National Aeronautics and Space Administration

Enabling Earth Observations for Land Applications with NASA's Applied Remote Sensing Training Program (ARSET)

Ecological Society of America 2024 Annual Conference

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esa ANNUAL MEETING
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About ARSET

ARSET: Empowering the Global Community through Training

- **ARSET provides accessible, relevant, and cost-free training on remote sensing satellites, sensors, methods, and tools. ARSET hosts online and in-person trainings.**

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

ARSET Trainings 2009-2023

- 180+ trainings
- 100,000+ participants
- 182 countries
- 17,000+ organizations

EARTH SCIENCE APPLIED SCIENCES CAPACITY BUILDING

About ARSET Trainings

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

- Visit the ARSET website to learn more.

AGRICULTURE

CLIMATE & RESILIENCE

DISASTERS

ECOLOGICAL CONSERVATION

HEALTH & AIR QUALITY

WATER RESOURCES

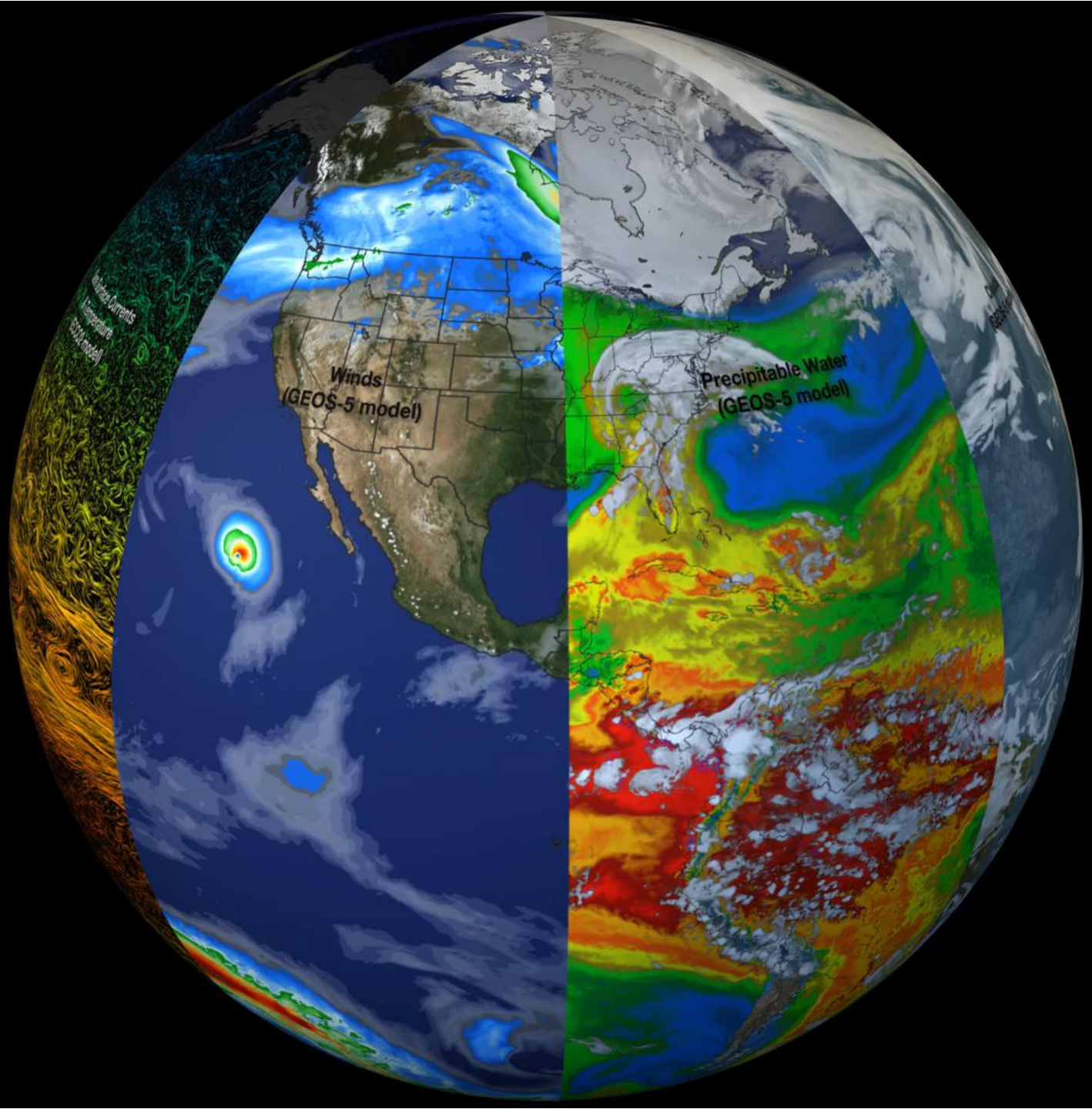
Training Learning Objectives

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

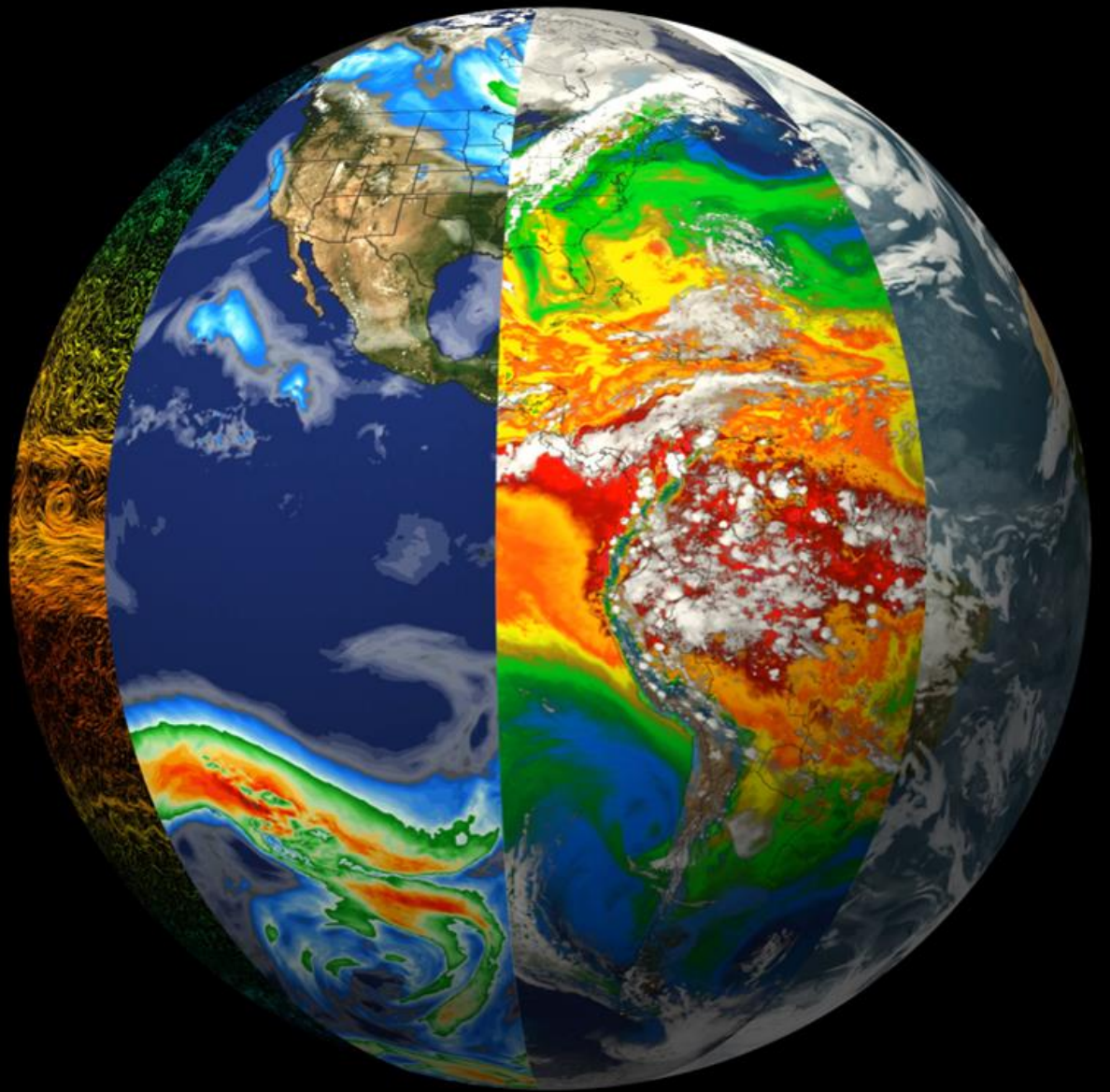
- Explore ways remote sensing is used to study Earth Systems.
- Identify NASA resources for learning more about how to use and access remote sensing data.
- Identify remote sensing data and products that can be used for fire mapping and monitoring
- Access the Fire Information for Resource Management System (FIRMS) and NASA Worldview for monitoring active fires and gathering information about historical fires.

Intro to Remote Sensing


NOAA 21
Aura
Landsat 8
Terra
GPM-CORE
SMAP
CYGNSS-4
Aqua
CALIPSO
Cloudsat
GOES-14
CYGNSS-3
Suomi NPP
Sentinel-6
Michael Freilich
ICESat-2
Landsat 9
Jan 10 2023 13:12

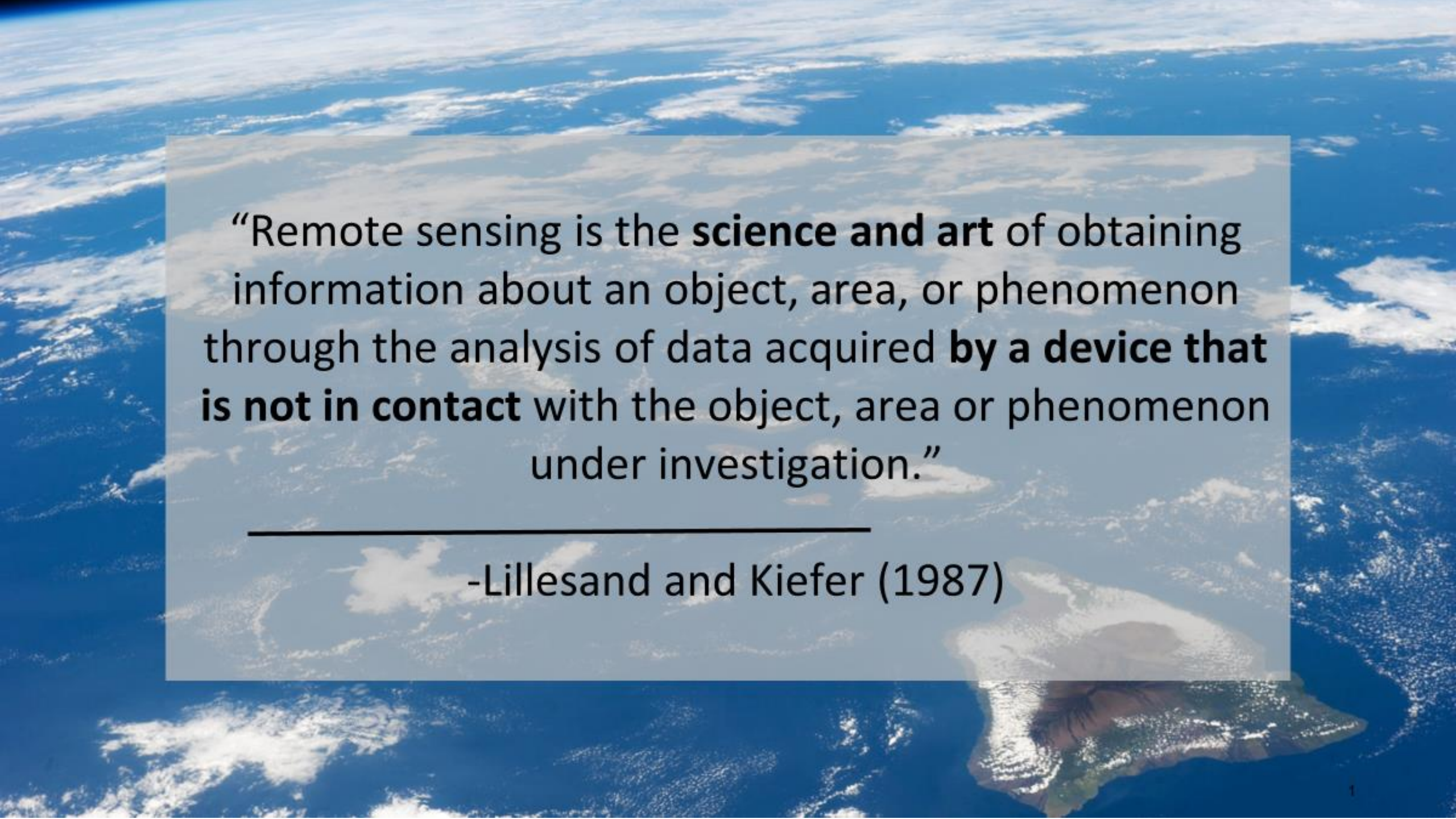

Winds
(GEOS-5 model)
Precipitable Water
(GEOS-5 model)

Earth is a System of Systems.....



Animation by NASA Science Visualization Studio (SVS)

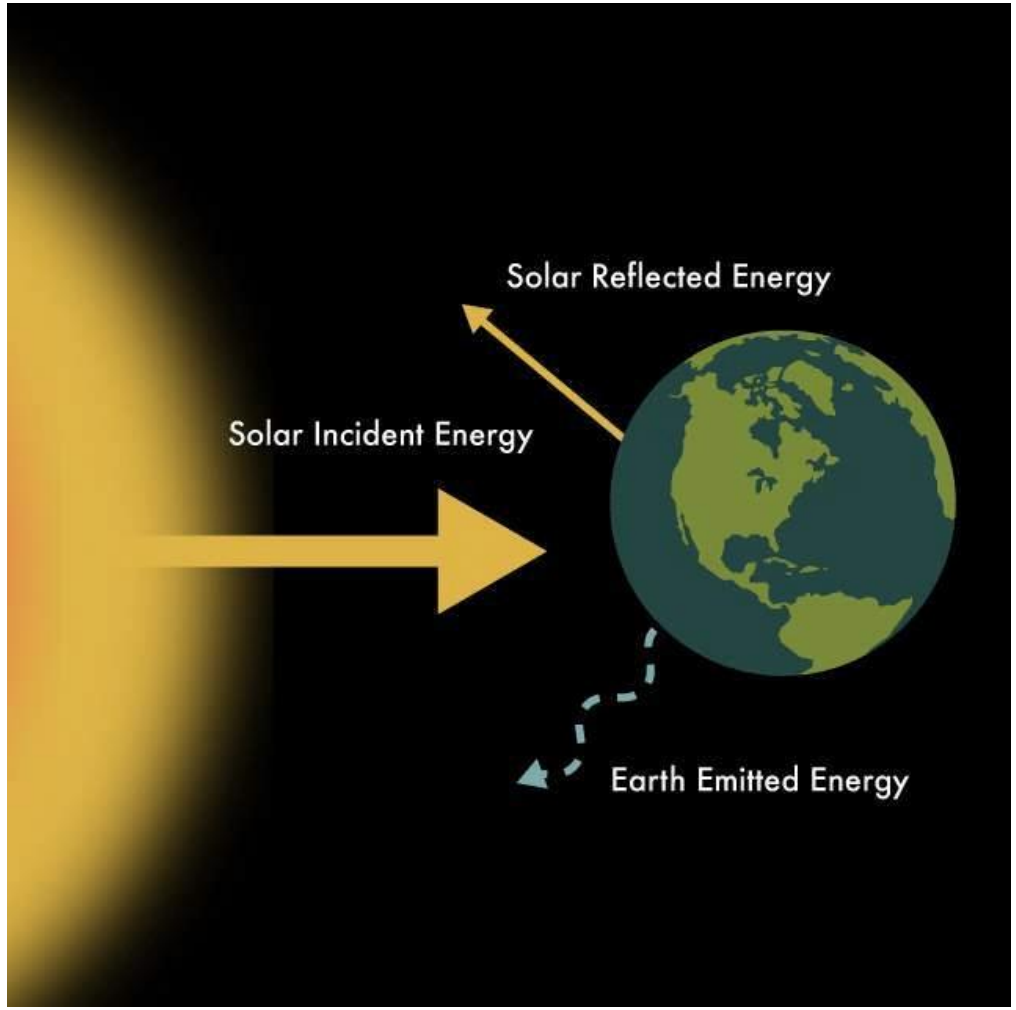
Earth: A System of Systems



"Remote sensing is the **science and art** of obtaining information about an object, area, or phenomenon through the analysis of data acquired **by a device that is not in contact** with the object, area or phenomenon under investigation."

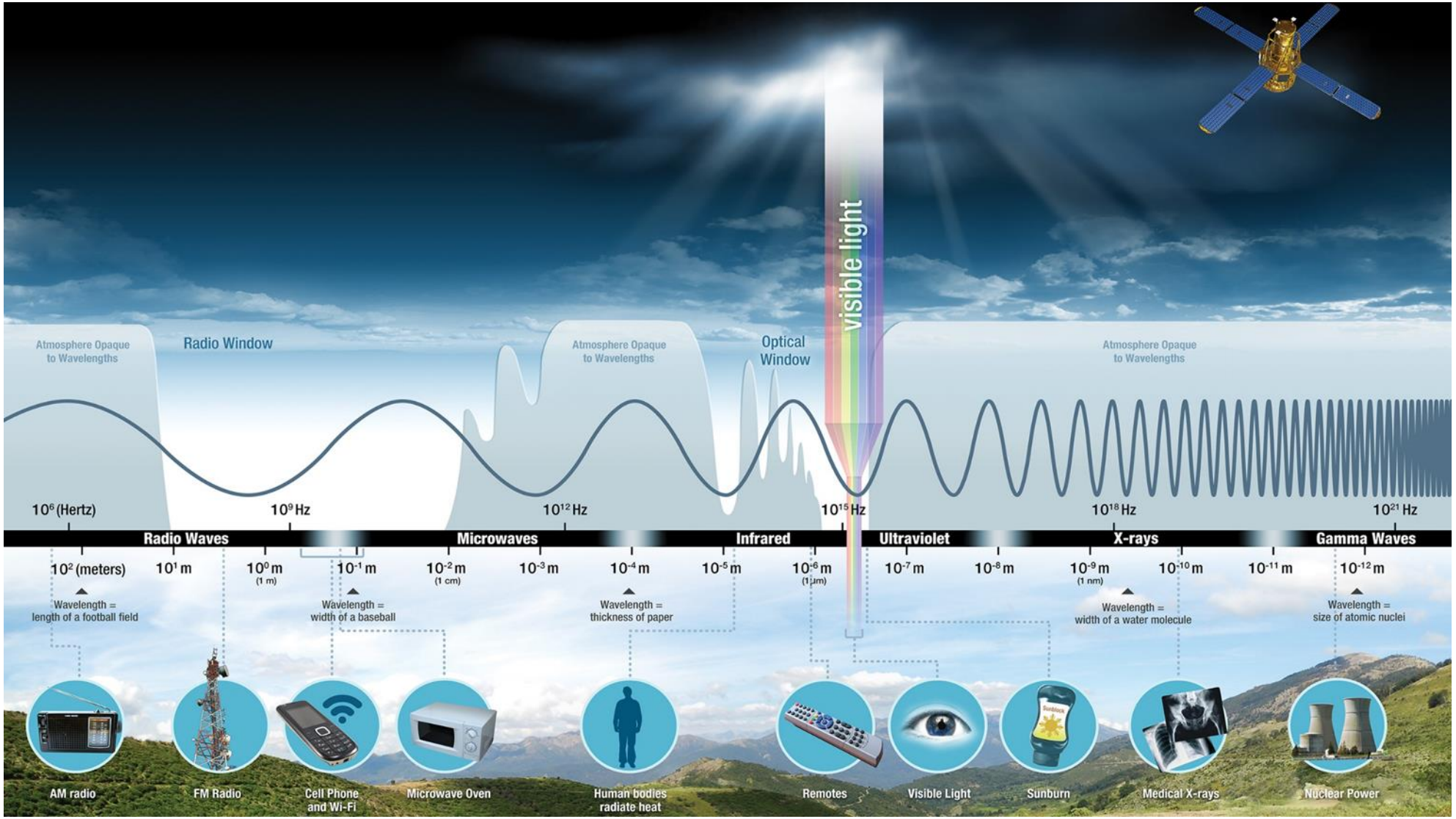
-Lillesand and Kiefer (1987)

Electromagnetic Radiation



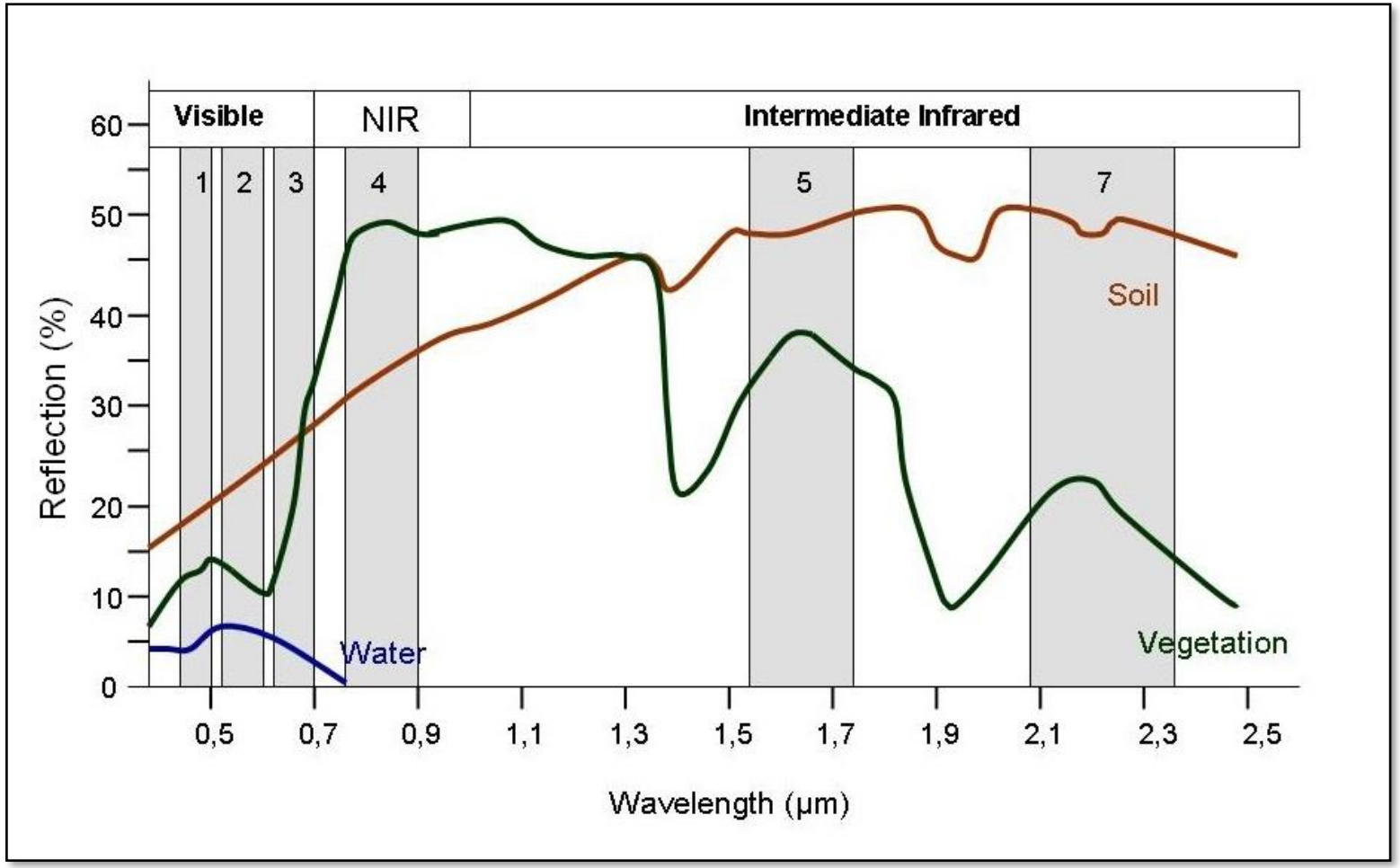
- The energy Earth receives from the sun is called **electromagnetic radiation**.
- Radiation is reflected, absorbed, and emitted by the Earth's atmosphere or surface, as shown by the figure on the left.
- Satellites carry instruments or sensors that measure electromagnetic radiation reflected or emitted from both terrestrial and atmospheric sources.

Electromagnetic Spectrum



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.



Interaction with Earth's Surface: Vegetation

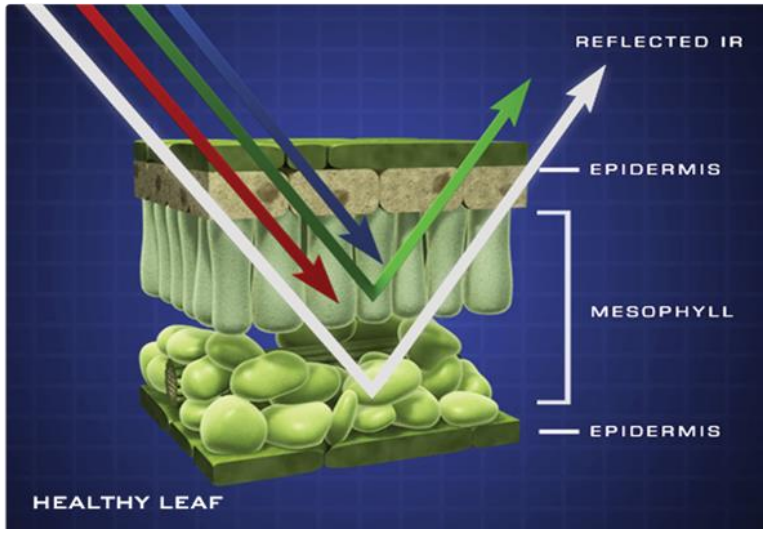


Image Credits: NASA/Jeff Carns & Ginger Butcher

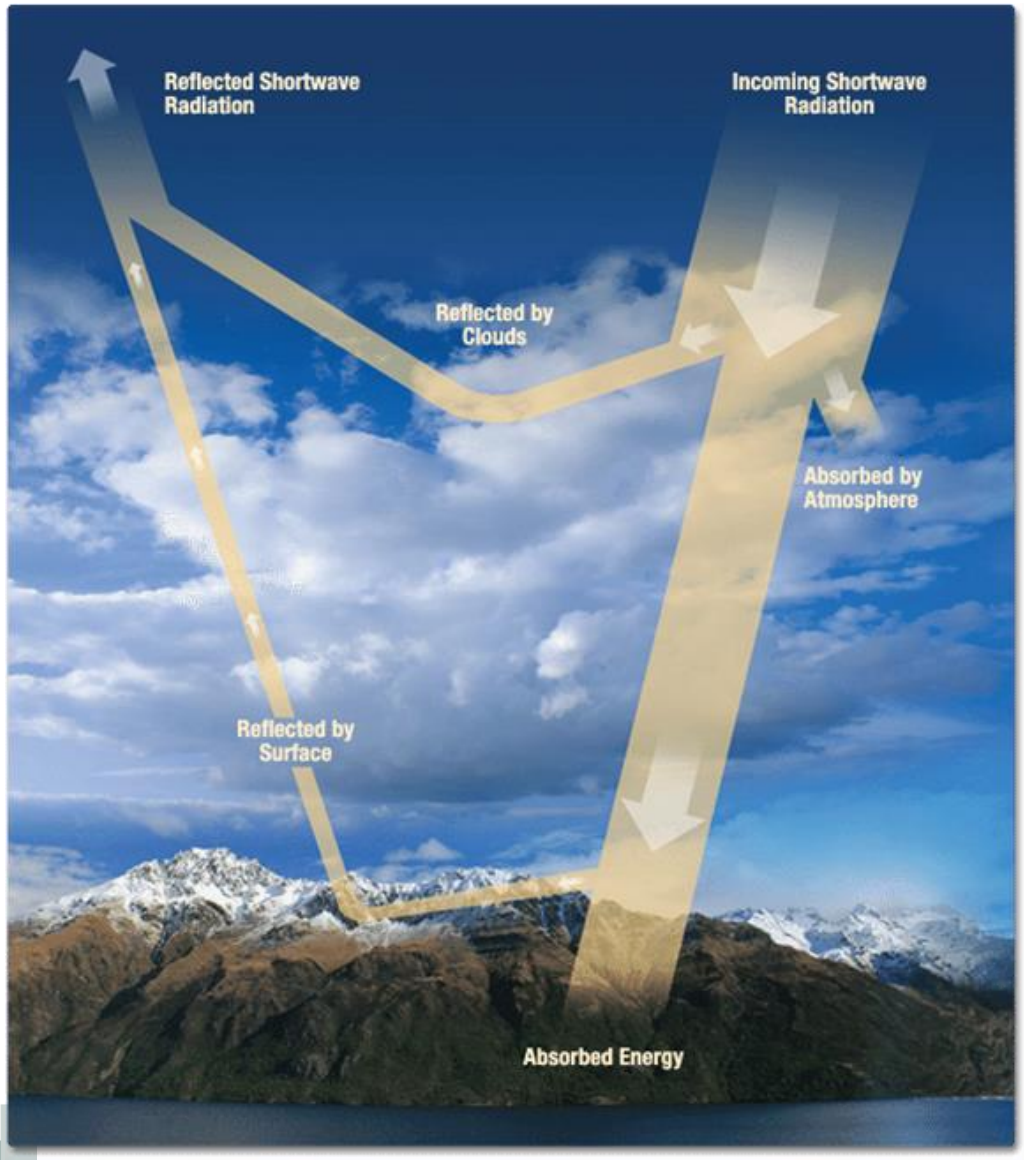
- Example: Healthy, green vegetation **absorbs Blue** and **Red** wavelengths (used by chlorophyll for photosynthesis) and **reflects Green** and **Infrared**.
- Since we cannot see infrared radiation, we see healthy vegetation as green.
- The amount of reflected energy is dependent on the health of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

Spectral Signature: Water

Image Credit: NASA Earth Observatory, using Landsat data courtesy of USGS.

- Longer visible wavelengths (green and red) and near-infrared radiation are absorbed more by water than shorter visible wavelengths (blue) – so water usually looks blue or blue-green.
- Satellites provide the capability to map optically active components of upper water column in inland and near-shore waters.

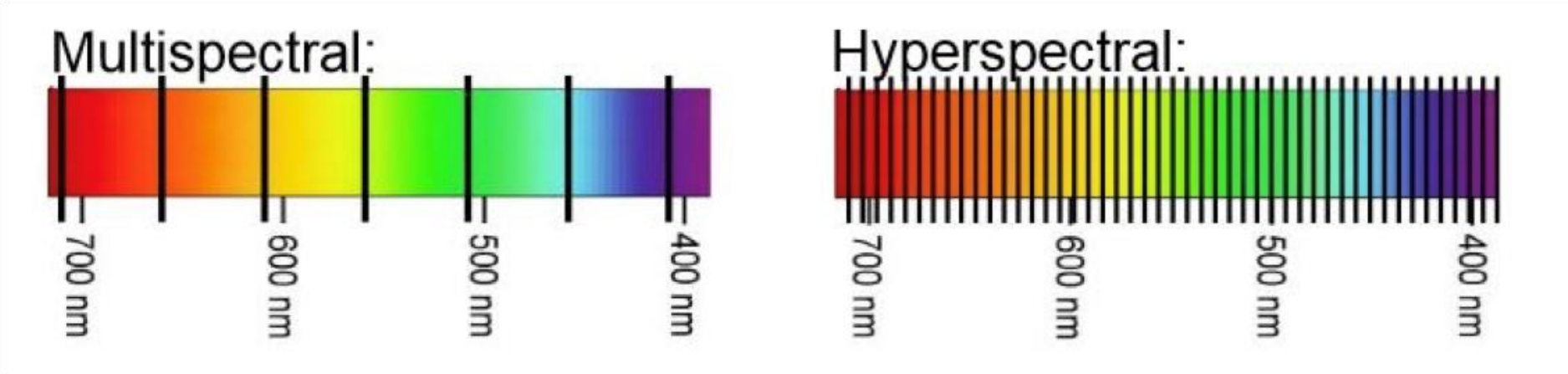
Spectral Signature: Atmosphere



- From the sun to the Earth and back to the sensor, electromagnetic energy passes through the atmosphere twice.
- Much of the incident energy is absorbed and scattered by gases and aerosols in the atmosphere before reaching the Earth's surface.
- Atmospheric correction removes the scattering and absorption effects from the atmosphere to obtain the surface reflectance characterizing surface properties.

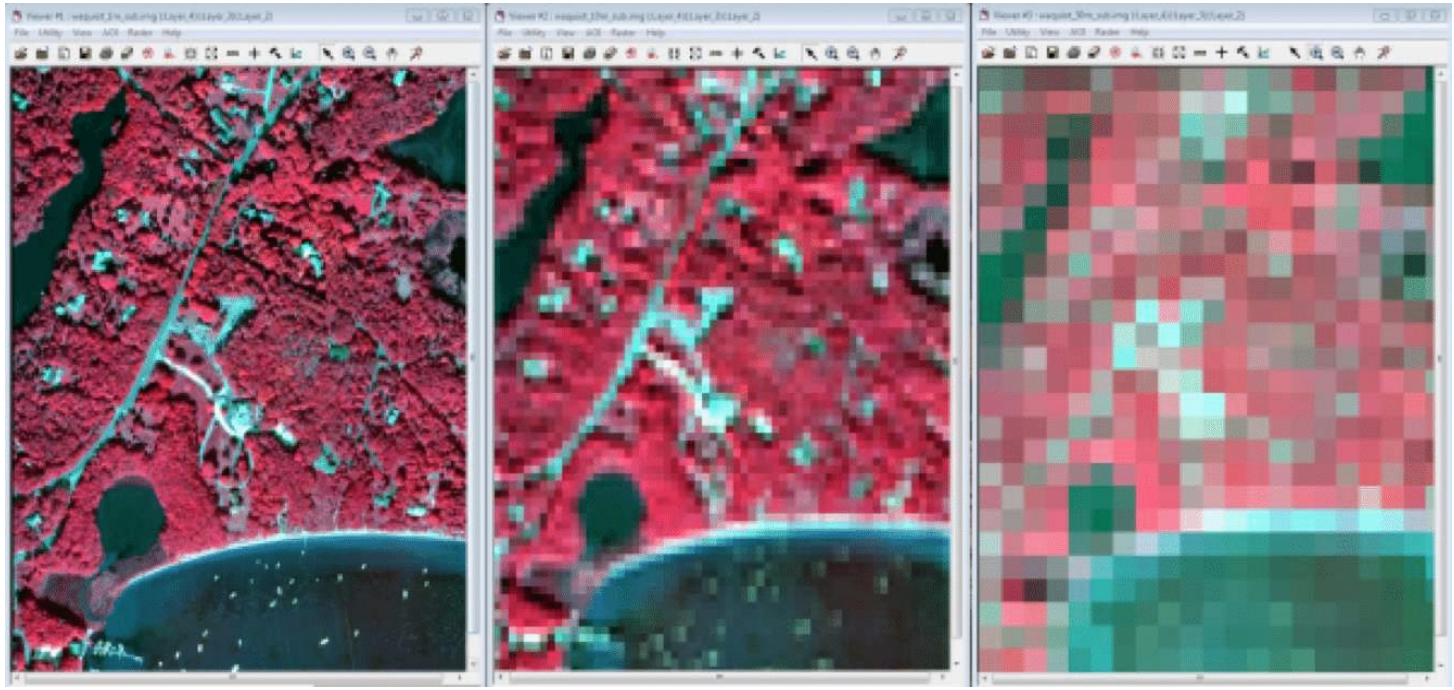
Spectral Resolution

- Resolution depends upon satellite orbit configuration and sensor design. Different sensors have different resolutions.
- Signifies the number and width of spectral bands of the sensor. The higher the spectral resolution, the narrower the wavelength range for a given channel or band.
- More and finer spectral channels enable remote sensing of different parts of the Earth's surface.
- Typically, multispectral imagery refers to 3 to 10 bands, while hyperspectral imagery consists of hundreds or thousands of (narrower) bands (i.e., higher spectral resolution). Panchromatic is a single broad band that collects a wide range of wavelenaths.



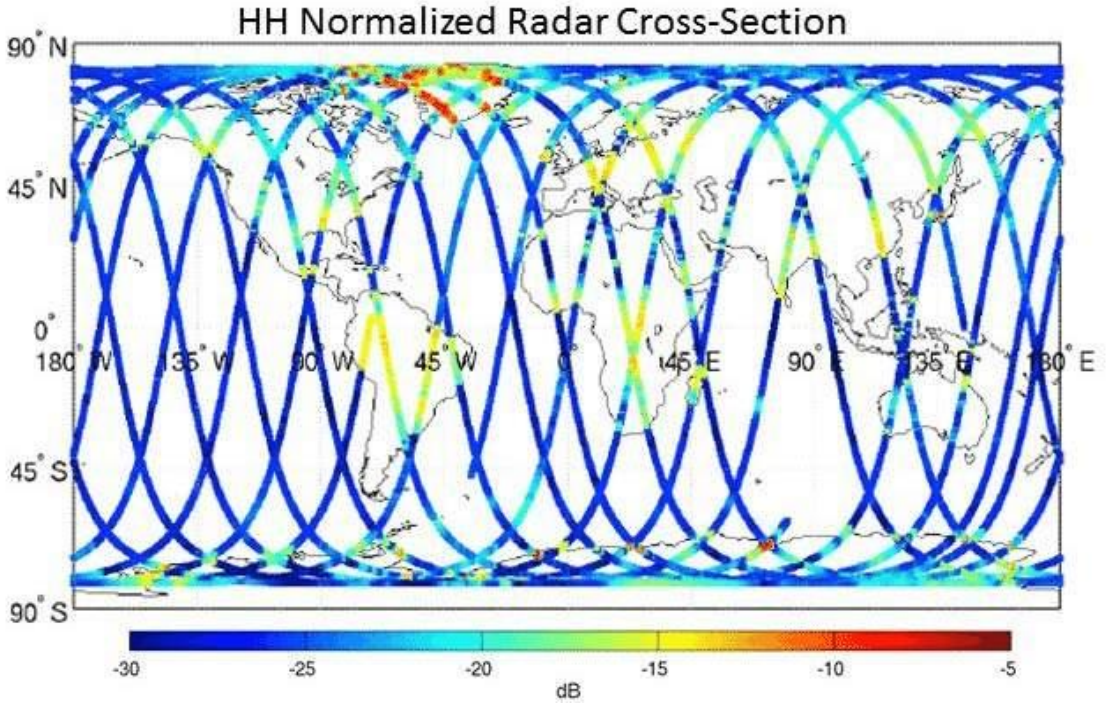
Spatial Resolution

- Different sensors have different resolutions.
- Signifies the ground surface area that forms one pixel in the image.
- The higher the spatial resolution, the less area is covered by a single pixel.
- On the right shows the same image at different spatial resolutions: (from left to right) 1 m, 10 m, and 30 m.



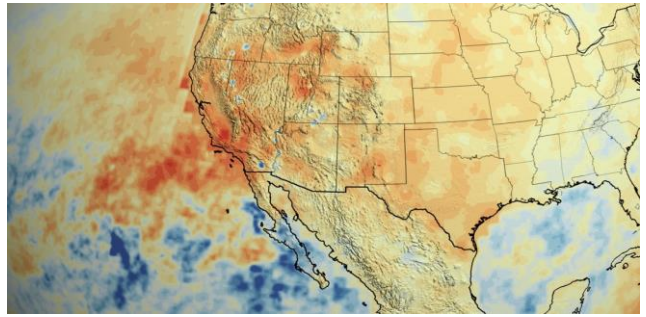
Temporal Resolution

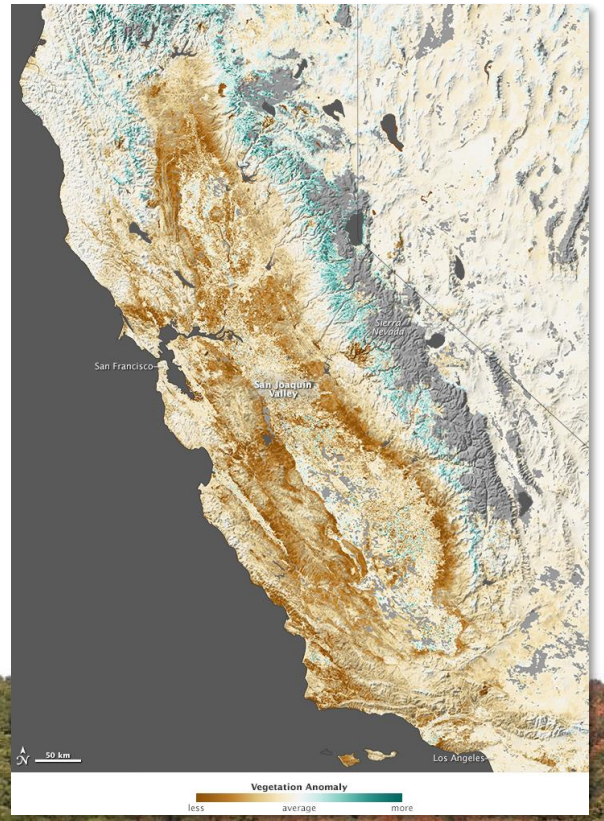
- The time it takes for a satellite to complete one orbit cycle—also called "revisit time"
- Depends on satellite/sensor capabilities, swath overlap, and latitude
- Some satellites have greater temporal resolution because:
  - They can maneuver their sensors
  - They have increasing overlap at higher latitudes

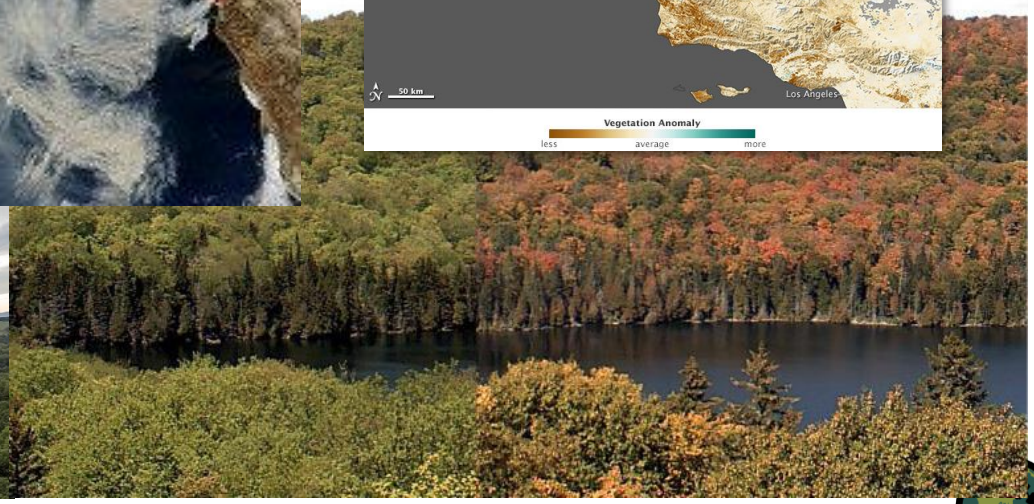


What can remote sensing be used for?

- Many things!
  - Conservation and Biodiversity
  - Floods/Droughts
  - Wildfires
  - Water Quality
  - Weather and Climate patterns
  - Agriculture and Food Security
  - And more…







Global Precipitation every 30 minutes

NASA SVS

Painting the
World with Water

Liquid Precipitation Rate

0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50

mm/hour

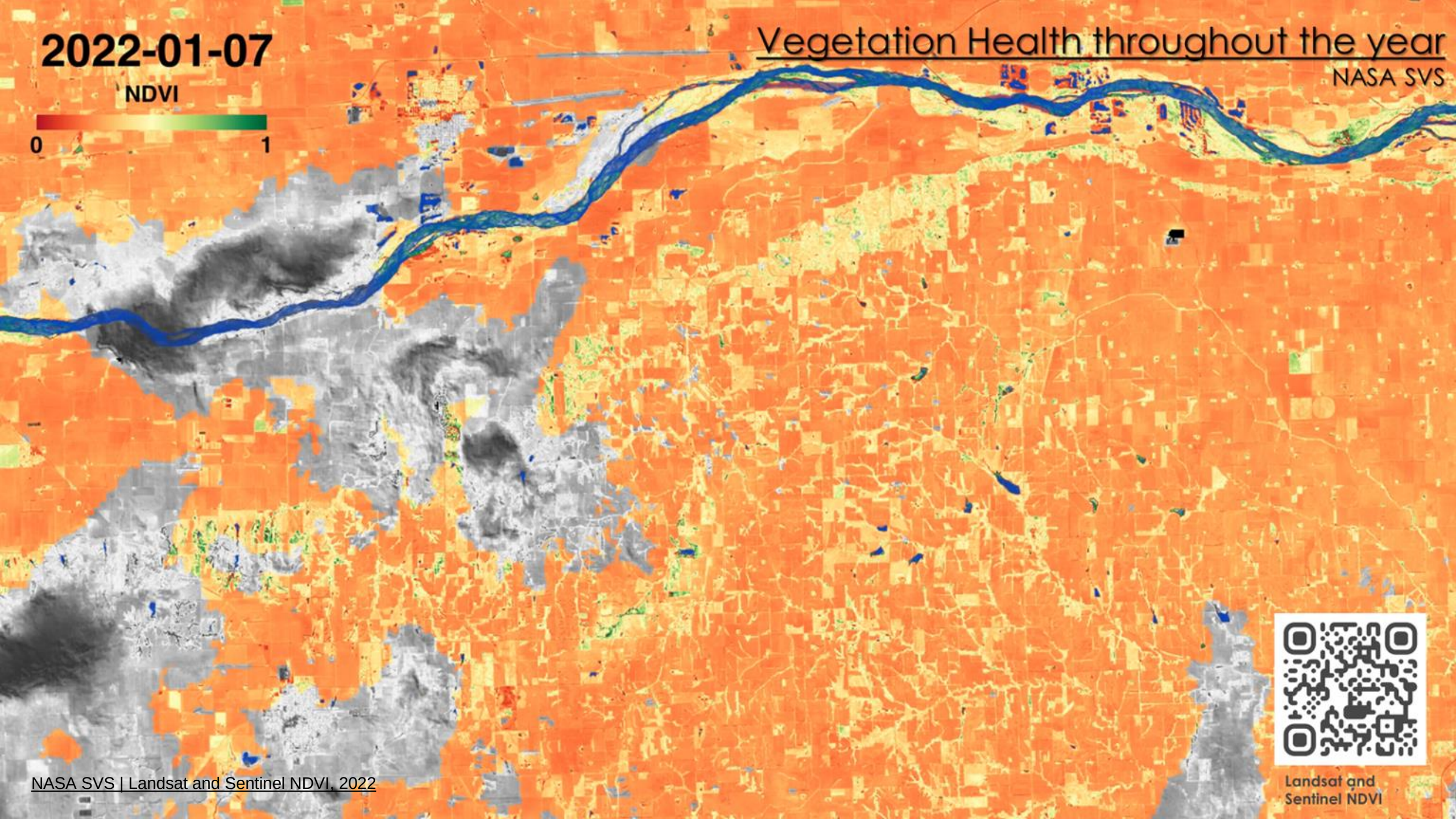
Frozen Precipitation Rate

0.1 0.2 0.3 0.5 1.0 2.0 3.0 5.0 10 20 50

mm/hour

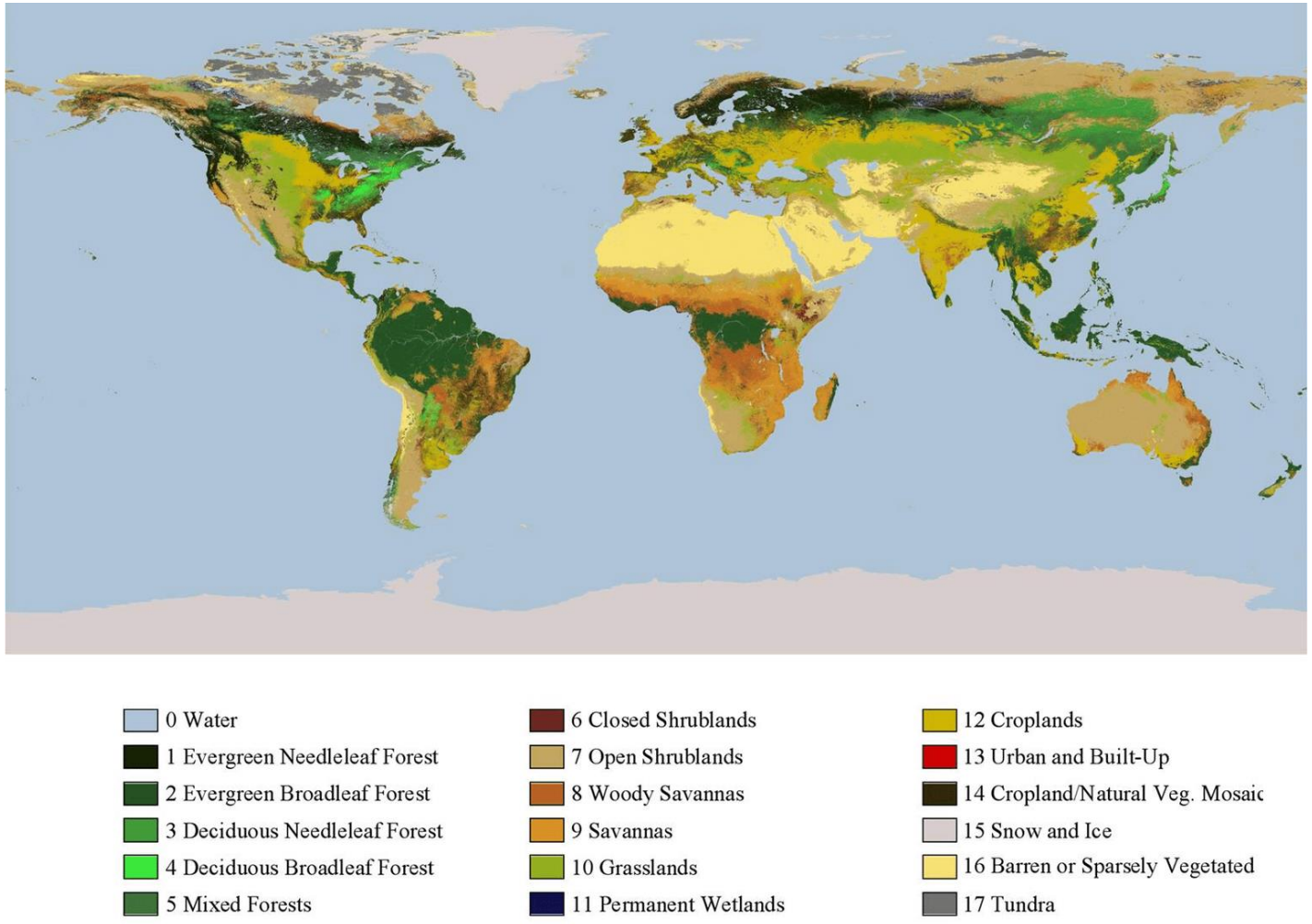
7/25/2014 00:55

NASA SVS | Painting the World with Water


2022-01-07
NDVI
0
1
Vegetation Health throughout the year
NASA SVS
NASA SVS | Landsat and Sentinel NDVI, 2022
Landsat and
Sentinel NDVI

Advantages of Remote Sensing

- Provides information where there are no ground-based measurements.
- Provides globally consistent observations.
- Provides continuous monitoring of our planet.
- Earth systems models integrate surface-based and remote sensing observations and provide uniformly gridded, frequent information of water resources data parameters.
- Data are freely available and there are web-based tools for data analysis.



Disadvantages of Remote Sensing

- It is very difficult to obtain high spectral, spatial, temporal, and radiometric resolution all at the same time.
- Limited by atmospheric conditions, such as cloud cover or haze.
- Applying satellite data may require additional processing, visualization, and other tools.
- While the data are generally validated with selected surface measurements, regional and local assessment is recommended.

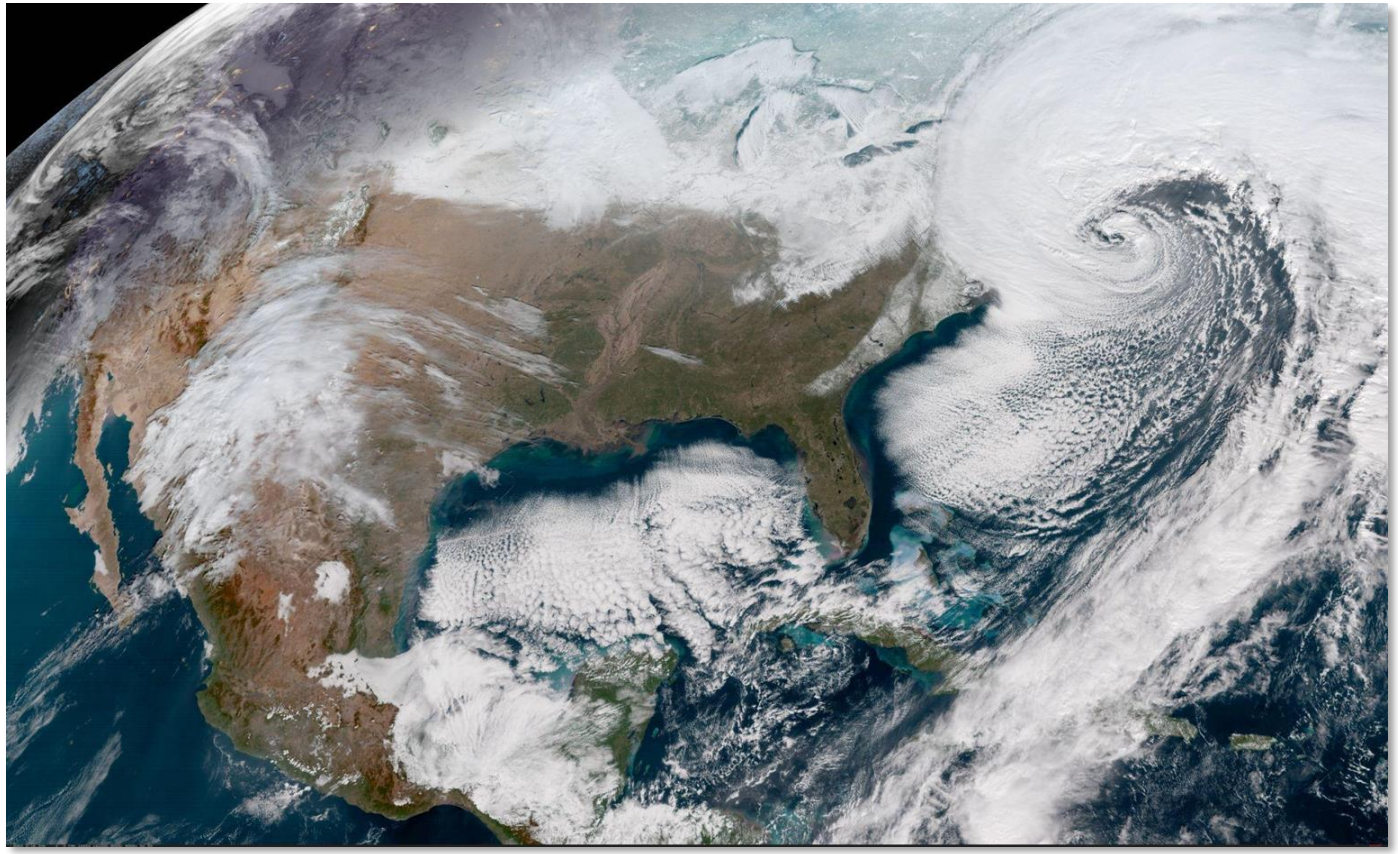
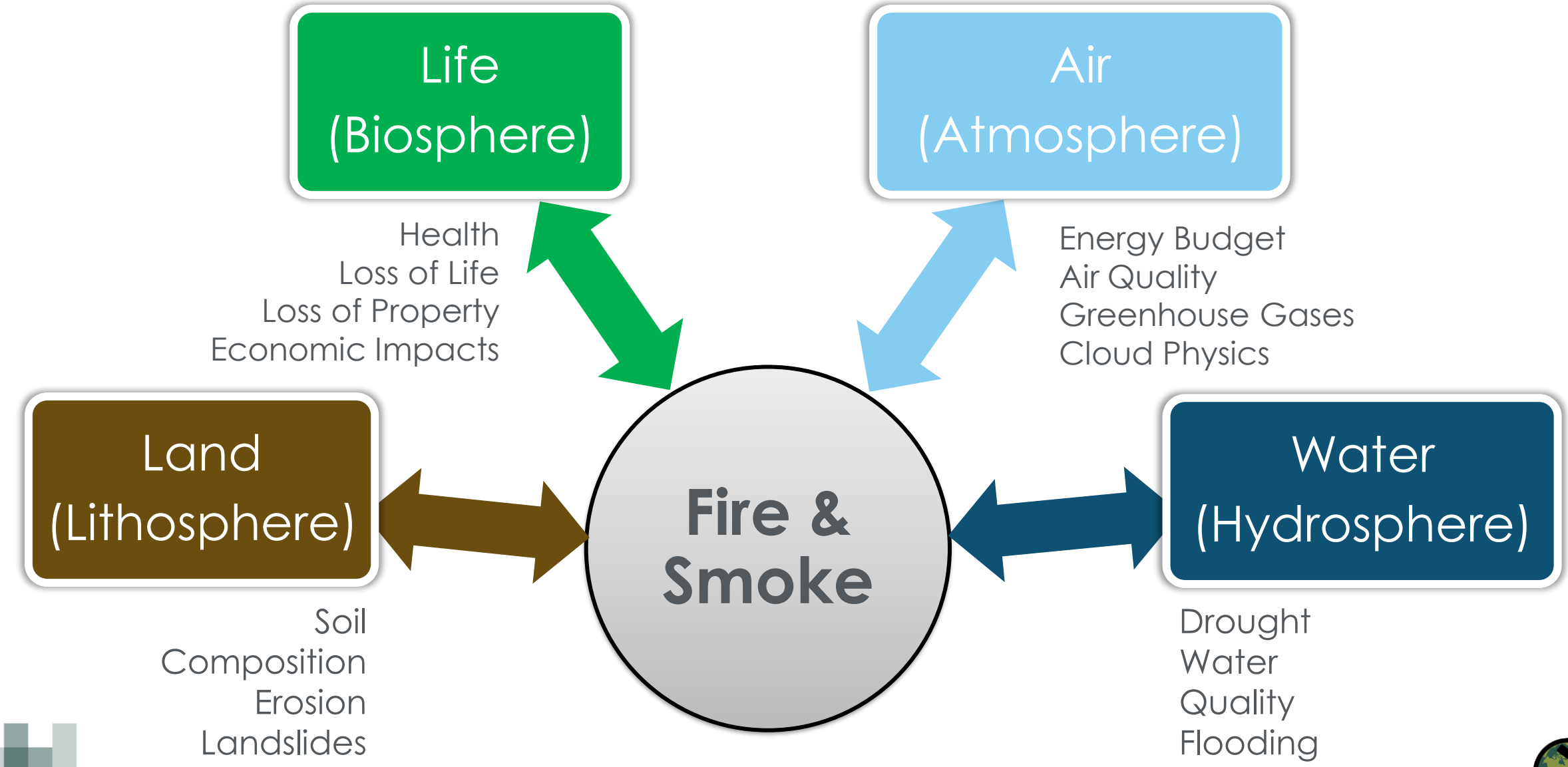


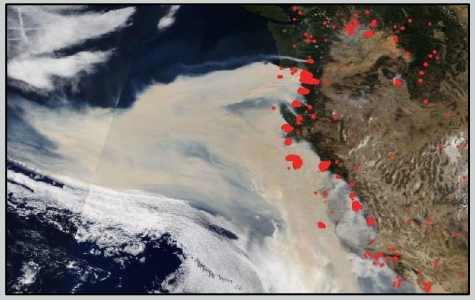
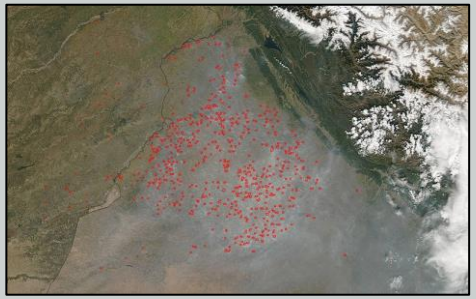
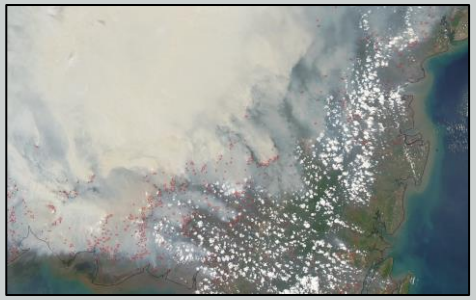
Image Credit: NOAA

Let’s talk about fire

Fire in the Earth System



Types of Fire

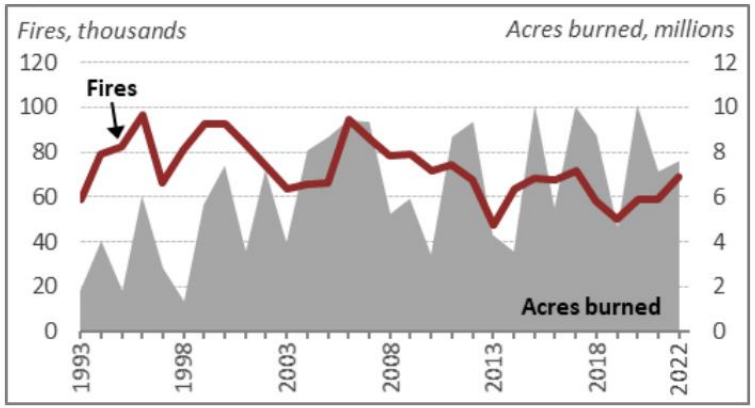
	Wildfire or Wildland	Deforestation	Agricultural	Peat
				
What does it burn?	Forests, Shrub, Grass	Forests	Crops, Grasses, Shrubs	Peat (soil-like material)
When does it burn?	Dry Seasons, Variable from Year to Year	Seasonal	Seasonal	Seasonal, Variable from Year to Year
Why did it burn?	Natural (lightning), or Humans (prescribed burns, accidental, arson)	Humans (forest clearing for livestock and crops)	Humans (burn prior to or after a growing season to clear fields for crops)	Natural (permafrost thaw), Humans (clear land for crops and animal grazing)
How did it burn?	Higher Intensity (can burn millions of acres if not controlled)	High Intensity	Lower Intensity	Very Low Intensity (burns underground, difficult to put out)

Wildfires

- Highly impact human lives, infrastructure, ecosystems, and wildlife.
- The 10-year average cost of fire suppression in the US is estimated to be **$2,358,603,800**

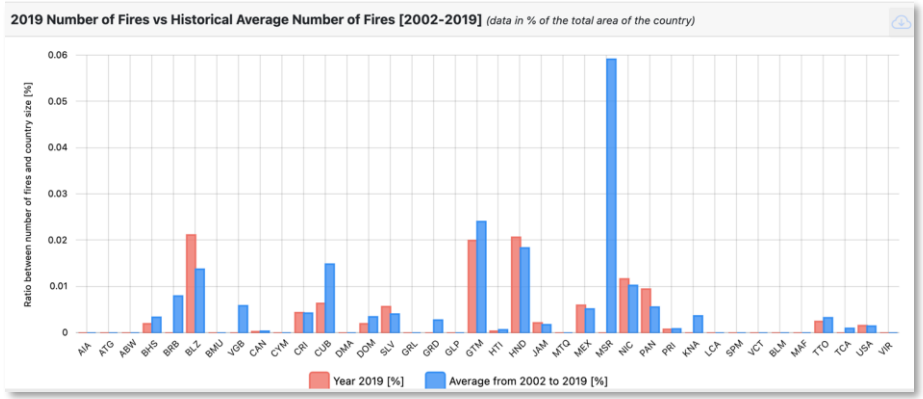
  (National Interagency Fire Center).
- While many wildfires are caused by humans, climate change is expected to increase wildfire activities due to warmer and drier conditions (Climate Change Indicators)
- Frequency, intensity, and extent of fires vary inter-annually depending on a complex connection between weather and climate conditions and ecosystem processes.

Figure 1. Annual Wildfires and Acres Burned, 1993-2022



Source: NICC Wildland Fire Summary and Statistics annual reports.
Note: Data reflect wildland fires and acres burned nationwide, including wildland fires on federal and nonfederal lands.

IN FOCUS



Global Wildfire Information System (GWIS)

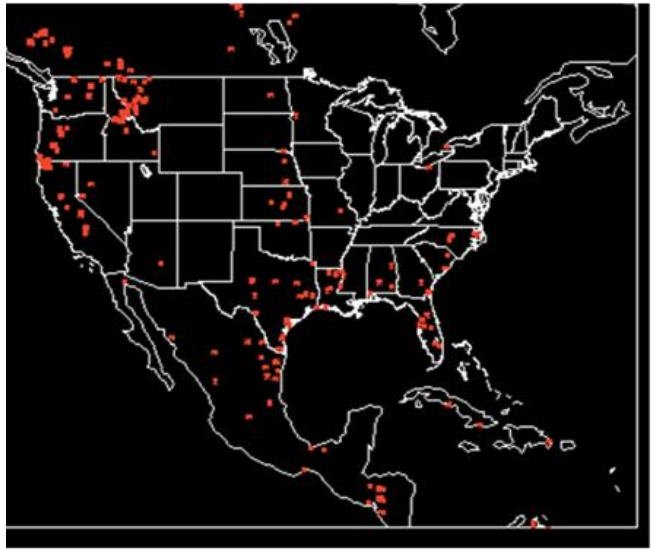
Post Fire Impacts

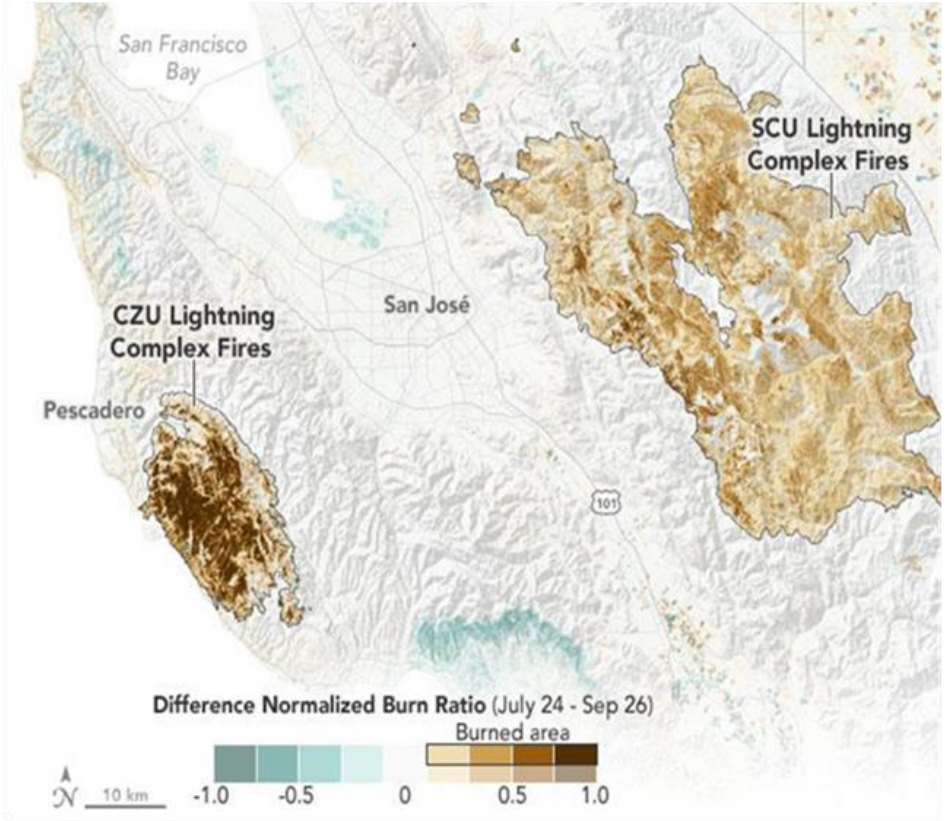
- Fires are a part of the natural forest, grassland, and tundra environment.
- Fires have long-lasting impacts to surrounding human lives and infrastructure.
- Some of the major post-fire impacts on environment are:
  - Release of carbon dioxide and soot particles in the atmosphere, thereby influencing climate
  - Change in soil chemistry and reduction in soil fertility
  - Destruction of vegetation leading to increased runoff and soil erosion
  - Influence on nutrient cycling and flow
  - Destruction of ecosystems and wildlife

http://www.geog.leeds.ac.uk/courses/level3/geog3320/studentwork/groupd/positiveandnegative.html

Monitoring Fires From Satellites

- **Detection of**
  - Smoke
  - Temperature Anomalies
  - Light
- **Post-fire mapping of**
  - Extent
  - Severity
- **Satellites/Sensors**
  - MODIS
  - VIIRS
  - GOES (NOAA)
  - Landsat
  - Sentinel-2 (ESA)
  - Sentinel-1 (ESA)

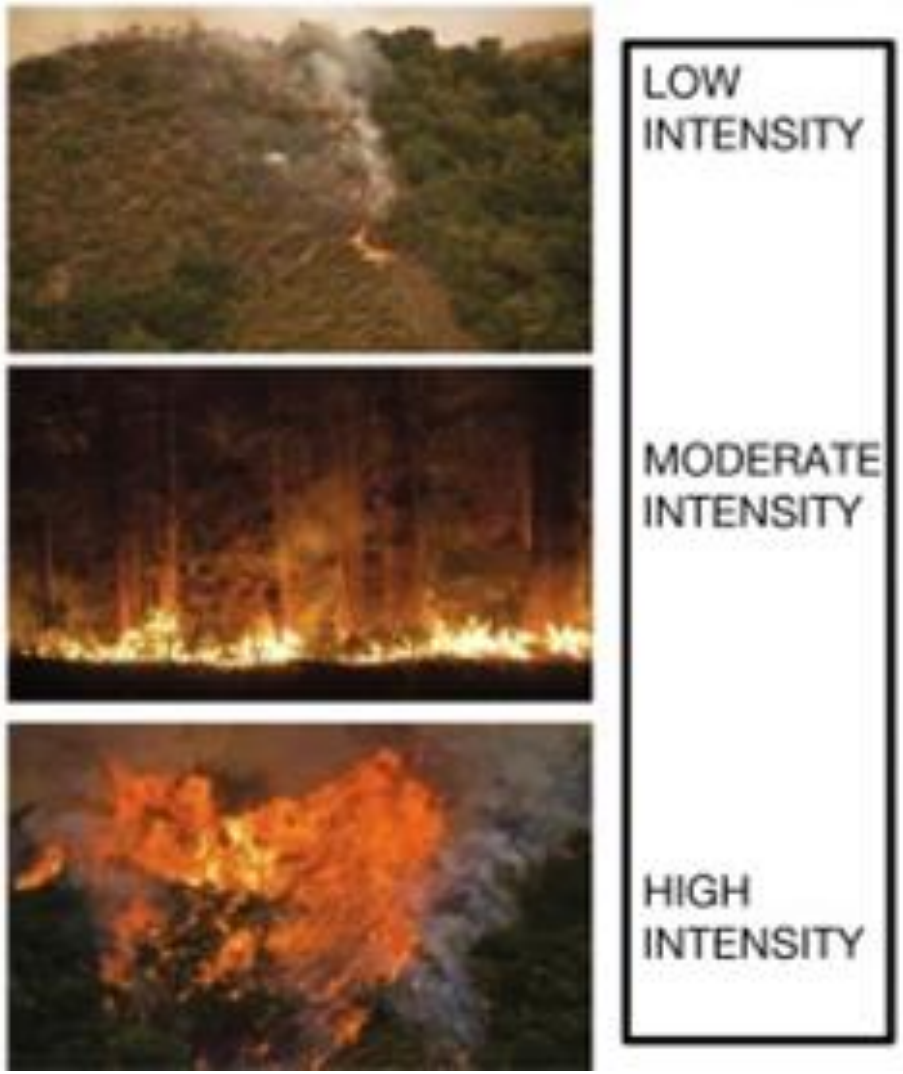




Smoke from Canadian wildfires from MODIS (top left), Fire detections from VIIRS (bottom left), Burn severity of the CZU and SCU Lightning Complex Fires in California (above). Image Credit: NASA

Fire Intensity

- The **amount of energy or heat release per unit time or area** and encompasses several specific types of fire intensity measures.
- Byram (1959): "The rate of energy or heat release per unit time, per unit length of fire front, regardless of its depth."
- Fire intensity dictates burn severity.

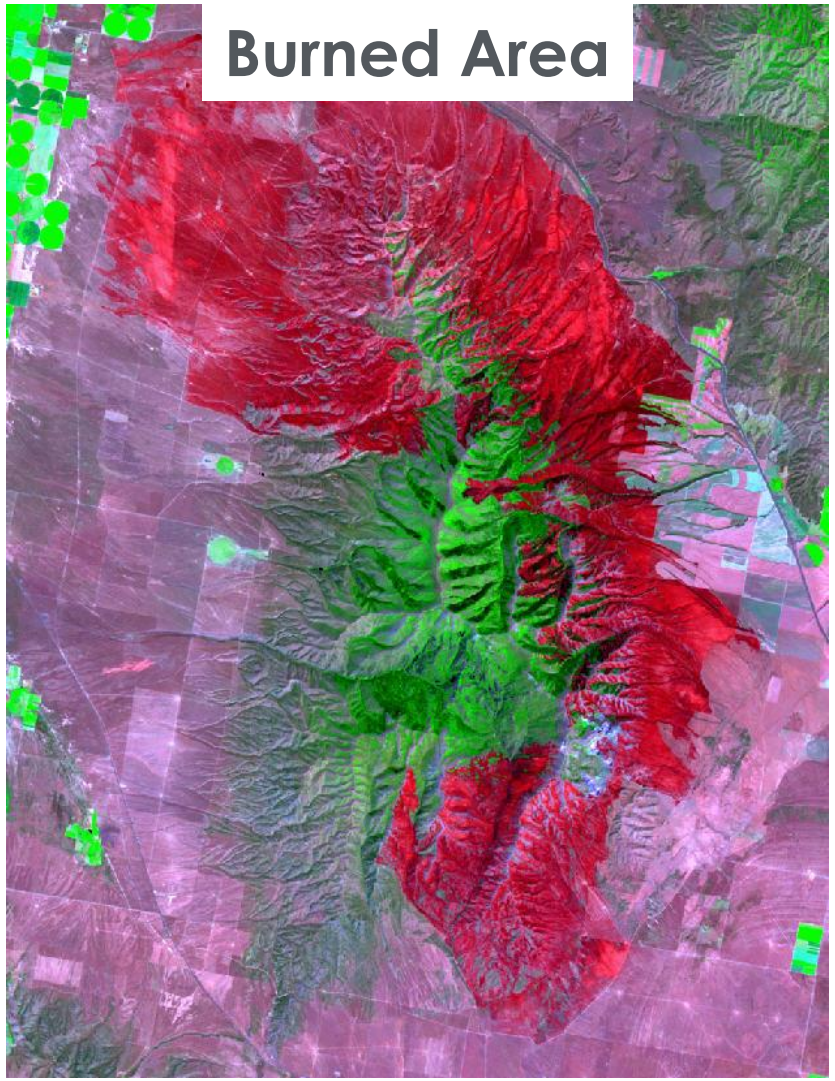


Burn Severity

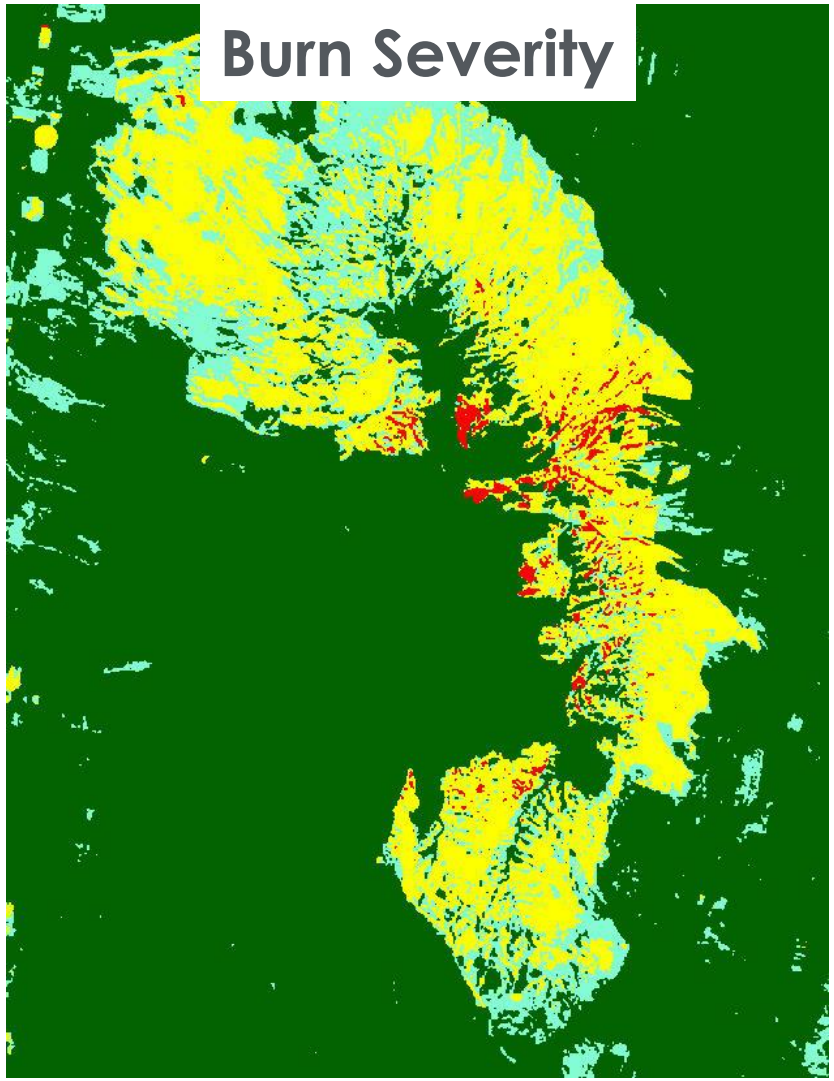
- The **effect of a fire on ecosystem properties**, often defined by the degree of mortality of vegetation
- Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time

Example of high severity burned area. Image Credit: USDA Forest Service Gen. Tech. Rep. RMRS-GTR-243. 2010

Remote Sensing Perspective: Burned Area and Burn Severity

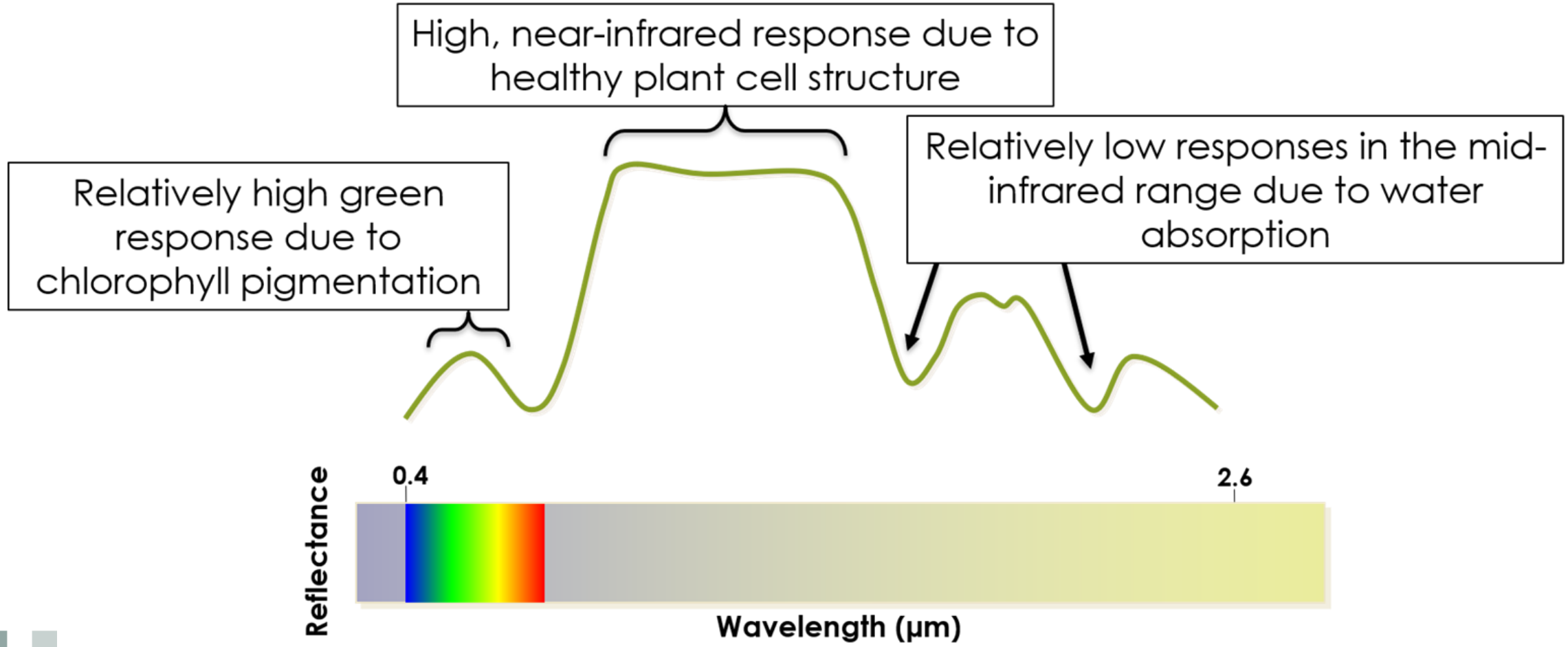


- Burned area uses imagery to assess the extent of impacts on vegetation for a particular fire event.
- Burn severity compares burned area information to pre-fire imagery to assess relative magnitude of burn impacts.



Typical Vegetation Spectral Response

Spectral Response Curve of Typical Vegetation from 0.4 to 2.6 µm

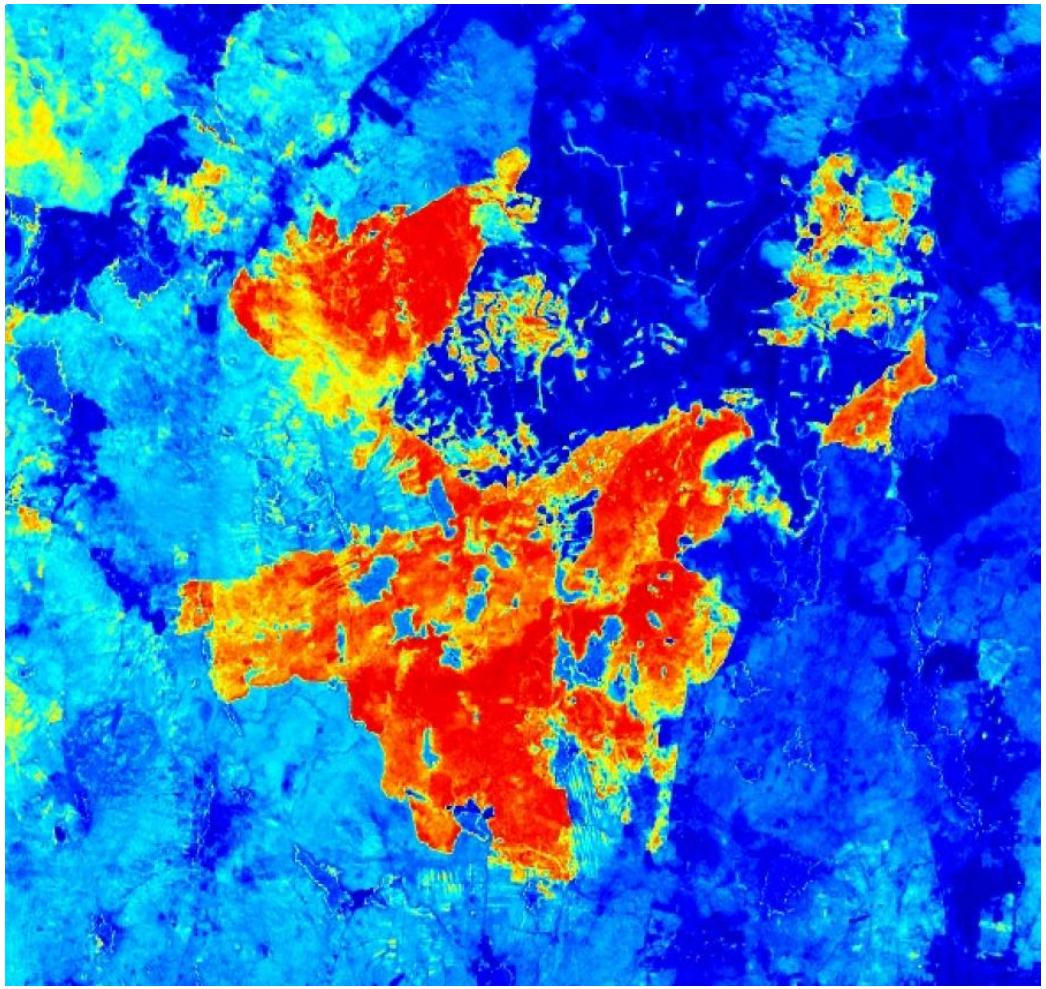


What is a spectral index?

- 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

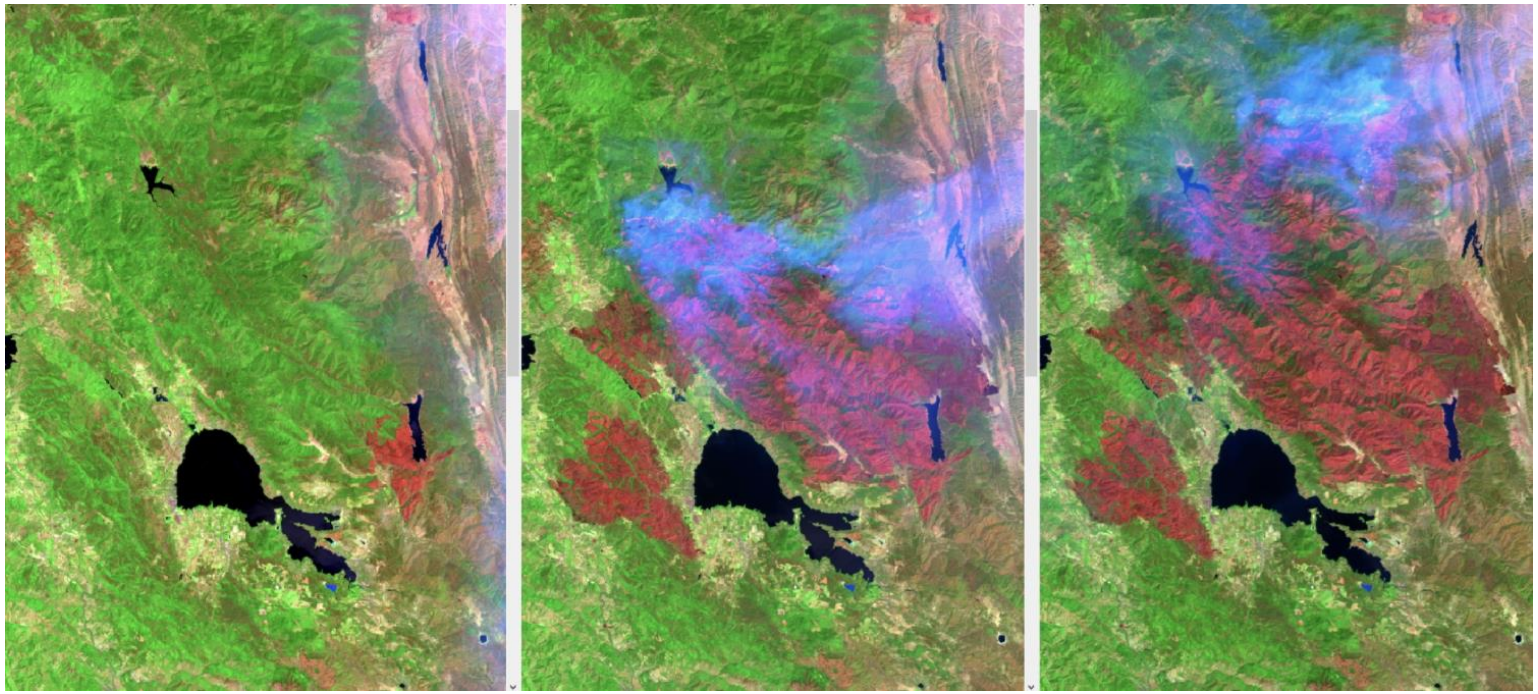
- Vegetation Health
- Burned Area Mapping and Fire Severity
- Water Content
- Biophysical Parameters (i.e., biomass)
- Geologic Mapping



Moisture Index of Wildfire (Wildfire in red, orange)

Burned Area: Normalized Burn Ratio (NBR)

- Used to identify burned areas
- Compare pre- and post-burn to identify burn extent and severity



July 26 Aug 11 Aug 27

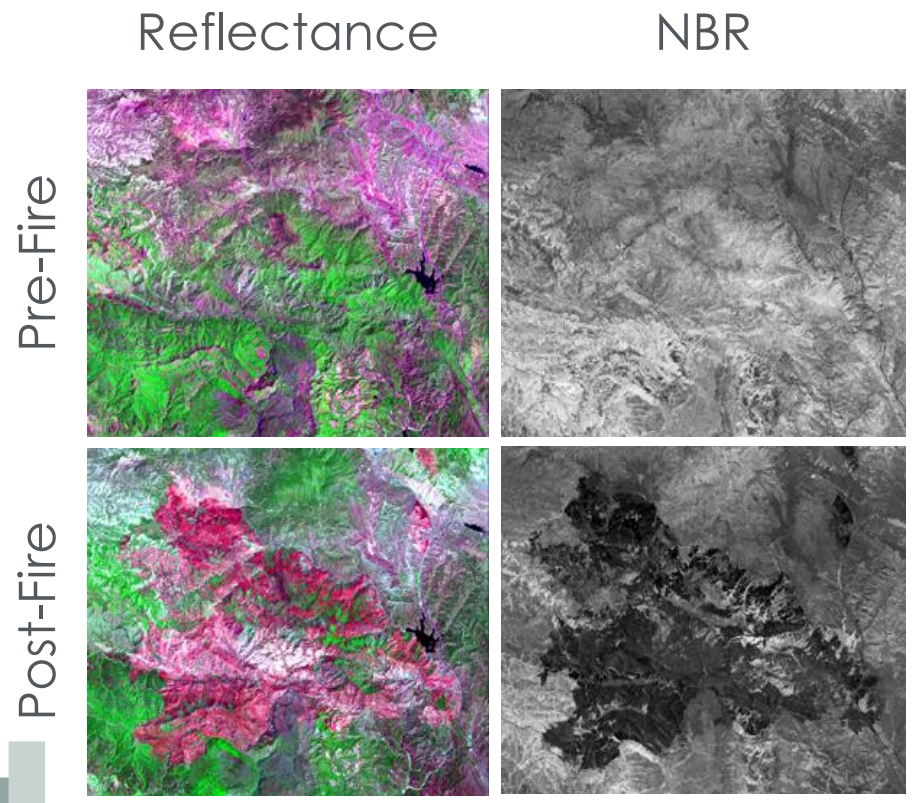
Mendocino Complex Fires, 2018

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

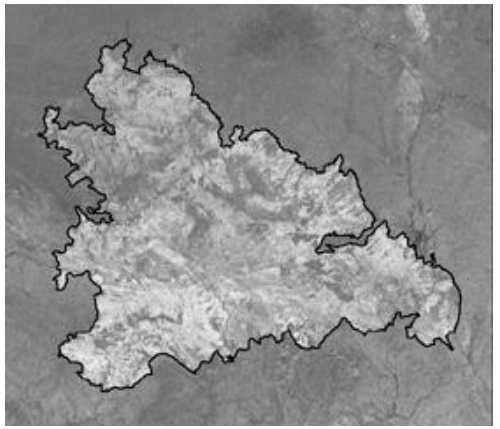
Burn Severity: Differenced Normalized Burn Ratio (dNBR)

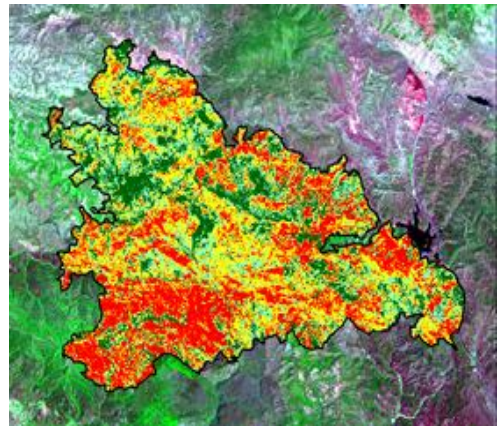
- **Normalized Burn Ratio (NBR)**
- Establishes extent of burned area before and after fire event

- **Differenced Normalized Burn Ratio (dNBR)**
- Provides a comparison of pre- and post-fire conditions to determine severity
- dNBR = Pre-Fire NBR – Post-Fire NBR



Difference



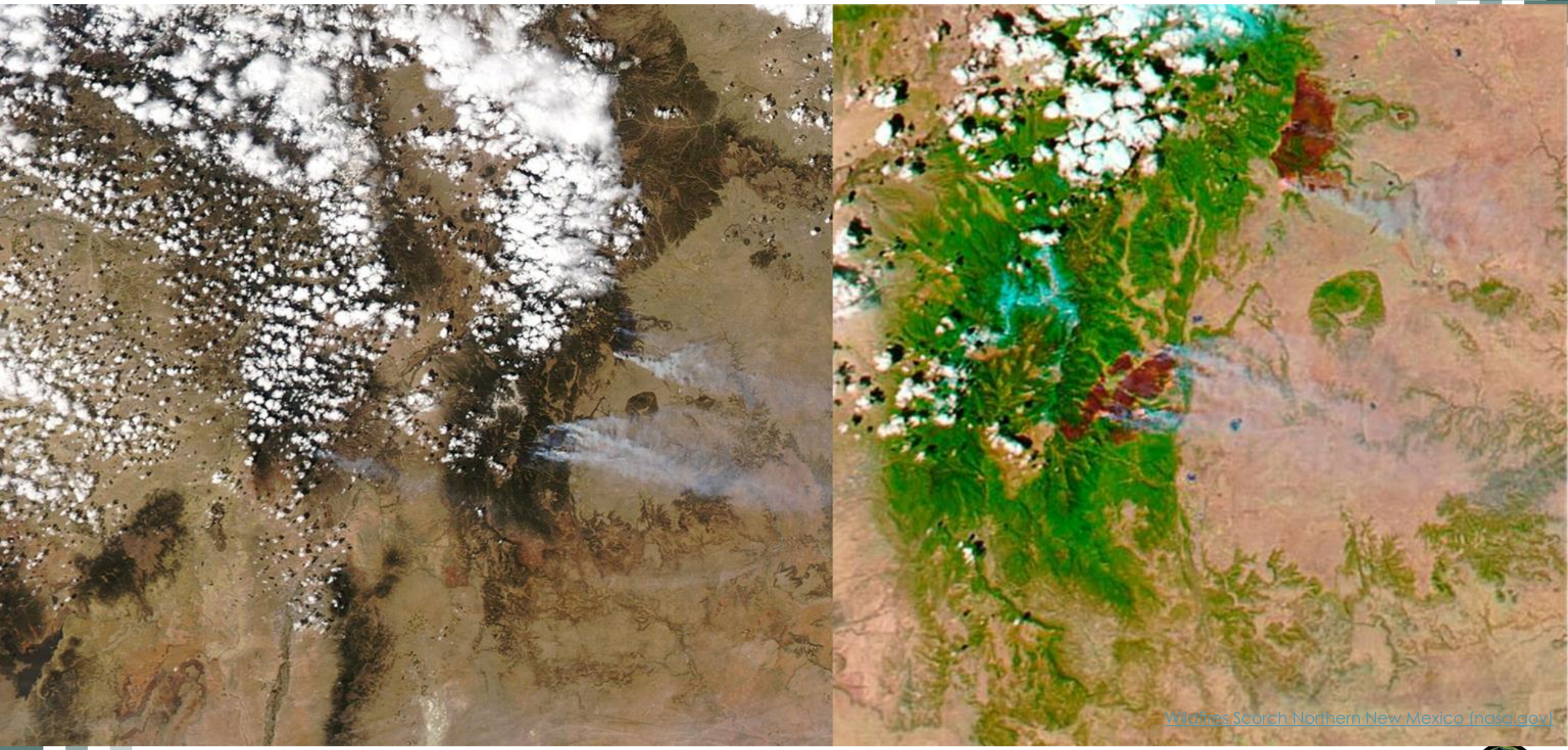


Hermit's Peak/Calf Canyon Fire

Wildfires Continue to Burn Across New Mexico (nasa.gov)

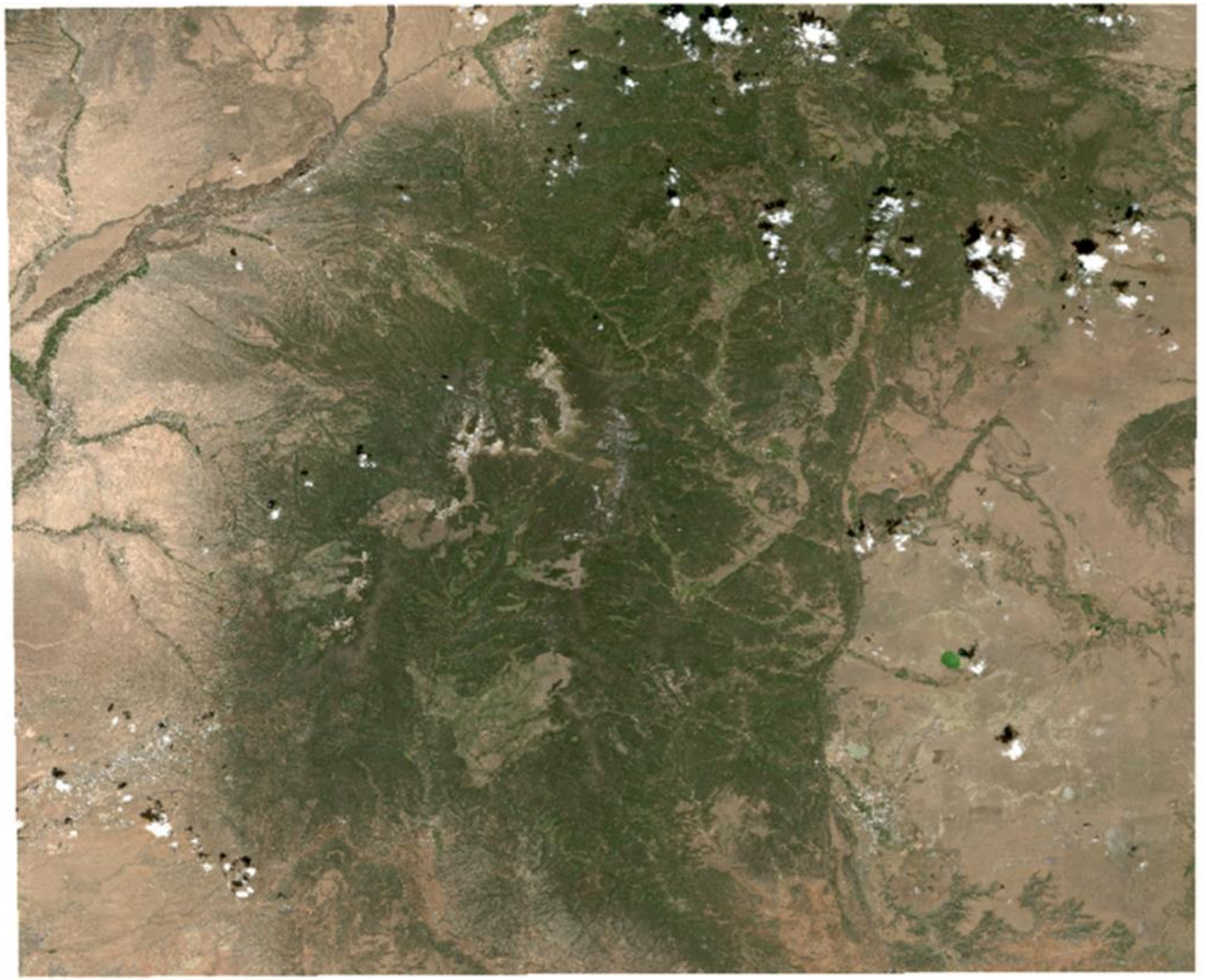
Credit: Sativa Cruz

Geraint Smith Photography

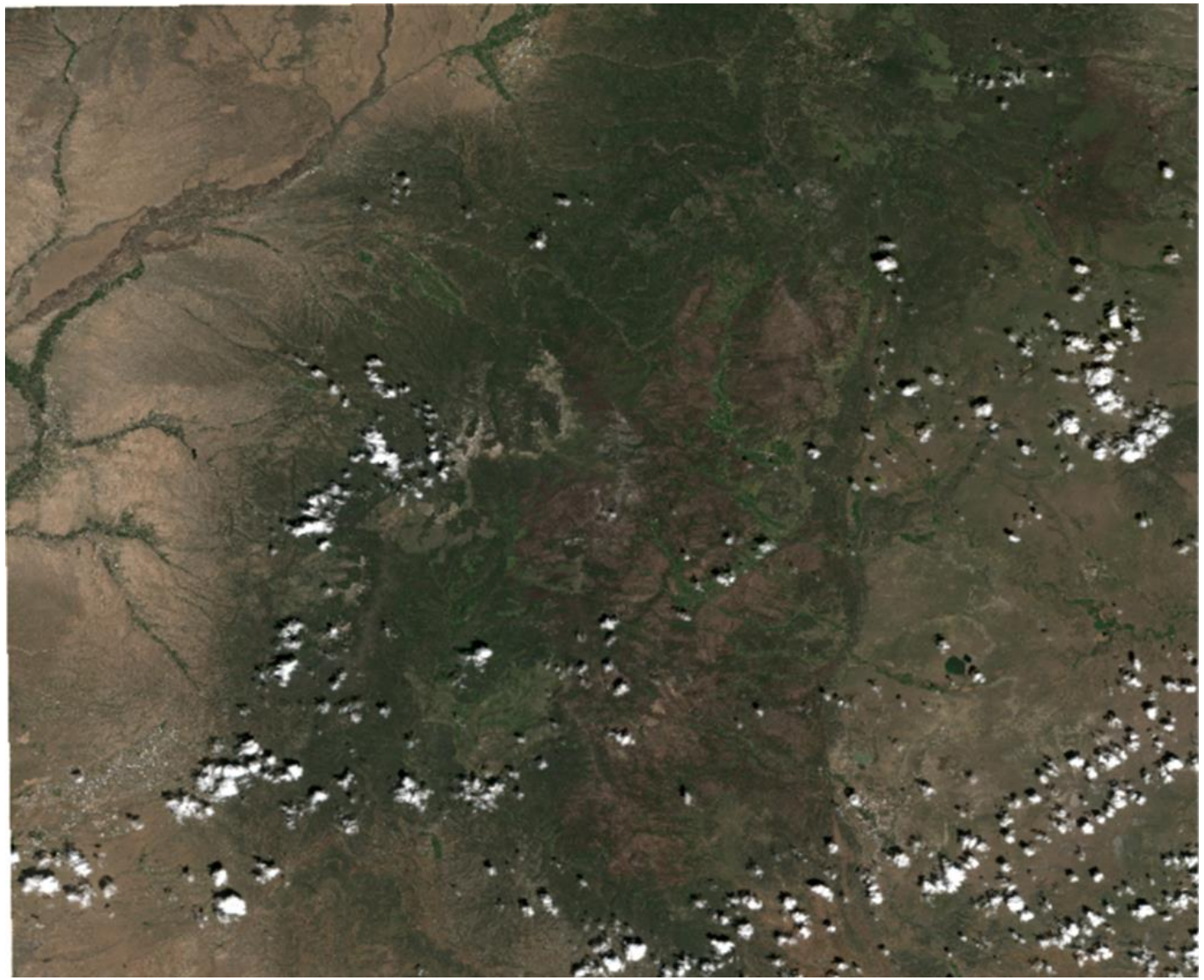


Wildfires Scorch Northern New Mexico (nasa.gov)

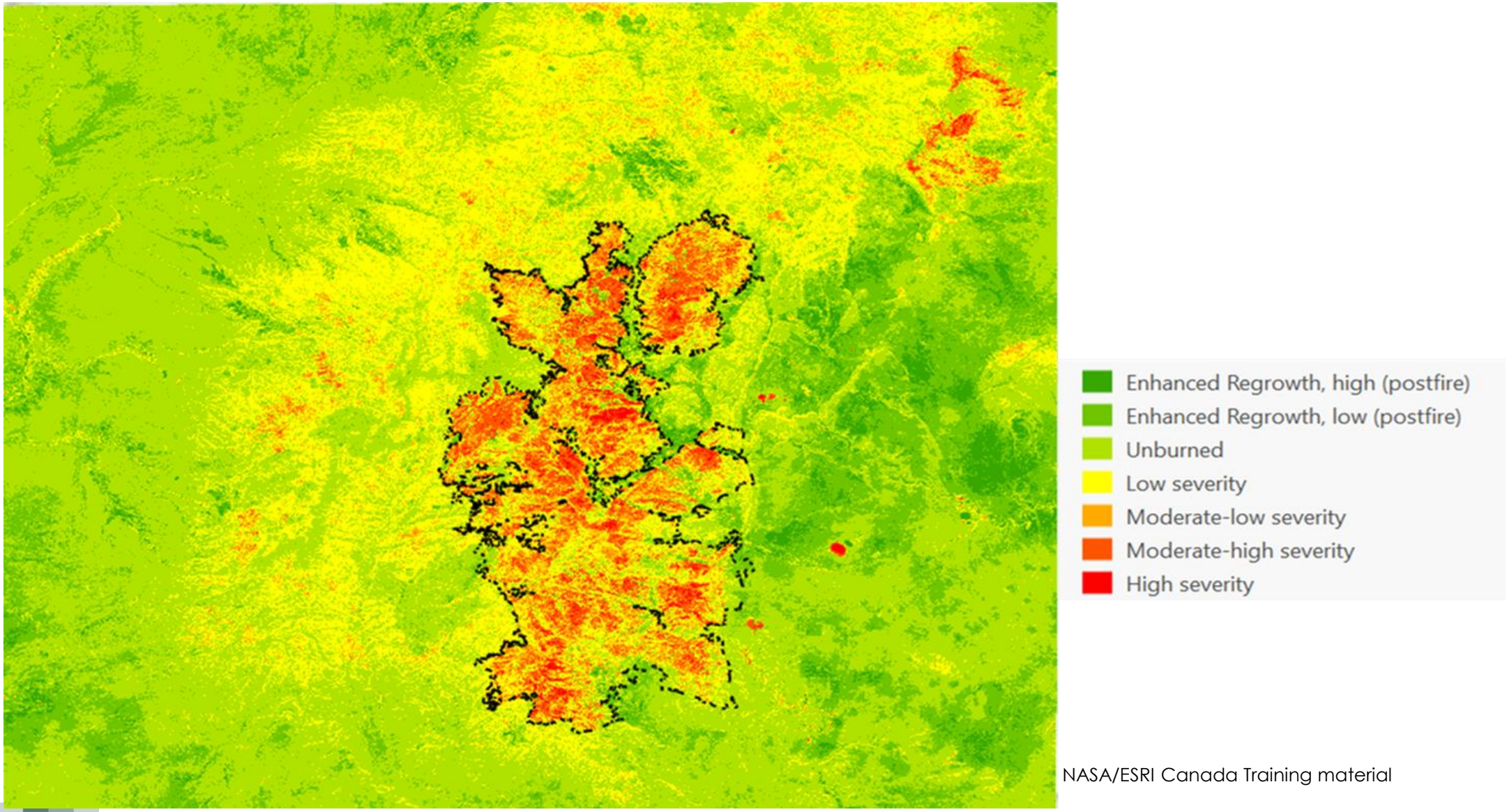
Prefire Image



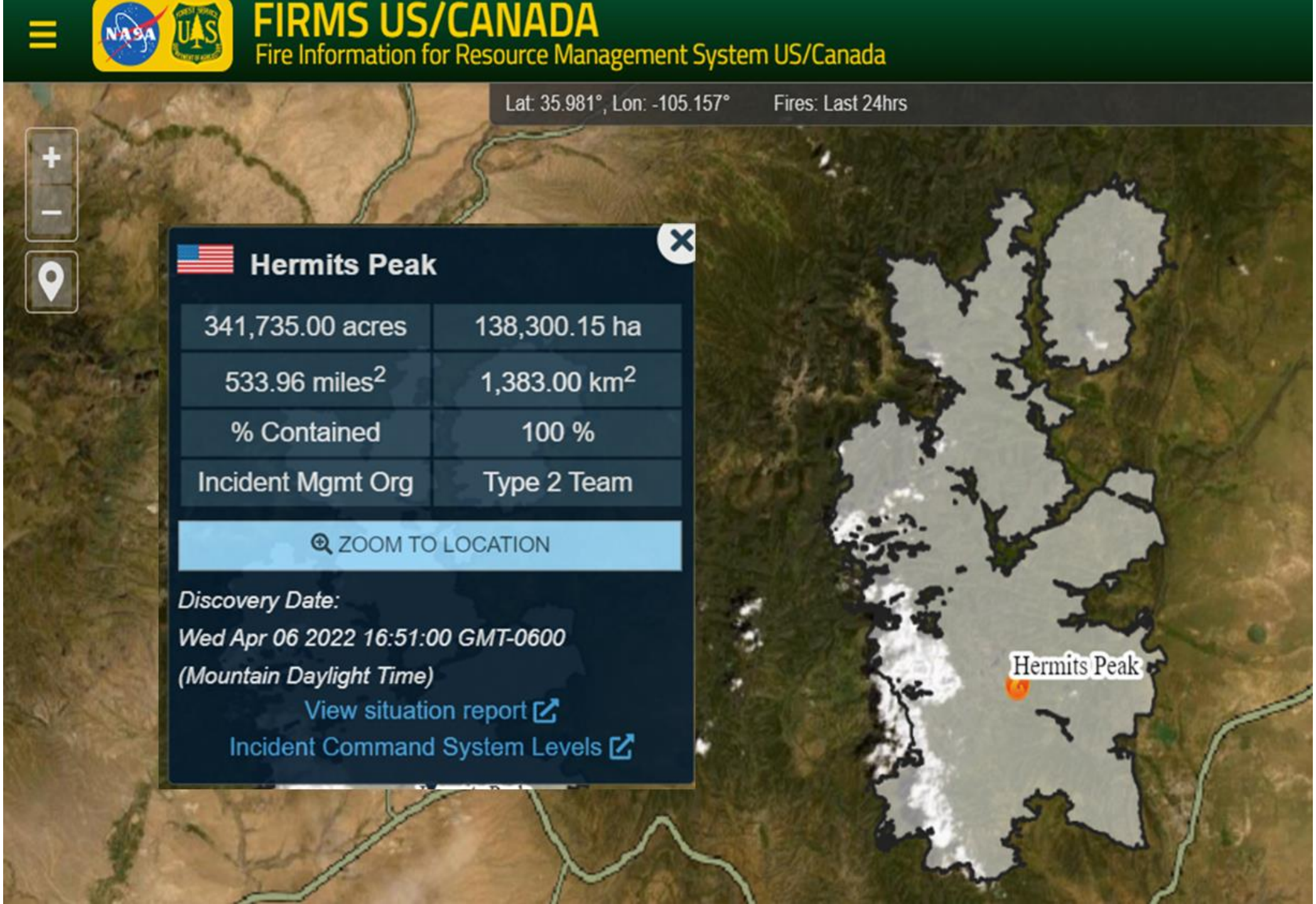
Post Fire Image



Burn Severity Map



NASA/ESRI Canada Training material

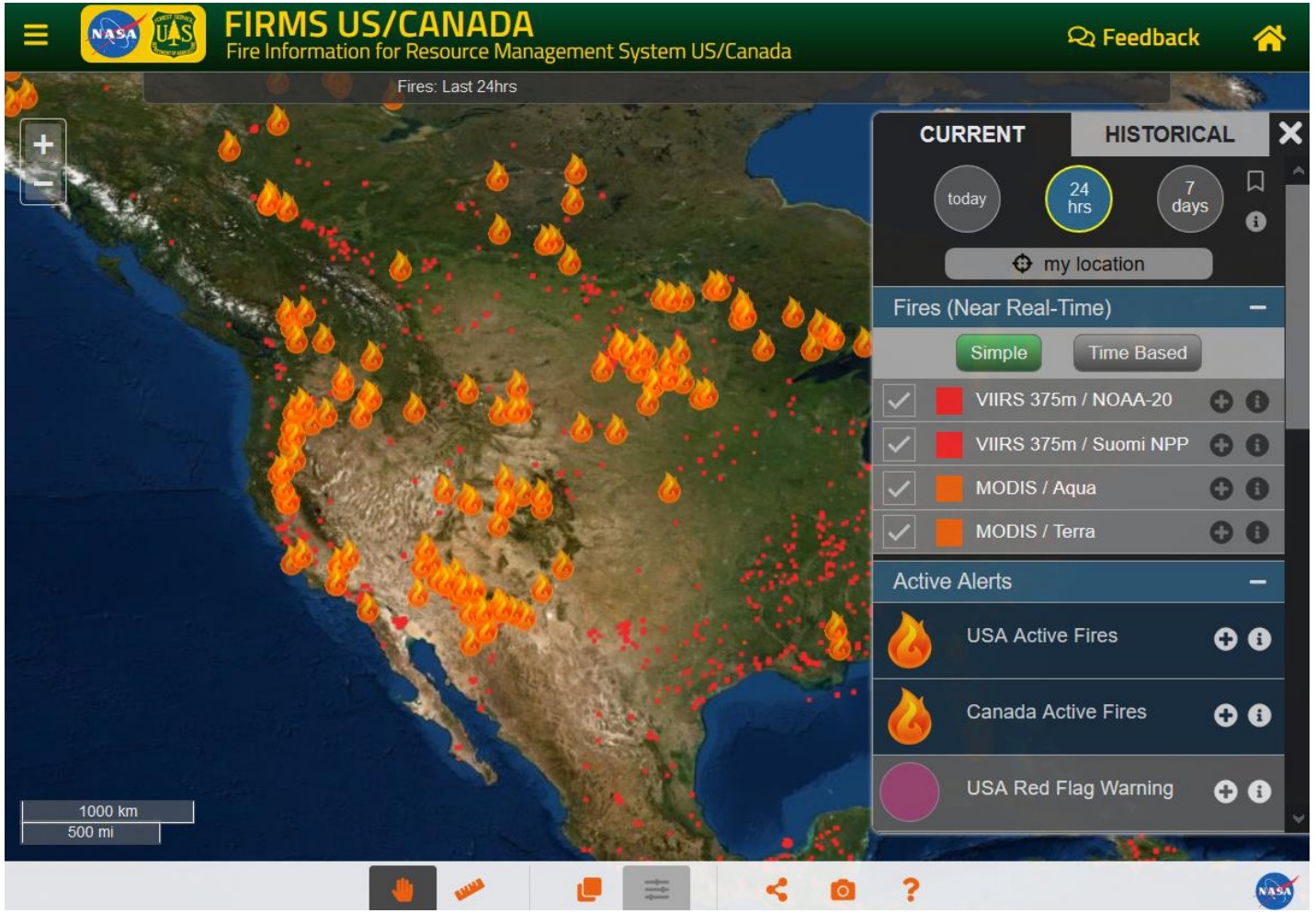

FIRMS US/CANADA
Fire Information for Resource Management System US/Canada
Lat: 35.981°, Lon: -105.157°
Fires: Last 24hrs
Hermits Peak
341,735.00 acres
138,300.15 ha
533.96 miles2
1,383.00 km2
% Contained
100 %
Incident Mgmt Org
Type 2 Team
ZOOM TO LOCATION
Discovery Date:
Wed Apr 06 2022 16:51:00 GMT-0600
(Mountain Daylight Time)
View situation report
Incident Command System Levels
Hermits Peak

Demo: FIRMS for Wildfires

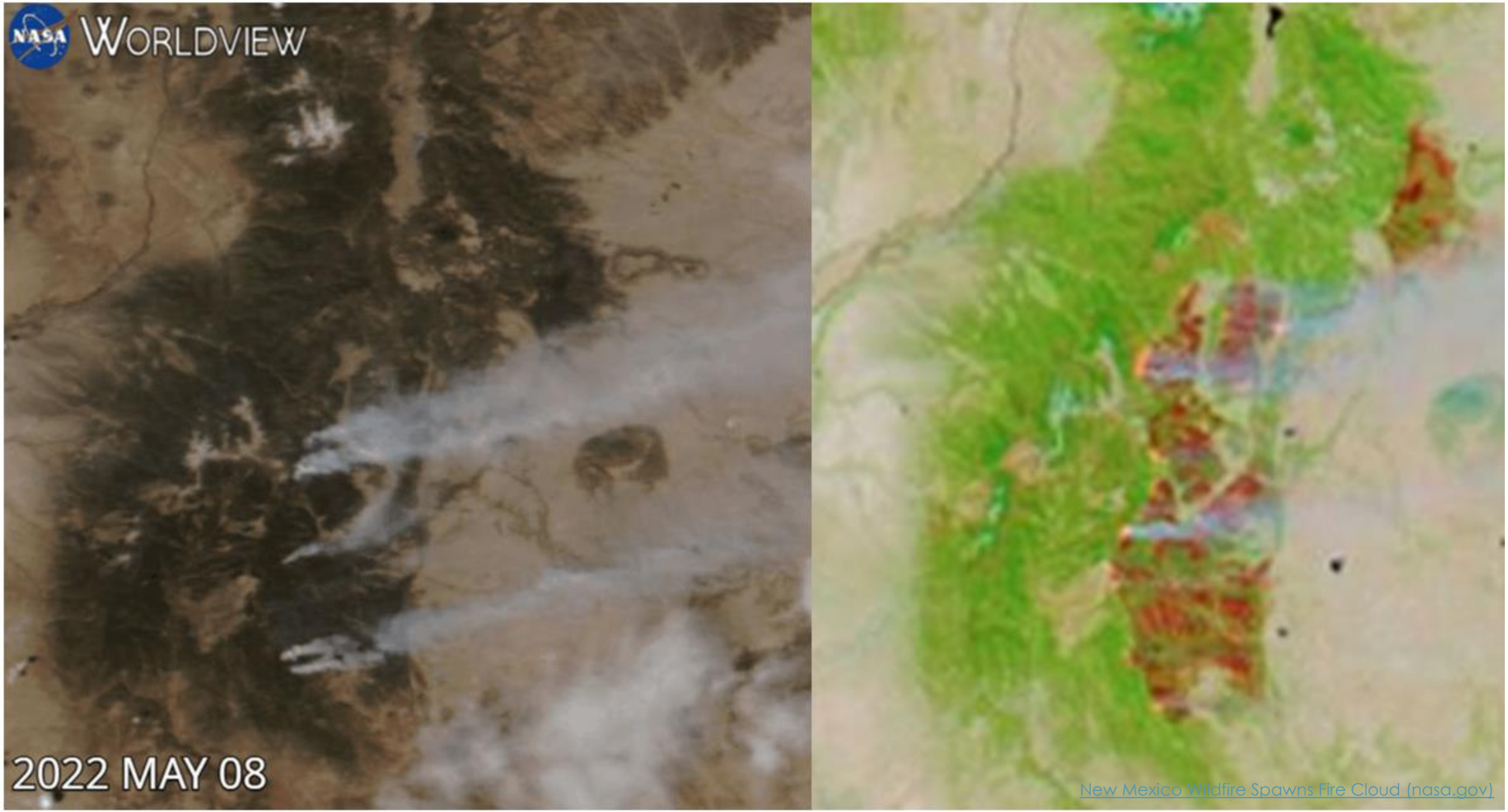
Fire Information for Resource Management System

Fire Information for Resource Management System (FIRMS) for active and historical fires

- Data available globally
- Fire Map
  - VIIRS and MODIS fire detection and active fire data
- Near Real-Time (NRT) data replaced with standard science-quality data as they become available (usually with a 2-3-month lag)
- MODIS Burned Area Product
- Data Download:
  - https://firms2.modaps.eosdis.nasa.gov/download/



https://firms.modaps.eosdis.nasa.gov/

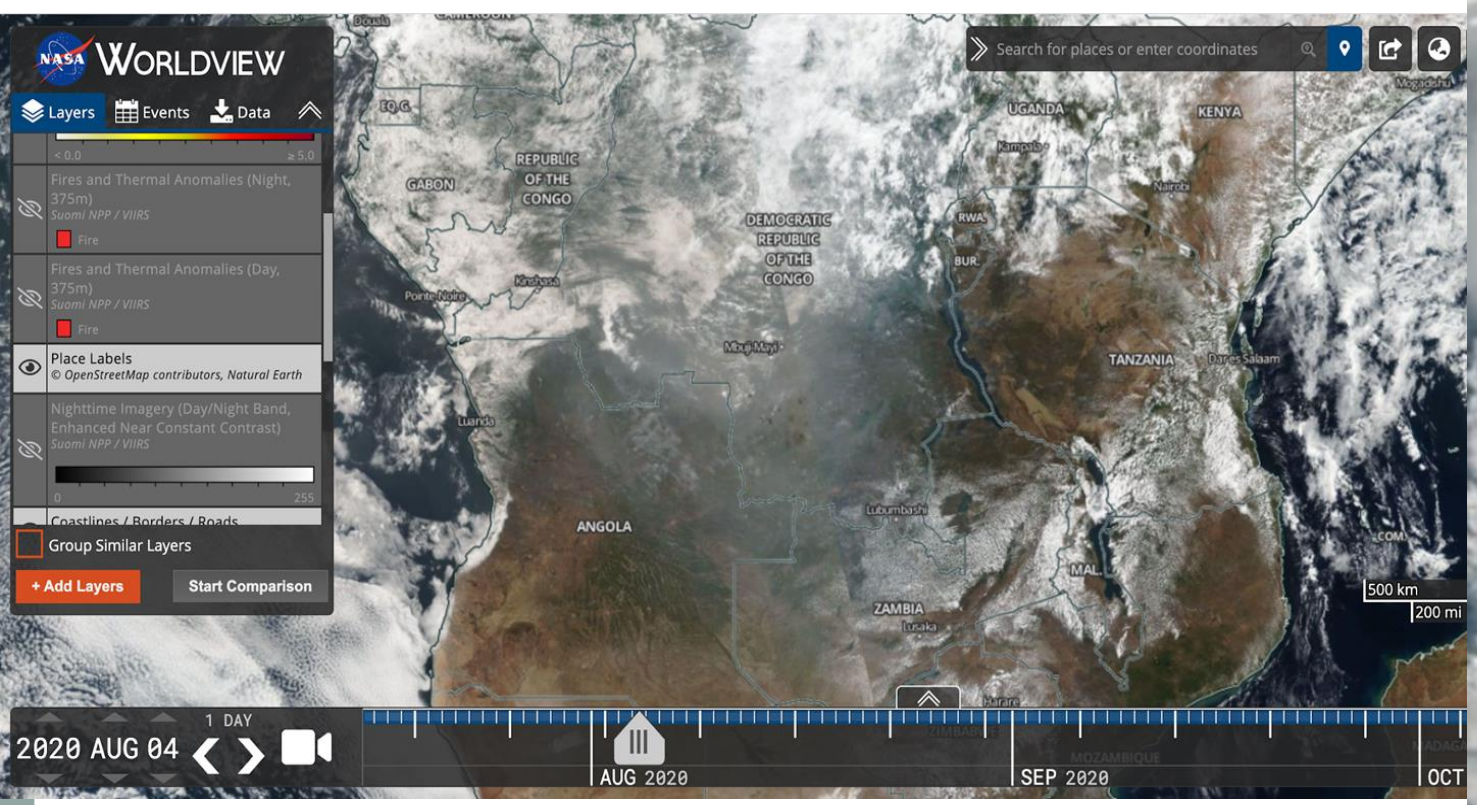


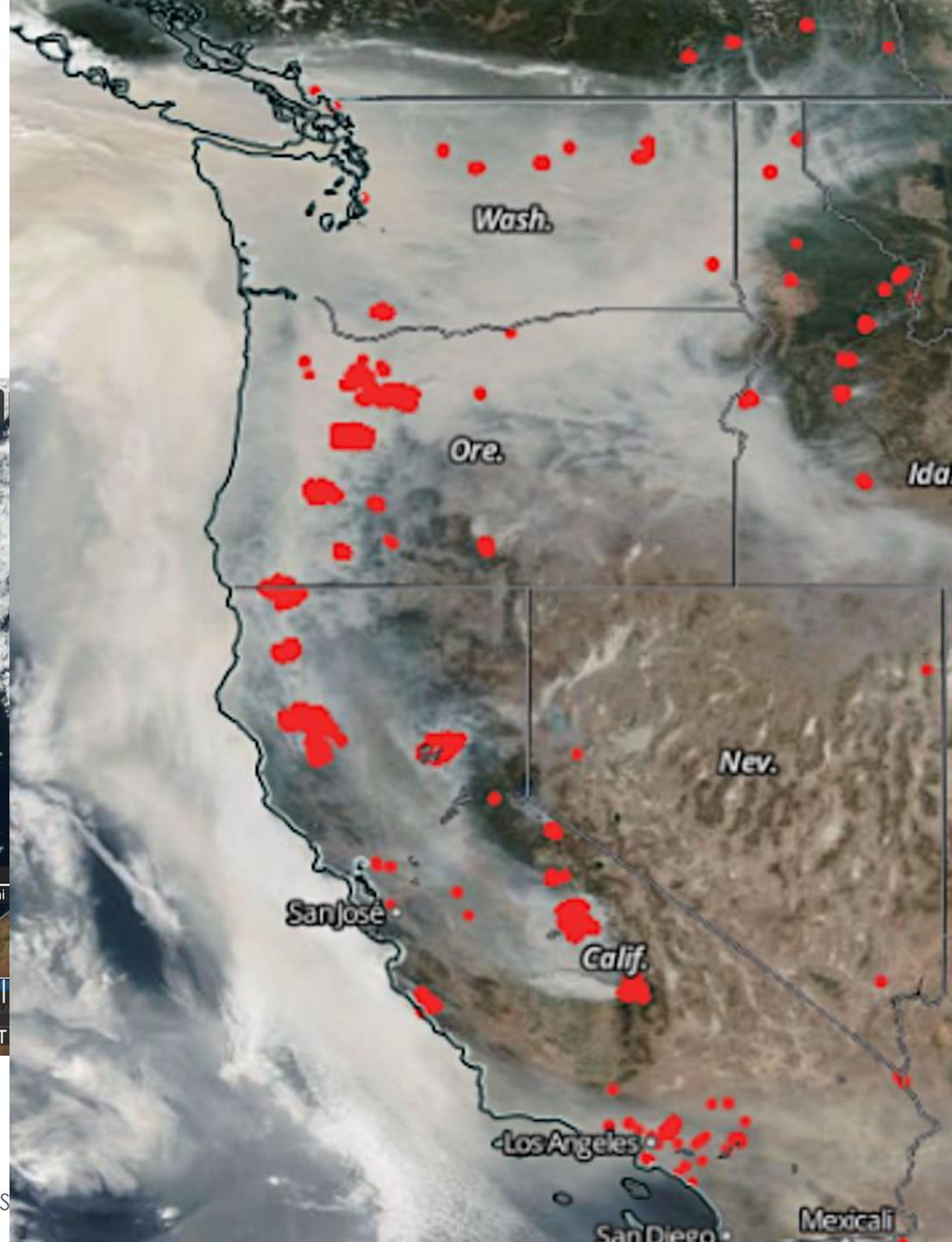
New Mexico Wildfire Spawns Fire Cloud (nasa.gov)

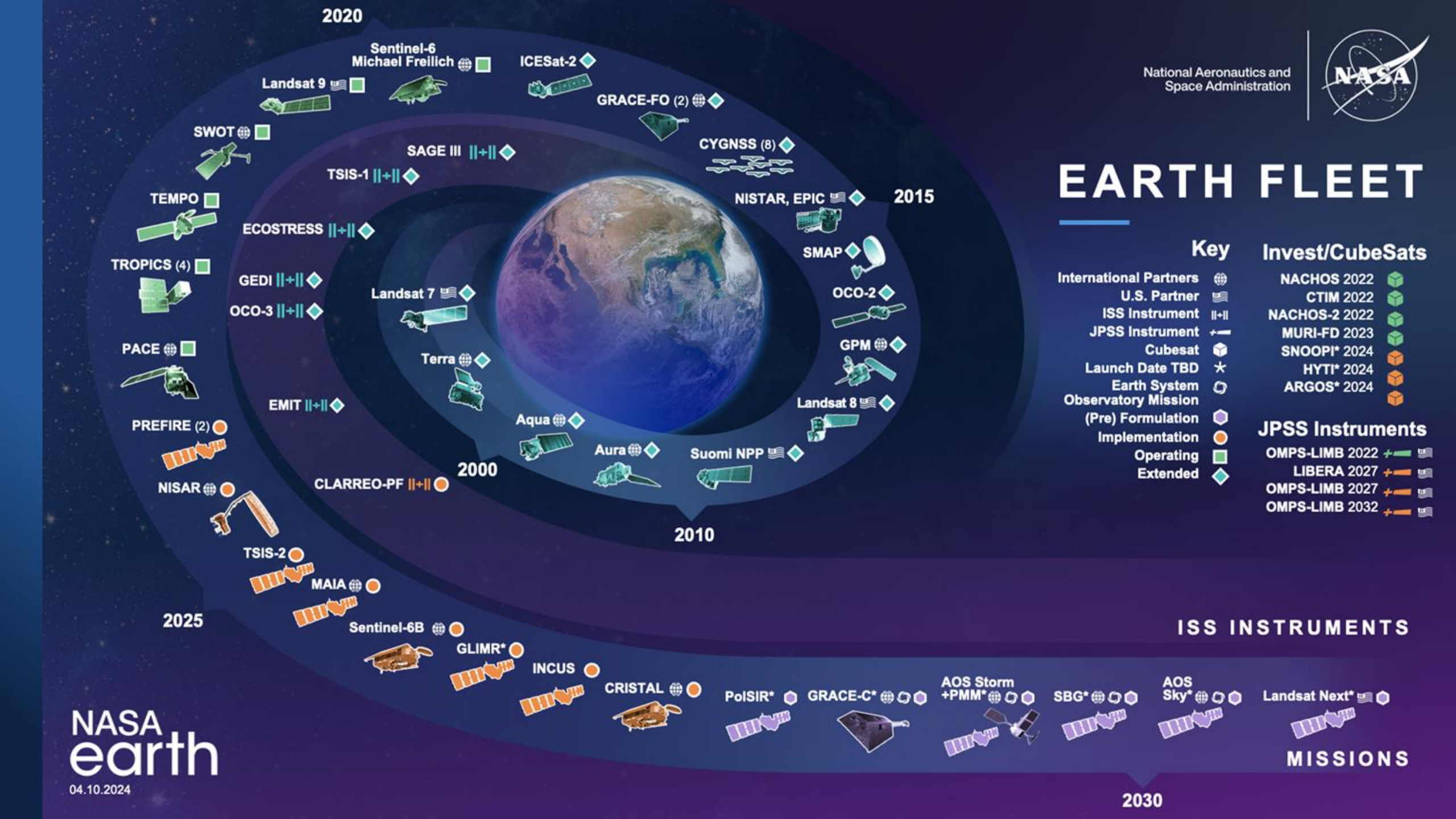
Demo: NASA Worldview

Worldview - NASA Near Real Time Data Visualization

https://worldview.earthdata.nasa.gov/







National Aeronautics and Space Administration

NASA

EARTH FLEET

Key

- International Partners
- U.S. Partner
- ISS Instrument
- JPSS Instrument
- Cubesat
- Launch Date TBD
- Earth System Observatory Mission
- (Pre) Formulation
- Implementation
- Operating
- Extended

Invest/CubeSats

- NACHOS 2022
- CTIM 2022
- NACHOS-2 2022
- MURI-FD 2023
- SNOOPI* 2024
- HYTI* 2024
- ARGOS* 2024

JPSS Instruments

- OMPS-LIMB 2022
- LIBERA 2027
- OMPS-LIMB 2027
- OMPS-LIMB 2032

NASA earth

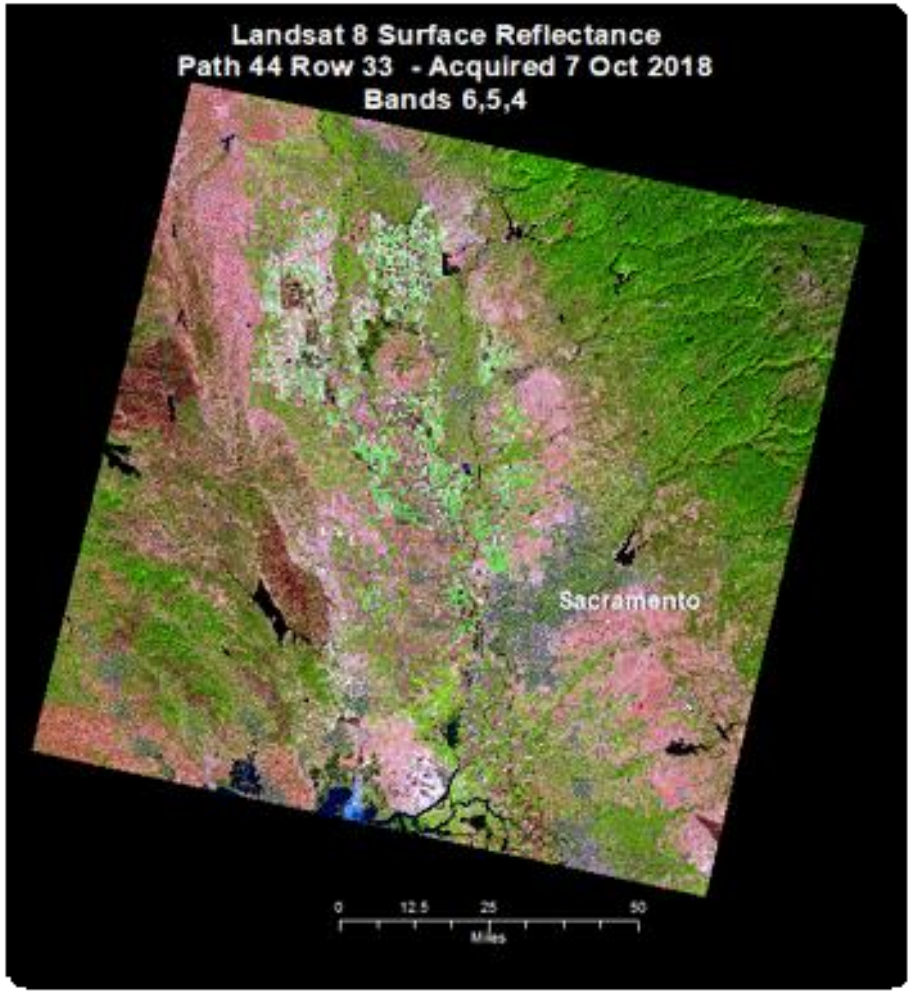
04.10.2024

Landsat

- First Landsat launched in 1972
- NASA created and launched
- USGS maintains data
- Passive Sensor - Obtains values of reflectance from Earth's surface
- 30-meter pixels
- Image of the entire Earth every 16 days

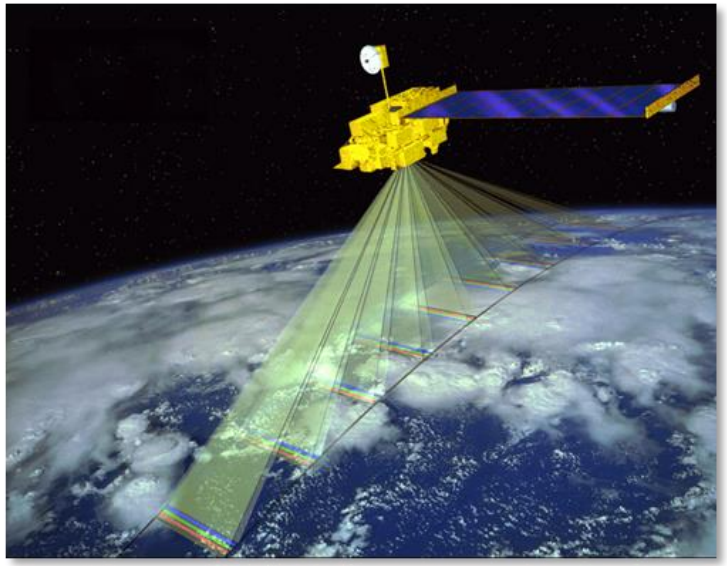
Applications:

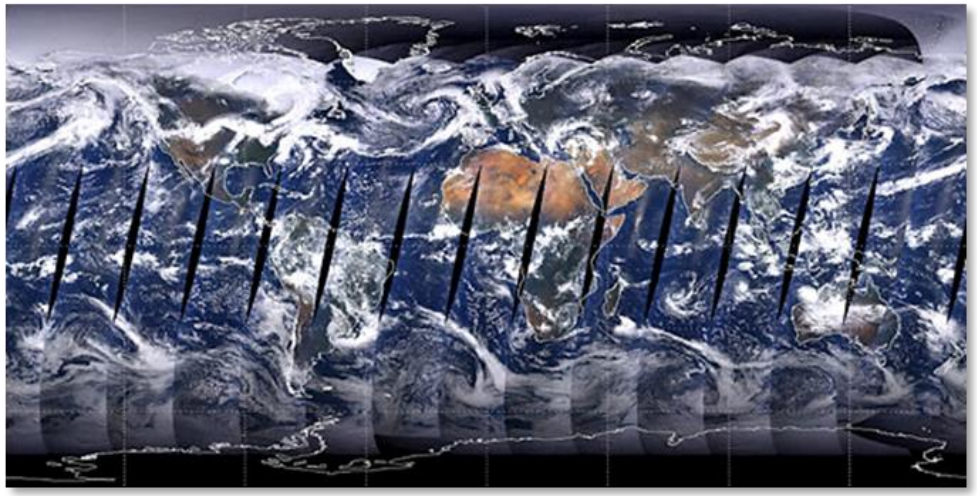
- Vegetation health
- Deforestation
- Fires
- Agriculture
- Species habitats
- Water Quality



Moderate Resolution Imaging Spectroradiometer (MODIS)

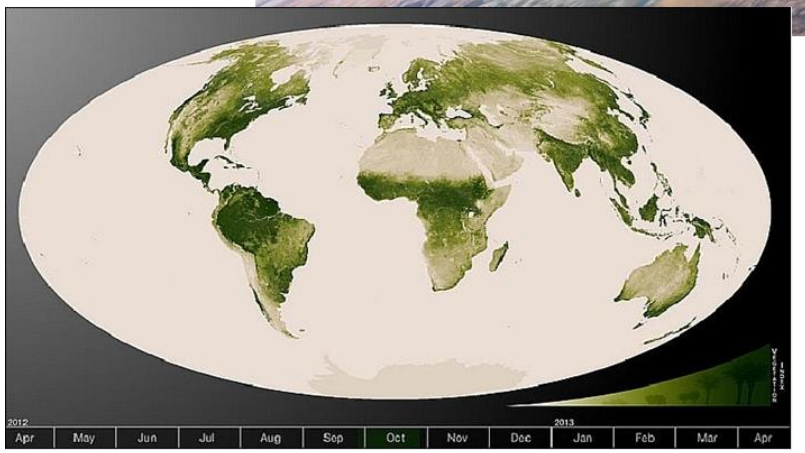
- Spatial Resolution
  - 250 m, 500 m, 1 km
- Temporal Resolution
  - Daily, 8 day, 16 day, monthly, quarterly, yearly
  - 2000–present
- Data Format
  - Hierarchical data format – Earth Observing System Format (HDF–EO8)
- Spectral Coverage
  - 36 bands (major bands include blue, green, red, IR, NIR, MIR)
    - Bands 1-2: 250 m
    - Bands 3-7: 500 m
    - Bands 8-36: 1000 m





Visible Infrared Imaging Radiometer Suite (VIIRS)

- A sensor onboard the Suomi National Polar-Orbiting Partnership (NPP)
- Data available globally from January 2012 to present
- Revisit Time: 1 day
- Spatial Resolution: 375m and 750m
- Similar to MODIS (with some differences)
- Visible, near-infrared channels (reflectance)
- Shortwave and longwave infrared (brightness temperature)
- Products:
  - Surface reflectance
  - Vegetation indices
  - Thermal anomalies

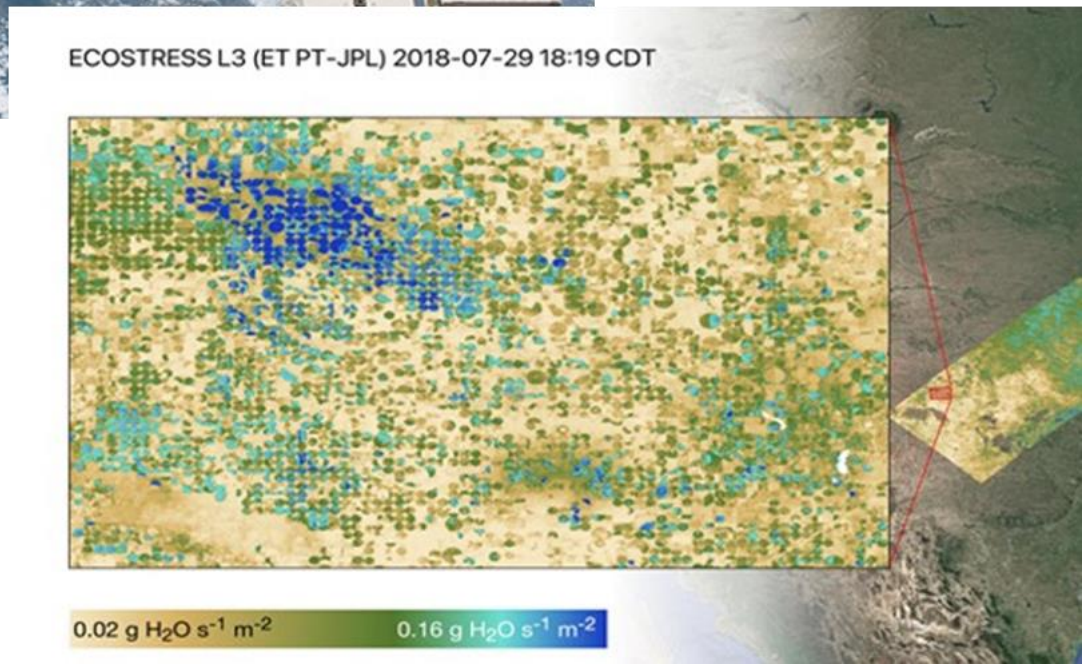


Suomi NPP satellite (above); Global vegetation map (left). Image Credit: NASA/NOAA)

The ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS)

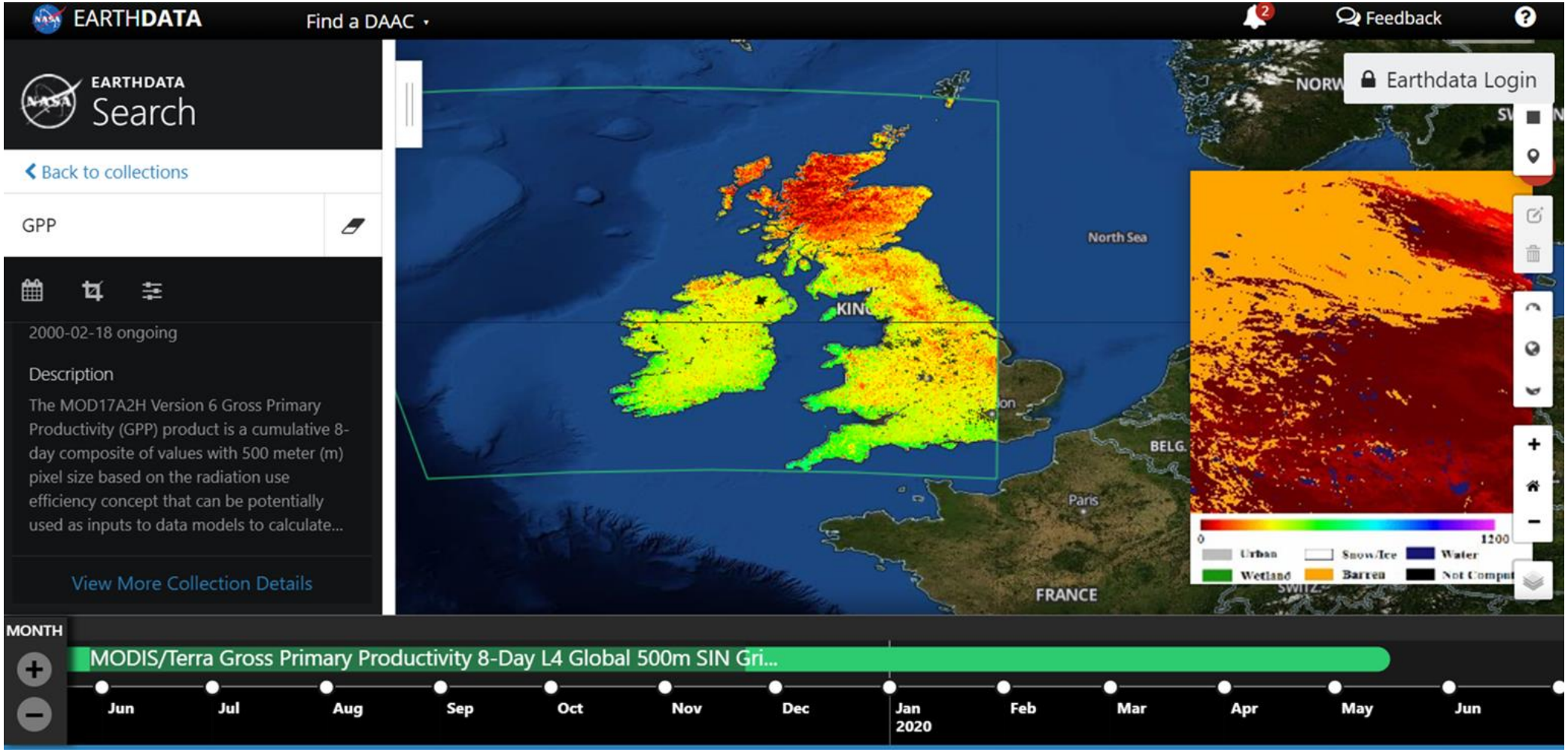
- Primarily used to measure Evapotranspiration (ET)
- Onboard the International Space Station (ISS)
- Spatial resolution: 400 km
- Data coverage: 12 key climate zones and Fluxnet sites
- Repeat time: hourly at those locations
- Data available on LP DAAC, Earthdata, AppEEARS, and USGS Earth Explorer

ECOSTRESS onboard the ISS (left) and ET from crop lands (below). Image Credits: NASA/Dr. Joshua Fisher

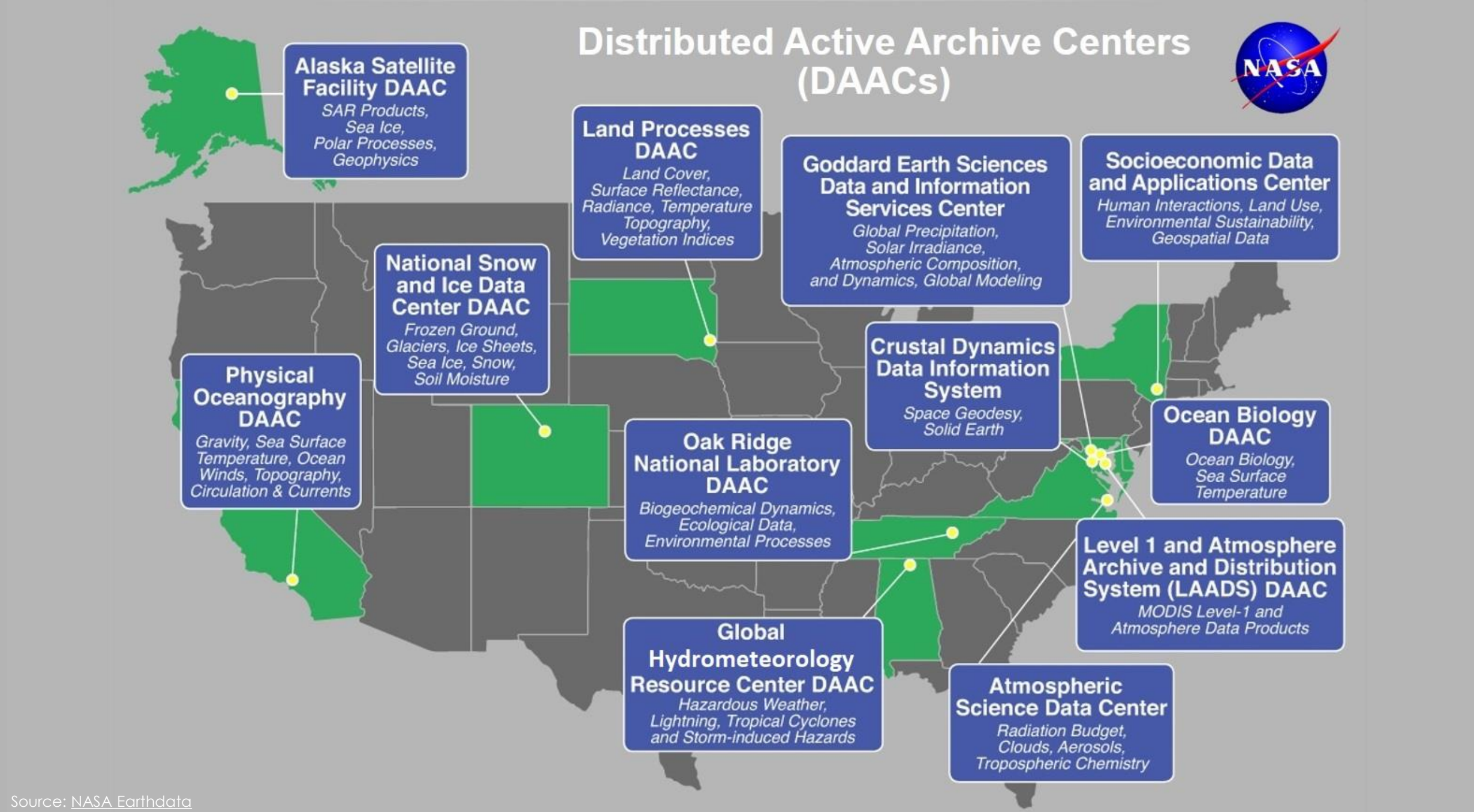



EARTHDATA
OPEN ACCESS FOR OPEN SCIENCE
Data
Topics
Learn
Engage
https://www.earthdata.nasa.gov/
Your Gateway to NASA Earth Observation Data
The Earth Science Data Systems (ESDS) Program provides full and open access to NASA's collection of Earth science data for understanding and protecting our home planet. Begin your Earthdata exploration by clicking on any of the discipline icons above.
Get Started
Find Data
Use Data

Earthdata Search



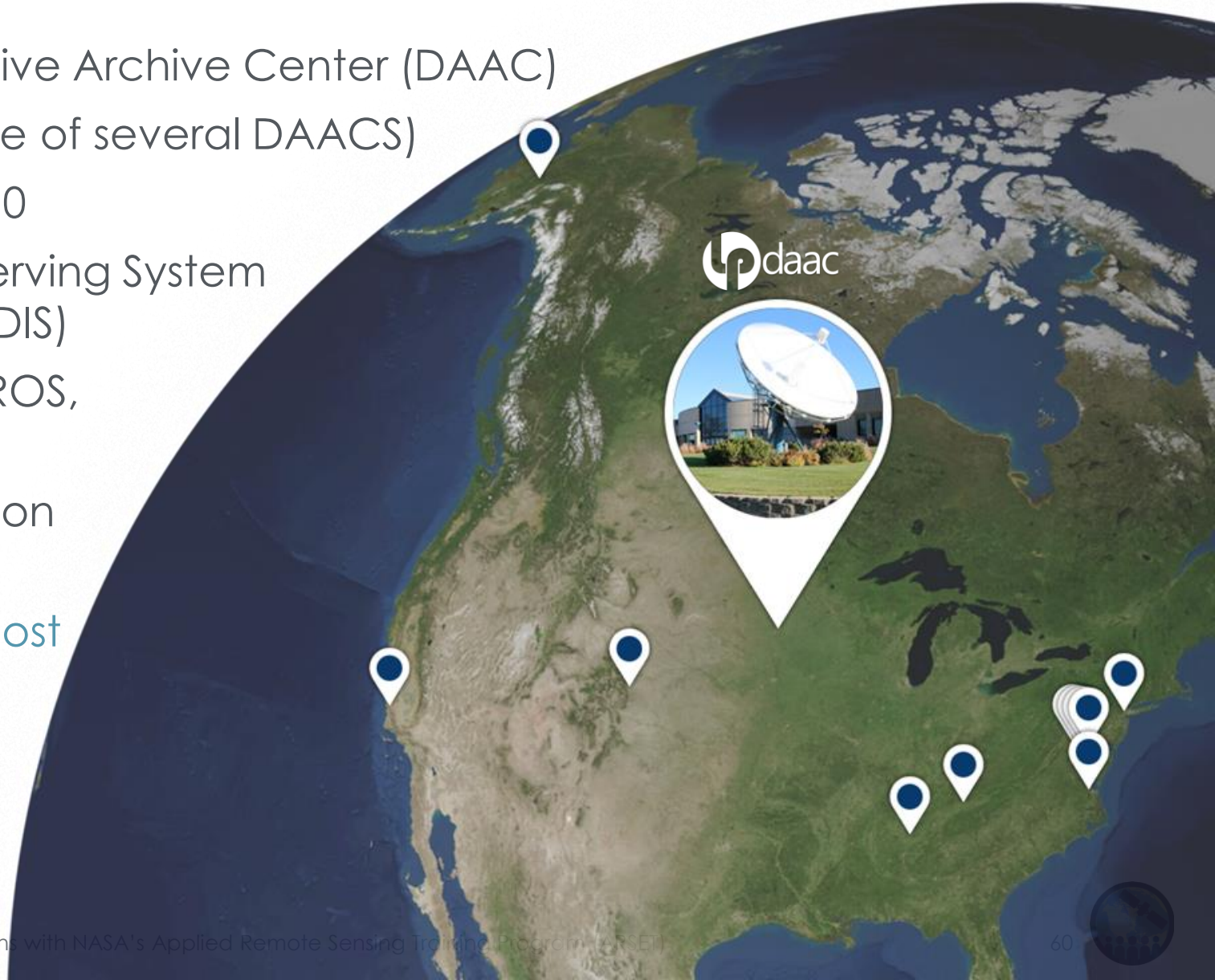
https://search.earthdata.nasa.gov/



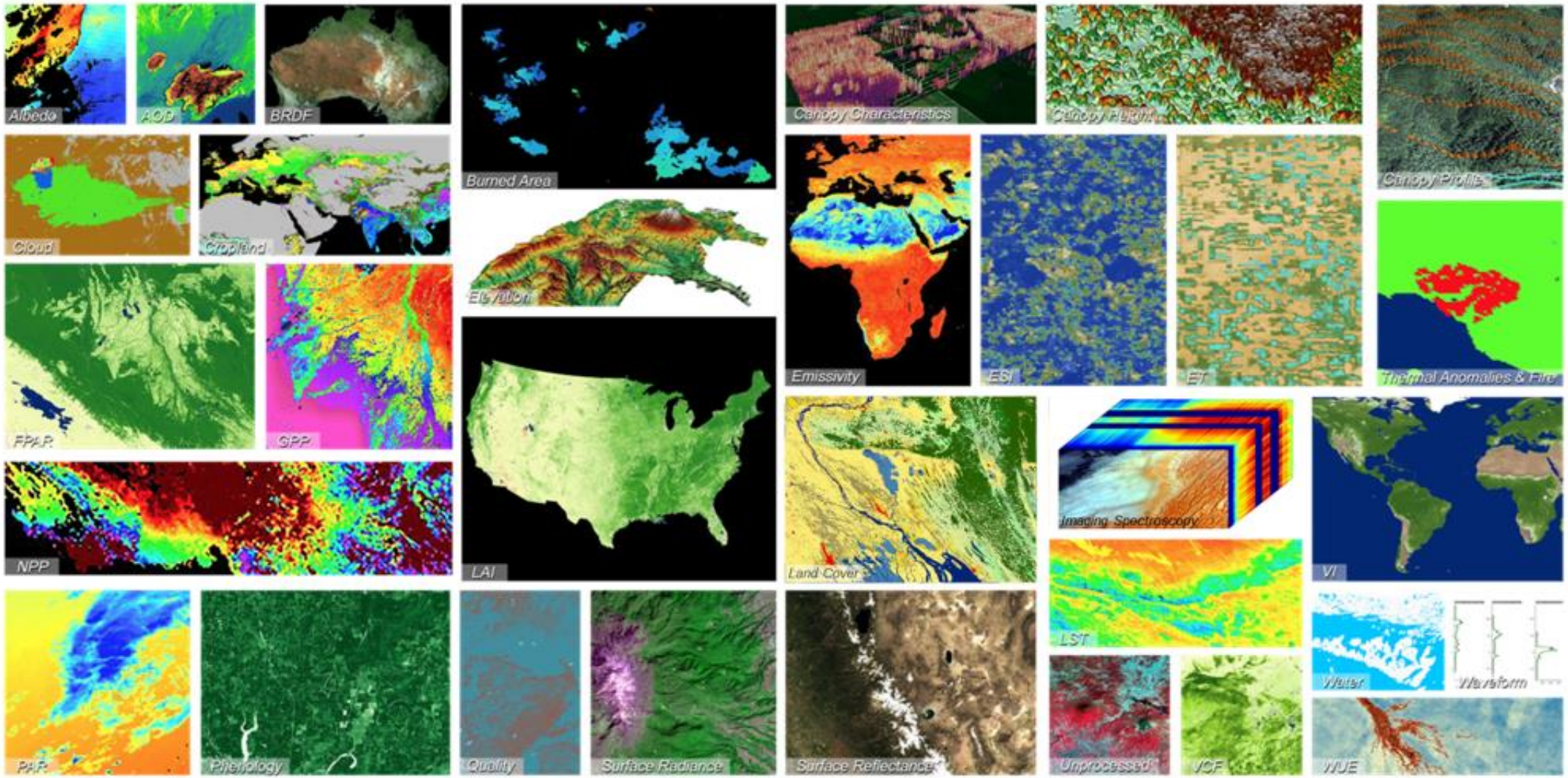
Source: NASA Earthdata

The LP DAAC

- Land Processes (LP) Distributed Active Archive Center (DAAC)
- NASA's Land Discipline Archive (one of several DAACS)
- A NASA-USGS Partnership since 1990
- Sponsored by the NASA Earth Observing System Data and Information System (EOSDIS)
- Located and Managed at USGS EROS, Sioux Falls, SD
- GEDI data products can be found on GEDI Data Resources Github
- Data & resources available at no cost



TYPES OF EARTH OBSERVATION VARIABLES



Application for Extracting and Exploring Analysis Ready Samples (AppEEARS)

- Cloud-based computing using MODIS and VIIRS
- Time series analysis of user-specified points or areas
- Outputs include time series data in csv format for easy analysis
- Example: Monitoring changing reservoir levels in Cape Town, South Africa
- AppEEARS data products found on [LPDAAC AppEEARS site]

ARSET Trainings- Ecological Conservation

Biodiversity Applications for Airborne Imaging Systems

- 1,342 participants from 700 unique organizations, 108 countries, and 44 US states

Connecting Citizen Science with Remote Sensing

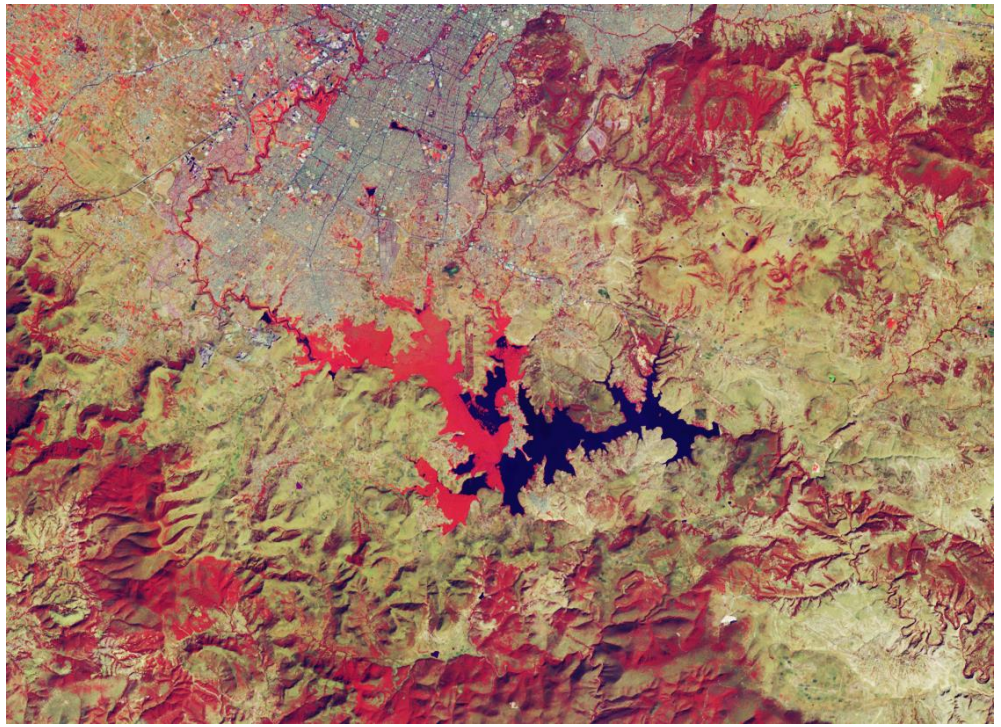
- 1,170 participants from 600 unique organizations, 107 countries, and 39 US states

Evaluating Ecosystem Services with Remote Sensing

- 1,668 participants from 800 unique organizations, 120 countries, and 42 US states

Spectral Indices for Land and Aquatic Applications

- 854 participants from 425 unique organizations, 96 countries, and 43 US states



Upcoming:
Invasive Species Monitoring with Remote Sensing
August 14-28, 2024.

ARSET - Invasive Species Monitoring with Remote Sensing | NASA Applied Sciences

Training Summary

In this training we:

- Provided examples of ways remote sensing is used to study Earth Systems.
- Shared NASA resources for learning more about how to use and access remote sensing data.
- Focused on fire applications of remote sensing data and products that can be used for mapping and monitoring
- Demoed the Fire Information for Resource Management System (FIRMS) and NASA Worldview for monitoring active fires and gathering information about historical fires.

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- ARSET Website
- Follow us on X (formerly Twitter)!
  - @NASAARSET
- ARSET YouTube

Visit our Sister Programs:

- DEVELOP
- SERVIR

Resources

- Applied Remote Sensing Training Program | NASA Applied Sciences
- Earthdata Search | Earthdata (nasa.gov)
- NASA | LANCE | FIRMS
- NASA Worldview
- LP DAAC - Homepage (usgs.gov)


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!