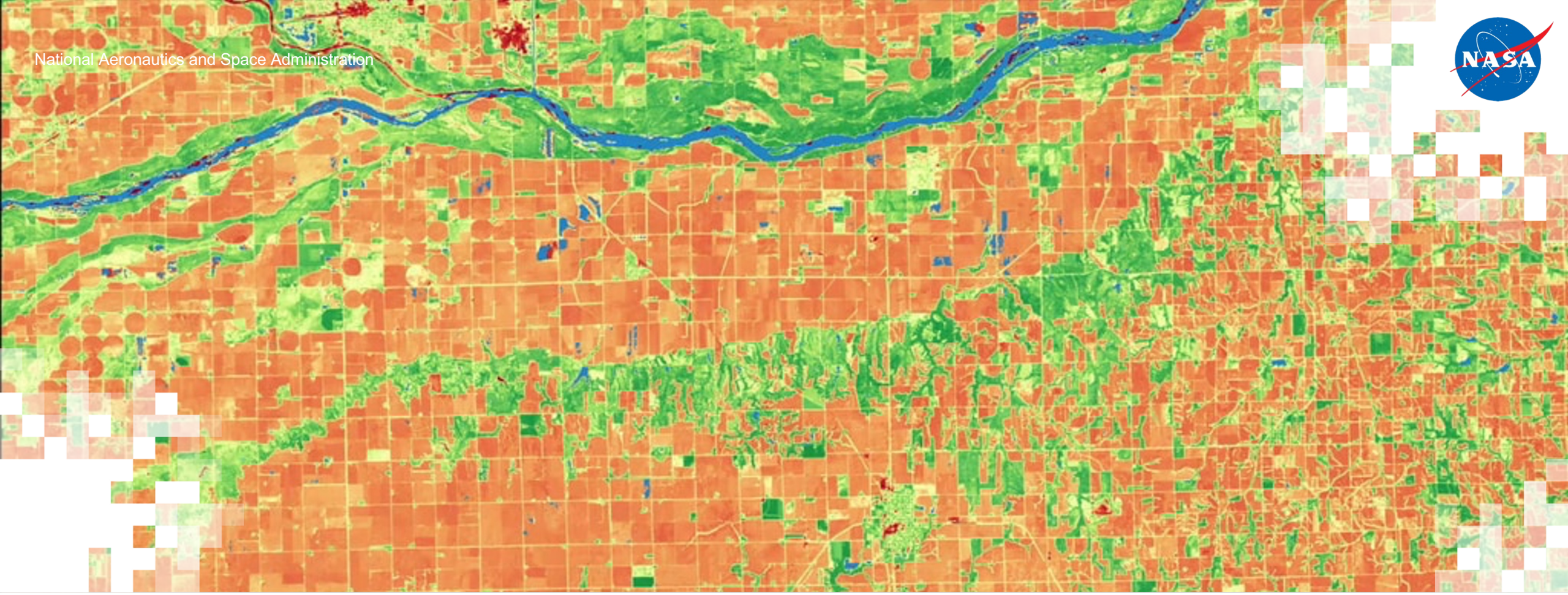


Spectral Indices for Land and Aquatic Applications

Part 1: Overview of Spectral Indices

Amber McCullum (BAERI), Britnay Beaudry (BAERI), Juan Torres-Pérez (NASA ARC), Sativa Cruz (BAERI)

October 26, 2023

Part 1 – Trainers

Britnay Beaudry

Instructor

Ecological Conservation

Amber Jean McCullum

Team Lead

Ecological Conservation

Juan Torrez-Perez

Instructor

Ecological Conservation

Sativa Cruz

Instructor

Ecological Conservation

About ARSET

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools.**

- Trainings include a variety of applications of satellite data and are tailored to audiences with a variety of experience levels.


AGRICULTURE


CLIMATE & RESILIENCE


DISASTERS


ECOLOGICAL CONSERVATION

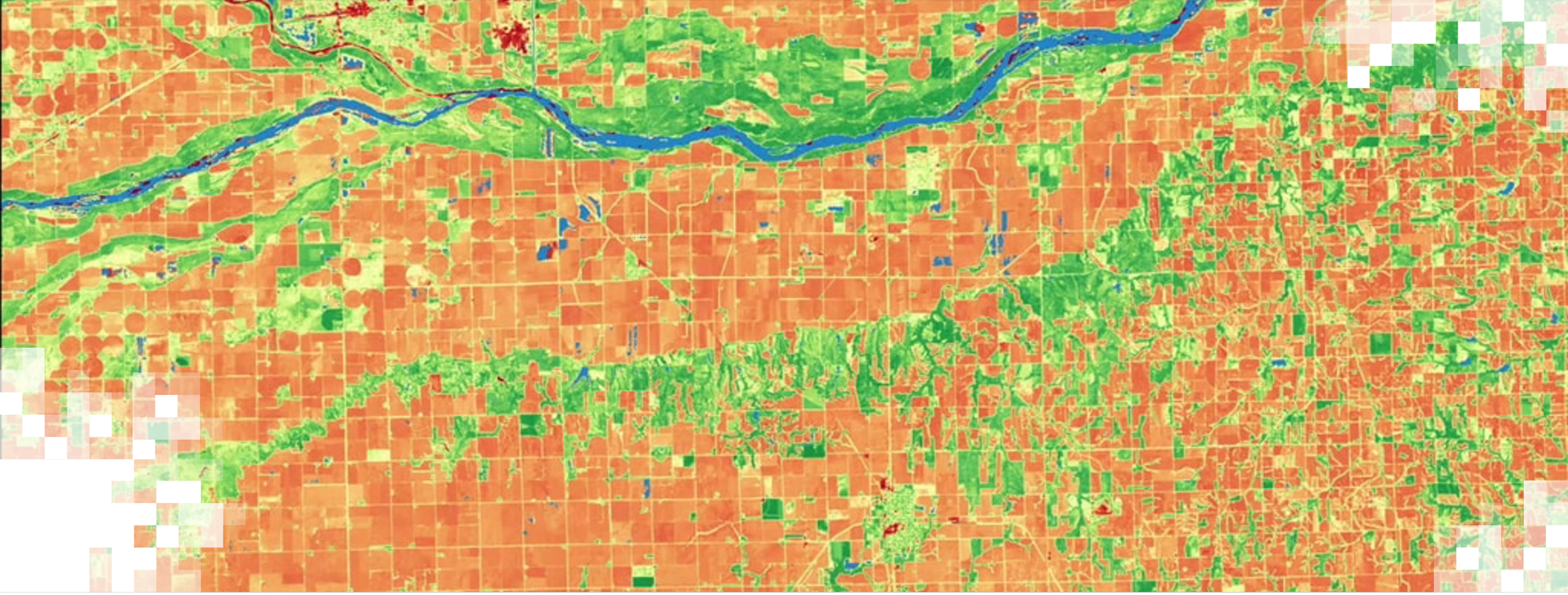

HEALTH & AIR QUALITY


WATER RESOURCES

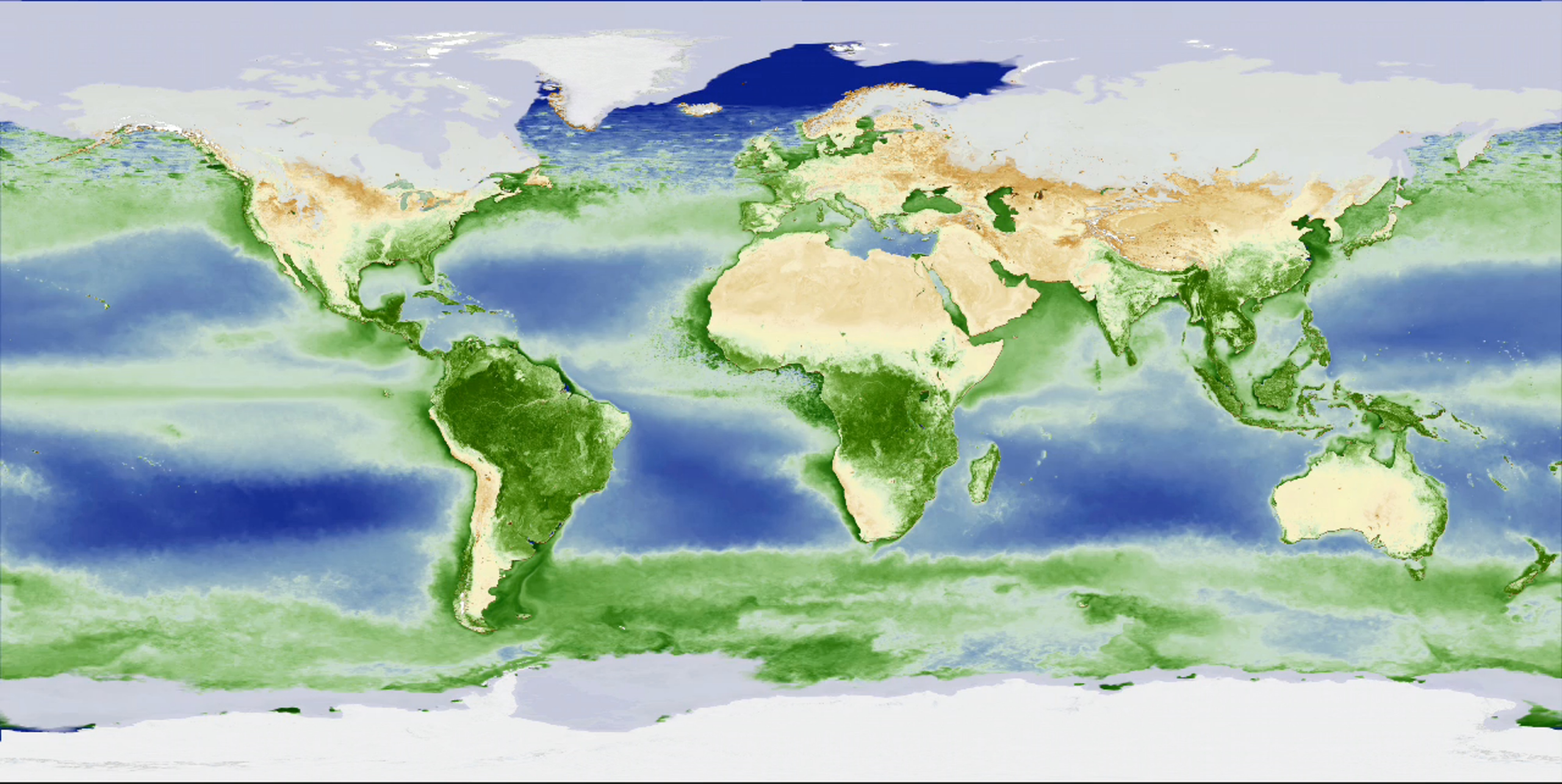
About ARSET Trainings

- Online or in-person
- Live and instructor-led or asynchronous and self-paced
- Cost-free
- Bilingual and multilingual options
- Mostly use open-source software and data
- Accommodate differing levels of expertise

- Visit the ARSET website to learn more.



Spectral Indices for Land and Aquatic Applications
Training Overview

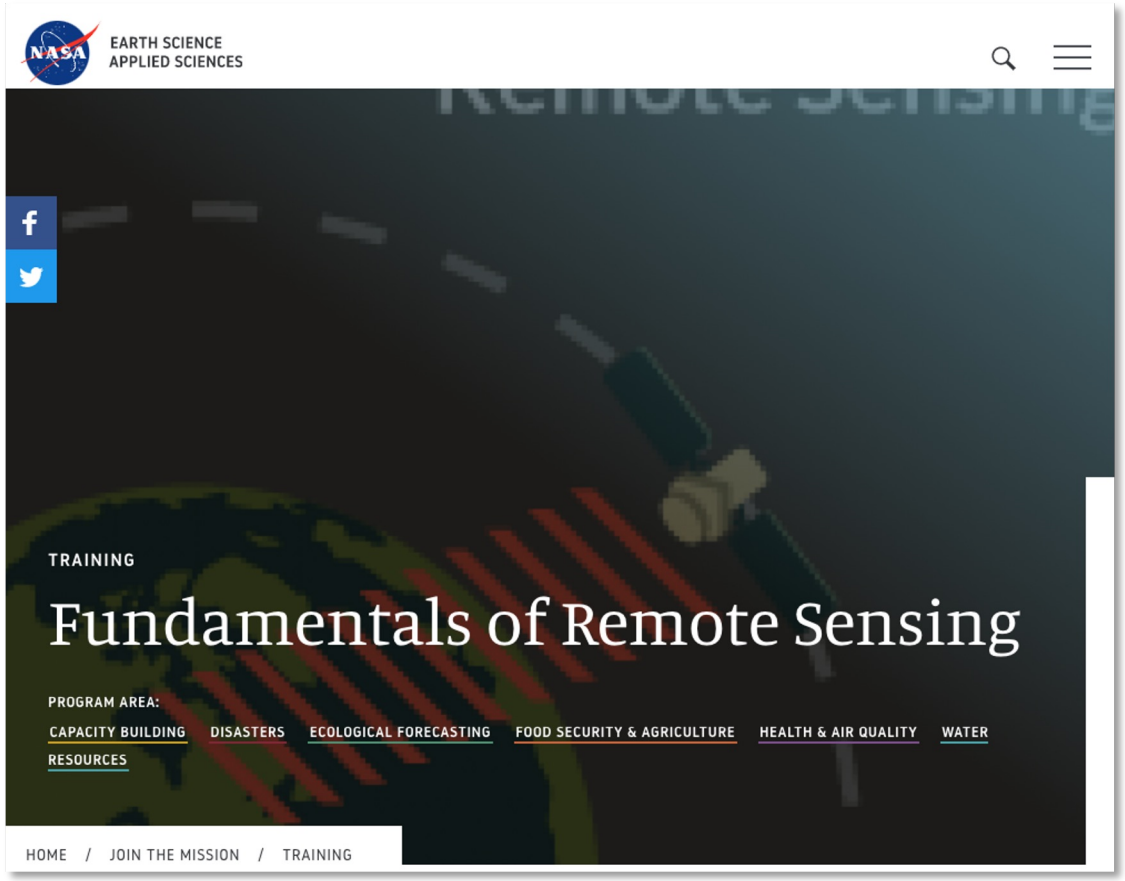

Jan
Dec
Land Vegetation (NDVI)
-0.1
0.9
Ocean Chlorophyll Concentration (mg/m3)
0.01
0.1
1
10
20

Purpose of this Training

- To provide an overview of commonly used spectral indices for aquatic and land applications.
- Learners will see examples of spectral index calculations with diverse sensors including Landsat 9 (OLI-2), Sentinel-2 MSI, and the Harmonized Landsat Sentinel-2 datasets.
- Demos using Google Earth Engine will be shown for both aquatic and land applications.

Prerequisites

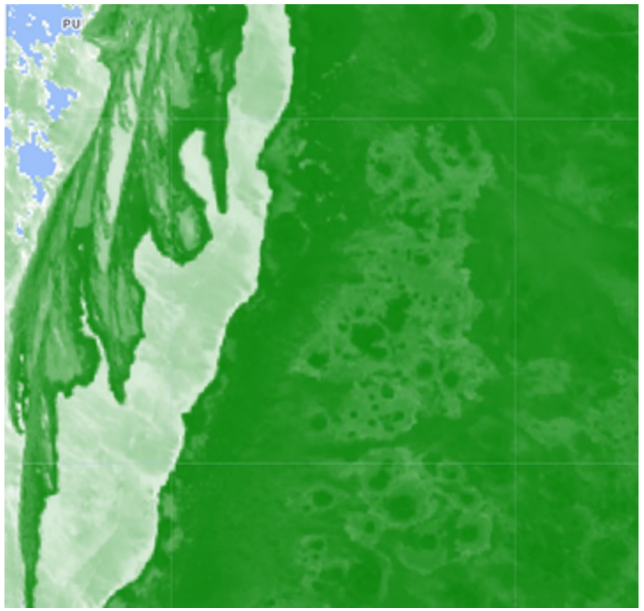
- Fundamentals of Remote Sensing
  - Or equivalent experience



Training Learning Objectives

By the end of this training series, participants will be able to:

- Recognize commonly used spectral indices in land and aquatic environments
- Distinguish between spectral indices to select those best suited for a given land or aquatic system of interest
- Compute spectral index calculations over appropriate areas of interest
- Acquire spectral index products from a variety of sources



Training Outline

Part 1

Overview of Spectral Indices

October 26, 2023

11-12 and 15-16 ET

Part 2

Spectral Indices for Aquatic Applications

November 2, 2023

11-12 and 15-16 ET

Part 3

Spectral Indices for Land Applications

November 9, 2023

11-12 and 15-16 ET

Homework

Opens November 9 – Due November 23 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

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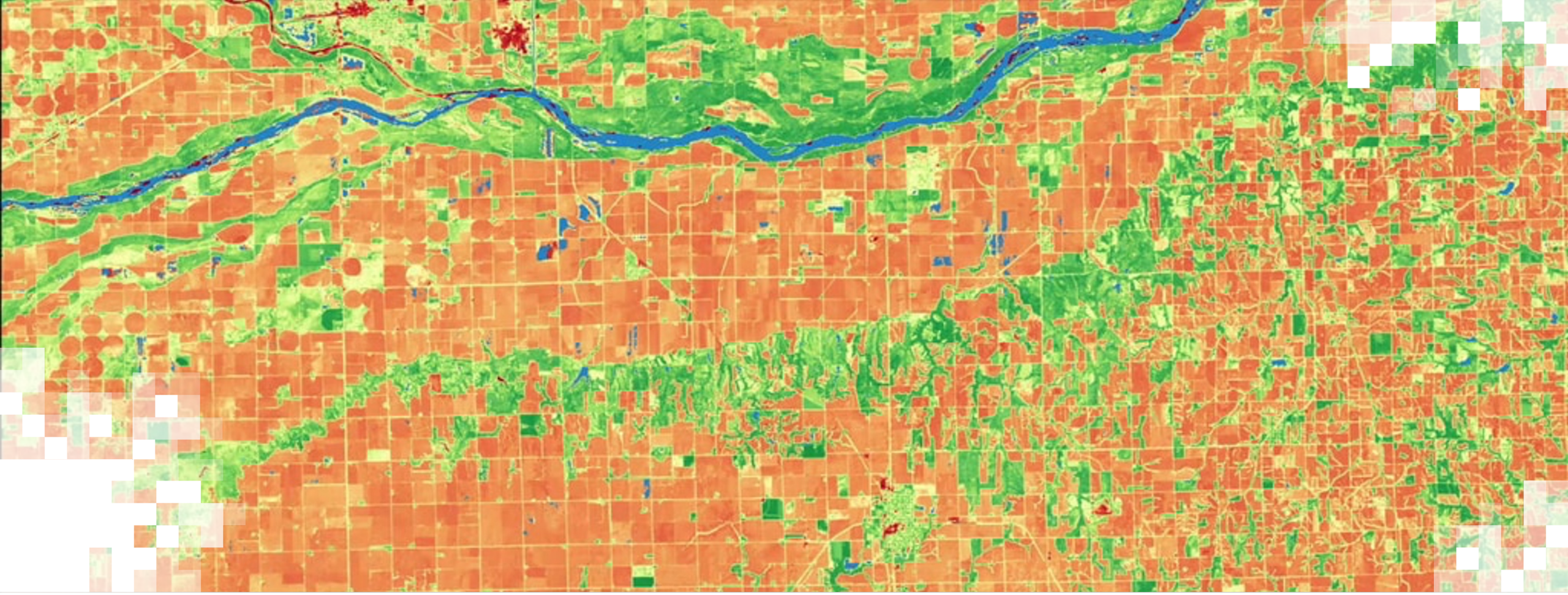
Part 1 Objectives

By the end of Part 1, participants will be able to:

- Understand basic spectral properties of imagery
- Define "spectral index"
- Describe the Normalized Difference Vegetation Index (NDVI) and its applications
- Identify and access NDVI data products
- Compute the NDVI over an area using Google Earth Engine

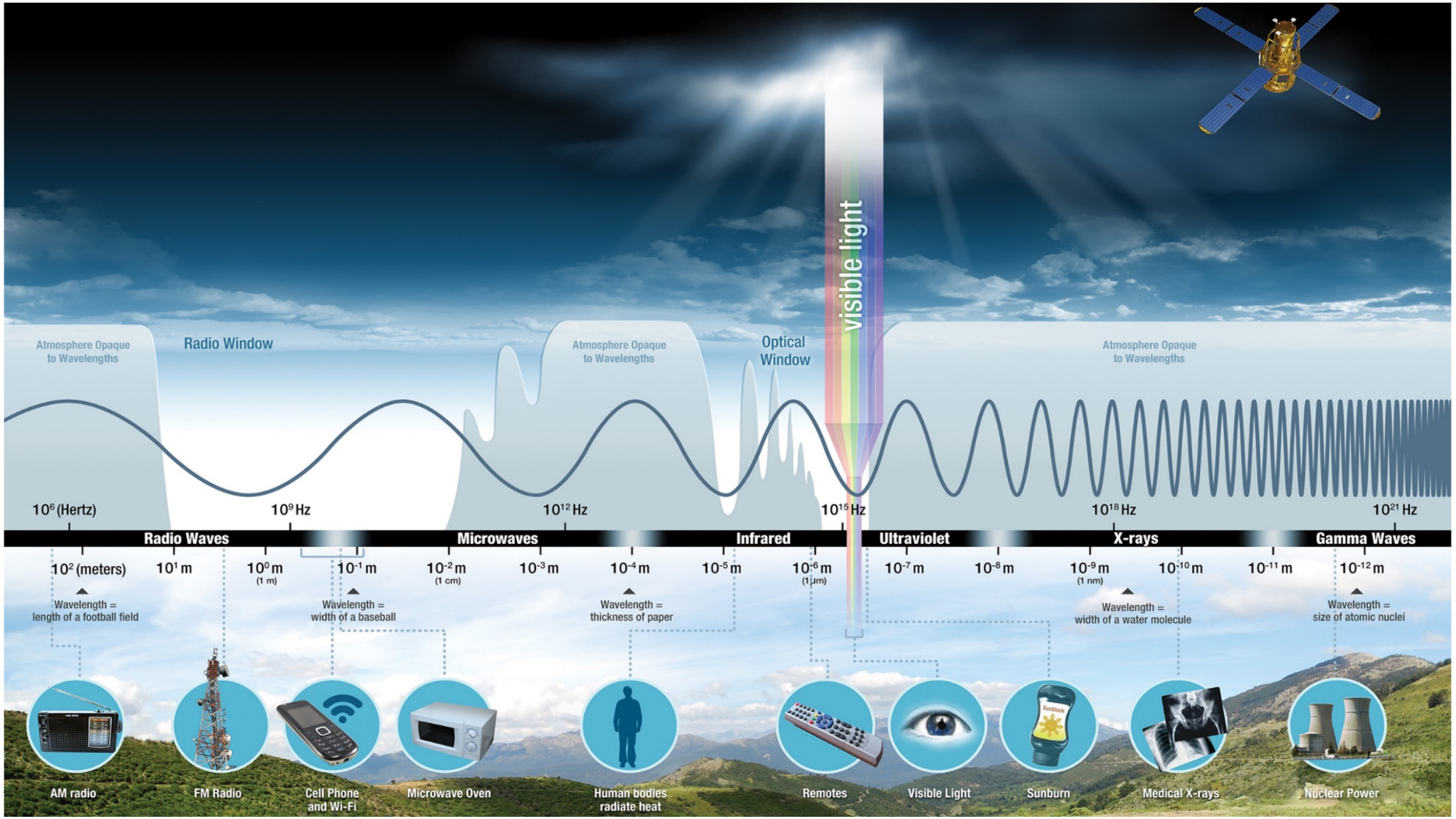
How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.



Part 1:
Spectral Properties of Imagery

Electromagnetic Spectrum



What is measured with passive remote sensing instruments?

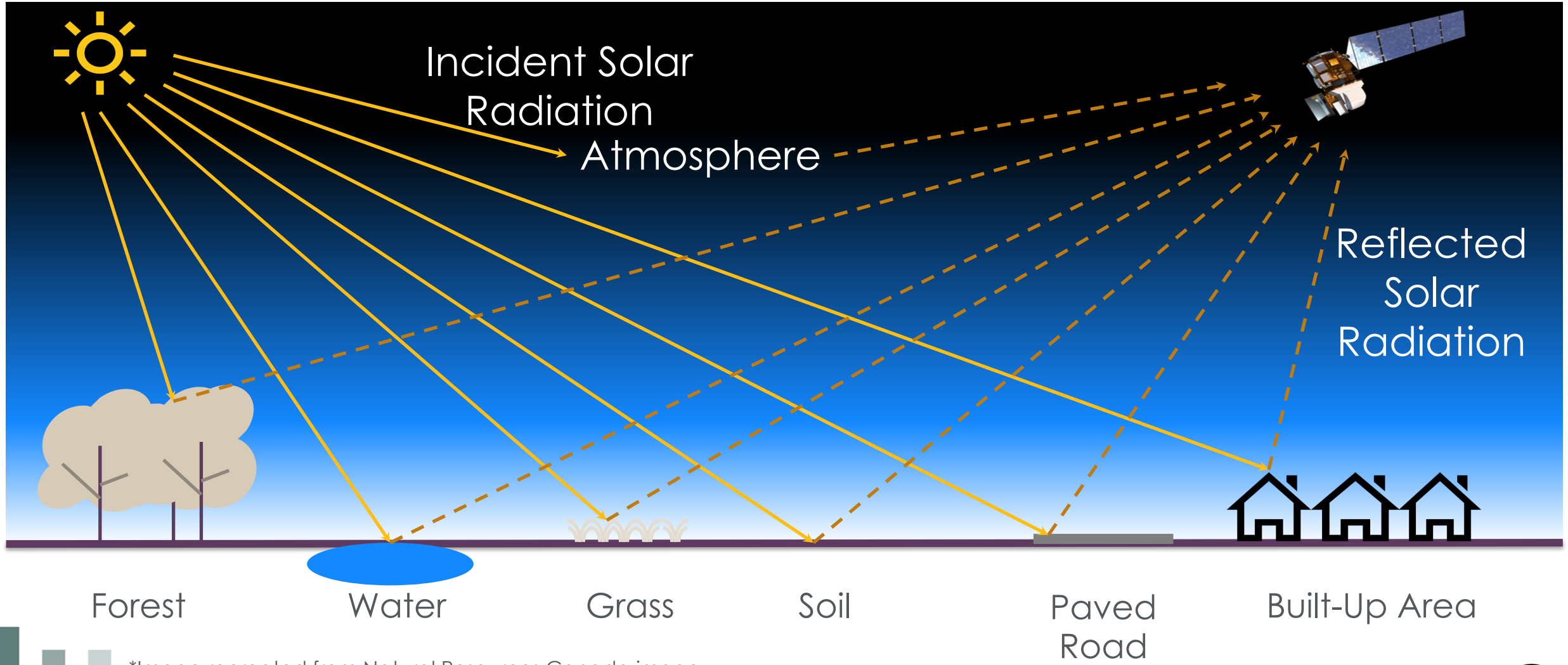


*Image recreated from Natural Resources Canada image

Interaction with Earth's Surface: Vegetation

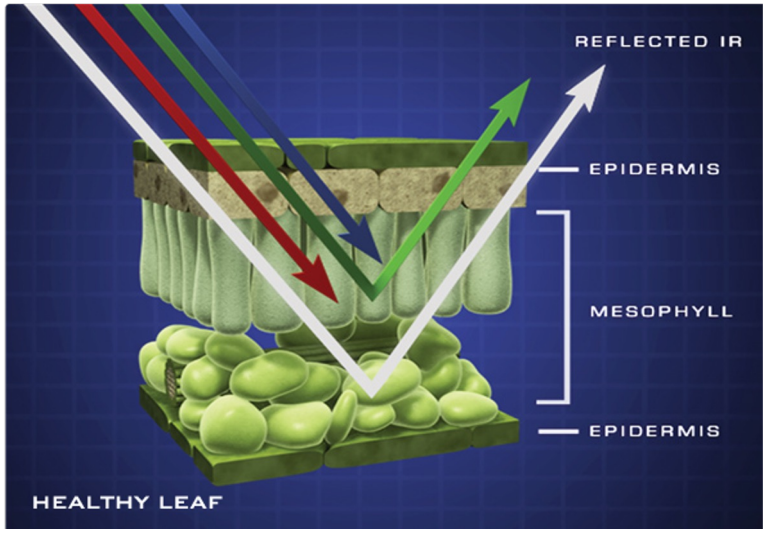
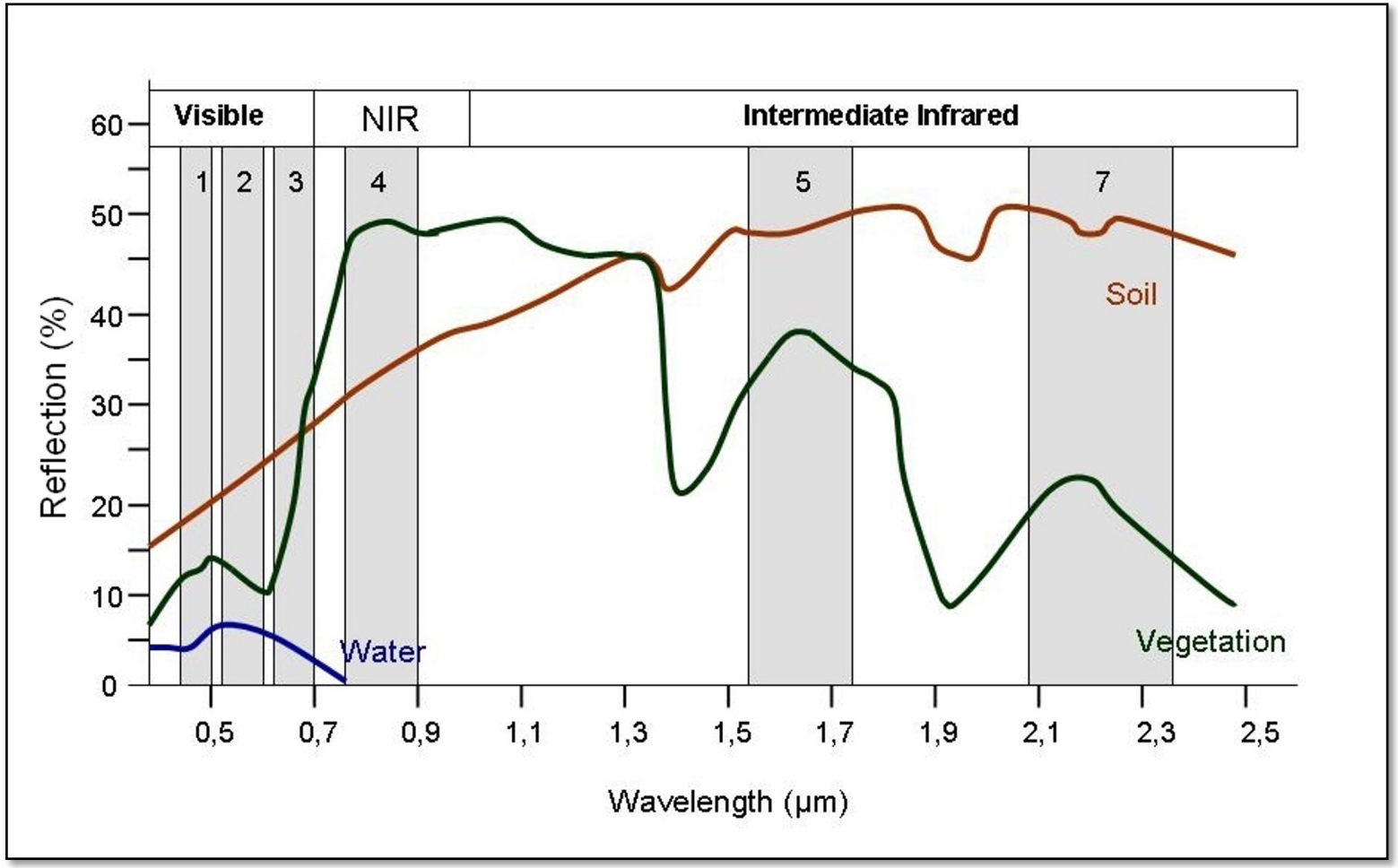


Image Credits: NASA/Jeff Carns & Ginger Butcher

- Example: Healthy, green vegetation **absorbs** **Blue** and **Red** wavelengths (used by chlorophyll for photosynthesis) and **reflects** **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.

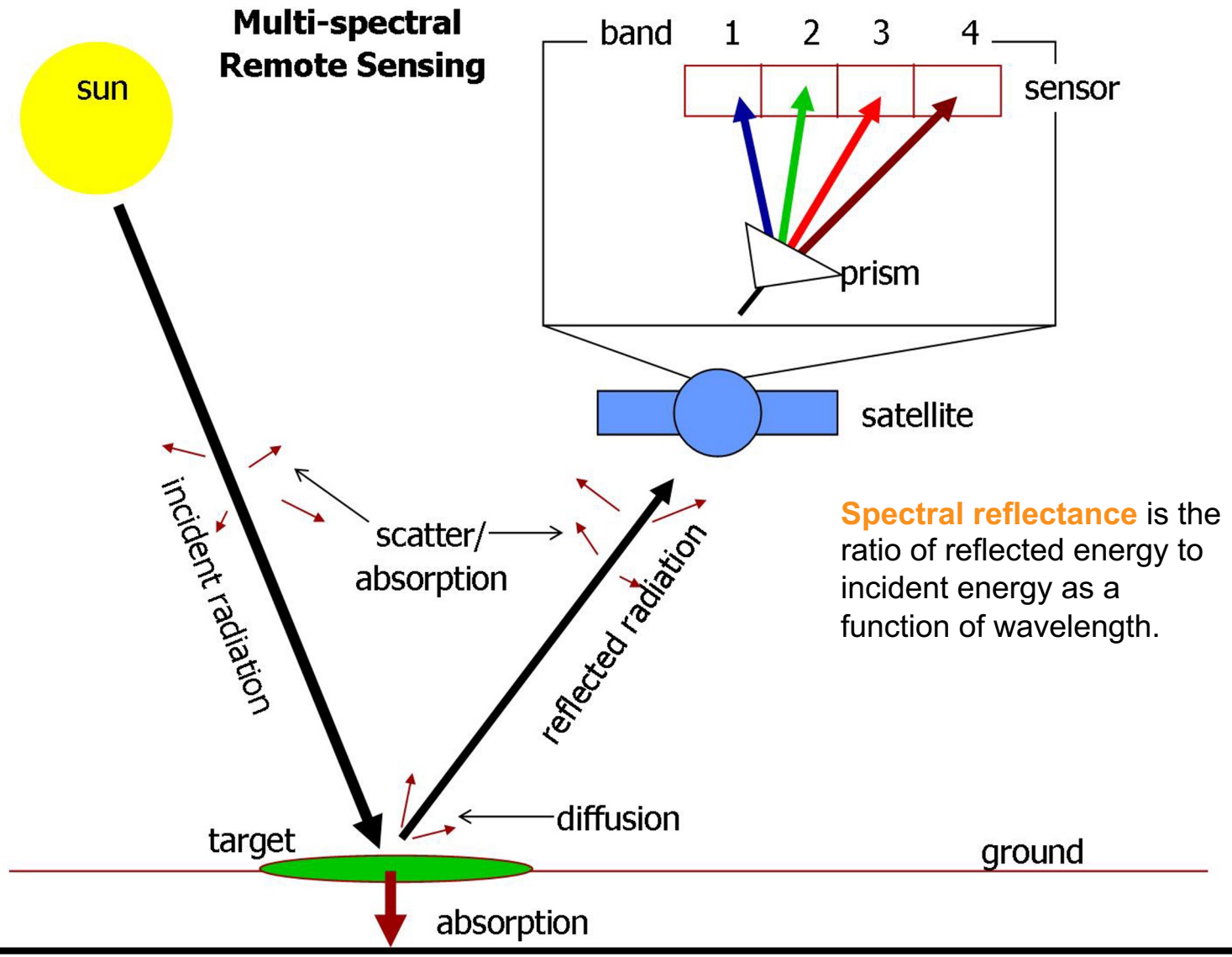
Spectral Signatures

- Every surface on Earth reflects and absorbs energy in different ways.
- Different surfaces have different spectral signatures.
- In this example, you can see the differences between Water, Vegetation, and Soil signatures.



Spectral Resolution

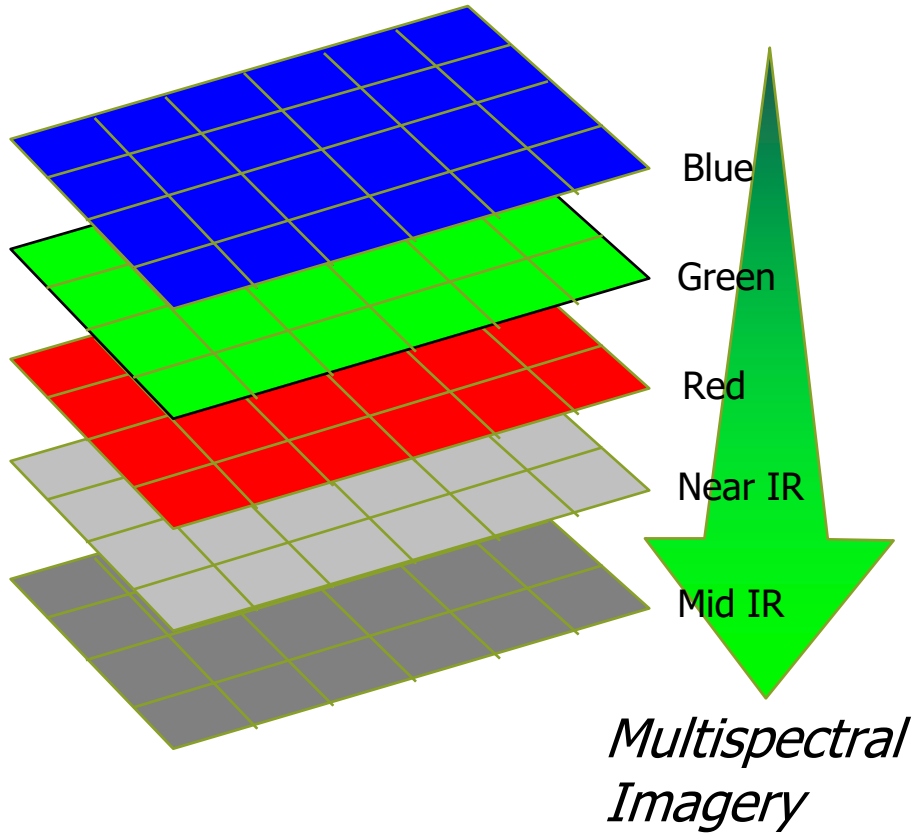
- The ability of a sensor to define wavelength intervals.
- Each "band" represents a different part of the electromagnetic spectrum.



Spectral reflectance is the ratio of reflected energy to incident energy as a function of wavelength.

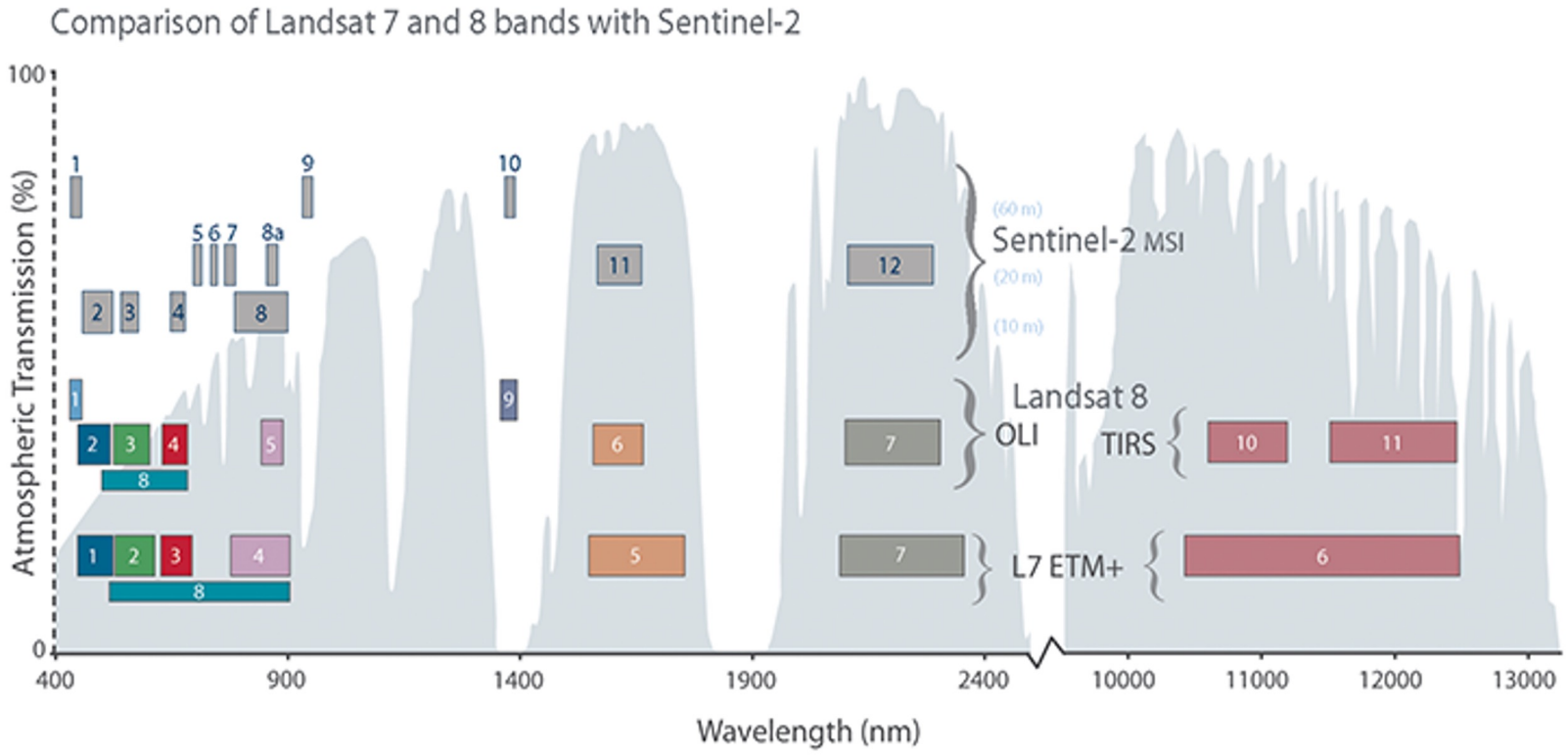
Spectral Resolution: Image Bands

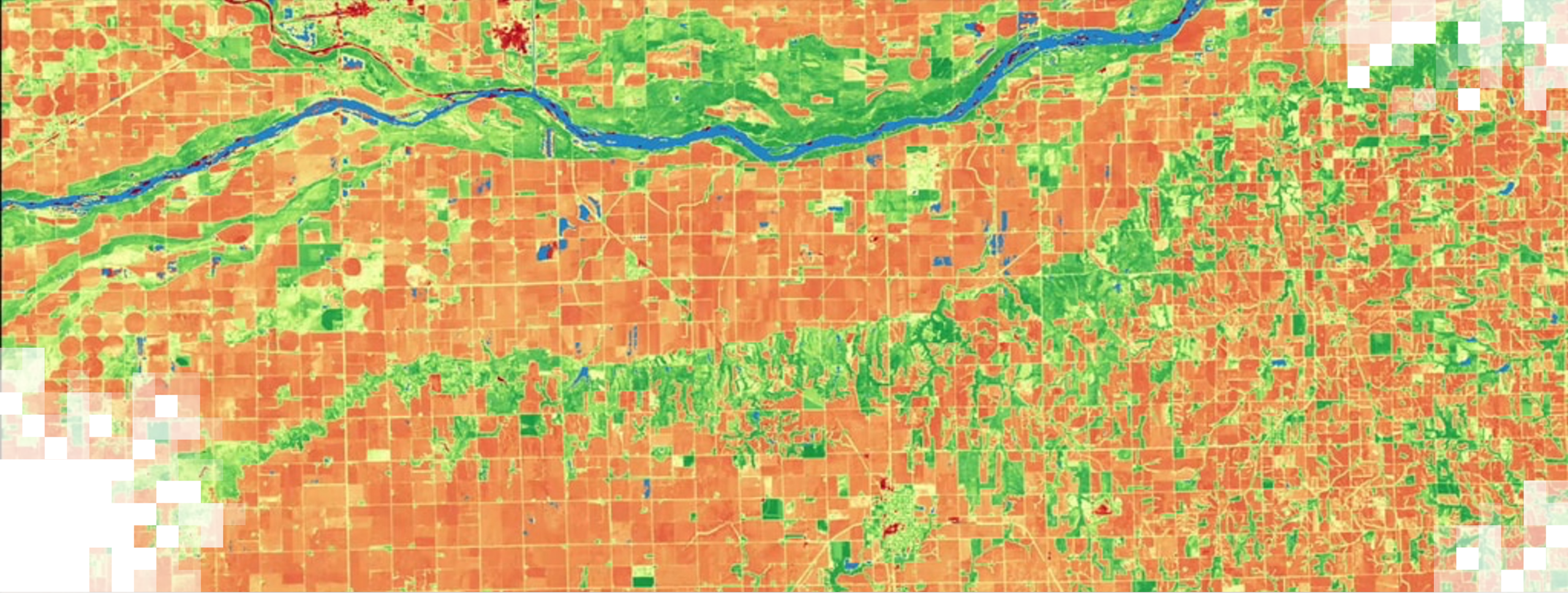
Each image band is a different layer in an image.



Spectral Characteristics of Landsat and Sentinel-2

- Landsat instruments measure primarily light that is **reflected** from Earth's surface (with one exception).
- Landsat instruments are designed to detect visible and infrared (near and mid) wavelengths.





Part 2:

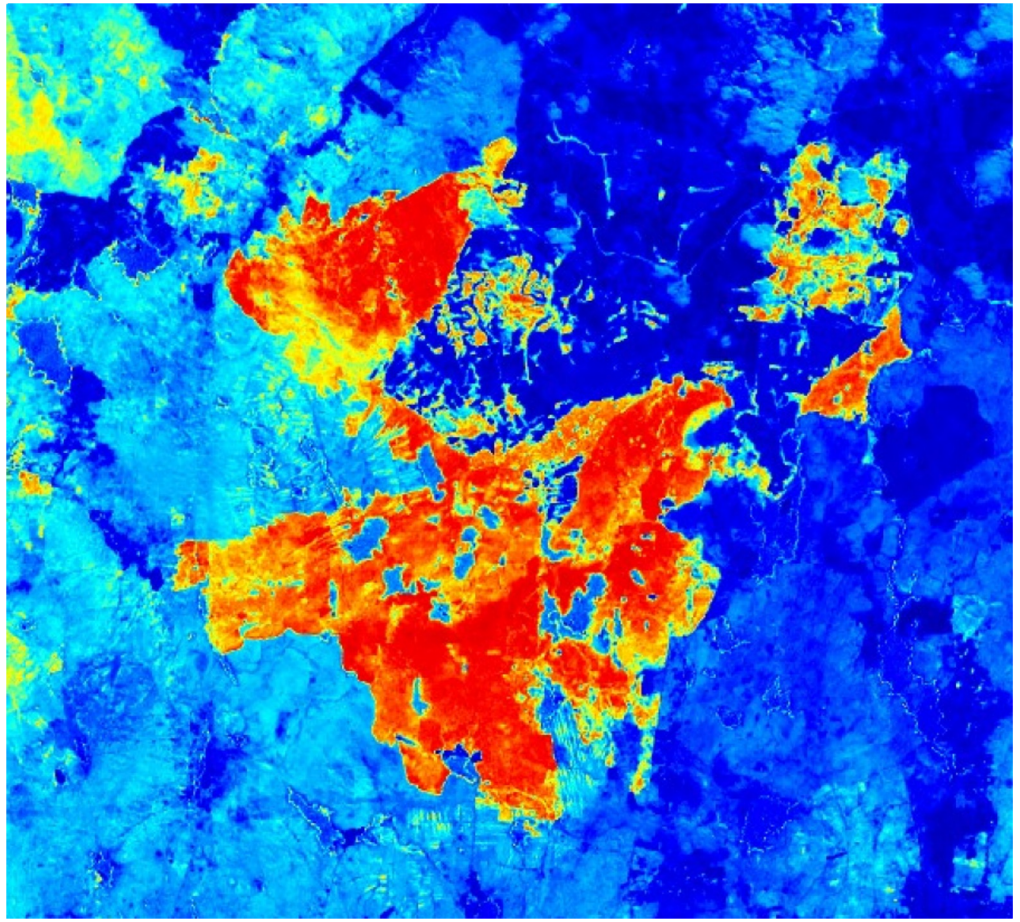
Spectral Indices and NDVI

What is a spectral index?

- A mathematical equation that is applied on the various spectral bands of an image per pixel
- Simple band ratios that highlight a specific process or property on the land surface
- Reduce effects of atmosphere, instrument noise, sun angle: allows for consistent spatial and temporal comparisons

Applications of Spectral Indices

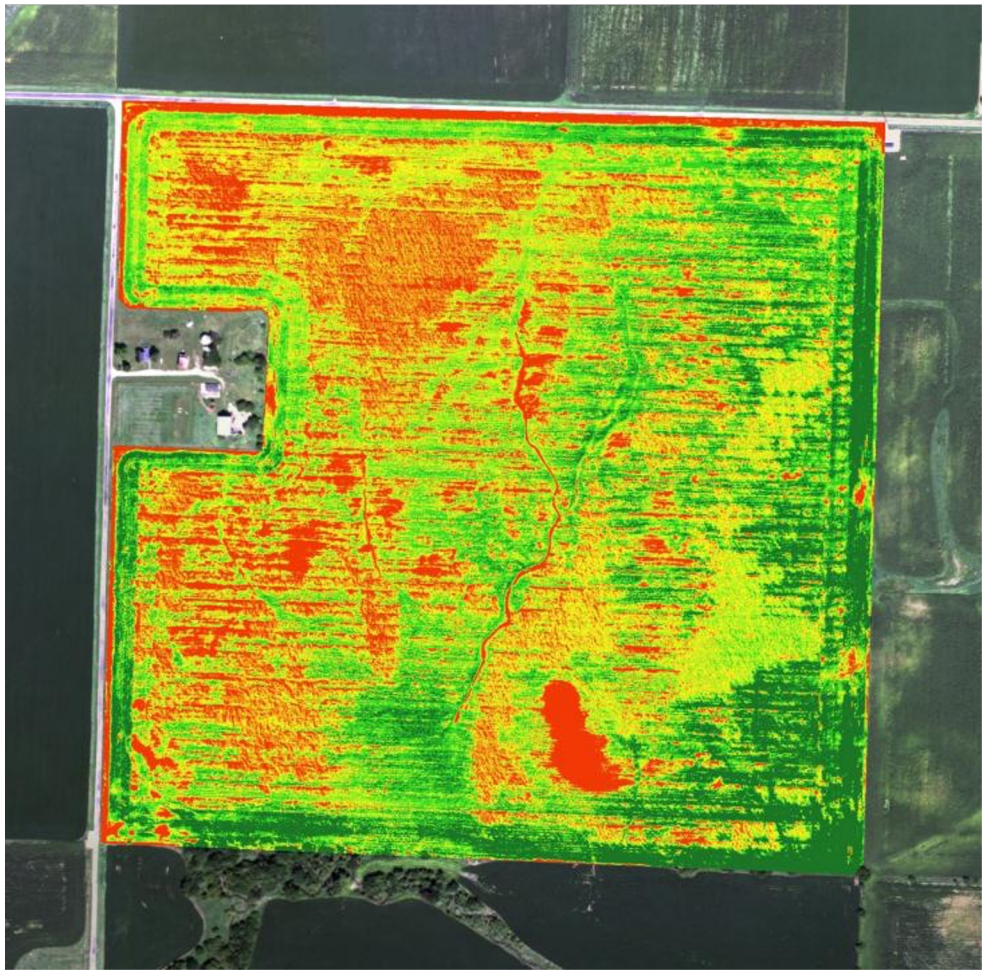
- Vegetation Health
- Burned Area Mapping and Fire Severity
- Water Content
- Biophysical Parameters (i.e., biomass)
- Geologic Mapping



Moisture Index of Wildfire (Wildfire in red, orange)

Normalized Difference Vegetation Index (NDVI) Applications

- Vegetation Health
  - Crop Health
- Phenology
- Drought Indicator
  - Soil Moisture
- Leaf Area Index (LAI)
- Carbon Monitoring



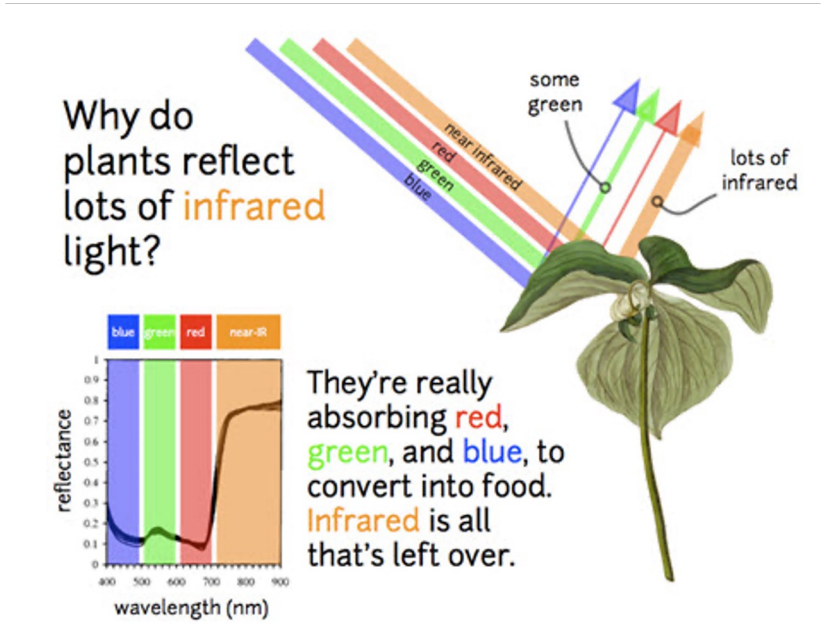
Credit: http://geovantage.com/applications/precision-agriculture/crop-health/

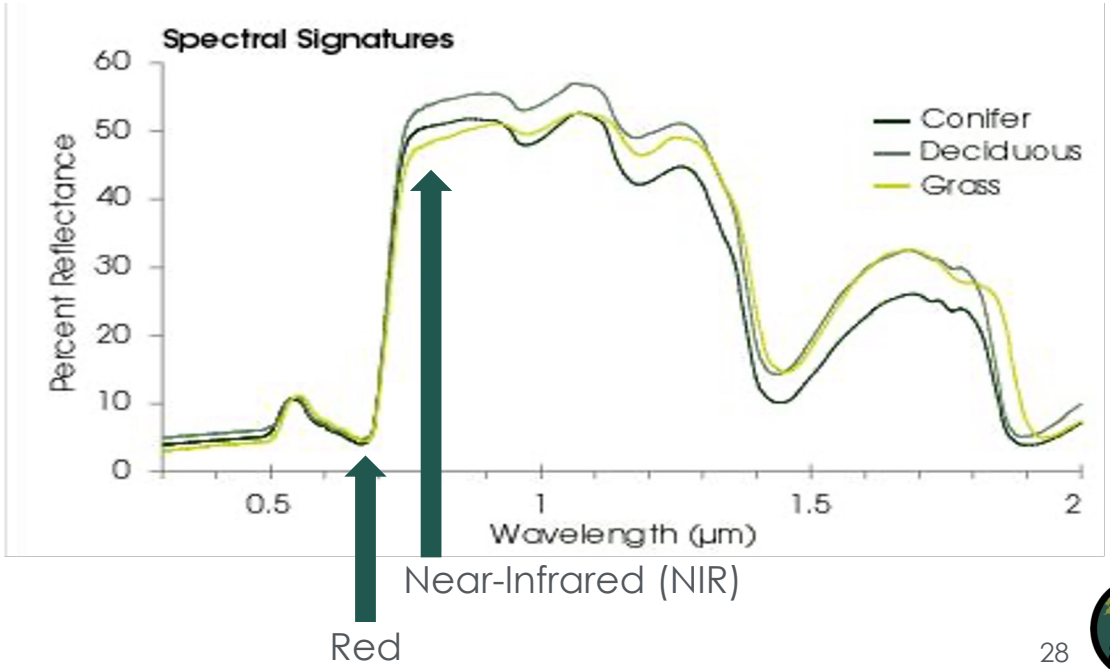
Spectral Indices we will Cover in this Training

- **NDVI** - Normalized Difference Vegetation Index — **Part 1**
- **NDTI** - Normalized Difference Turbidity Index
- **NDCI** - Normalized Difference Chlorophyll Index
- **FAI** - Floating Algae Index
- **AFAI** - Alternate Floating Algae Index
- **NDAVI** - Normalized Difference Aquatic Vegetation Index — **Part 2**
- **EVI** - Enhanced Vegetation Index
- **SAVI** - Soil-Adjusted Vegetation Index
- **NBR** - Normalized Burn Ratio — **Part 3**

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: Overview

- NDVI Formula:

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

- 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.

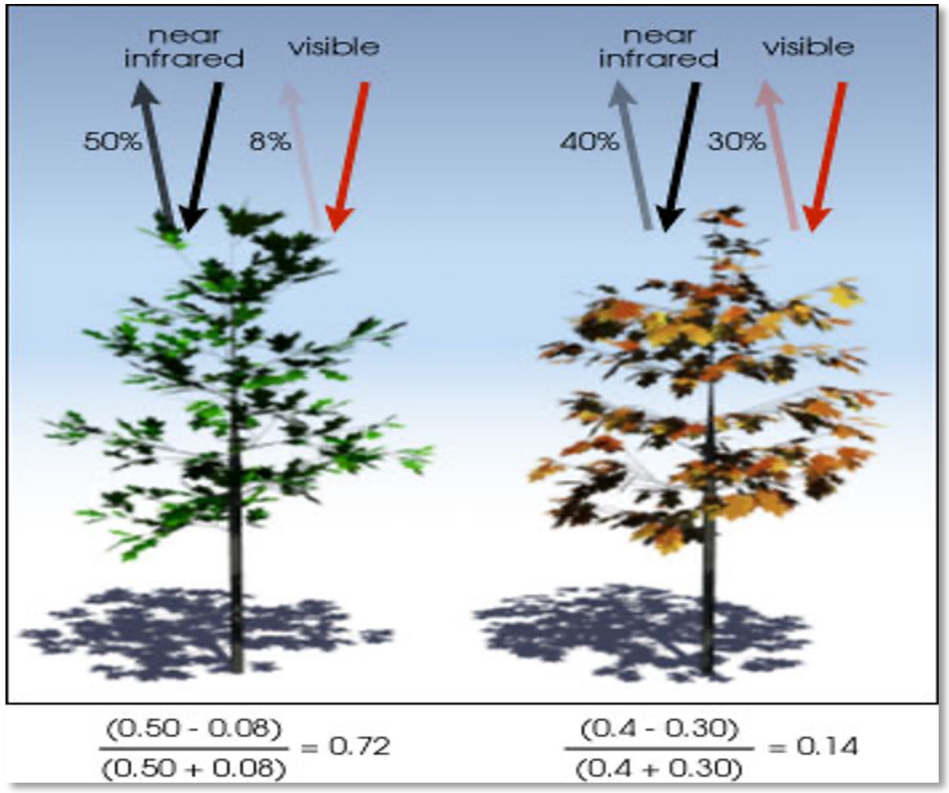
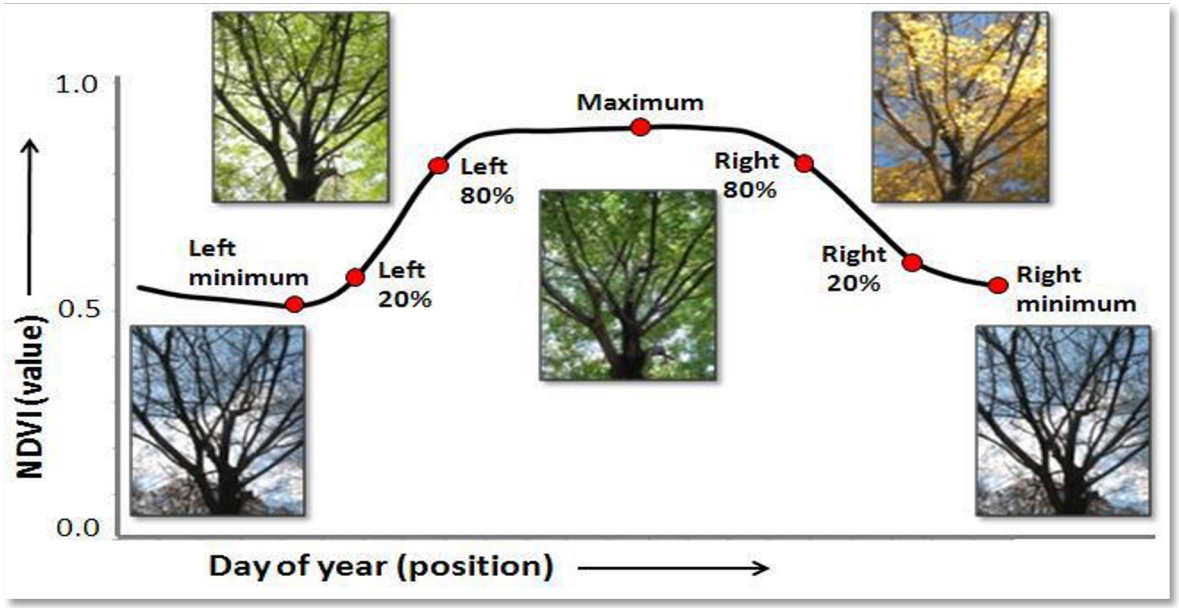


Image Credit: Robert Simmon

NDVI and Seasonality

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



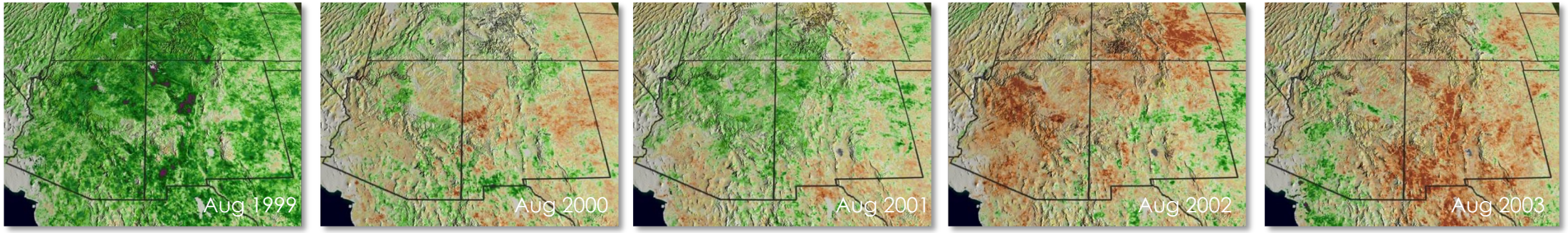
NDVI Images of North America in Winter and Summer

Credit: spacegrant.montana.edu

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



Landsat Bands

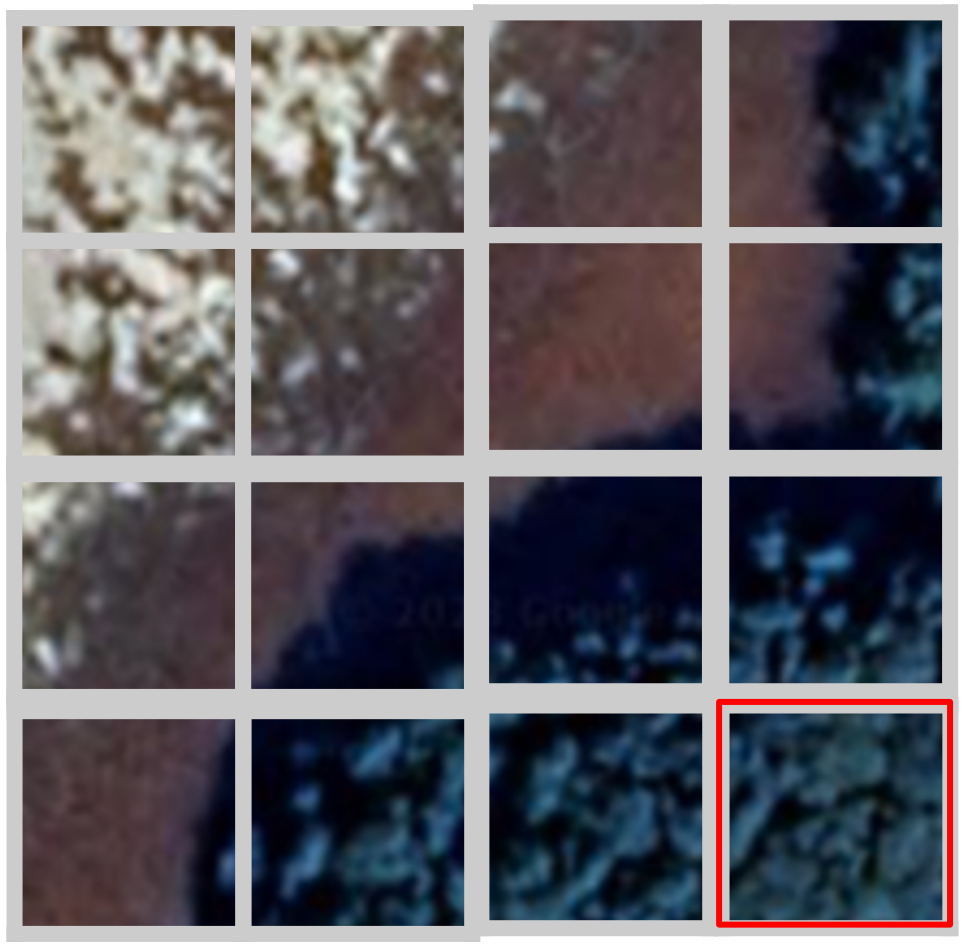
Landsat 8 & 9 OLI and *TIRS* Bands (µm)			**Landsat 7 ETM+ Bands (µm)**		
Band 1	30 m Coastal/Aerosol	0.43-.045			
Band 2	30 m Blue	0.45-.051	Band 1	30 m Blue	0.44-0.51
Band 3	30 m Green	0.53-0.60	Band 2	30 m Green	0.52-0.60
Band 4	30 m Red	0.63-0.68	Band 3	30 m Red	0.63-0.69
Band 5	30 m NIR	0.85-0.88	Band 4	30 m NIR	0.77-0.90
Band 6	30 m SWIR-1	1.57-1.65	Band 5	30 m SWIR-1	1.55-1.75
Band 10	100 m *TIR-1*	10.60-11.19	Band 6	60 m TIR	10.40-12.50
Band 11	100 m *TIR-2*	11.50-12.51			
Band 7	30 m SWIR-2	2.11-2.29	Band 7	30 m SWIR-2	2.08-2.35
Band 8	15 m Pan	0.5-0.68	Band 8	15 m Pan	0.52-0.90
Band 9	30 m Cirrus	1.36-1.38			

Sentinel-2B Bands

Sentinel-2B Bands *Central Wavelength (nm)*			
Band 1	60 m	Blue (Coastal and Aerosol)	*442*
Band 2	10 m	Blue	*492*
Band 3	10 m	Green	*559*
Band 4	10 m	Red	*665*
Band 5	20 m	Visible and Near Infrared (VNIR)	*704*
Band 6	20 m	Visible and Near Infrared (VNIR)	*739*
Band 7	20 m	Visible and Near Infrared (VNIR)	*780*
Band 8	10 m	Visible and Near Infrared (VNIR)	*833*
Band 8a	20 m	Visible and Near Infrared (VNIR)	*864*
Band 9	60 m	Short Wave Infrared (SWIR)	*943*
Band 10	60 m	Short Wave Infrared (SWIR)	*1377*
Band 11	20 m	Short Wave Infrared (SWIR)	*1610*
Band 12	20 m	Short Wave Infrared (SWIR)	*2186*

Spectral - Sentinel Online (esa.int)

NDVI Example Calculation

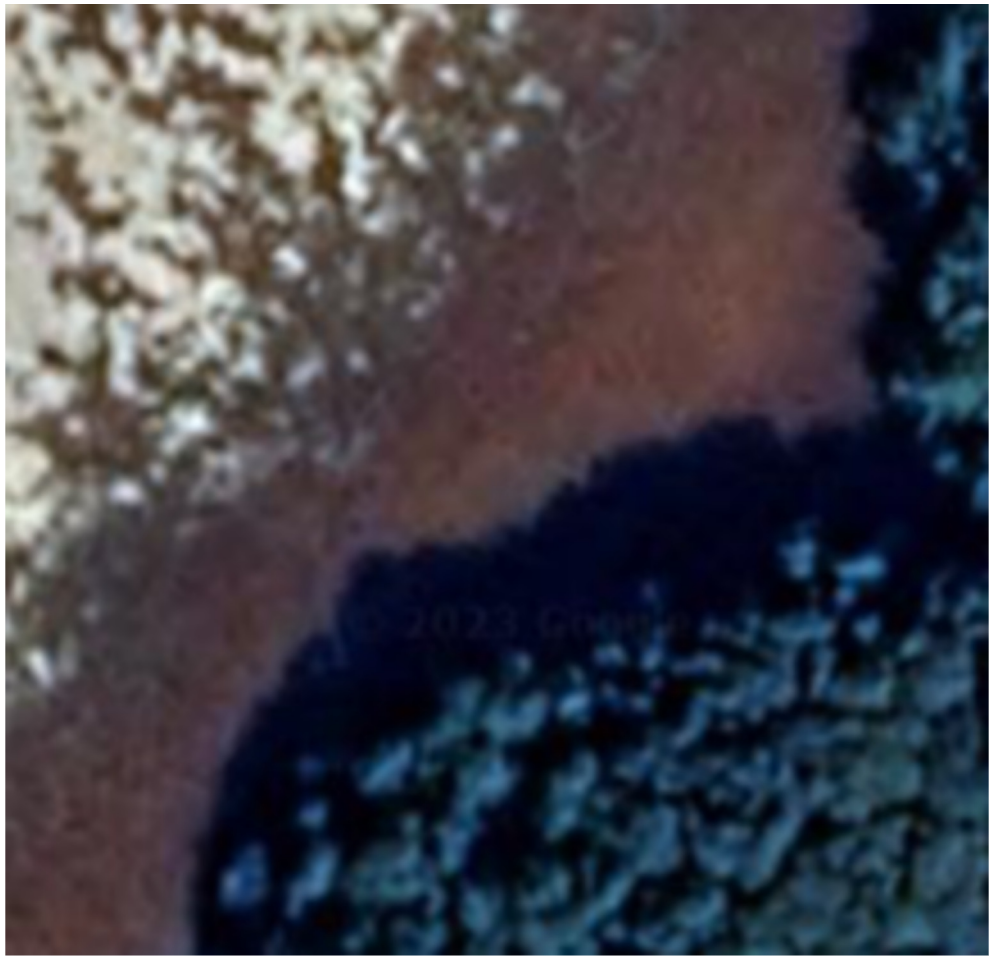


Near Infrared
(Landsat 9 Band 5)

.1144

Red
(Landsat 9 Band 4)

.0344



Near Infrared | Red

.1144 − .0344

.1144 + .0344

NDVI = .538

Near Infrared	
.0214	.0313
.0031	.1144

−

Red	
.0473	.0444
.0415	.0344

.0214	.0313
.0031	.1144

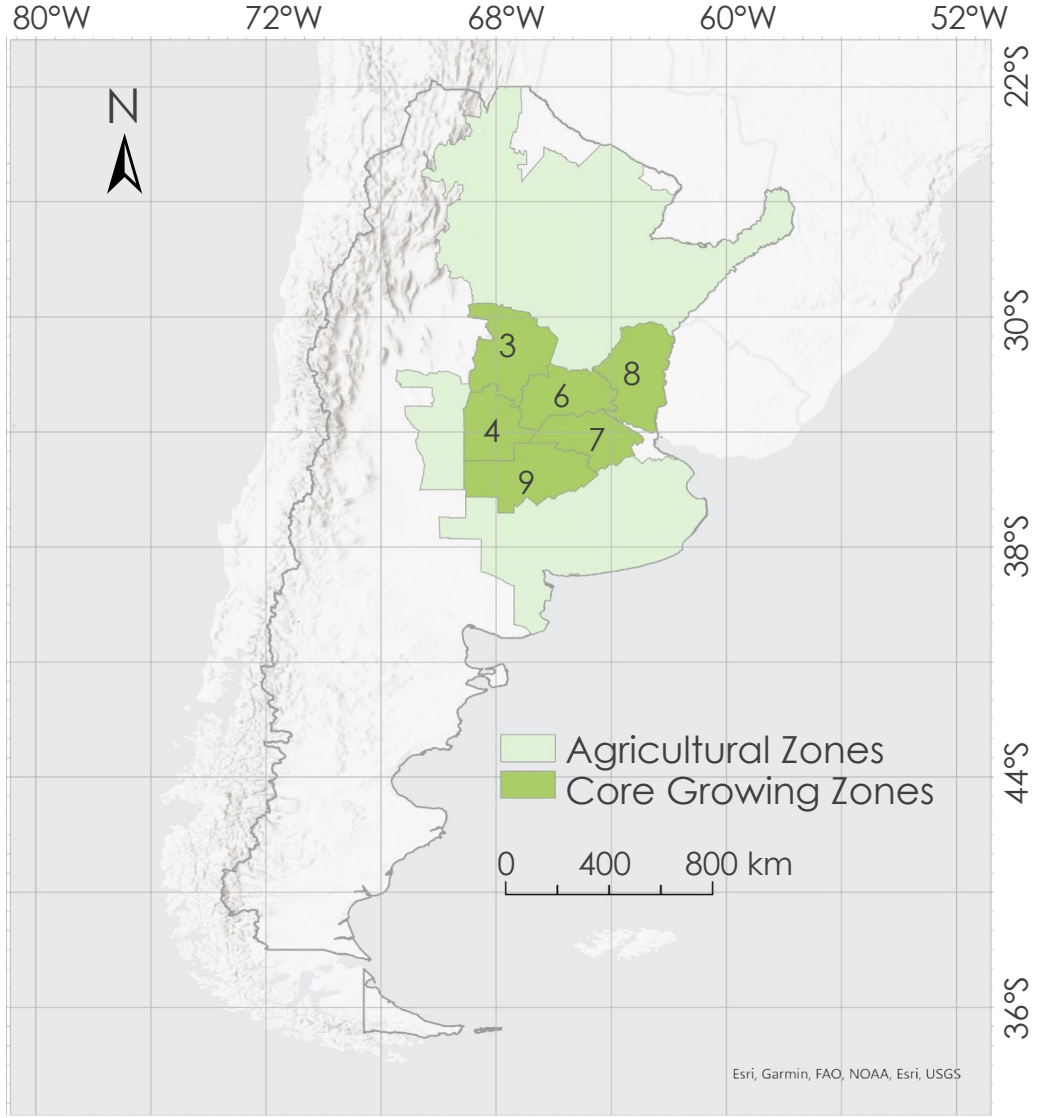
+

.0473	.0444
.0415	.0344

=

NDVI	
-.377	-.174
-.862	.538

NDVI Example: Argentina



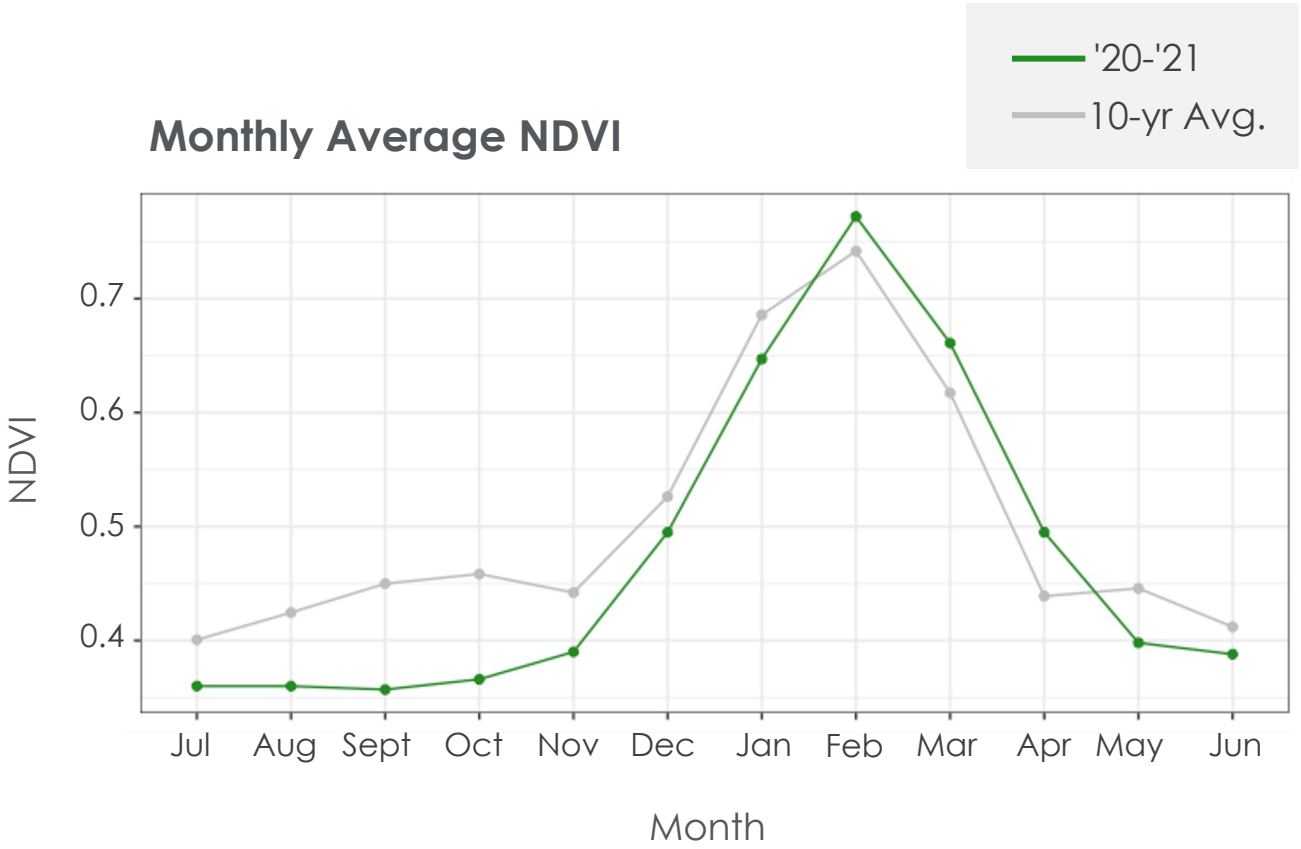
Argentina
Agriculture & Food Security

Crop Monitoring and Forecasting for Argentina Using NASA Satellite Observations

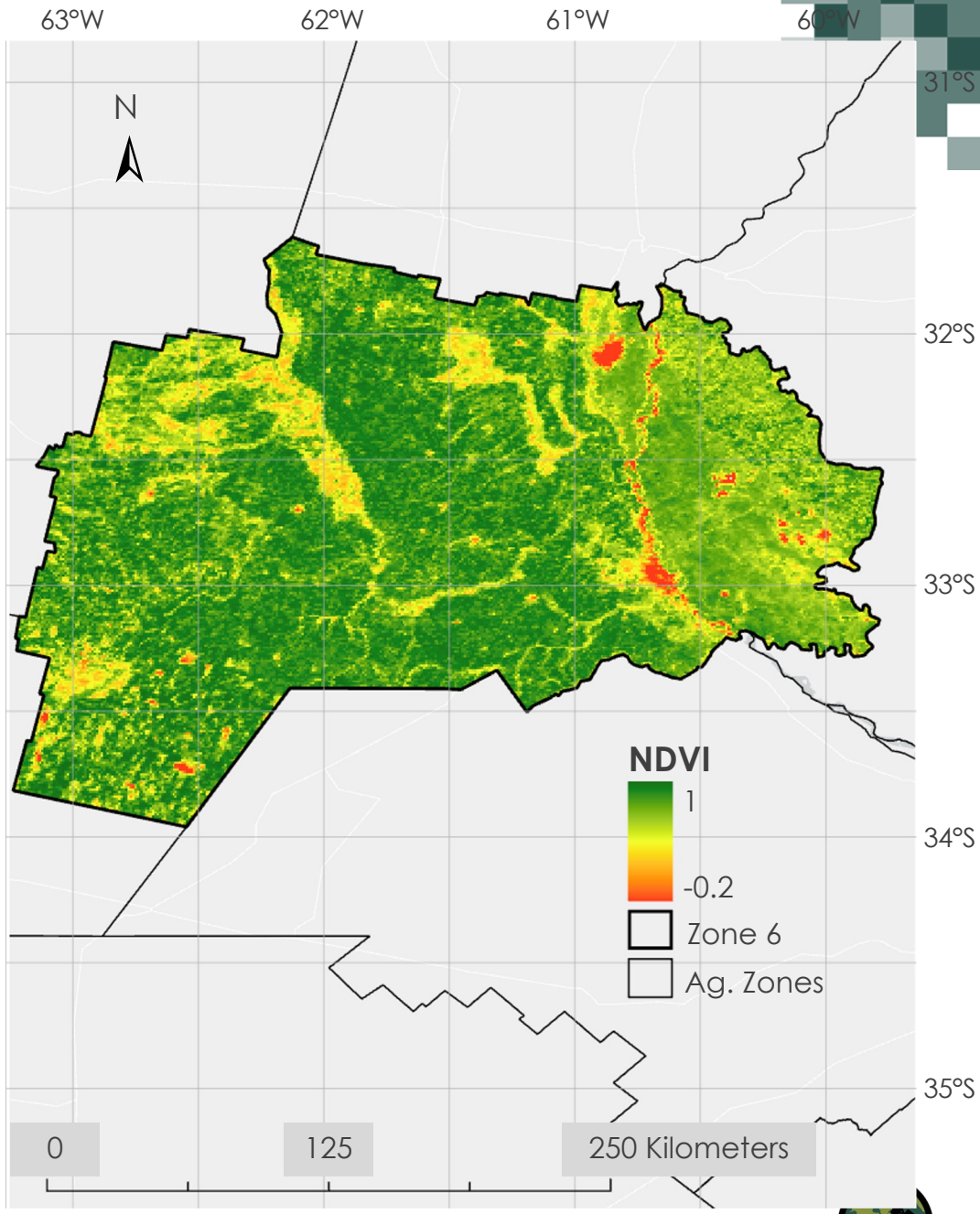
Project Team: Brooke Egley, Ryan Lam, Tyler Pantle, Sienna Templeman, & Caroline Williams
Advisors: Dr. John D. Bolten, Dr. Nazmus Sazib
PI: Dr. Nicole Ramberg-Phil

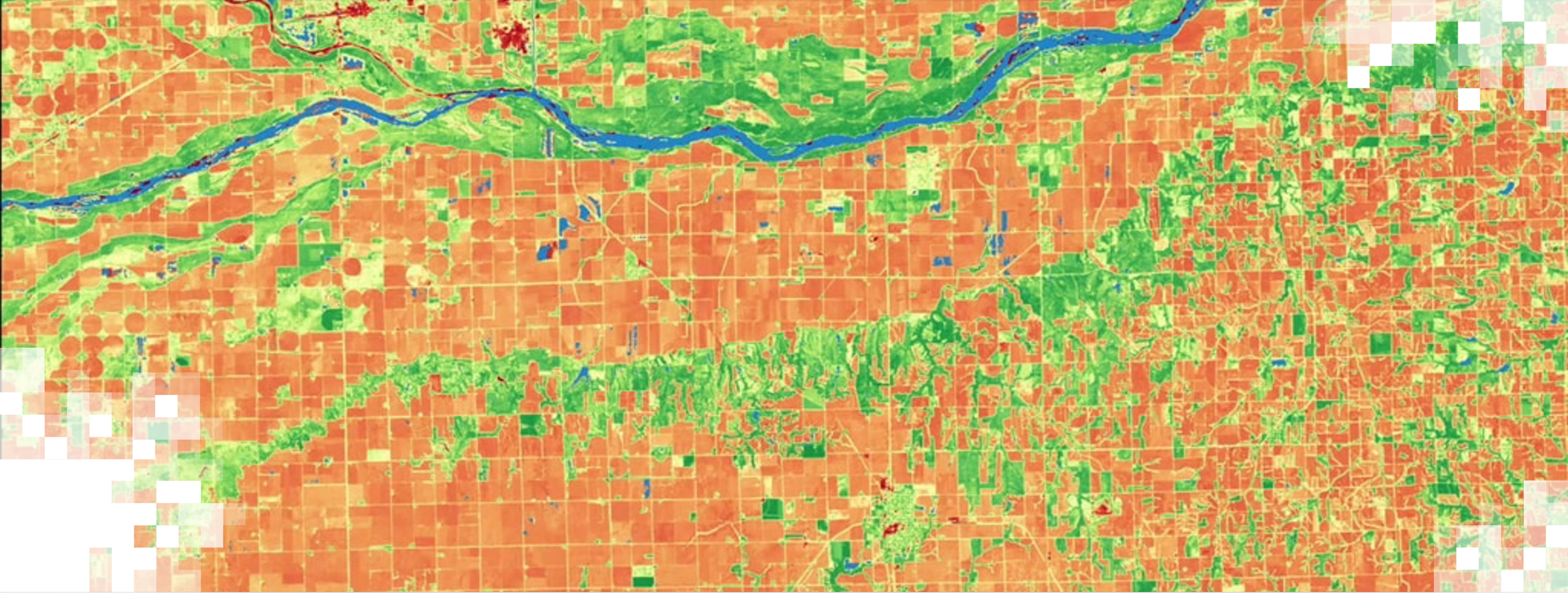
NASA DEVELOP: GSFC

Results: Vegetation – Zone 6



https://appliedsciences.nasa.gov/what-we-do/projects/crop_monitoring_and_forecasting_for_argentina_using_nasa_satellite_observations

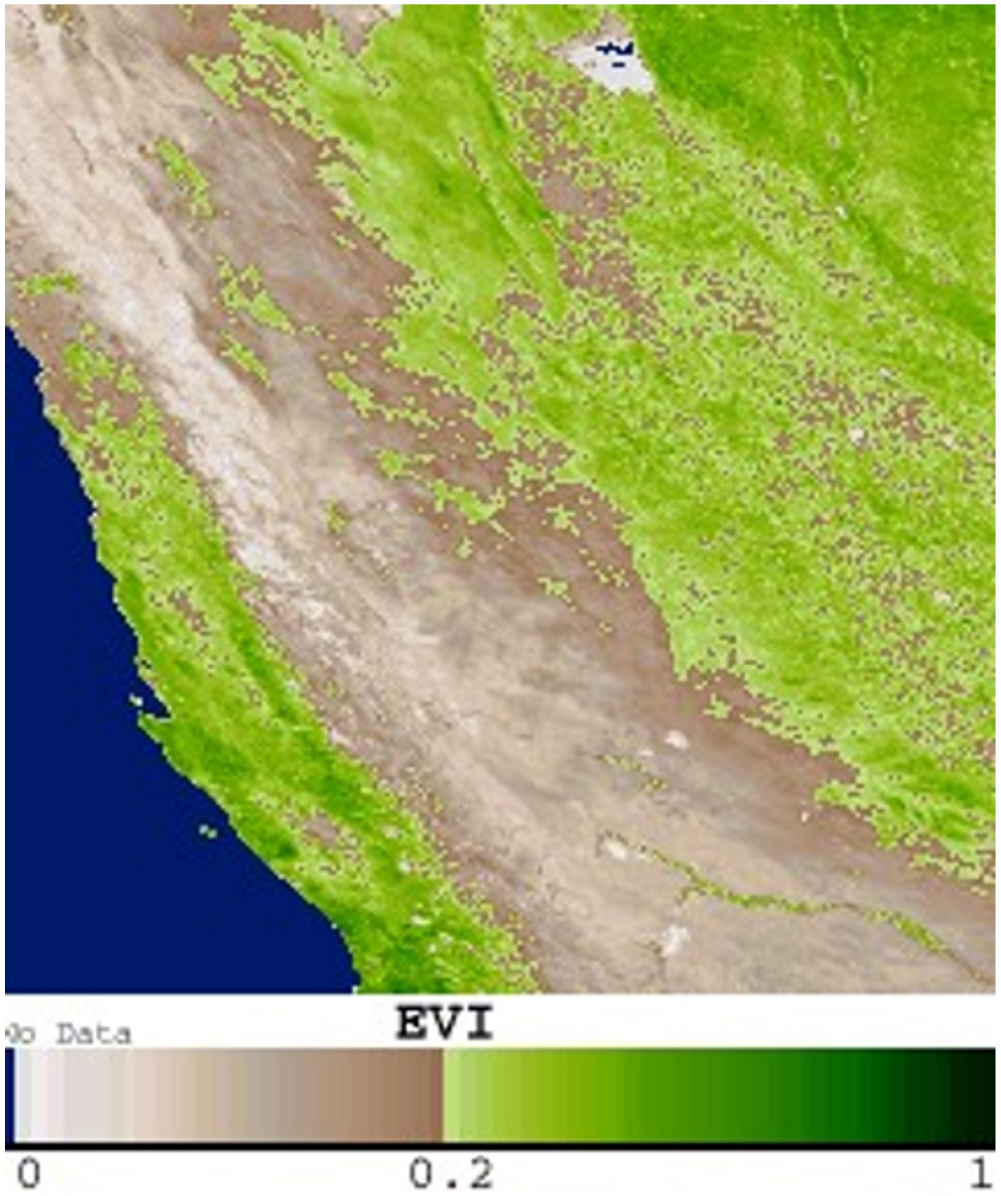




Part 3:
NDVI Data Products

MODIS NDVI and EVI Products

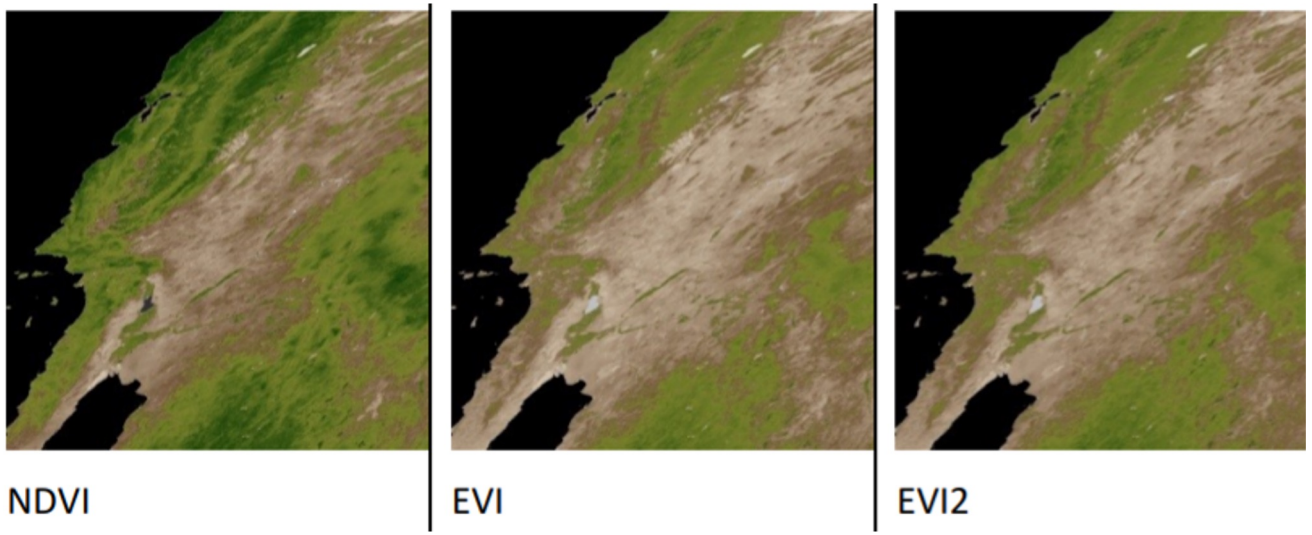
- 16-day Composites
- 250 m, 500 m, and 1 km Resolutions
- Retrieved from daily, atmosphere-corrected, bidirectional surface reflectance
- Collection Names: MOD13 (Terra) and MYD13 (Aqua)
  - Multiple subsets based on spatial resolution
- Product available via the Land Processes Distributed Active Archive Center (LP DAAC) tools:
  - AppEEARS
  - Data Pool
  - Earthdata Search
  - OPeNDAP



MODIS EVI from April 2020 of the western coast of Africa. Image Credit: USGS/NASA

VIIRS NDVI and EVI Products

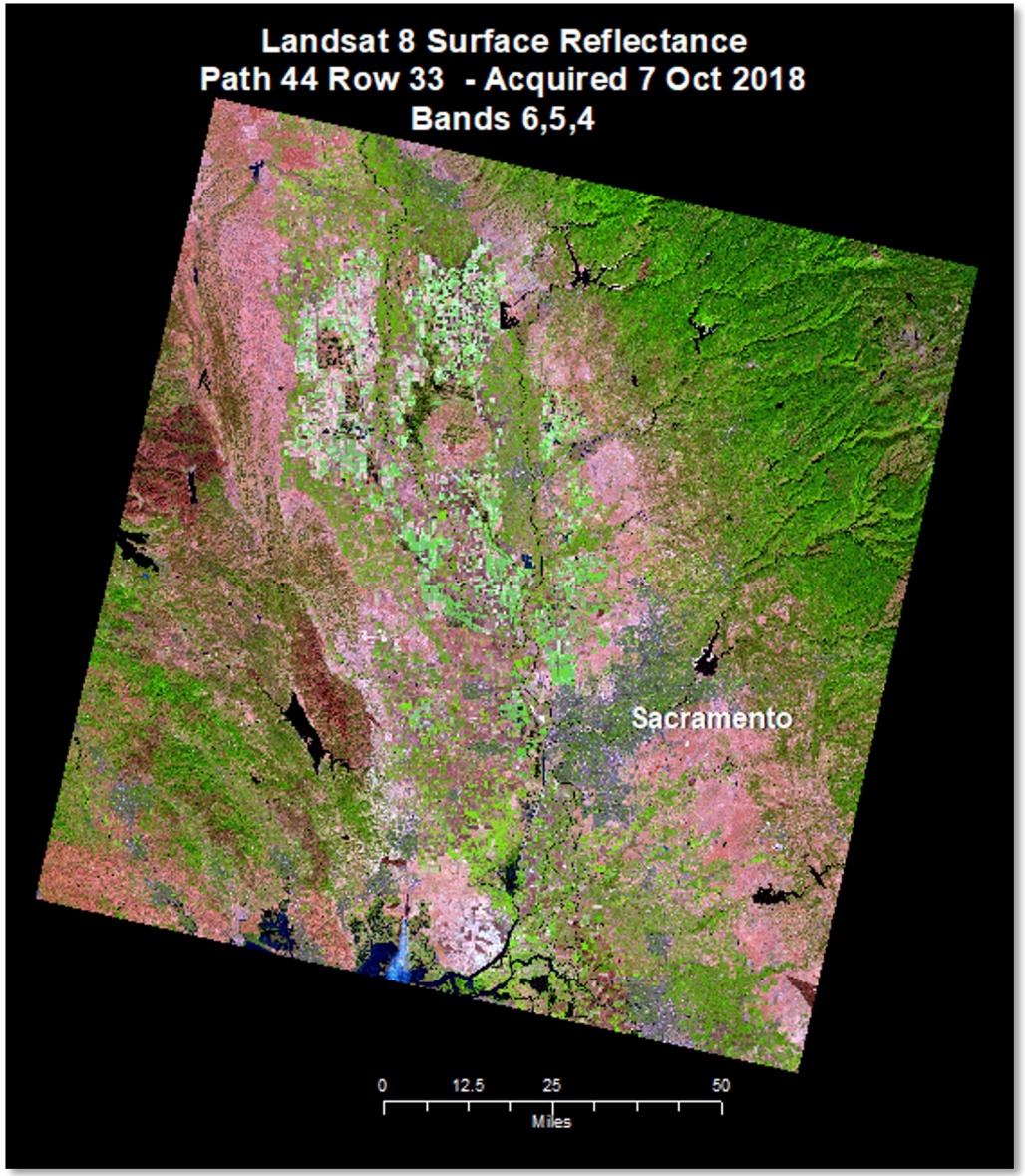
- 16-day Composites of NDVI, EVI, and EVI2
- 500 m, 1 km ,and 0.05-degree Resolutions
- Algorithm selects the best available pixel in a 16-day window
- Collection Name: VNP13
  - Multiple subsets based on spatial resolution
- Product available via the Land Processes Distributed Active Archive Center (LP DAAC) tools:
  - AppEEARS
  - Data Pool
  - Earthdata Search
  - OPeNDAP



NDVI, EVI, and EVI2 from VIIRS over western North America Image Credit: USGS/NASA

Landsat Products

- Temporal Resolution: 16 days
- Spatial Resolution: 30 m
- Multiple products available: NDVI, EVI, SAVI, NDMI, NBR
- Available upon request from: USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface



Animation of the multiple Landsat vegetation indices available. Image Credit: USGS/NASA

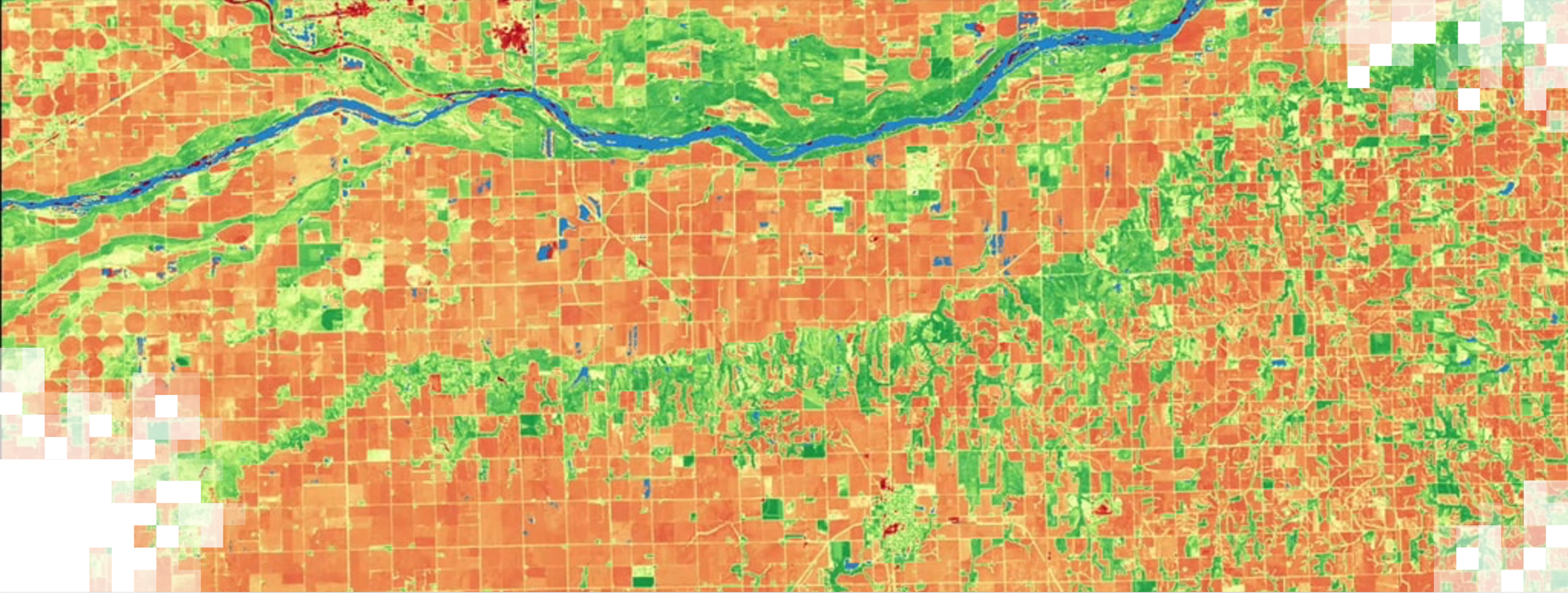
Combined Satellite Products: NDVI and EVI

- The Vegetation Index and Phenology (VIP)
- Daily, weekly, monthly, yearly
- 0.05-degree Resolution (5,600 m)
- NDVI, EVI, EVI2
- 34 years of a consistent, global record of vegetation indices and landscape phenology.
- Based on MODIS, AVHRR, and Satellite Pour l'Observation de la Terre (SPOT) data inputs
- Making Earth System Data Records for Use in Research Environments (MEaSUREs) Program

NDVI AVHRR Composite for September 17-30, 2013. Image Credit: USGS/NASA

Satellite Needs Working Group (SNWG)

- Conducts biennial survey to document Earth Observing needs to NASA and other agencies
- Identified needs and new data products:
  - Harmonization of data sets from Landsat and Sentinel-2 (operational)
  - Multi-satellite products for surface water extent, surface disturbance/change detection, and surface deformation (in development)
  - ICESat-2 Quick Look products (operational)
  - Enhanced downlink bandwidth for the NISAR Mission (in development)
  - Expanded access for Federal agencies to commercial data purchased and evaluated by NASA (operational)



Index Calculation in Google Earth Engine

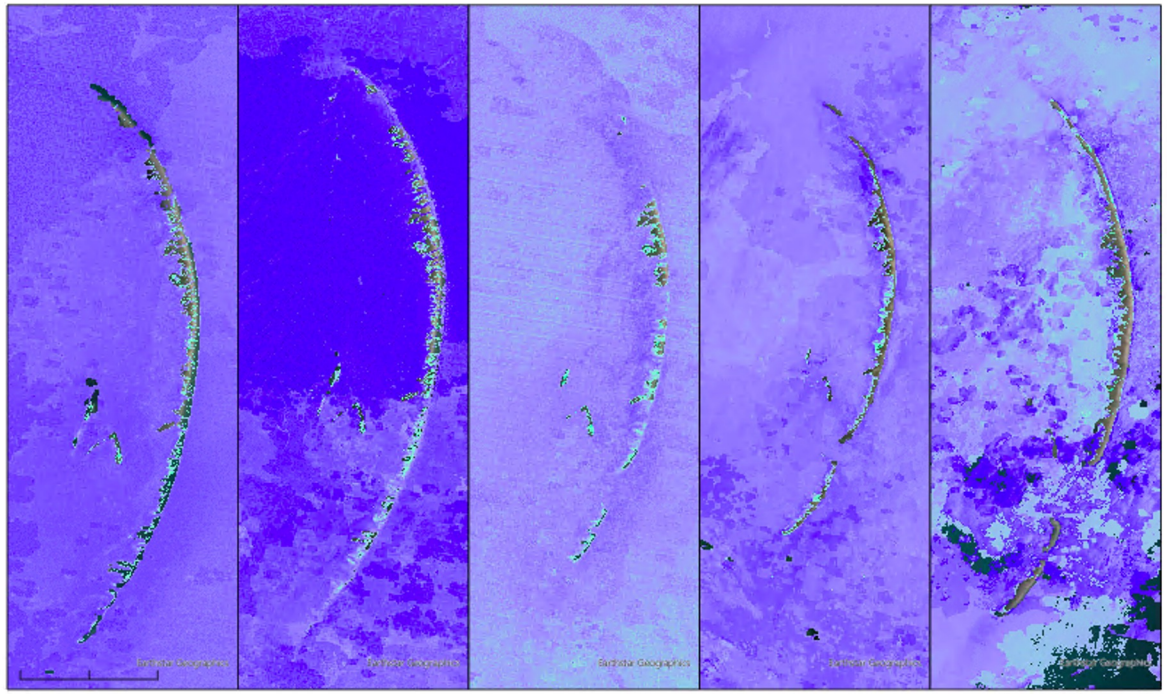
CODE LINK:
https://code.earthengine.google.com/1c9a5811b4892272233def83baa7f902

Summary

- Every surface on Earth reflects and absorbs energy in different ways.
  - Using this information from different bands of a satellite image can help us better understand the features on Earth.
- A spectral index is a mathematical equation that is applied on the various spectral bands of an image per pixel.
  - Simple band ratios that highlight a specific process or property on the land surface.
- The NDVI is the most used vegetation index globally.
  - It is a simply ratio between the NIR and Red bands and can be used to identify vegetation vigor.
- There are many other spectral indices that can be used for aquatic and land applications – stay tuned!

Looking Ahead to Part 2

- In Part 2 of this webinar series, we will concentrate on **aquatic applications of spectral indices** including, but not limited to, the Normalized Difference Turbidity Index (NDTI), the Normalized Difference Chlorophyll Index (NDCI), and the Normalized Difference Aquatic Vegetation Index (NDAVI).



NDAVI around the Chandeleur Islands from Summer 2000 – Summer 2020

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 9/Nov/2023
  - Access from: Spectral Indices for Land and Aquatic Applications
  - Answers must be submitted via Google Forms
  - **Due by 23/Nov/2023**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

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Thank You!