National Aeronautics and Space Administration

# Assessing the Impacts of Fires on Watershed Health

## Part 3: Using Google Earth Engine to Monitor Post-Fire Impacts

Britnay Beaudry (BAERI/NASA Ames), Sativa Cruz (BAERI/NASA Ames),
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July 13, 2023

# Assessing the Impacts of Fires on Watershed Health
## **Overview**

# Training Learning Objectives

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

- Distinguish, compare, and contrast the biophysical conditions pre-and post-fire
- Analyze the key fire science criteria to select the appropriate data from satellites/instruments for a given watershed
- Acquire land use & land cover maps for the region of interest
- Select river basin and sub-basin boundaries for their region of interest
- Recognize how to develop a river basin-scale model using SWAT to simulate the quality and quantity of surface and groundwater

Source: NASA

# Prerequisites

- Fundamentals of Remote Sensing
- Satellite Observations and Tools for Fire Risk, Detection, and Analysis
- Using Google Earth Engine for Land Monitoring Applications
- Texas A&M Instructional Videos for SWAT

Source: NASA

# Training Outline

**Part 1**

Satellite Observations and Tools for Fire Risk

July 6, 2023

11:00 - 12:30 EDT

or 15:00 - 16:30 EDT

**Part 2**

Earth Observations and The Soil & Water Assessment Tool (SWAT) for Assessing Post-Fire Water Quality in Watersheds

July 11, 2023

11:00 - 12:30 EDT

or 15:00 - 16:30 EDT


**Homework**

Opens July 13 – Due July 27 – 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.

# Assessing the Impacts of Fires on Watershed Health

## **Part 3: Using Google Earth Engine to Monitor Post-Fire Impacts**

# Part 3 – Trainers

**Britnay Beaudry**

Instructor

Ecological Conservation

**Sativa Cruz**

Instructor

Ecological Conservation

**Amber Jean McCullum**

Ecological Conservation Team Lead

**Juan Torrez-Perez**

Instructor

Ecological Conservation

# Part 3 Objectives

By the end of Part 3, participants will be able to:

- Identify urban extent and population datasets
- Acquire a global land cover map and datasets useful for assessing the impact of fire on communities
- Evaluate the severity of post-fire burns within a watershed of interest

Source: NASA

# Case Study: Woolsey Fire

- ~100,000 acres burned
- State and national parklands were affected (88% of federal parkland was burned) and closed for months
- More than 250,000 people were successfully evacuated
- Approximately $52 million in fire suppression costs alone

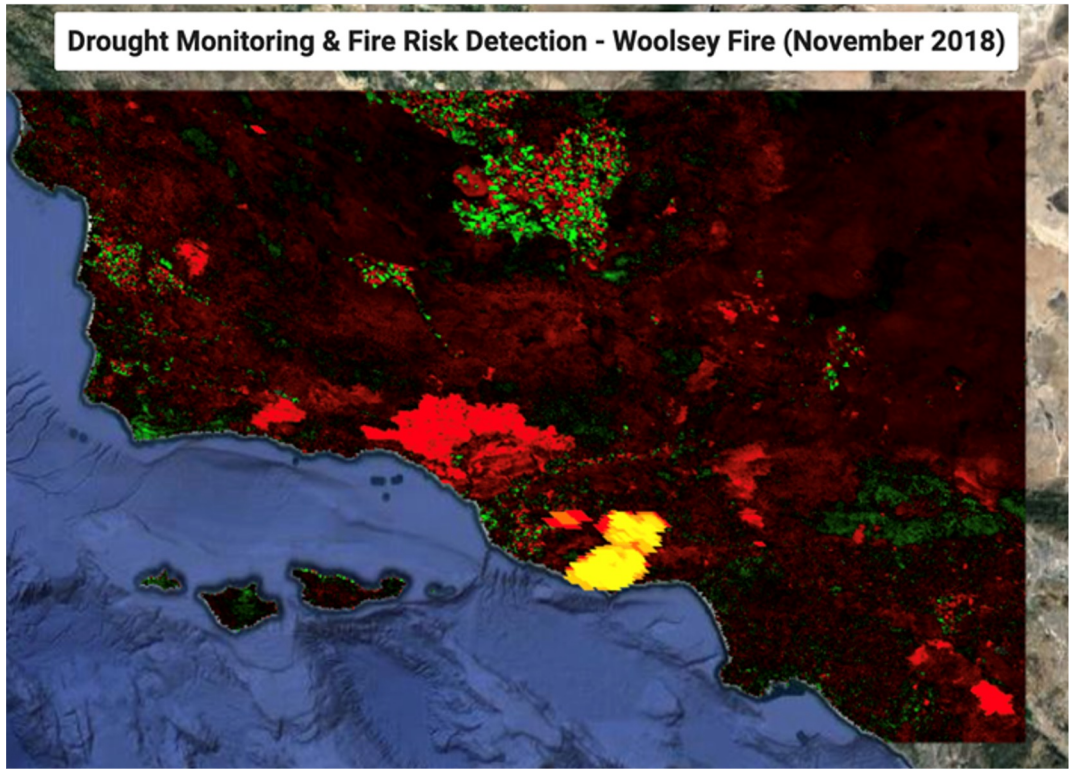
November 9th, 2018 Credit: Forest Service USDA

# What We Learned in Part 1

**Part 1: Conducted a pre-fire risk assessment for the Woolsey Fire using GEE and:**

- Provided examples of fire science criteria for drought conditions in a given watershed pre-fire to select the appropriate data from satellites/instruments for a watershed of interest
- Demonstrated how to delineate river basins and subbasins for a watershed of interest
- Calculated anomalies in biophysical and meteorological conditions for a watershed of interest

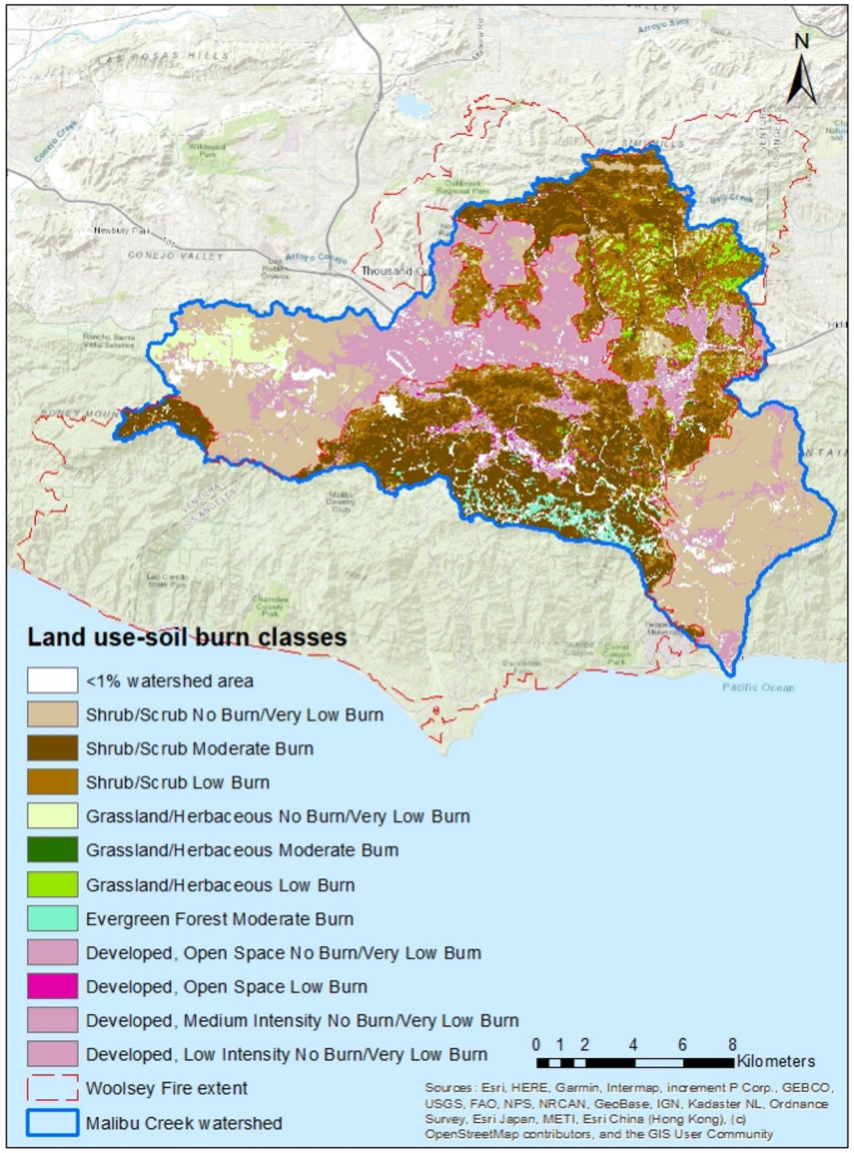
NDVI anomalies and Woolsey Fire



# What We Learned in Part 2

**Part 2: Demonstrated a river basin-scale model using Soil and Water Assessment Tool (SWAT) and learned how to:**

- Identify physically-based model components necessary to run a SWAT model to predict the impact of management on water and sediment in a watershed
- Ingest Earth remote sensing data into SWAT model using NASAaccess
- Recognize best practices used to conduct calibration in SWAT




Fire Simulation in SWAT

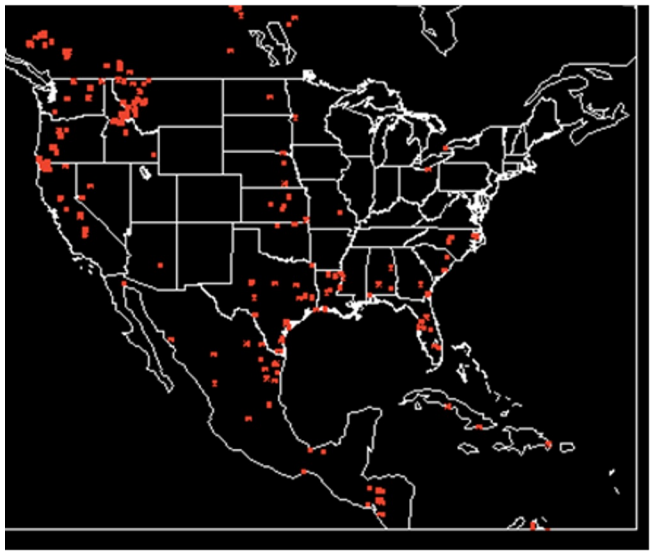
# How to Ask Questions

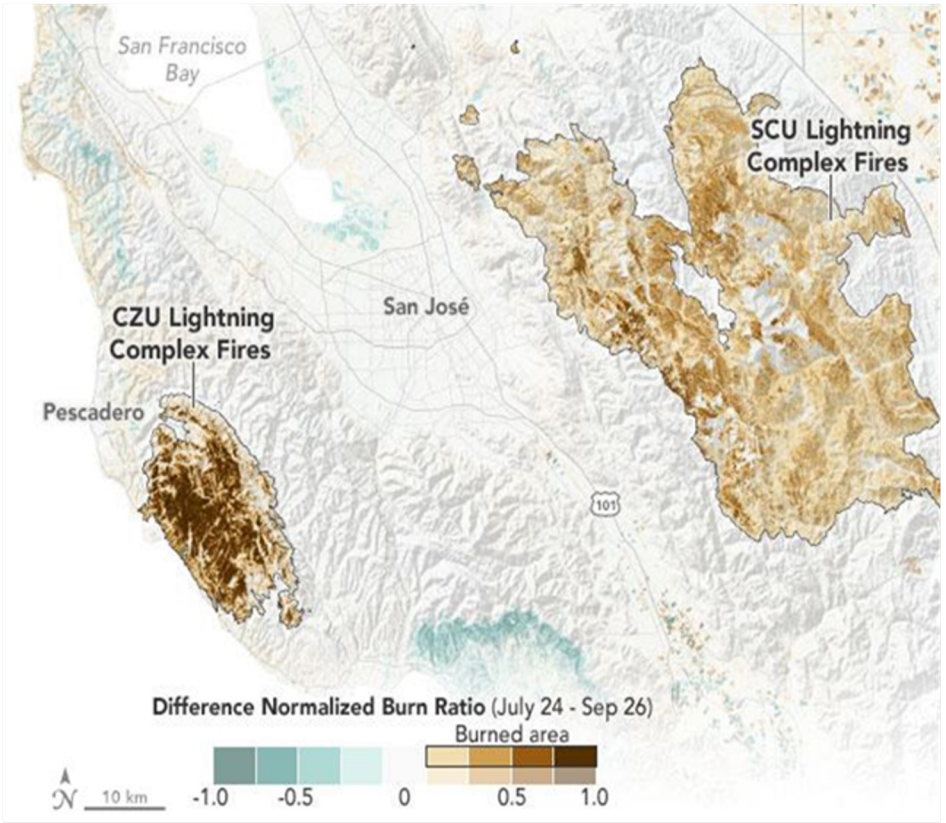
- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document,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

# Burned Area and Burn Severity Mapping

# 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

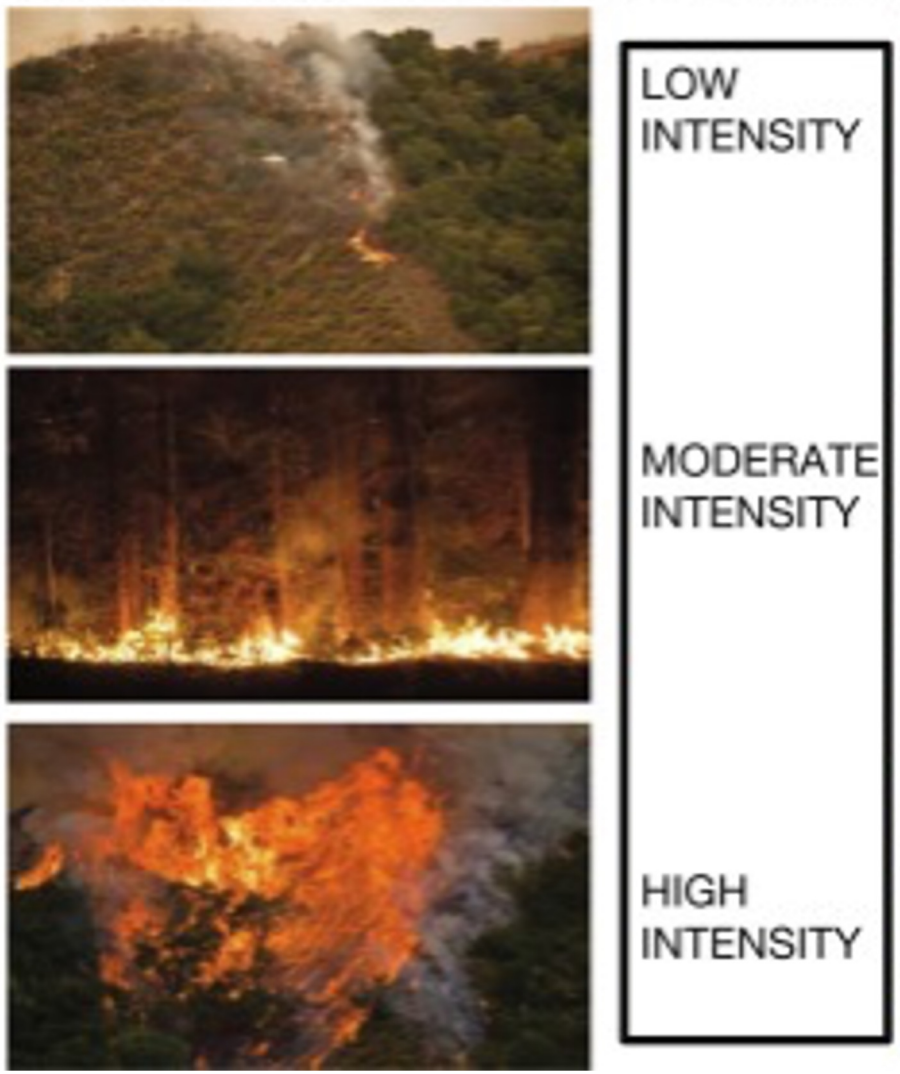
# Post Fire Impacts

- 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

# 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.



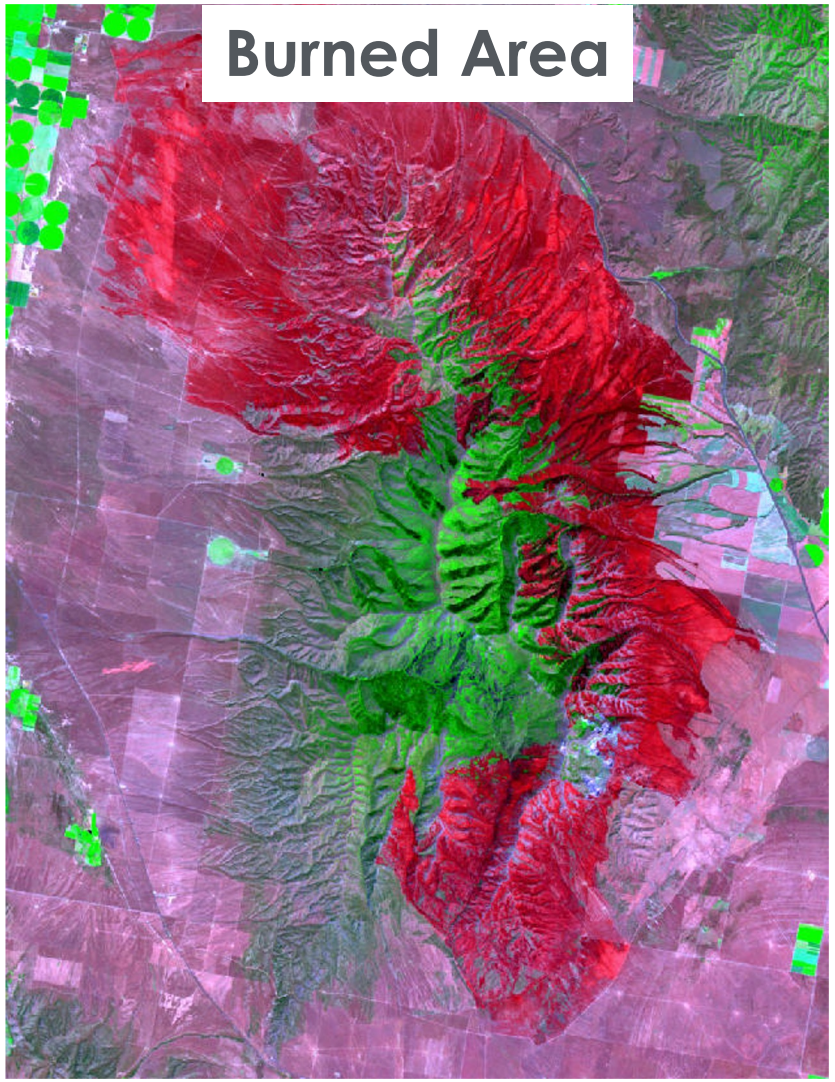

Example scale of fire intensity. Image Credit: NPS.gov, NIFC.gov, K. Crocker, D. A. DellaSala

# Burn Severity

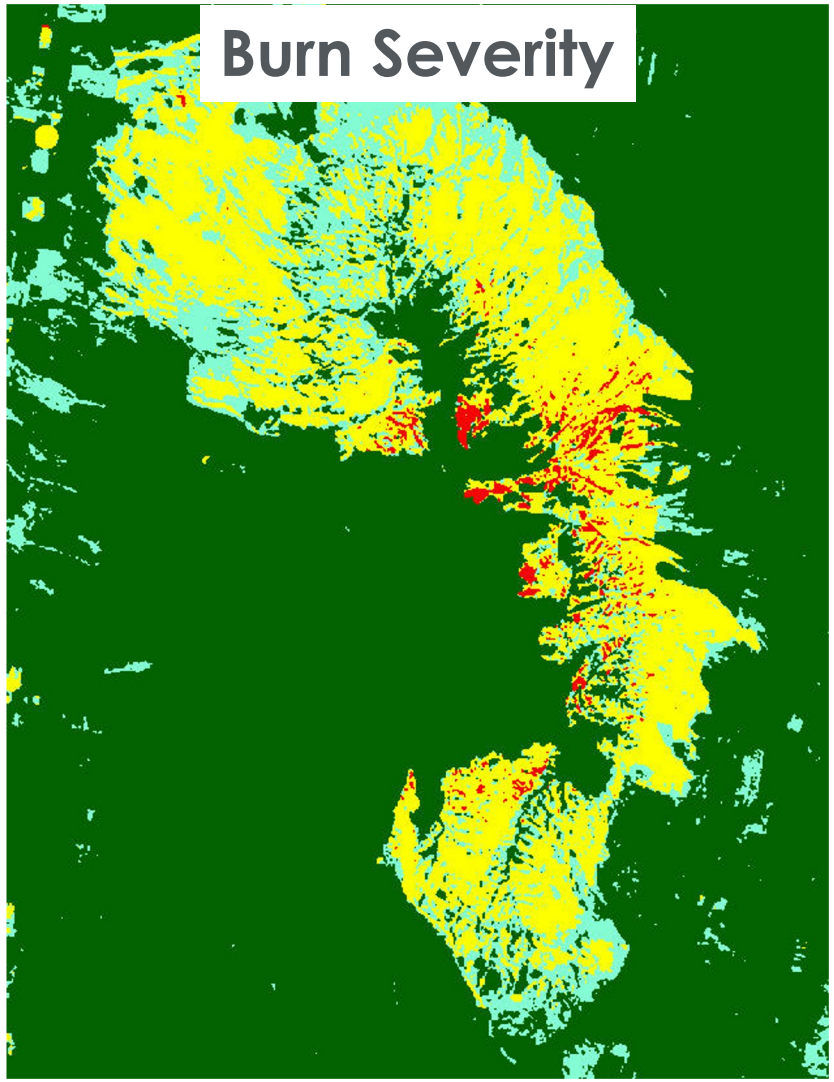
- The **effect of a fire on ecosystem properties**, often defined by the degree of mortality of vegetation
- Degree to which a site has been altered or disrupted by fire; loosely, a product of fire intensity and residence time

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

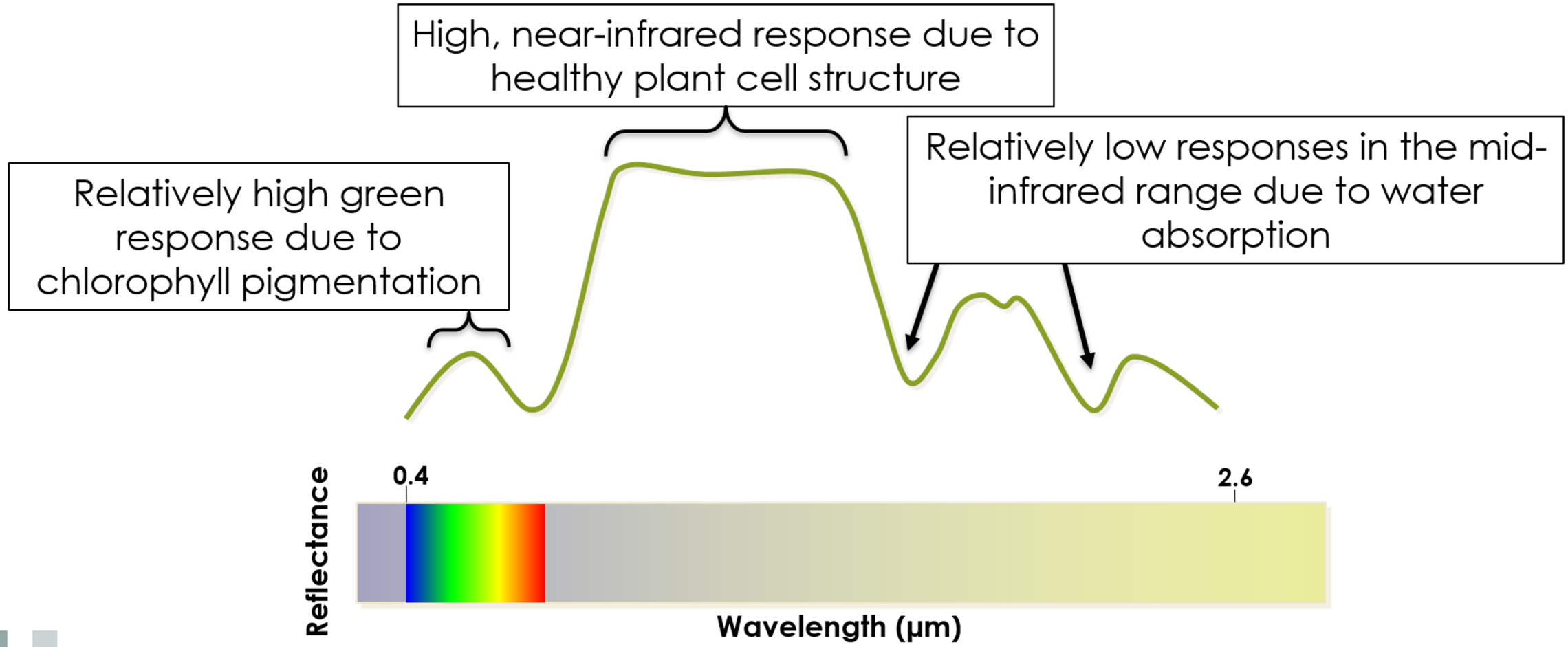



- Burned area uses imagery to assess the extent of impacts on vegetation for a particular fire event.
- Burn severity compares burned area information to pre-fire imagery to assess relative magnitude of burn impacts.

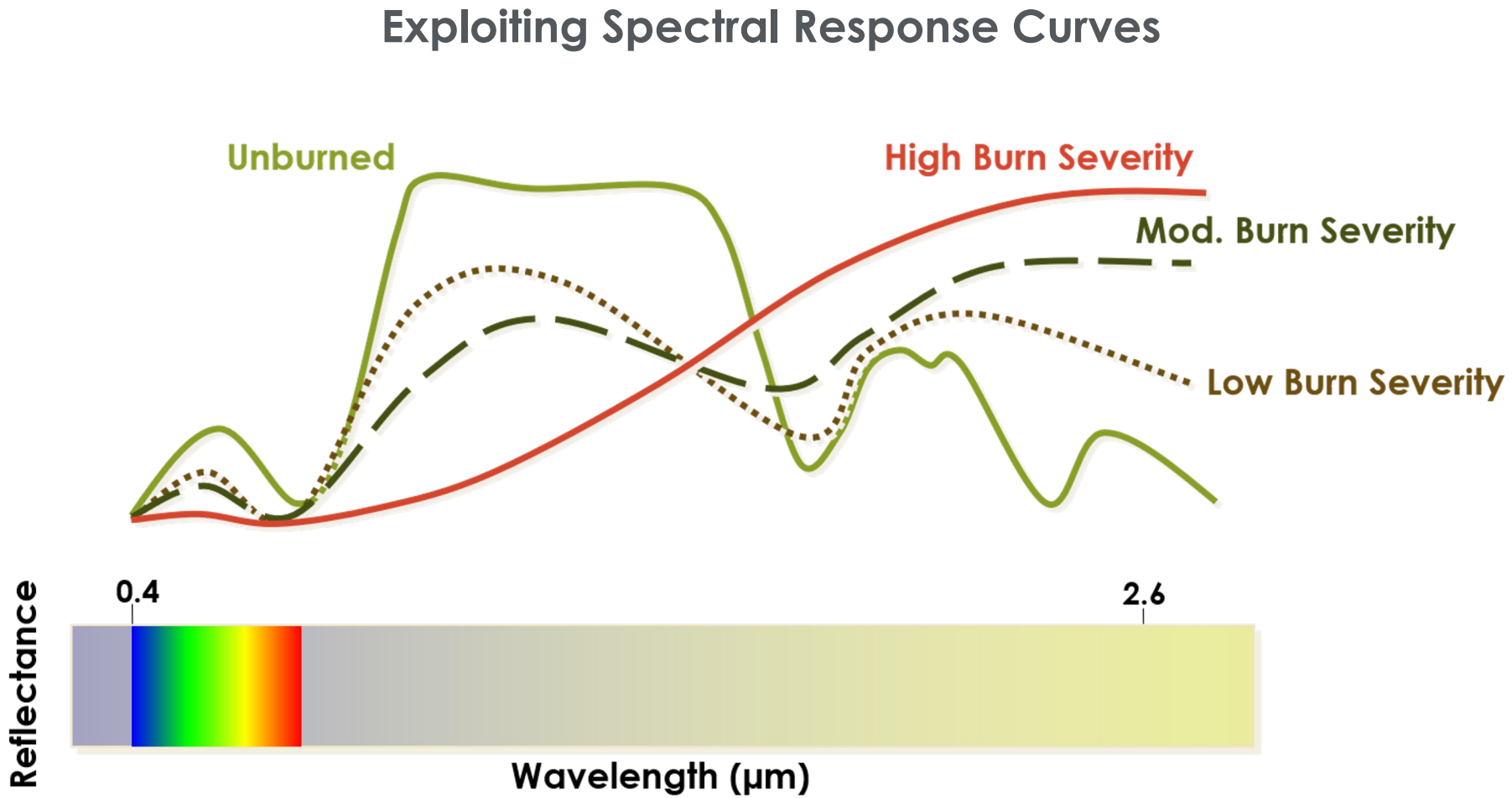


# Typical Vegetation Spectral Response

## Spectral Response Curve of Typical Vegetation from 0.4 to 2.6 µm

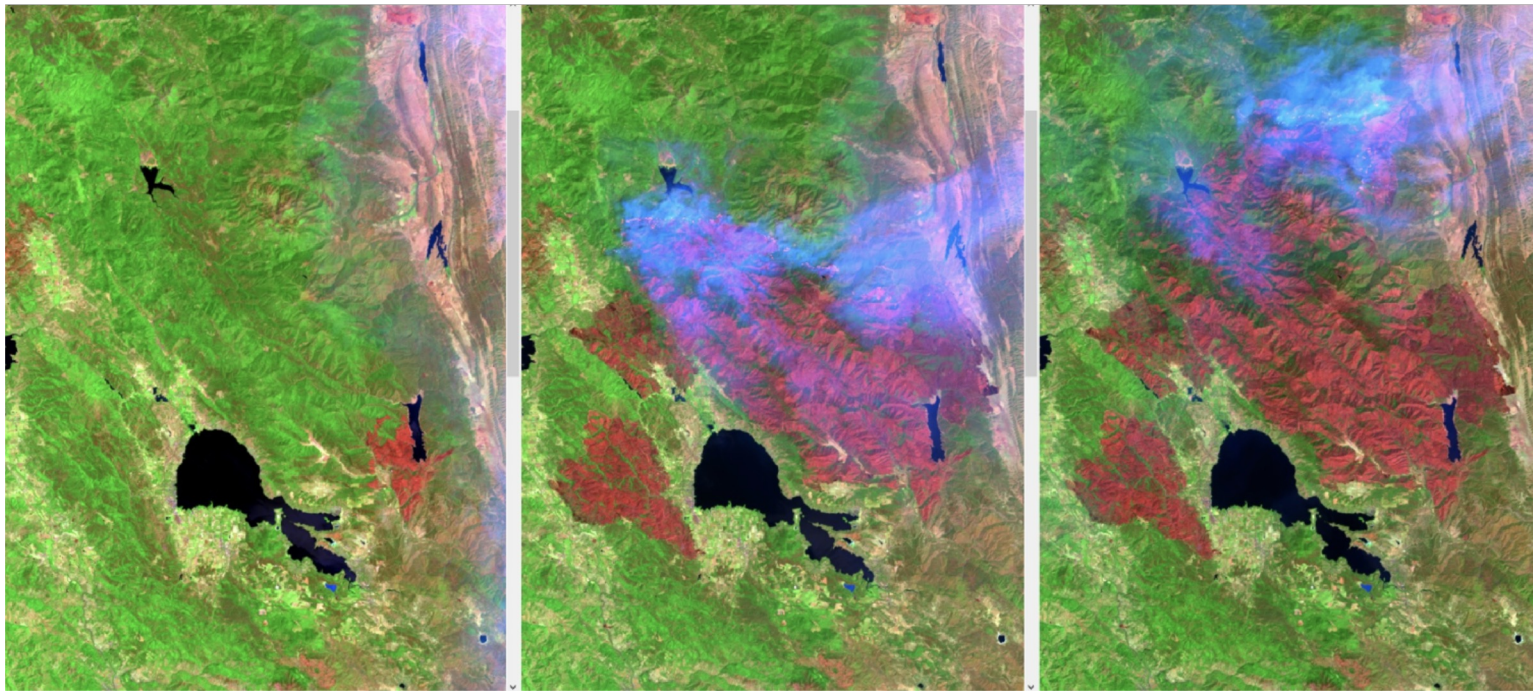


# Healthy Vegetation vs. Burned Areas



# 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

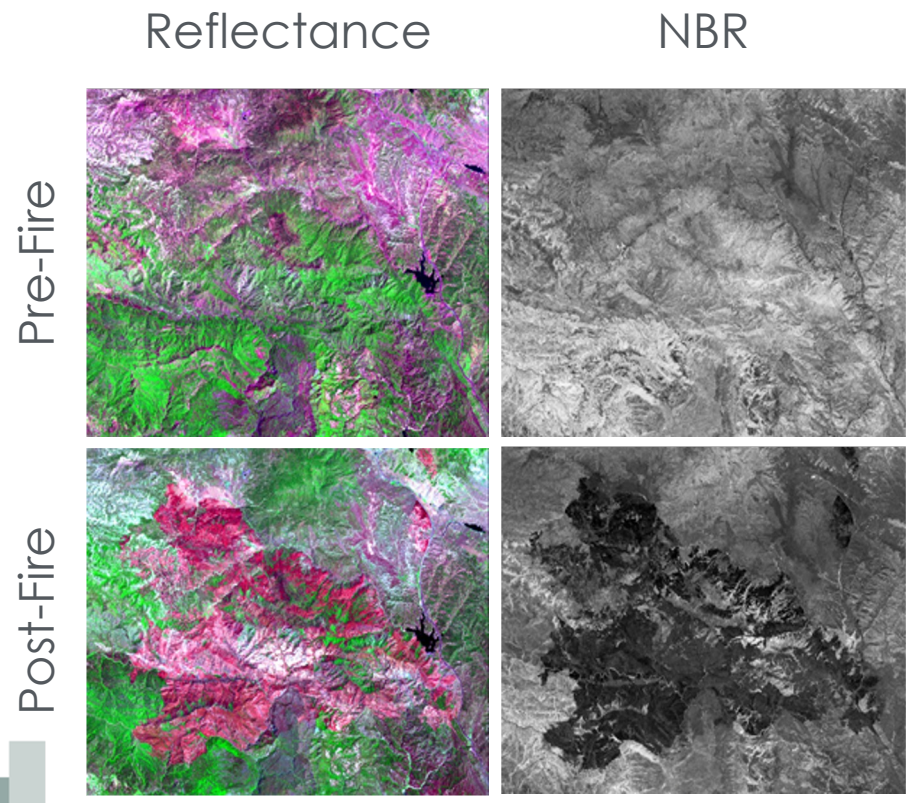
Mendocino Complex Fires, 2018

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

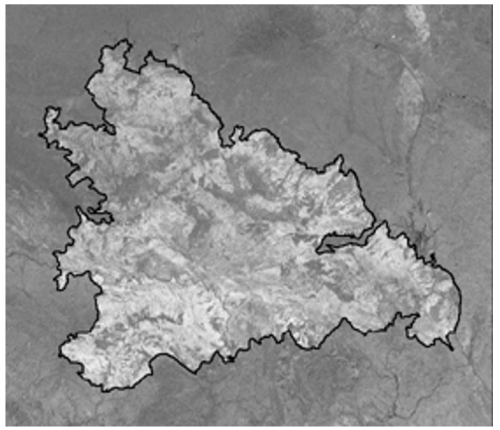
# Burn Severity: Differenced Normalized Burn Ratio (dNBR)

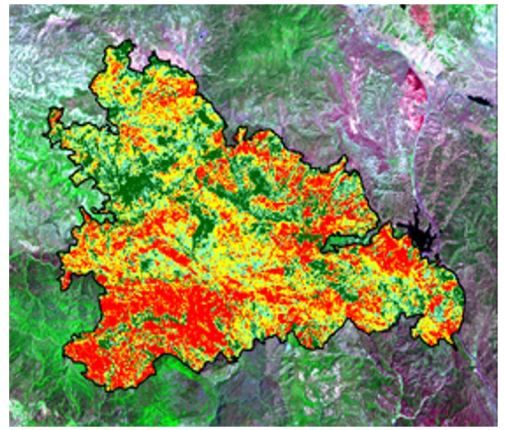
- **Normalized Burn Ratio (NBR)**
- Establishes extent of burned area before and after fire event

- **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



# Google Earth Engine for Post Fire Mapping

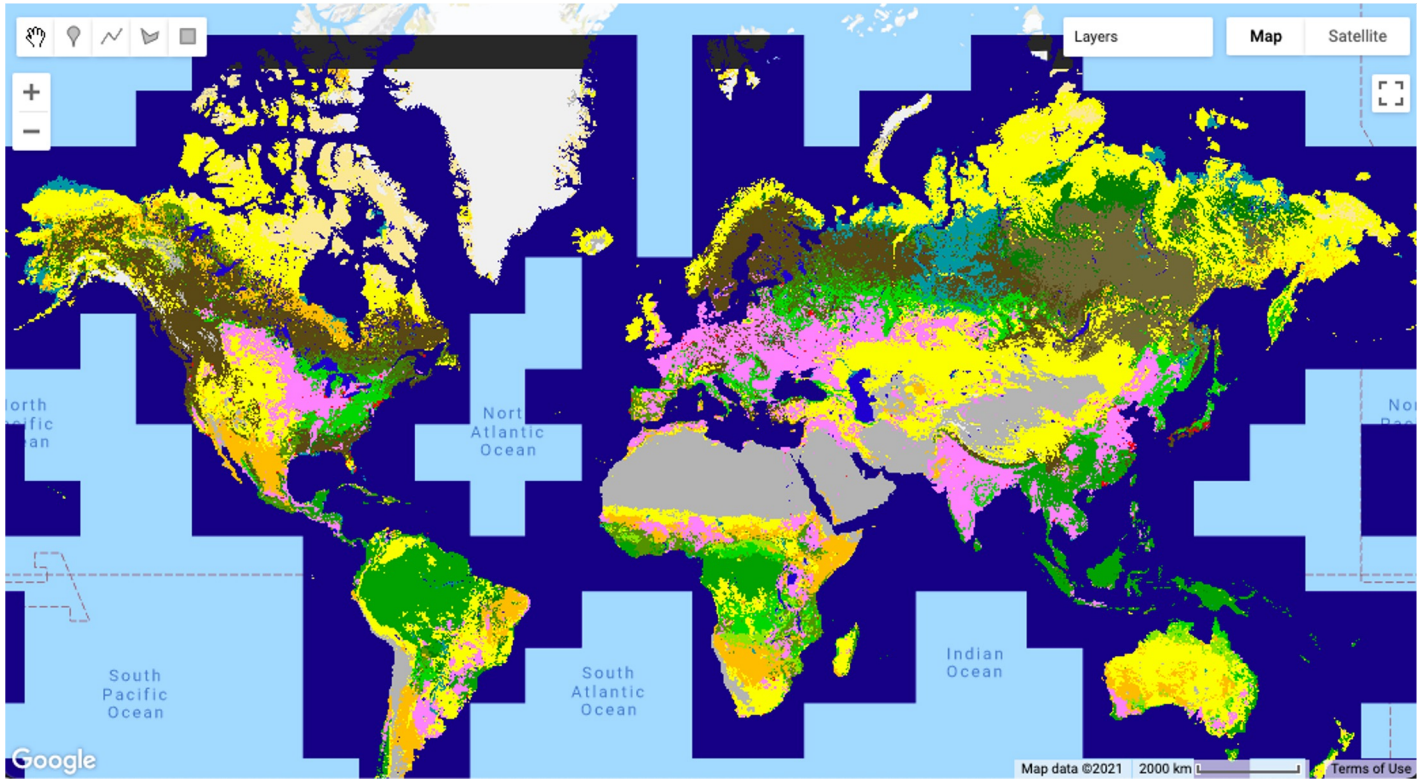
# GEE Land Applications

- Long-term monitoring of landscape change and land cover type
- Computation of indices relevant to land management such as normalized difference indices for vegetation, water, snow, soil, and urban areas
- Landscape time series analysis and change detection
- Summary statistics
- Validation and accuracy assessment methods
- Visualization and presentation of results

Time series of MODIS NDVI displayed using Google Earth Engine. Image Credit: Google Earth Engine Developers

# Available Satellite Sensor Data in GEE: Land Cover Products

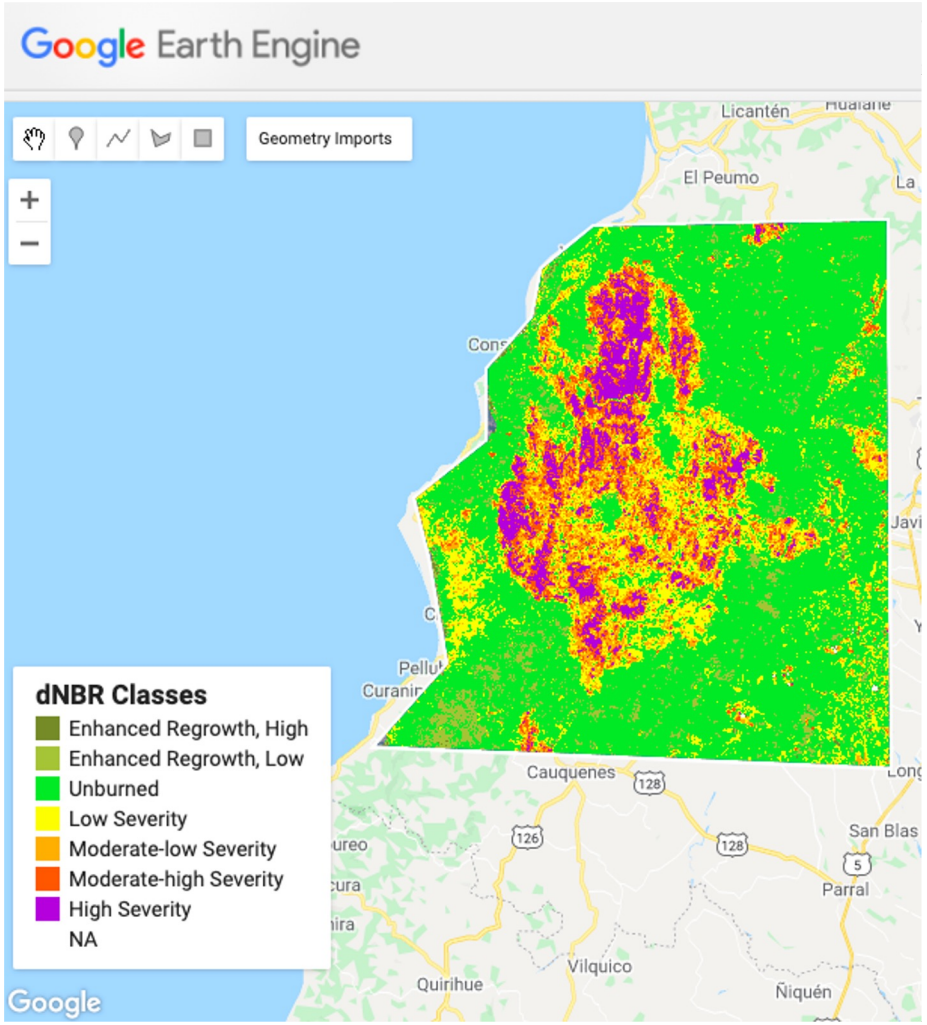
- A variety of land cover data products are available in GEE, including:
  - Copernicus Global Land Cover Layers
  - MODIS Land Cover Type Yearly Global 500m
  - Global PALSAR-2/PALSAR Forest/Non-Forest Map
  - USGS National Land Cover Database
- GEE Data Catalog:
  - https://developers.google.com/earth-engine/datasets/tags/landcover




Copernicus Global Land Cover Layers: CGLS-LC100 collection 3 displayed globally in GEE. Credit: Earth Engine Data Catalog

# Applications of GEE for Land Management: Burn Severity

- Burn severity mapping completed in GEE manipulates pre-loaded Sentinel-2 or Landsat 8 data and uses the GEE platform as a means to quality control and filter data.
- Normalized Burn Ratio (NBR) and differenced NBR (dNBR) are calculated.
- Thresholding rates the severity of wildfire burning to complete a full burn severity assessment.
- Refer to the step-by-step UN-SPIDER burn severity in GEE training




Example of burn severity mapping using Sentinel-2 data in Empedrado, Chile in February 2017. This map was produced using the UN-SPIDER Burn Severity with GEE script. Credit: UN-SPIDER

# Advantages and Disadvantages of GEE

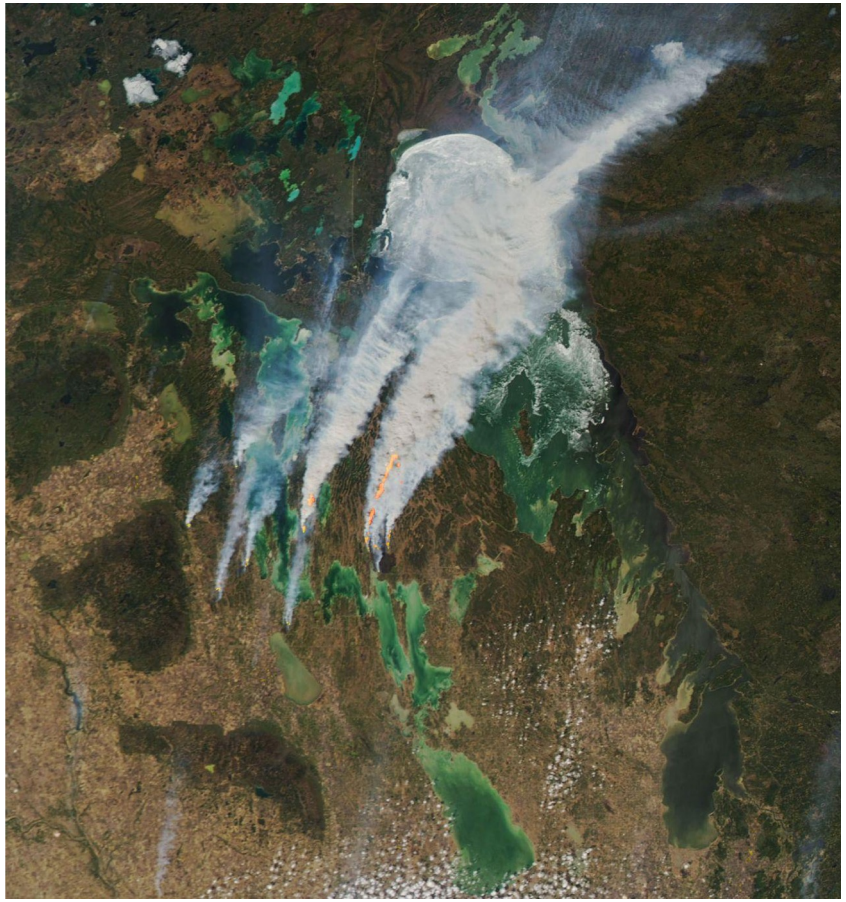
## Advantages

- Allows processing of remote sensing data directly on Google's servers (cloud-computing)
- Free for non-commercial use
- Access and integration of many geospatial datasets at multiple scales
  - Ability to monitor global phenomena
- Built in functions for quick processing
- Flexible access through APIs (Climate Engine built in this manner)

## Disadvantages

- Processing and storage limits
  - Inability to perform "batch jobs" without cost
- Only free for non-commercial user
- Complex operations can be challenging
  - Restricted programming framework
  - Aggregate layers make it difficult to determine the date of specific pixels

# Evaluating Environmental, Social and Economic Impacts



Source: NASA

Example of Measurable Impacts

(Morton et.al, 2003)

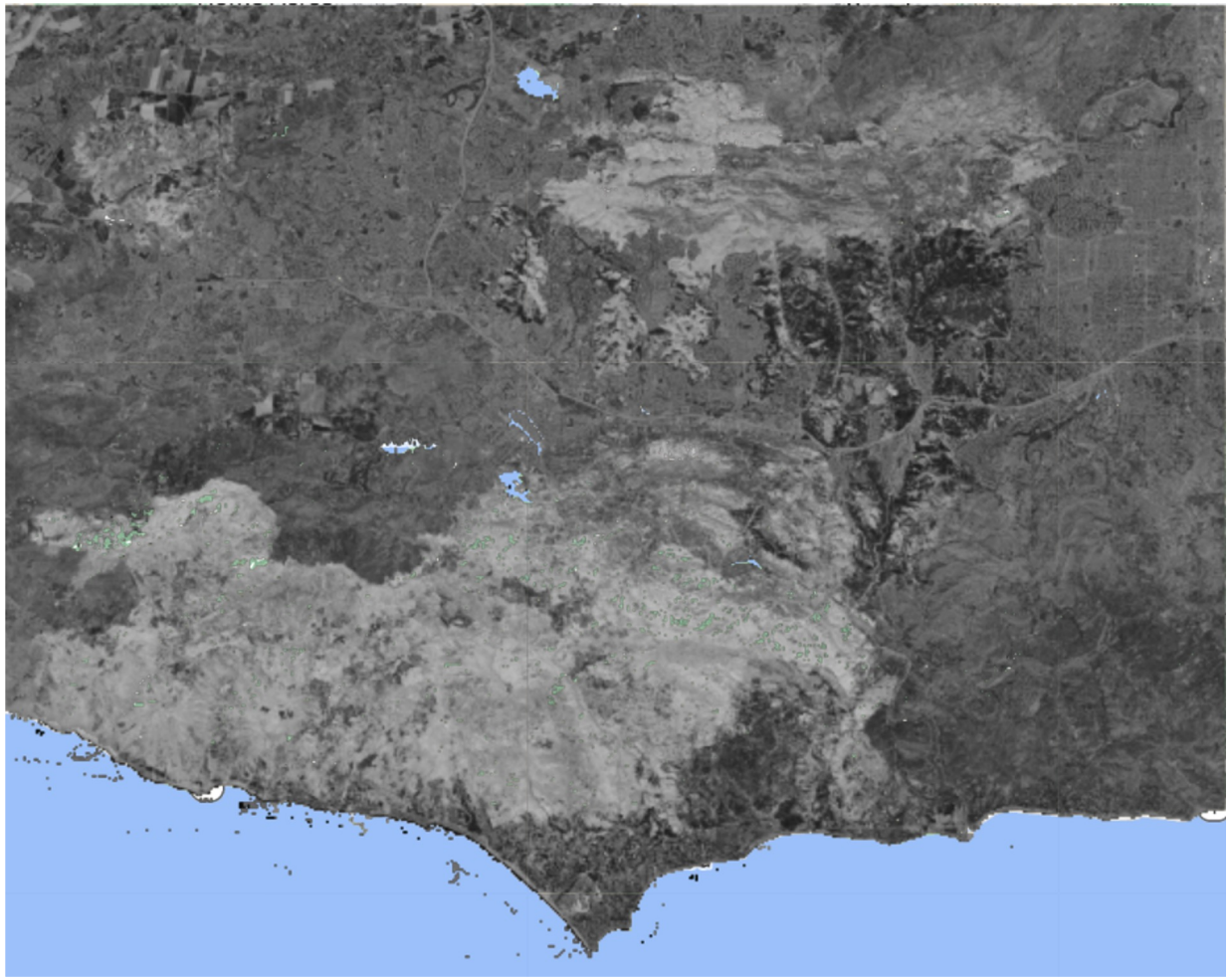
- Total acres burned
- Cost of fire suppression
- Damage to homes and structures
- Alteration of wildlife habitat
- Damage to watersheds and water supply
- Damage to public recreation facilities
- Evacuation of adjacent communities
- Tourism impacts
- Damage to timber resources
- Destruction of cultural and archaeological sites
- Costs of rehabilitation and restoration
- Public health impacts
- Transportation Impacts

# Google Earth Engine Case Study Analysis

# Woolsey Fire

- Landsat 8 Level 2 Collection 2 Tier 1 data
  - Cloud masked
  - USGS scale factor corrected
  - Global Coverage
  - 30m resolution
  - Data availability from March 2013 to Present
  - Pre-Fire dates: Nov 5, 2017 - 2018
  - Post-Fire dates: Nov 22, 2018 - Feb 28, 2019

# Normalized Burn Ratio (NBR)

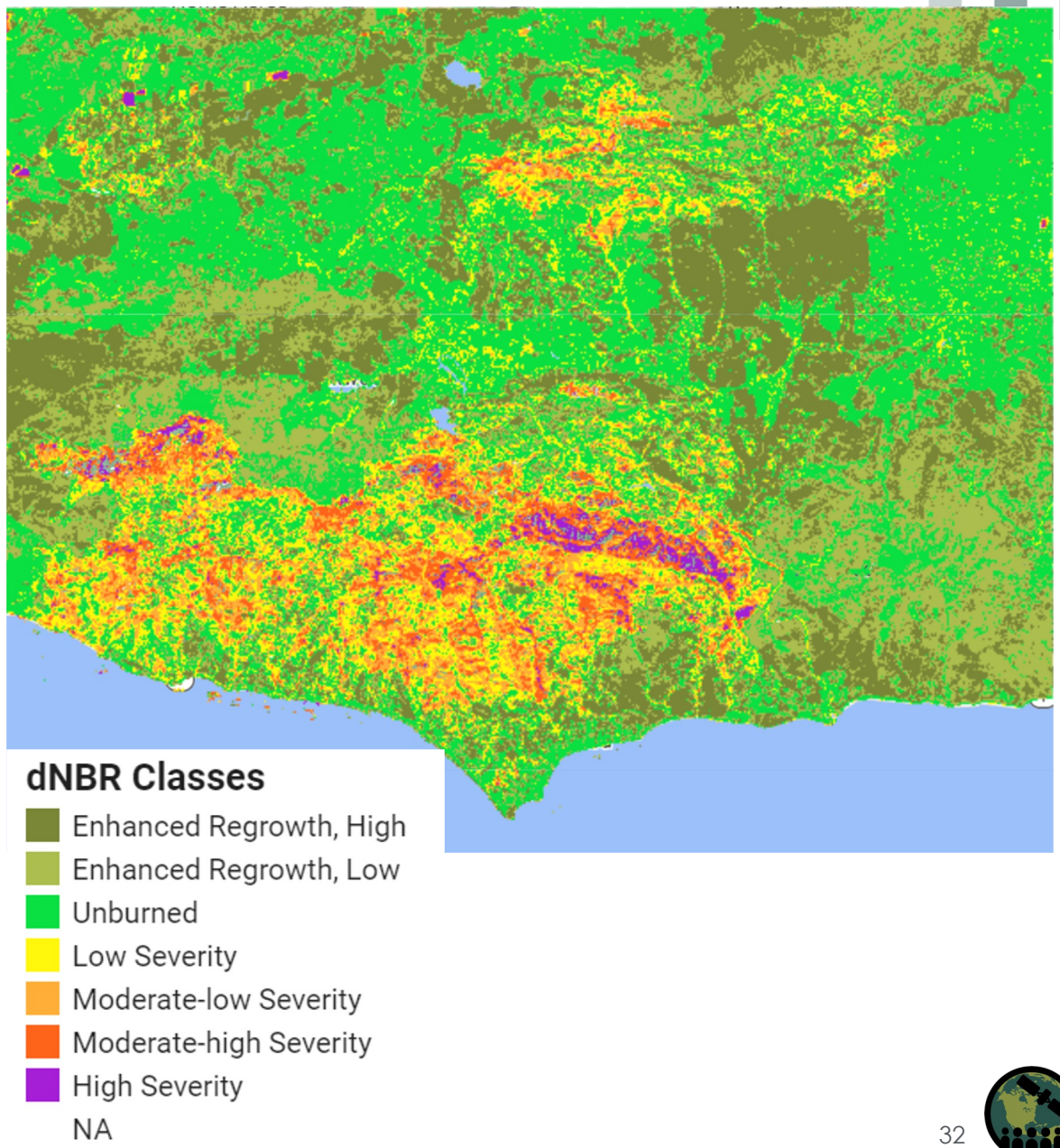


$$NBR = \frac{(NIR - SWIR)}{NIR + SWIR}$$

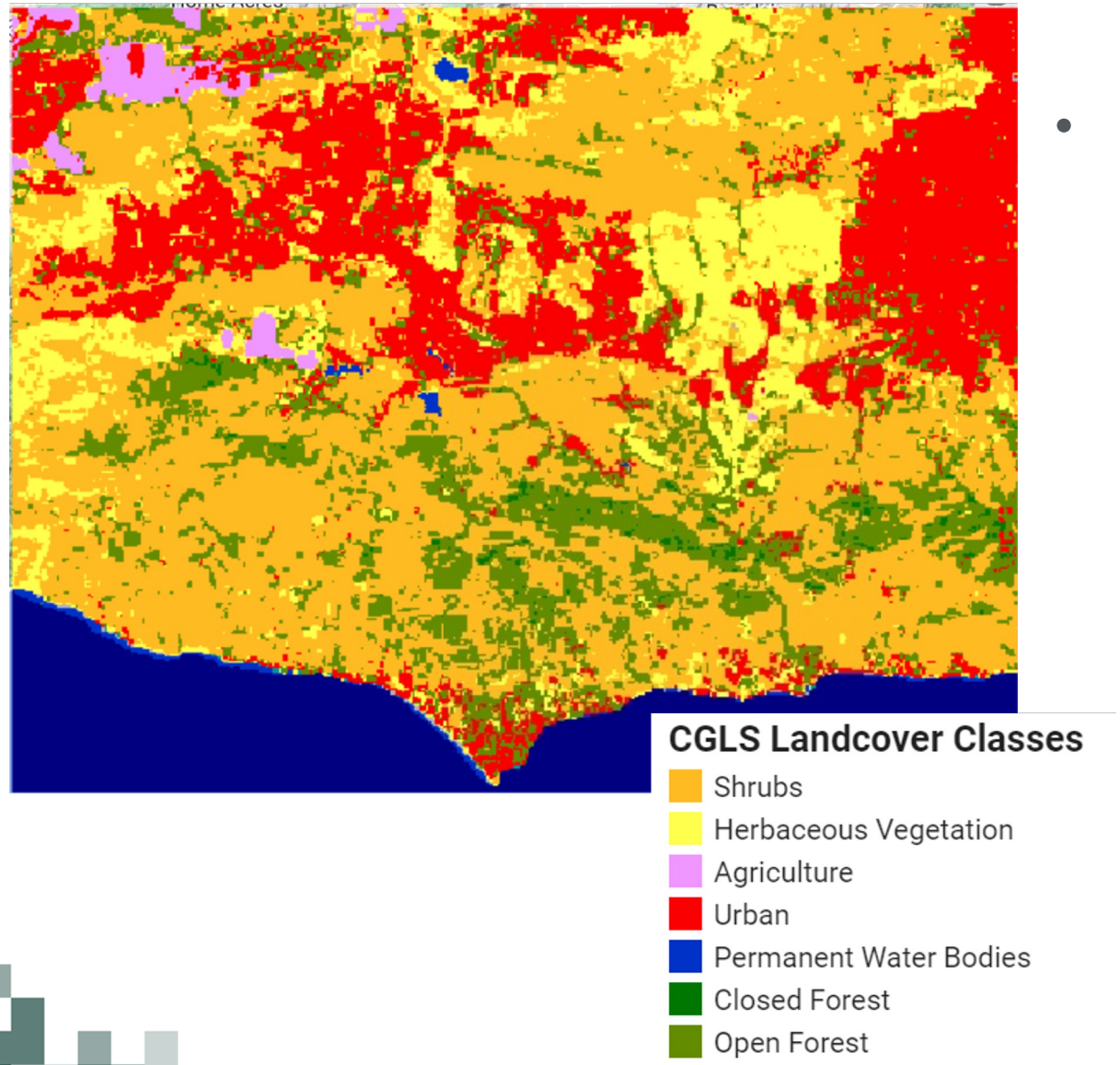
- Derived from Landsat 8 data
  - 30m resolution
  - Pre- and Post-Fire dates
- Darker colors indicate healthy vegetation while lighter colors indicate bare ground and recently burnt areas.

# Burn Severity (classified dNBR)

- Burn severity thresholds are based on USGS proposed classifications from *Keeley, J. E. (2009)*.
  - It is a classified dNBR
    - dNBR = Pre-Fire NBR – Post-Fire NBR
  - 30m Resolution (from Landsat 8 data)



# Land Cover

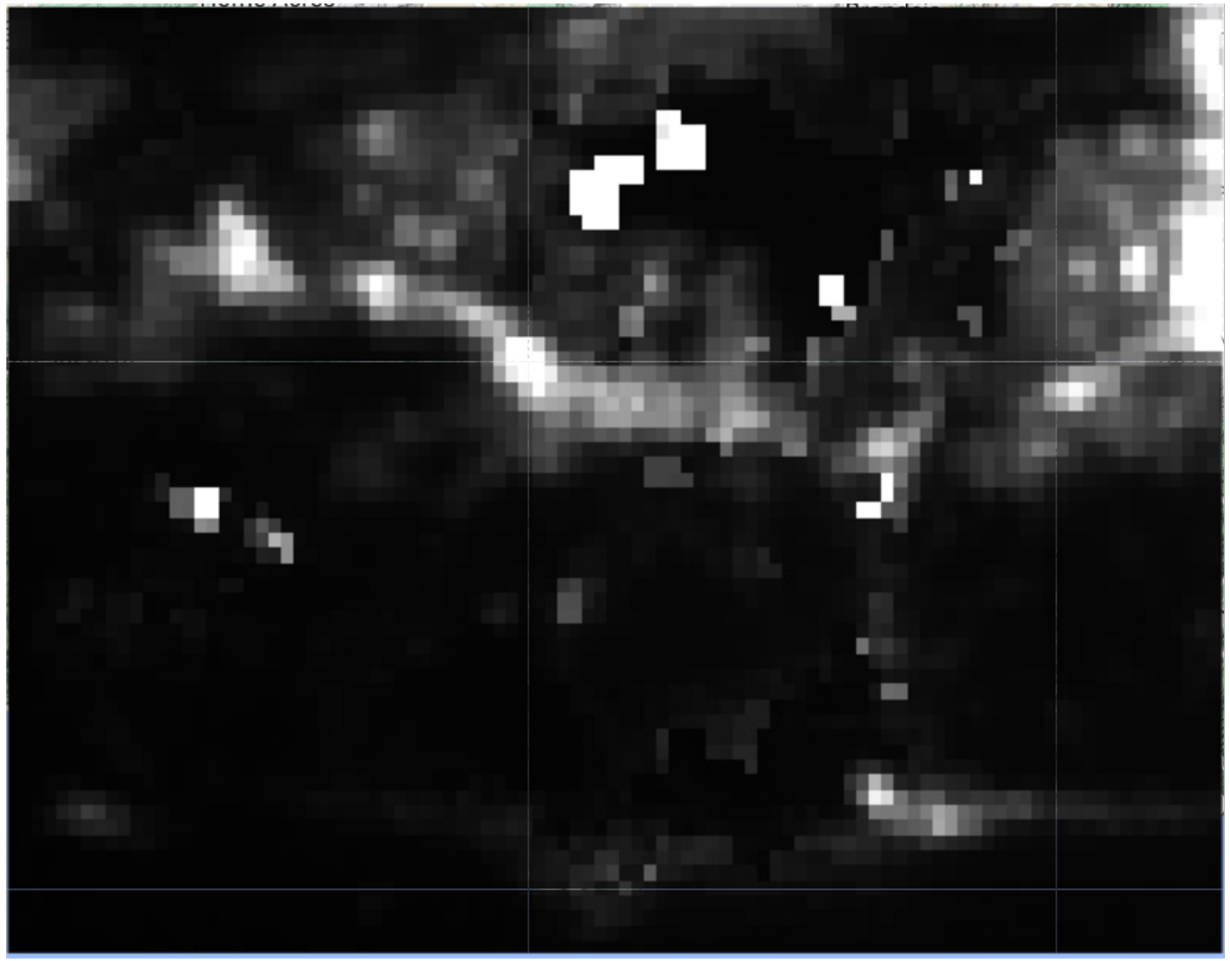



- Copernicus Global Land Service (CGLS)
  - Data is calculated on an annual basis.
  - Current data availability is from 2015 - 2019, but data availability from 2020 - Present is expected to be released soon.
    - We used 2018 data for this training.
  - 23 land cover classifications, but our study area only used 7.
  - Global Coverage
  - 100m Resolution

# Population Density

- The Global Human Settlement Layer (GHSL)
  - Distribution and density of population, expressed as the number of people per cell, for reference epochs: 1975, 1990, 2000, 2015
    - 2015 data was used for this training.
  - Global Coverage
  - 250m Resolution

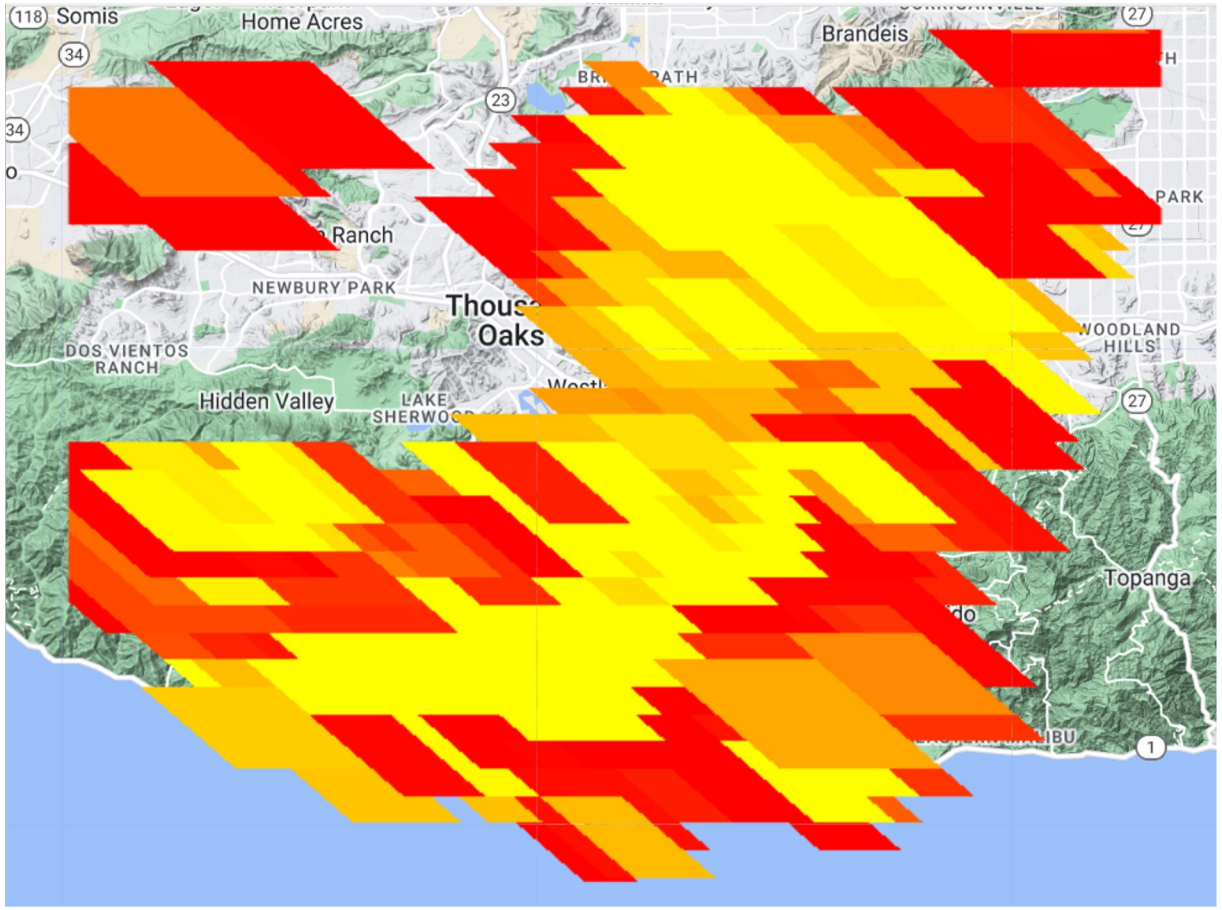
# Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB)



- Visible Infrared Imaging Radiometer Suite (VIIRS) Day/Night Band (DNB)
  - Average radiance composite images using nighttime data
  - Data is composited monthly.
    - We monitor before (October 2018), during (November 2018), and after (December 2018) the fire in this training.
  - Resolution is 463.83 meters.
  - Data availability is April 2012 – Present.
  - Global Coverage

# FIRMS: Fire Information for Resource Management System

- Fire Information for Resource Management System (FIRMS)
  - The LANCE fire detection product as a raster
  - Data available Nov 2000 – Present.
  - Global Coverage
  - Resolution: 1000 meters (1 km)



# Woolsey Fire In GEE

For this exercise, we will:

1. Define study area, apply scale factor, and cloud mask data pre- and post-fire
2. Calculate the Normalized Burn Ratio (NBR) for the pre- and post-fire images
3. Calculate the differenced NBR (dNBR) for the pre- and post-fire images
4. Classify the burn severity, add a legend, and identify burned areas
5. Add land cover data and calculate hectares of burned urban area
6. Load human population data and estimate the number of people affected
7. Visualize nighttime data before, during, and after the fire
8. Visualize FIRMS data during active fire dates
9. Visualize pre- and post-fire NDVI

## WOOLSEY FIRE CODE LINK:

https://code.earthengine.google.com/b4cd79e42d18f9674b8370e4d3682bb4

# NOAA's Hazard Mapping System (HMS)

Implemented in 2003

Addresses user demands

Outputs Include:

- Active fire detection
- Smoke information for 24 hr period
- Near real-time polar and geostationary satellite observations

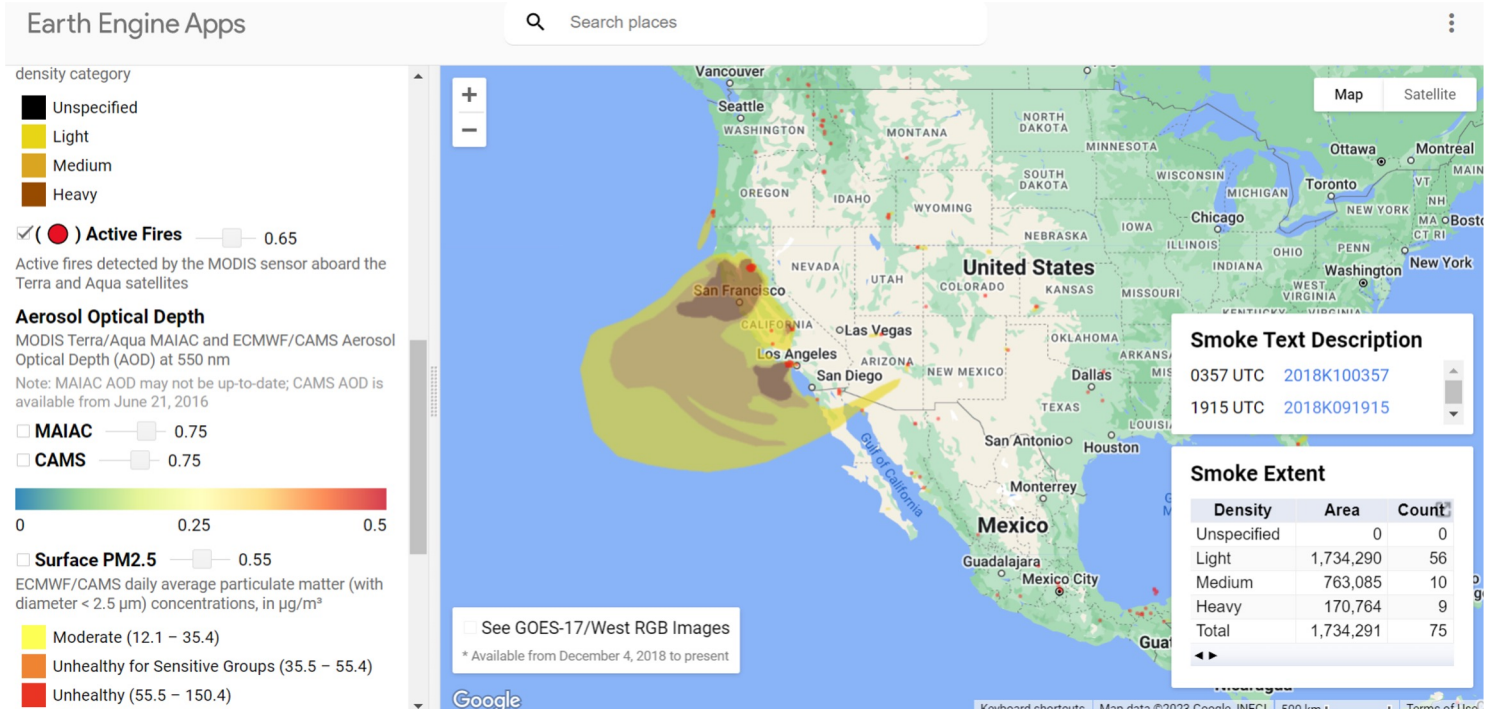
Published on HMS data mapping interface, with GIS-friendly formats


NOAA Hazard Mapping System Fire and Smoke Product

# HMS Smoke Explorer in Google Earth Engine

- Google Earth Engine App
- Adjust parameters for on-the-fly analysis
- Layers Available Include:
  - Active Fires
  - Aerosol Optical Depth
  - Surface PM2.5
- Time series chart produced of smoke plumes by year

[More than 20 California cities have unhealthy air quality from wildfires - CBS News]




[HMS Smoke Explorer]

# Assessing the Impacts of Fires on Watershed Health
## **Summary**

# Part 3 Summary

- Monitoring changes in NBR and dNBR can help identify the extent and severity of wildfires.
- Land cover types and human population data can be used to estimate the affected population from a natural hazard.
- Data sources such as the VIIRS Day-Night Band, FIRMS, etc. can be used to further understand fire extent and the affected population within a study area.

# Training Summary

There are a variety of remote sensing satellites, sensors, indicators, and datasets relevant to understanding fire risk and post fire impacts.

GEE can be used to:

- Delineate river basins and subbasins for a watershed of interest
- Calculate anomalies in biophysical and meteorological conditions
- Map burn severity and datasets relevant to post fire impacts on landscapes and populations

SWAT can be used to develop a river basin-scale model and to quantitatively constrain fire-related increases in water quantity and quality parameters.

# Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 07/13/2023
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by July 27, 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.

# Acknowledgements


**Guest Speakers**

Ibrahim Mohammed (SAIC/NASA)

Mandy Lopez (NASA JPL)

**Water & Disasters Team**

Amita Mehta (NASA/UMBC/GESTAR II)

Sean McCartney (NASA/SSAI)

Erika Podest (NASA JPL/Caltech)

**Ecological Conservation Team**

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Britnay Beaudry (BAERI/NASA ARC)

Sativa Cruz (BAERI/NASA ARC)

# Contact Information

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# Resources

- https://developers.google.com/earth-engine/datasets/catalog/landsat
- https://developers.google.com/earth-engine/datasets/catalog/sentinel-2
- https://www.mtbs.gov/
- https://www.ospo.noaa.gov/Products/land/hms.html#maps
- Fire Information for Resource Management System Web Map
- https://gwis.jrc.ec.europa.eu/apps/gwis_current_situation/index.html


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

# Thank You!