Ice Breaker

Ice Breaker Questions

- What's something you're passionate about outside of work?
- What inspired you to pursue your current career path?
- What's the most interesting place you've ever been to?

- If you could switch jobs with anyone in the company for a week, who would it be?
- Who would you choose if you could pick one person, living or dead, to have dinner with?
- What professional opportunity are you looking forward to in the next three months?

Earth Observations in Support of Insurance & Finance Sector Decision-Making

Earth Observations and Data for Monitoring Wildfires

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November 12, 2025

Learning Objectives

- By the end of this presentation attendees will be able to:
  - Identify and analyze data products from Earth observations and Earth system models to assess pre-fire conditions.
  - Monitor active wildfire and burnt area using Earth observations.
  - Identify NASA webtools for monitoring wildfires.

Outline

- Overview of Earth observations data for monitoring pre-fire and active fire conditions.
- Demonstrations: Eaton Fire, Los Angeles County, January 2025
  - Monitor pre-fire hydrologic and vegetation conditions using GEE.
  - Monitor fire ignition and spread conditions.
- Monitor active fires using NASA webtools: Worldview, FIRMS
- Calculate Normalized Burn Ratio using GEE

Overview of Earth Observations for Monitoring Wildfires

Factors Influencing Pre-fire Conditions, Fire Ignition, and Spread

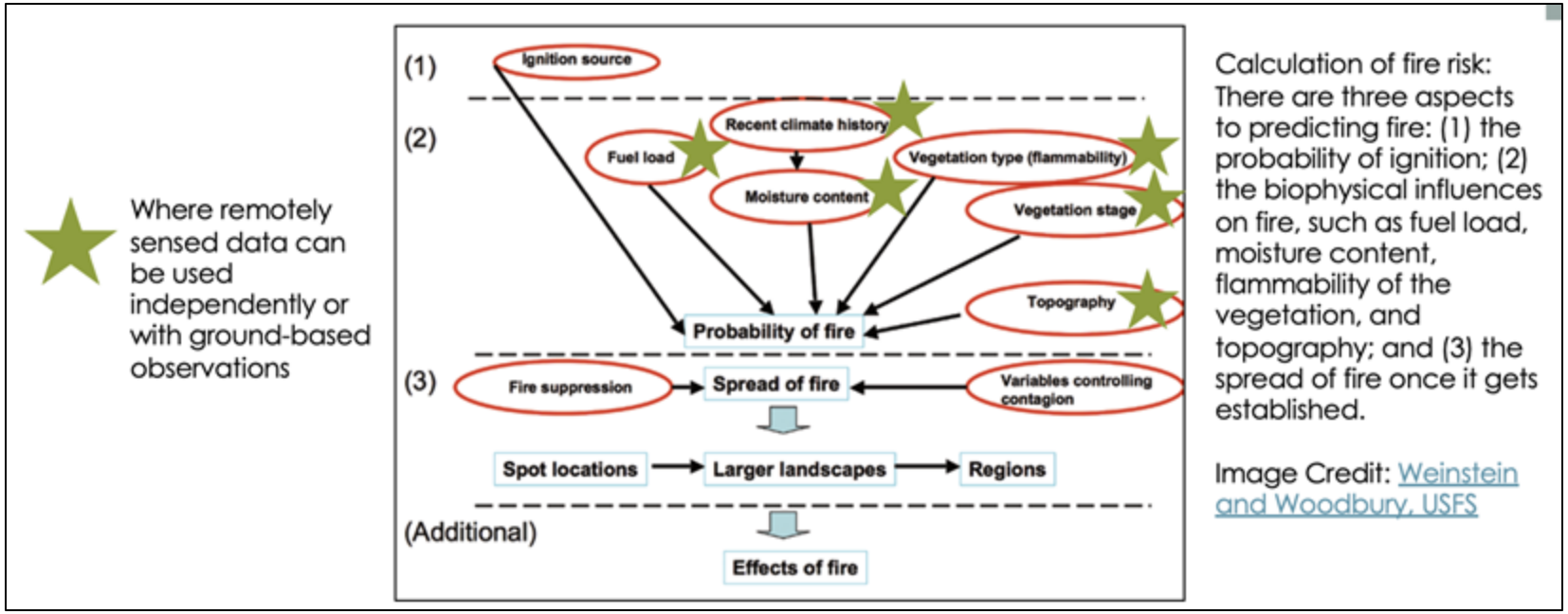
- Precipitation
- Soil Moisture
- Vegetation
- Winds
- Surface temperature and humidity
- Lightning
- Topography

ARSET Wildfire Trainings

Credit: Salam2009

Pre-fire Risk Mapping

- The probability that a fire might start in a certain area.
- Risk is determined by compiling relevant factors that influence fire ignition and behavior.

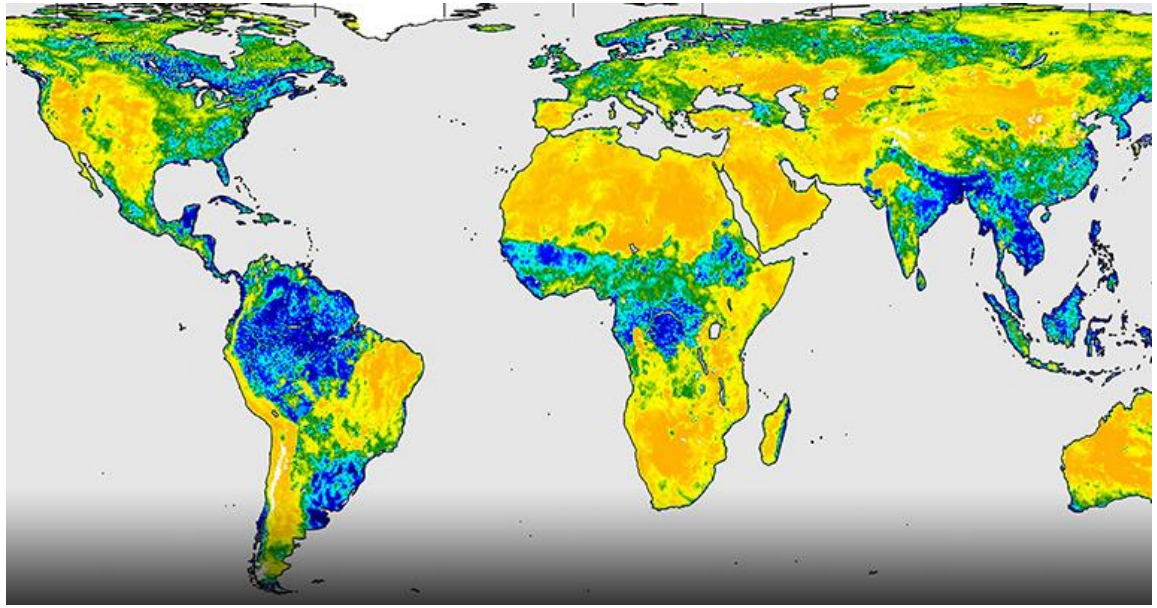


Comprehensive fire risk maps are challenging to produce due to the many factors that impact the probability of fire.

We first focus on pre-fire conditions by monitoring precipitation, soil moisture, fire fuel in a watershed.

Earth Observations for Monitoring Pre-fire Risk

- Precipitation
  - GPM/IMERG
- Soil Moisture
  - SMAP/NLDAS
- Vegetation
  - Terra/Aqua/NPP/JPSS
- Surface temperature and humidity
  - MERRA-2

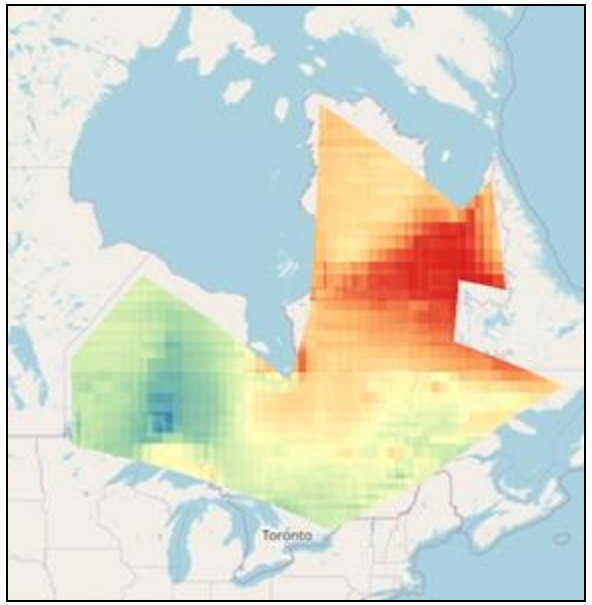


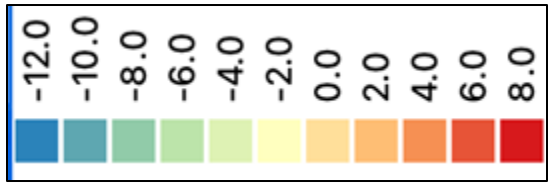
Credit: National Snow and Ice Data Center

Example: Fires in Quebec – June 2023

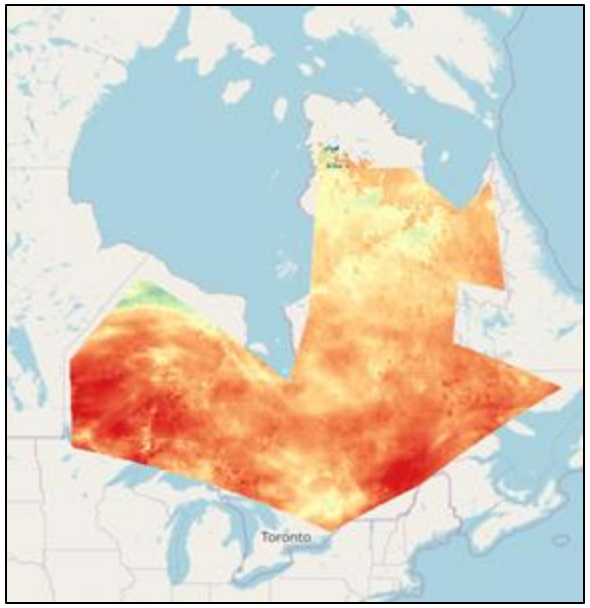
Dry and Warm Anomalies Indicating Fire Risk

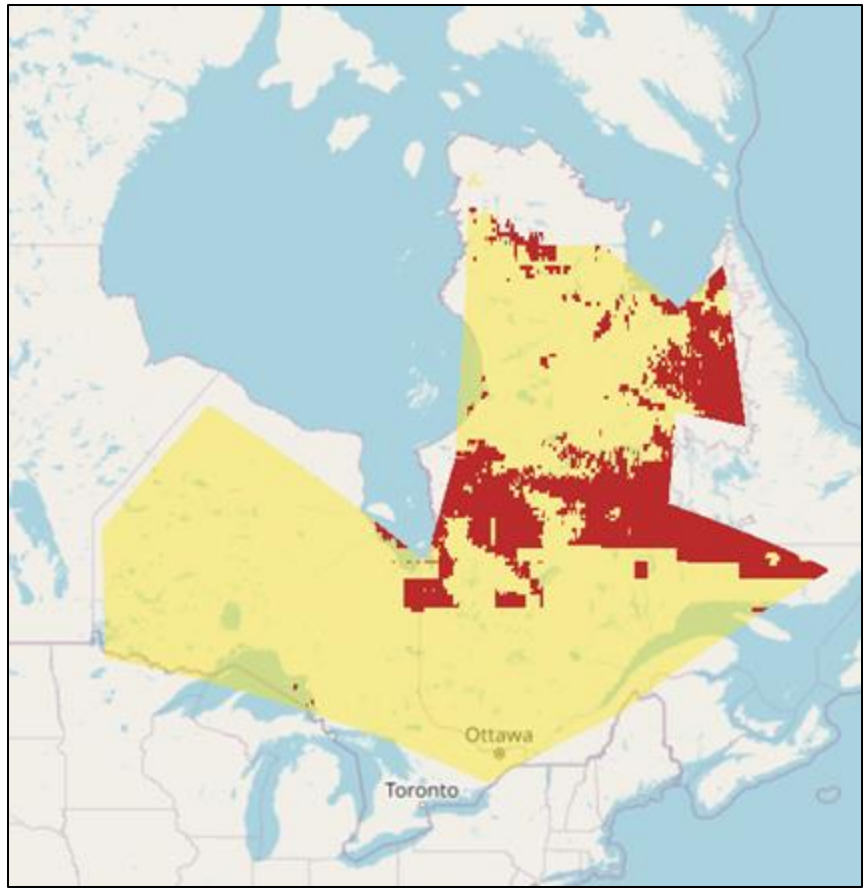
MERRA-2: Surface Skin Temperature Anomalies for May 2023





IMERG: Precipitation Anomalies for May 2023





Note: Anomalies are calculated by subtracting 2001-2022 Mean quantities from May 2023.

Demonstration: Eaton Fire, January 2025

Examine Pre-fire Hydrologic Conditions and Fuel Availability

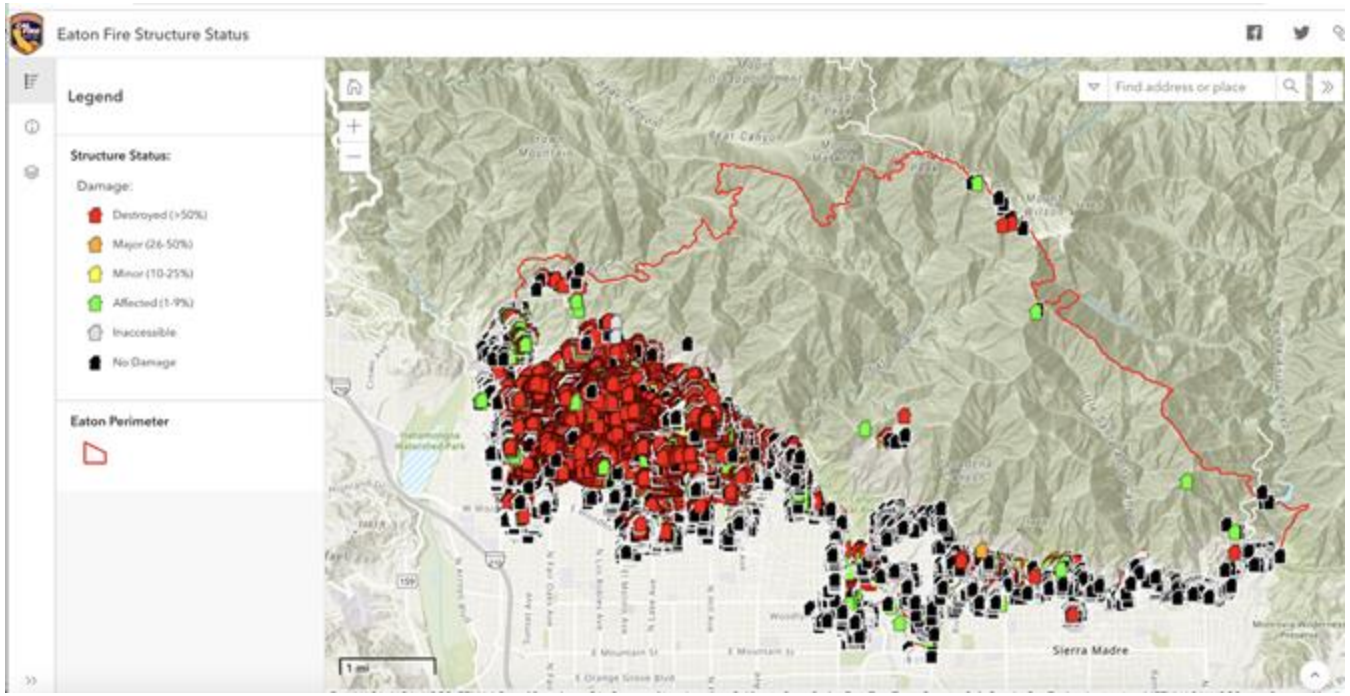
Pre-fire Anomalies: Precipitation, Soil Moisture, Vegetation Index

Eaton Fire

- The Eaton Fire ignited in the hills of Eaton Canyon, near Altadena, on the evening of January 7, 2025.
- Around January 11, it had expanded to 57 square kilometers.
- The fire lasted for 24 days, destroyed approximately 9400 structures and caused 19 fatalities.

Source: CAL FIRE

Eaton Fire Structure Status



Credit: CAL FIRE Forestry Maps

Soil Moisture, Precipitation, Winds – Earth Observations for Fire Ignition and Spread

- Pre-fire Soil Moisture Anomalies (demo)
  - GEE Code: https://code.earthengine.google.com/5a18aff4133e075b00e572490dd48fe3
- Pre-fire Precipitation Anomalies (demo)
  - GEE Code: https://code.earthengine.google.com/a463080a28460f4e48151d356c839299
- Pre-fire Winds (demo)
  - GEE Code: https://code.earthengine.google.com/a31a33d879c70326208584c95d760b18
- * Lightning
  - * Geostationary Lightning Mapper

* ARSET: Introduction to Lightning Observations and Applications

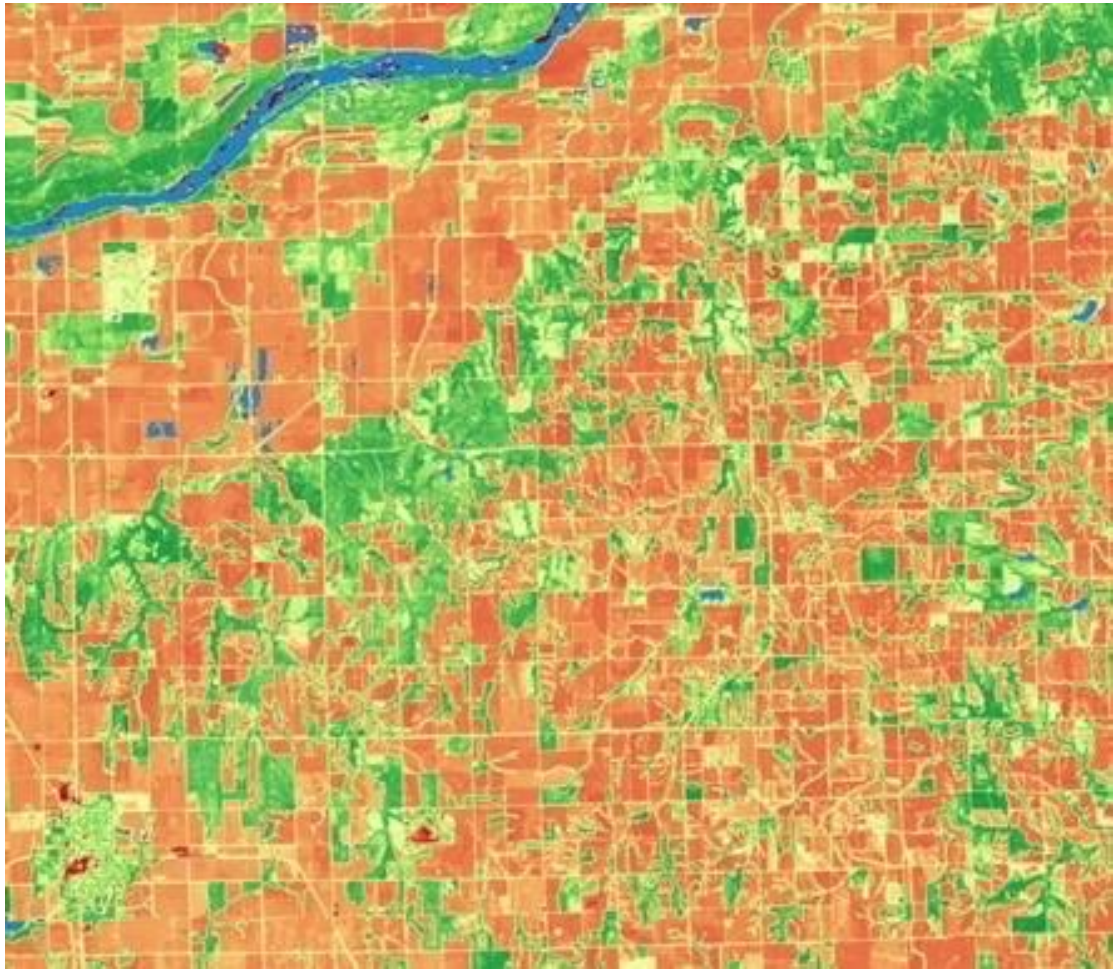
Spectral Indices for Vegetation

Learning Objectives

- By the end of this presentation attendees will be able to:
  - Recognize commonly used spectral indices for land applications
  - Acquire vegetation and fire index products from a variety of sources
  - Compute vegetation index anomalies over areas of interest
  - Identify fire indices that measure wildfire area and magnitude

What is a Spectral Index?

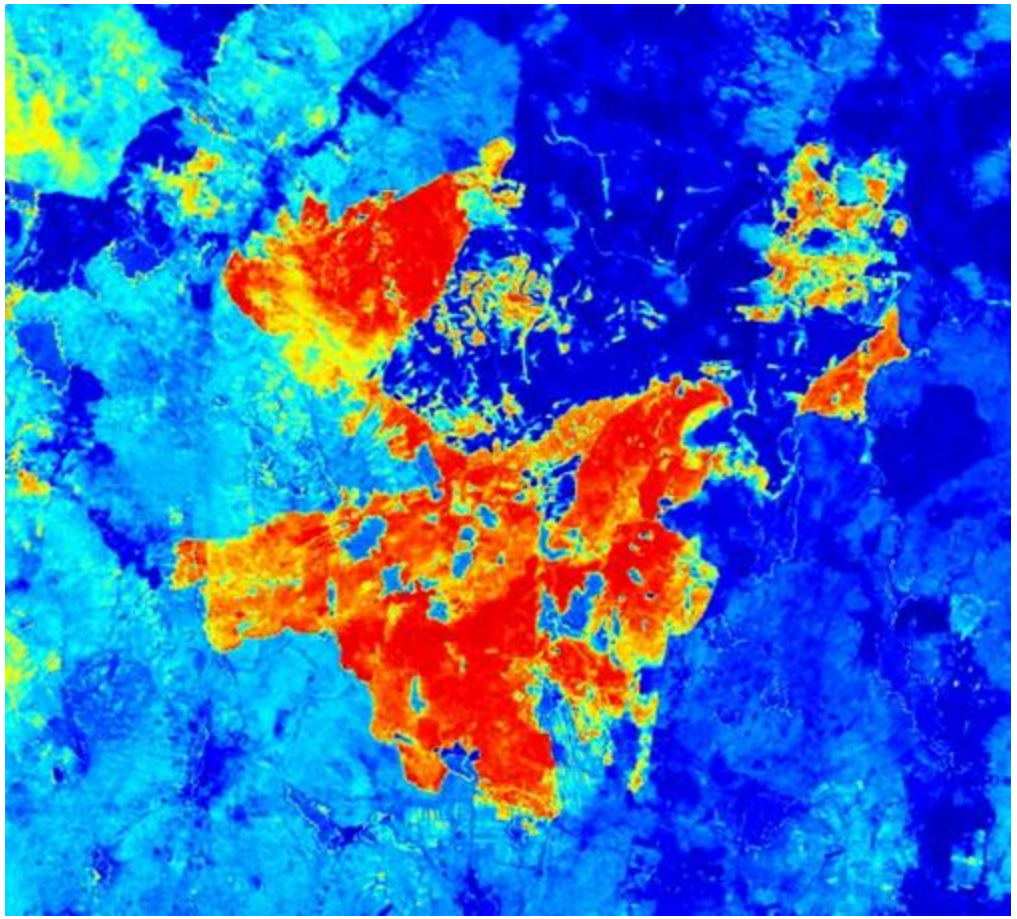
- A mathematical calculation performed on each pixel using values from multiple spectral bands of an image.
- Minimize atmospheric interference, instrument noise, and illumination variations for consistent spatial and temporal comparisons.
- Enable consistent comparisons across time and space, typically normalized between -1 and +1.
- Fundamental tools in remote sensing that transform complex multispectral data into meaningful, interpretable information about Earth's surface conditions and processes.



Agricultural fields near Columbus, Nebraska from 2022.
Credit: NASA Scientific Visualization Studio

Applications of Spectral Indices

- Water quality, delineation, and flood mapping
- Vegetation health, phenology, decadal trends
- Geologic mapping
- Burned area mapping and fire severity
- Biophysical parameters (i.e., biomass)

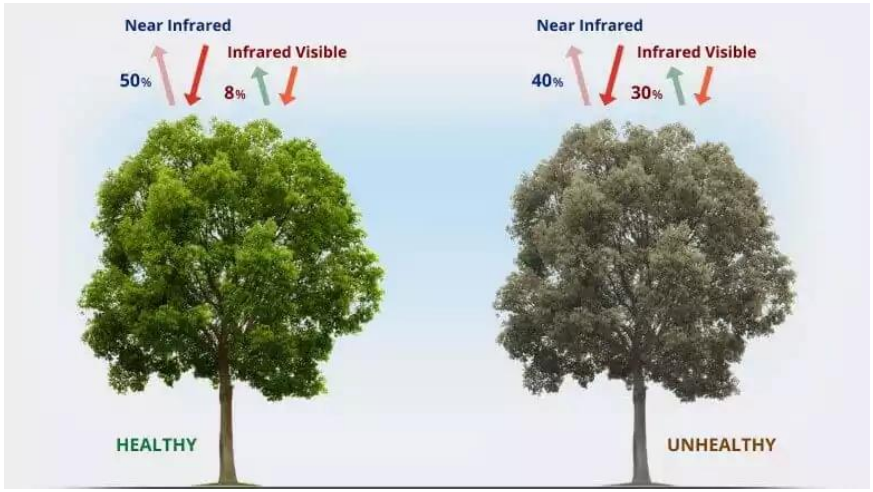


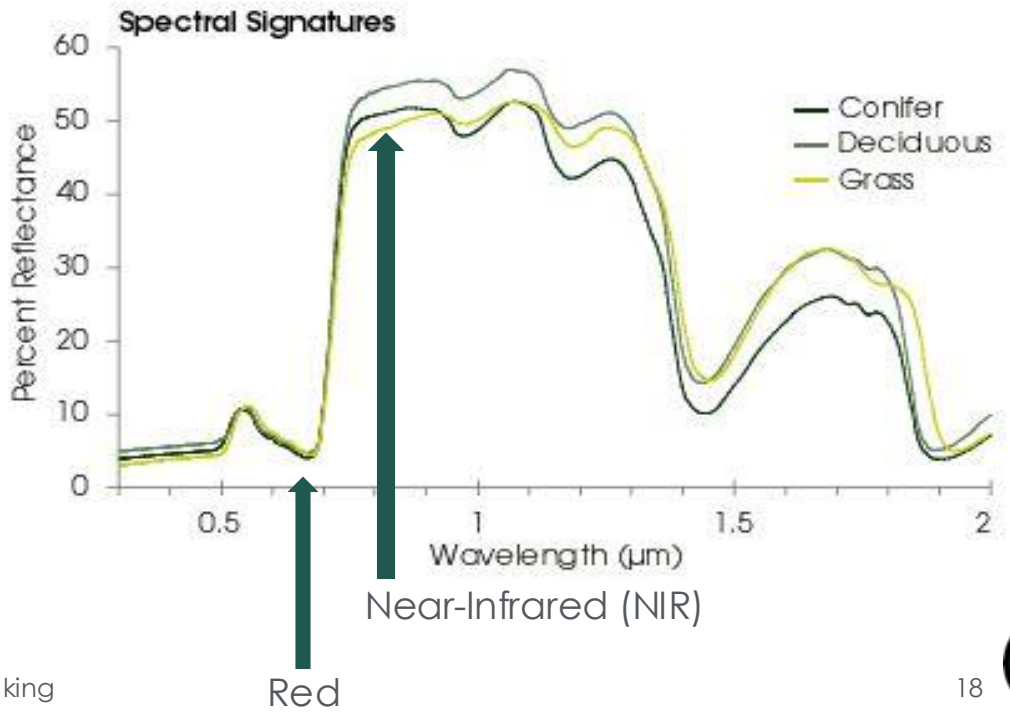
Moisture Index of Wildfire (wildfire in red, orange)

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 values range from -1.0 to 1.0
  - -1.0 to 0.0: Water Bodies and Non-Vegetation
  - Values approaching 1 represent peak vegetation biomass
  - NDVI Formula:

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



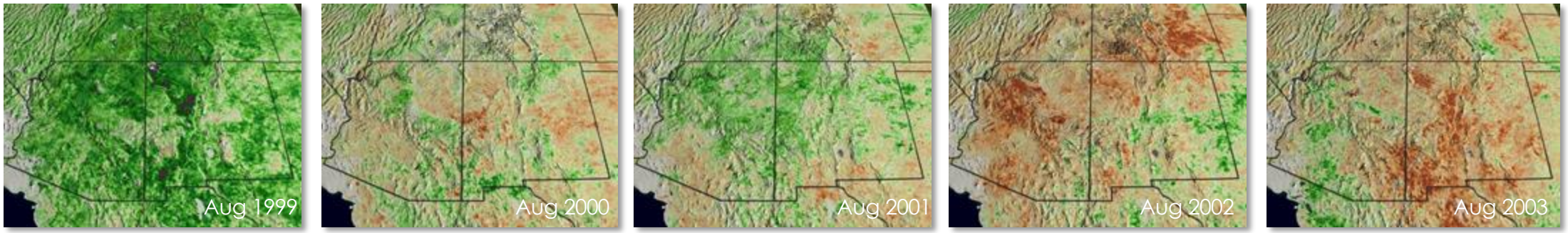


NDVI Anomaly

- Statistical measure comparing present vegetation health to long-term average
- Current measurement (day, month, year, etc.) minus reference period average
- Basic NDVI Anomaly (Interpretation):
  - Positive values = above normal vegetation
  - Zero = typical conditions for that time/place
  - Negative values = below normal vegetation

$$NDVI\ Anomaly = Current\ NDVI - Longterm\ Mean$$

NDVI Anomalies in the Southwestern United States



NDVI Anomaly

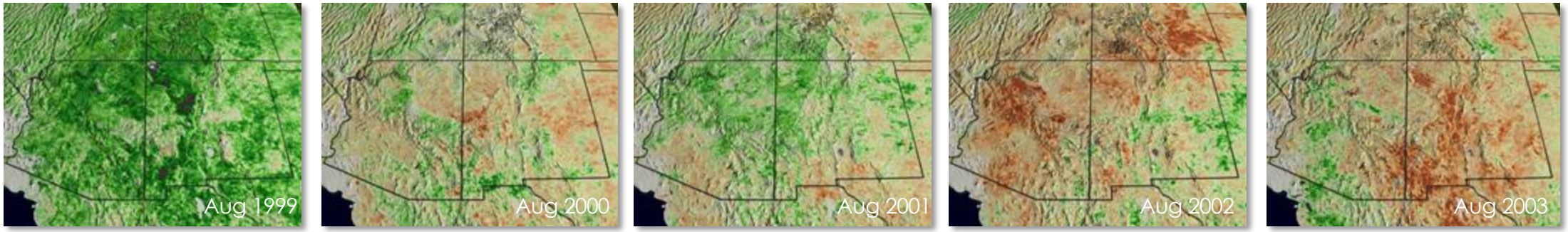
- **Standardized NDVI Anomaly** (Z-Score)

$$Standardized\ NDVI\ Anomaly = \frac{Current\ NDVI - Longterm\ Mean}{Standard\ Deviation}$$

- **Percentage NDVI Anomaly**

$$NDVI\ Percentage\ Anomaly = \frac{Current\ NDVI - Longterm\ Mean}{Longterm\ Mean} * 100$$

NDVI Anomalies in the Southwestern United States



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.
- Adjusts for canopy background and some atmospheric conditions.

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

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).

$$SAVI = \left[\frac{(NIR - R)}{(NIR + R + L)} \right] (1 + L)$$

Satellites and Sensors for Vegetation Indices

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

Image Credits: USGS, ESA

Landsat 8 & 9 – Spectral 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-2 a, b, c – Spectral Bands

Sentinel-2 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*

Harmonized Landsat and Sentinel-2

- Harmonized Landsat and Sentinel-2 (HLS)
- 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
- HLSL30 (Landsat)
  - Source: Landsat 8/9 OLI data
  - Resolution: 30m
  - Processing: Surface reflectance, atmospheric correction
- HLSS30 (Sentinel-2)
  - Source: Sentinel-2A/B/C MSI data
  - Resolution: 30m (resampled from native resolution)
  - Processing: Surface reflectance, atmospheric correction
- User's Guide

Credit: NASA Earth Observatory

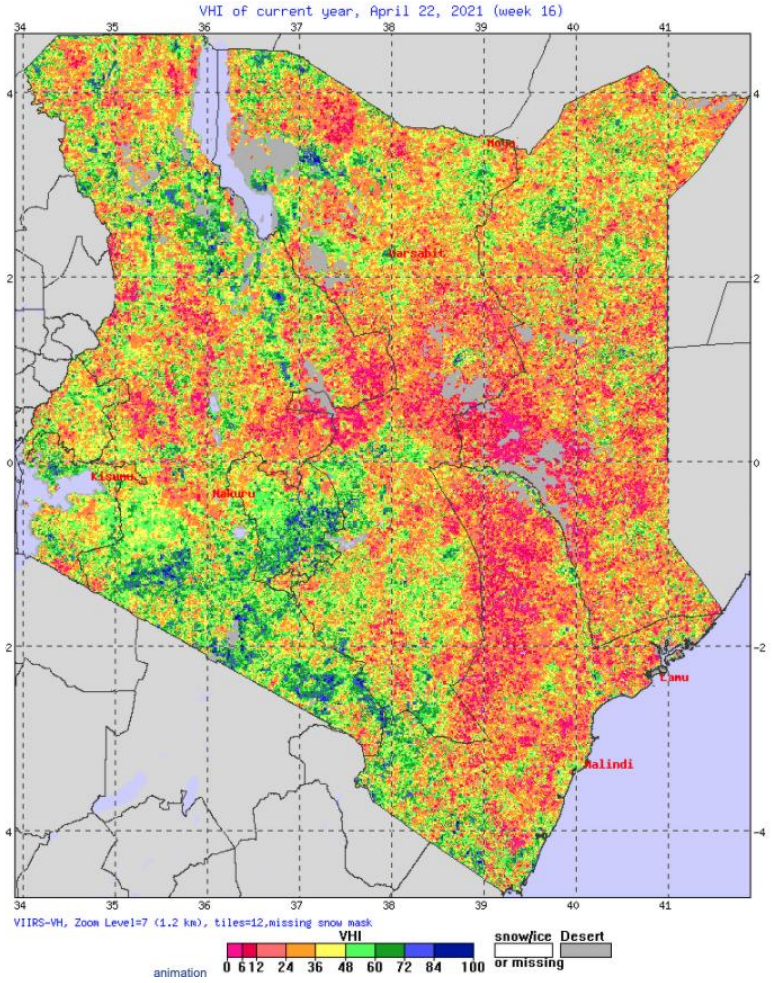
Terra & Aqua

- Sensor: Moderate Resolution Imaging Spectroradiometer (MODIS)
- Vegetation-Based Fire Applications:
  - Vegetation Stage and Health: NDVI, EVI
  - High Temporal Resolution Phenology
- Spatial Resolution:
  - 250 m, 500 m, 1 km
- Temporal Resolution:
  - Daily, 8-day, 16-day, monthly, quarterly, yearly
  - 2000–present
- Spectral Coverage:
  - 36 bands

Time lapse of MODIS NDVI in Africa.
Credit: Google Earth Engine Developers

Suomi National Polar-orbiting Partnership (NPP)

- Sensor: Visible Infrared Imaging Radiometer Suite (VIIRS)
- Vegetation-Based Fire Applications:
  - Vegetation Health: VIIRS Vegetation products include Vegetation Condition Index, Temperature Condition Index, and Vegetation Health Index
- Launched in 2012; collects visible and infrared imagery
- Daily temporal resolution and global coverage
- Spatial Resolution:
  - 5 moderate resolution bands: 375 m
  - 16 coarse resolution bands: 750 m

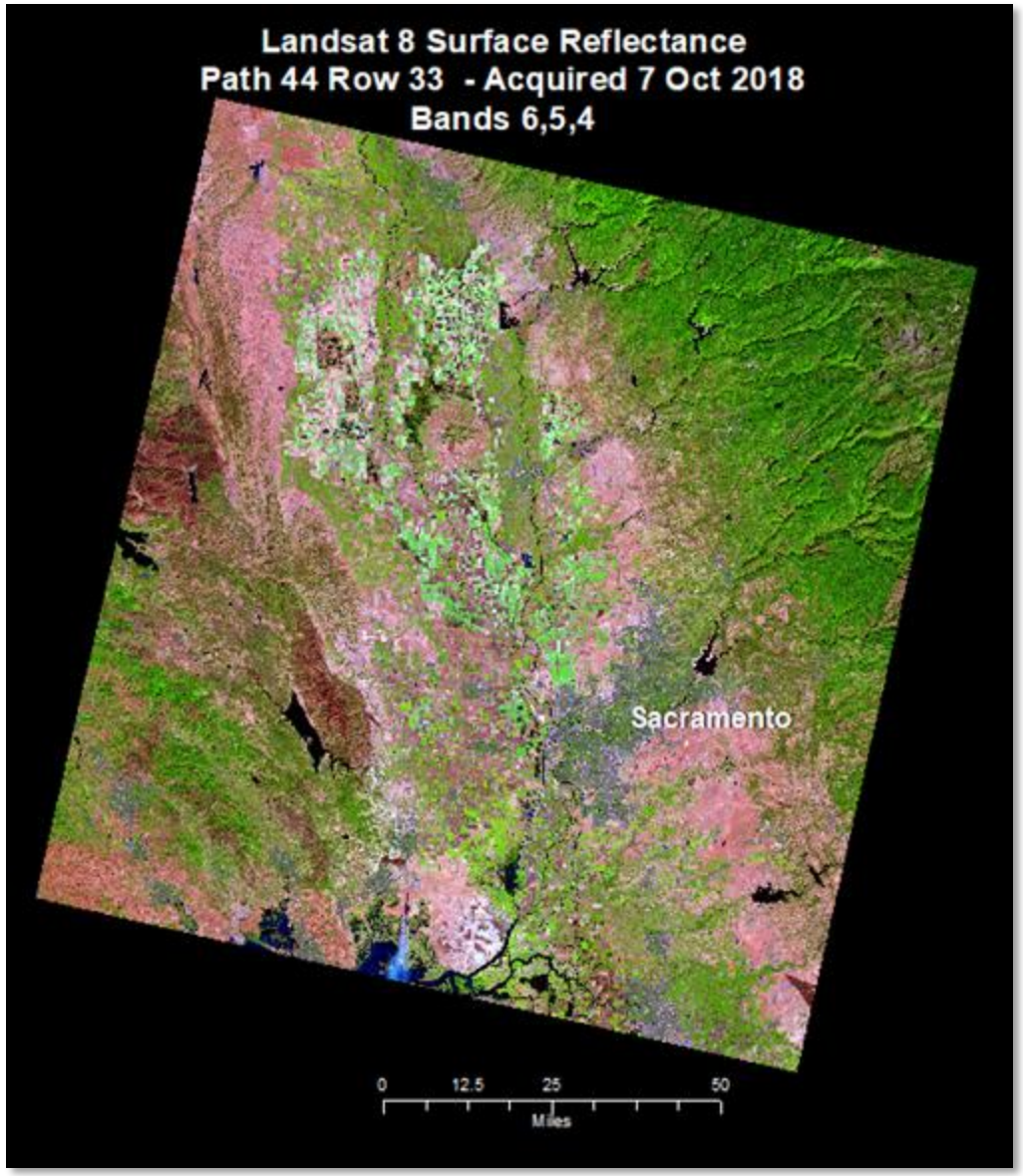


Credit: NOAA NESDIS

Vegetation Index Data Products

Landsat NDVI and EVI Products

- Temporal Resolution: 8-day & 16-day composites
- Spatial Resolution: 30 m
- Multiple products available: NDVI, EVI, SAVI, NDMI, NBR
- Data access:
  - USGS EROS
  - NASA Webtools
  - Google Earth Engine
    - NDVI
    - EVI



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

HLS Spectral Data Products

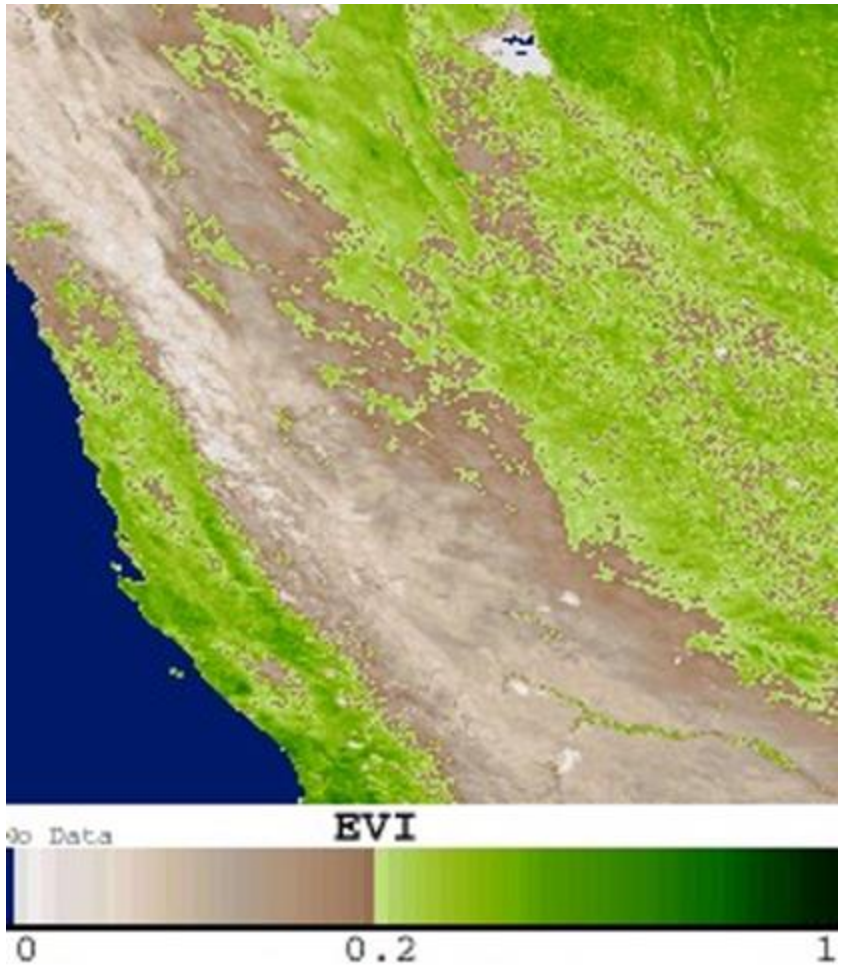
- Temporal Resolution: 2–3-day
- Spatial rresolution: 30 m
- Multiple products available: NDVI, EVI, SAVI, NDMI, NBR
- Data access:
  - NASA Earthdata Search
  - Common Metadata Repository (CMR)
  - Google Earth Engine
    - HLSL30
    - HLSS30

- NASA GitHub

Credit: NASA

MODIS NDVI and 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
- Data access:
  - NASA Webtools
  - Earthdata Search
  - Google Earth Engine

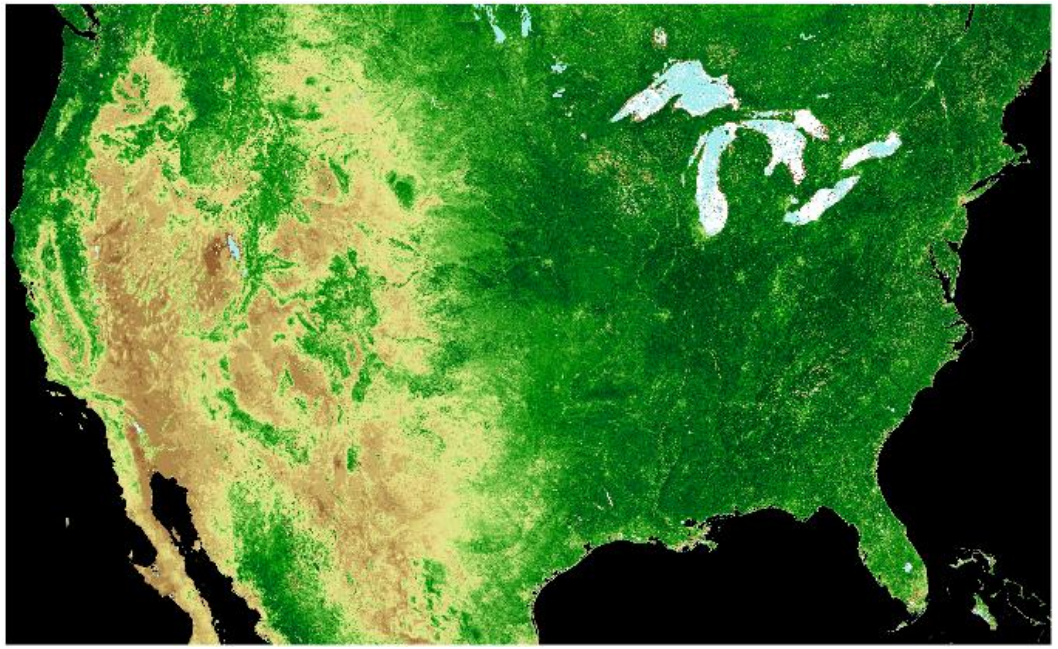


MODIS EVI from April 2020 of the western coast of Africa.
Credit: USGS/NASA

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 & JP113
  - Multiple subsets based on spatial resolution
  - User Guide
- Data access:
  - NASA Webtools
  - Earthdata Search
  - Google Earth Engine



NDVI composite over continental US from Suomi-NPP VIIRS
Credit: USGS

Demo – NDVI Anomalies

Eaton Fire

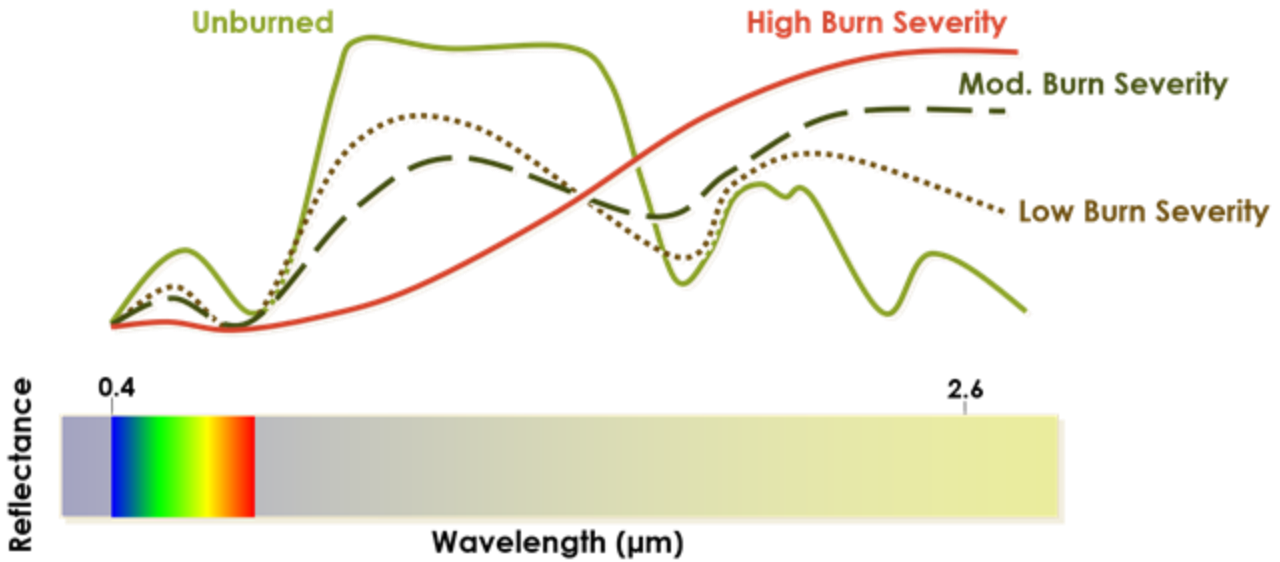
- Basic NDVI Anomaly:
  https://code.earthengine.google.com/afc59a3cf645c2c8c49a990d050d833c
- Standardized NDVI Anomaly (Z-Score)
  https://code.earthengine.google.com/dbc390e2550d7a148fbda14fd27233d4
- Percentage NDVI Anomaly
  https://code.earthengine.google.com/43f57dddde9bbe70efb591780c7d8187

Spectral Indices for Wildfires

Spectral Indices for Fire Applications

- Used to assess fire-related conditions:
  - Pre-fire risk
  - Active fire detection
  - Burn scar mapping
  - Post-fire recovery monitoring
- Common Indices:
  - NDMI (Normalized Difference Moisture Index)
  - NDVI (Normalized Difference Vegetation Index)
  - NBR (Normalized Burn Ratio)
  - dNBR (Differenced NBR)

Exploiting Spectral Response Curves

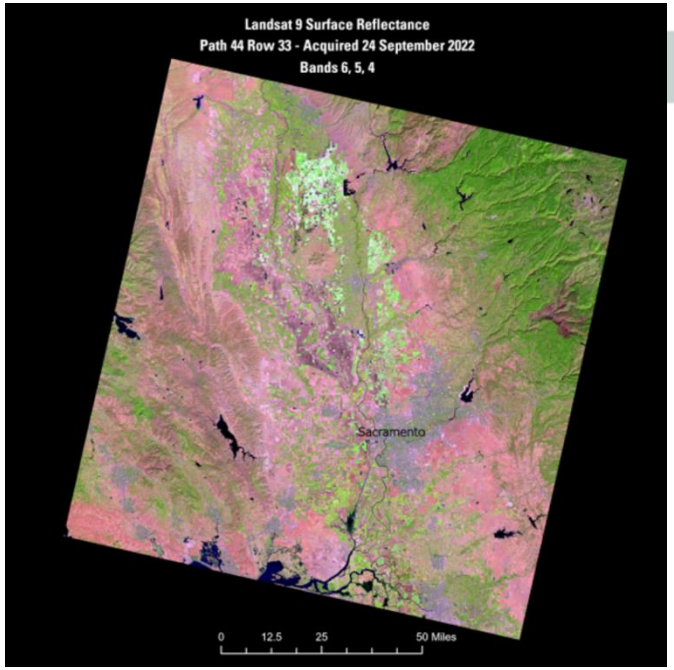


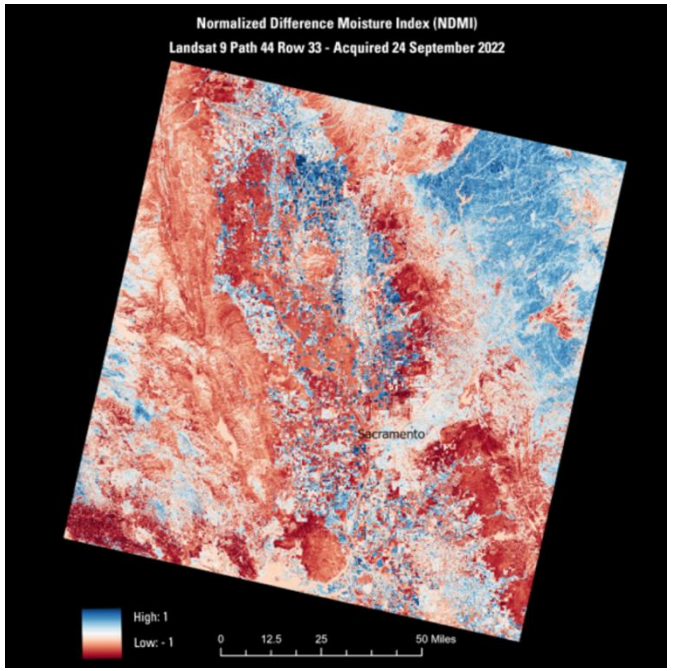
NDMI (Normalized Difference Moisture Index)

- Measures vegetation moisture content and canopy water stress
- Combined with NDVI provides comprehensive vegetation health assessment
- Identifies water stress before visible symptoms
- Crucial information for fire risk assessment, water resource management, drought monitoring, and agricultural decision-making
- **> 0.6**: High vegetation moisture content
- **0.4 – 0.6**: Moderate moisture content
- **0.2 – 0.4**: Low vegetation moisture content
- **0 – 0.2**: Very low vegetation water content
- **< 0**: Non-vegetated or extremely dry

$$NDMI = \frac{(NIR - SWIR1)}{(NIR + SWIR1)}$$

*SWIR1: 1.57–1.65 µm – Strong water absorption feature



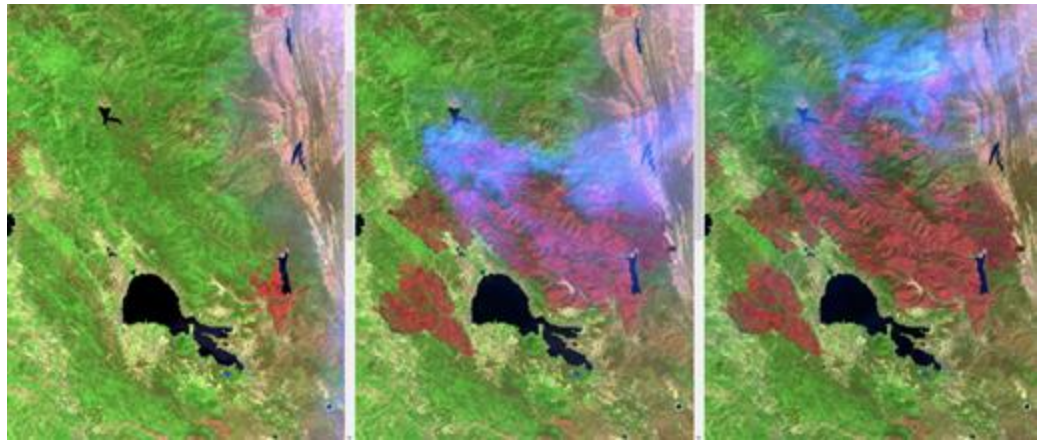


Credit: USGS

Normalized Burn Ratio (NBR)

- Compare pre- and post-burn to identify burn extent and severity.
- Healthy Vegetation:
  - High NIR reflectance: Leaf structure scattering
  - Low SWIR2 reflectance: Water absorption
  - Result: High positive NBR values (0.4–0.6)
- Burned Areas:
  - Reduced NIR reflectance: Destroyed vegetation structure
  - Increased SWIR2 reflectance: Exposed soil, ash, charcoal
  - Result: Low or negative NBR values
- **> 0.4**: Healthy vegetation
- **0.1 – 0.4**: Moderate vegetation
- **0.0 – 0.1**: Sparse vegetation
- **< 0.1**: Burned areas
- **< 0.0**: Severely burned

$$NBR = \frac{(NIR - SWIR2)}{(NIR + SWIR2)}$$

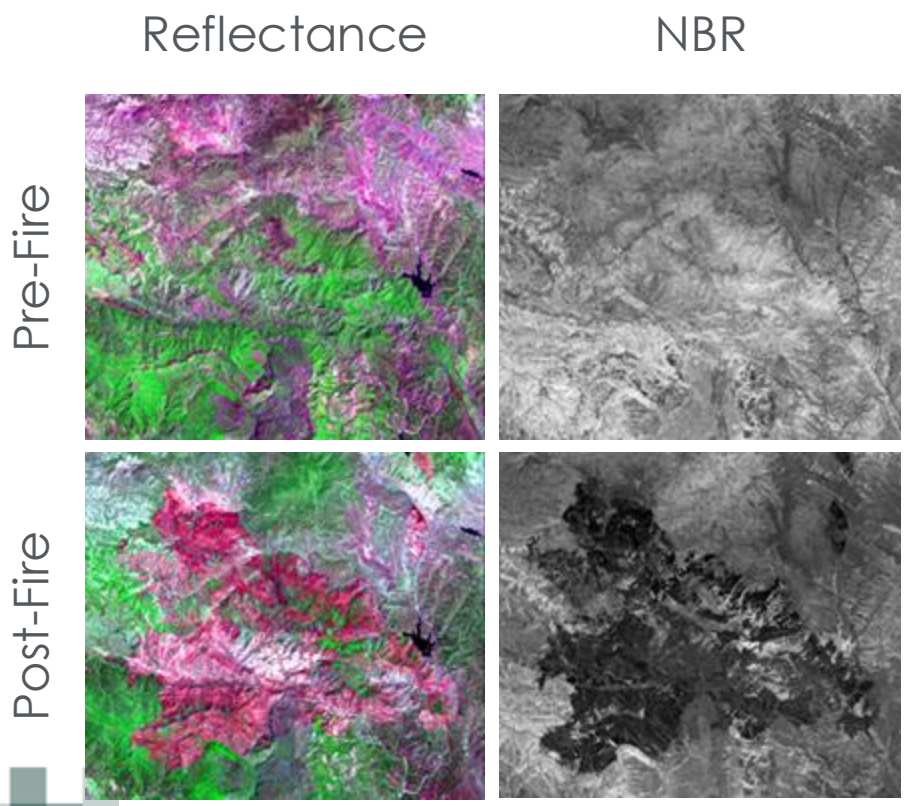


Differenced Normalized Burn Ratio (dNBR)

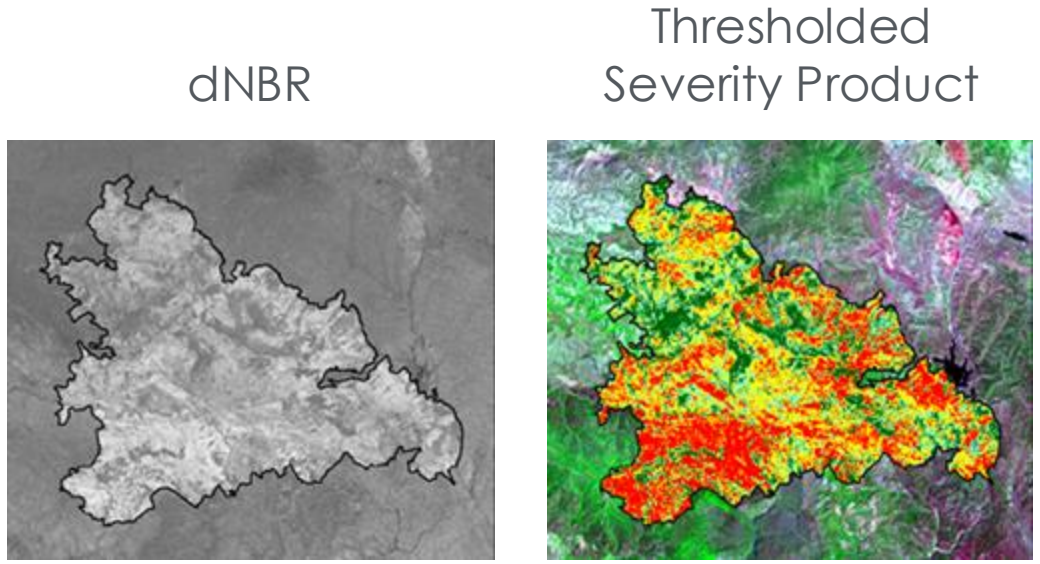
- **Normalized Burn Ratio (NBR)**
- Establishes extent of burned area before and after fire event

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

$$dNBR = Prefire\ NBR - Postfire\ NBR$$



Difference



Differenced Normalized Burn Ratio (dNBR)

- Burn scar mapping (burn perimeter delineation)
- Burn severity assessment (vegetation mortality & erosion risk assessment)
- Temporal analysis (pre-fire conditions, repeat fire analysis, and recovery monitoring)
- **Higher dNBR values**: Greater vegetation damage
- **Negative dNBR**: Vegetation improvement (rare, indicates recovery or error)
- **Near zero dNBR**: Little change (unburned areas)

Severity Level	dNBR Range
Enhanced Regrowth, high (post-fire)	dNBR < -0.25
Enhanced Regrowth, low (post-fire)	-0.25 ≤ dNBR < -0.1
Unburned	-0.1 ≤ dNBR < 0.1
Low Severity	0.1 to 0.27
Moderate-low Severity	0.27 to 0.44
Moderate-high Severity	0.44 to 0.66
High Severity	dNBR ≥ 0.66

Burn severity levels obtained calculating dNBR, proposed by USGS.

Demo – Wildfire Damage Assessment

Eaton Fire

- This script analyzes fire severity using the Normalized Burn Ratio (NBR) calculated from Landsat data.
- The script can be adapted for any fire event by modifying the parameters.
- ANALYSIS WORKFLOW:
- (1) Load median composite pre- and post-fire Landsat images to reduce cloud interference
- (2) Calculate the Normalized Burn Ratio (NBR) for both time periods
- (3) Calculate the differenced NBR (dNBR = pre-NBR minus post-NBR)
- (4) Classify burn severity using USGS standard thresholds
- (5) Calculate area statistics for each severity class
- (6) Export results for further analysis

- GEE Code: https://code.earthengine.google.com/7937763e4f714a9fa1413fe93fd3fef2

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, NBR for burn detection, and EVI for dense vegetation analysis.
- **Fire applications combine multiple approaches:** pre-fire risk assessment with NDMI, active detection with thermal sensors, burn severity mapping with dNBR, and recovery monitoring through NBR time series.
- **Case studies demonstrate** practical applications for pre-fire assessment, fire severity, and recovery monitoring using spectral indices and cloud-based analysis platforms.

Resources

- ARSET Trainings:
  - Spectral Indices for Land and Aquatic Applications
  - Assessing the Impacts of Fires on Watershed Health
  - Using Earth Observations for Pre- and Post-Fire Monitoring
  - Satellite Observations and Tools for Fire Risk, Detection, and Analysis
  - Introduction to NASA Earth Observations and Tools for Wildfire Monitoring and Management
- LANDFIRE
- Climate Engine
- Google Earth Engine Tutorials
- Monitoring Trends in Burn Severity (MTBS)
- Global Wildfire Information System (GWIS)
- Fire Information for Resource Management System (FIRMS)


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!