



National Aeronautics and
Space Administration

National Association of Conservation Districts Workshop Series Two

From Vegetation Health to Water Quality: Earth Observation Vegetation Indices for Agricultural Applications

Kait Lemon

Applied Remote Sensing Training (ARSET)

Kaitlyn.I.Lemon@nasa.gov



Credit: [NASA](#)

NASA Applied Remote Sensing Training (ARSET) Program



Today's Agenda

- Introduction
- Section 1. Reviewing NASA's Optical Earth Observing Satellite Constellation and Spectral Bands
- Section 2. Calculating and Analyzing Vegetation Dynamics using Vegetation Indices from Optical Satellite Sensors
- Section 3. Accessing Harmonized Landsat Sentinel-2 (HLS) Vegetation Indices with AppEEARS
- Section 4. Visualizing and Interpreting Vegetation Index Raster Images using GIS Software
- Training Conclusion



Learning Objectives

- Download NASA data products for a specific region using shapefile uploads and drawn polygons
- Calculate and analyze vegetation indices using optical satellite imagery
- Interpret changes in vegetation indices over time (or across a time interval) to determine vegetation health, bare ground, and surface water availability
- Visualize and manipulate NDVI in GIS software

Reviewing NASA's Optical Earth Observing Satellite Constellation and Spectral Bands



Satellite Characteristics Overview

What parts of the Earth can the sensor see?

Orbits: Polar/Non-Polar Orbit vs. Geostationary

Can the sensor make observations at night? Can it see through clouds?

Energy Source: Passive vs. Active

Can the sensor make observations at night? Can it see through clouds?

Spectral range: Visible, UV, IR, Microwave...

What features will I be able to see?
How often are observations made over my location of interest?

Resolution Type and Quality: Spatial, Temporal, Spectral, Radiometric

Is the data product I want available from this sensor?

Application: Weather, Ocean Color, Land Mapping, Air Quality, Radiation Budget, etc.

Satellites and Sensors: Optical Sensors

Satellites Orbits	Sensors	Spectral Measurements	Temporal Coverage, Observation Time, and Resolution	Spatial Coverage and Resolution
Landsat 8 Landsat 9 polar	TIRS, OLI TIRS-2, OLI-2	Visible, Near IR, Middle IR, Thermal IR	2/2013 – Present 11/2021– Present 10:30 am/pm local time 16 Day	Global Swath: 136 km 30 m
Terra Aqua Polar	MODIS	Visible, Near IR, Middle IR, Thermal IR	12/1999 – Present (10:30 am/pm) 4/2002 – Present (13:30 am/pm) 1-2 Days	Global Swath: 2330 km 250 m to 1 km
SNPP JPSS polar	VIIRS	Visible, Near IR, Middle IR, Thermal IR	10/28 2011– Present 11/18 2017 – Present 11/10 2022 – Present 1:30 am/pm local time 12 Hours	Global Swath: 3040 km 375 m, 750 m
Sentinel 2A Sentinel 2B & 2C Polar	MSI	Visible, Near IR	6/23/2025 – Present 3/7/2017– Present 10:30 am/pm 5 Day	Global Swath: 290 km 10 m, 20 m, 30 m
PACE Polar	OCI	Visible, Near IR, Shortwave IR	2/8/2024 –Present 1 AM/PM 1 to 2 Days	Global Swath: ~2500 km 1 km

Landsat and Sentinel-2

- **Landsat 8 & 9**

- Launched in 2013 and 2021
- Sensor: Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS)
- Multispectral: 30 and 100-meter pixel bands, 15-meter panchromatic band, 8-day revisit

- **Sentinel-2 a, b, c**

- Launched in 2015, 2017, 2024
- Sensor: Multispectral Instrument (MSI)
- Multispectral: 10, 20, and 60-meter pixel bands, 2–5-day revisit

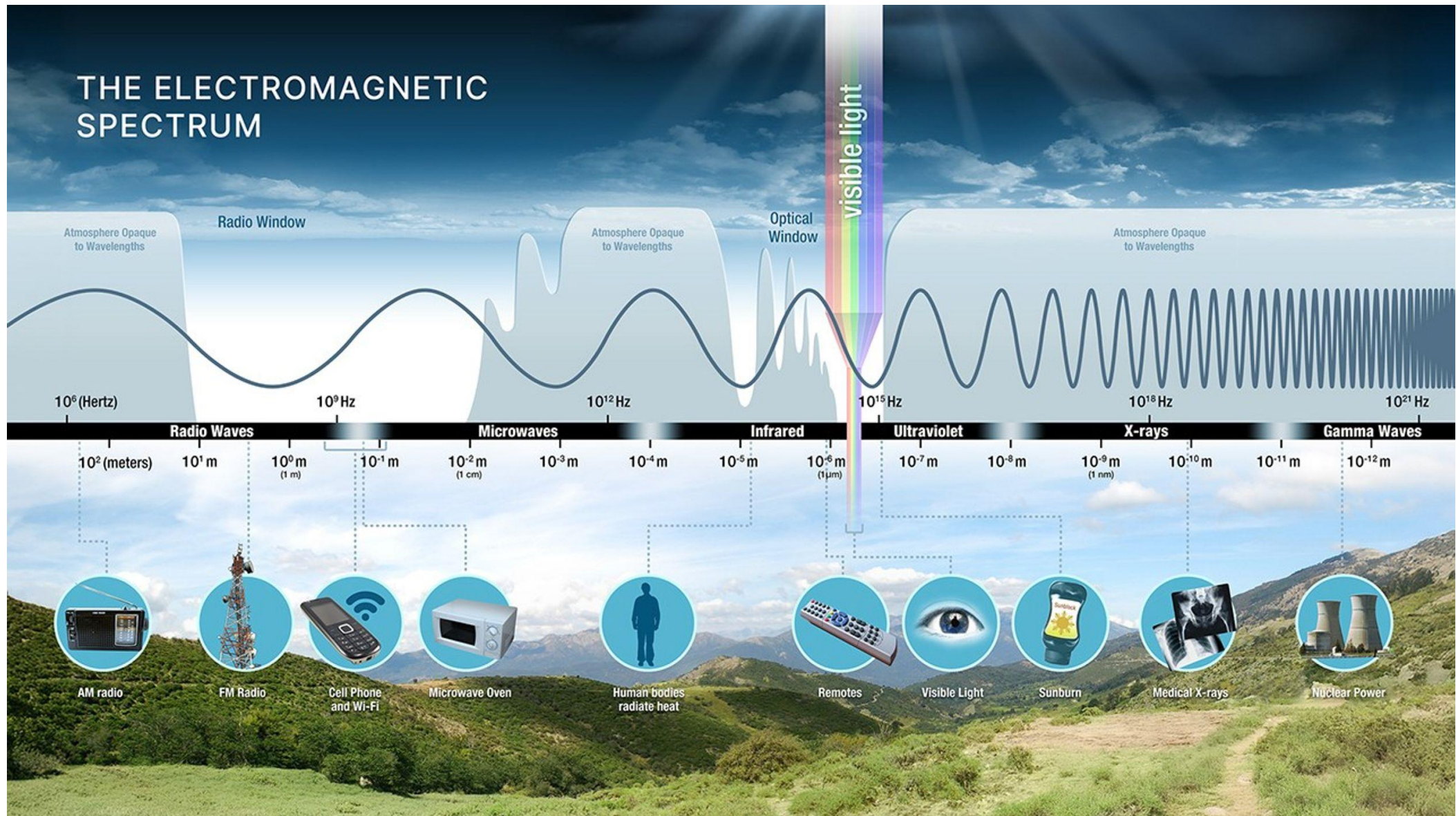
- **Vegetation-Based Applications:**

- Vegetation extent and type
- Vegetation stage and health: variety of vegetation indices, including NDVI, EVI, SAVI
- Vegetation moisture: NDWI



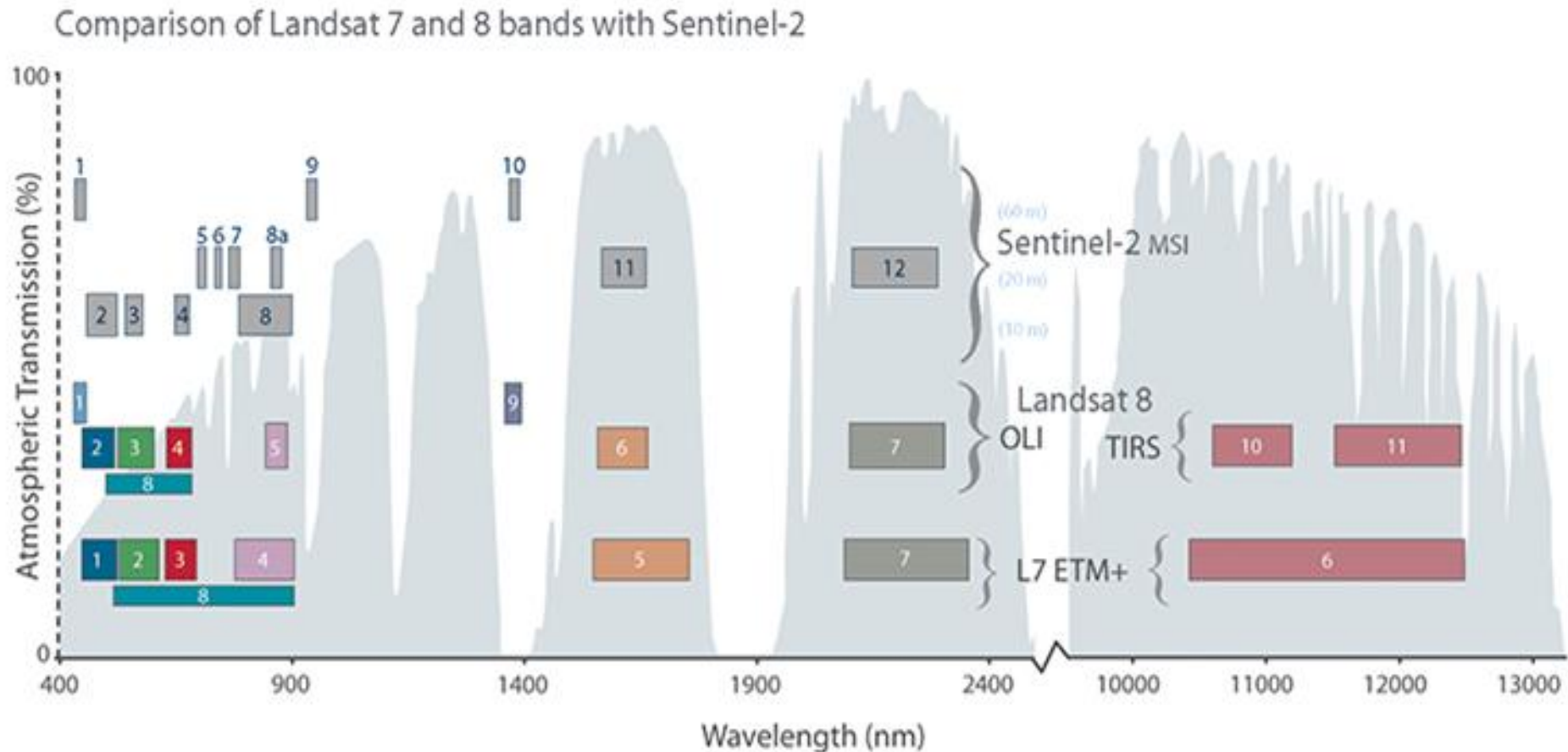
Image Credits: [USGS](#), [ESA](#)

Atmospheric Windows



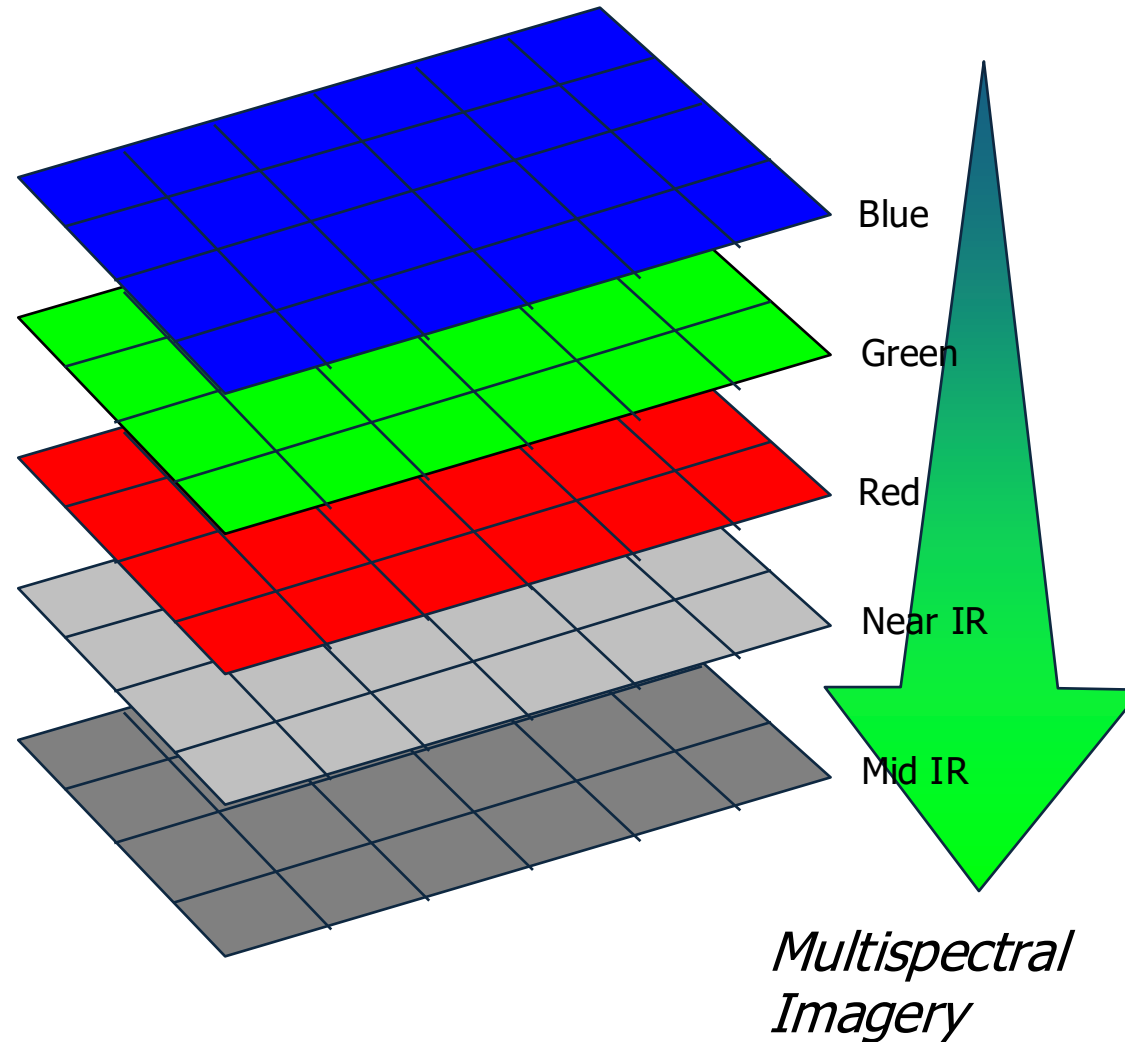
Spectral Characteristics of Landsat and Sentinel-2

- 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



Spectral Resolution: Image Bands

Each image band is a different layer in an image



Interaction with Earth's Surface: Vegetation

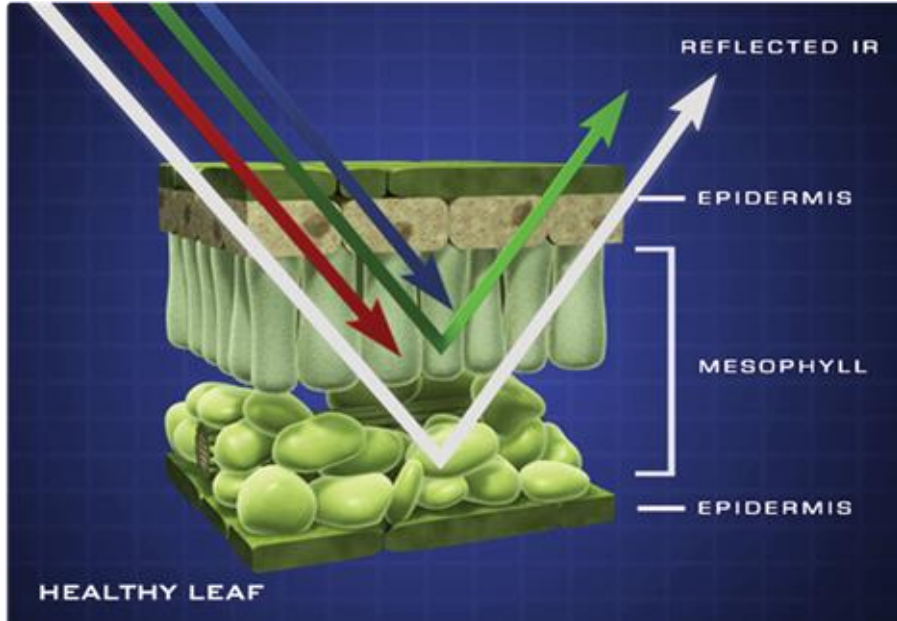
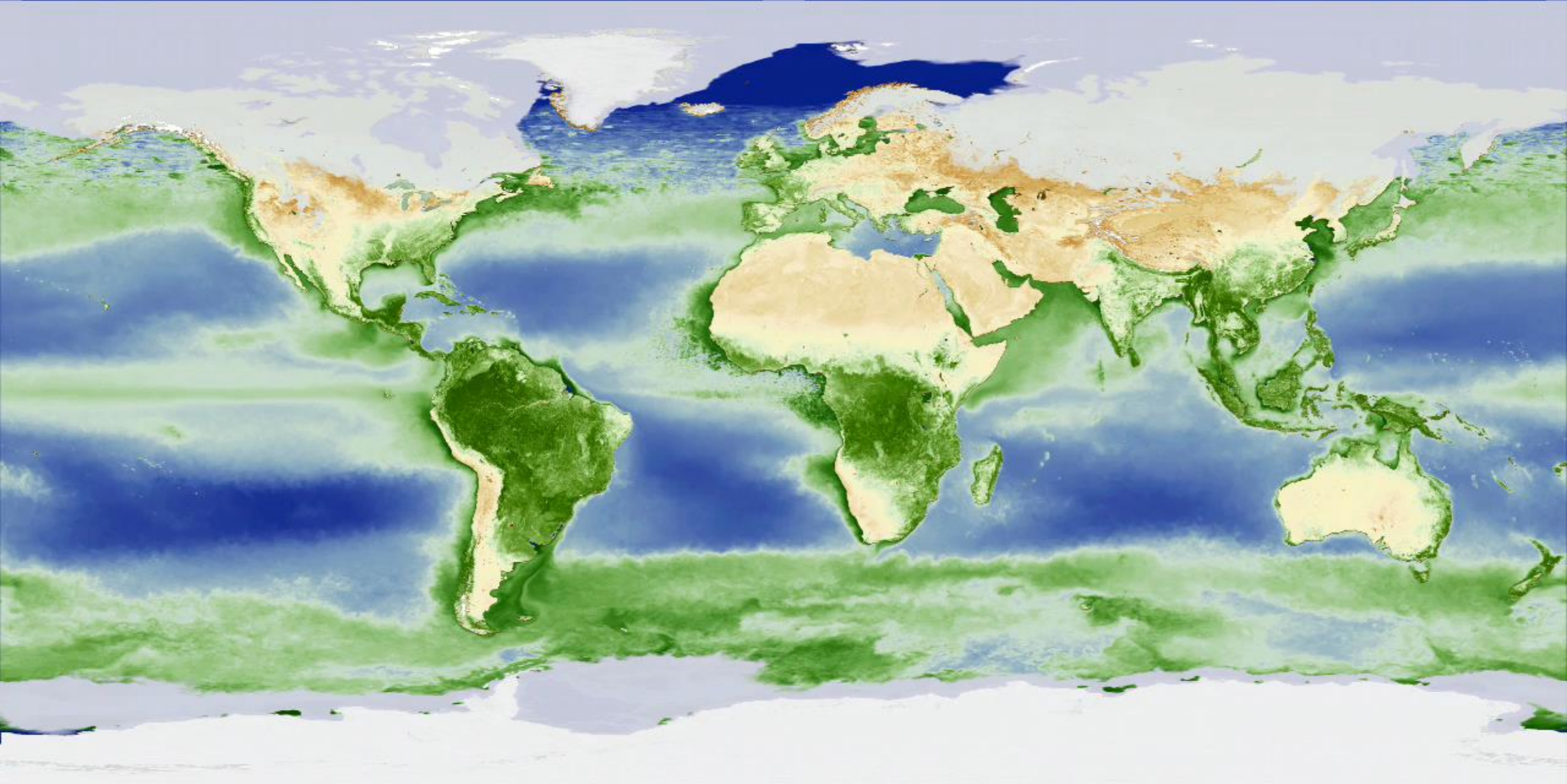


Image Credits: NASA/Jeff Carns & Ginger Butcher

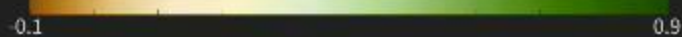
- Healthy, green vegetation:
 - **absorbs Blue** and **Red** wavelengths (photosynthesis), and
 - **reflects Green** and **Infrared**.
- Due to reflection of green wavelength and since we cannot see infrared radiation, we see healthy vegetation as green.
- The amount of reflected energy is dependent on the health of the vegetation, water content, and phenological stage.

Calculating and Analyzing Vegetation Dynamics using Vegetation Indices from Optical Satellite Sensors

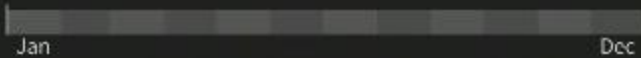




Land Vegetation (NDVI)

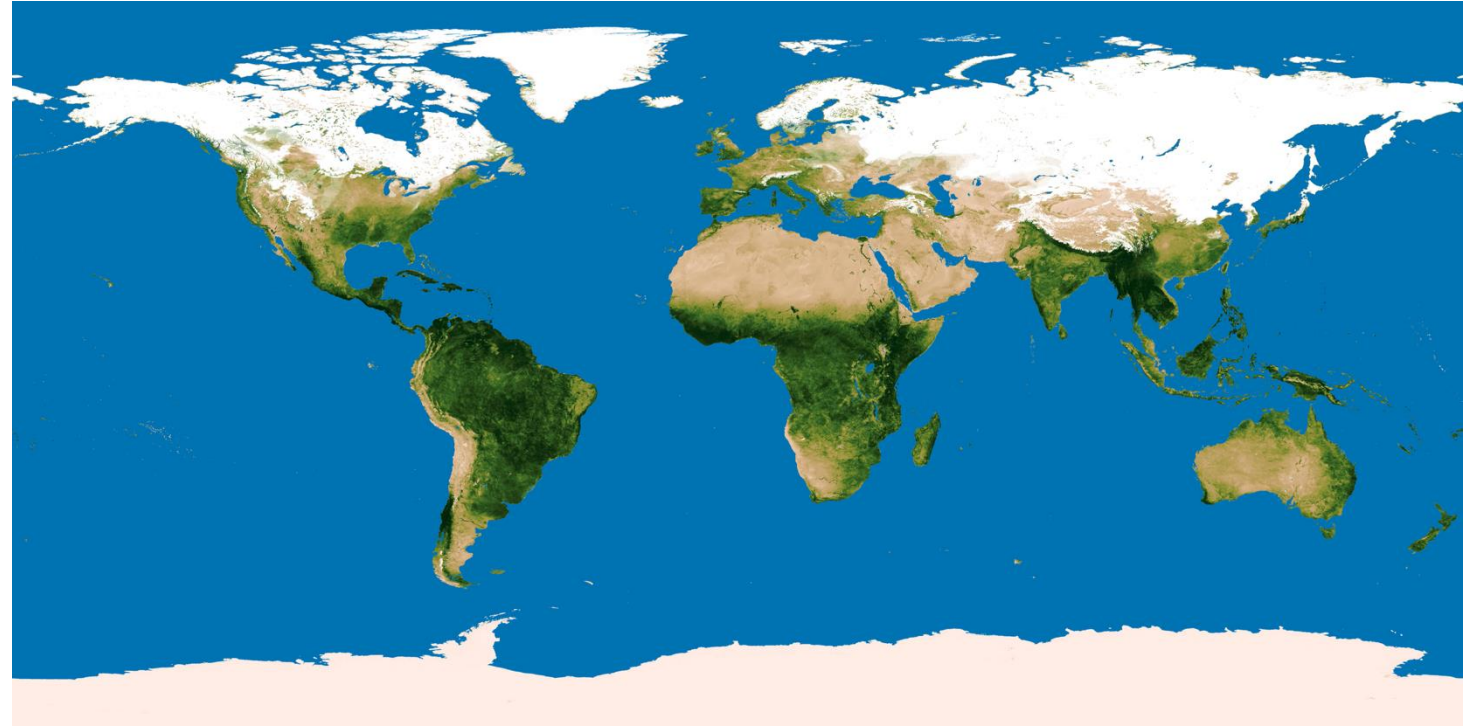


Ocean Chlorophyll Concentration (mg/m^3)



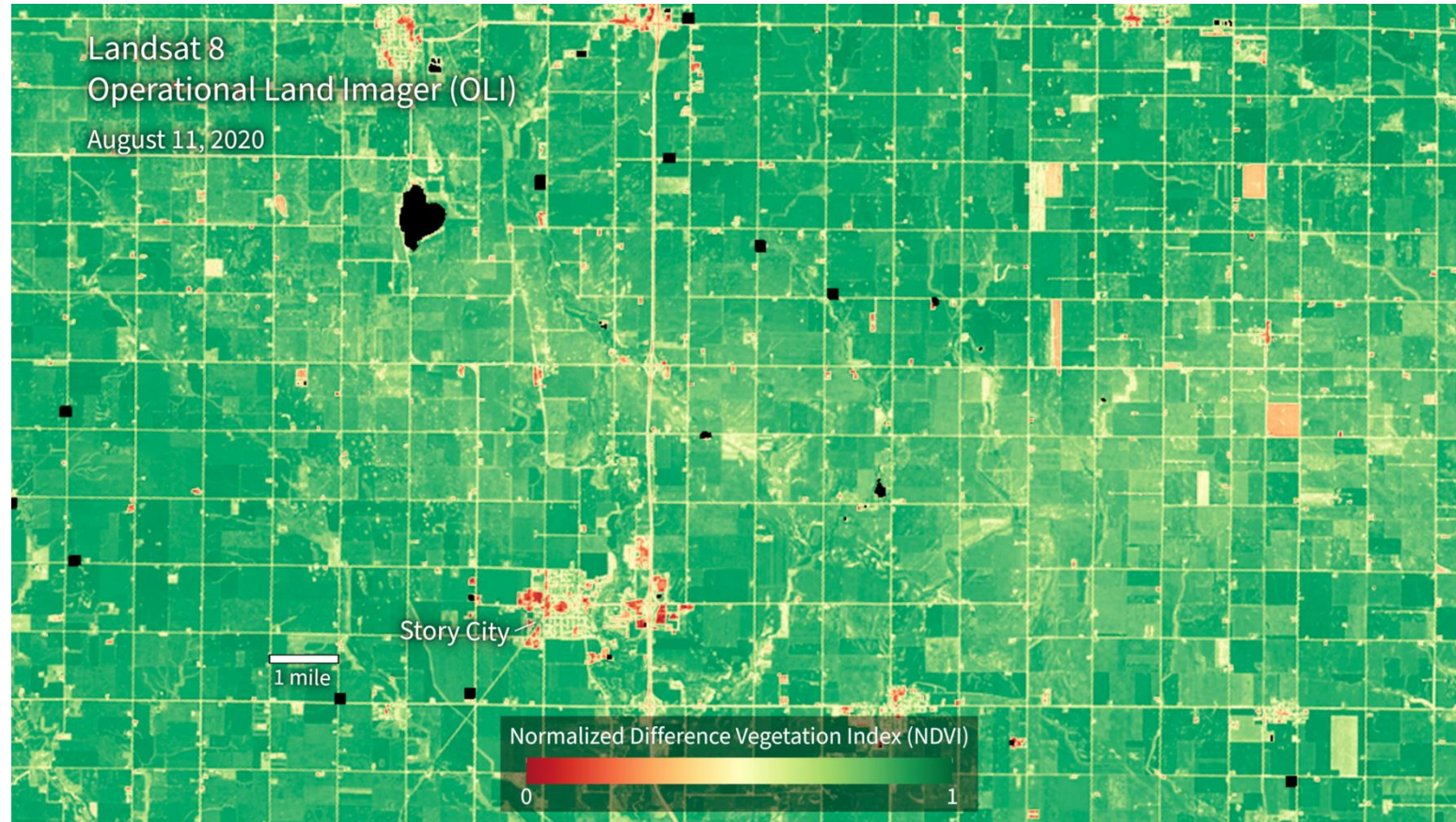
Vegetation Index

- A mathematical **calculation performed on each pixel** using values from multiple spectral bands of an image
- Typically normalized **between -1 and +1**
- **Transforms** complex multispectral data **into meaningful, interpretable information** about Earth's surface conditions and processes



Common Vegetation Indices

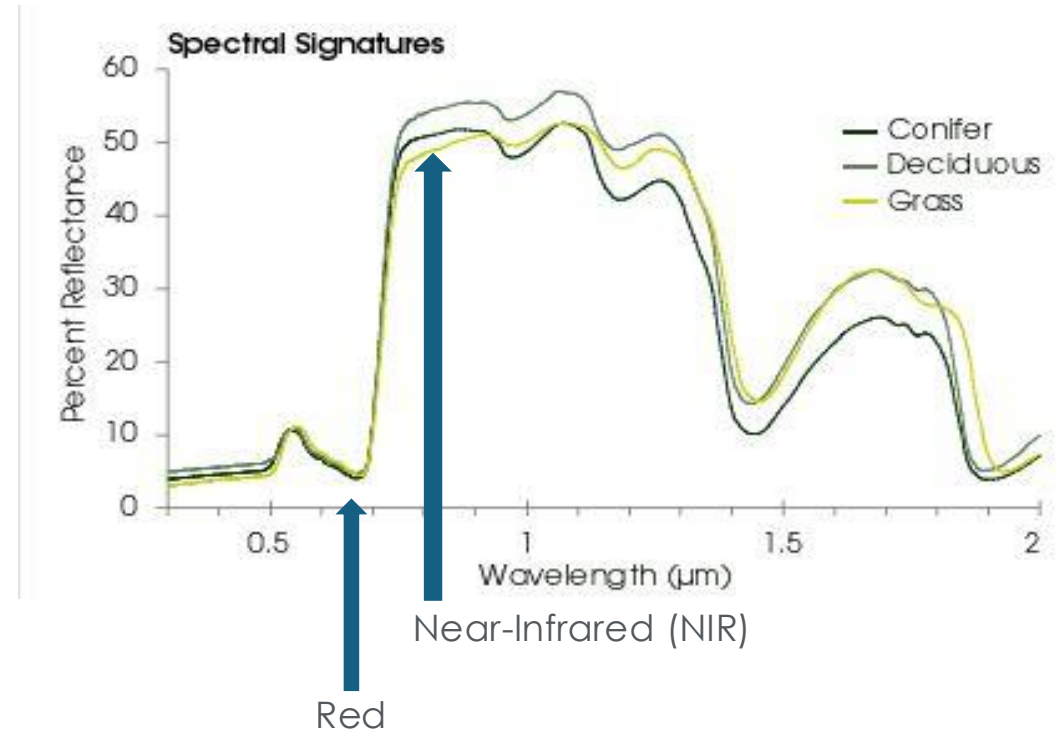
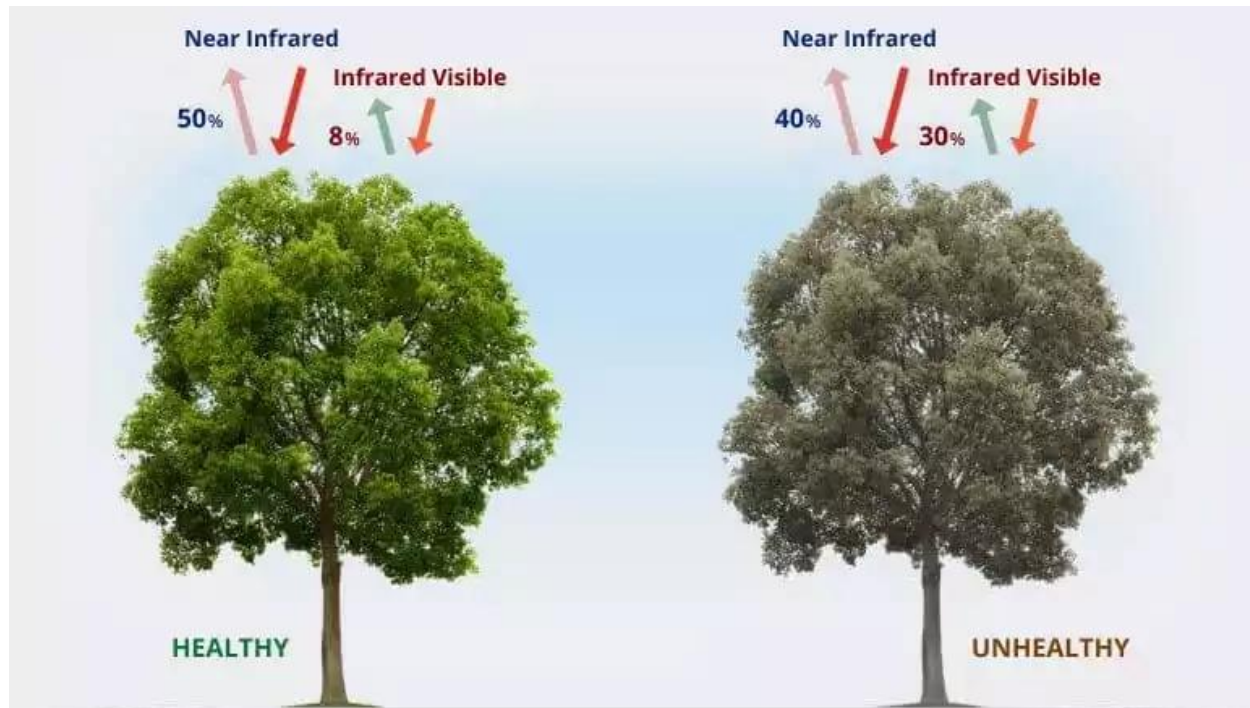
- **NDVI** - Normalized Difference Vegetation Index
- **EVI** - Enhanced Vegetation Index
- **SAVI** - Soil Adjusted Vegetation Index
- **NDMI** - Normalized Difference Moisture Index
- **NDWI** - Normalized Difference Water Index



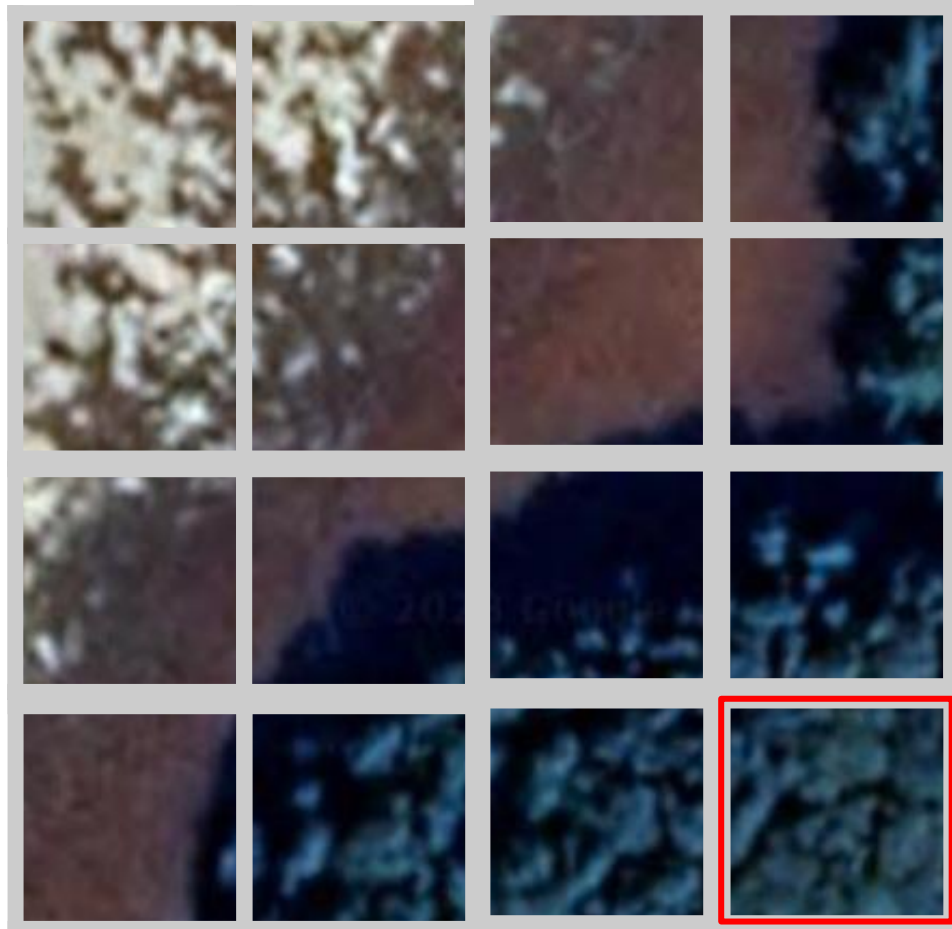
Normalized Difference Vegetation Index (NDVI)

- NDVI evaluates vegetation condition and chlorophyll content
- Chlorophyll strongly absorbs visible light, and the cellular structure of leaves strongly reflects near-infrared light.

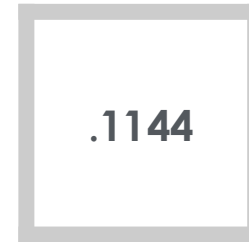
NDVI Formula:
$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$



NDVI Sample Calculation



Near Infrared
(Landsat 9 Band 5)



Red
(Landsat 9 Band 4)





Near Infrared



.1144

—

Red



.0344



.1144

+



.0344

=



.538

Near Infrared

Red

NDVI

.0214	.0313
.0031	.1144

-

.0473	.0444
.0415	.0344

=

-.377	-.174
-.862	.538

.0214	.0313
.0031	.1144

+

.0473	.0444
.0415	.0344



NDVI Value Classification

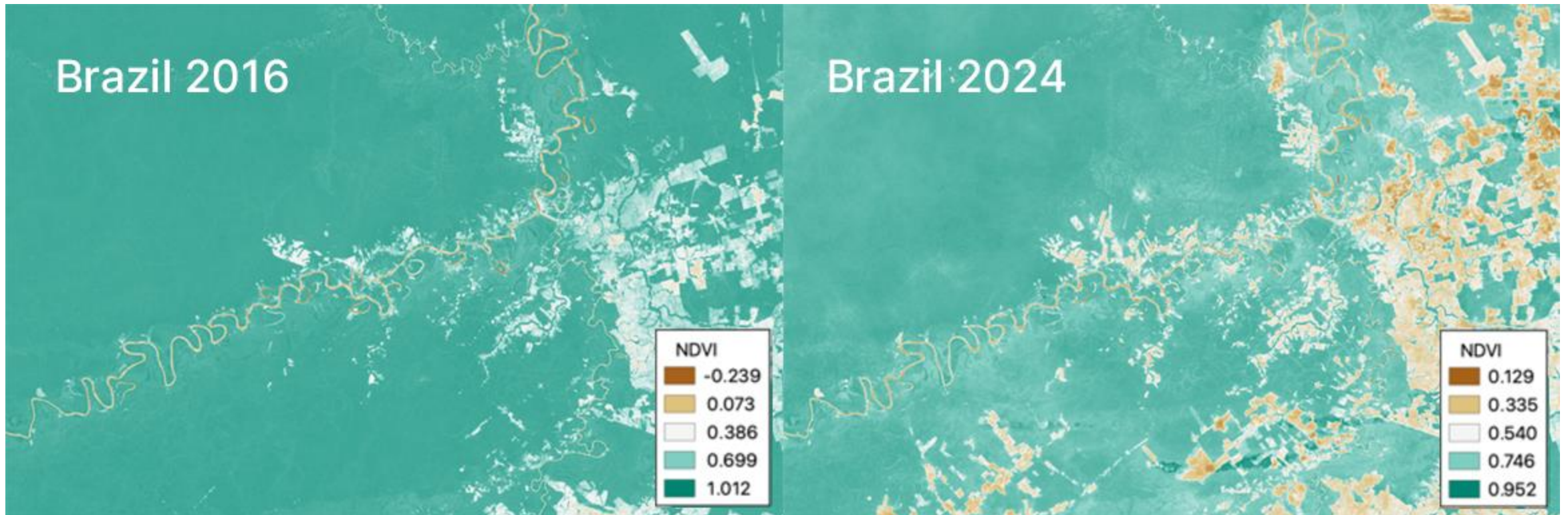
NDVI Values	Classification
-1.0 to 0.0	Non-vegetated surfaces like water, clouds, or snow
0.0 to 0.1	Bare soil, rock, concrete, or completely dead areas
0.1 to 0.3	Sparse vegetation, grasslands, or early cultivation stages
0.4 to 0.6	Moderate vegetation cover (ex. Developing crops or shrubs)
0.7 to 1.0	Dense, healthy vegetation, (ex. Forests, mature crops)



Credit: NASA

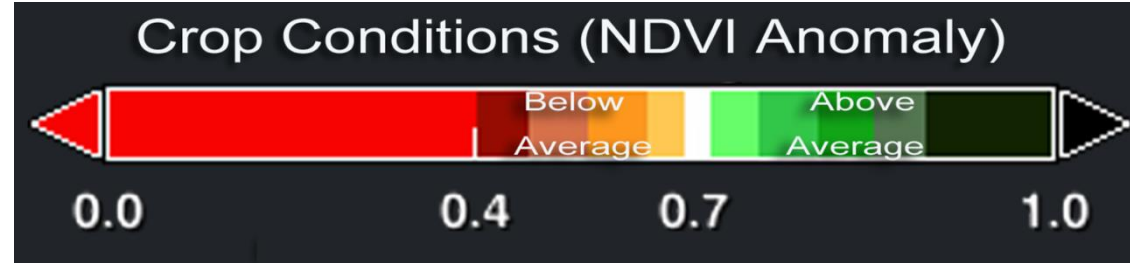
Calculating Change in NDVI

- Change between two NDVI dates can be used to detect crop stress, farmland productivity, or crop loss
- NDVI Change Calculation: $NDVI\ Change = Current\ NDVI - Historic\ NDVI$

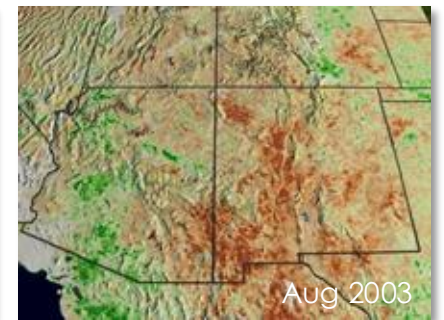
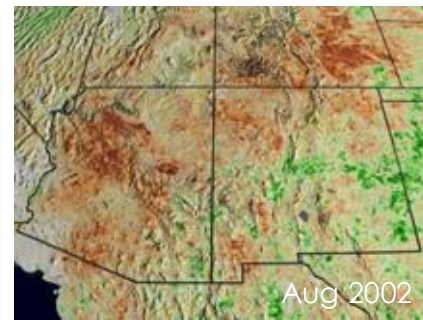
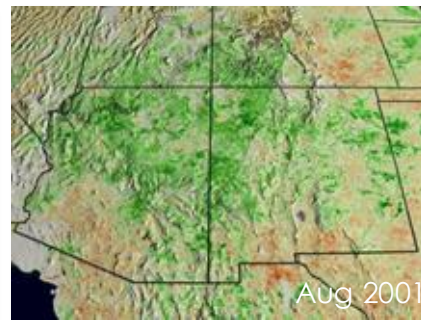
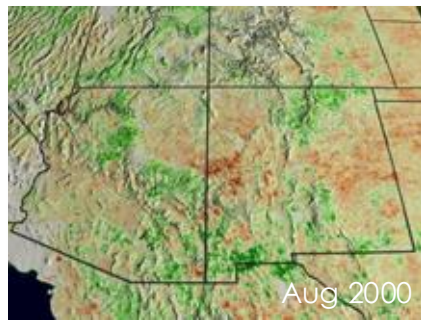


Calculating NDVI Anomaly

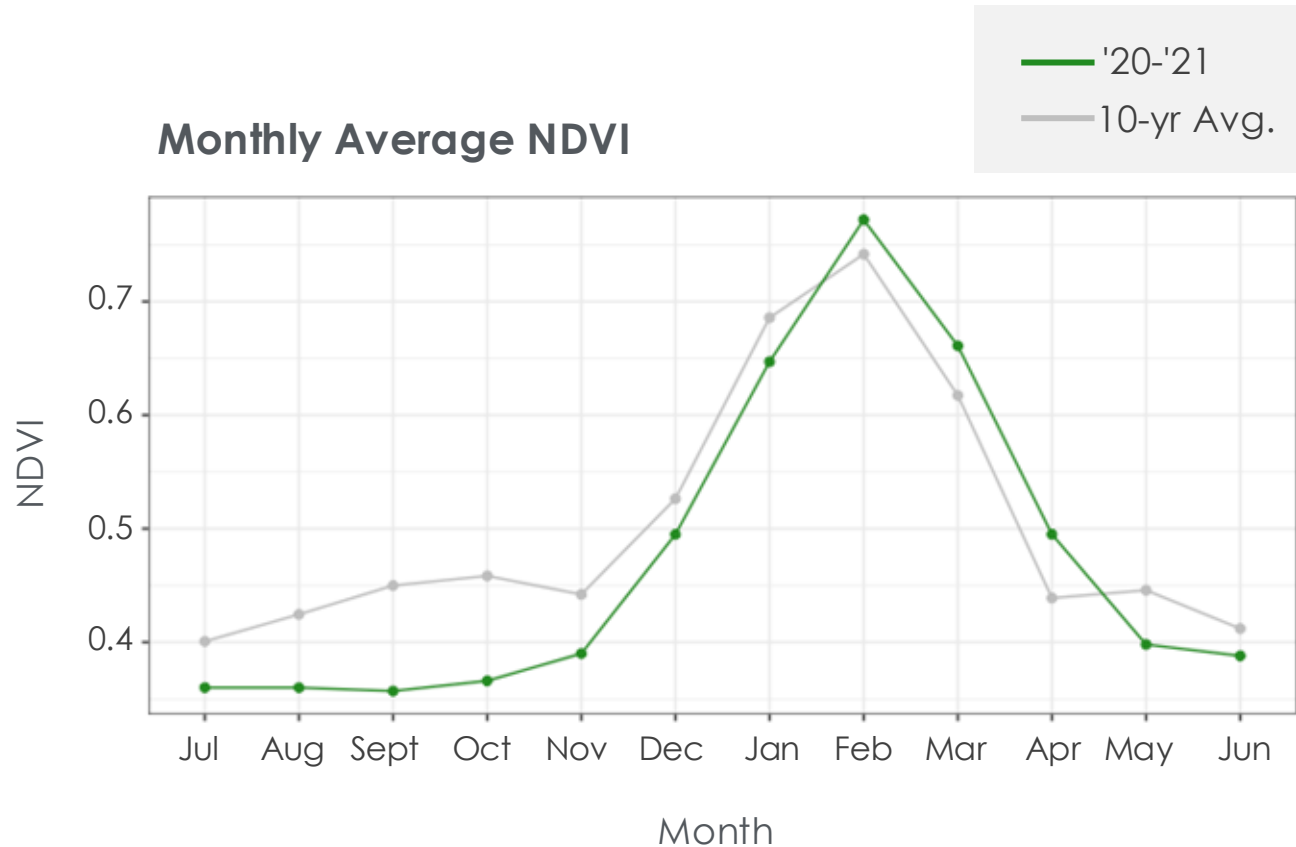
- Statistical measure comparing present vegetation health to long-term average
- Current measurement (day, month, year, etc.) minus reference period average
- $NDVI\ Anomaly = Current\ NDVI - Longterm\ Mean$



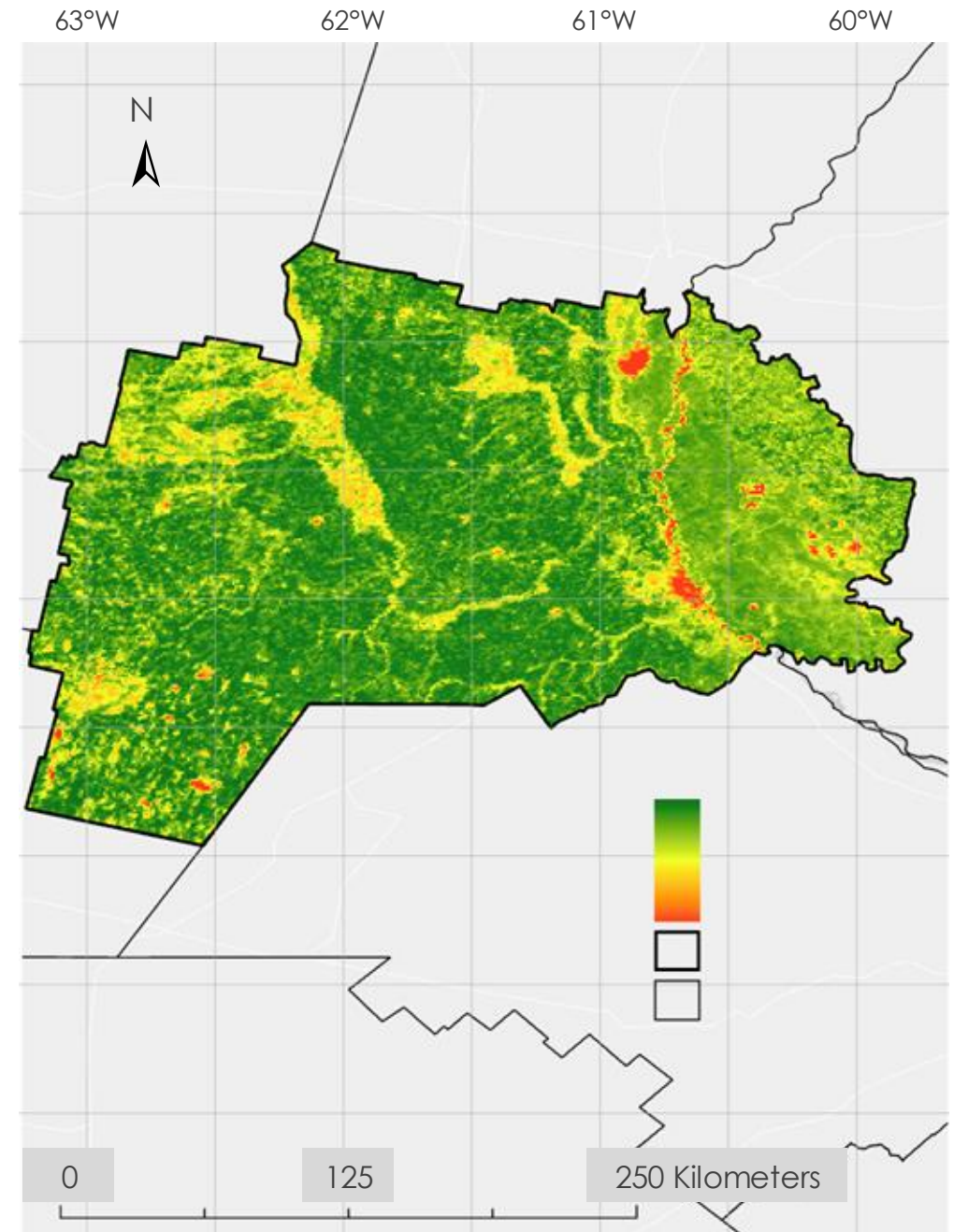
NDVI Anomalies in the Southwestern United States



Example NDVI Analysis



<https://appliedsciences.nasa.gov/what-we-do/projects/crop-monitoring-and-forecasting-for-argentina-using-nasa-satellite-observations>



Additional Vegetation Indices

Enhanced Vegetation Index (EVI)

- Can be used in place of NDVI to examine vegetation greenness
- More sensitive in areas with dense vegetation, making it better for fuels assessment in dense forests.

$$EVI = G * \left(\frac{(NIR - R)}{(NIR + C1 * R - C2 * B + L)} \right)$$

Constants

$$G = 2.5$$

$$C1 = 6$$

$$C2 = 7.5$$

$$L = 1$$

Soil Adjusted Vegetation Index (SAVI)

- Used to correct NDVI for the influence of soil brightness in areas where vegetative cover is low
- Better index for areas with sparse vegetation and high bare soil coverage.
- Contains a soil brightness correction factor (L)

$$SAVI = \frac{(NIR - R)}{(NIR + R + L)} (1 + L)$$

Additional Vegetation Indices

Normalized Difference Moisture Index ([NDMI](#))

- Measures vegetation water content
- Used to monitor agricultural drought and detect early plant water stress
- NDMI Values:
 - Below 0.2: Indicates drought conditions or stress
 - 0.2-0.4: Potentially under low to moderate water stress
 - Above 0.4: Healthy vegetation, no water stress

$$NDMI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

Normalized Difference Water Index ([NDWI](#))

- Can identify open water features
- Allows water to stand out against vegetation and soil
- Can track seasonal flooding

$$NDWI = \frac{(Green - NIR)}{(Green + NIR)}$$

Accessing Analysis Ready Data Through AppEEARS



HLS Vegetation Indices

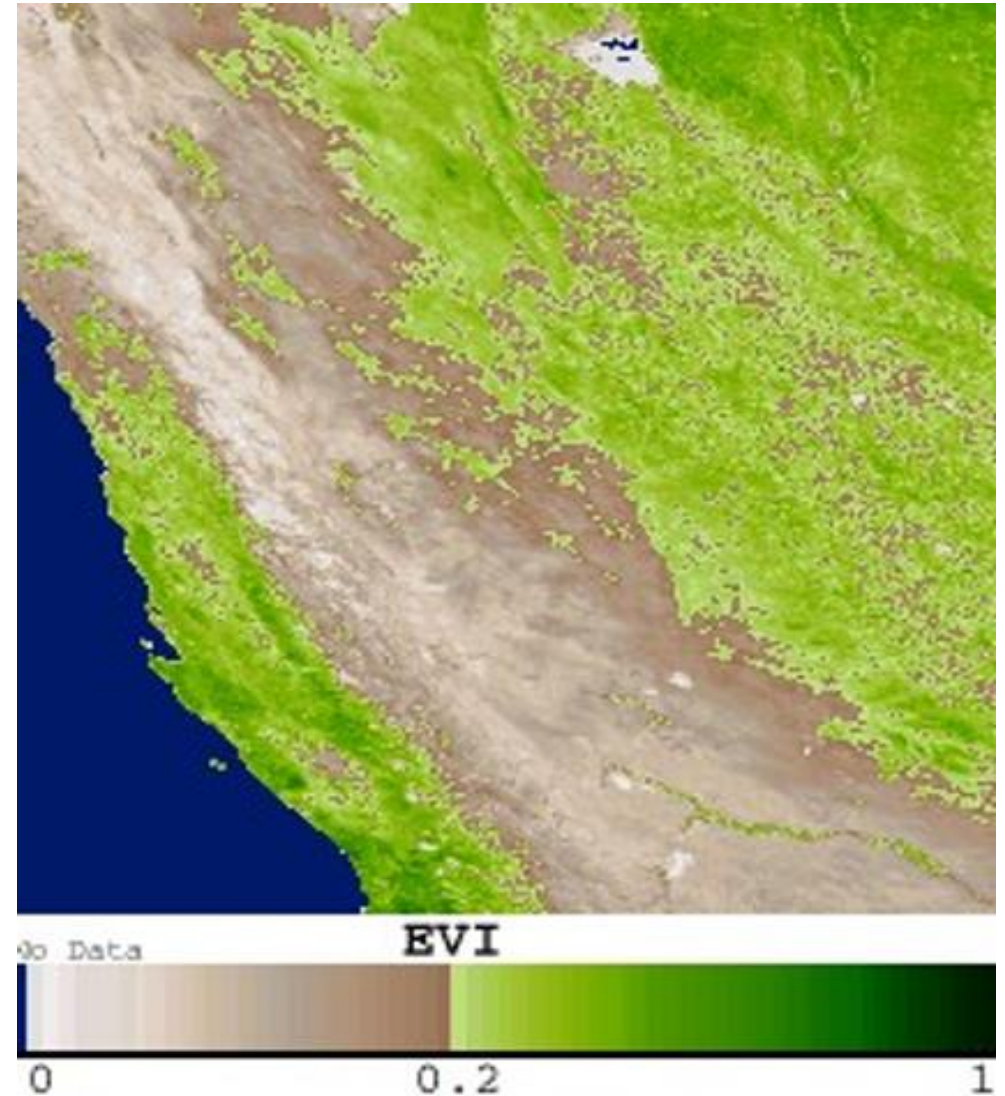
- Harmonized Landsat and Sentinel-2 ([HLS](#)) Project
- Combines data from NASA's Landsat 8/9 and ESA's Sentinel-2A/B/C satellites to create a unified, analysis-ready dataset
- Increased temporal frequency: 2–3-day revisit globally
- Analysis-ready data: Pre-processed surface reflectance
- Two vegetation index products;
 - Landsat 30-meter Vegetation Index ([HLSL30VI](#))
 - Sentinel-2 30-meter Vegetation Index ([HLSSS30VI](#))
- Each product contains a suite of nine vegetation indices including greenness, vegetative moisture content, burned area, and vegetation change



Credit: [NASA HLS NDVI](#)

MODIS Vegetation Indices

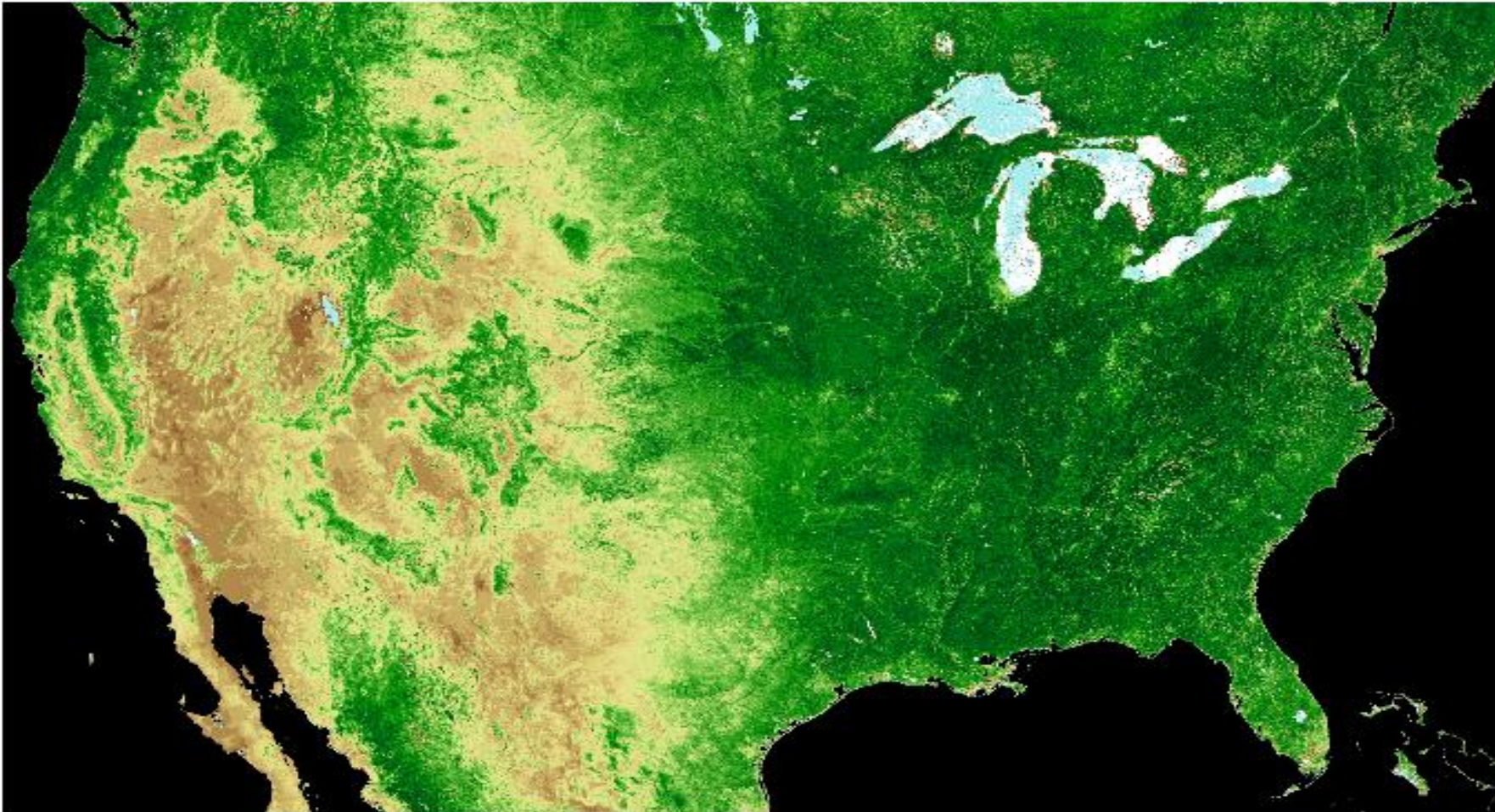
- NDVI & EVI Products
 - 16-day and monthly composite
 - 250 m, 500 m, and 1 km spatial resolutions
 - Retrieved from daily, atmosphere-corrected, bidirectional surface reflectance
 - Collection Names: [MOD13 \(Terra\)](#) and [MYD13 \(Aqua\)](#)
 - Multiple subsets based on spatial resolution



MODIS EVI from April 2020 of the western coast of Africa.
Credit: [USGS/NASA](#)

VIIRS Vegetation Indices

- NDVI, EVI, & EV2
 - 16-day Composites
 - 500 m, 1 km ,and 0.05-degree Resolutions
 - Algorithm selects the best available pixel in a 16-day window



NDVI composite over
continental US from
Suomi-NPP VIIRS
Credit: [USGS](#)

AppEEARS

 EARTHDATA

Other DAACs ▾

 AppEEARS

Extract ▾

Explore

Help ▾

Sign In

Welcome to AppEEARS!

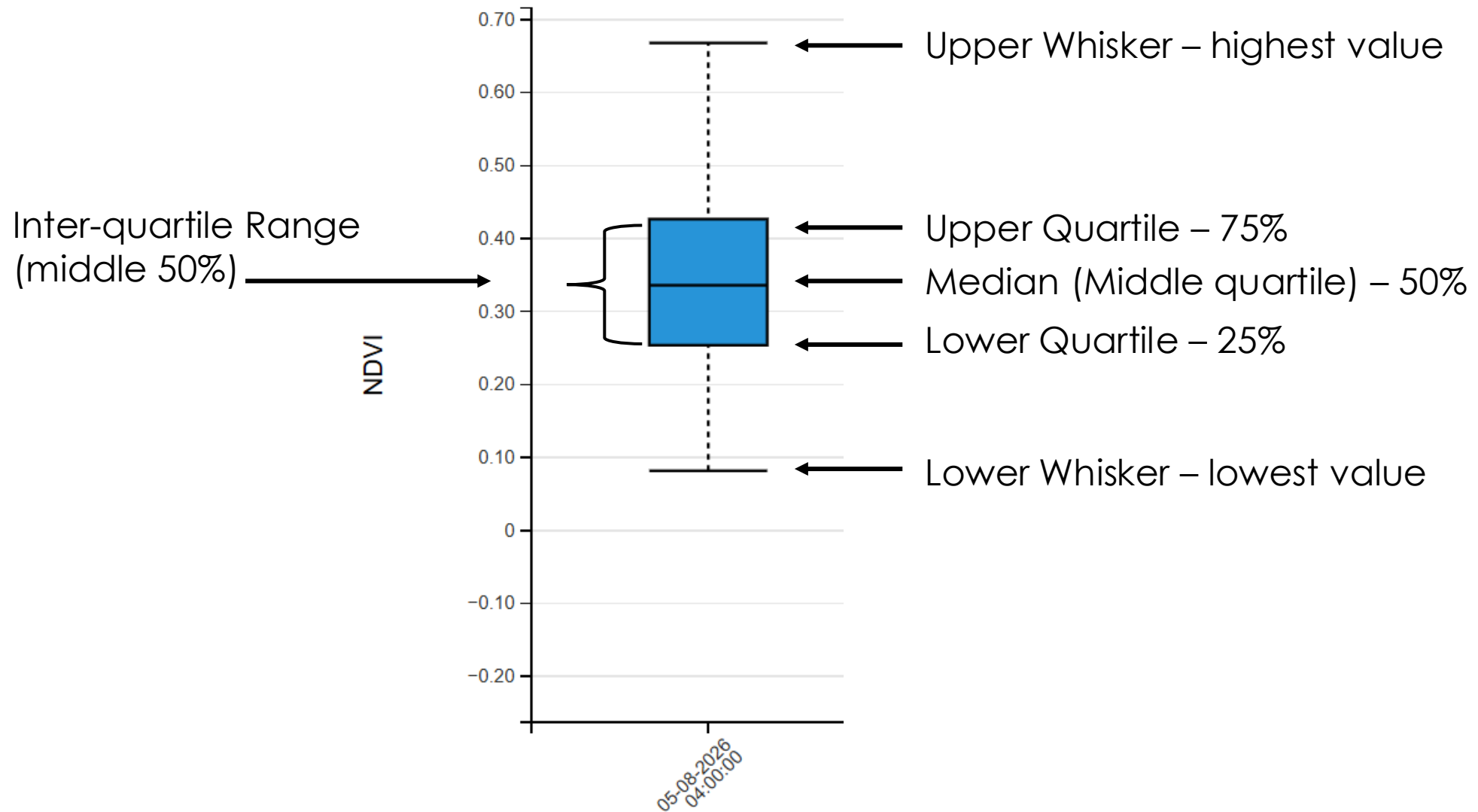
Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

The Application for Extracting and Exploring Analysis Ready Samples (**AppEEARS**) offers a simple and efficient way to access and transform geospatial data from a variety of federal data archives. AppEEARS enables users to subset **geospatial datasets** using spatial, temporal, and band/layer parameters. Two types of sample requests are available: **point samples** for geographic coordinates and **area samples** for spatial areas via vector polygons. Sample requests submitted to AppEEARS provide users not only with data values, but also associated quality data values. Interactive visualizations with summary statistics are provided for each sample within the application, which allow users to preview and interact with their samples before downloading their data. Get started with a sample request using the Extract option above, or visit the [Help page](#) to learn more.

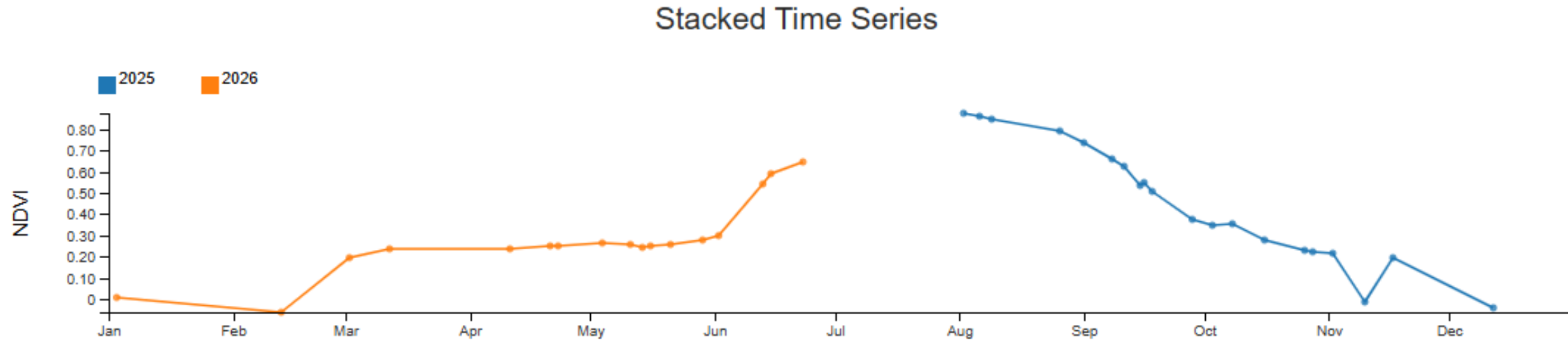
AppEEARS Interface

- Extract Area and Point Sample Data
 - Using shapefiles, drawn polygons, or coordinates
- Query data by date ranges
- Mosaiced and clipped for HLS data
- Can select projection and file format
- Provides summary statistics and visualization to extract with the results and do some exploratory analysis prior to the data download
- Reduces download volume significantly
- Reproducible and traceable data

Box Plots



Time Series Plots

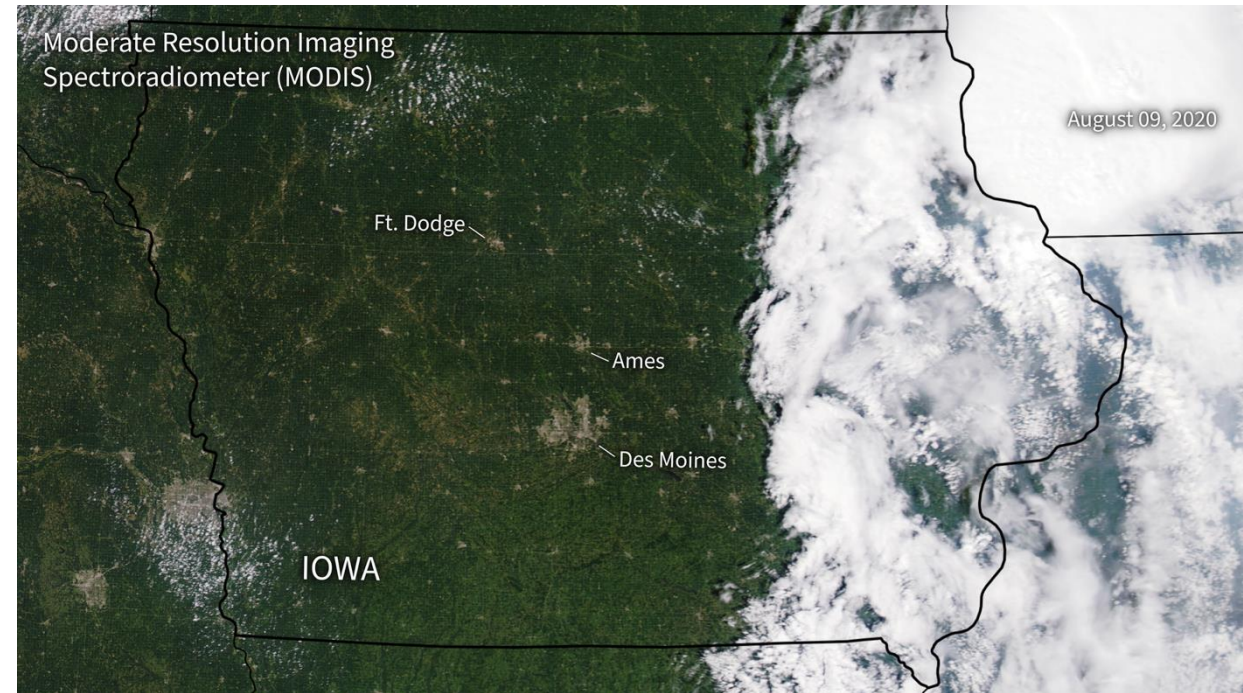


Demo – AppEEARS



AppEARS Case Studies – Iowa Derecho

- On **August 10, 2020**, a devastating, hurricane-strength derecho swept across the Midwest, causing widespread destruction
- Striking Iowa with little warning, the storm brought maximum wind gusts of 130 to 140 mph
- It devastated 14 million acres of crops, left hundreds of thousands without power, and caused up to \$11 billion in damages



[Credit: NASA SVS | 2020 Iowa Derecho](#)

Hands on Exercise Time



Hands on Practice – Part 1. Coordinates

Step 1. Navigate to AppEEARS <https://appeears.earthdatacloud.nasa.gov/>

Step 2. Log in using your earth data login

Step 3. Extract NDVI point data for Channel Islands Santa Rosa Fire Torrey Pine Stand

Coordinates:

33.978342176182196, -120.00833129882812

33.978925824863836, -120.01080322265625

33.978342176182196, -120.00942993164062

33.97844517300837, -120.008056640625

33.97875416348688, -120.0105972290039

Step 4. Enter in Channel Islands Fire Dates

May 1st – June 30th, 2026

Step 5. Select HLS NDVI Layer for Download (*optional, include a second vegetation index*)

Step 6. Title, and submit

AppEEARS Case Studies – Channel Islands NP Fire

- On **May 15, 2026**, a fire was spotted from aircraft on the southeastern side of Santa Rosa Island, part of California's Channel Islands National Park
- The blaze spread over the next several days, ultimately burning 18,379 acres—about one-third of the island
- The **Landsat satellite images** are false-color to help distinguish burned areas (brown) from healthy vegetation (green)
- Torrey Pines are the rarest native pine in the United States, with a large population being wiped out with the fire



[Credit: NASA](#)

Hands on Practice – Part 2. Shapefile Upload

Step 1. Navigate to AppEEARS <https://appeears.earthdatacloud.nasa.gov/>

Step 2. Log in using your earth data login

Step 3. Extract NDVI area data using the downloaded GeoJSON (shapefile) for Iowa

Step 4. Enter in dates: July 1st, 2020 – September 30th, 2020

Step 5. Select HLS NDVI

Step 6. Select file name date formation

Step 7. Select geographic projection

Step 8. Title and submit

Demo & Exercise: Visualizing and Interpreting Vegetation Index Raster Images using GIS Software



Hands on Exercise Time



Hands on Practice – GIS Raster Analysis

Step 1. Open QGIS

Step 2. Download and unzip NDVI raster images

Step 3. Drag and Drop Raster images into QGIS

Step 4. Change symbology and add color ramp

Step 5. Do for second image

Step 6. Open Raster > raster calculator > calculate NDVI change (*NDVI Change = Current NDVI – Historic NDVI*)

Step 7. Change symbology for NDVI change layer

Step 8. Add open street maps, explore data

Summary

- **Spectral indices are mathematical formulas** combining spectral bands to highlight surface features, reduce noise, and enable consistent cross-sensor monitoring using standard formats
- **Key monitoring satellites/sensors include** MODIS & VIIRS for daily global coverage, Landsat 8/9 for 30m resolution, Sentinel-2 for 10–20m resolution, and HLS for combined 2–3-day revisit time
- **Vegetation index anomalies are calculated** using 10+ year baselines to compute climatological means, then determining current departures via absolute, standardized, or percentage formulas
- **Essential indices** include NDVI for vegetation health, NDMI for moisture content, NDWI for water detection, and EVI for dense vegetation analysis