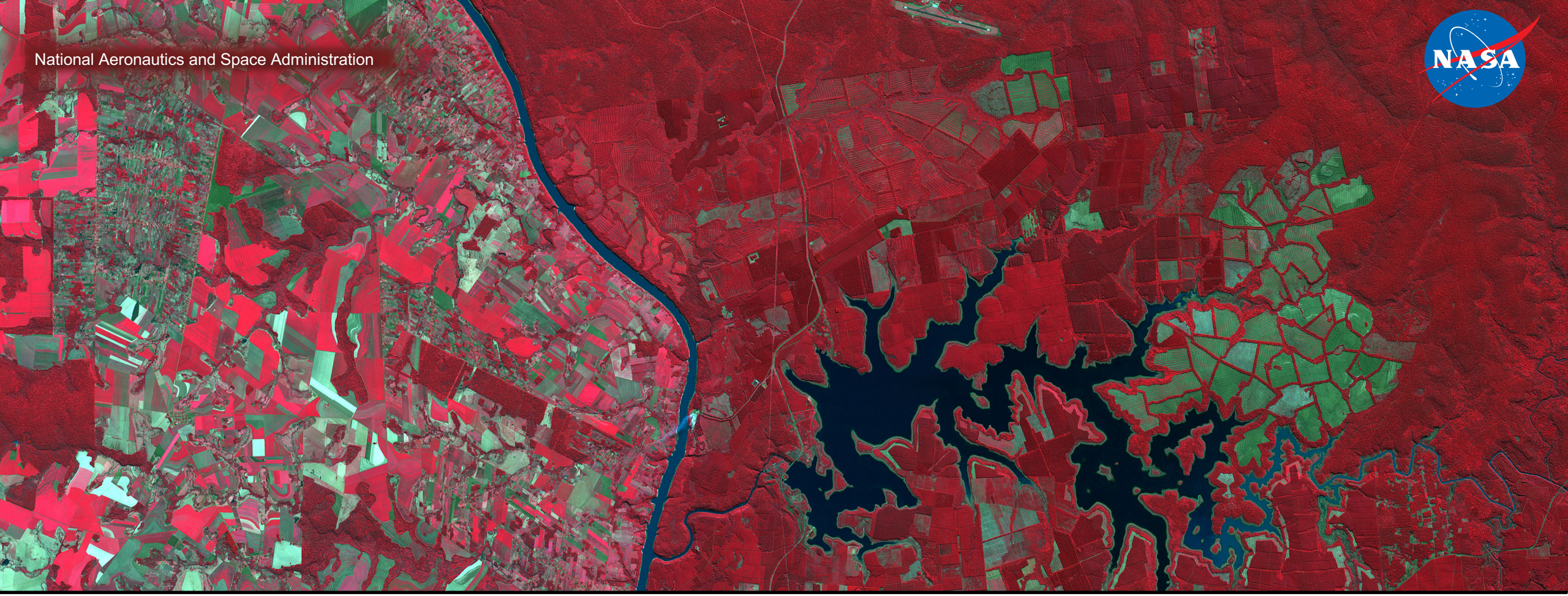


Overview of Land Cover Remote Sensing

Amita Mehta, Ana Prados, Erika Podest

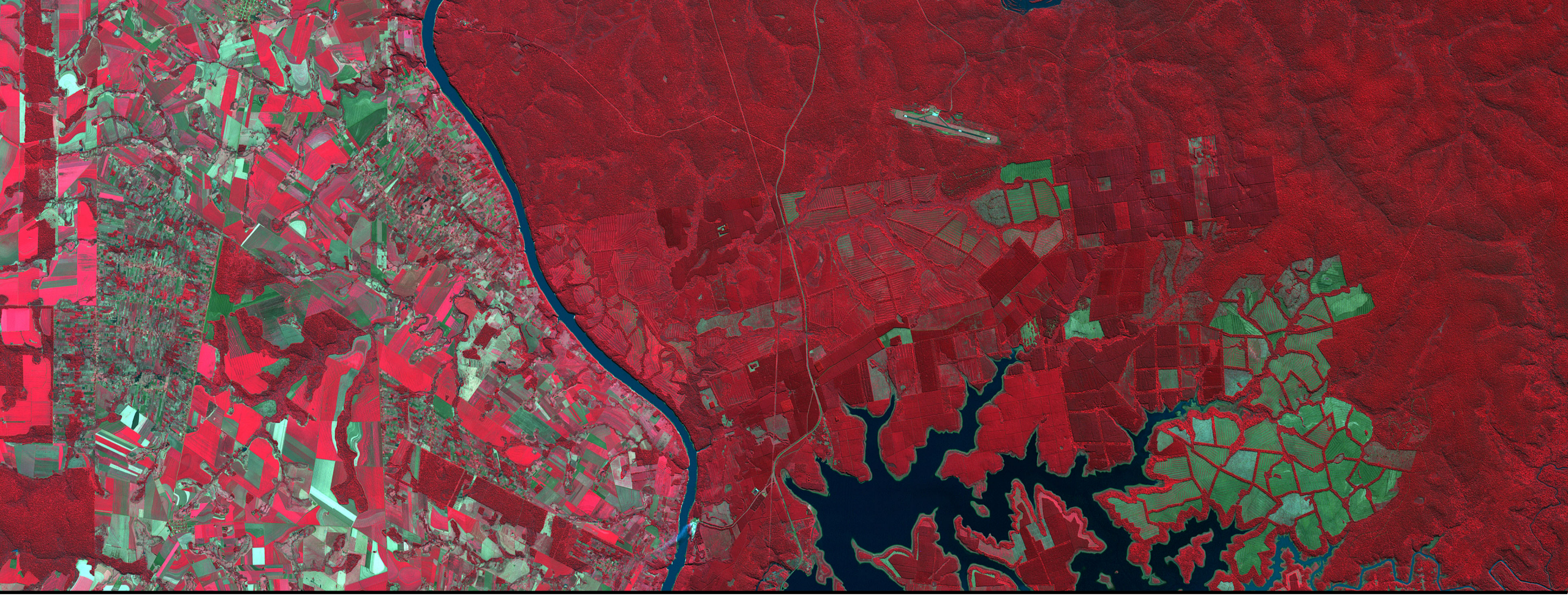
Contributors: Cynthia Schmidt, Amber McCullum

Learning Objectives

- Understand the basics of remote sensing of Land Cover
- Identify NASA satellites and sensors used for deriving Land Cover data
  - Describe Land Cover data access
  - Describe Normalized Difference Vegetation Index

Presentation Outline

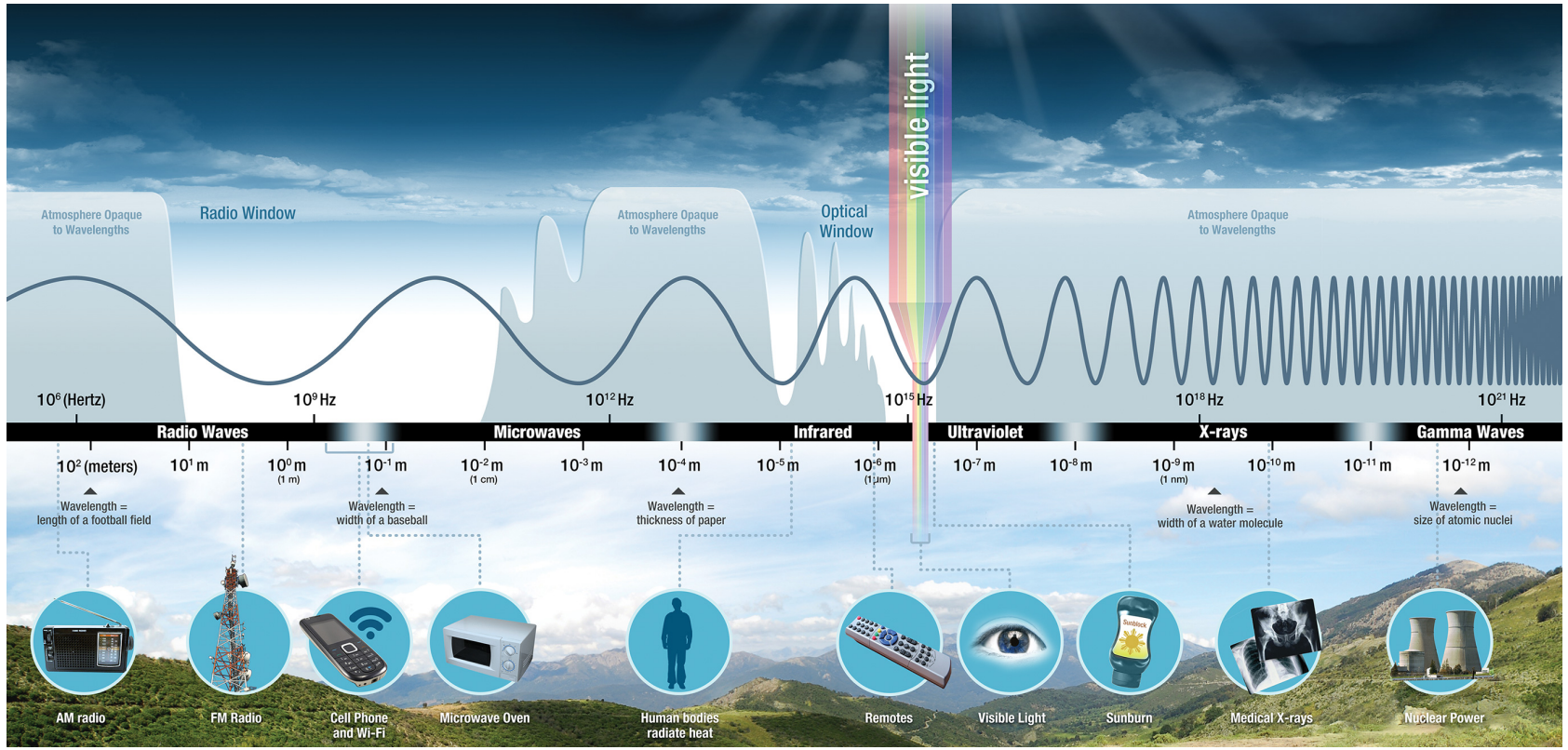
- Basics of Land Remote Sensing
- NASA Satellites and Sensors for Monitoring Land Cover
- Land Cover Datasets
- MODIS Normalized Difference Vegetation Index (NDVI) Data



Basics of Land Remote Sensing

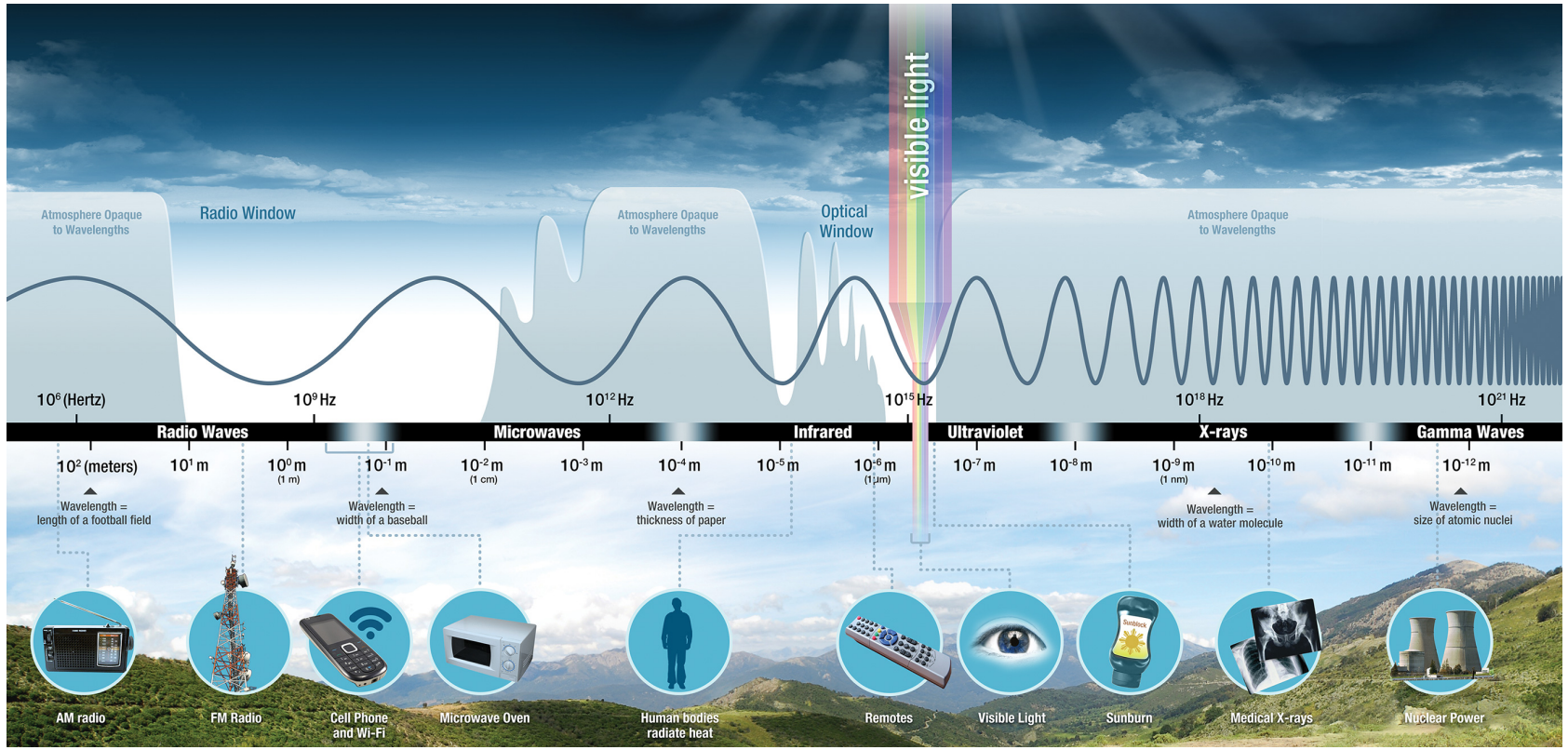
Spectral Bands Used for Land Remote Sensing

- Derived from:
  - Reflected optical radiation
  - Reflected Microwave (Synthetic Aperture Radar – 300 KHz to 50 Ghz)



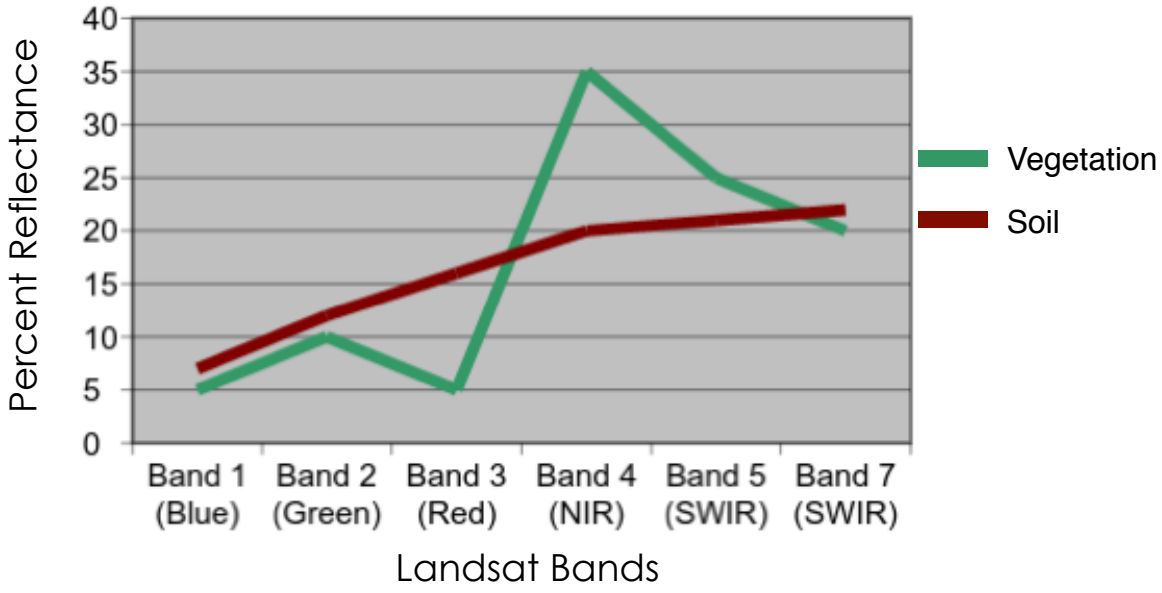
Spectral Bands Used for Land Remote Sensing

- We will focus on Land Cover from
  - Reflected optical radiation



Land Cover Mapping Basics

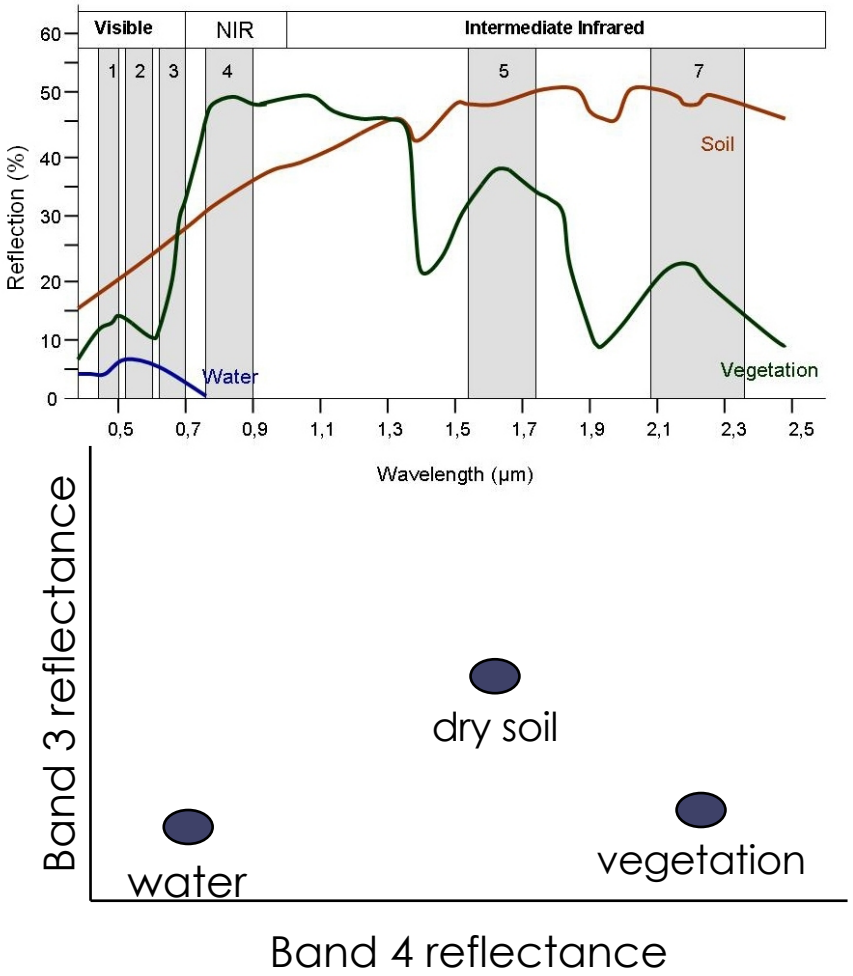
- Objects on the ground reflect electromagnetic radiation differently in different wavelengths
- That is called the object's **spectral signature**
- Example: Green vegetation absorbs Red wavelengths but reflects NIR wavelengths



Land Cover Mapping Basics

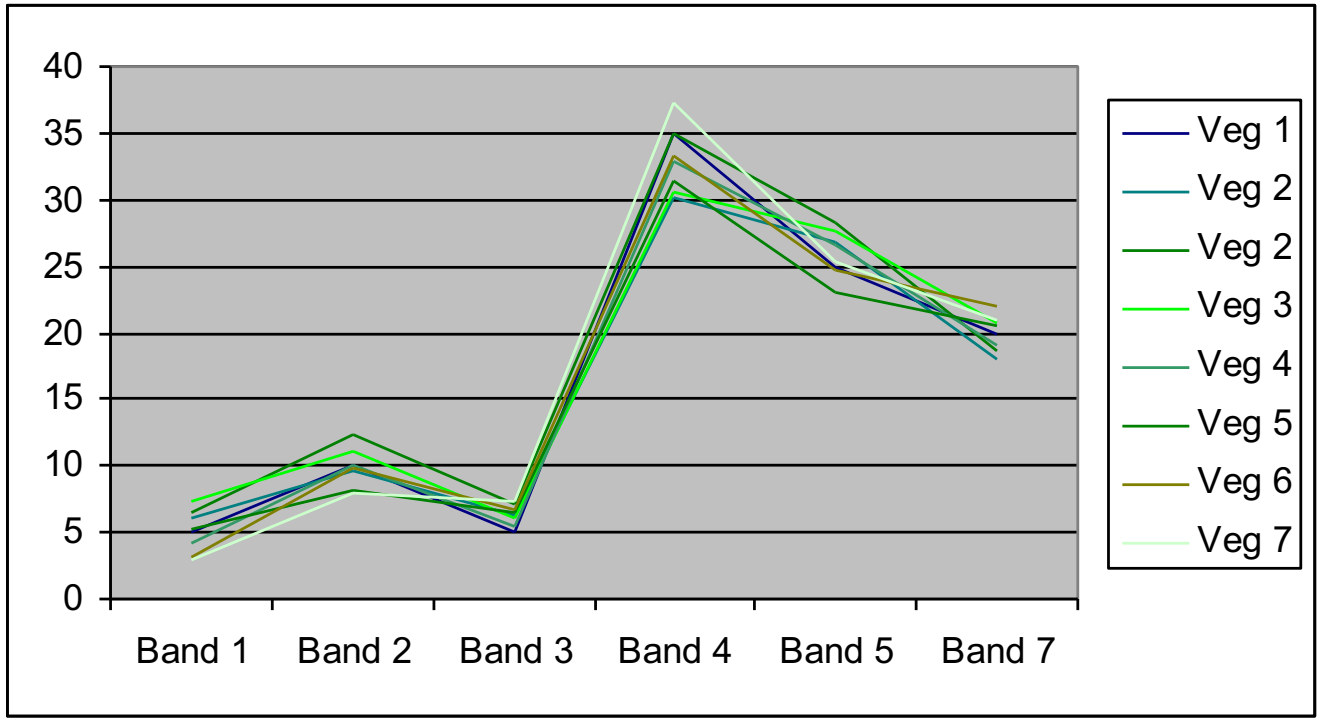
- Spectral signatures by plotting Band 3 (Red) vs. Band 4 (NIR) reflectance values:
  - Objects (soil, water, and vegetation) fall in different places in the plot
- Special software is developed that uses this to distinguish between different land cover types

Spectral Plots



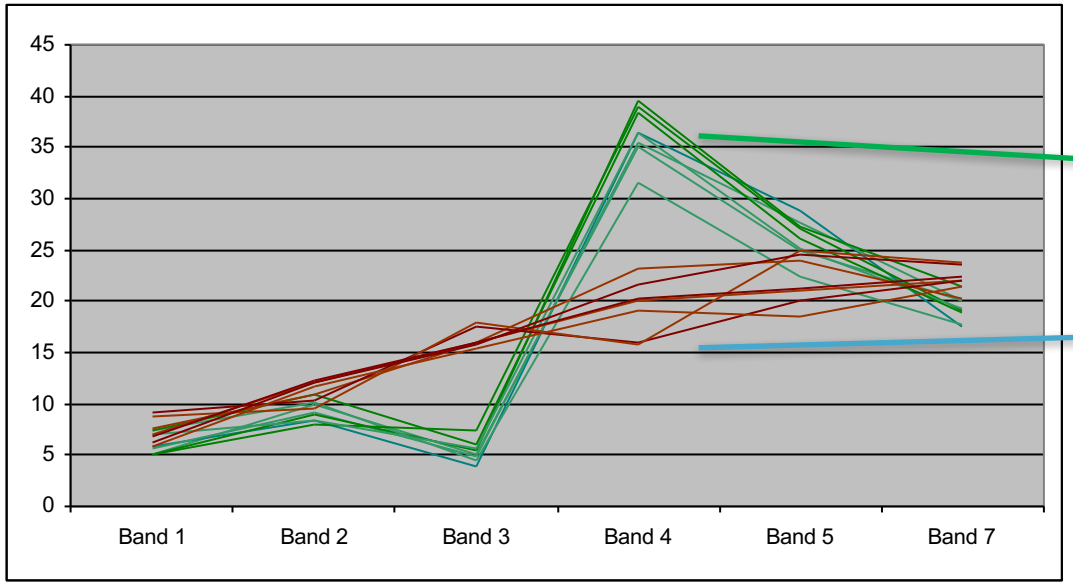
Spectral Signatures

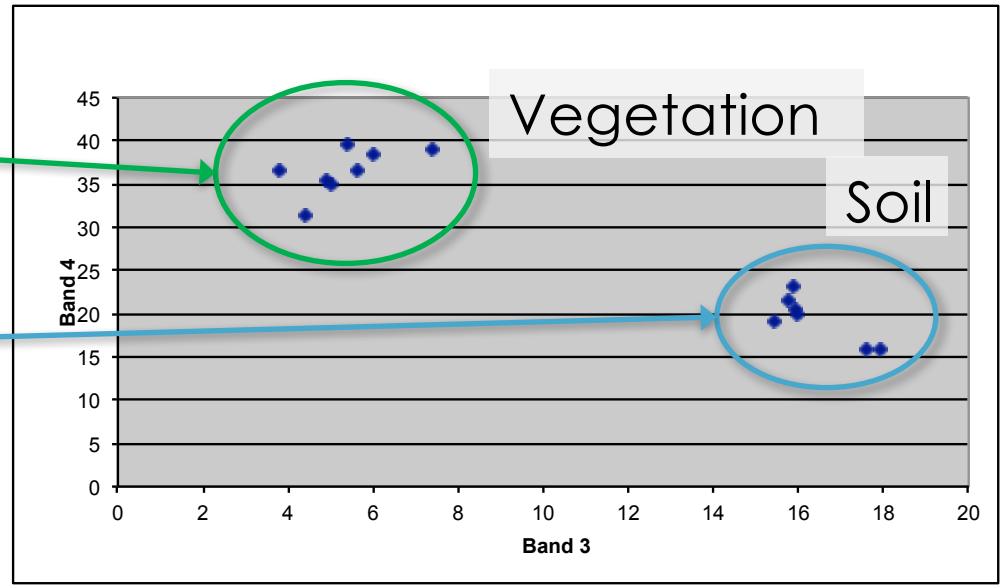
- There is some variation in reflectance values at different wavelengths
- Depending on the land cover classes you want, the trick is to identify this variability

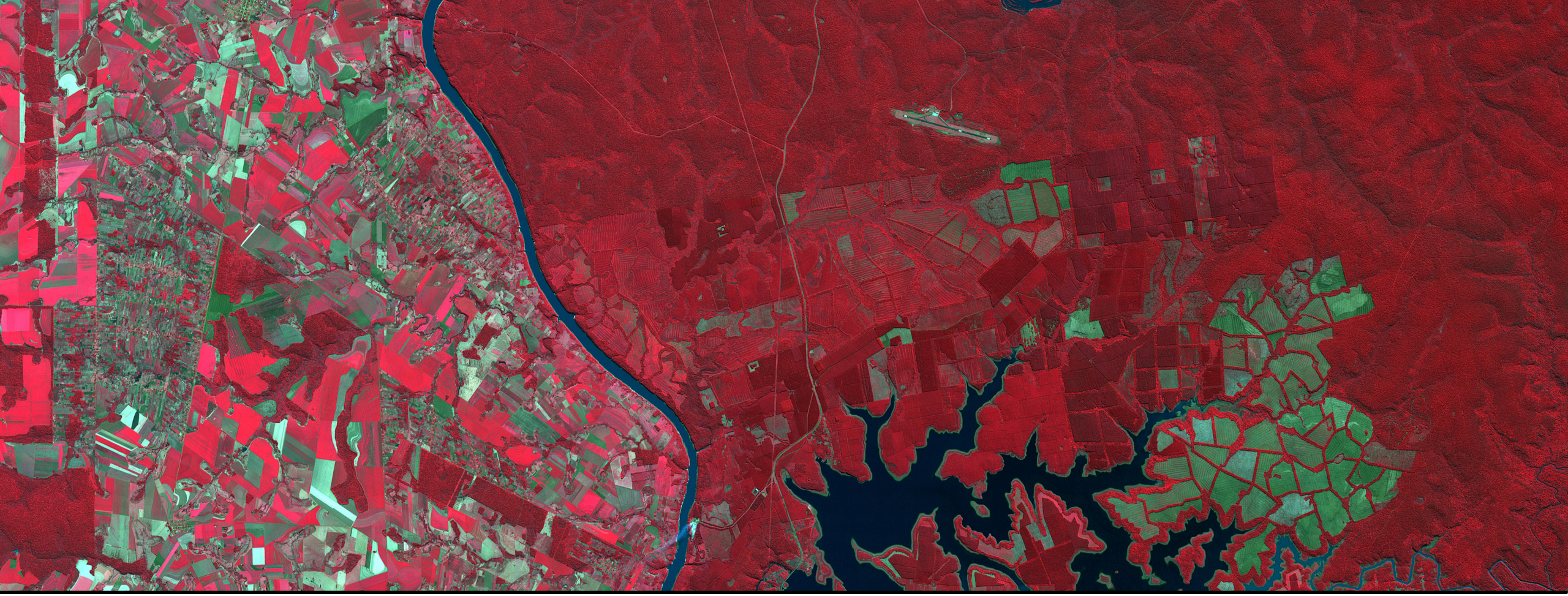


Spectral Variation

- Easier: distinguishing between broad classes
  – e.g. vegetation and soil
- Harder: distinguishing within broad classes
  – e.g. vegetation types
- Variation within and between type (broad classes) is below



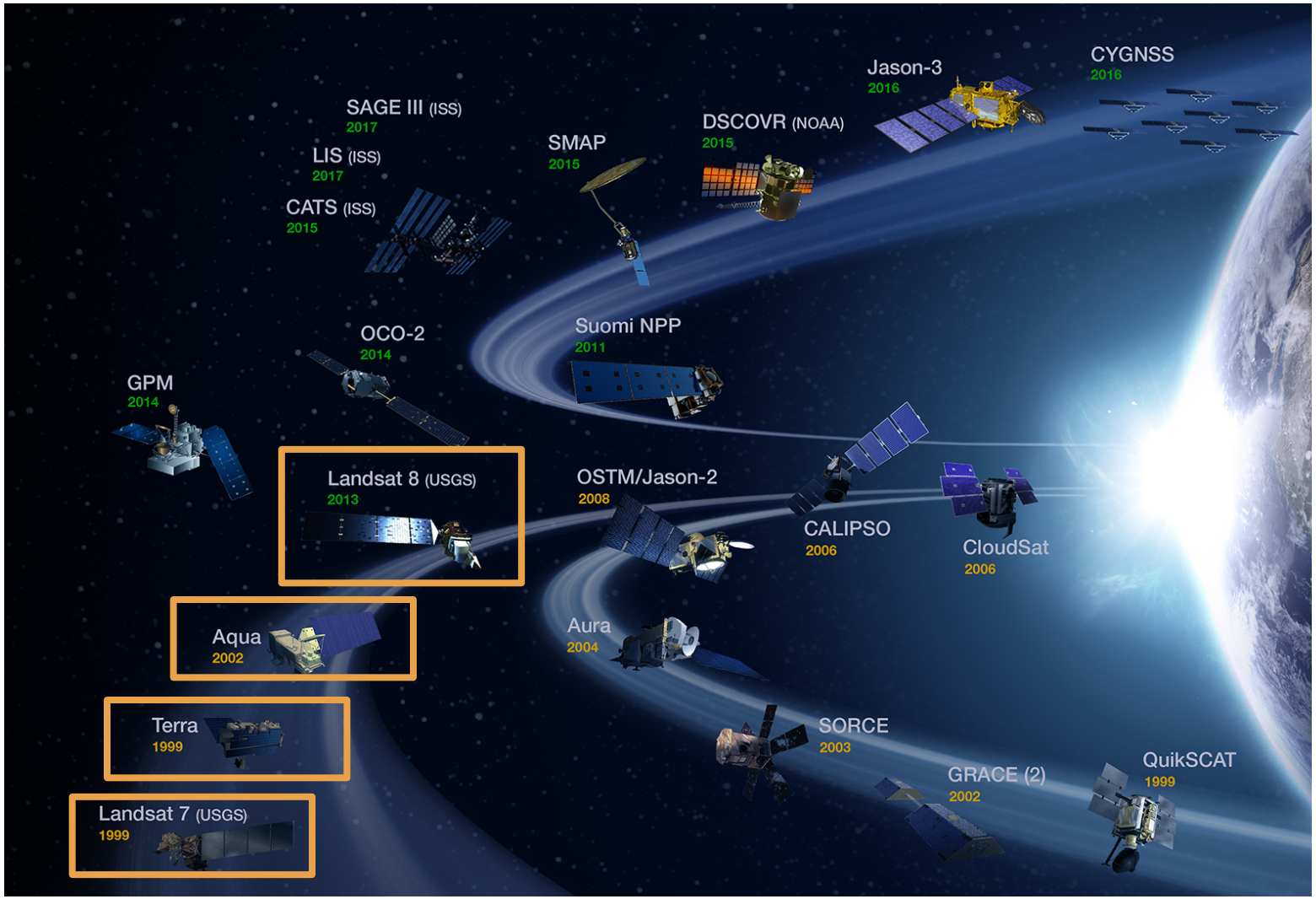




NASA Satellites and Sensors for Monitoring Land Cover

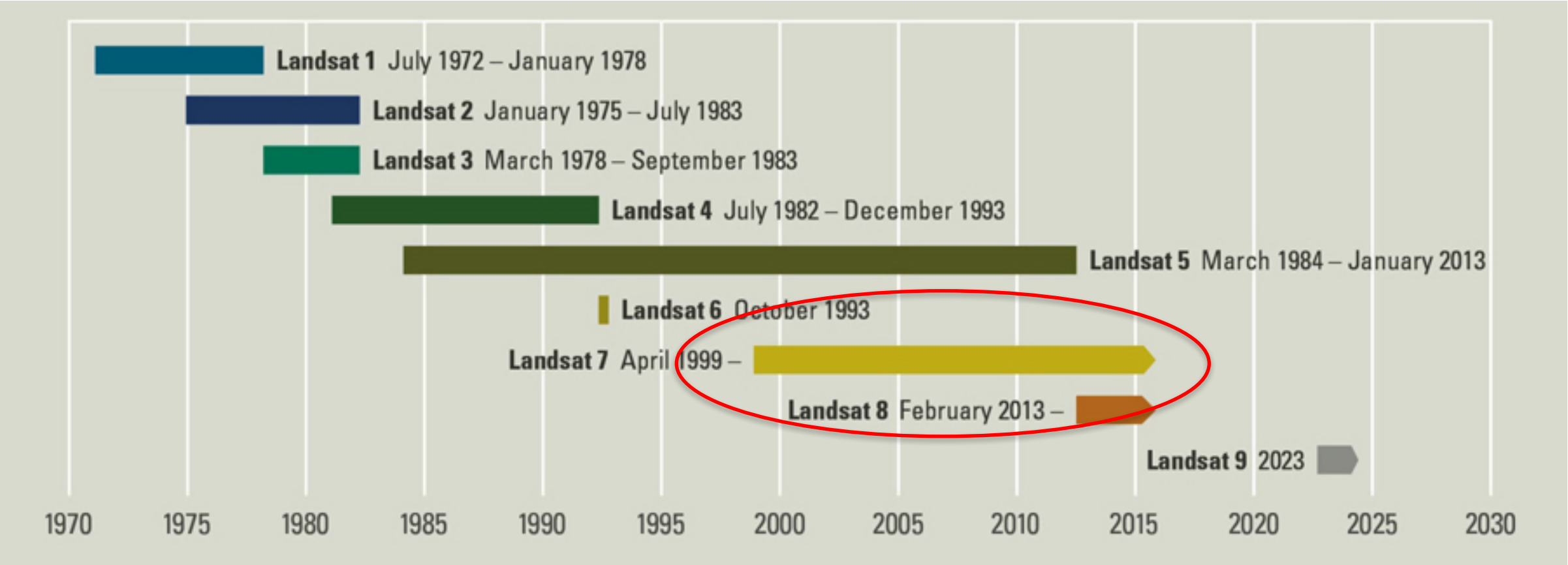
Satellites For Land Cover Monitoring

- Current Satellite Missions:
  - Landsat 7 & Landsat 8
  - Terra
  - Aqua
  - Suomi National Polar Partnership (SNPP)



Landsat Satellites and Sensors

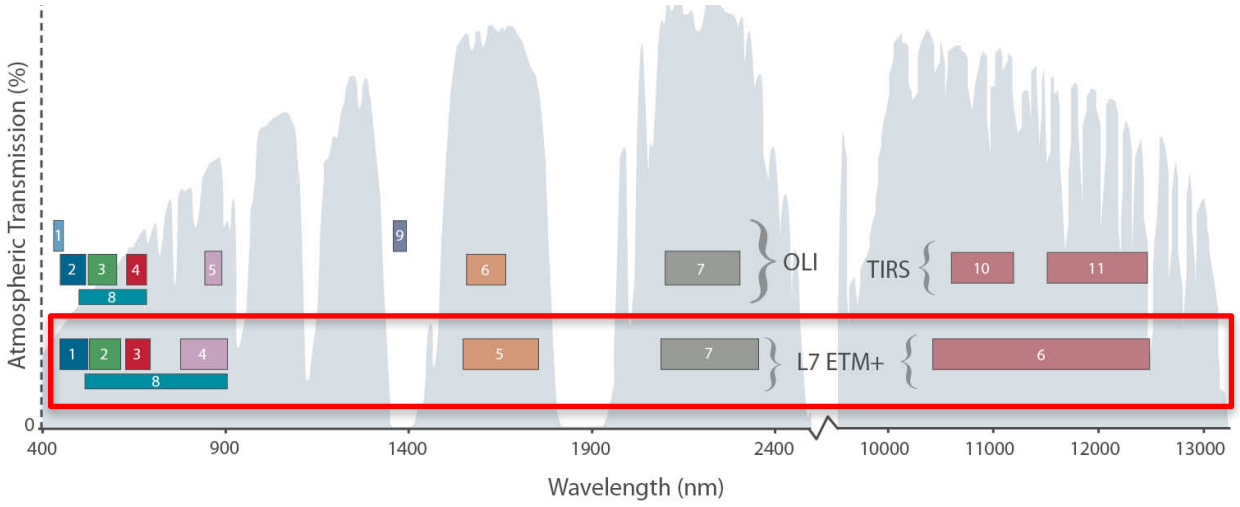
http://landsat.gsfc.nasa.gov/



Enhanced Thematic Mapper (ETM+)

http://landsat.gsfc.nasa.gov/landsat-7/

- Onboard **Landsat 7**
- Polar orbiting satellite
- Spatial Coverage and Resolution:
  - Global, Swath: 185 km
  - Spatial Resolution:
    - 15 m, 30 m, 60 m
- Temporal Coverage and Resolution:
  - April 15, 1999 – present
  - 16-day revisit time



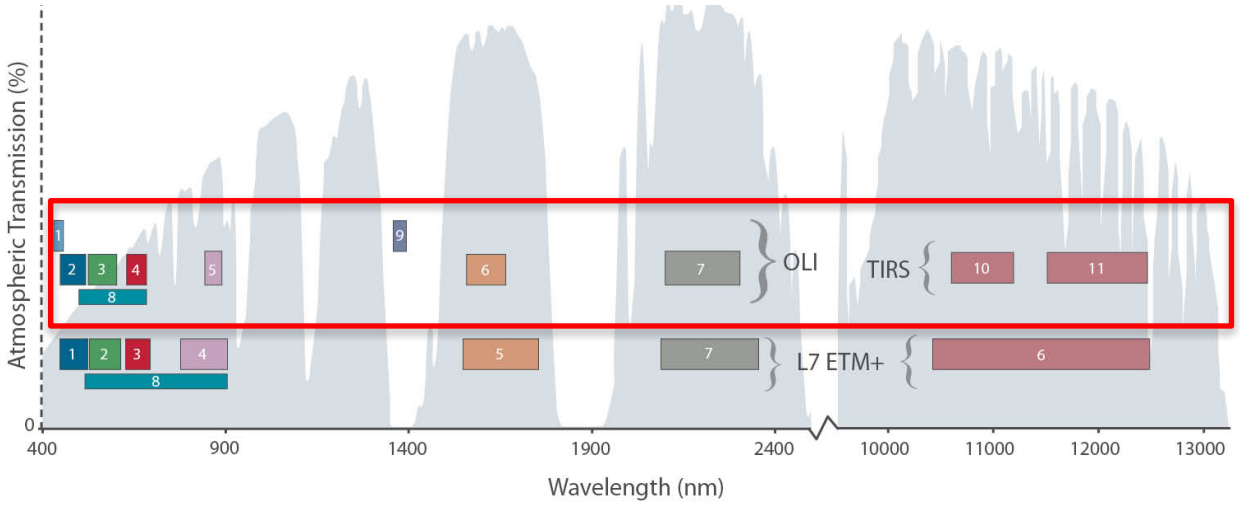
Spectral Bands: 8

- Major Bands: blue-green, green, red, thermal IR, panchromatic
  - Bands 1-5, 7: 30 m
  - Band 6: 60 m
  - Band 8: 15 m

Operational Land Imager (OLI)

http://landsat.gsfc.nasa.gov/landsat-8/

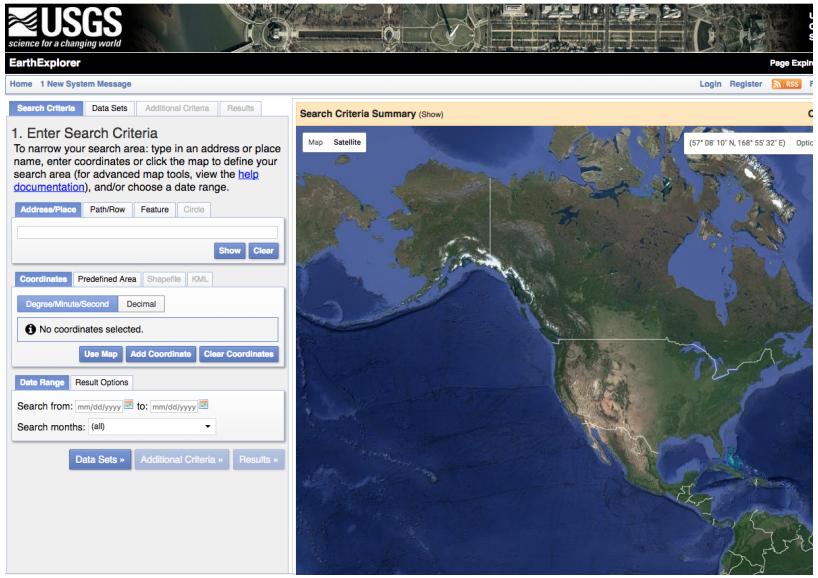
- Onboard Landsat 8
- Polar orbiting satellite
- Spatial Coverage and Resolution
  - Global, Swath: 185 km
  - Spatial Resolution: 15 m, 30 m
- Temporal Coverage and Resolution:
  - Feb 11, 2013 – present
  - 16-day revisit time

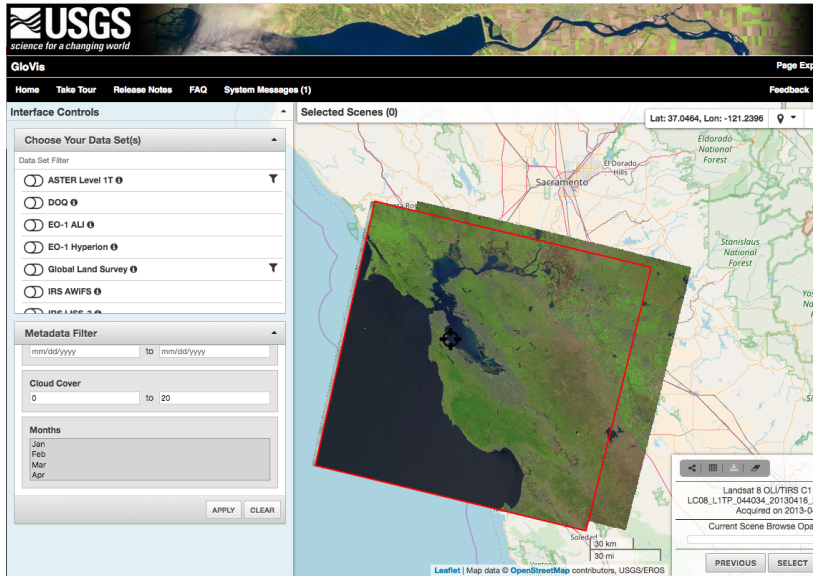


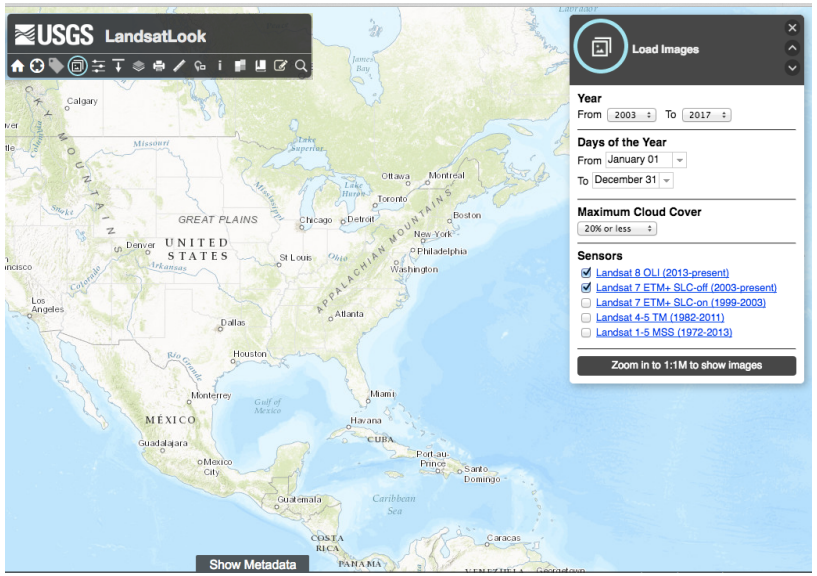
Spectral Bands: 9

- Major Bands: blue, blue-green, red, near IR, shortwave, panchromatic
  - Bands 1-7, 9: 30 m
  - Band 8: 15 m

Get Landsat Images and Band Reflectance Data







Earth Explorer:

http://earthexplorer.usgs.gov/

GloVis

http://glovis.usgs.gov/

Landsat Look Viewer:

http://landsatlook.usgs.gov/

Terra and Aqua Satellites and Sensors

Terra

http://terra.nasa.gov

- Polar orbit, 10:30 a.m. equator crossing time
- Global Coverage
- December 18, 1999 – Present
- 1-2 observations per day
- Sensors:
  - ASTER, CERES, MISR, MODIS, MOPITT

Aqua

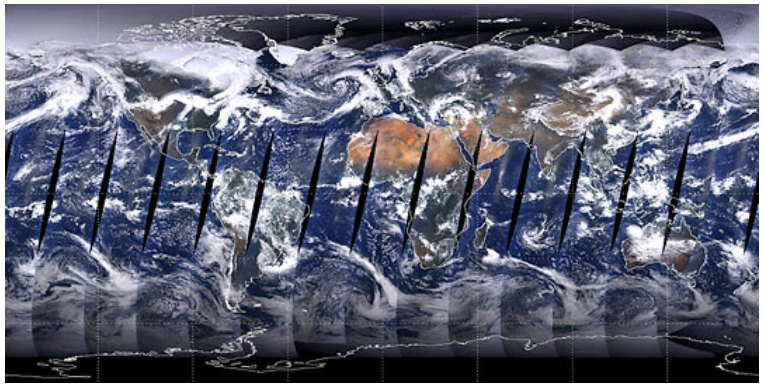
http://aqua.nasa.gov/

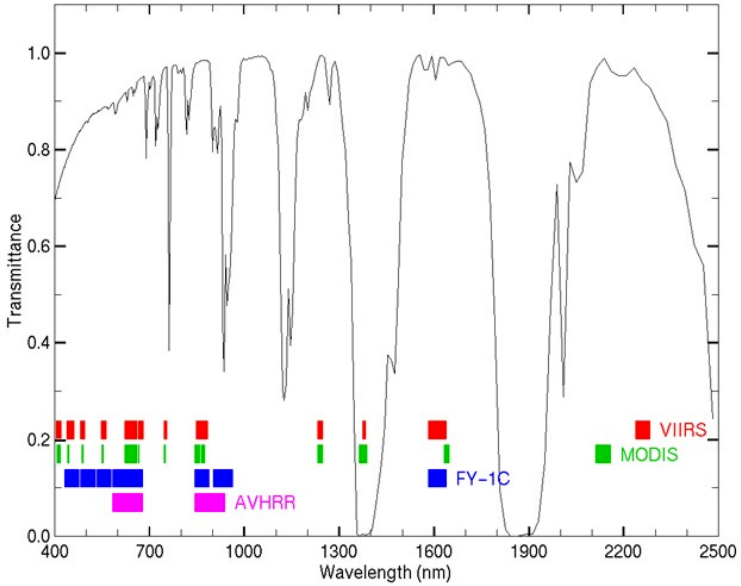
- Polar orbit, 1:30 p.m. equator crossing time
- Global Coverage
- May 4, 2002 – Present
- 1-2 observations per day
- Sensors:
  - AIRS, AMSU, CERES, MODIS, AMSR-E

MODerate Resolution Imaging Spectroradiometer (MODIS)

http://modis.gsfc.nasa.gov/

- Spatial Resolution
  - Global, swath: 2,330 km
  - 250 m, 500 m, 1 km
- Temporal Resolution
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000 – present
- Data Format
  - Hierarchal data format – Earth Observing System Format (HDF–EO8)

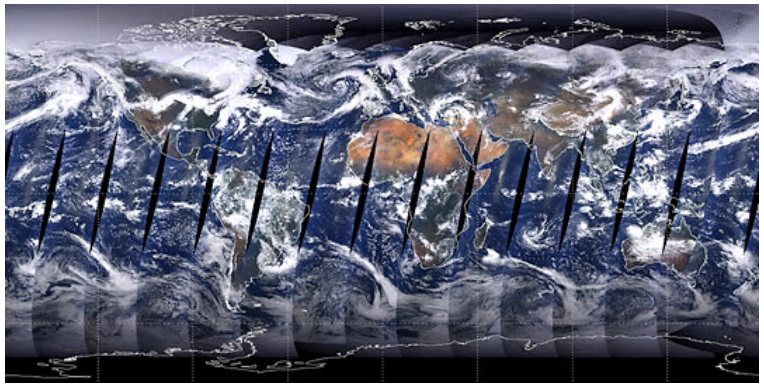


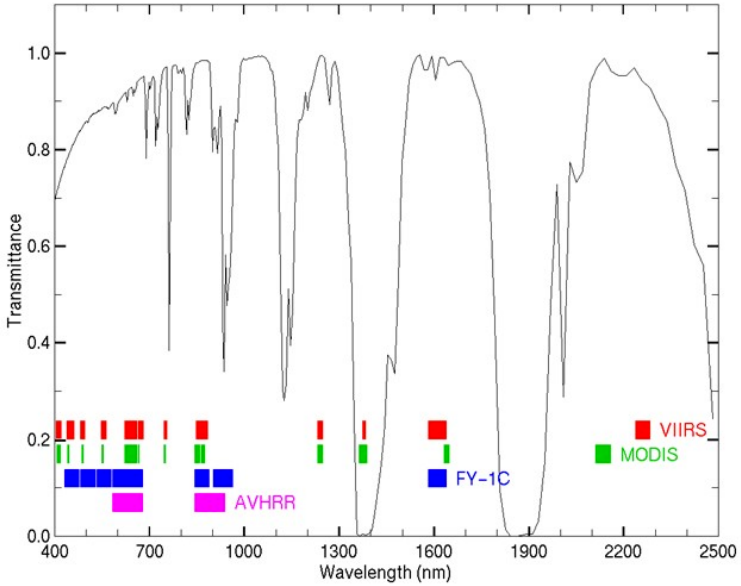


MODerate Resolution Imaging Spectroradiometer (MODIS)

http://modis.gsfc.nasa.gov/

- Spectral Coverage
  - 36 bands (major bands include red, blue, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1000 m





Get MODIS Band Reflectance Data

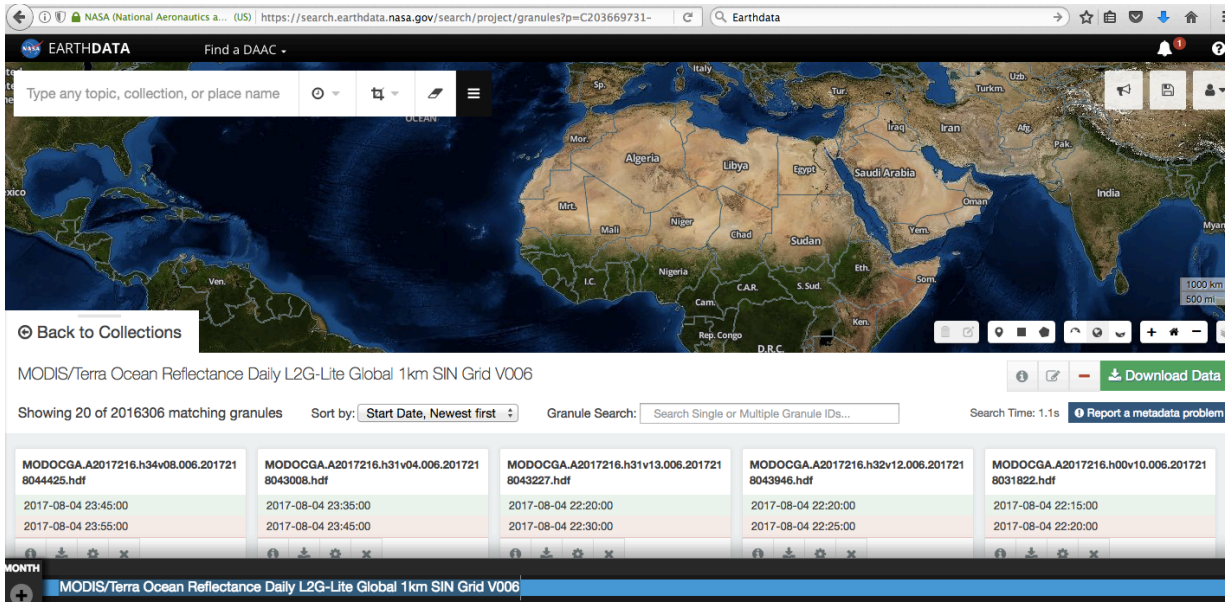
Land Processing Distributed Active Archive Center

http://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/

BAND #	RANGE nm	RANGE um	KEY USE
	Reflected	Emitted	
1	620–670		Absolute Land Cover Transformation, Vegetation Chlorophyll
2	841–876		Cloud Amount, Vegetation Land Cover Transformation
3	459–479		Soil/Vegetation Differences
4	545–565		Green Vegetation
5	1230–1250		Leaf/Canopy Differences
6	1628–1652		Snow/Cloud Differences
7	2105–2155		Cloud Properties, Land Properties
8	405–420		Chlorophyll
9	438–448		Chlorophyll
10	483–493		Chlorophyll
11	526–536		Chlorophyll

NASA Earthdata

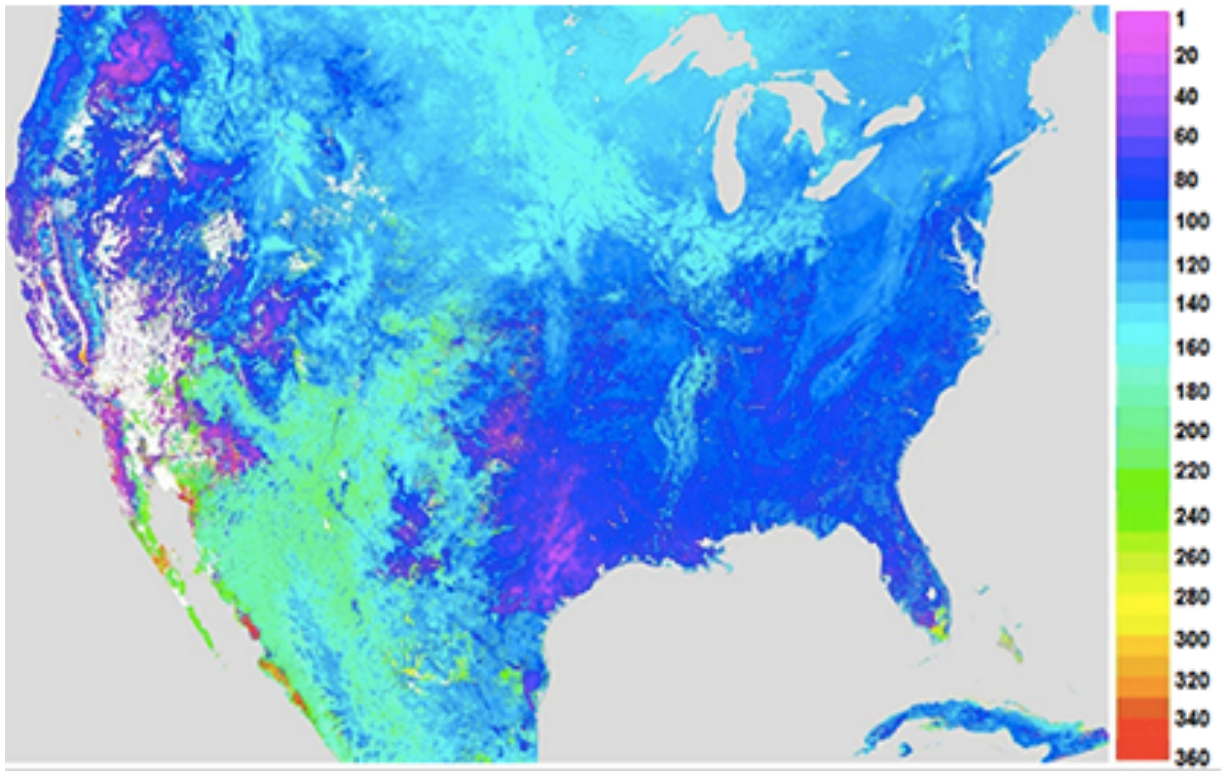
http://earthdata.nasa.gov/



Visible Infrared Imaging Radiometer Suite (VIIRS)

http://jointmission.gsfc.nasa.gov/viirs.html

- Onboard **Suomi NPP**
- Polar orbiting satellite
- Functionality similar to MODIS
- Spatial Coverage and Resolution:
  - Global, Swath Width: 3,040 km
  - Spatial Resolution: 375 – 750 m
- Temporal Coverage and Resolution:
  - Oct 2011 – present
  - 1-2 times per day



VIIRS phenology product (greenup onset, DOY)

Get VIIRS Band Reflectance Data and Land Products Data

EOS Products	Algorithms Delivered to Land SIPS	Product Integration and Testing	Draft ATBD Delivery	Delivery of User's Guide	Products Delivered to assigned DAAC
Surface Reflectance	✓	✓	✓	✓	✓
LAI/FPAR	✓	✓	✓	✓	Fall, 2017
Snow Products	✓	✓	✓	✓	✓
MAIAC	Fall, 2017	Spring, 2018	Winter, 2018	Winter, 2018	Spring, 2018
BRDF/Albedo	✓	Underway	✓	✓	Fall, 2017
Burned Area	✓	Pending	Winter, 2018	Winter, 2018	Winter, 2018
Active Fires	✓	✓	✓	✓	✓
Vegetation Index	✓	✓	✓	✓	Summer, 2017
LST&E	✓	✓	✓	✓	Fall, 2017
Ice Surface Temp	✓	✓	✓	✓	✓
Sea Ice Cover	✓	✓	✓	Fall, 2017	Fall, 2017
Phenology	✓	Underway	✓	✓	Winter, 2018
Black Marble	✓	Underway	Fall, 2017	Fall, 2017	Fall, 2017

Land Process Distributed Active Archive Center

- https://lpdaac.usgs.gov/dataset_discovery/viirs/viirs_products_table

Example: Satellite Image Classification for Land Cover

- Requires delineating boundaries of classes in n-dimensional space using class statistics
- Each group of pixels is characterized by:
  - min.
  - max.
  - mean
  - standard deviation
- All the pixels in the image that fall within those statistics are given those labels

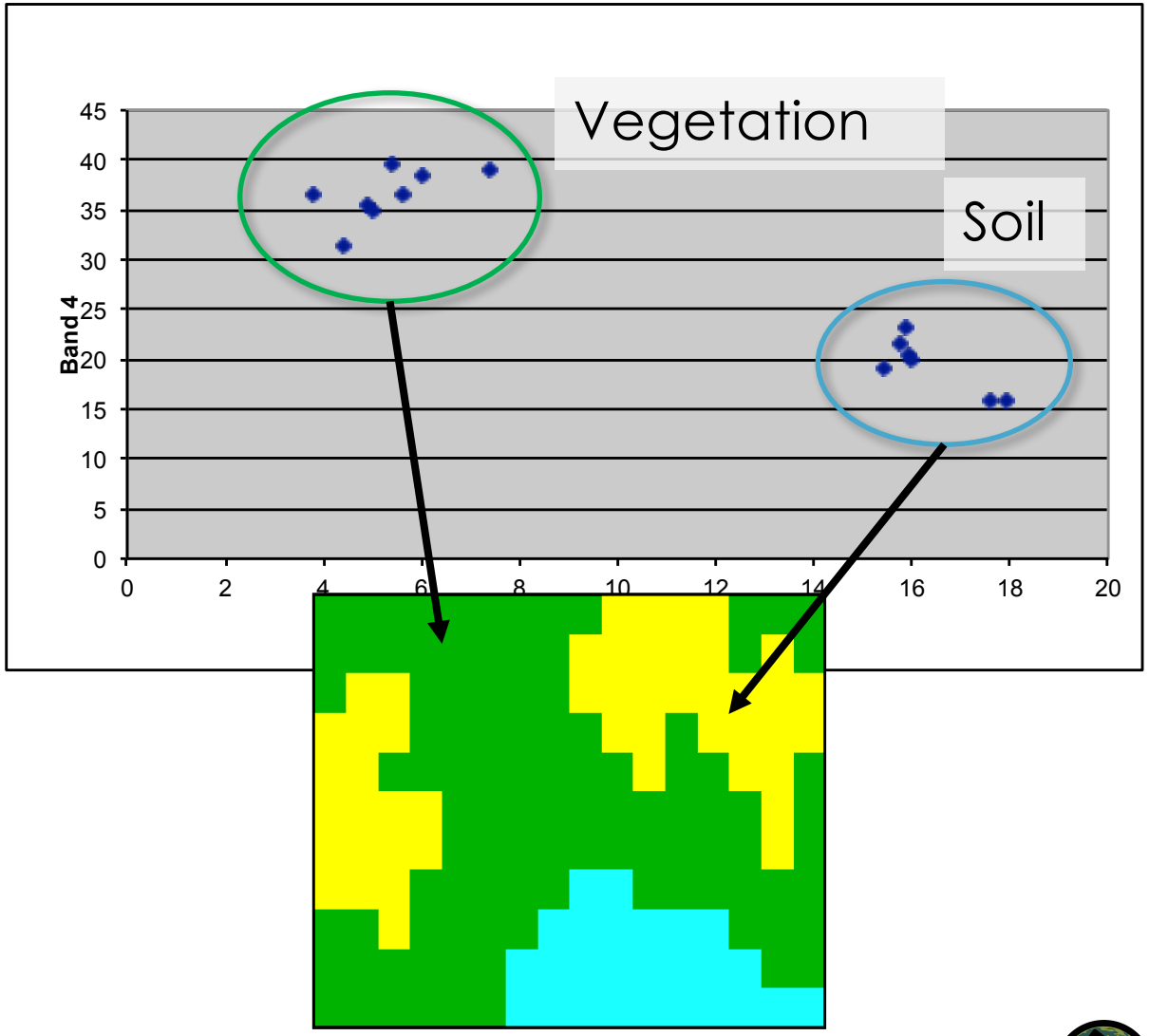
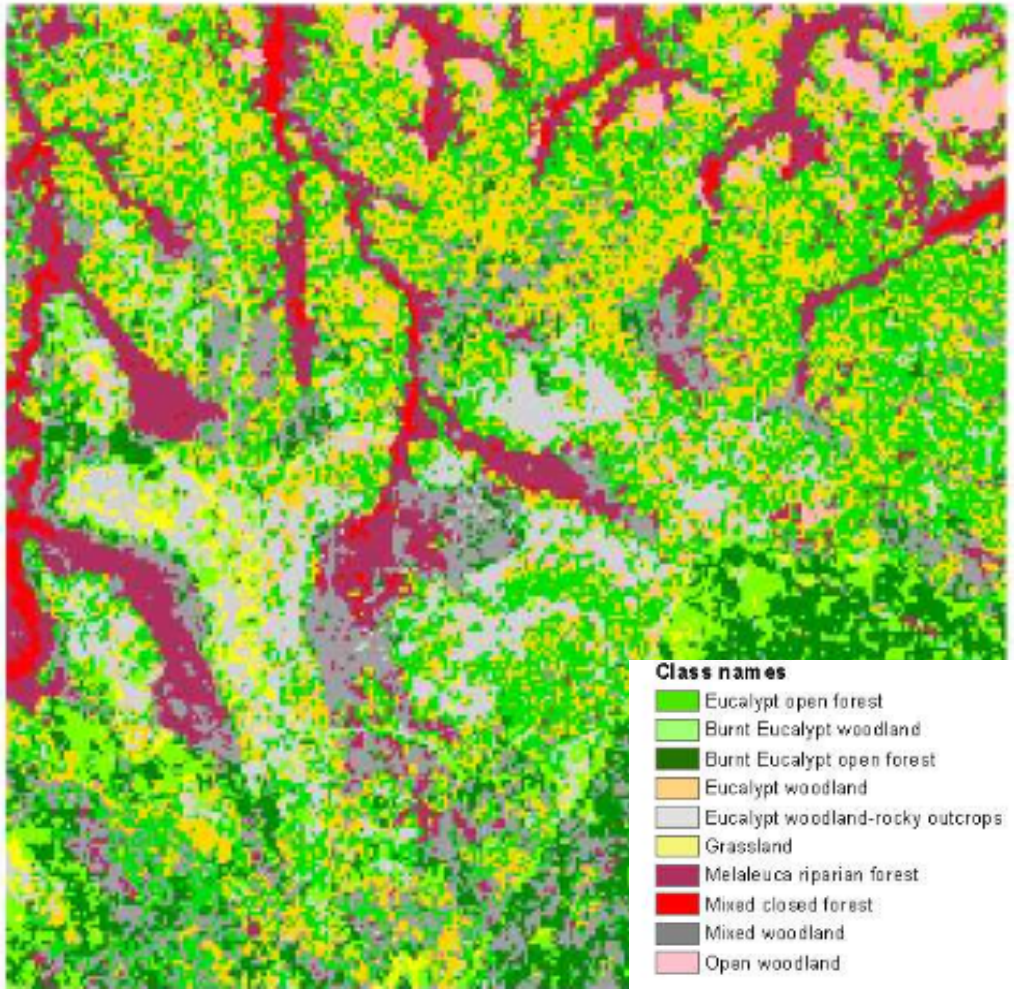


Image Classification: Approaches

Pixel-Based

- Each pixel is grouped in a class
- Useful for multiple changes in land use within a short period of time

Best for complete data coverage and a need for methods to ensure time series consistency at the pixel level

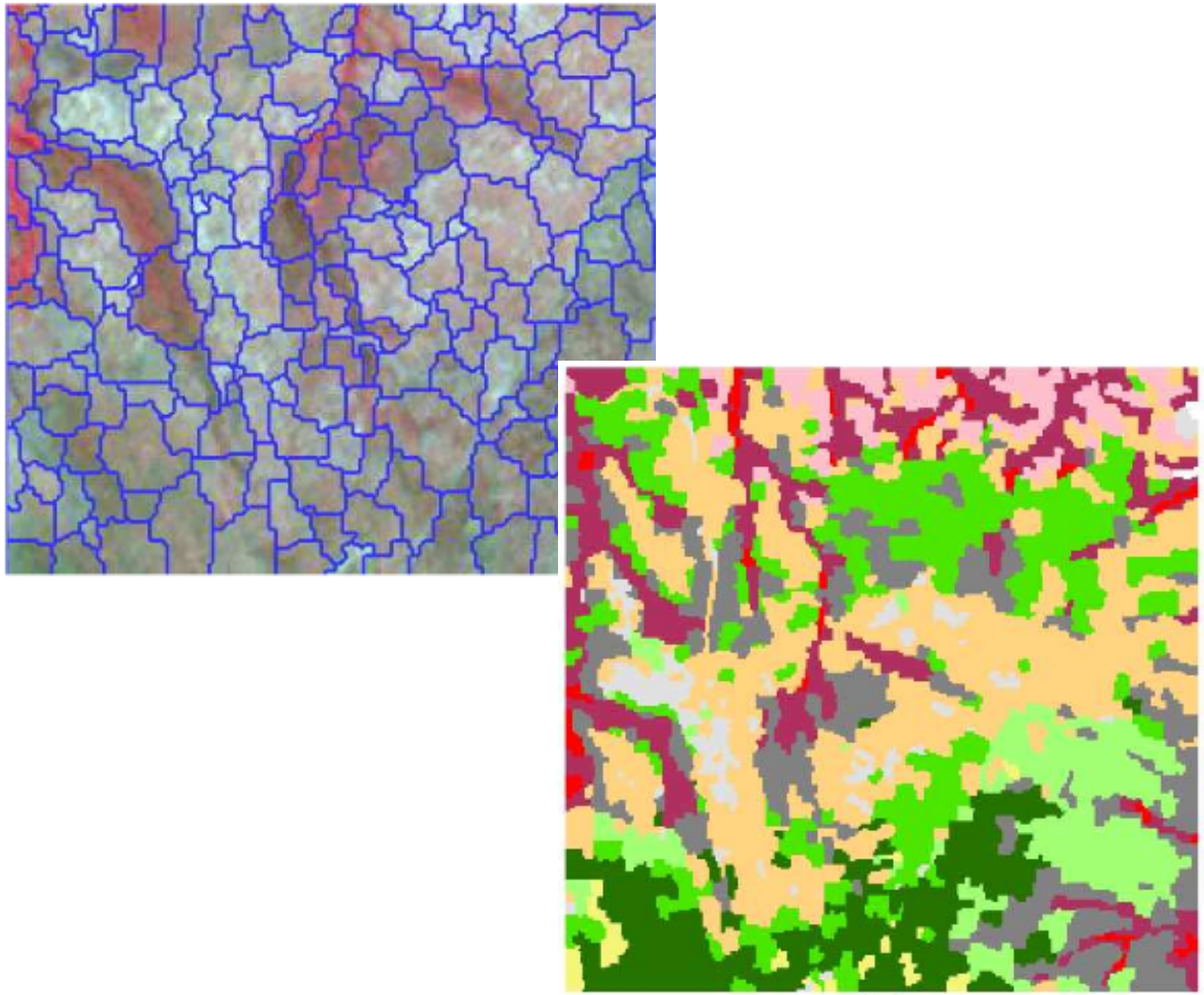


Whiteside, T., & Ahmad, W. (2005, September). A comparison of object-oriented and pixel-based classification methods for mapping land cover in northern Australia. *Proceedings of SSC2005 Spatial intelligence, innovation and praxis: The national biennial Conference of the Spatial Sciences Institute*.

Image Classification: Approaches

Object-Based

- Pixels with common spectral characteristics are first grouped together (segmentation)
- Useful for:
  - reducing speckle noise in radar images
  - high resolution imagery

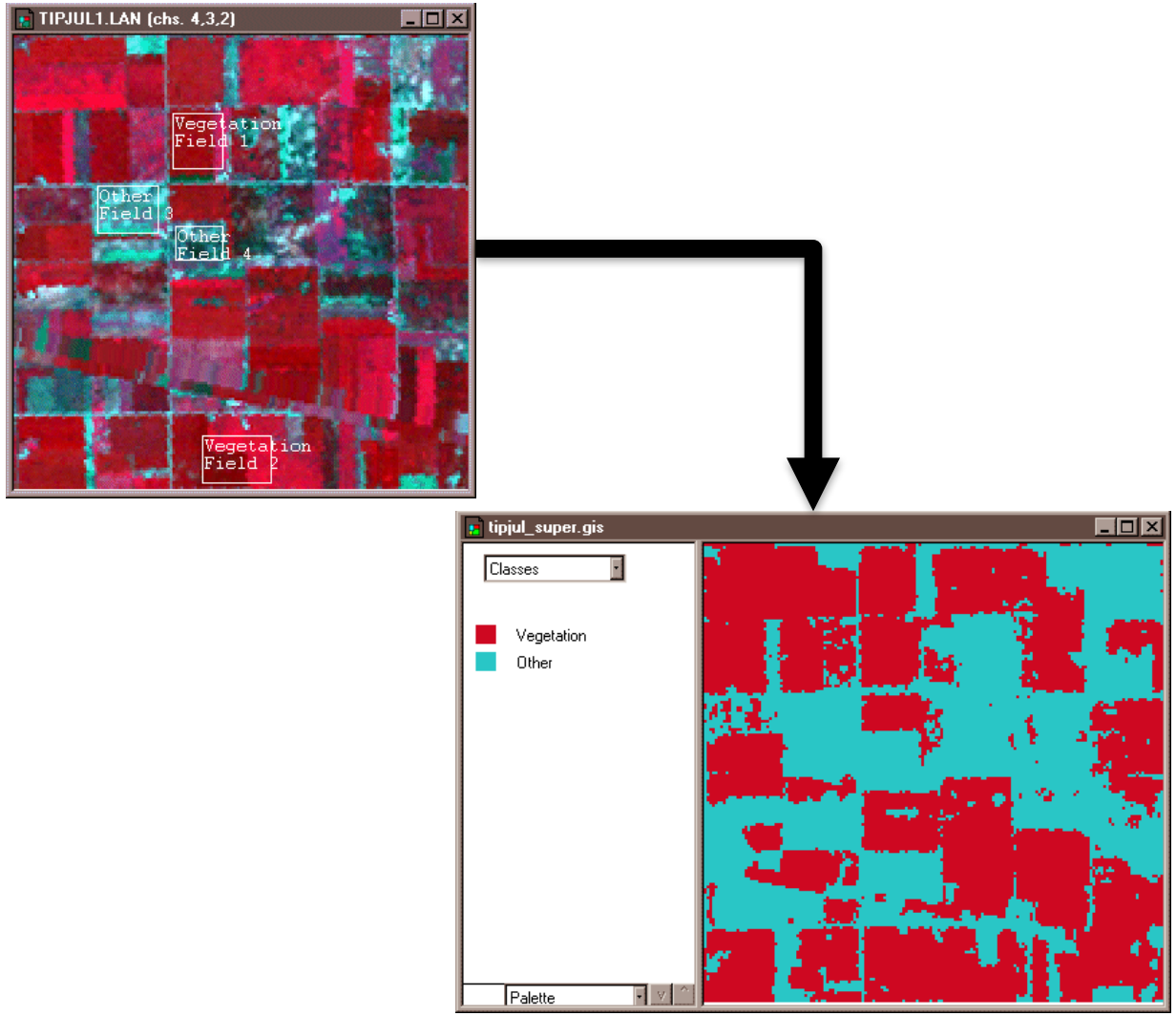


Whiteside, T., & Ahmad, W. (2005, September). A comparison of object-oriented and pixel-based classification methods for mapping land cover in northern Australia. *Proceedings of SSC2005 Spatial intelligence, innovation and praxis: The national biennial Conference of the Spatial Sciences Institute*.

Satellite Image Classification: Methods

Supervised

- Uses expert-defined areas of known veg. types to tune parameters of classification algorithms
- Algorithm then automatically identifies and labels areas similar to the training data

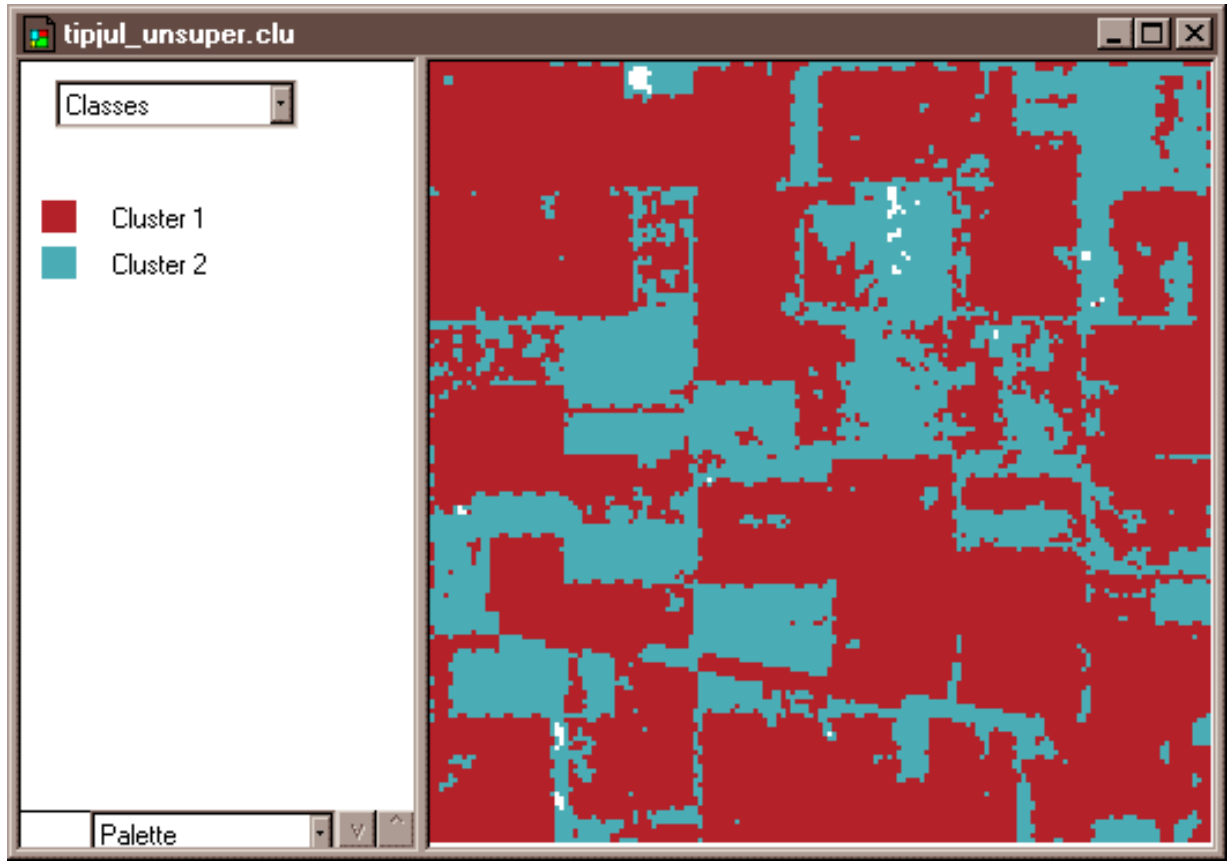


Credit: David DiBiase, Penn State Department of Geography

Satellite Image Classification: Methods

Unsupervised

- Uses classification algorithms to assign pixels into one of a number of user-specified class groupings
- Interpreters assign each of the groupings of pixels a value corresponding to a land cover class

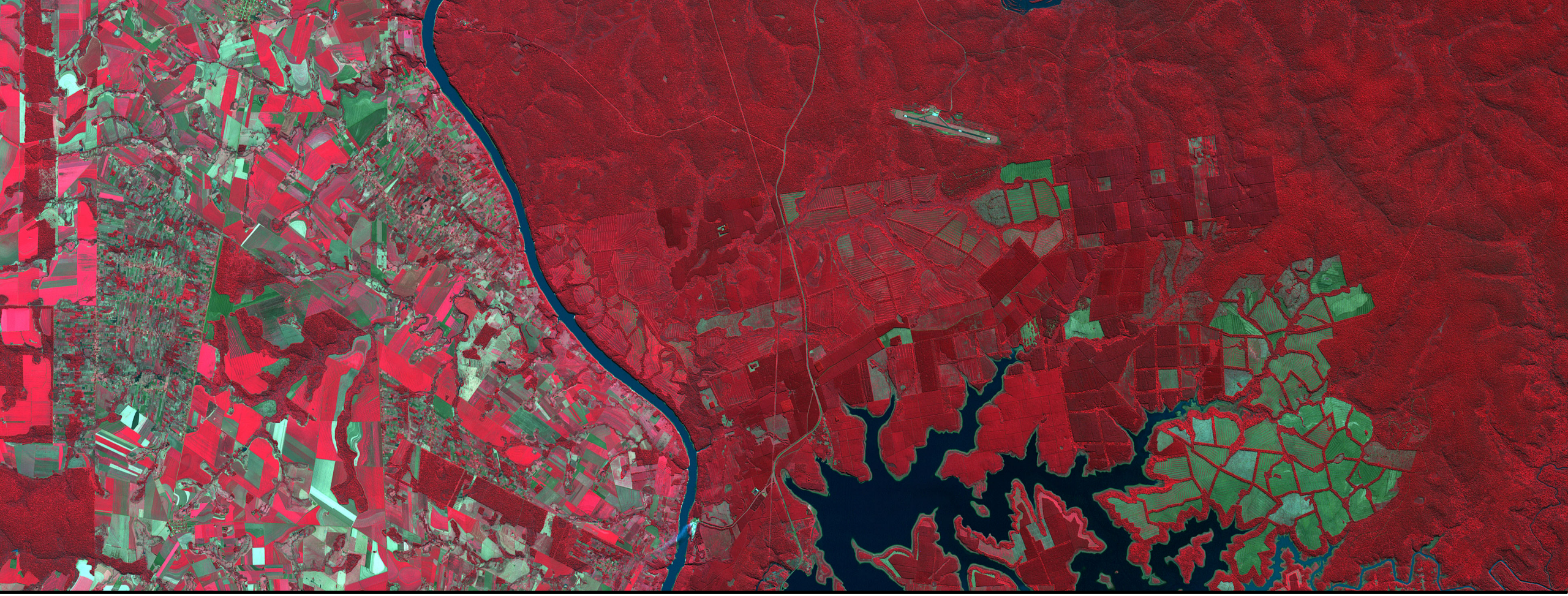


Credit: David DiBiase, Penn State Department of Geography

QGIS: Semi-Automatic Classification Plugin (SCP)

- Developed by Luca Congedo
- Free, open-source plugin for QGIS that allows for supervised classification
- It provides:
  - Several tools for the download of imagery
  - Preprocessing (Digital Numbers to Top of Atmosphere Reflectance)
  - Training site selection and analysis
  - Classification algorithms
- Documentation: Congedo, Luca (2016). Semi-Automatic Classification Plugin Documentation.
  - https://fromgistors.blogspot.com/p/semi-automatic-classification-plugin.html

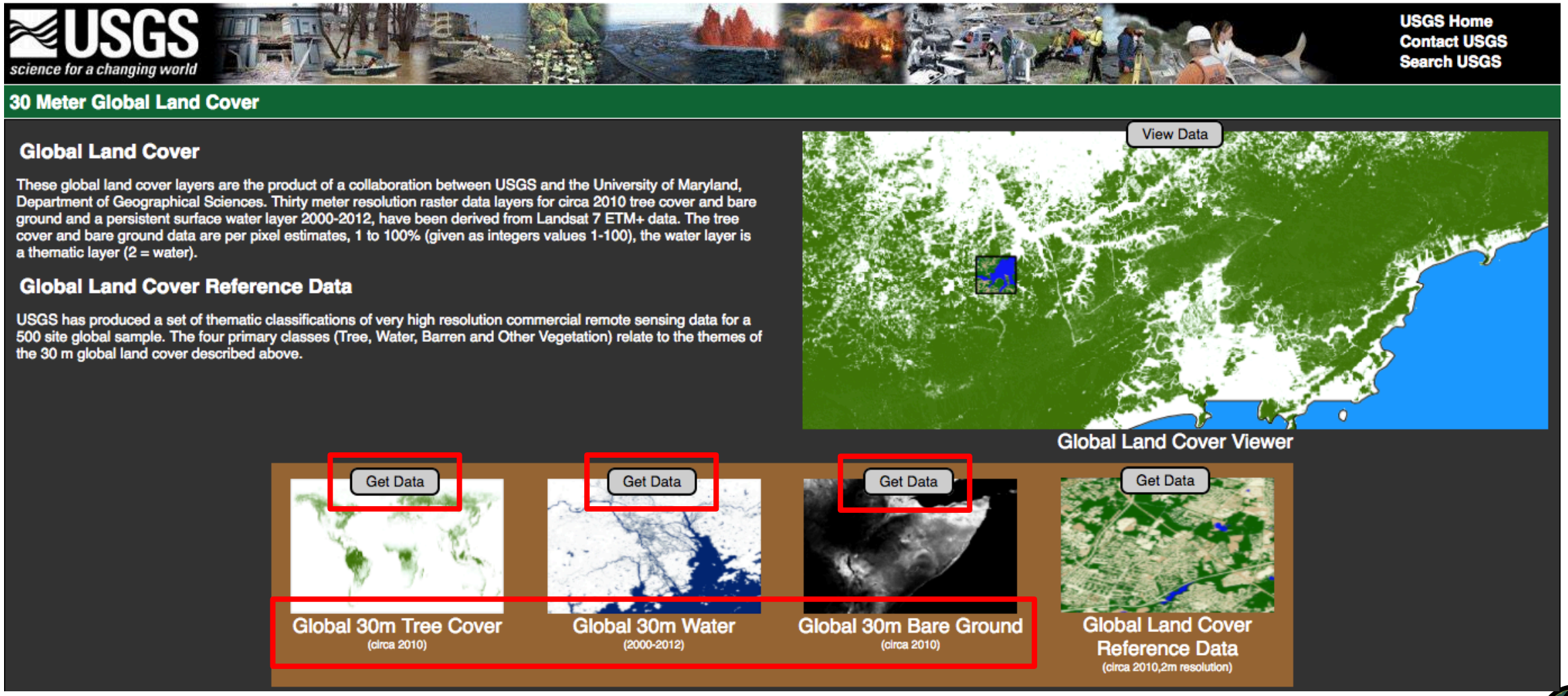
See ARSET Land Cover Classification webinar for details: http://arset.gsfc.nasa.gov/land/webinars/advanced-land-classification



Land Cover Datasets

Landsat Land Cover Data

https://landcover.usgs.gov/glc/



Landsat Land Cover

https://landcover.usgs.gov/glc/

- Based on Landsat 7 ETM+ composites, cloud free images from 2000-2012
- Four Classes: Tree Cover, Water, Bare Ground, and Other Vegetation
- Spatial Resolution of 30 m
- Tree Cover and Bare Ground/Other Vegetation represent 2010 values
- Reference Land Cover Data available based on high resolution commercial satellites for 500 global sites

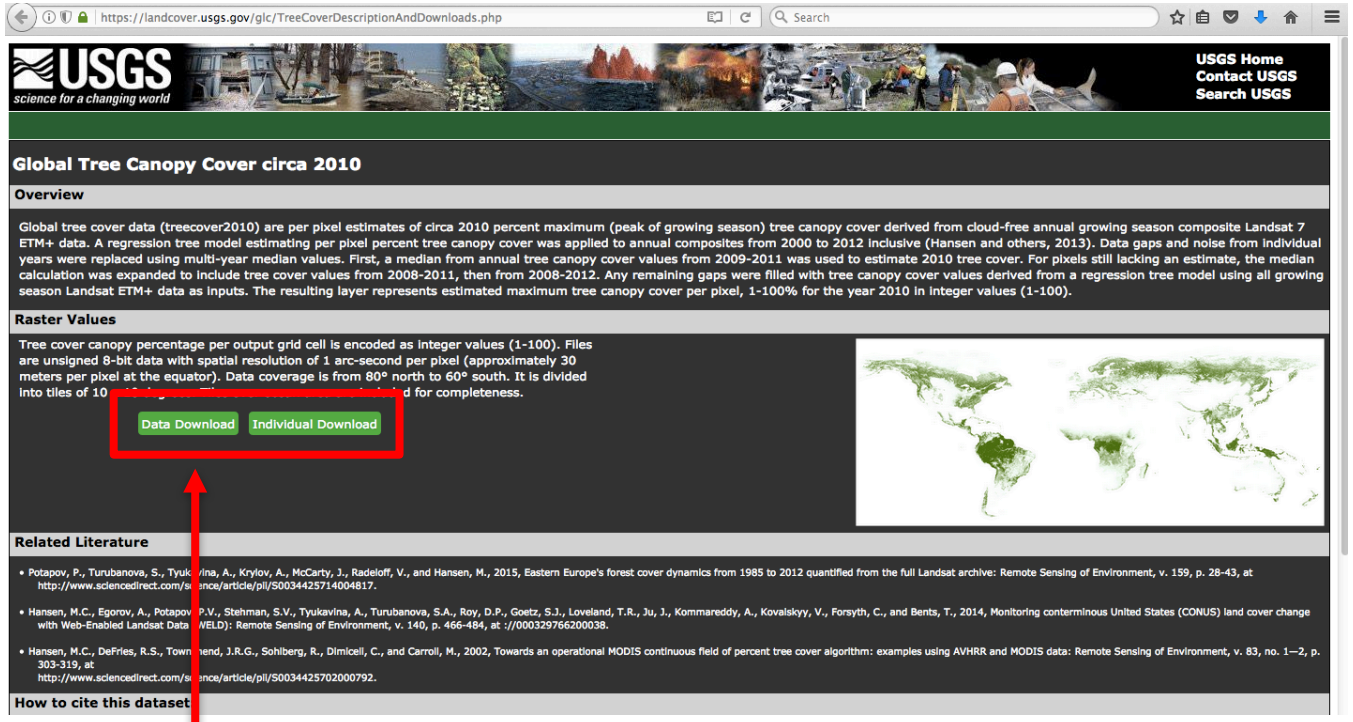
Landsat Land Cover

https://landcover.usgs.gov/glc/

- Data gaps filled by multi-year median
- Data represent peak of growing season (maximum tree cover-minimum bare ground) in per cent
- Permanent Water Surfaces derived from 2000-2012 growing season composites
- Data available in 10°x10° tiles

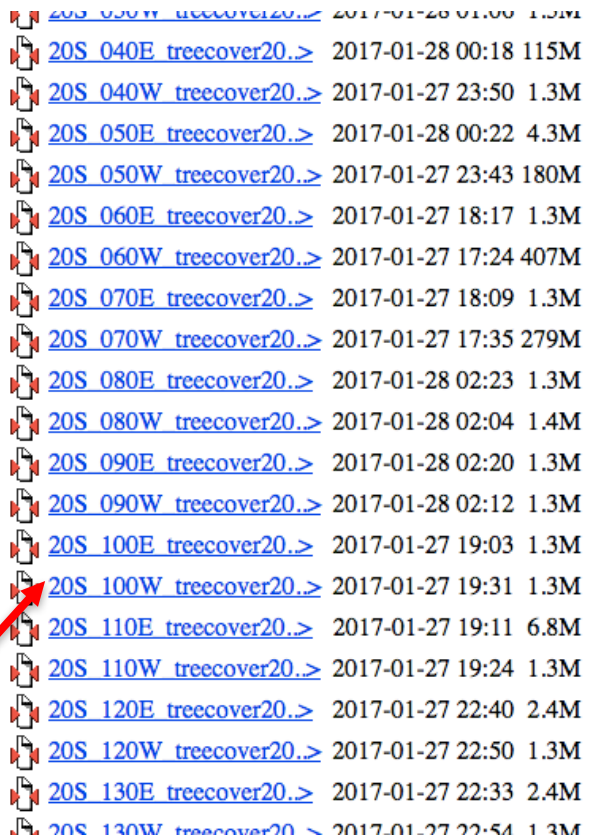
Landsat Land Cover Data Access

https://landcover.usgs.gov/glc/



Download Individual Tile or All Tiles

List of Tiles by Lat-Lon

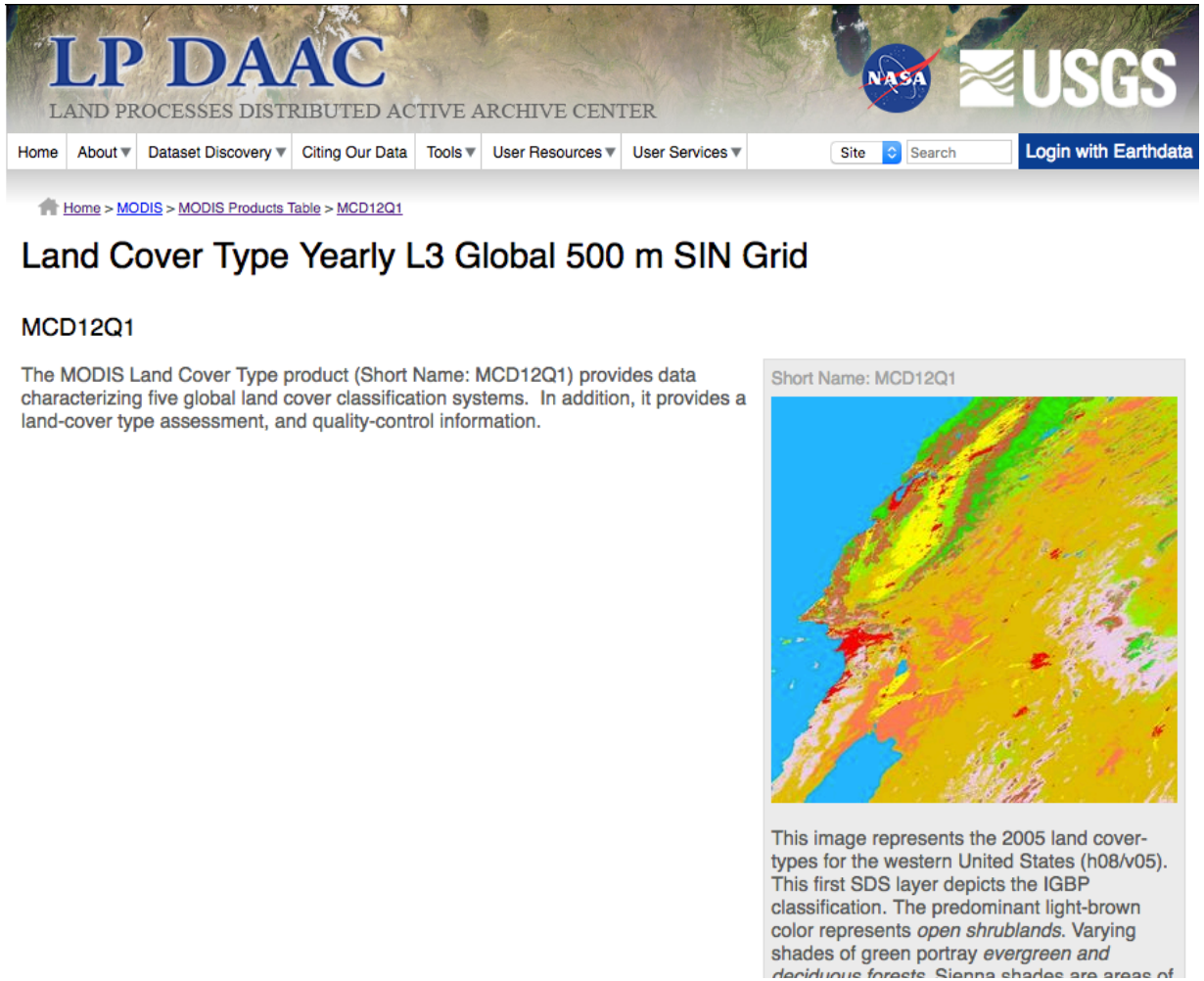


Click to download data for individual tile in GeoTIFF format

MODIS Land Cover Data (Product Name: MCD12Q1)

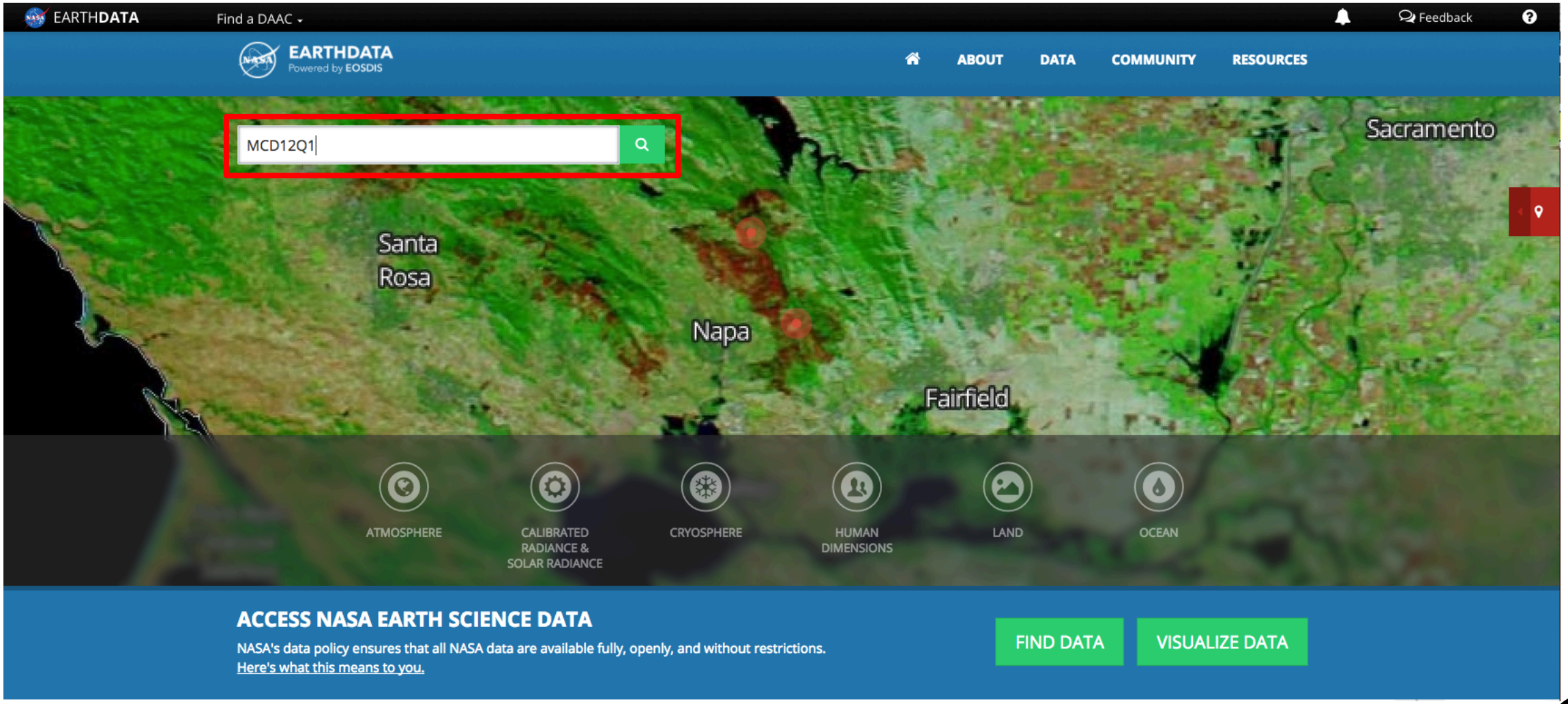
https://lpdaac.usgs.gov/dataset_discovery/modis/modis_products_table/mcd12q1

- Annual Composites from Terra and Aqua MODIS
- Spatial resolution: 500 meter
- Primary Land Cover Type Scheme: International Geosphere Biosphere Program (IGBP) global vegetation classification scheme
  - 11 vegetation classes
  - 3 developed classes
  - 3 non-vegetated classes



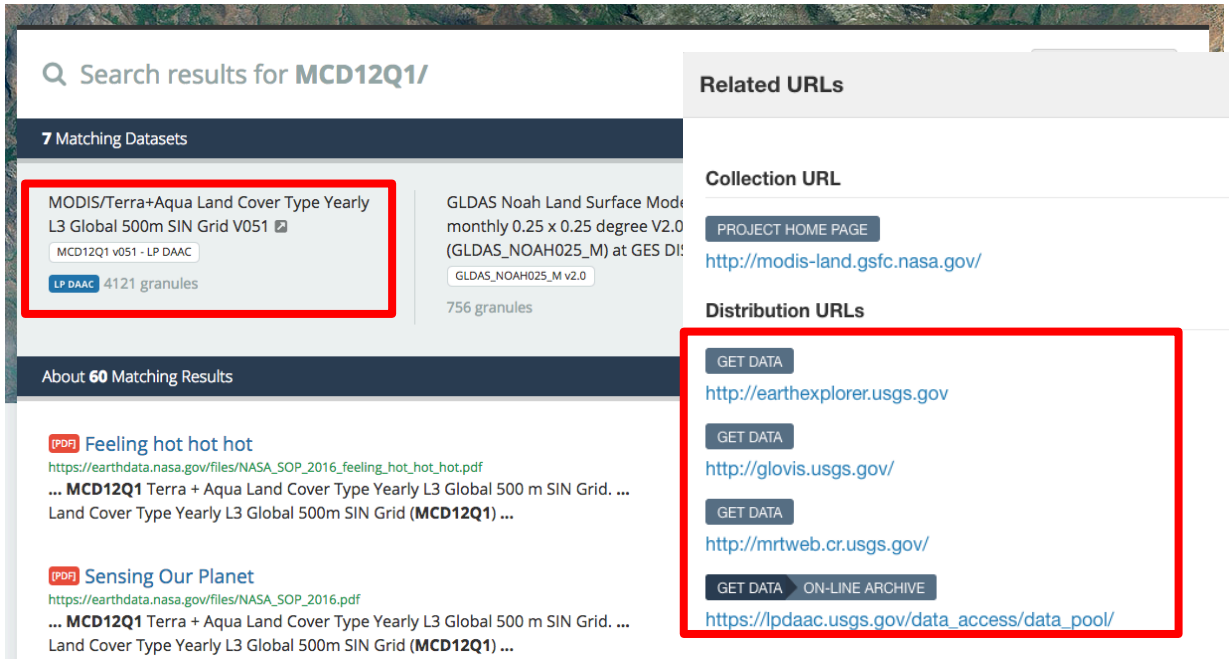
MODIS Land Cover Data Search

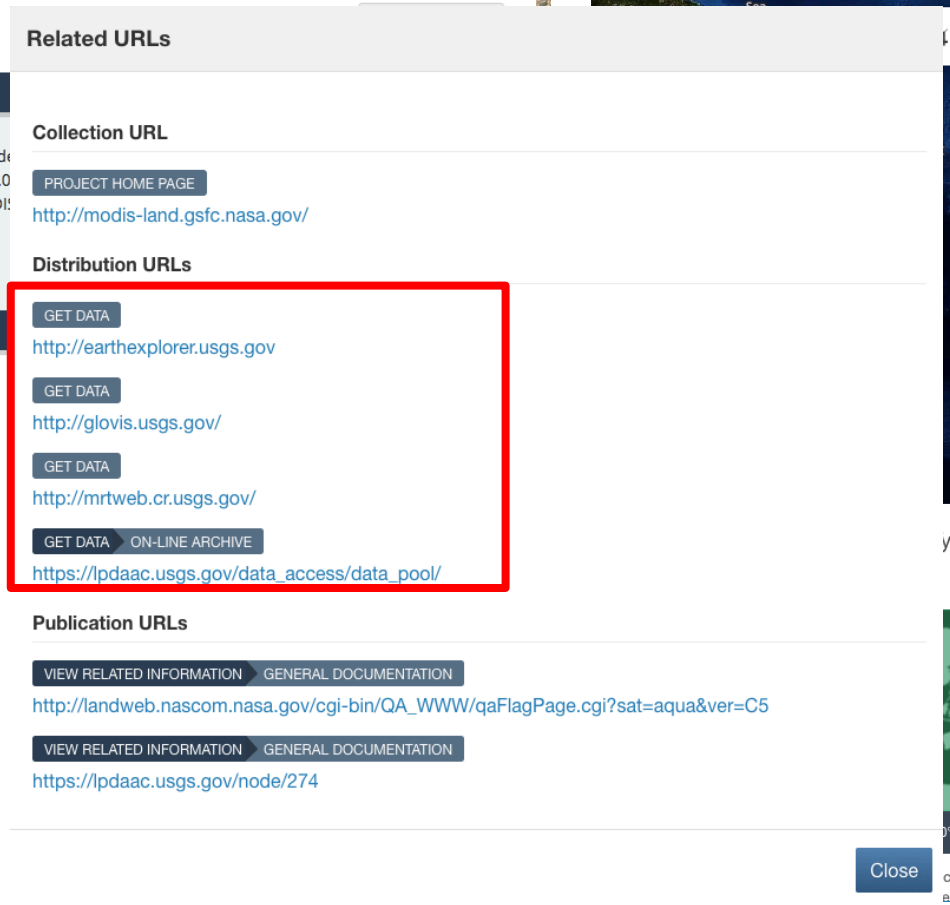
https://earthdata.nasa.gov/

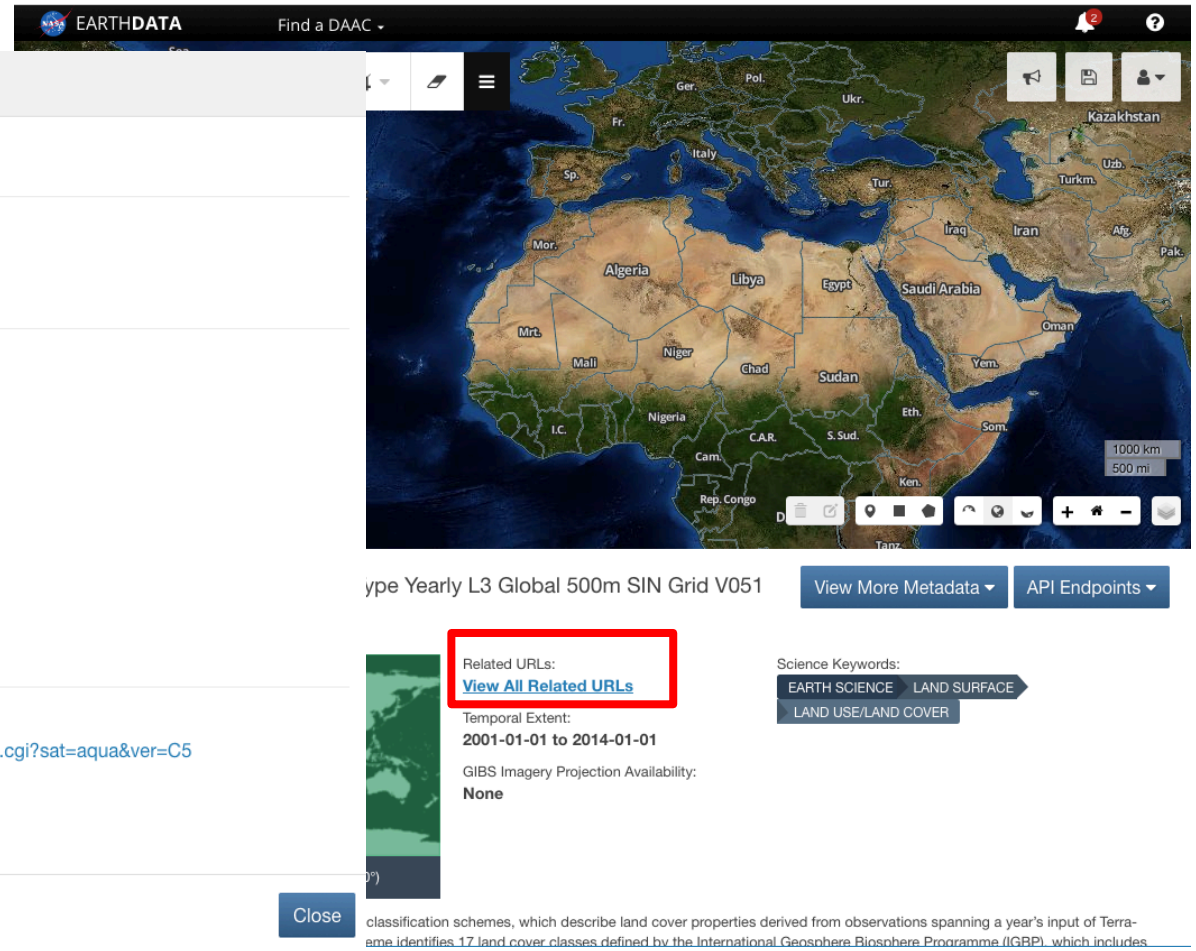


MODIS Land Cover Data Access

https://earthdata.nasa.gov/search?q=MCD12Q1/

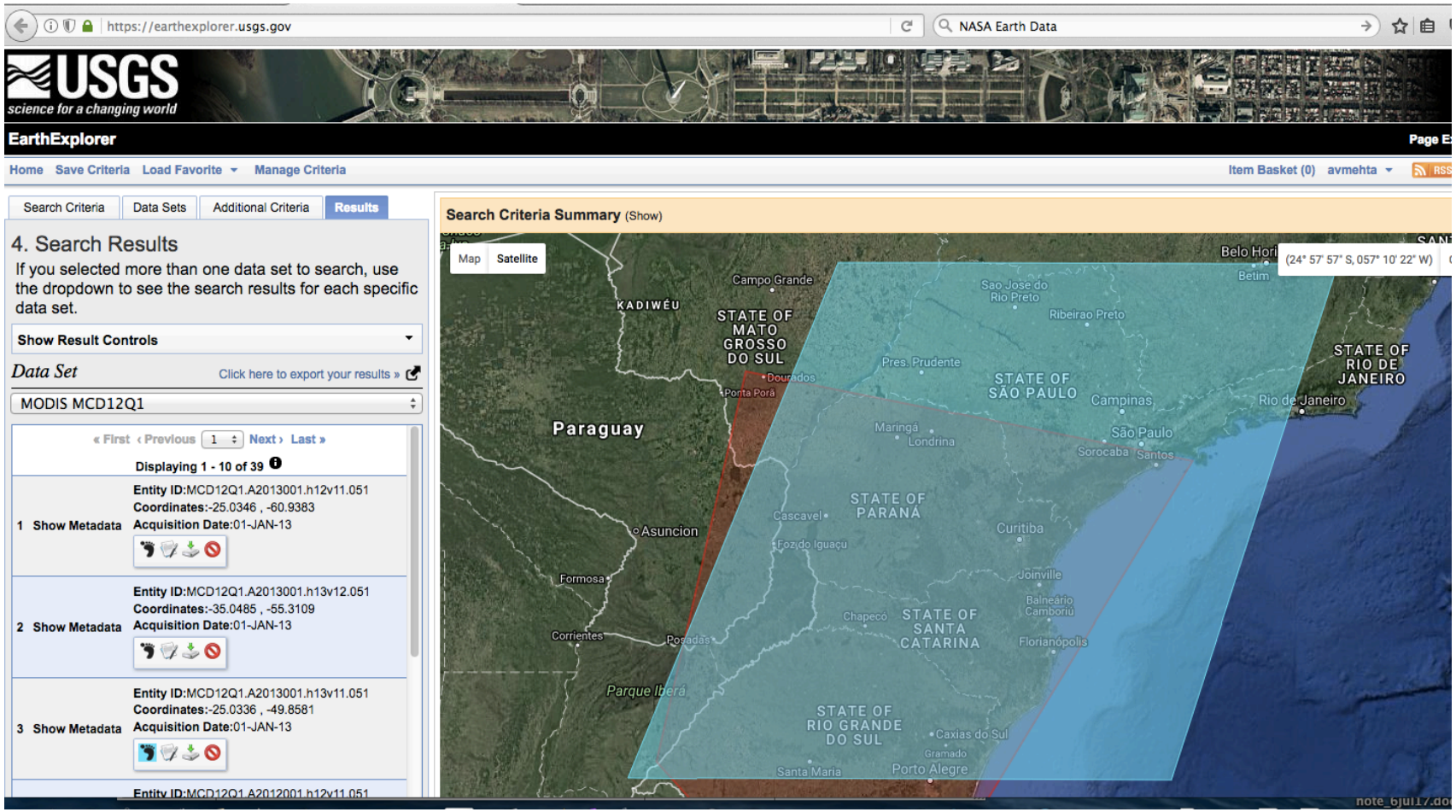






MODIS Land Cover Data Download

https://earthexplorer.usgs.gov/

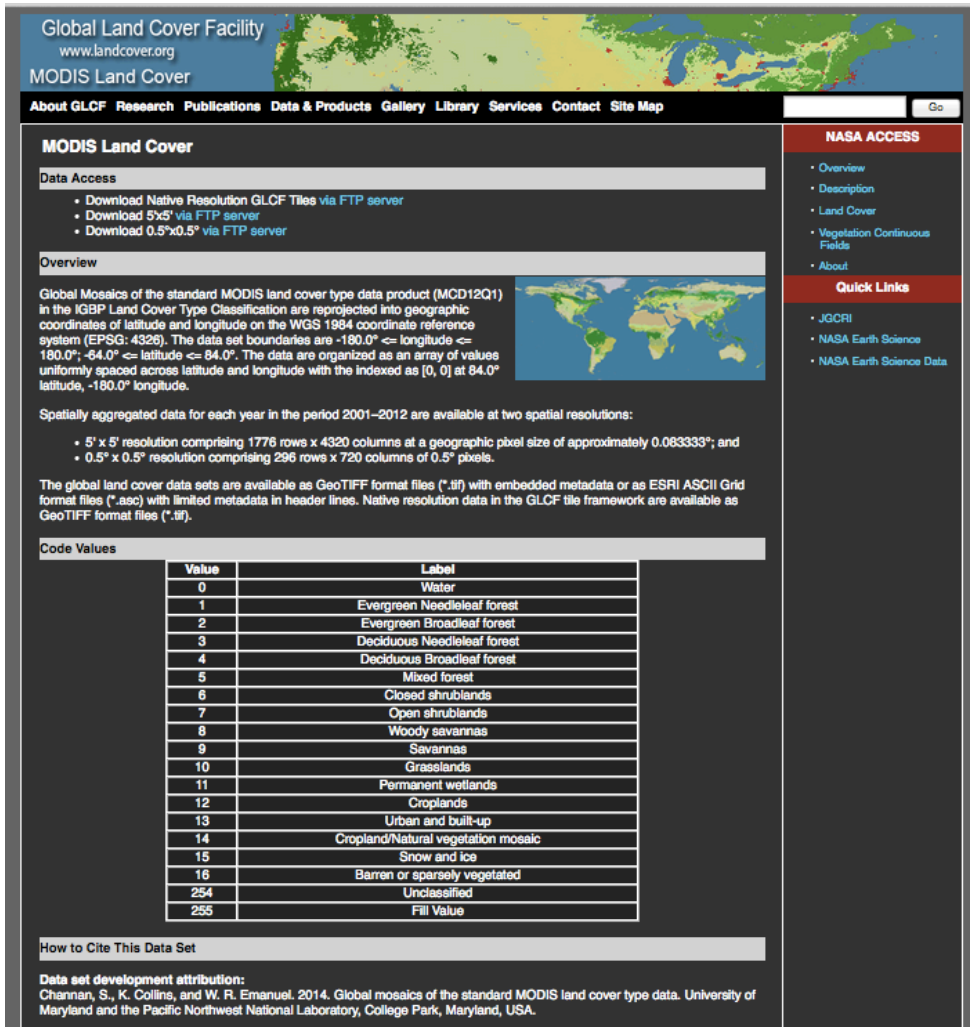


- Data Download in sinusoidal grid, in HDF Format
- Software available from LPDAAC for re-projection and conversion to NetCDF or GeoTiff

https://lpdaac.usgs.gov/tools/modis_reprojection_tool

MODIS Land Cover Data Download

http://glcf.umd.edu/data/lc/



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MODIS Land Cover

Data Access

- Download Native Resolution GLCF Tiles via FTP server
- Download 5'x5' via FTP server
- Download 0.5°x0.5° via FTP server

Overview

Global Mosaics of the standard MODIS land cover type data product (MCD12Q1) in the IGBP Land Cover Type Classification are reprojected into geographic coordinates of latitude and longitude on the WGS 1984 coordinate reference system (EPSG: 4326). The data set boundaries are -180.0° <= longitude <= 180.0°; -64.0° <= latitude <= 84.0°. The data are organized as an array of values uniformly spaced across latitude and longitude with the indexed as [0, 0] at 84.0° latitude, -180.0° longitude.

Spatially aggregated data for each year in the period 2001–2012 are available at two spatial resolutions:

- 5' x 5' resolution comprising 1776 rows x 4320 columns at a geographic pixel size of approximately 0.083333°; and
- 0.5° x 0.5° resolution comprising 296 rows x 720 columns of 0.5° pixels.

The global land cover data sets are available as GeoTIFF format files (*.tif) with embedded metadata or as ESRI ASCII Grid format files (*.asc) with limited metadata in header lines. Native resolution data in the GLCF tile framework are available as GeoTIFF format files (*.tif).

Code Values

Value	Label
0	Water
1	Evergreen Needleleaf forest
2	Evergreen Broadleaf forest
3	Deciduous Needleleaf forest
4	Deciduous Broadleaf forest
5	Mixed forest
6	Closed shrublands
7	Open shrublands
8	Woody savannas
9	Savannas
10	Grasslands
11	Permanent wetlands
12	Croplands
13	Urban and built-up
14	Cropland/Natural vegetation mosaic
15	Snow and ice
16	Barren or sparsely vegetated
254	Unclassified
255	Fill Value

How to Cite This Data Set

Data set development attribution:
Channan, S., K. Collins, and W. R. Emanuel. 2014. Global mosaics of the standard MODIS land cover type data. University of Maryland and the Pacific Northwest National Laboratory, College Park, Maryland, USA.

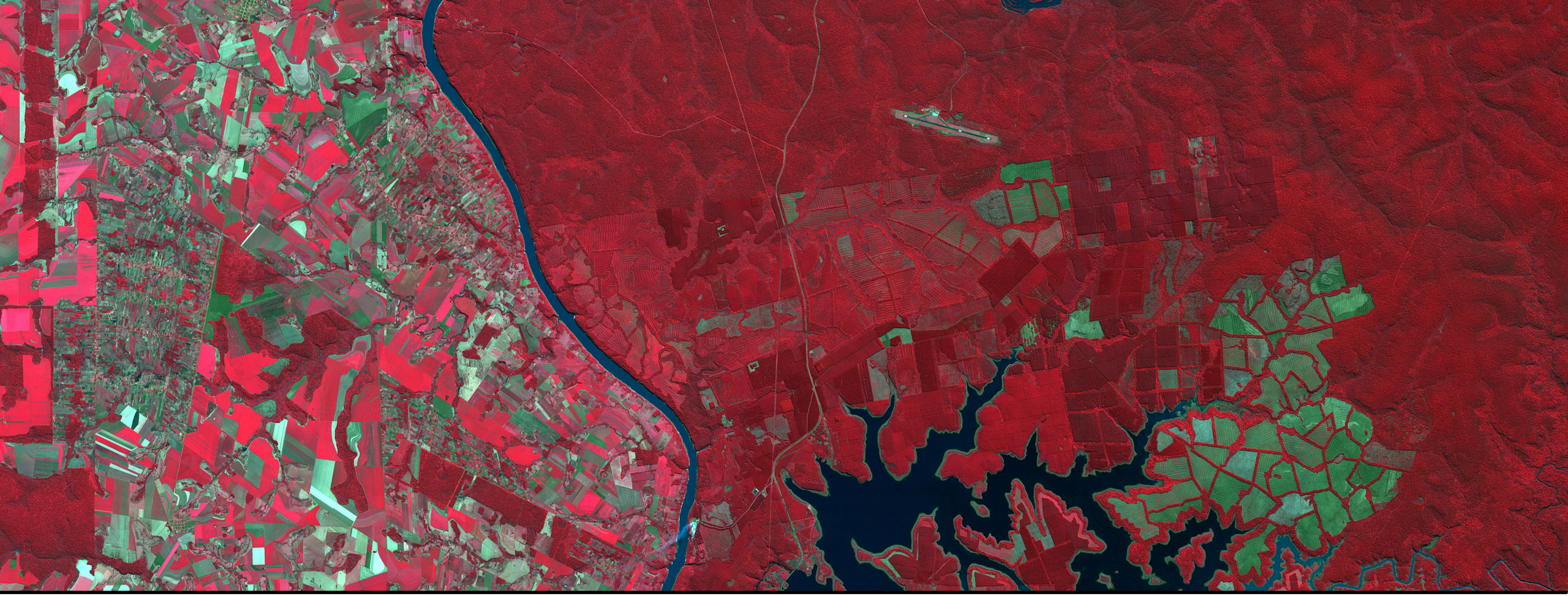
NASA ACCESS

- Overview
- Description
- Land Cover
- Vegetation Continuous Fields
- About

Quick Links

- JGCRI
- NASA Earth Science
- NASA Earth Science Data

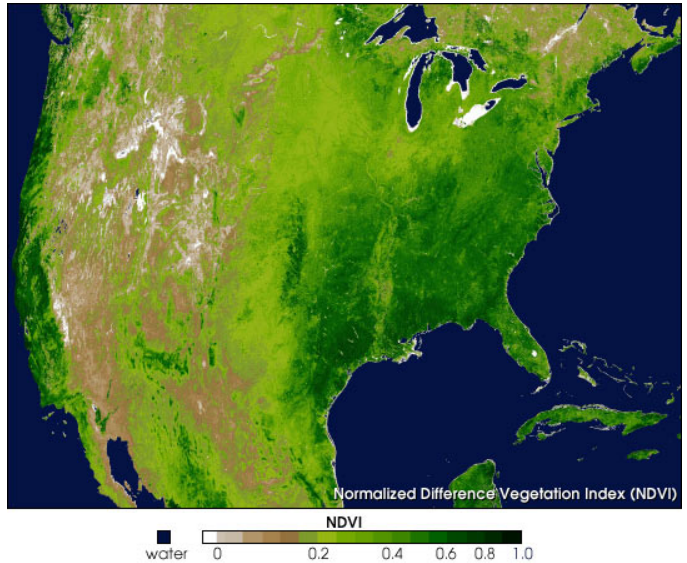
- Available from Global Land Cover Facility
- Also available in .tiff format at 0.0833° and 0.5° resolutions

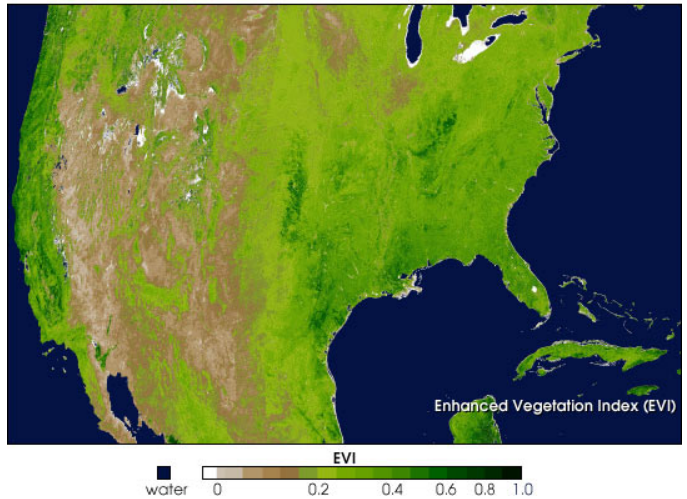


MODIS NDVI

MODIS Vegetation Indices Product Overview

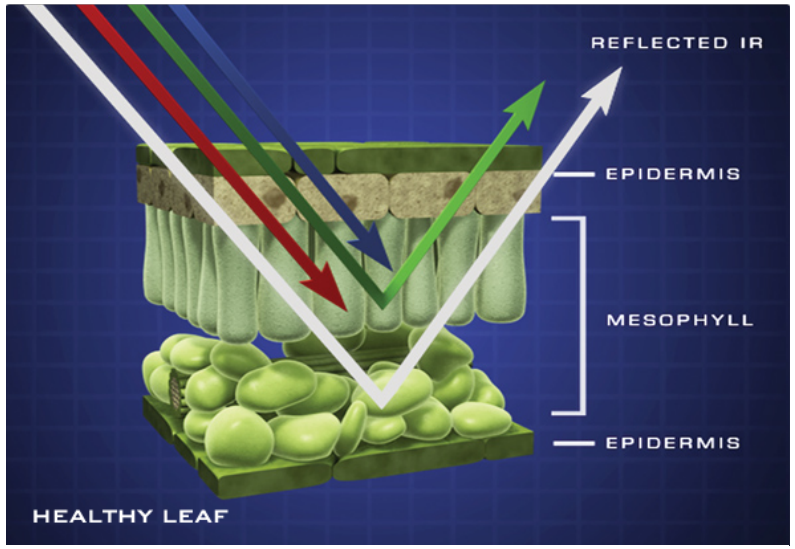
- Vegetation Indices:
  - NDVI (Normalized Difference Vegetation Index)
    - 16 day, 250 meter spatial resolution as a gridded level 3 product
    - Used for characterizing land surface processes
    - Anomalies can be used to identify drought
  - EVI (Enhanced Vegetation Index)
    - Minimizes canopy background
    - Improvement in dense vegetation conditions

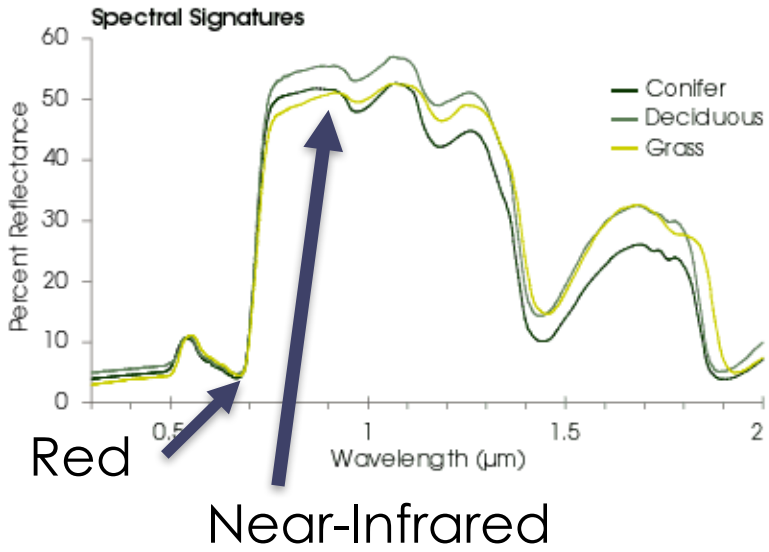




What is NDVI?

- 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



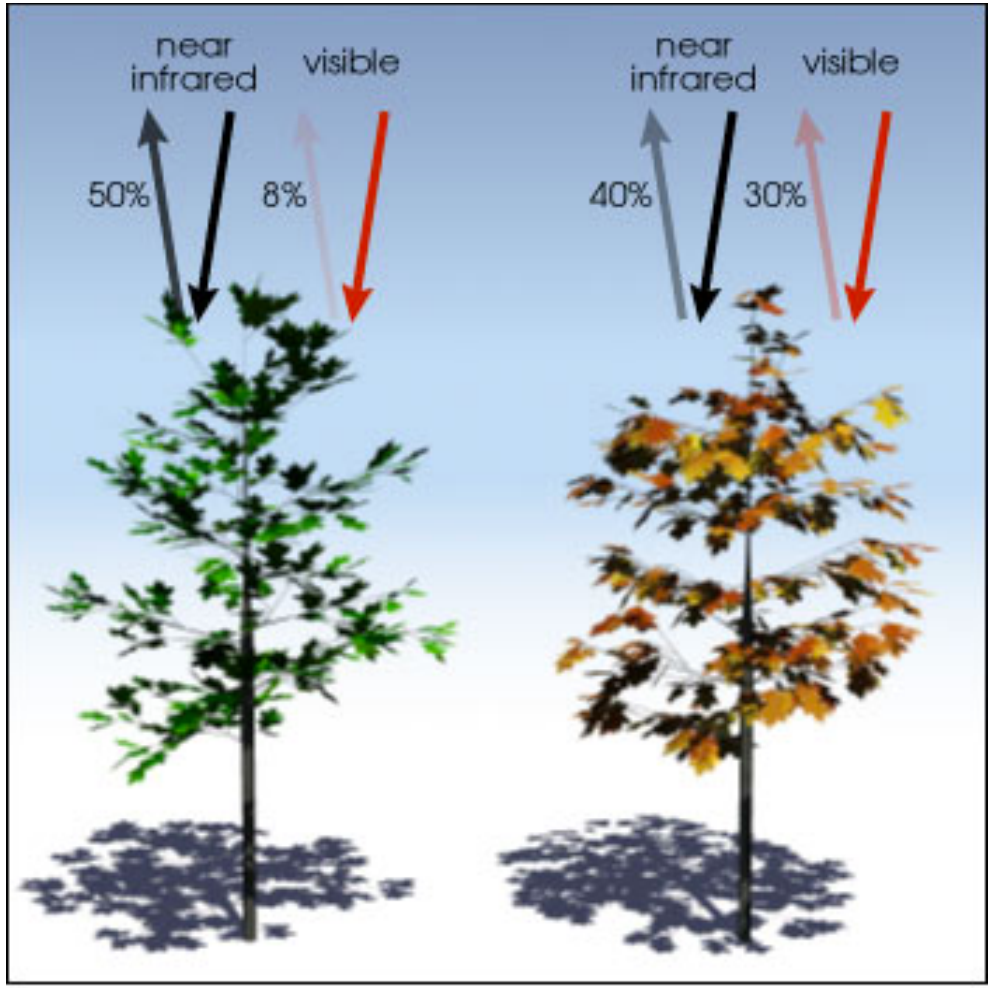


What is NDVI?

- NDVI formula:

$$\frac{\text{Near Infrared - Red}}{\text{Near Infrared + Red}}$$

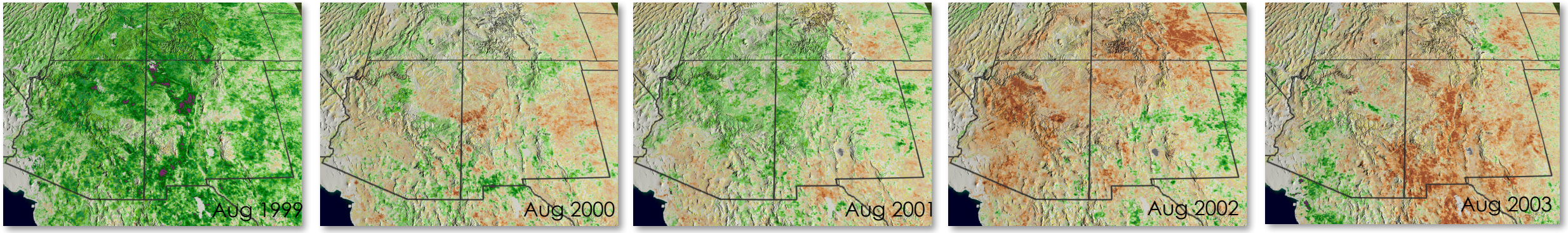
- Values range from -1.0 to 1.0
  - Negative values to 0 mean no green leaves
  - Values close to 1 indicate the highest possible density of green leaves



$$\frac{(0.50 - 0.08)}{(0.50 + 0.08)} = 0.72 \qquad \frac{(0.4 - 0.30)}{(0.4 + 0.30)} = 0.14$$

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

MODIS Vegetation Indices

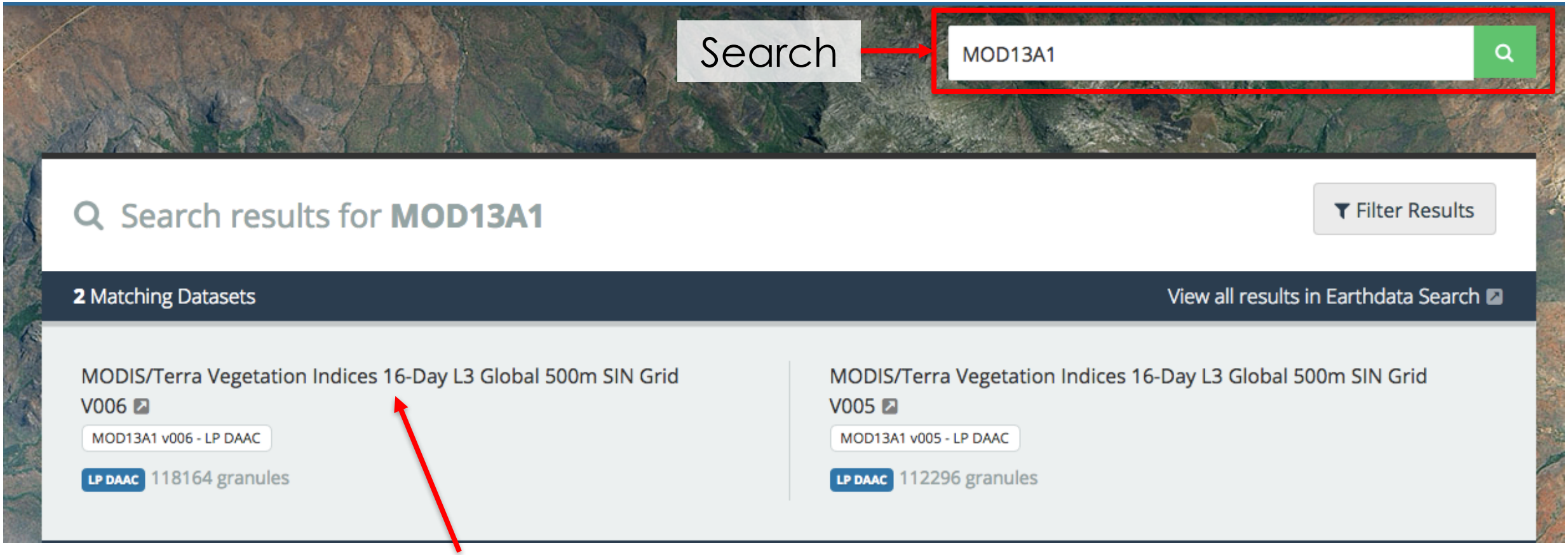
http://modis-land.gsfc.nasa.gov/vi.html

See links below to the Product Description pages posted at the LP DAAC (product details, data access links, and more....)

Product Name	Terra Product ID	Aqua Product ID
Vegetation Indices 16-Day L3 Global 250m	MOD13Q1	MYD13Q1
Vegetation Indices 16-Day L3 Global 500m	MOD13A1	MYD13A1
Vegetation Indices 16-Day L3 Global 1km	MOD13A2	MYD13A2
Vegetation Indices 16-Day L3 Global 0.05Deg CMG	MOD13C1	MYD13C1
Vegetation Indices Monthly L3 Global 1km	MOD13A3	MYD13A3
Vegetation Indices Monthly L3 Global 0.05Deg CMG	MOD13C2	MYD13C2

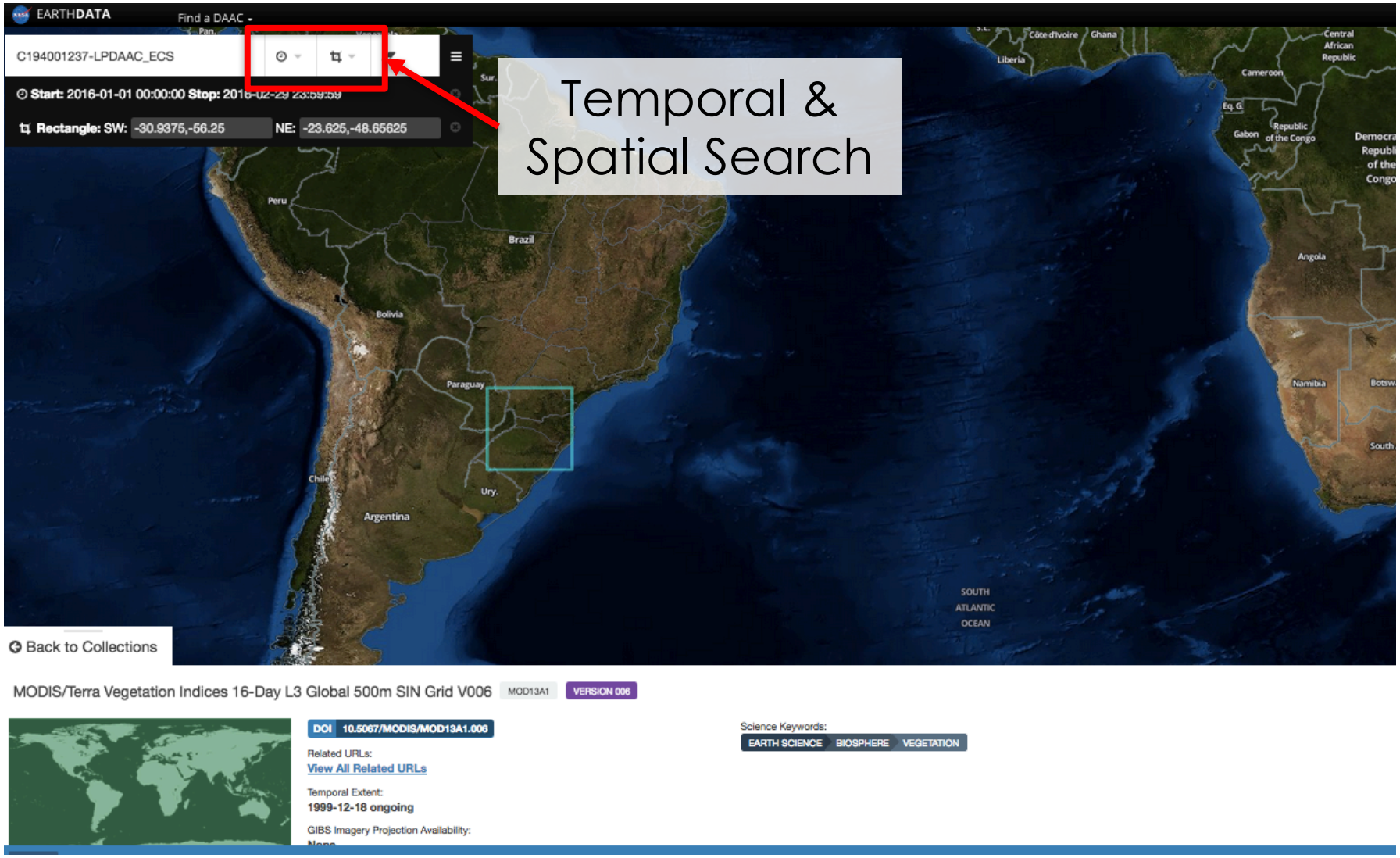
MODIS NDVI Data Search and Access

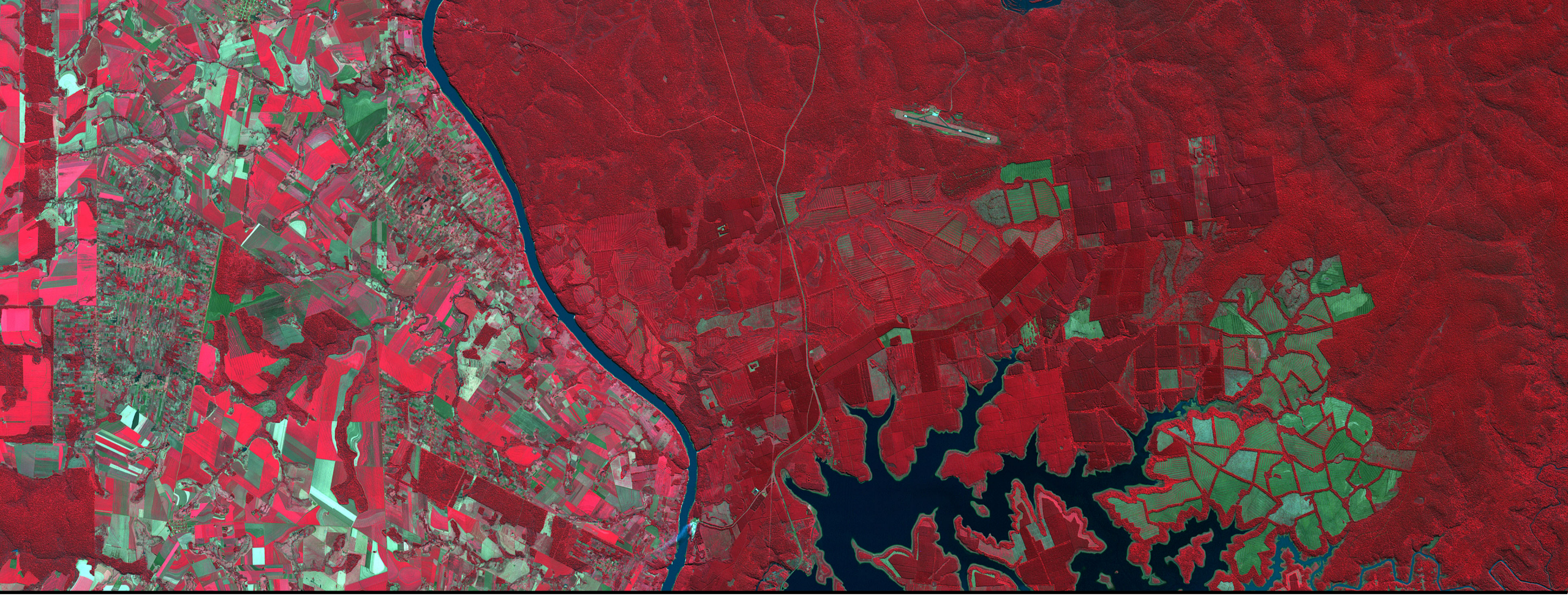
https://earthdata.nasa.gov/search?q=MOD13A1



Access

MODIS NDVI Data Download





Next: Access Landsat Land Cover for SFW and Analyze MODIS NDVI over SFW