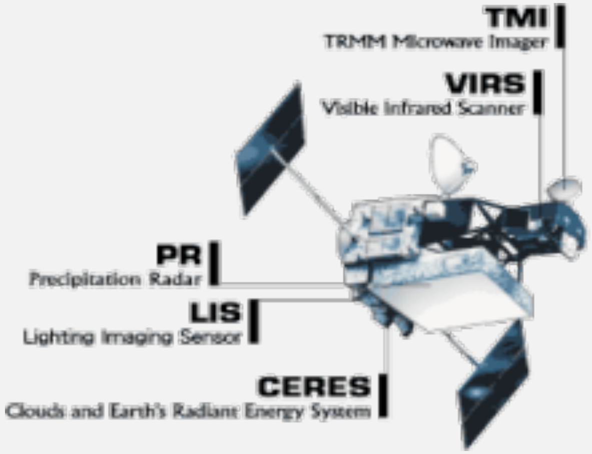


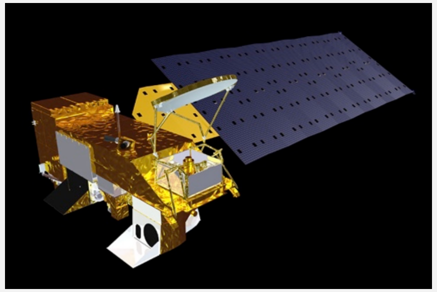


Satellite and Sensor Characteristics

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

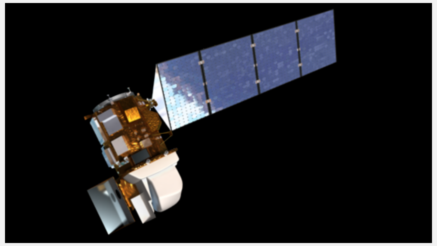
Satellites vs. Sensors

- Satellites carry sensors or instruments
- Earth-observing satellite remote sensing instruments are named according to
  - the satellite (platform)
  - the instrument (sensor)



Aqua Satellite

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



Landsat 8 Satellite

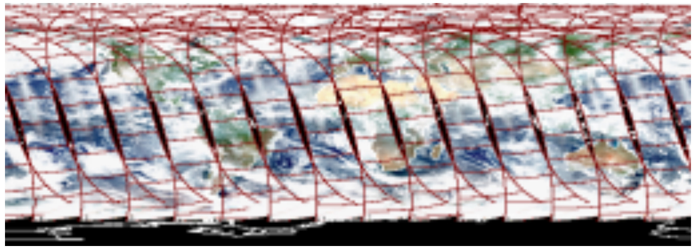
- Instruments
  - OLI
  - TIRS

Orbits: Spatial Coverage & Temporal Resolution

Polar Orbiting

- Global coverage
- Varied measurement frequency (1 per day – 1 per month)
- Larger swath size means higher temporal resolution

Aqua “ascending orbit” daytime



Non-Polar Orbiting

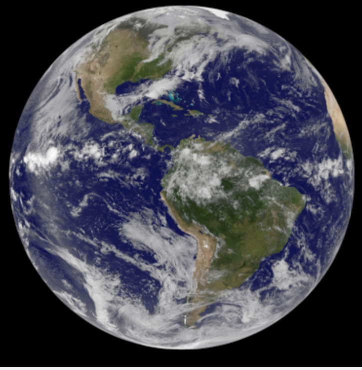
- Non-Global coverage
- Varied measurement frequency (less than 1 per day)
- Larger swath size means higher temporal resolution

TRMM Image

Geostationary

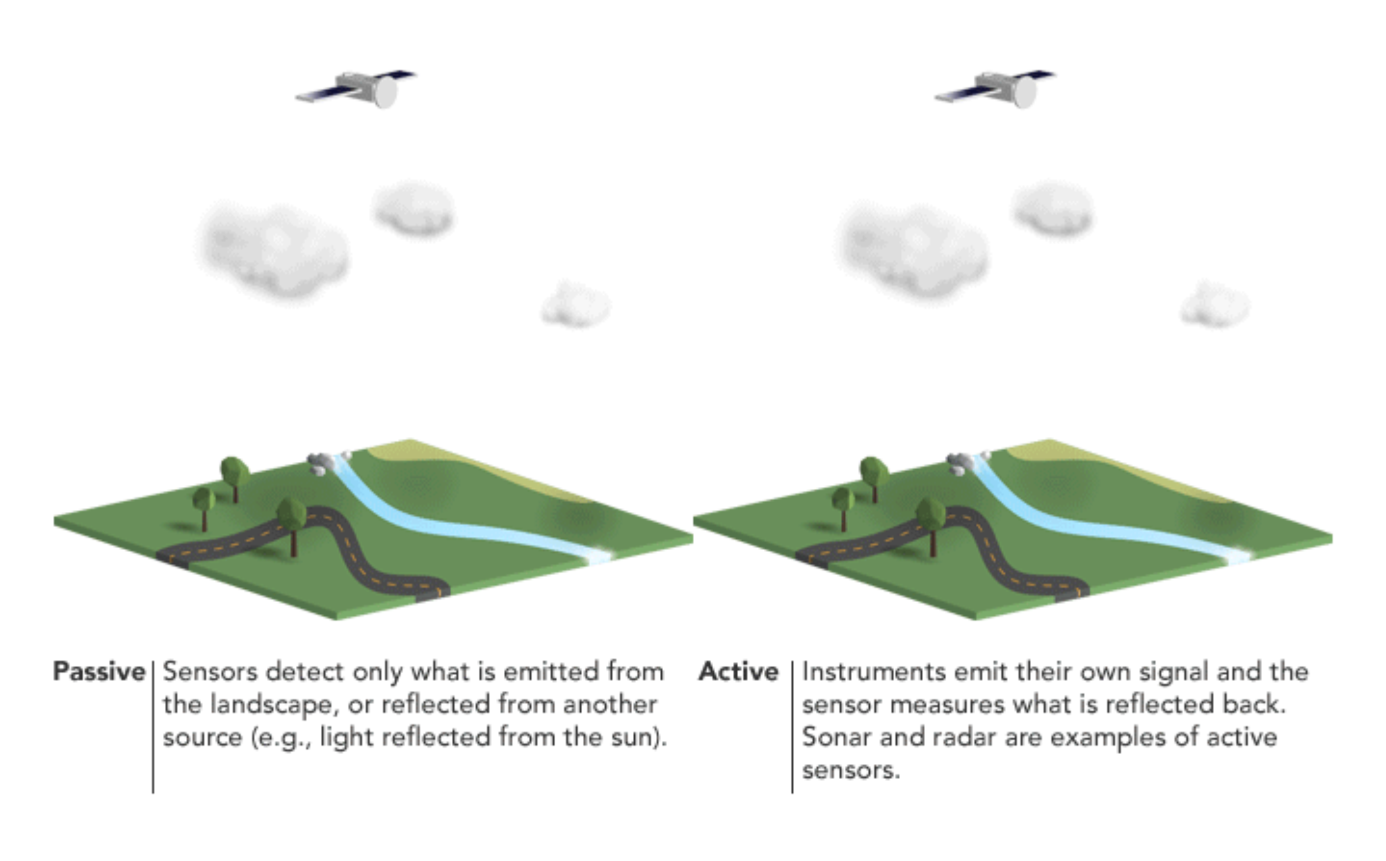
- Limited spatial coverage – more than one satellite needed for global coverage
- Multiple observations per day

GOES Image



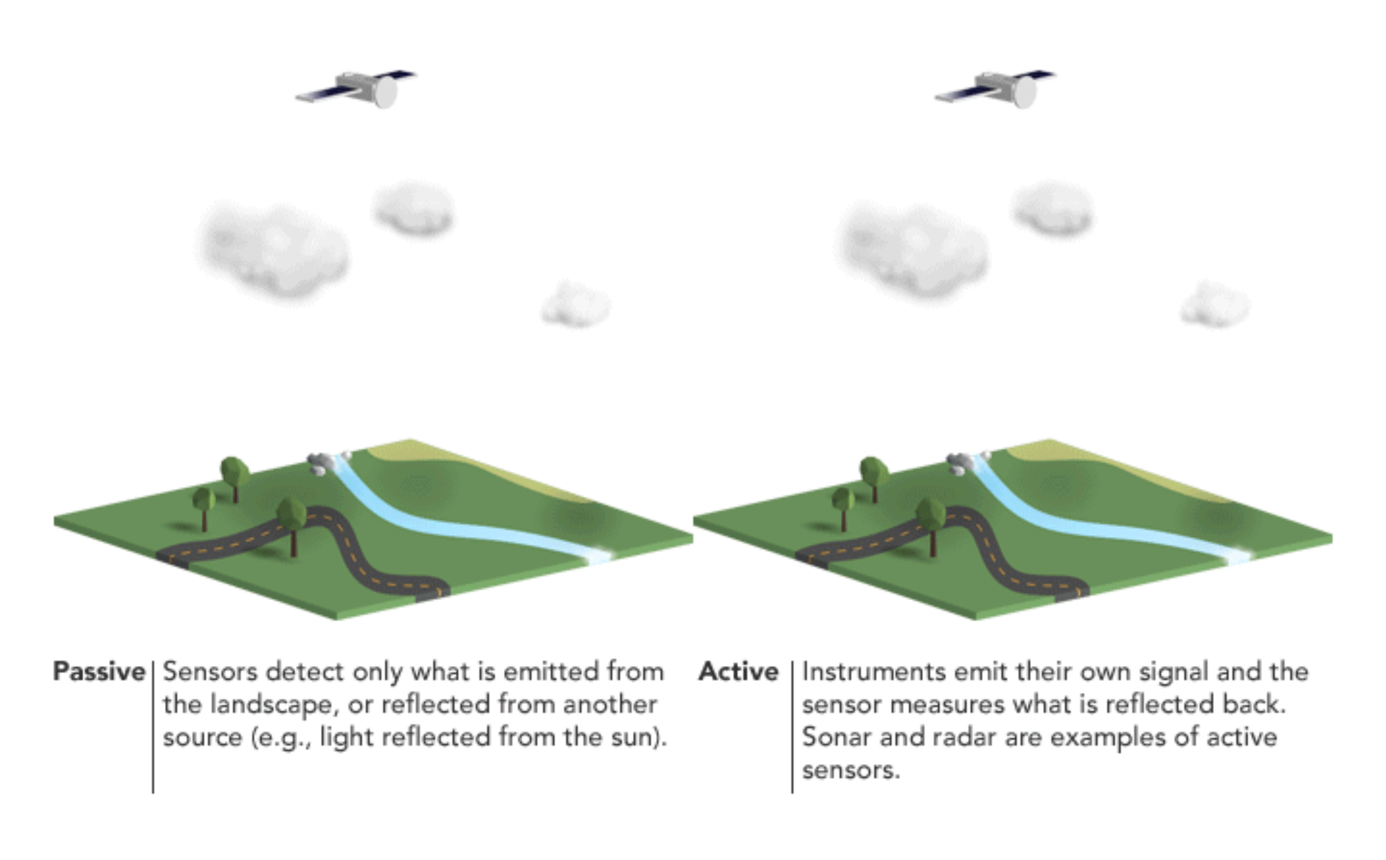
Satellite Sensors: Passive

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



Satellite Sensors: Active

- Emit beams of radiation 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



Spatial Resolution

There is a tradeoff between spatial resolution and spatial extent

1 m 10 m 30 m

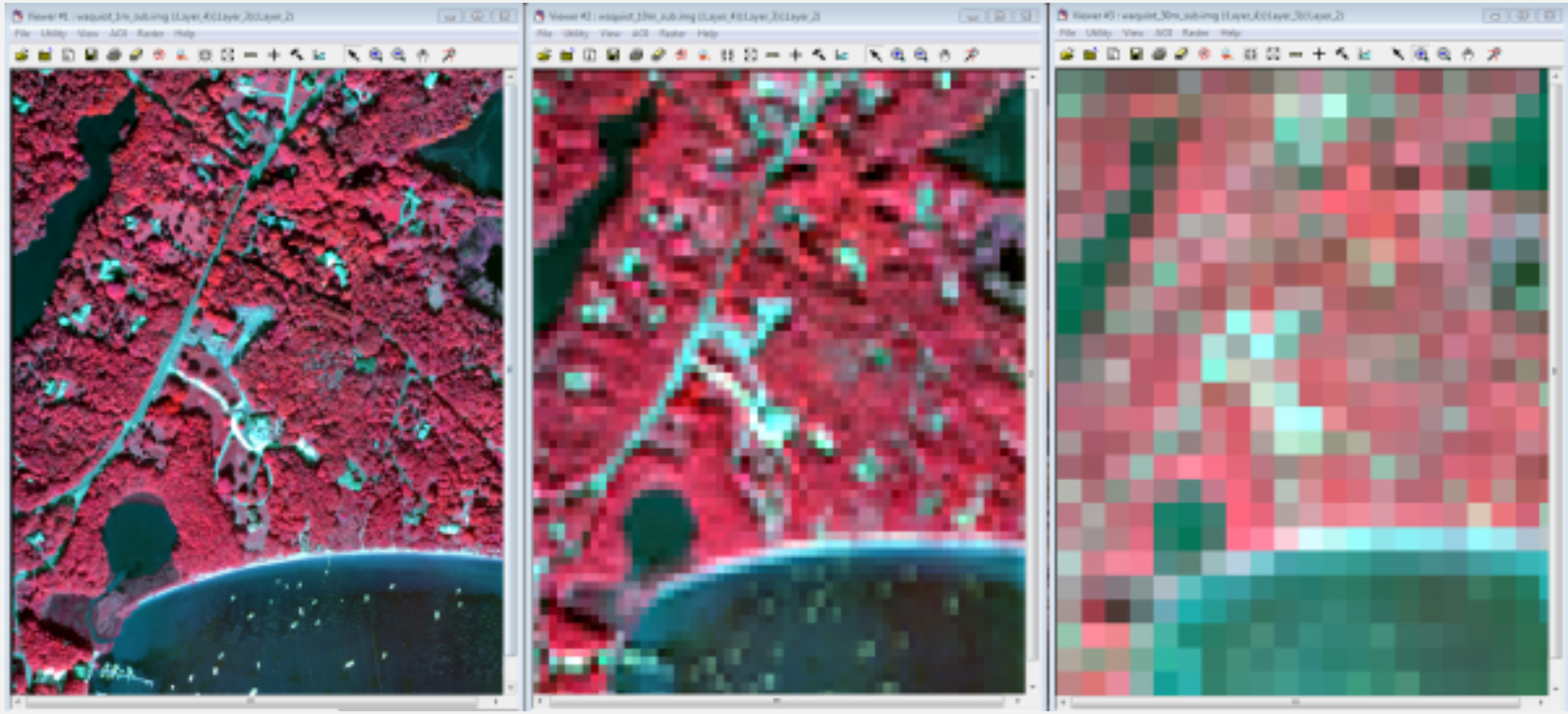
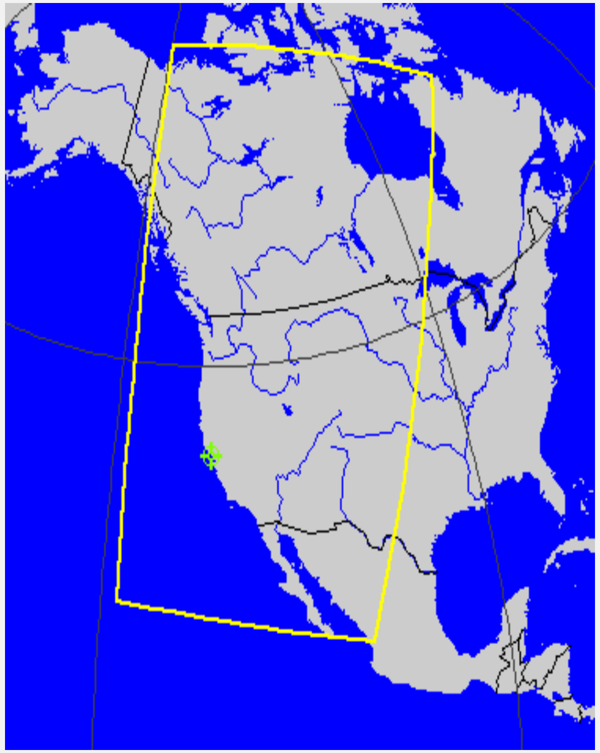


*Image Credit: NOAA

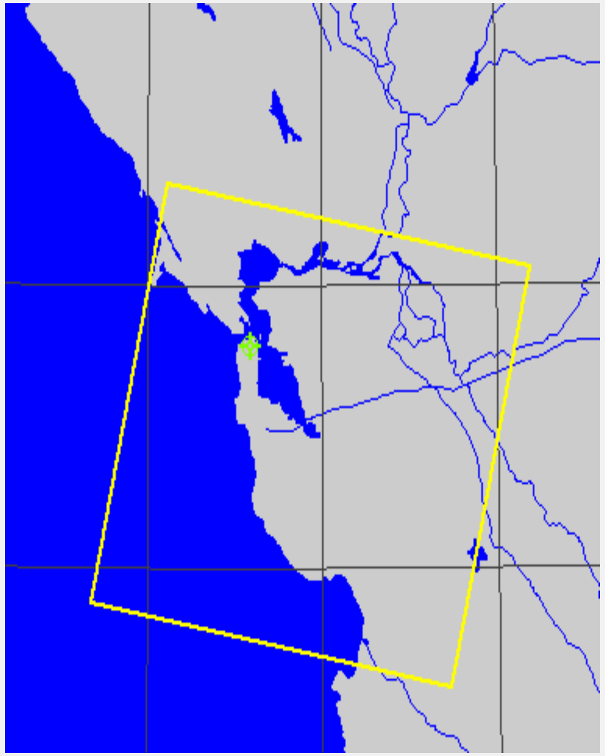
Spatial Resolution vs. Extent

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

MODIS (250m – 1km)

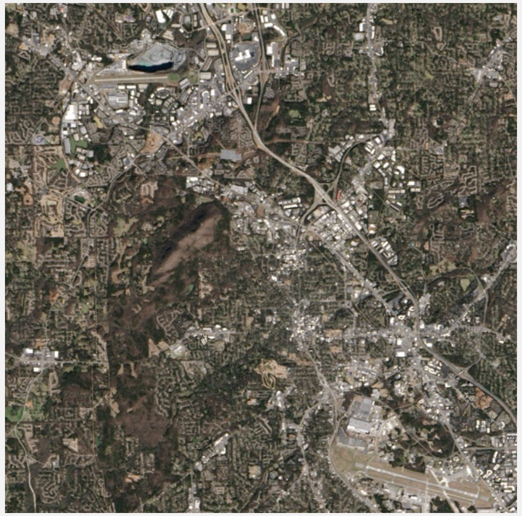


Landsat (30m)

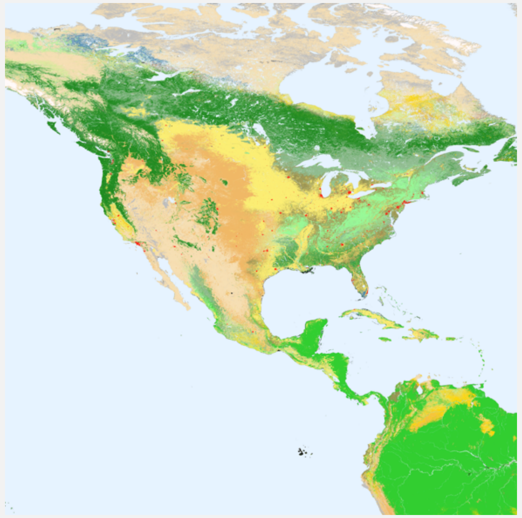


NASA Satellite Missions with Different Spatial Resolution

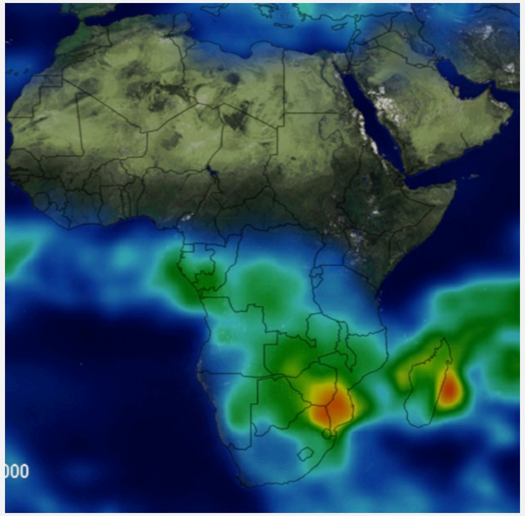
Landsat
Kennesaw Mountain, GA
30 m



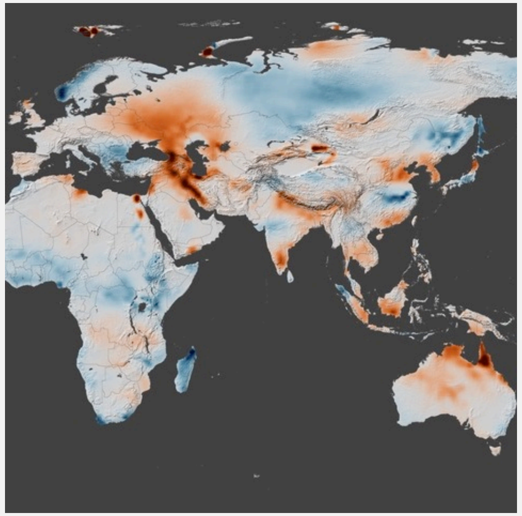
Terra MODIS
Land Cover
1 km^2



TRMM
Rain Rate
25 km_2



GRACE Terrestrial Water Storage
150,000 km^2 (or coarser)

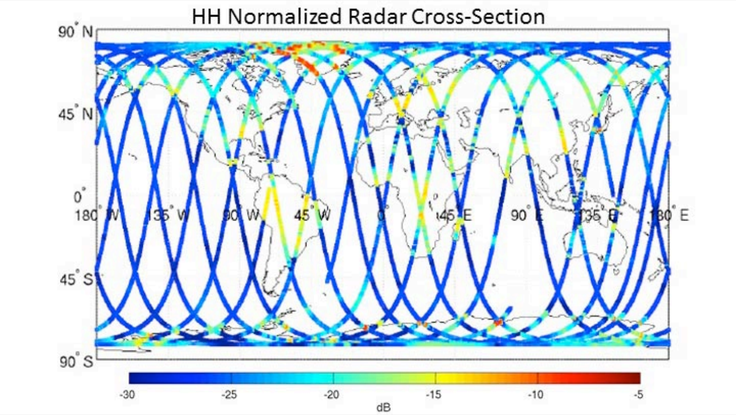


Temporal Resolution

- It takes time for a satellite to complete one orbit, this is called the *revisit time*
- Depends on the satellite and sensor capabilities, swath overlap, and latitude

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

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



This example shows a radar image path from NASA's Soil Moisture Active Passive satellite 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

Considerations when selecting the right remote sensing data source for your project

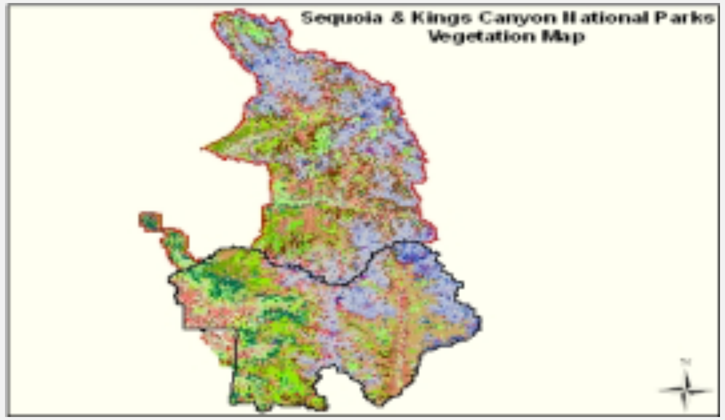
- What **geographical, phenological, and atmospheric** (especially persistant cloud cover) conditions exist?
- What are the **spectral regions**, and bands within them, and how do these relate to the potential for distinguishing the land-cover types of interest, and changes among them?
- What is the **spatial resolution** of the data and how appropriate is it, relative to the scale of the land-cover changes to monitor?
- What is the **temporal resolution** in terms of potential frequency of acquisition of non-cloudy observations compared to the desired frequency in monitoring?
- What is the **longevity of the image archive length**? Does this meet the historical mapping needs?
- What are the **cost implications** of this data in terms of purchase and analysis?
- What are the **future satellite development** and launch commitments?

Advantages and Disadvantages of Remote Sensing Observations

Remote Sensing Observations

- Advantages:
  - Capable of synoptic wall-to-wall coverage
  - Provide information where there is no ground-based measurements
  - Provide globally consistent observations

- Disadvantages:
  - Does not provide high level of detail at the ground level
  - Cannot detect land cover under canopy (optical)
  - Cannot detect much under water
  - Cost (of some remote sensing data)
  - Level of technical expertise required to process/interpret
  - Impossible to have high spatial, spectral and temporal resolution



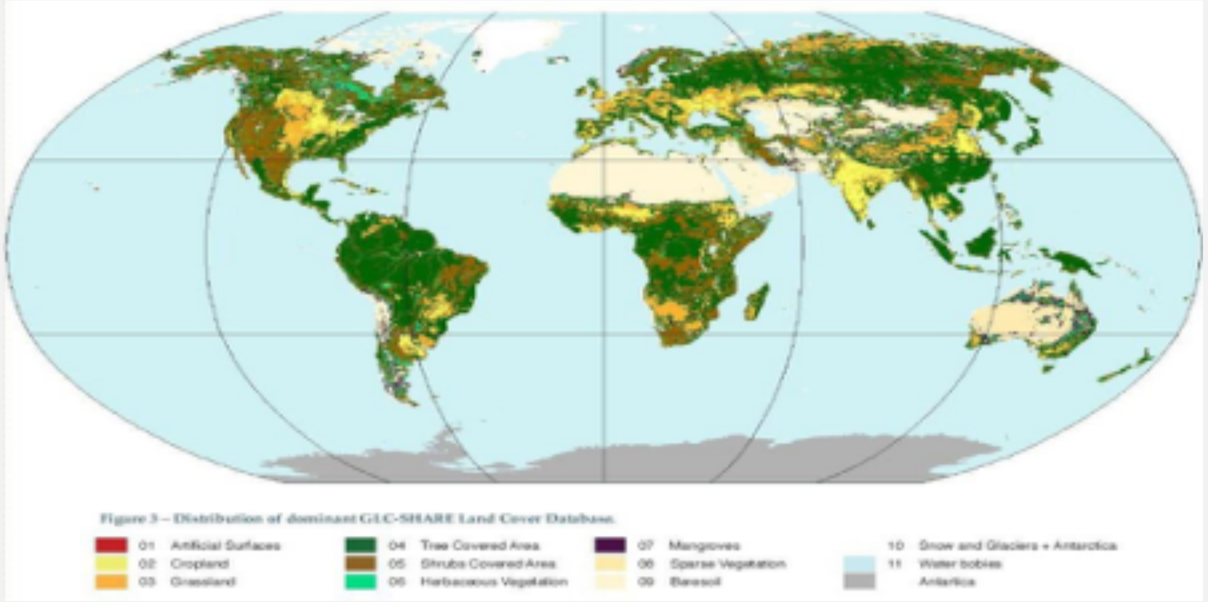
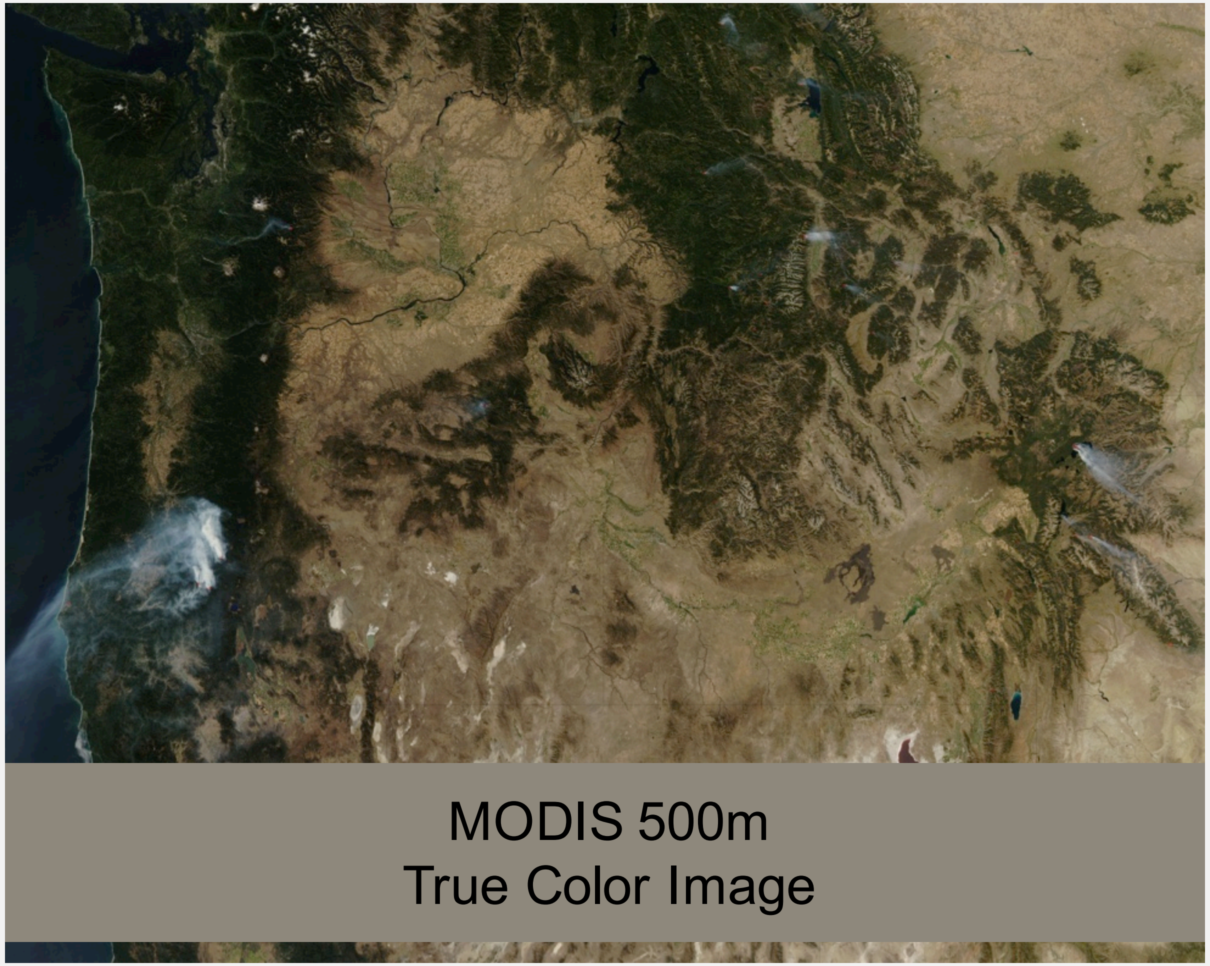


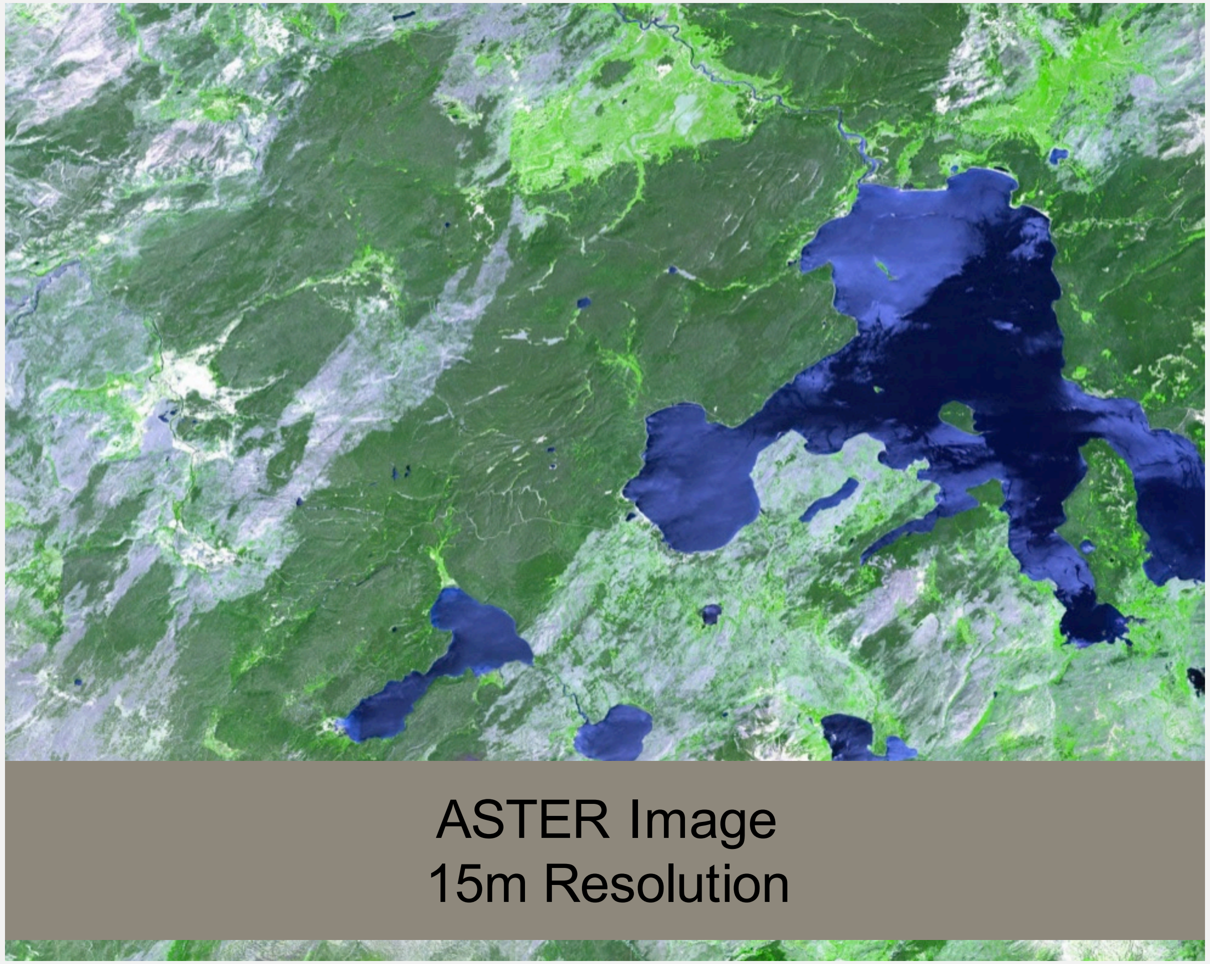
Figure 3 – Distribution of dominant GLC-SHARE Land Cover Database.

Remote Sensing Observations

Trade-Offs



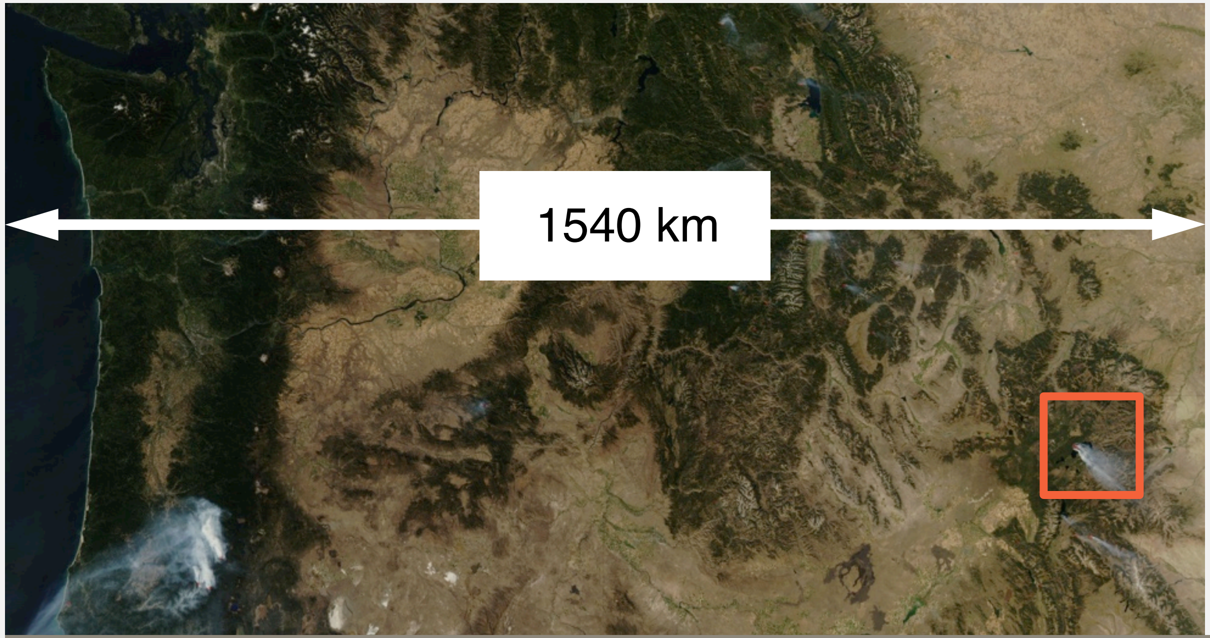
MODIS 500m
True Color Image

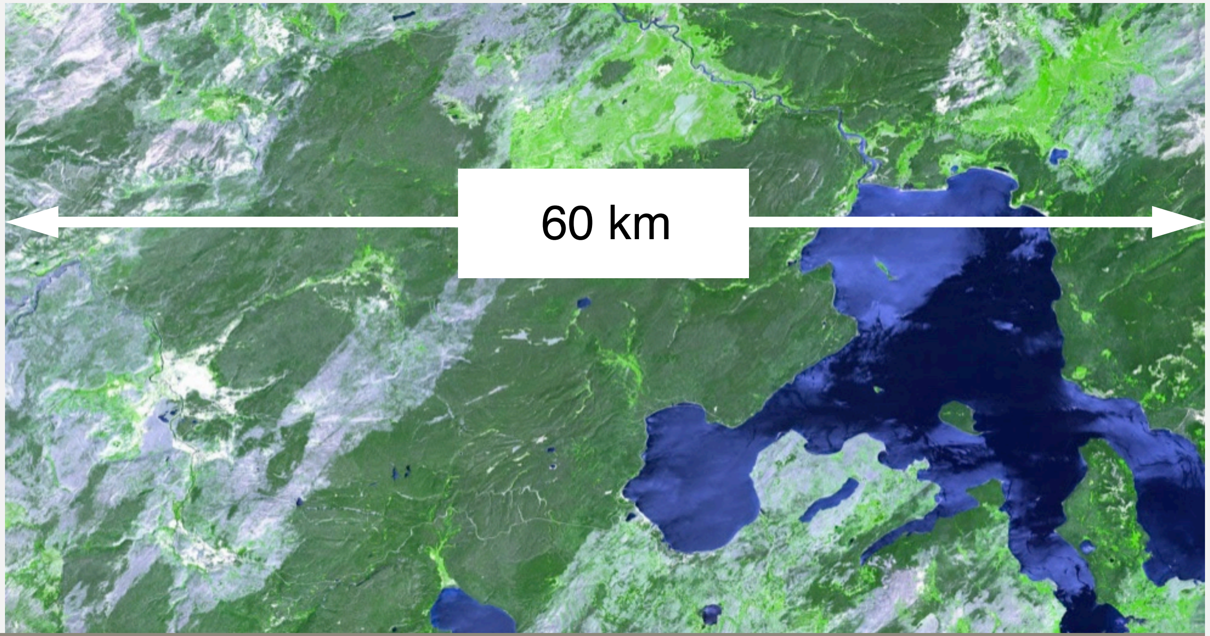


ASTER Image
15m Resolution

Remote Sensing Observations

Trade-Offs





- The different resolutions are the limiting factor for the utilization of the remote sensing data for different applications. The trade-off is because of technical constraints.
- Larger swatch size is associated with low spatial resolution and vice versa.
- Often satellite designs are application oriented

Remote Sensing Data Sources

Remote Sensing Data Sources

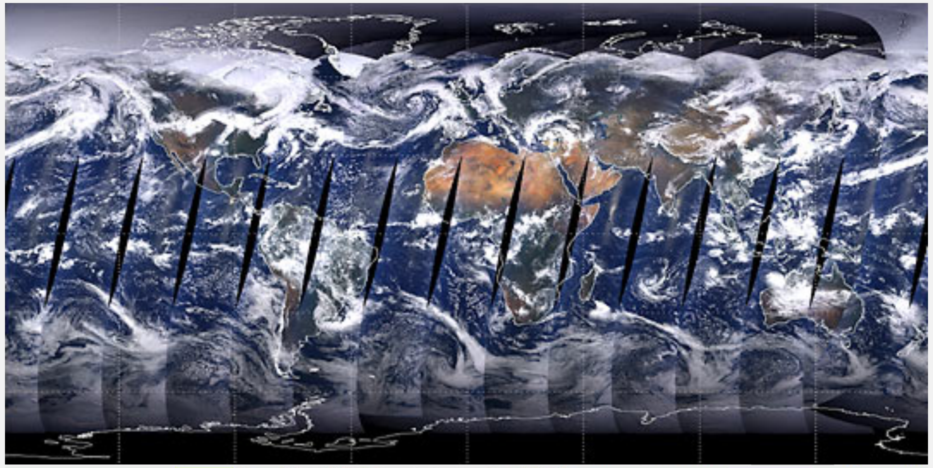
Overview

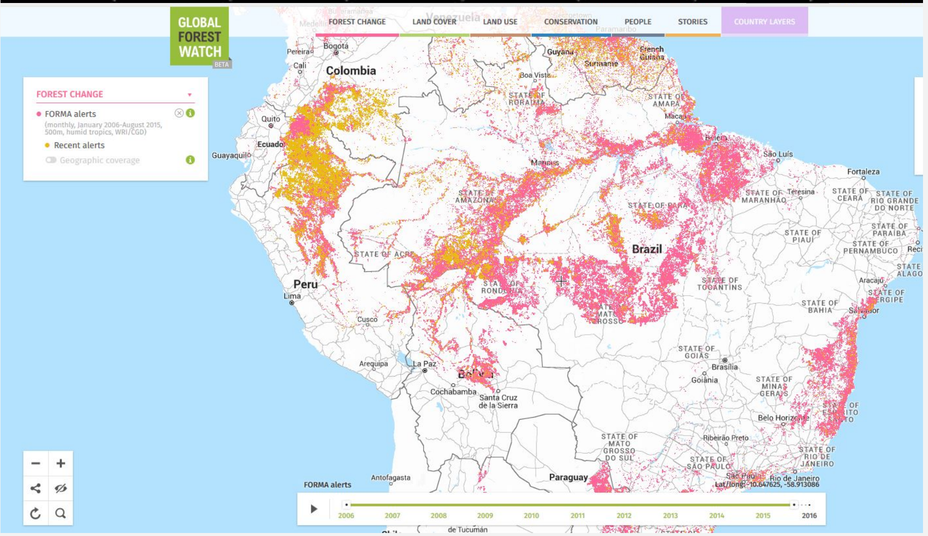
- Coarse spatial resolution (optical)
- Medium spatial resolution (optical)
- High spatial resolution (optical)
- Synthetic Aperture Radar (active)
- LiDAR

Remote Sensing Data Sources

Coarse Spatial Resolution (Optical)

- Greater than 250m
- Ex: MODIS, CBERS-2
- High temporal resolution useful for early warning and detection of forest clearing and degradation
- Example:
  - FORMA: a monitoring system that issues monthly forest loss alerts for the humid tropics. It generates alerts of likely forest clearing activity every 16 days at 500 m spatial resolution (Hammer et al. 2014)





* (bottom) FORMA alerts from Global Forest Watch

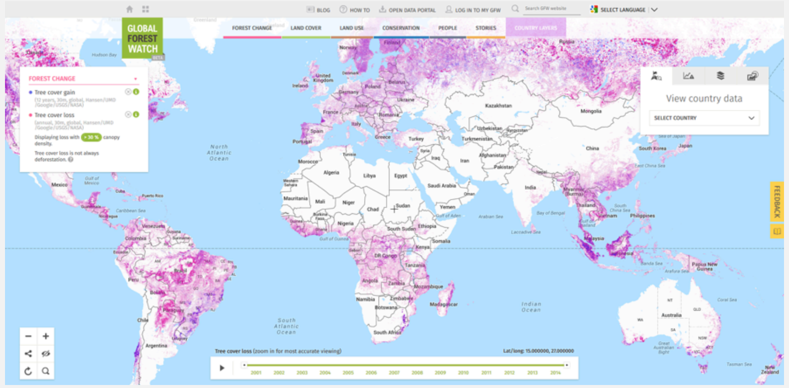
Remote Sensing Data Sources

Medium Spatial Resolution (Optical)

- 10m – 80m spatial resolution
- Most common: Landsat (30m) and more recently, Sentinel 2
- Benefits:
  - Historical archive (early 1980s)
  - Easily accessible and freely available
  - Global coverage
- Limitations: Areas of persistent cloud cover
- Example: Global Forest Watch (Hansen et al. 2013)

Landsat Satellite

Global Forest Watch



Remote Sensing Data Sources

High Spatial Resolution (Optical)

- Better than 10m spatial resolution
- Examples: Worldview 2 and 3
- Primarily used for accuracy assessment, sampling transects or hot spot assessment
- Benefits: Forest activity data can be monitored more accurately and with greater differentiation
- Limitations
  - Higher acquisition and processing costs
  - Spatial and temporal coverage may not be adequate
- Ex: Nilo Forest Reserve, Tanzania

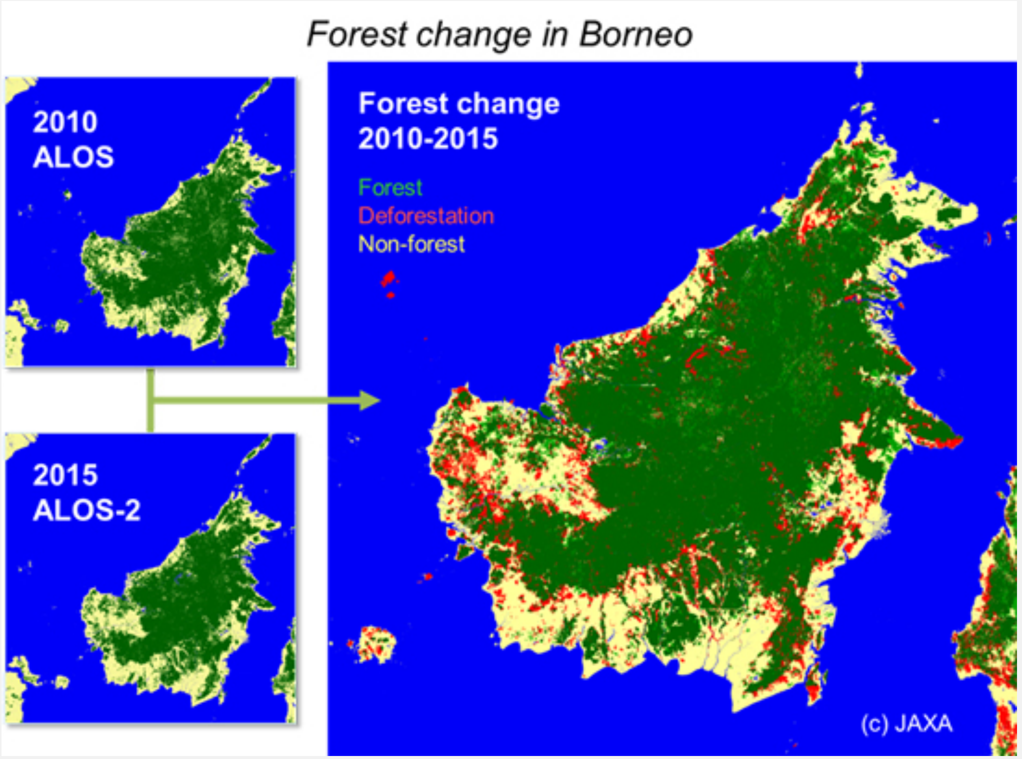
Nilo Forest Reserve, Tanzania

*Image Credits: (top) DigitalGlobe; (bottom) DigitalGlobe and Norsk Regnesentral

Remote Sensing Data Sources

Synthetic Aperture Radar

- 1-80m spatial resolution
- Examples: Sentinel 1A & B, Radarsat, ALOS
- Benefits
  - useful in areas of persistent cloud cover
  - can provide information on forest structure
  - complementary to optical data
- Limitations
  - difficult to process
  - not currently used operationally
- Example: Forest change in Borneo



* Source: Masanobu et al., 2014

Remote Sensing Data Sources

LiDAR

- Provides information on forest structure (e.g. tree height, canopy volume) and biomass
- Currently acquired using aircraft platform; no operational LiDAR satellites
- Benefits:
  - Provides detailed information of forest structure
  - Verification of biomass estimates; reduces need for ground sampling
- Disadvantages:
  - Expensive to acquire and process
- Example
  - National carbon map of Panama (right) by integrating field data with satellite image and LIDAR

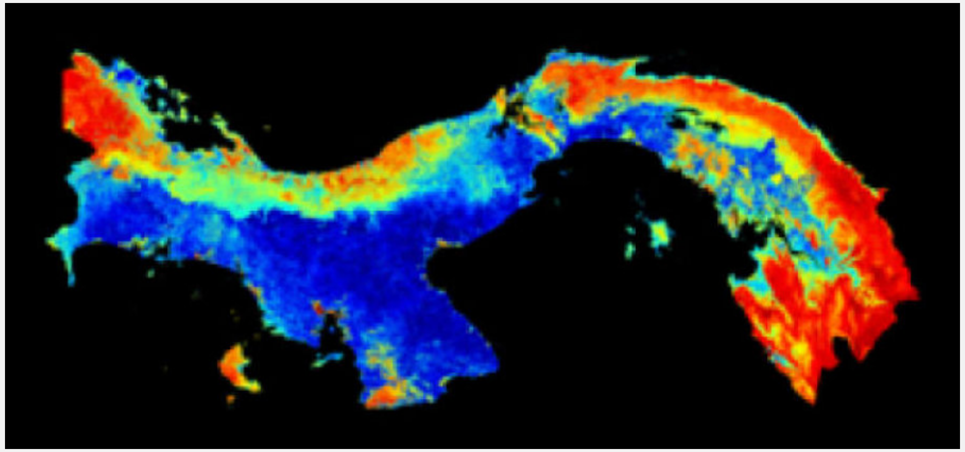


*Image Credit: Carnegie Institution

Land Cover Mapping & Change Detection

Turning Data Into Information: Image Classification

Landsat Image of Lake Tahoe

Land Cover Map of Lake Tahoe

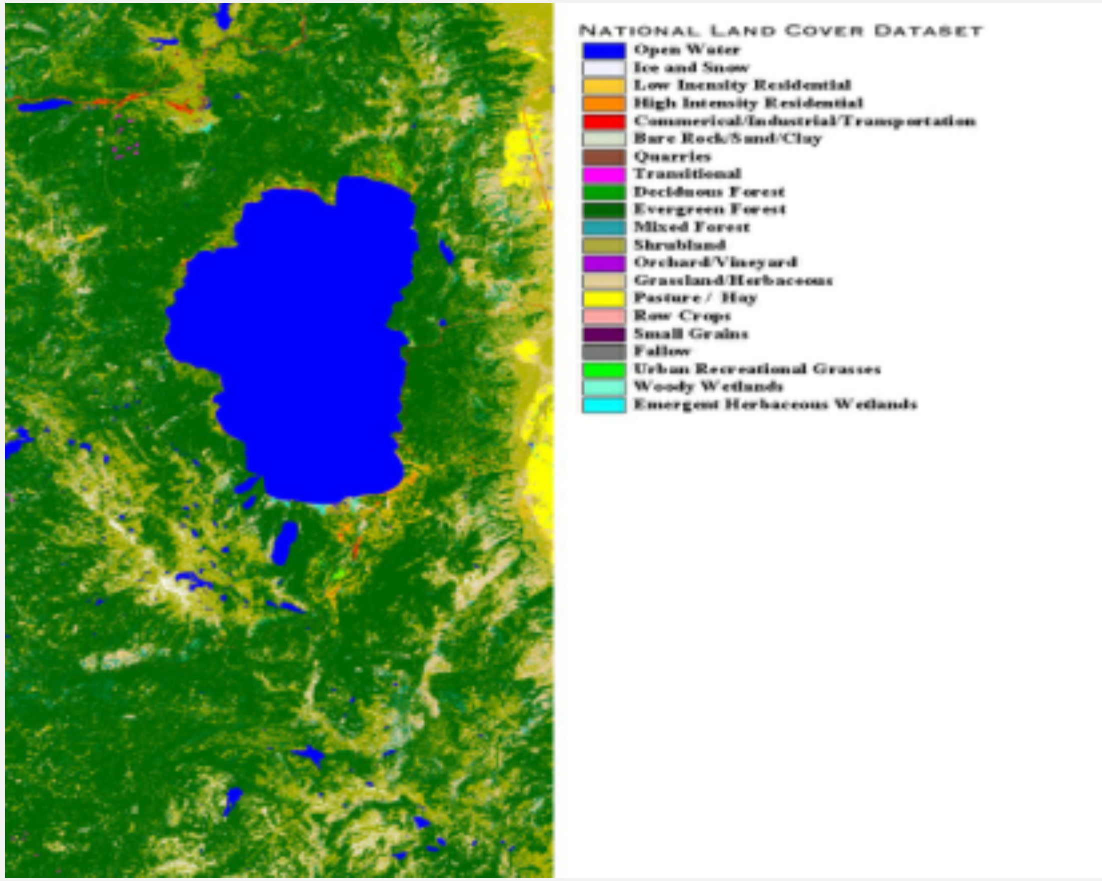
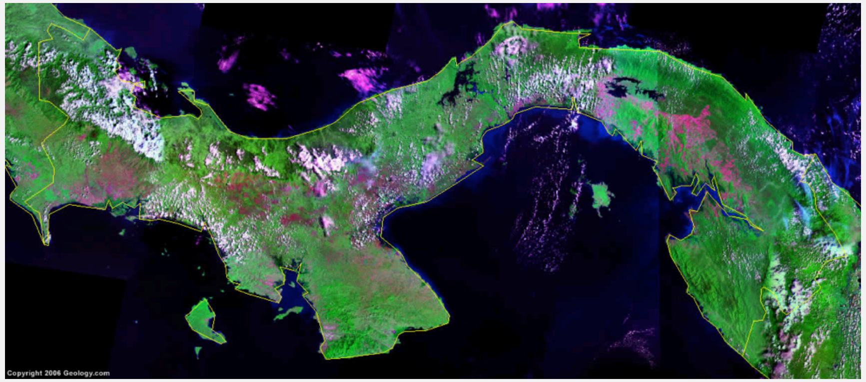


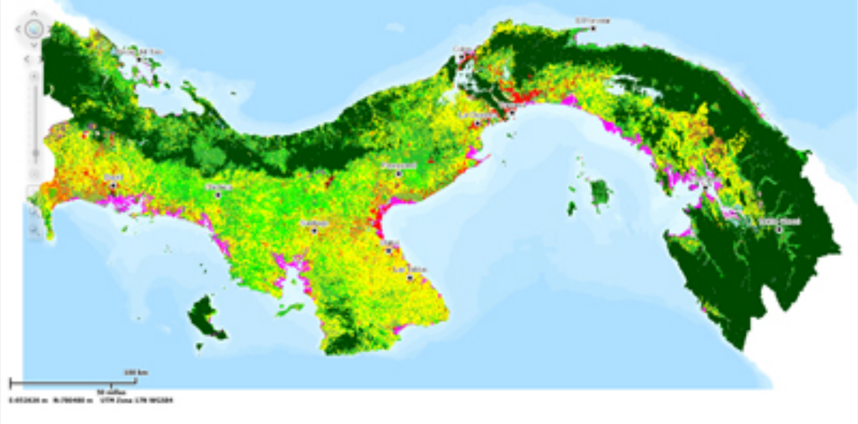
Image Classification

Overview

- Used for mapping forest/non-forest, land cover, or forest stratification
- There are many methods: visual interpretation, pixel-based (supervised, unsupervised), and object-based
- For improved results, often needs ground and/or other ancillary information (topographic or climatic data)
- Needs specialized software (commercial or open source) and training

Land Cover Map of Panama

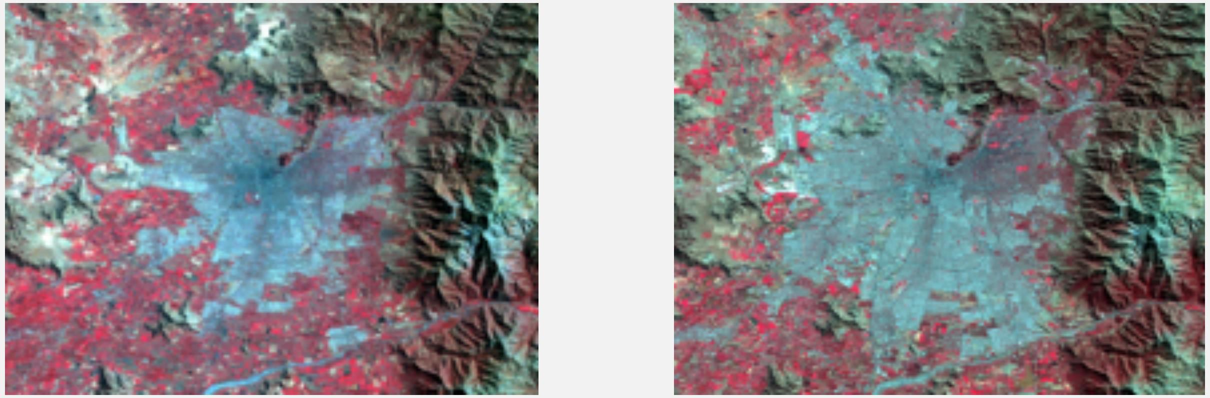




What is Change Detection?

- The comparison of information about an area on the Earth over two or more points in time
  - Where and when has change taken place?
  - How much change, and what type of change has occurred?
  - What are the cycles and trends in the change?

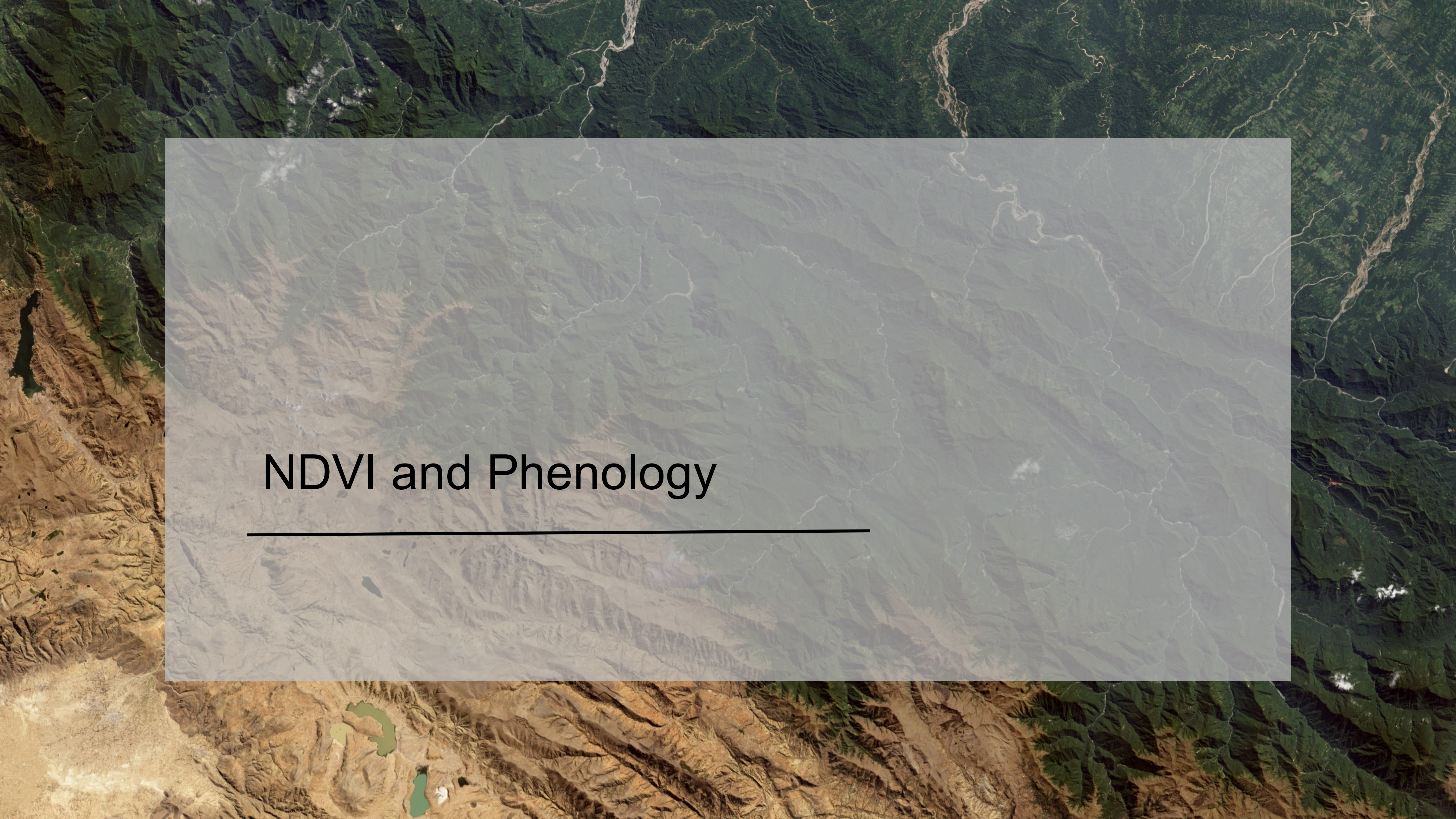
Bark Beetle Infestation in Colorado (2005-2011)



Santiago, Chile Urban growth (1975-2013), Landsat

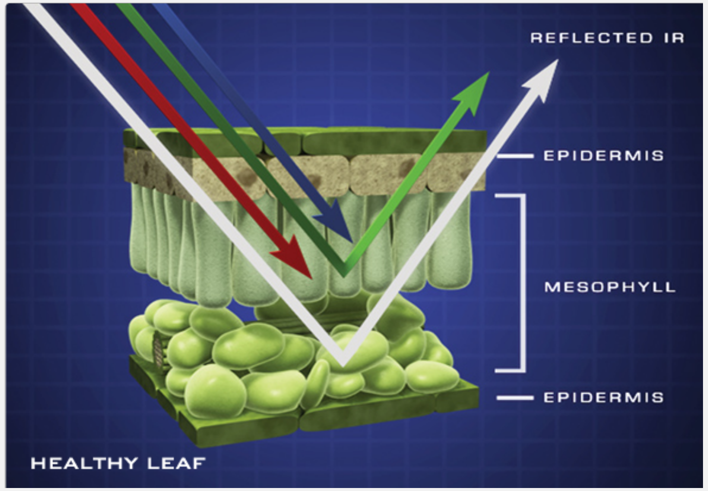
Source: earthshots.usgs.gov

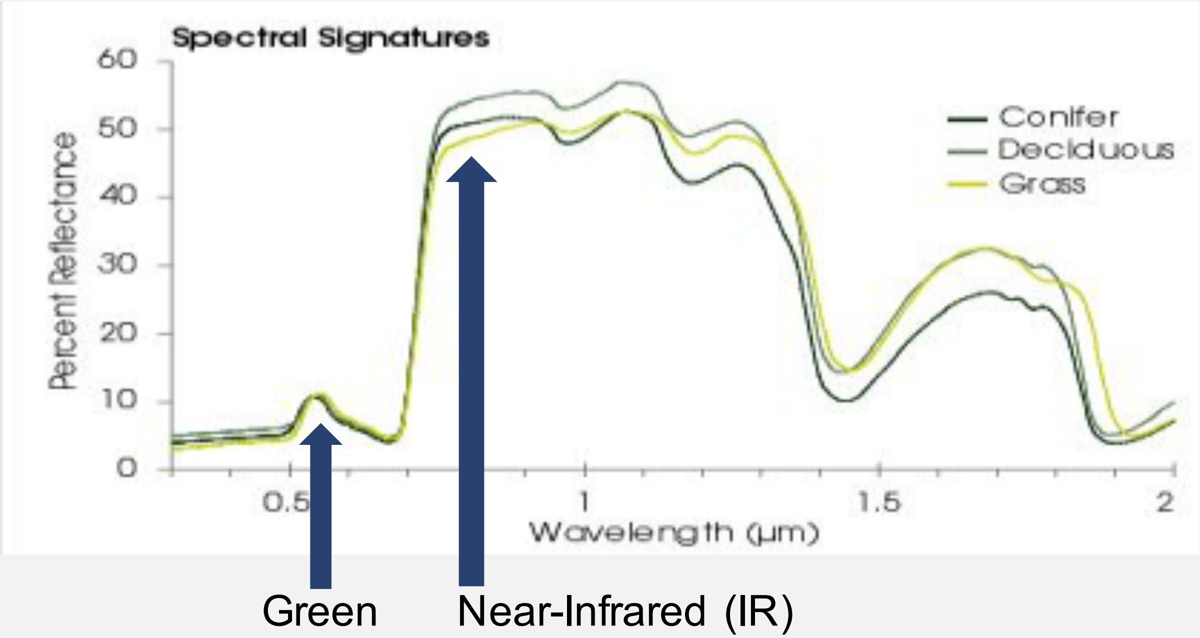
NDVI and Phenology



What is NDVI?

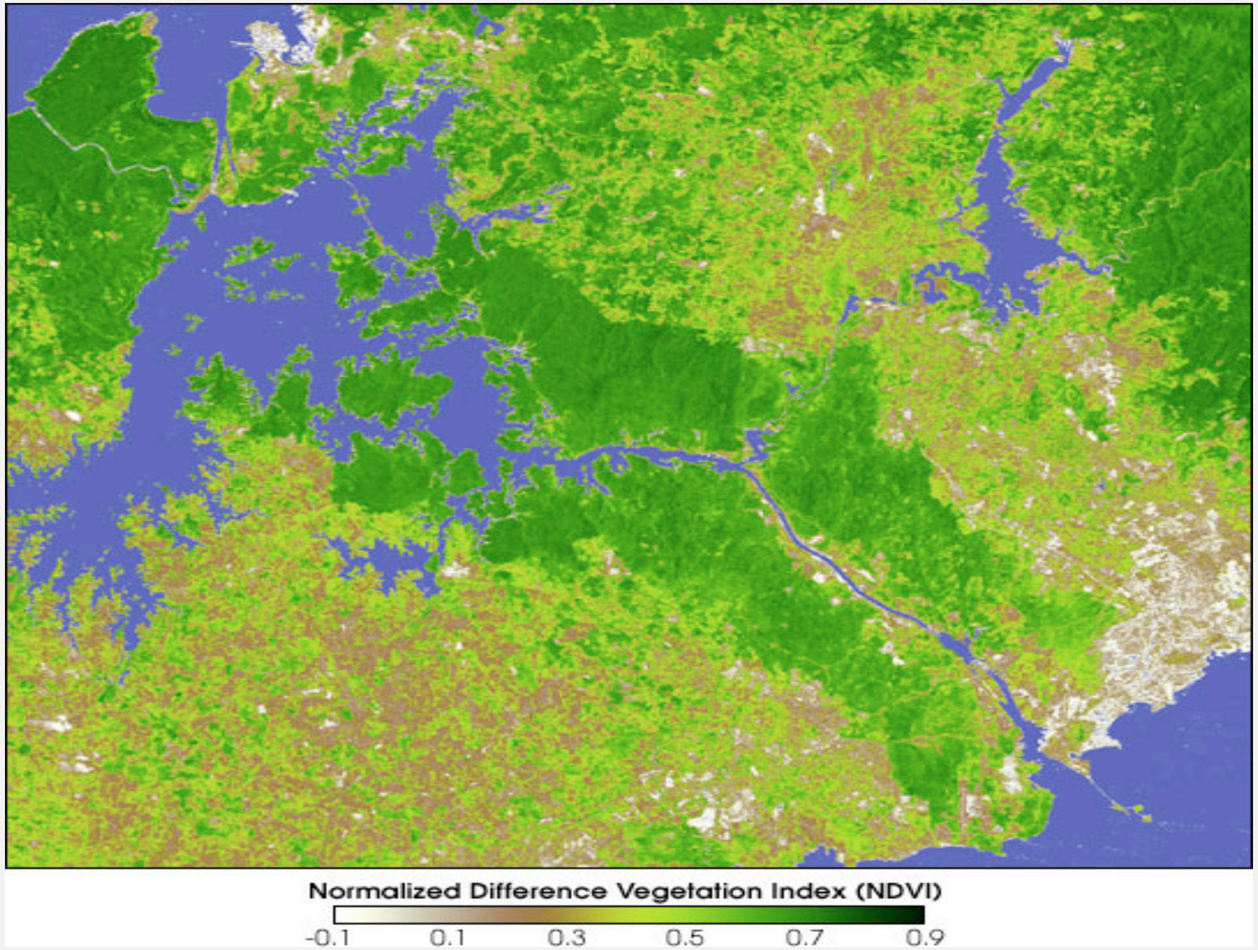
- Normalized Difference Vegetation Index
  - Based on the relationship between red and near-infrared wavelengths.
  - Chlorophyll strongly absorbs visible (red)
  - Plant structure strongly reflects near-infrared





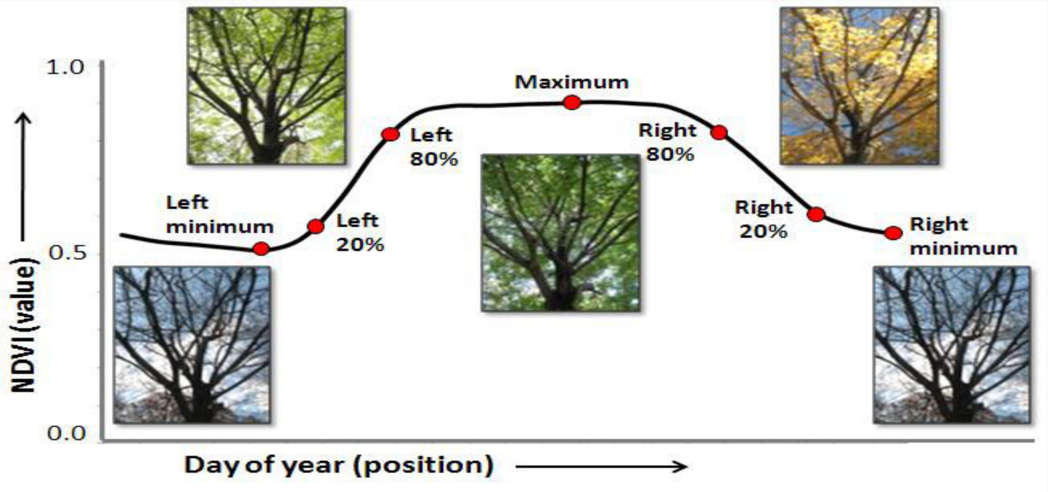
NDVI Example

- This is a Landsat NDVI image of the Panama Canal watershed
- The darker green the area, the higher the NDVI value, and the more green vegetation is present
- This image was acquired in March 2000 during Panama's annual dry season



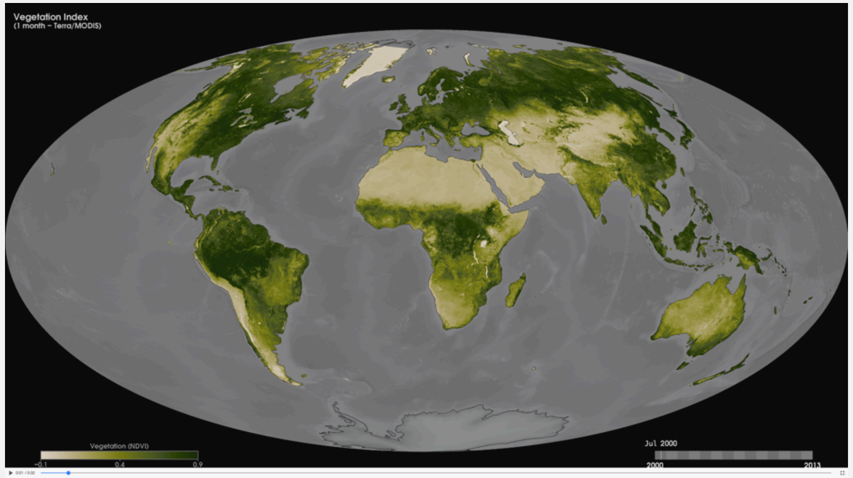
NDVI: Phenology

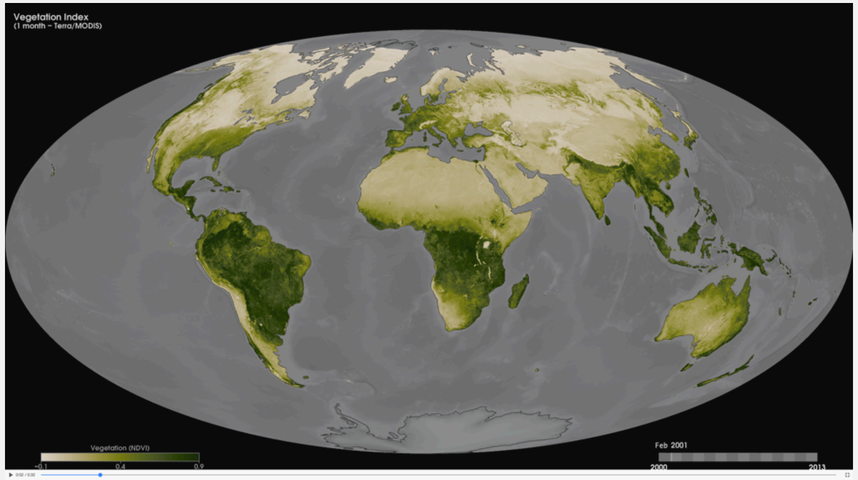
- Remote sensing is used to track the seasonal changes in vegetation
- Monthly NDVI images from MODIS or Landsat can be used to monitor phenology



NDVI

(left) Jul 2000 (right) Feb 2001

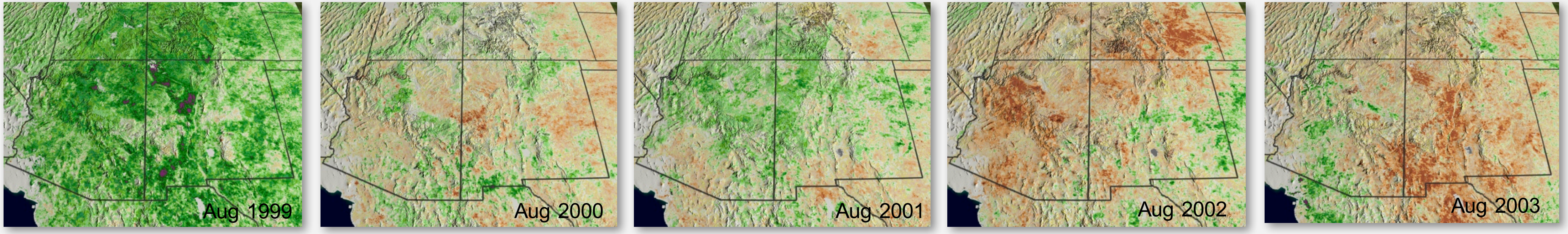




NDVI Anomalies

- Departure of NDVI from the long-term average, normalized by long-term variability
- Generated by subtracting the long-term mean from the current value for that month of the year for each grid cell
- Indicates if vegetation greenness at a particular location is typical for that period or if the vegetation is more or less green

NDVI Anomalies in the Southwestern United States



How Remote Sensing Data Products Can Apply to Aid IUCN Supported Conservation Initiatives

Programme Area 1: Valuing and Conserving Nature

- Animal movement
- Dynamic habitat index for biodiversity
- Citizen science approach to chimpanzee monitoring (Jane Goodall Foundation)
- Map of Life
- Google Earth Engine

- Commission on Ecosystem Management
  - IUCN Red List of Ecosystems
- Species Survival Comission
  - IUCN Red List of Threatened Species
- IUCN Green List
- Key Biodiversity Areas

SUSTAINABLE DEVELOPMENT GOALS

Convention on Biological Diversity

ipbes

Programme Area 2: Deploying Nature-Based Solutions to Address Climate Change, Food Security, and Economic and Social Development

- Vegetation carbon stock corridors
- Remote sensing for land change detection
- Firecast near real-time monitoring
- Google Earth