National Aeronautics and Space Administration

Using Earth Observations for Pre- and Post-Fire Monitoring

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Jan 18, 2022

Course Information

- Two, 3-hour sessions on January 18 and January 20 at **12:00-15:00 EST (UTC-5)**
  - Each session will feature lecture, hands-on guided exercises, a Q&A session, and "lab time" where instructors will be online to answer questions

- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-earth-observations-pre-and-post-fire-monitoring

- Prerequisites:
  - Fundamentals of Remote Sensing
  - Satellite Observations and Tools for Fire Risk, Detection, and Analysis or have equivalent experience

- For additional questions please email:
  - amberjean.mccullum@nasa.gov or
  - juan.l.torresperez@nasa.gov

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Answers must be submitted via Google Forms
  - **HW Deadline: Tuesday February 3**

- **Certificate of Completion:**
  - Attend both live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
  - You will receive certificates approximately three months after the completion of the course from: marines.martins@ssaihq.com

Course Outline

Learning Objectives

By the end of the training attendees will be able to:

- Identify land cover and climate variables related to wildfire risk
- Access and display geospatial wildfire risk data layers
- Create a burn severity map using satellite imagery
- Calculate burned area using satellite imagery

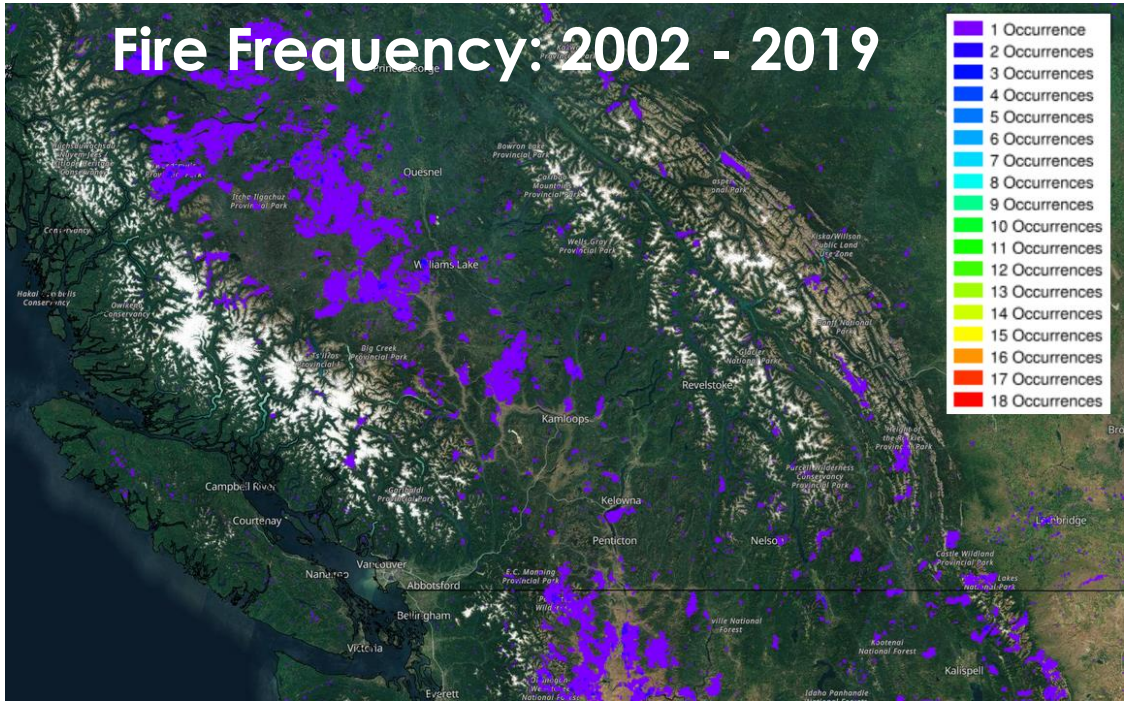
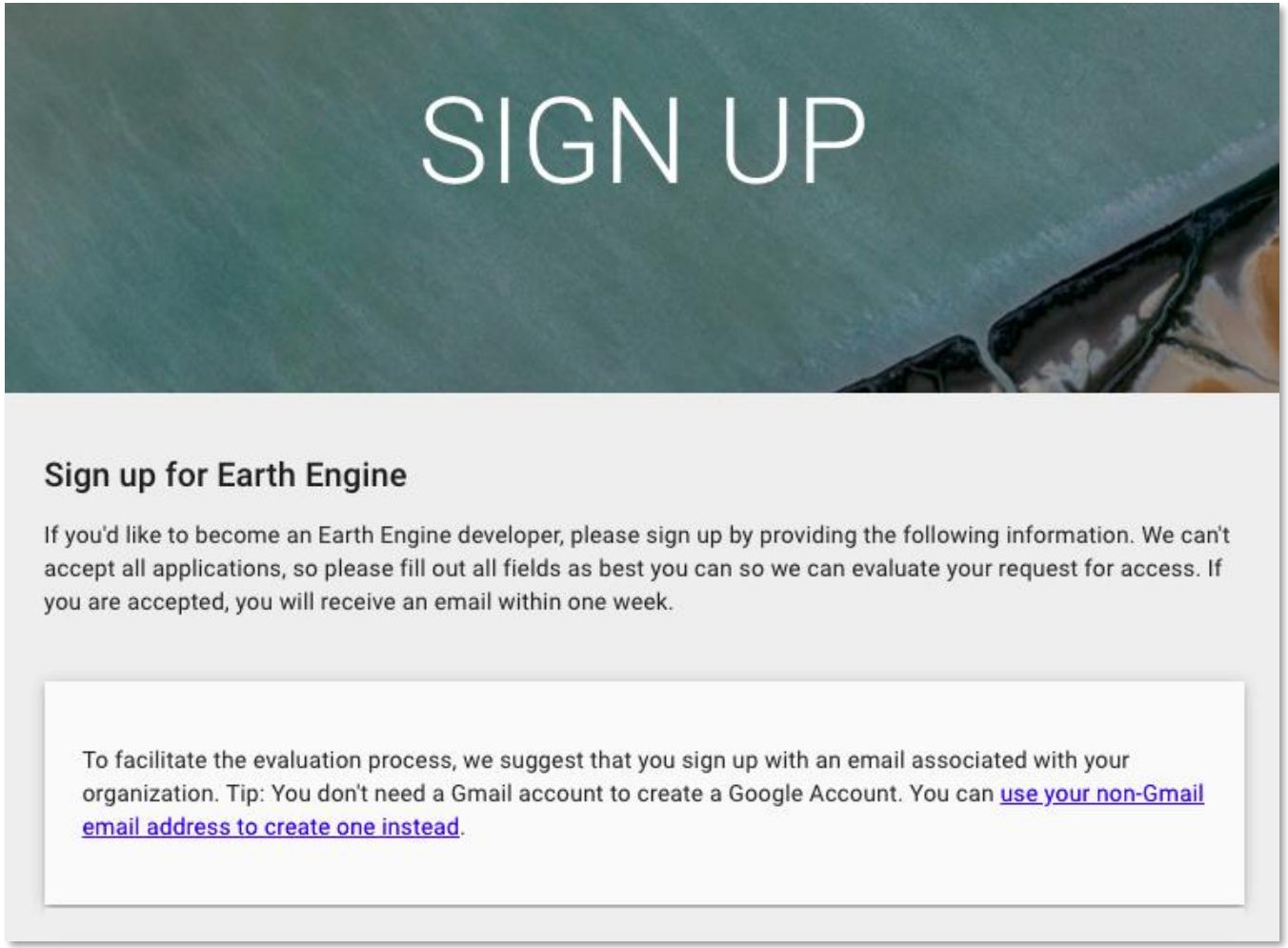


Image Credit: GWIS

Google Earth Engine Account Reminder

- Make sure you sign up for a Google Earth Engine account as soon as possible, if you haven't already, using the link below:
  - https://signup.earthengine.google.com/#!/
  - A Gmail address is not required. It is recommended that you use your work/institutional email.



Case Studies

Lytton, Canada Wildfires Jul-Aug 2021

Image Credits: The Guardian

Eastern Bolivia Wildfires Oct 2020

Image Credits: Earth Observatory

Part 1 Agenda

- Review of pre-fire biophysical and climatic conditions
- Highlights of pre-fire data and tools such as LANDFIRE, NASA's Global Fire Weather Database, The Global Wildfire Information System (GWIS), and the Global SERVIR Service Catalog
- Hands-On Exercise: Monitoring Pre-Fire Conditions
- Q&A
- Lab Time

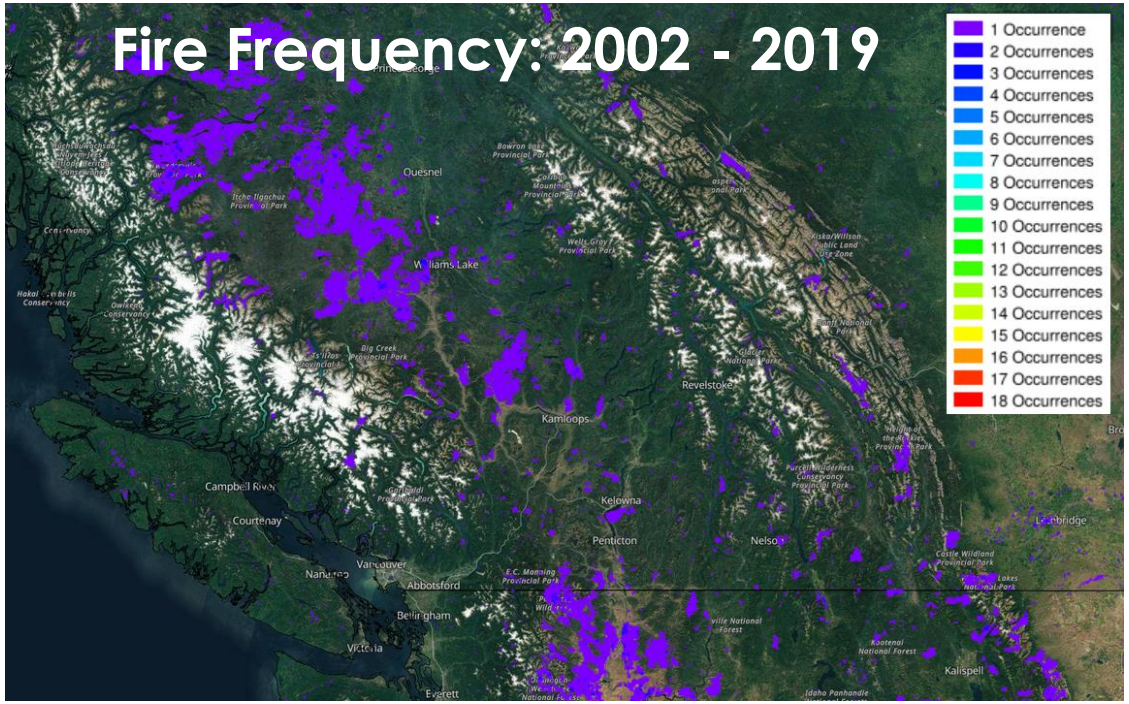


Image Credit: GWIS

Pre-Fire Conditions: Climate and Landscape

Pre-Fire Conditions

Climate and Hydrology

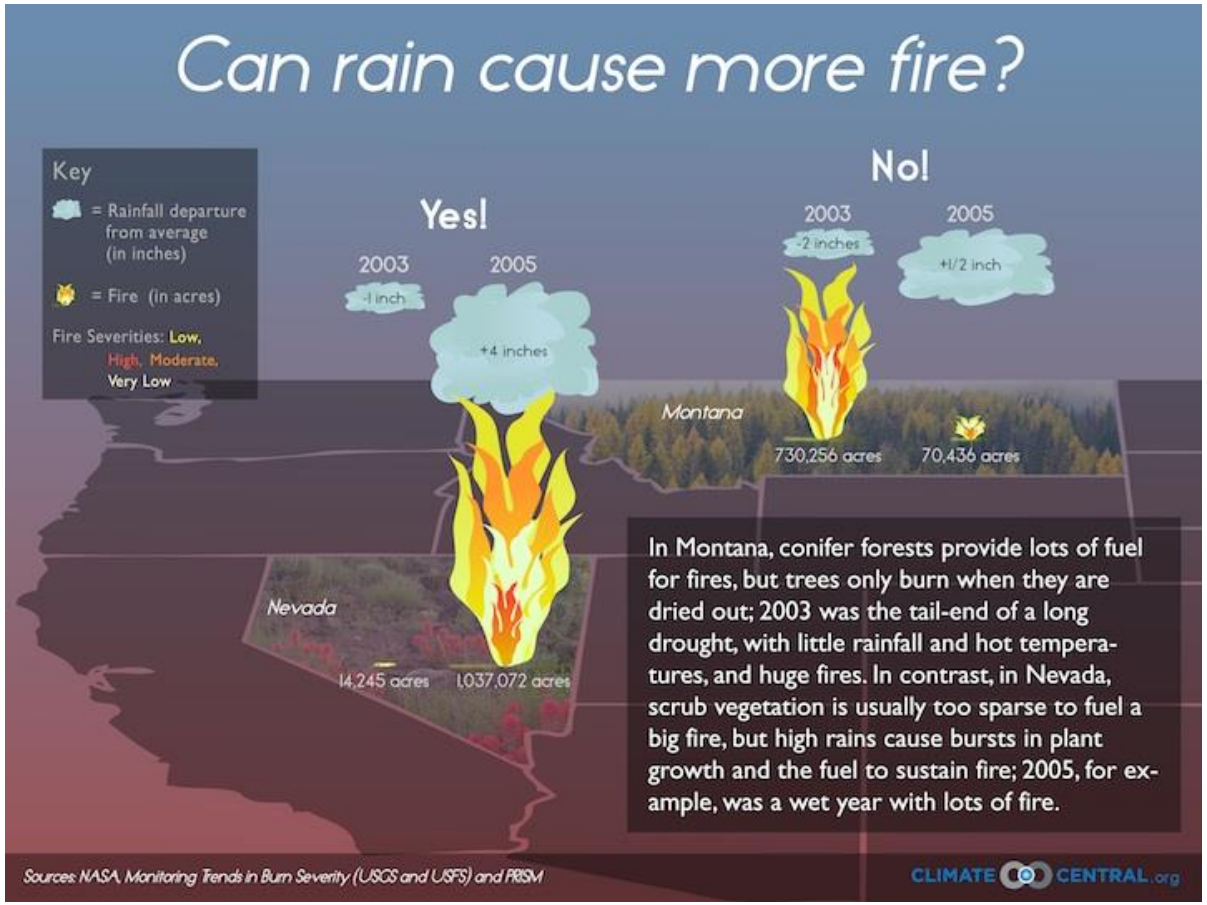
- Precipitation
- Temperature
- Soil Moisture
- Humidity
- Winds

Landscape and Vegetation

- Topography
  - Elevation, slope, aspect, features
- Vegetation Conditions
  - Type, extent, health, moisture content, structure

Precipitation and Wildfires

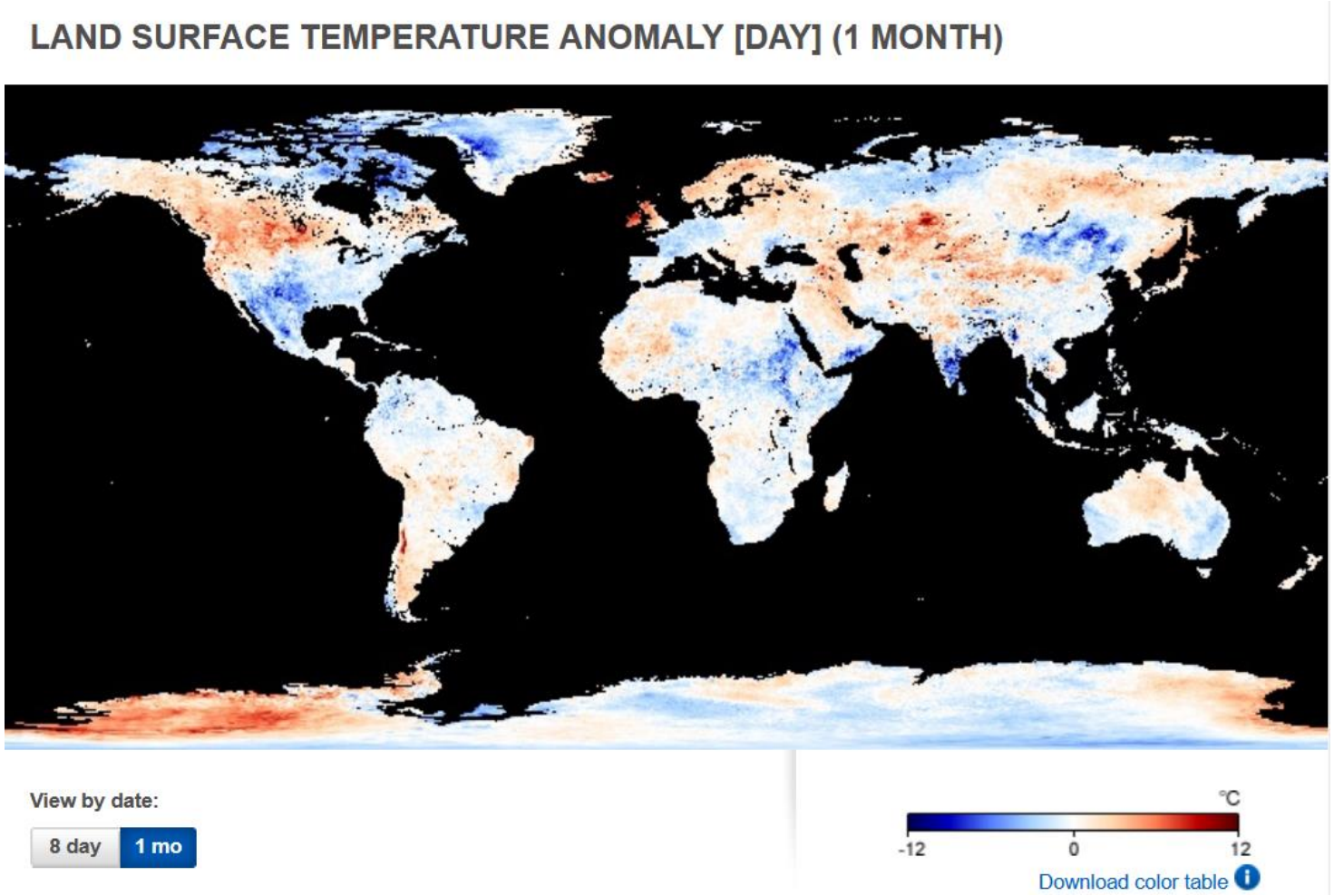
- Excessive precipitation during the growing season increases vegetation growth that becomes fuel for fire in the subsequent dry season.
- Pre-fire season rainfall and number of rainy days in fire seasons affect wildfire extent and severity (Holden et al., 2018, 2012).
- Precipitation patterns and amount affect surface temperature and soil moisture which also impact pre-fire risk.



https://www.climatecentral.org/gallery/graphics/can-rain-cause-more-fire

Temperature and Wildfires

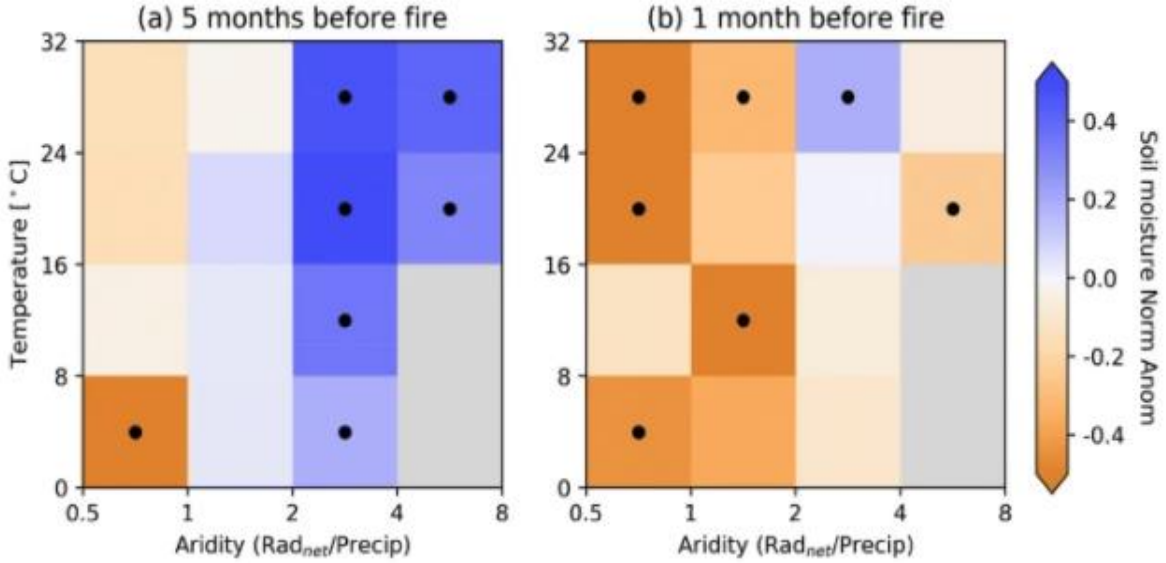
- Excessive heat during the growing season and the subsequent dry season decreases vegetation health and fuels become dry.
- Land surface temperature anomalies linked to greater fire occurrence.



July 2021 LST Anomalies: Image Credit: NEO

Soil Moisture and Wildfires

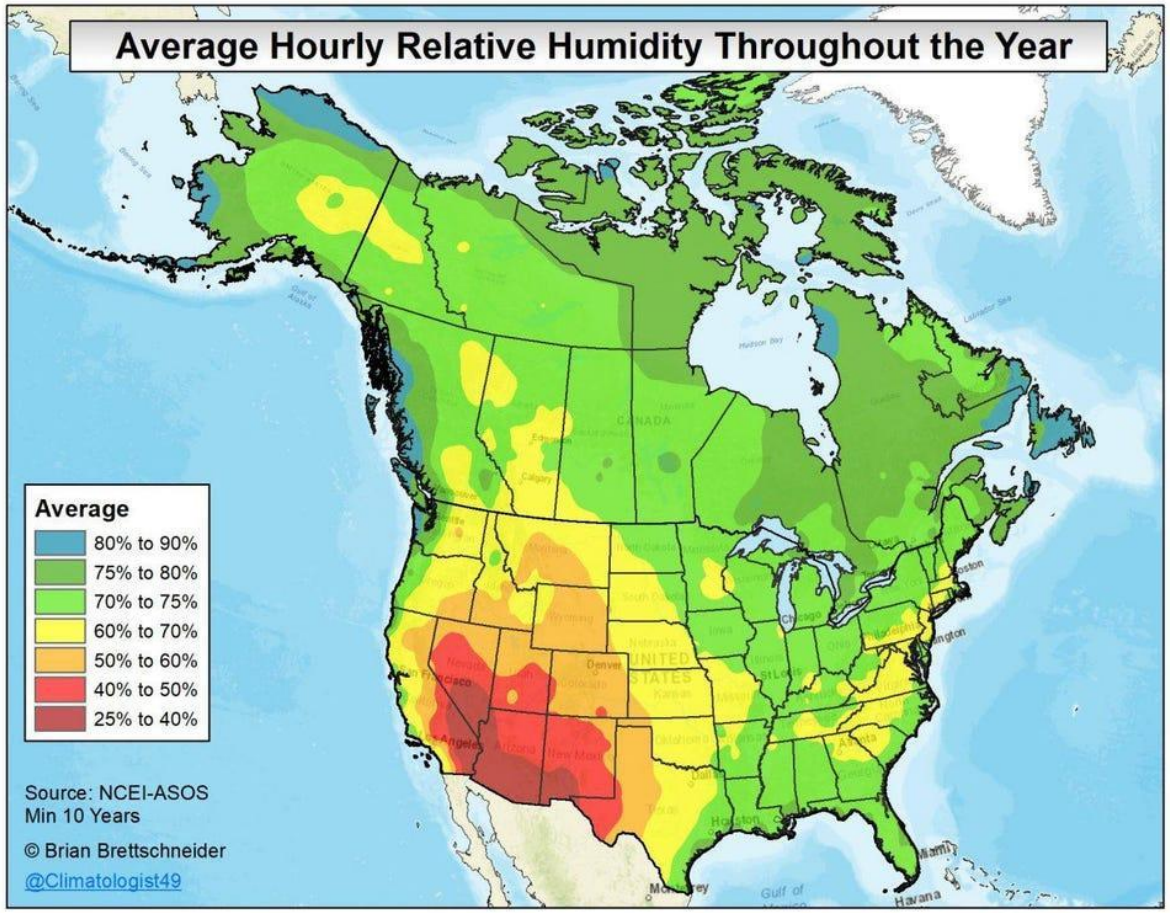
- Pre-fire season soil moisture anomalies (departure from long-term mean) help assess risk of wildfires.
- It has been noted that in arid regions, wetter soil moisture anomalies promote vegetation growth that can fuel fires. In humid regions, dry soil moisture anomalies generally precede fires (e.g., Sungmin et al., 2020).



Consecutive wet and dry soil moisture conditions promote wildfires. Normalized soil moisture anomalies at (**a**) 5 months and (**b**) 1 month before the month with the largest burned area. Grid cells are grouped with respect to long-term temperature and aridity. Median values across grid cells in each box are shown. Boxes with less than 25 grid cells are discarded and shown in gray. Black dots within the boxes denote significant anomalies at the 90%-level.

Humidity and Wildfires

- Relative Humidity (RH): The ratio of the amount of moisture in the air to the amount of moisture necessary to saturate the air at the same temperature and pressure.
- Low Humidity: Air takes moisture from the fuels: drying out vegetation.
- When RH decreases, fire behavior increases.



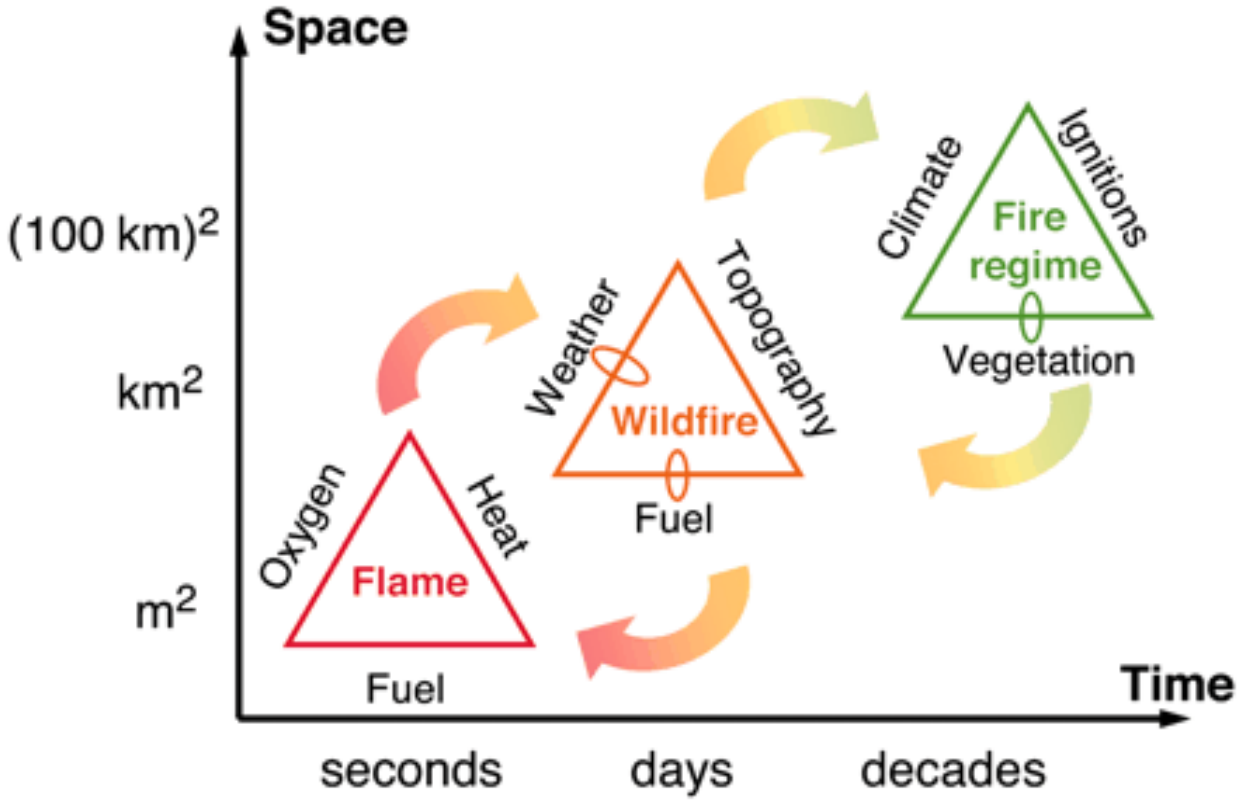
Winds and Wildfires

- Wind speeds affect wildfire spread.
- When wind speeds are high and fuels are critically dry, and the time available to prepare a more exacting prediction is limited (Alexander and Cruz 2019).

Image Credit: Mike Lewelling, National Park Service

Fire Weather

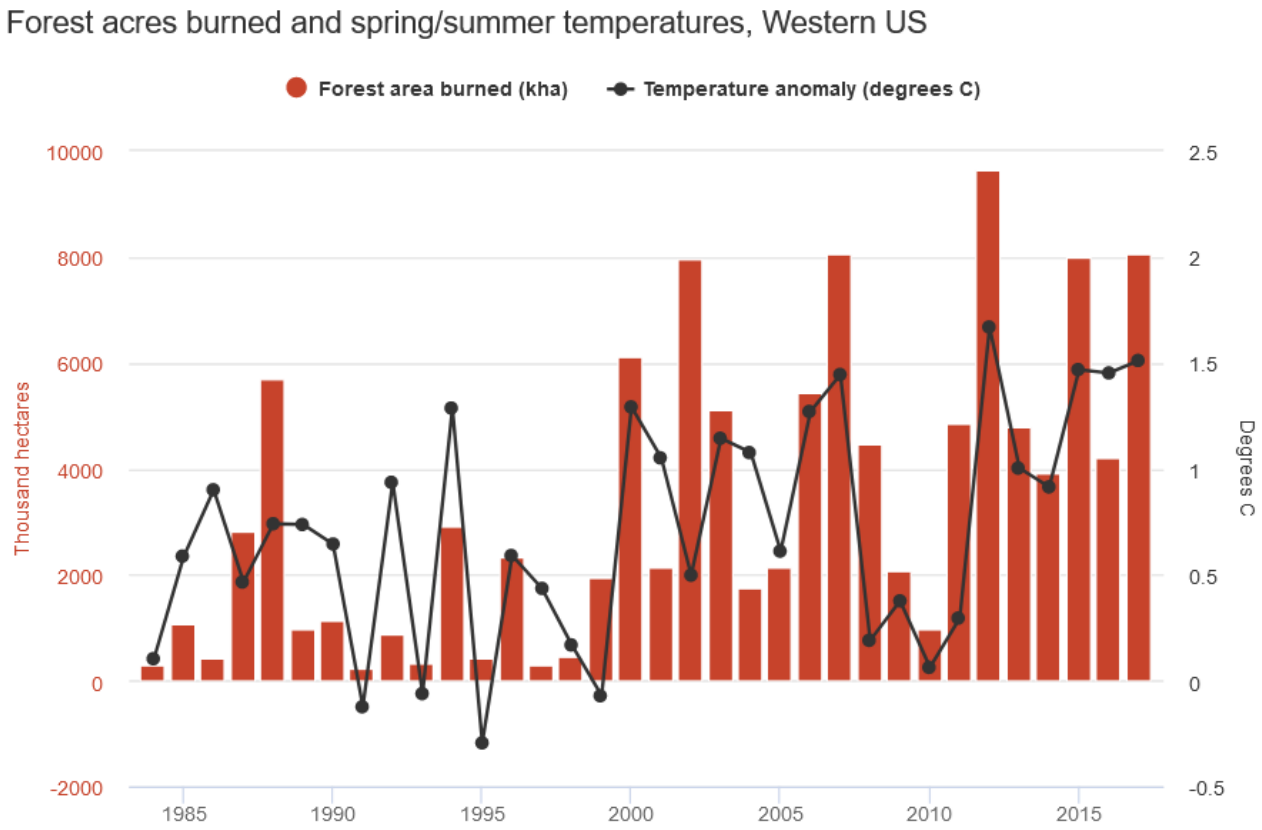
- Fire weather is a combination of temperature, precipitation, winds, and humidity conducive to high potential of fire activities.
- Climate conditions influence fire weather, soil moisture, and vegetation productivity, affecting fire activities.



Moritz et al. (2005): Controls on fire at different scales. Dominant factors that influence fire at the scale of a flame, a single wildfire, and a fire regime.

Climate Change and Wildfires

- Climate change has already led to an increase in wildfire season length, wildfire frequency, and burned area, especially in North America.
- Earlier spring melting and reduced snowpack.
- Increased frequency and severity of droughts.
- Longer wildfire seasons.



Red bars show western US forest area burned (in thousand hectares) using data provided to Carbon Brief by Prof John Abatzoglou, updated from the data used in Abatzoglou and Williams 2016. Black line shows March-August temperature anomalies relative to a 1961-1990 baseline period for the US west of 102 degrees longitude using data from NOAA; Chart by Carbon Brief using Highcharts.

Pre-Fire Conditions: Landscape and Vegetation

Pre-Fire Conditions

Climate and Hydrology

- Precipitation
- Temperature
- Soil Moisture
- Humidity
- Winds

Landscape and Vegetation

- Topography
  - Elevation, slope, aspect, features
- Vegetation Conditions
  - Type, extent, health, moisture content, structure

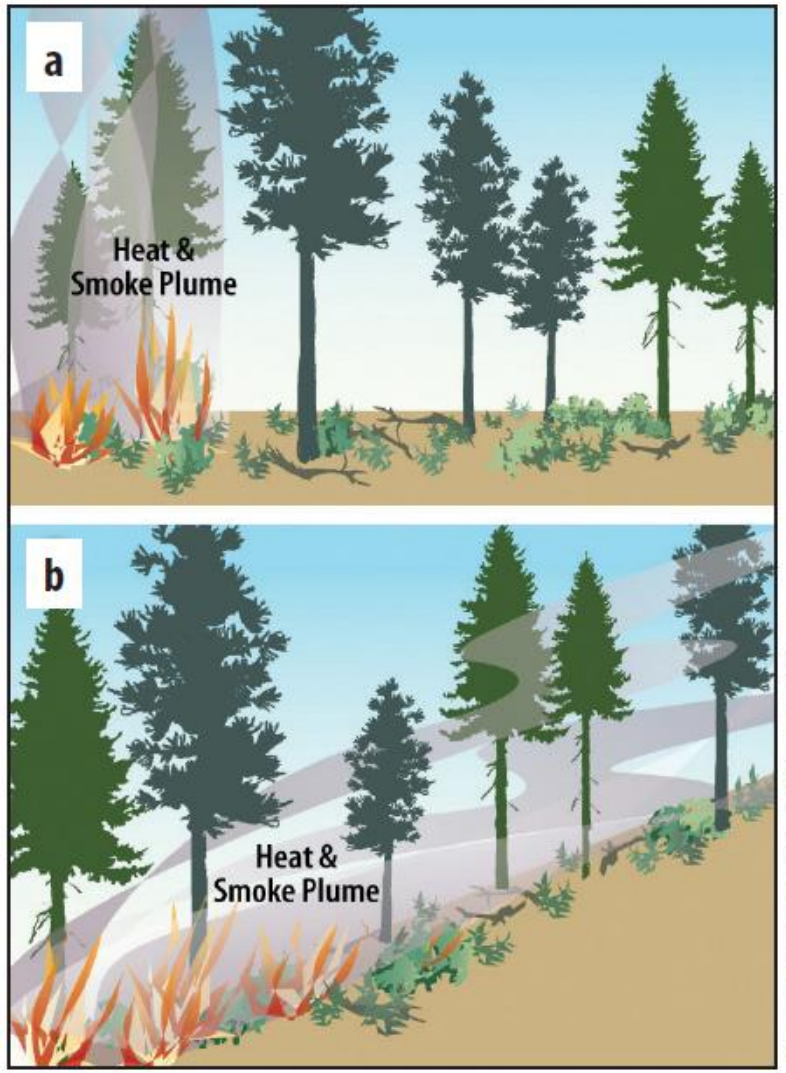
Topography: Elevation

- Elevation Impacts:
  - Amount and timing of precipitation
  - Wind exposure
  - Seasonal drying of fuels
  - Lightning strikes
- Examples: Lower elevations tend to dry out faster, thus they experience increased fire spread.

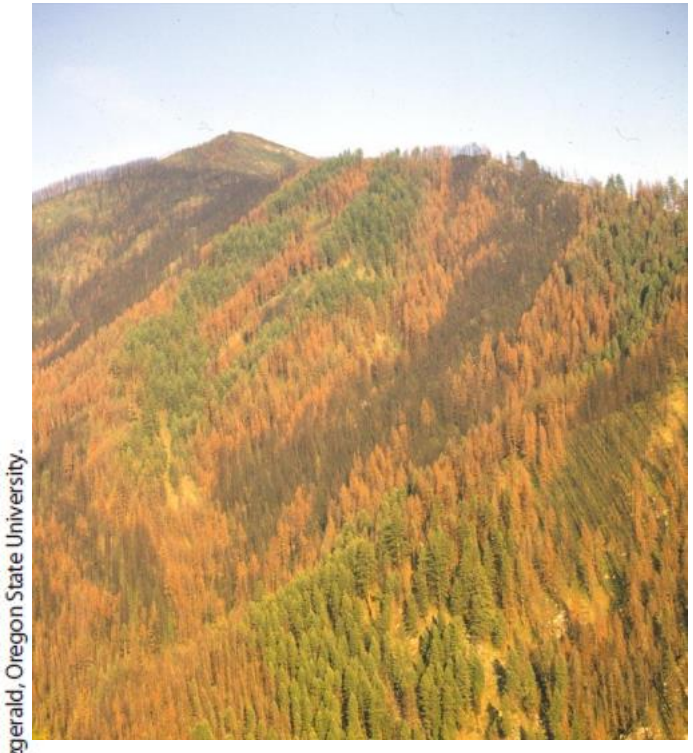
This perspective view, combining a Landsat image with SRTM topography, shows topography. Image Credit: NASA

Topography: Slope

- Increased Slope = Faster Fire Spread
- Slope Position: Where does the fire have room to move?
  - Fires that start at the bottom of the slope have greater area to spread.
  - As heat rises in front of the fire, it more effectively preheats and dries upslope fuels, making for more rapid combustion.



Fires spread more quickly uphill. Image Credit: Fitzgerald, Oregon State University



Stephen Fitzgerald, Oregon State University.

Uphill fire scars. Image Credit: University of Arizona

Topography: Aspect

- Direction of the Slope
  - Solar Radiation
    - Example: South-facing slopes have higher solar radiation and drier fuels.
  - Vegetation Type
    - Example: South and West facing slopes have less vegetation.

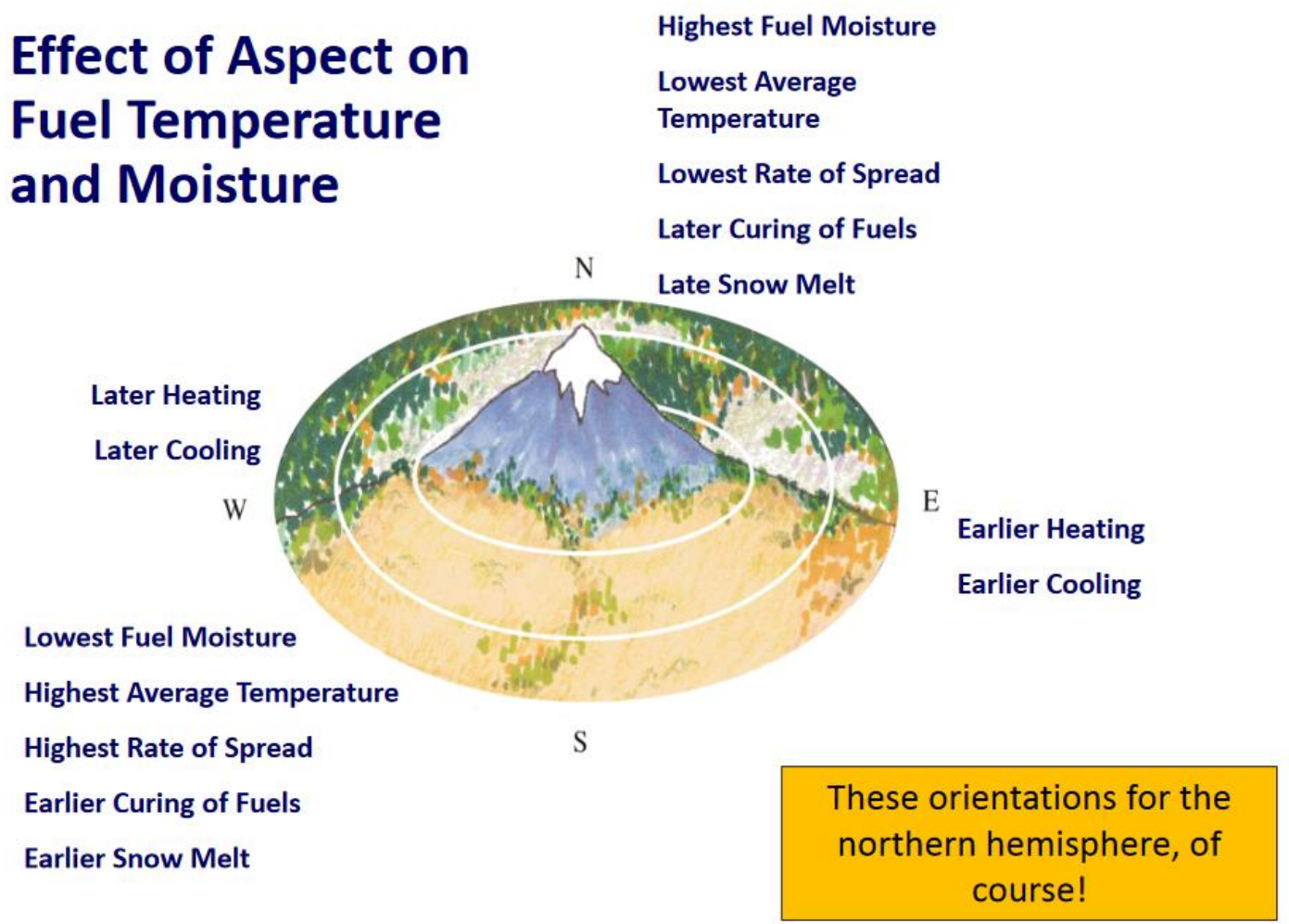
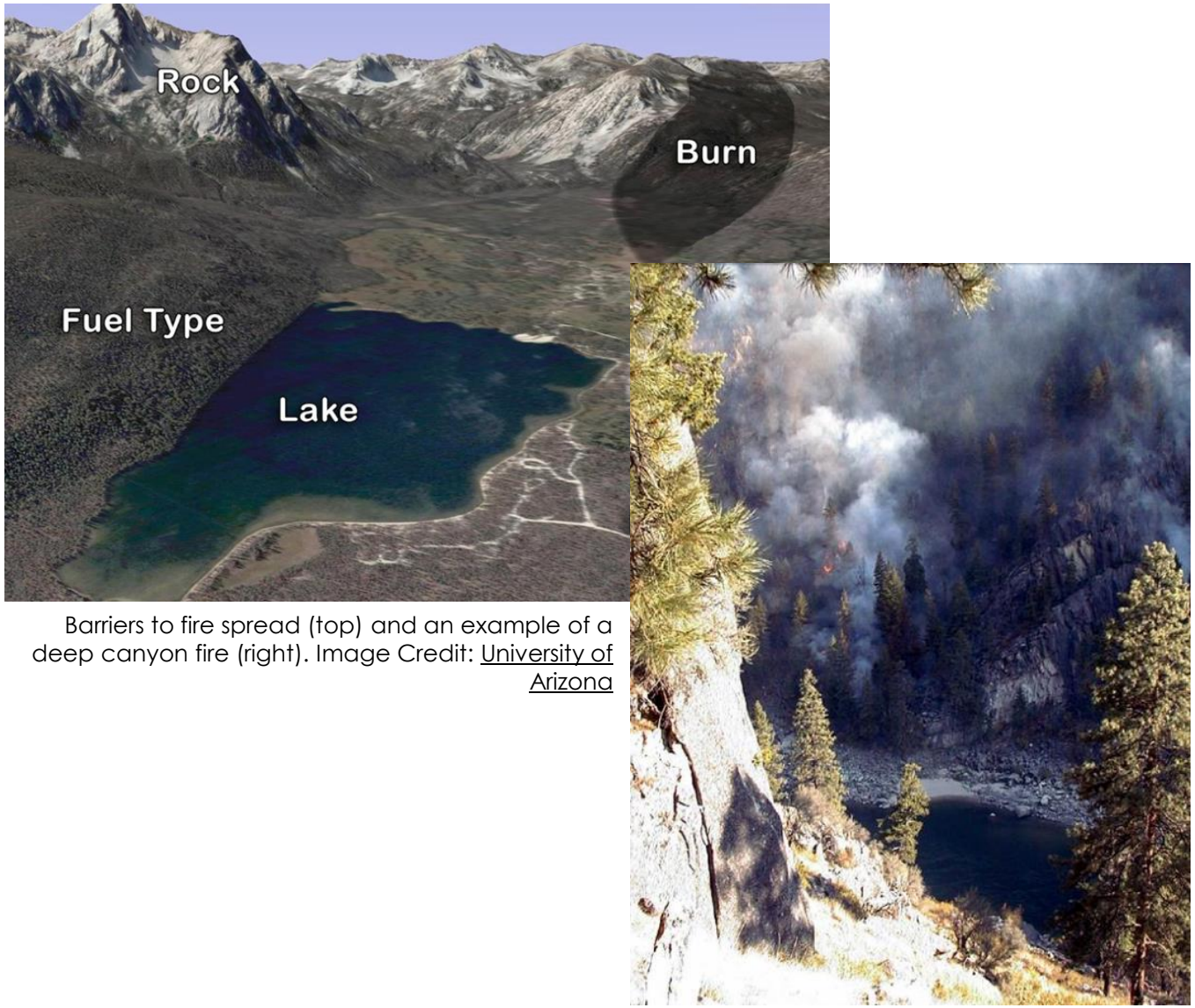


Image Credit: University of Arizona

Topographic Features

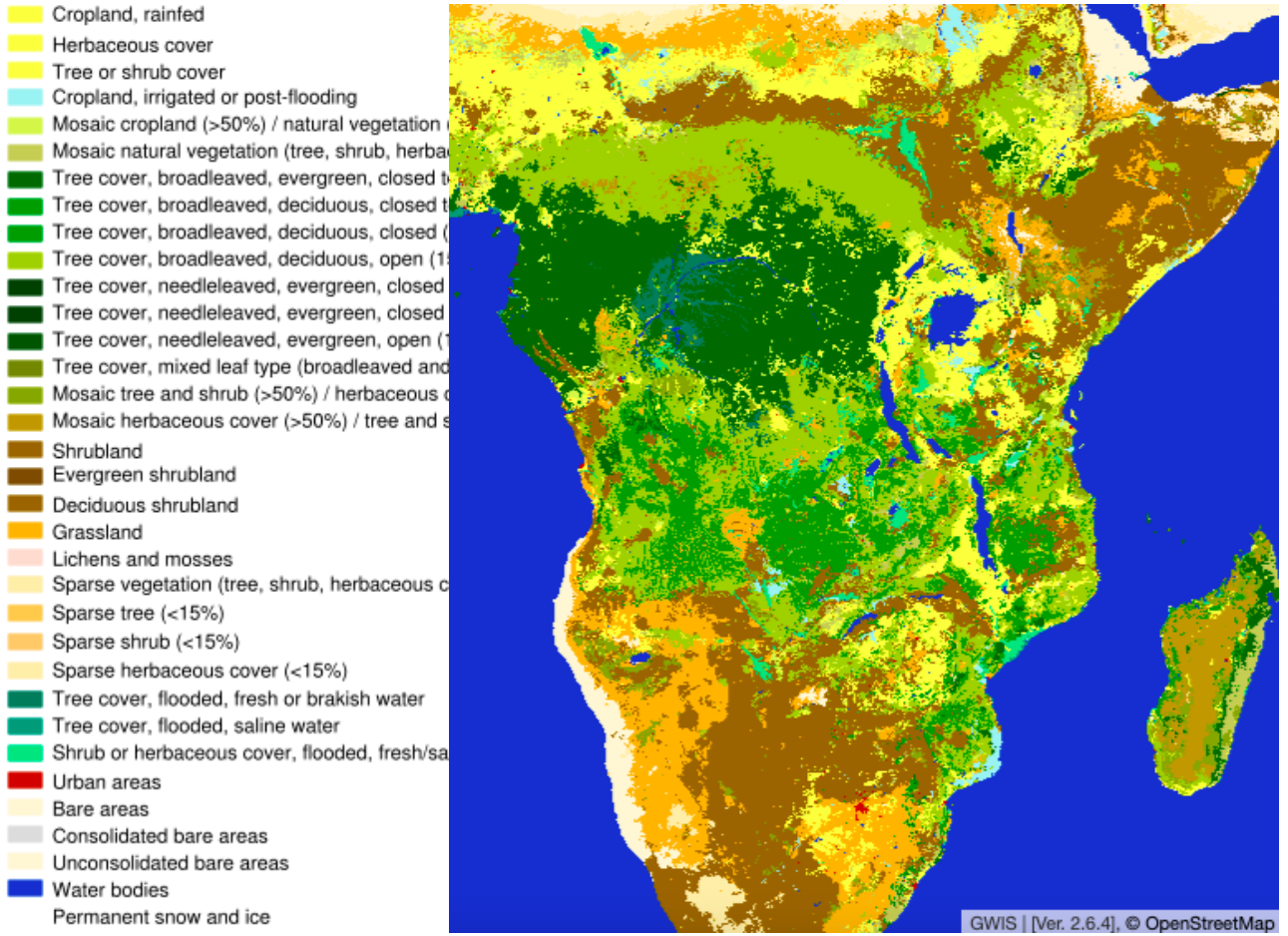
- Alter Fire Behavior
  - Increase Spread
    - Narrow and wide canyons increase wind and fire spread.
  - Decrease Spread
    - Rock outcroppings, rivers, lakes, etc. can act as barriers to spread.



Barriers to fire spread (top) and an example of a deep canyon fire (right). Image Credit: University of Arizona

Vegetation Type and Extent

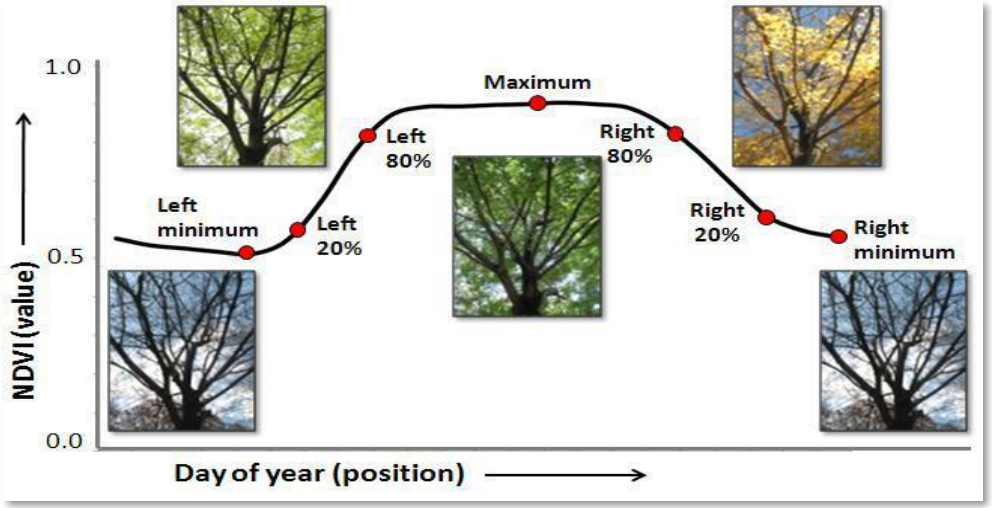
- Land Cover Classification: Grouping of spectrally similar pixels in remote sensing imagery based on land cover class (forest, shrubland, agriculture, etc.).
- Fuel behavior varies with vegetation type.
  - Example: Forests contain more biomass to sustain burning, but shrubland vegetations often ignites easier.
- ARSET Trainings
  - Land Cover Classification
  - Forest Mapping and Monitoring with SAR Data



Global Wildfire Information System (GWIS) land cover classification layer for Sub-Saharan Africa. Image Credit: GWIS

Vegetation Stage and Health

- Unhealthy vegetation has a higher percentage of dead branches and leaves, providing easier-to-burn fuel for fires. The stage of vegetation also dictates the amount and type of fuel available for fires.
- Vegetation Stage – Land Surface Phenology (LSP):
  - Use of satellites and sensors to track seasonal patterns of variation in vegetated land surfaces
  - ARSET Phenology Training
- Monitoring Stage and Health – Indices:
  - NDVI - Normalized Difference Vegetation Index
  - EVI - Enhanced Vegetation Index
  - SAVI - Soil-Adjusted Vegetation Index
  - Vegetation Index Anomalies

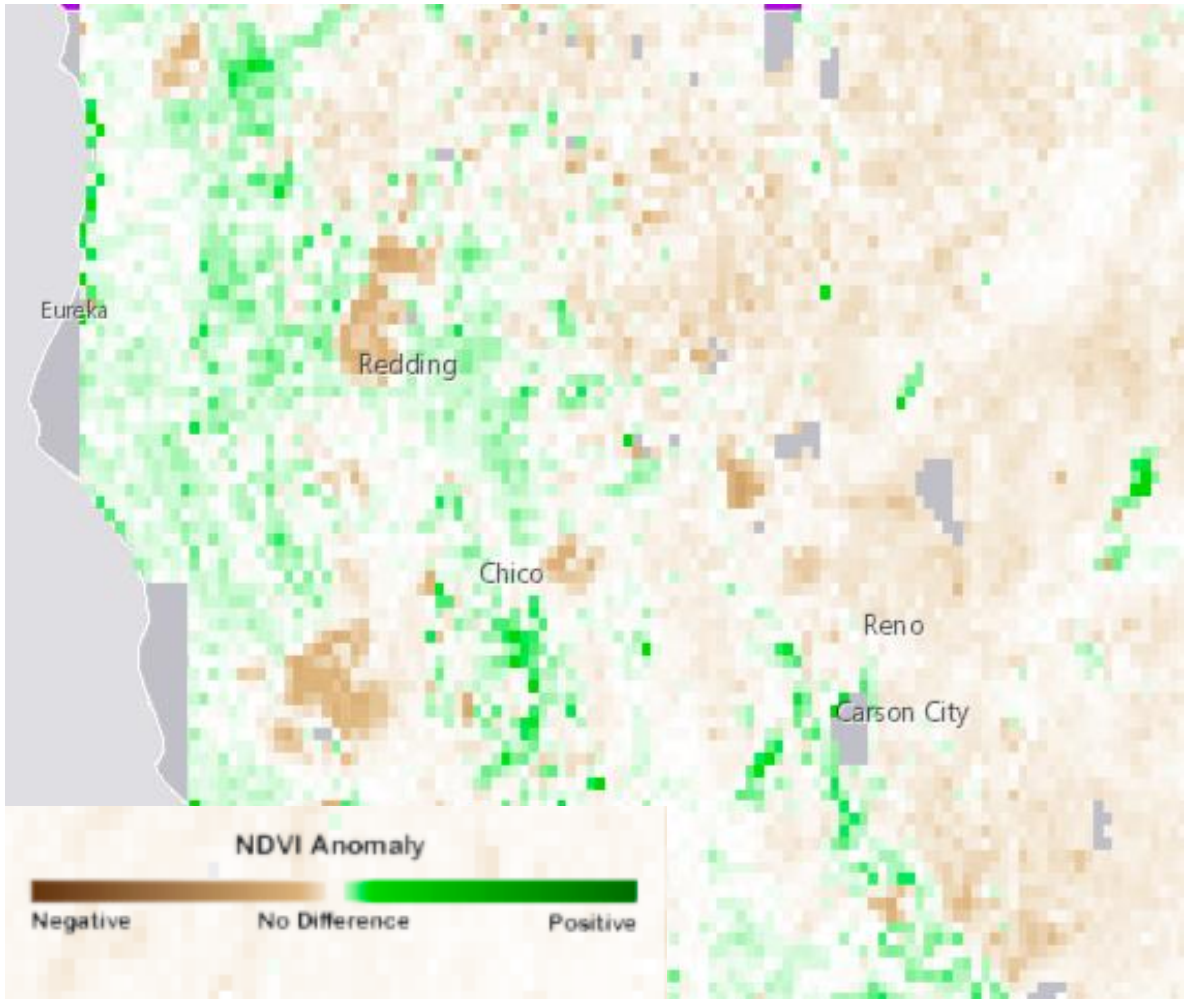


North America NDVI Images in Winter and Summer.

Image Credits: Montana Space Grant Consortium

Vegetation Index Anomalies

- Anomalies are a departure of a vegetation index from the long-term average and are generated by subtracting the long-term mean from the current value for that month of the year for each grid cell.
- These departures can indicate changes in vegetation health (due to drought, high temperatures, etc.).



VIIRS NDVI anomaly product for July 3, 2020 shows negative anomalies in northern California prior to August fires, indicating potential impacts to vegetation from dryness and high temperature.
Image Credit: Crop Monitor

Vegetation Moisture

- Low moisture vegetation (drier fuel) is more likely to ignite and contribute to the spread of fire.
- 75% of year-to-year variations in burned area can be explained by fuel aridity (Abatzoglou and Williams, 2016).
- Vegetation Indices:
  - Normalized Difference Water Index (NDWI), Normalized Dry Matter Index (NDMI), Evaporative Stress Index (ESI)
- Radar remote sensing of vegetation moisture.

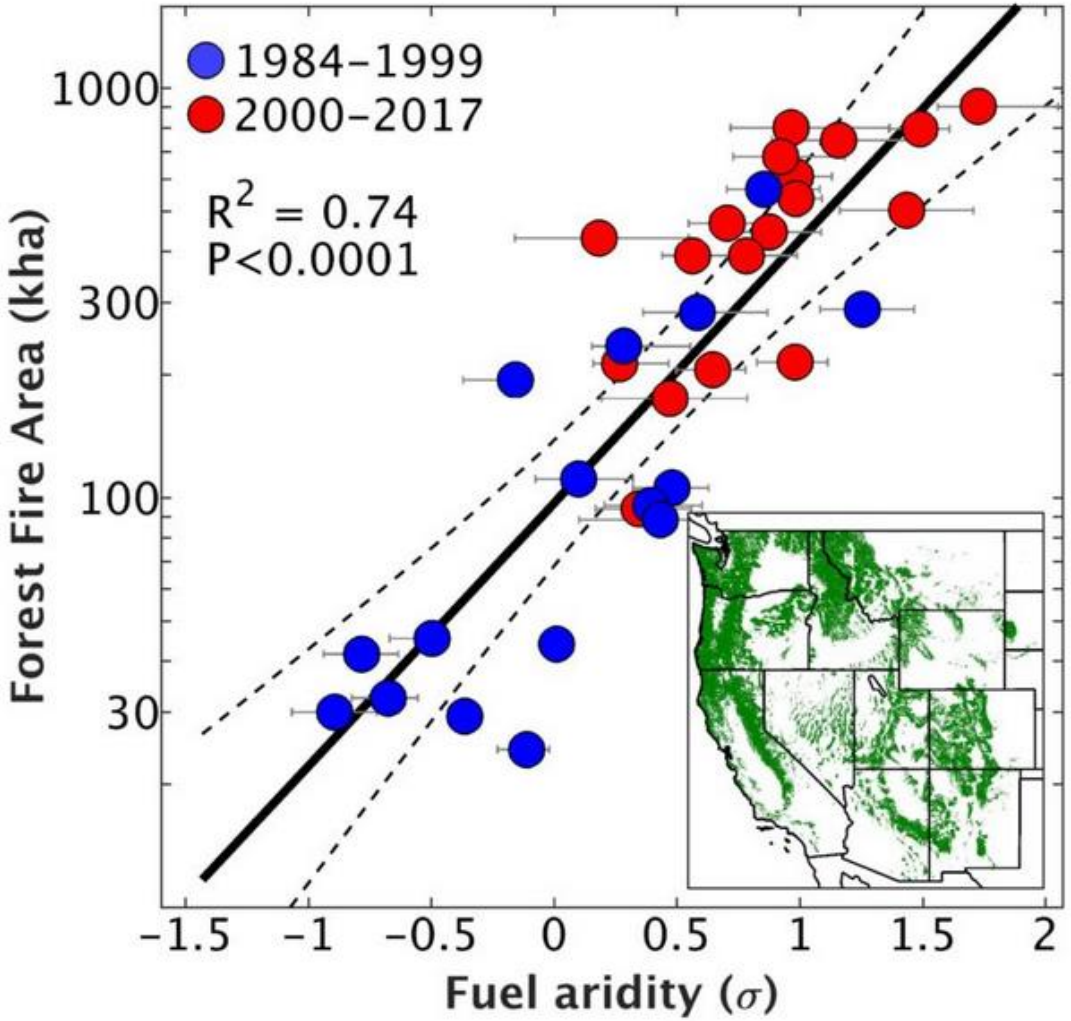
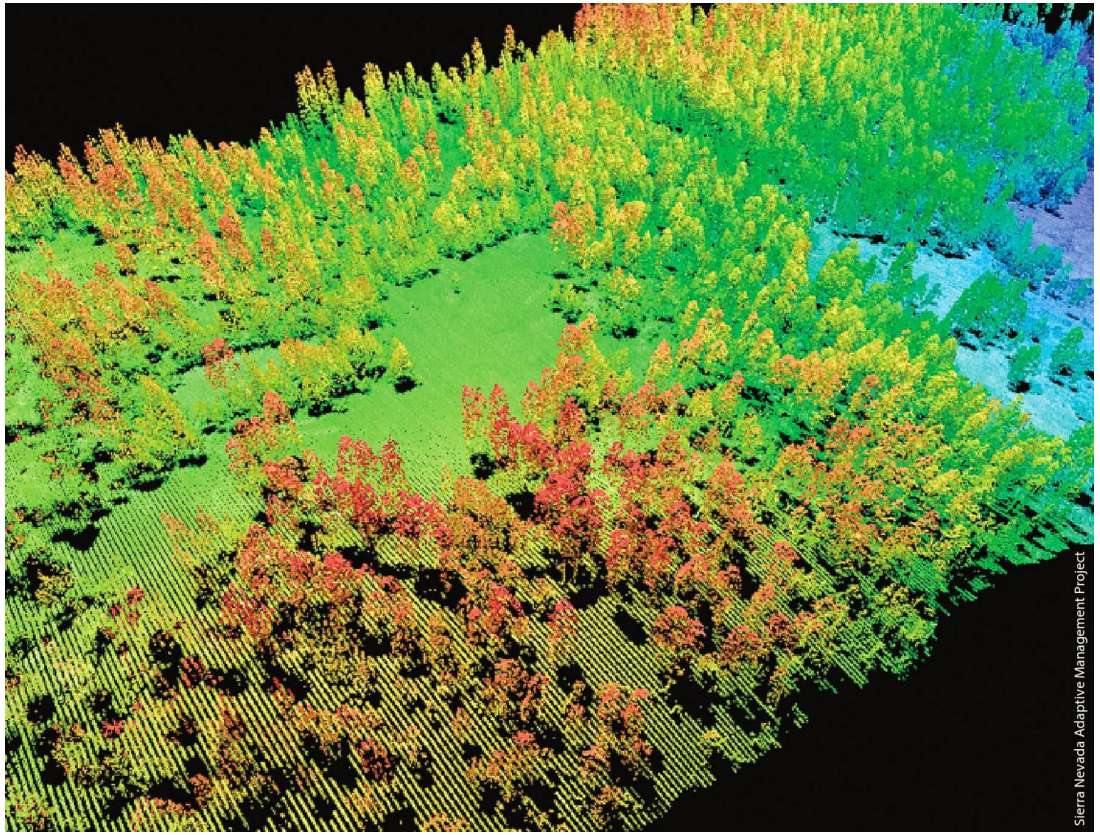


Image Credit: Abatzoglou and Williams 2016

Vegetation Structure

- Canopy Height and Density
  - The vertical and horizontal distribution of plant material in a forested ecosystem is a driver of fire spread.
- Canopy structure influences fire dynamics directly as fuel and indirectly through its influence on other variables in the fire environment, like fuel moisture below the canopy.
- Synthetic Aperture Radar (SAR) and Airborne Light Detection and Ranging (LiDAR) data can assess canopy structure over large areas.



Lidar points show trees in the Sierra National Forest, where much of the research on remote sensing has occurred. Image Credit: Keley and Tommaso, 2015

Canopy Height

- Forest Stand Height (FSH): Average height of trees in a forest stand
  - Indicator of age of forest and structure, especially the amount of Above Ground Biomass (ABG)
  - Can be used pre-fire to assess initial fuel availability

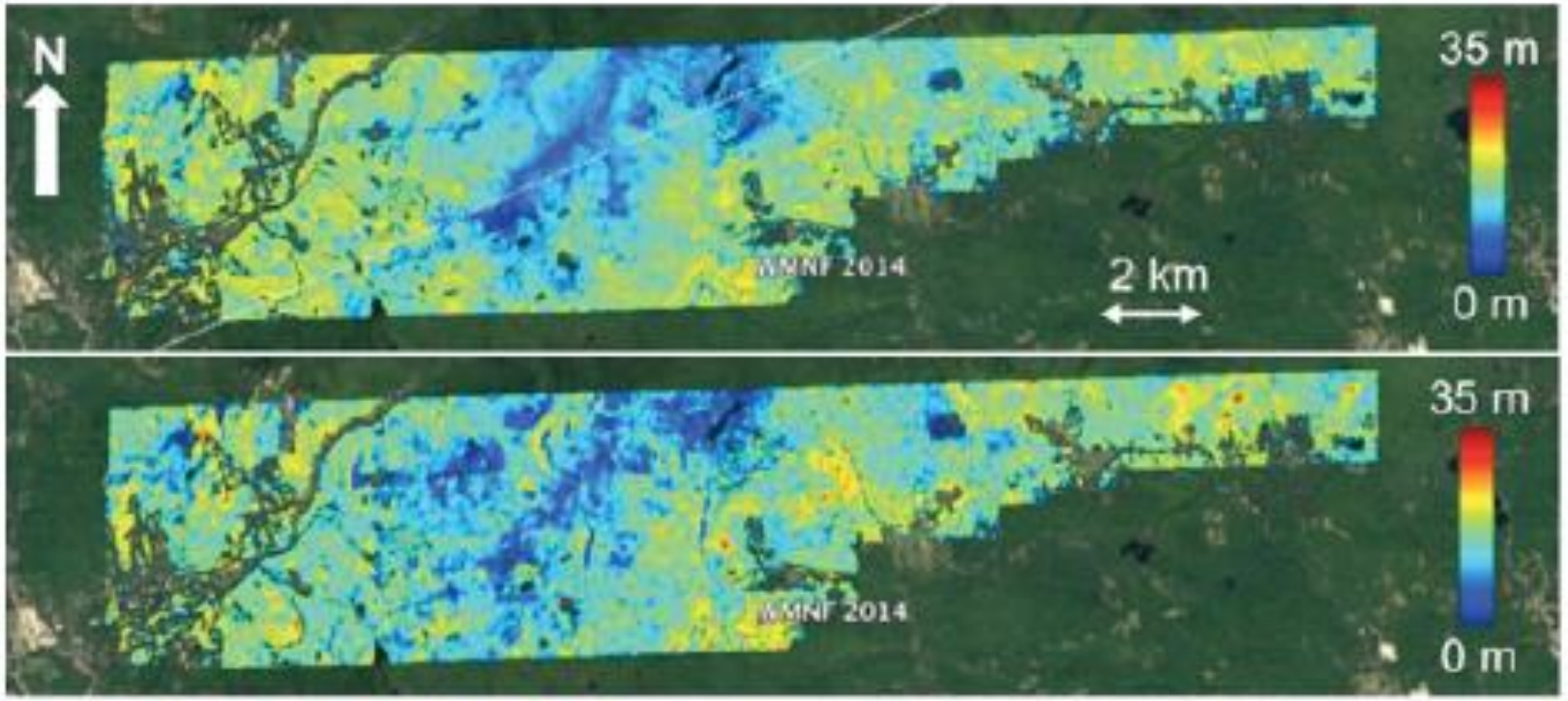
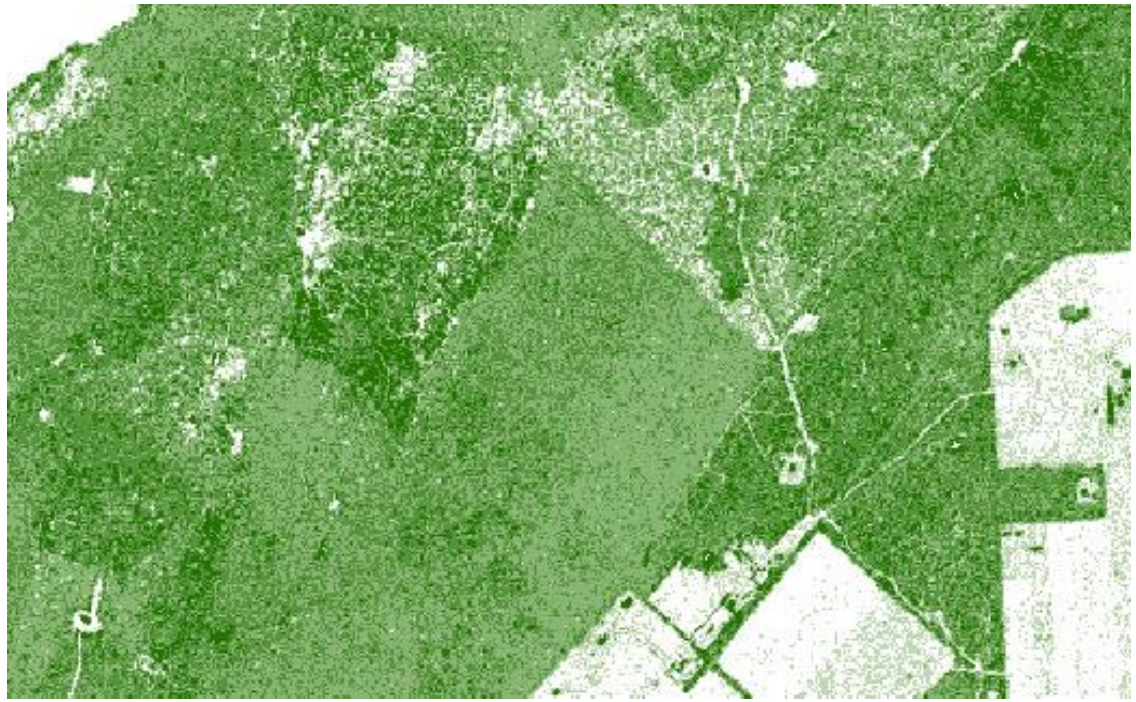


Image Credit: Li et al 2019

Canopy Density

- Characteristic structure elements that can influence fire behavior:
  - Openings
  - Single trees
  - Clumps of trees with adjacent or interlocking crowns
- Once areas with dense vegetation catch fire, the fire is more likely to spread given access to high fuel load.
- Airborne Light Detection and Ranging (LiDAR) data can assess canopy structure over a large area.



Canopy density, where darker green indicates increasing density.
Image Credit: ArcGIS

Fire Danger

2010 FAO Wildland Fire Management Terminology

Fire Danger: "A general term used to express an assessment of both fixed and variable factors of the fire environment that determine the ease of ignition, rate of spread, difficulty of control, and fire impact."

Fire Danger Rating: "A component of a fire management system that integrates the effects of selected fire danger factors into one or more qualitative indices of current protection needs."

Credit: Dr. Veerachai Tanpipat
ASEAN Wildland Fire Special Research Unit

Fire Danger

- In practice, fire danger is about:
  - **Topography**: Fires spread faster uphill. Fuels are drier on sun-facing slopes.
  - **Fuels**: Fire ignitions and behavior depend on the amount, structure, and condition of vegetation.
  - **Weather**: Weather controls fuel moisture and fire spread.

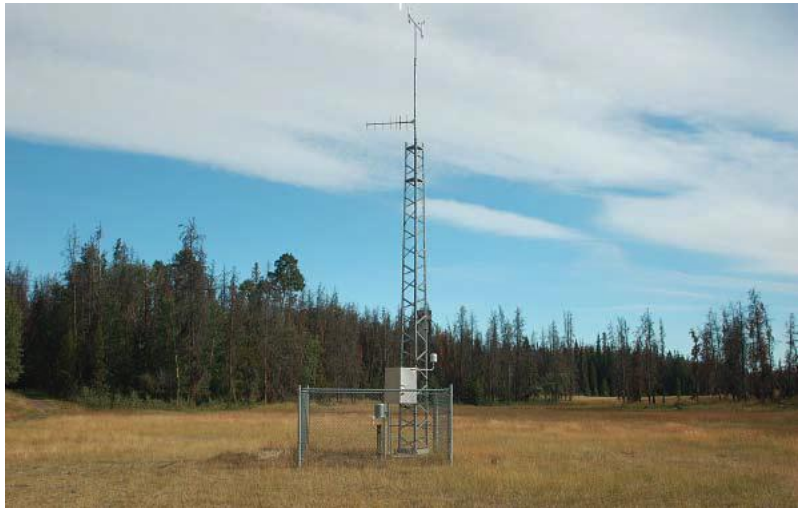
- Fire danger is distinct from **fire threat** (which includes negative impacts) or **fire occurrence prediction** (which includes sources of ignition).

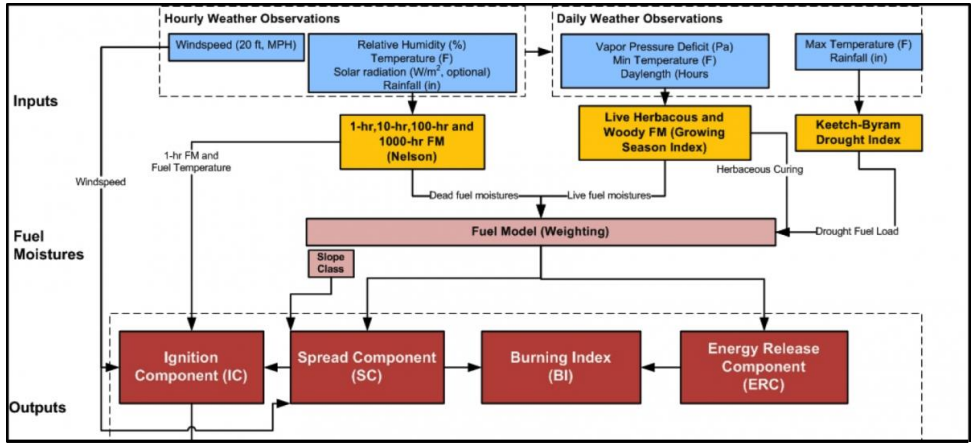
August 2007 experimental savannah fire on flat terrain in Kruger National Park, South Africa (Wooster et al., 2011, *ACP*)

October 2014 experimental coniferous fire on complex terrain in Banff National Park, Canada (Coogan et al., 2020, *CJFR*)

Fire Danger Rating Systems can be Simple or Complicated

- For example:
  - **Crossover Rule of Thumb:** Extreme fire behavior is possible when 2m air temperature (in °C) is greater than relative humidity.
  - **Nesterov Index:** Today's index depends on the temperature, dew point, and number of days since rain.
  - **2016 US National Fire Danger Rating System:** Burning Index depends on temperature, humidity, precipitation, wind speed, solar radiation, topography, and the choice from 4 fuel types.
- All are useful and can be combined with other data.

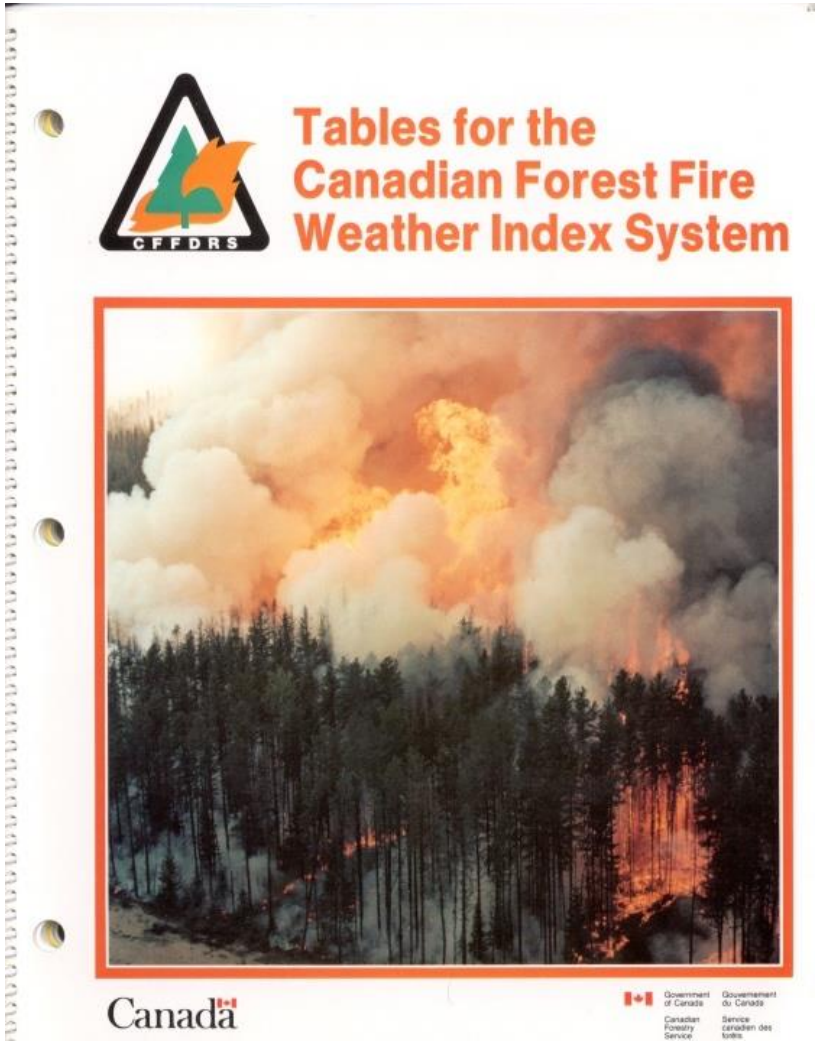




Structure of the US National Fire Danger Rating System

The Canadian Fire Weather Index (FWI) System

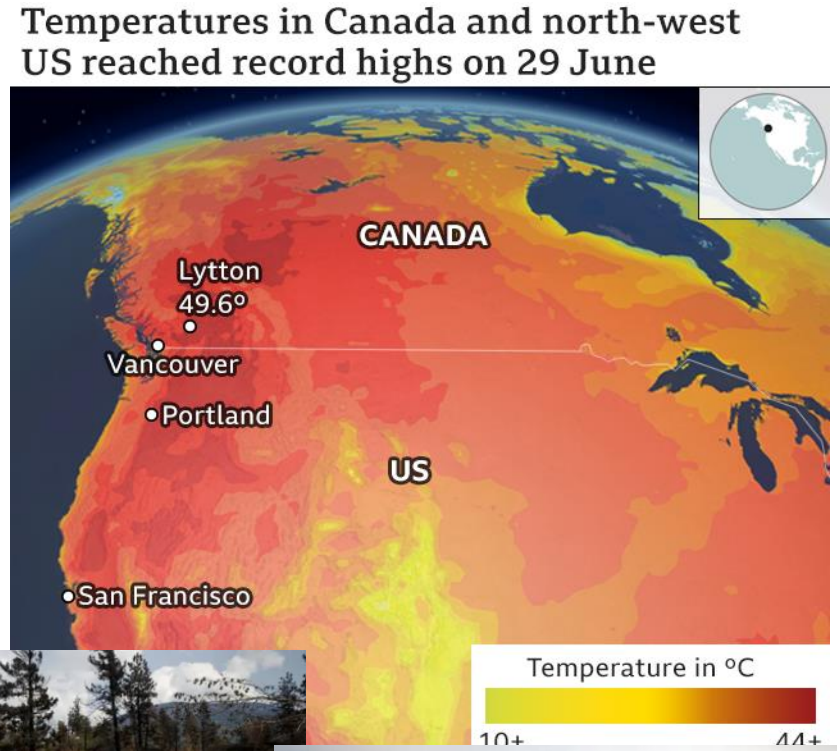
- It is an accounting system that tracks the moisture content of different fuel sizes and the potential fire behavior in a generic fuel type.
- Today's fire danger depends on past and present temperature, humidity, wind speed, and precipitation.
- It is designed to produce a maximum amount of information with a minimum amount of data.
- It is the most widely used fire danger rating system in the world.



Wildfire Case Studies and Tools

Lytton Creek Fire

- Began on June 30th, 2021
- Destroyed much of Lytton, Canada and killed two people
- Many First Nations communities affected
- One of multiple fires that occurred in British Columbia as a result of the 2021 Western North America heat wave
- High Temperatures: Highest ever recorded in Canada on June 29th, 2021
  - 49.6˚ C or 121.4 ˚ F
- High Winds: Up to 44 mph



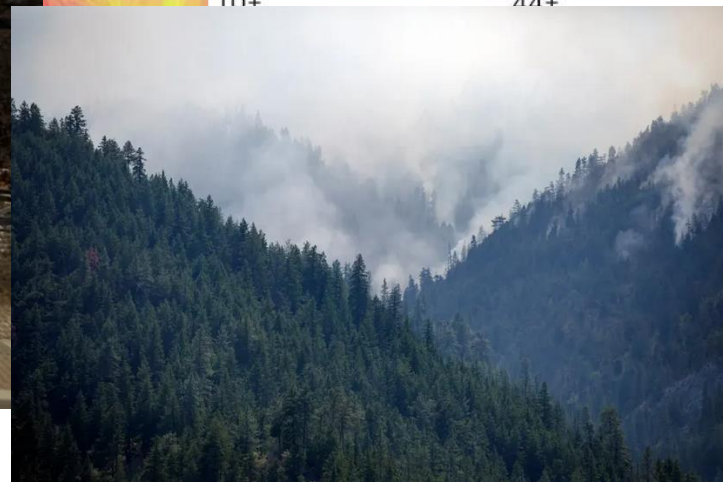
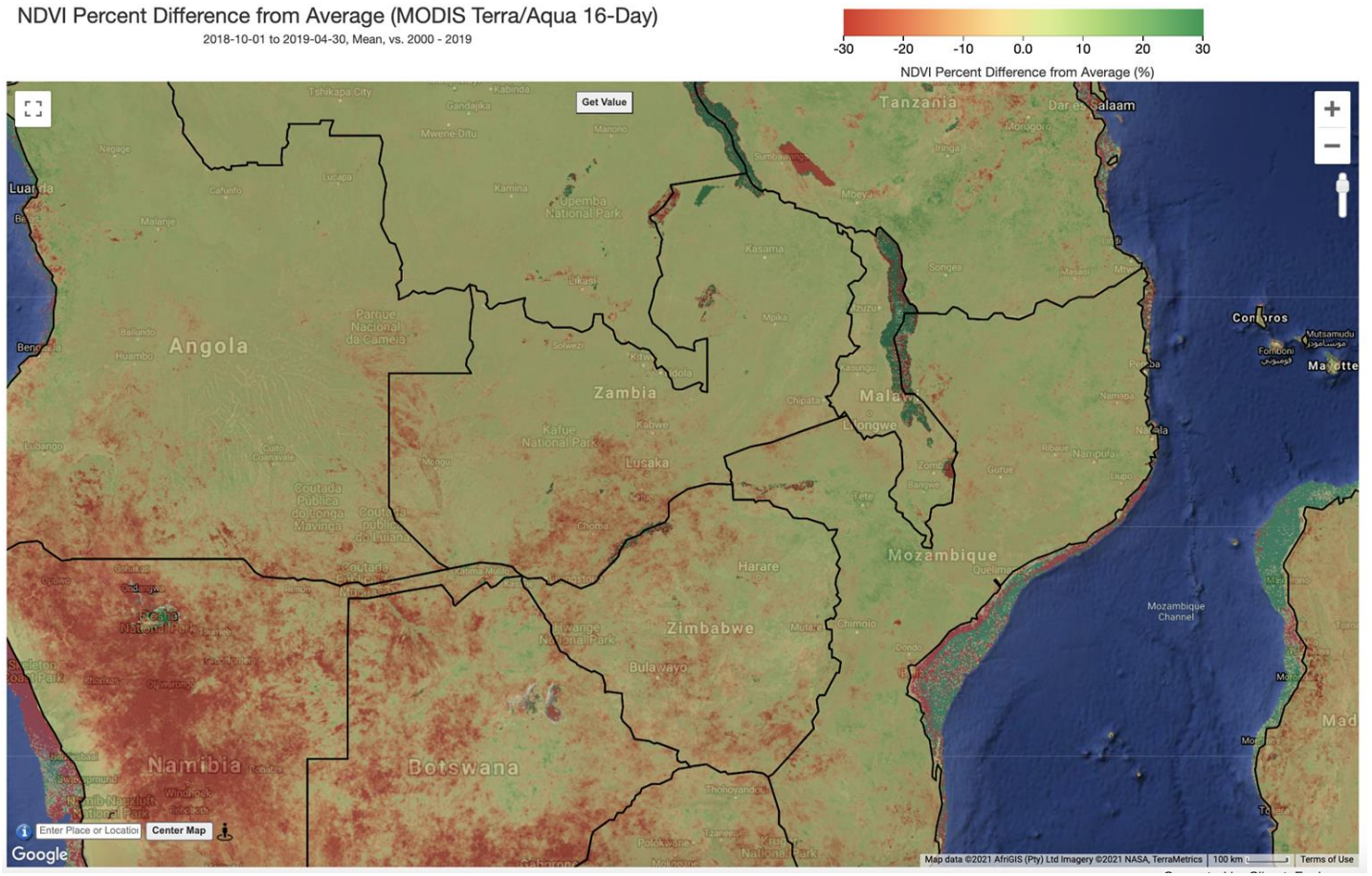


Image Credit: The Guardian

Climate Engine

http://climateengine.org/

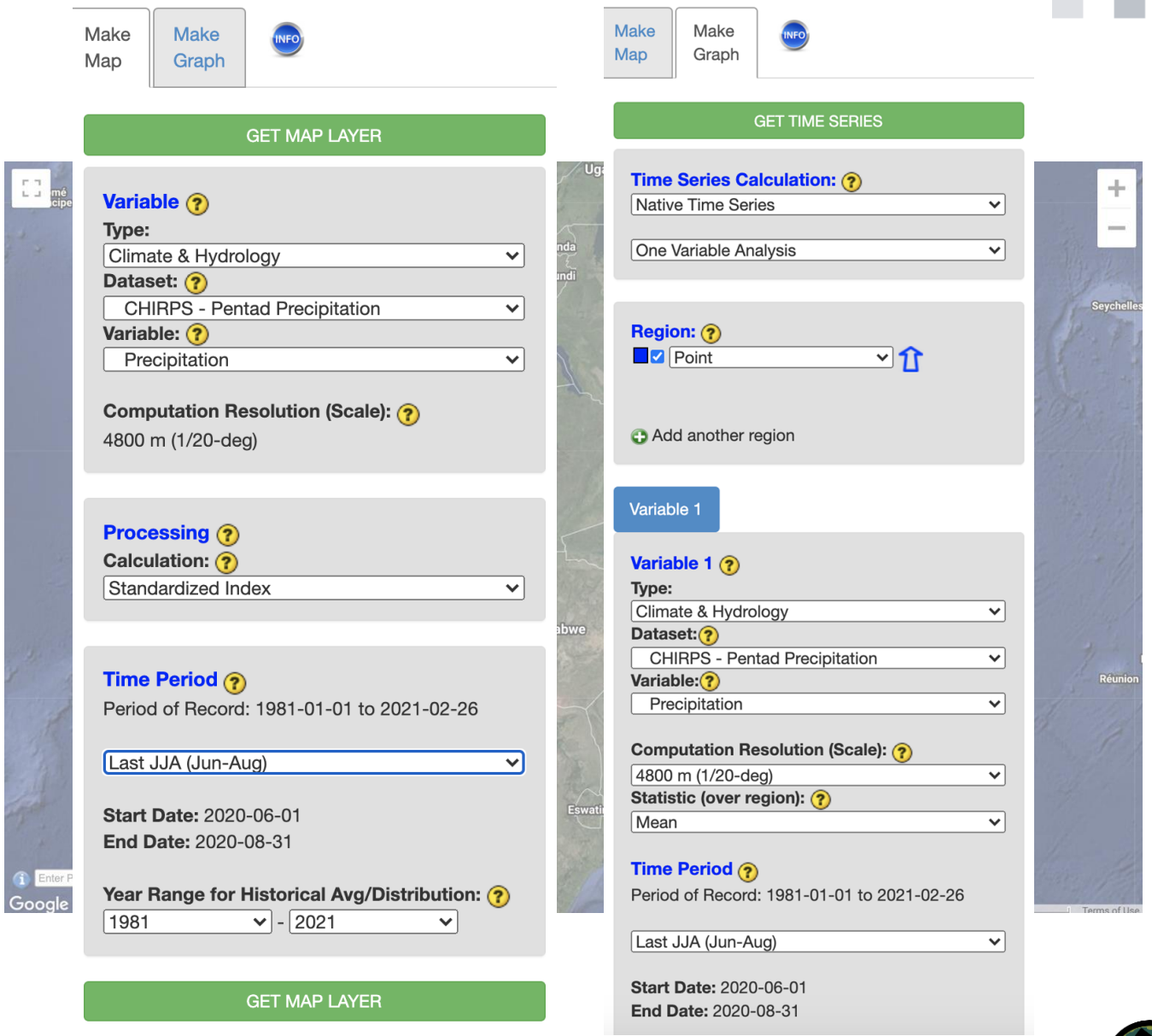
- Uses Google's Earth Engine for on-demand processing of satellite and climate data via web browser
- Time series and statistical summaries
- Downloadable results in GeoTIFF format and time series results as .csv or .xlsx format
- Share map or time series results with web URL links



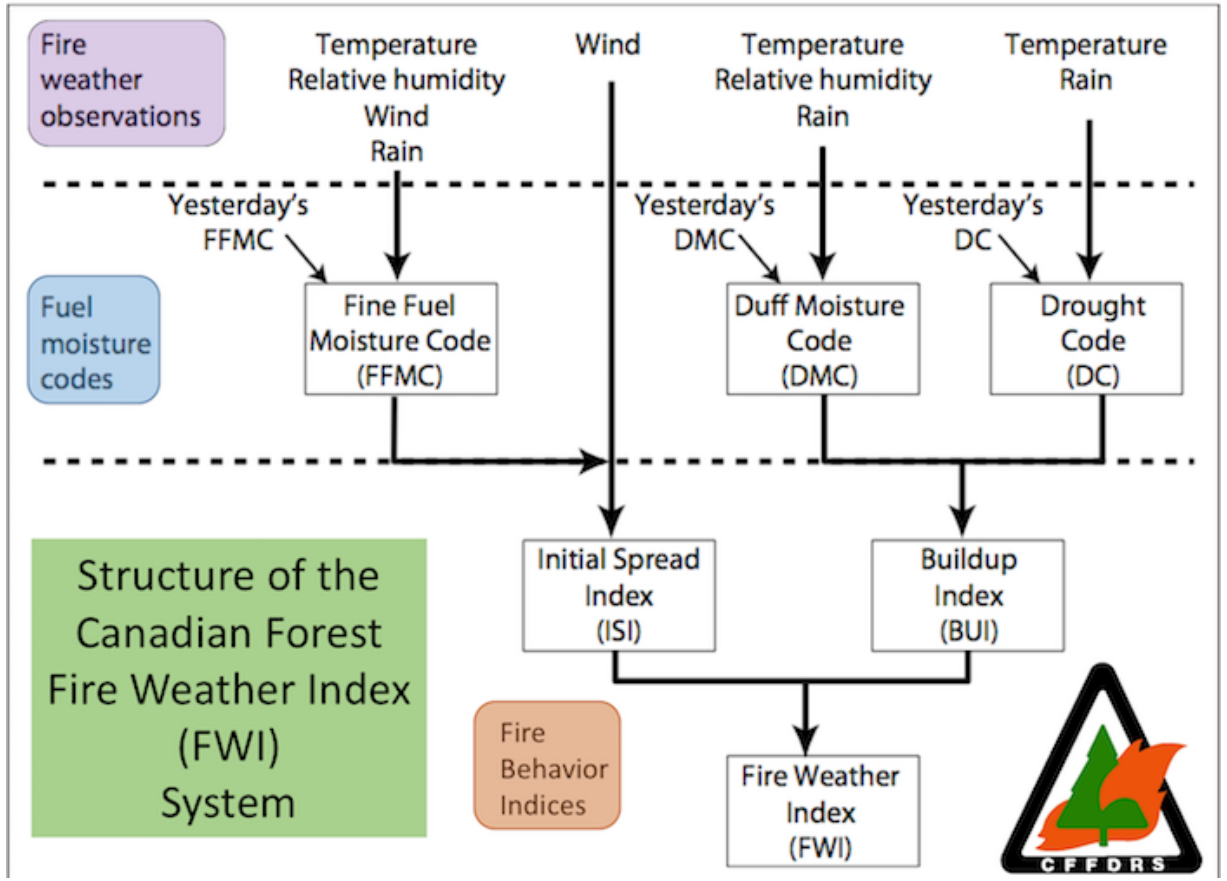
Climate Engine

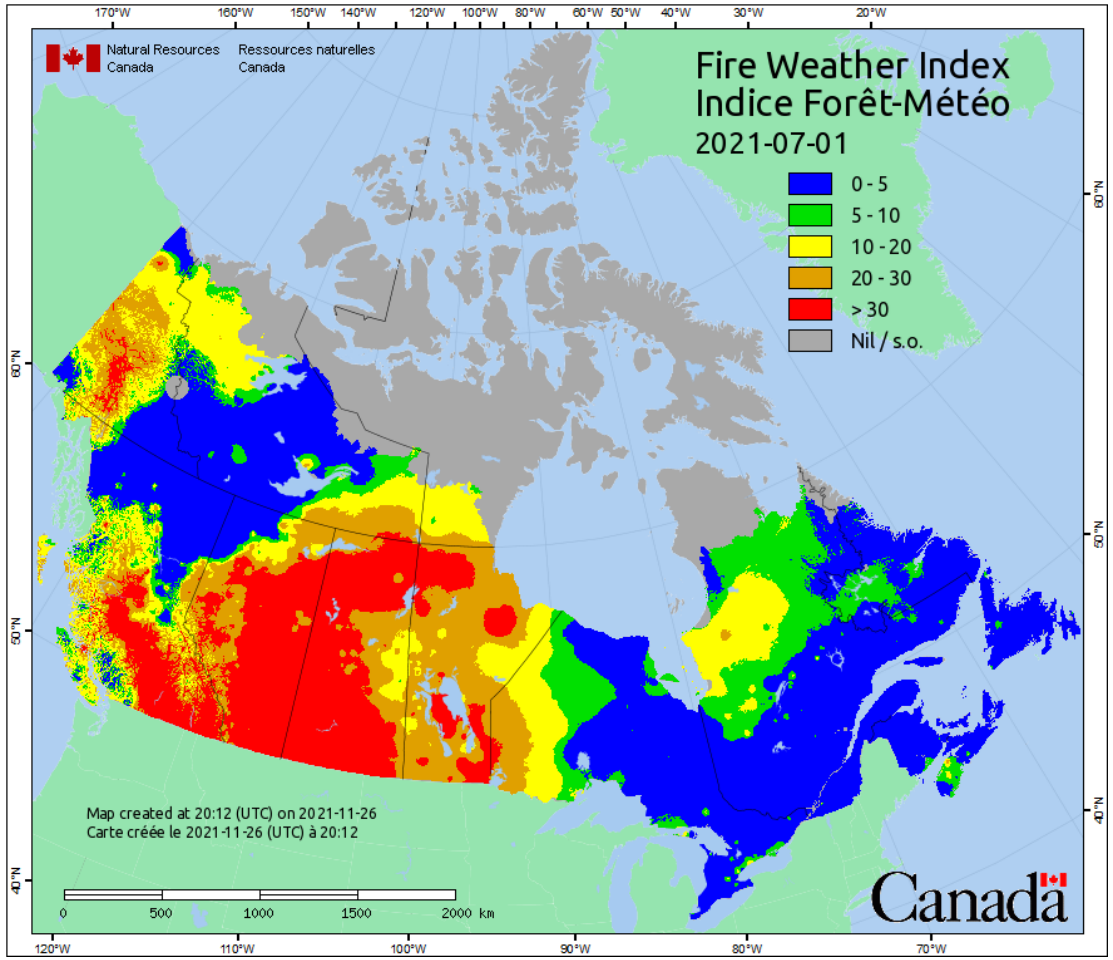
http://climateengine.org/

- Overcomes computational limitations of big data for use in real-time monitoring
- Fully customizable spatial and temporal analyses
- Comprehensive set of variables that provide early warning indicators of climate impacts such as drought, wildfire, and agricultural production

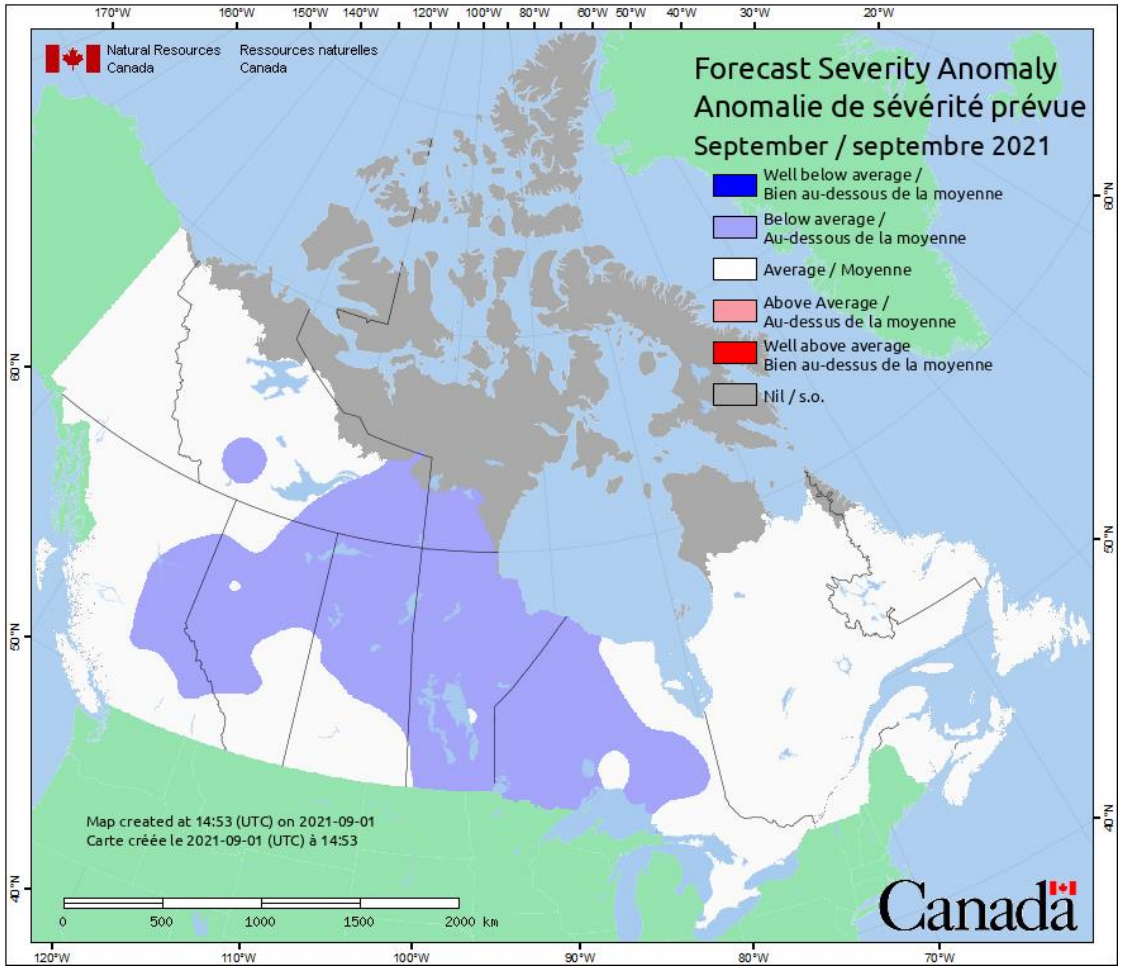


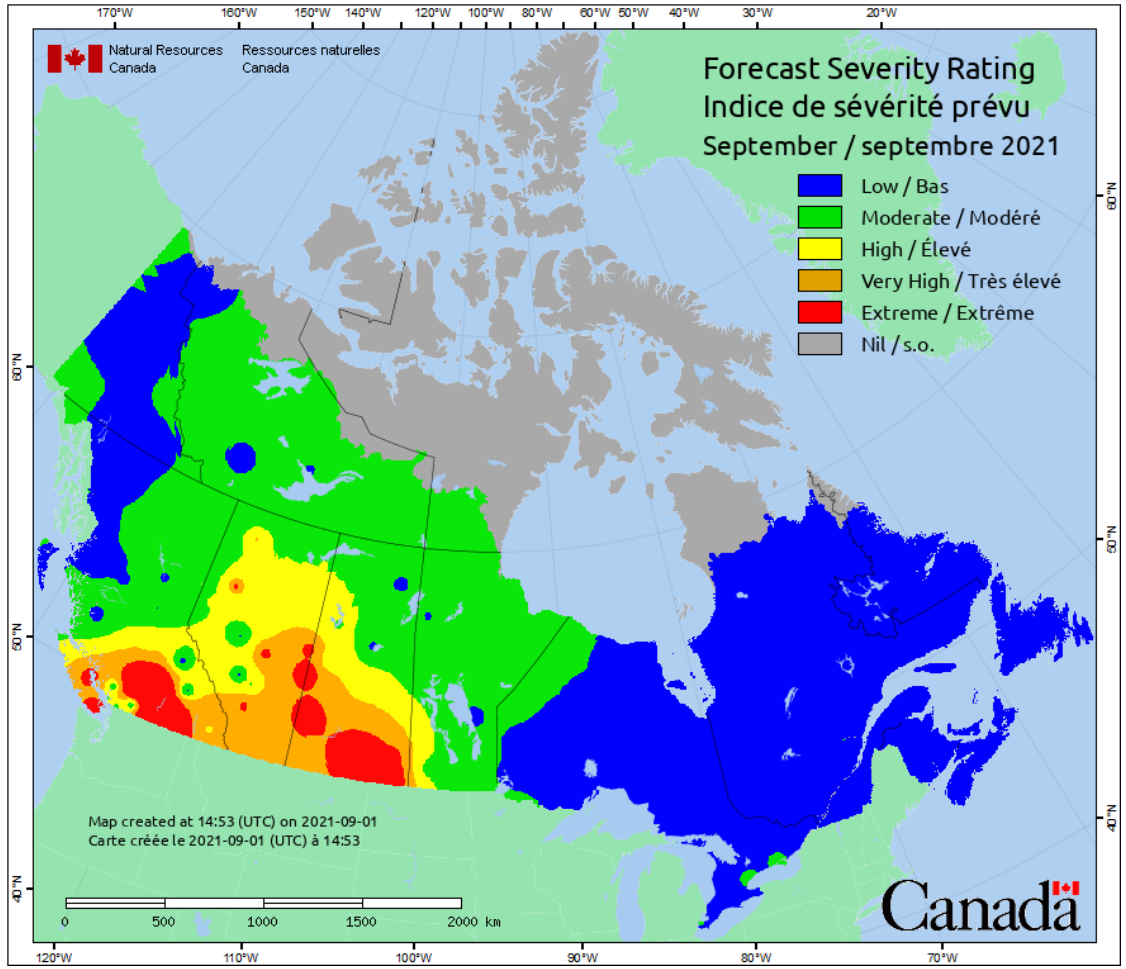
The Canadian Fire Weather Index (FWI) System





Canadian Monthly and Seasonal Forecasts

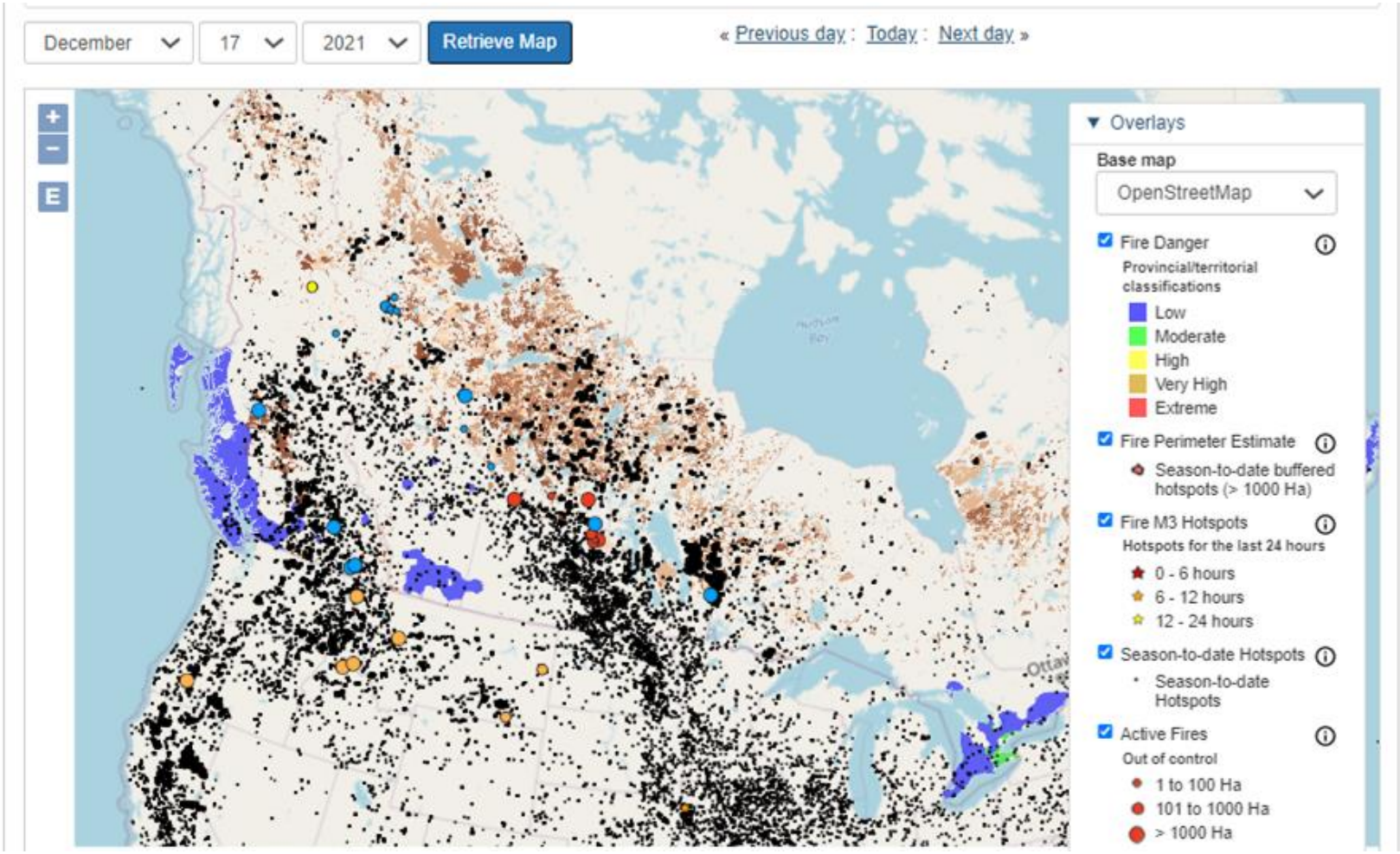




https://cwfis.cfs.nrcan.gc.ca/home

Natural Resources Canada (NRC) Interactive Map

- Display current or historical data layers for:
  - Fire Danger
  - Fire Perimeters
  - Fire Hotspots
  - Active Fires
  - Burned Area

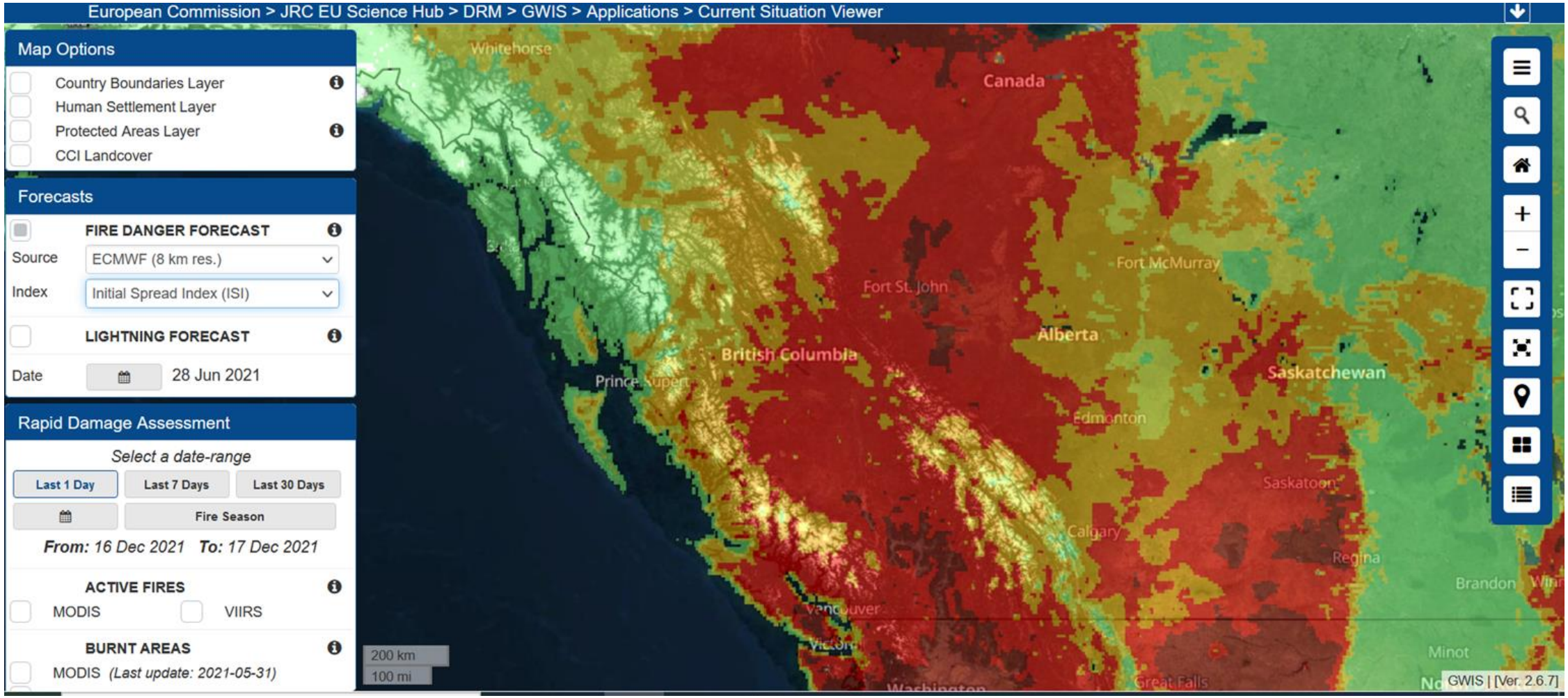


https://cwfis.cfs.nrcan.gc.ca/interactive-map

Global Wildfire Information System (GWIS)

- Joint initiative of the GEO 2017-2019 Work Programme and Copernicus, the European service that delivers near real-time data on a global level to meet user needs.
- Goal: Provide a comprehensive view and evaluation of fire regimes and fire effects at the global level
- Builds on the ongoing activities of the European Forest Fire Information System, The Global Terrestrial Observing System, the Global Observation of Forest Cover – Global Observation of Land Dynamics (GOFC-GOLD) Fire Implementation team, and the associated Regional Networks
- NASA recently funded several projects to enhance the current GWIS.
- GWIS Viewer: https://gwis.jrc.ec.europa.eu/

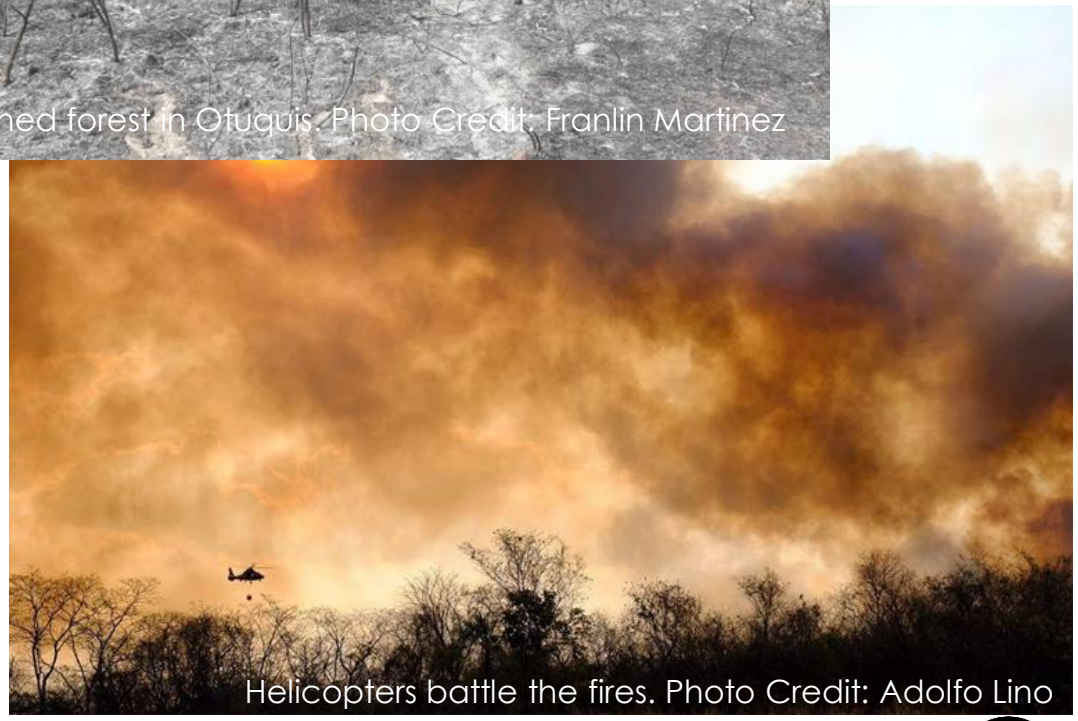
GWIS Current Situation Viewer



Bolivian Fires of 2020

- Multiple fires burning throughout August, September, and October 2020
- High temperatures and dry conditions
  - Prolonged regional drought due to climate variability (warm phase of the Atlantic Multidecadal Oscillation, AMO)
- State of emergency declared in October 2020
- Fires burning in Pantanal wetlands, in the Chiquitano forest, in the Beni savannas, and the Amazon rainforest
- More than 1.3 million acres burned
- Crops and livestock affected

Burned forest in Otuquis. Photo Credit: Franlin Martinez



Helicopters battle the fires. Photo Credit: Adolfo Lino

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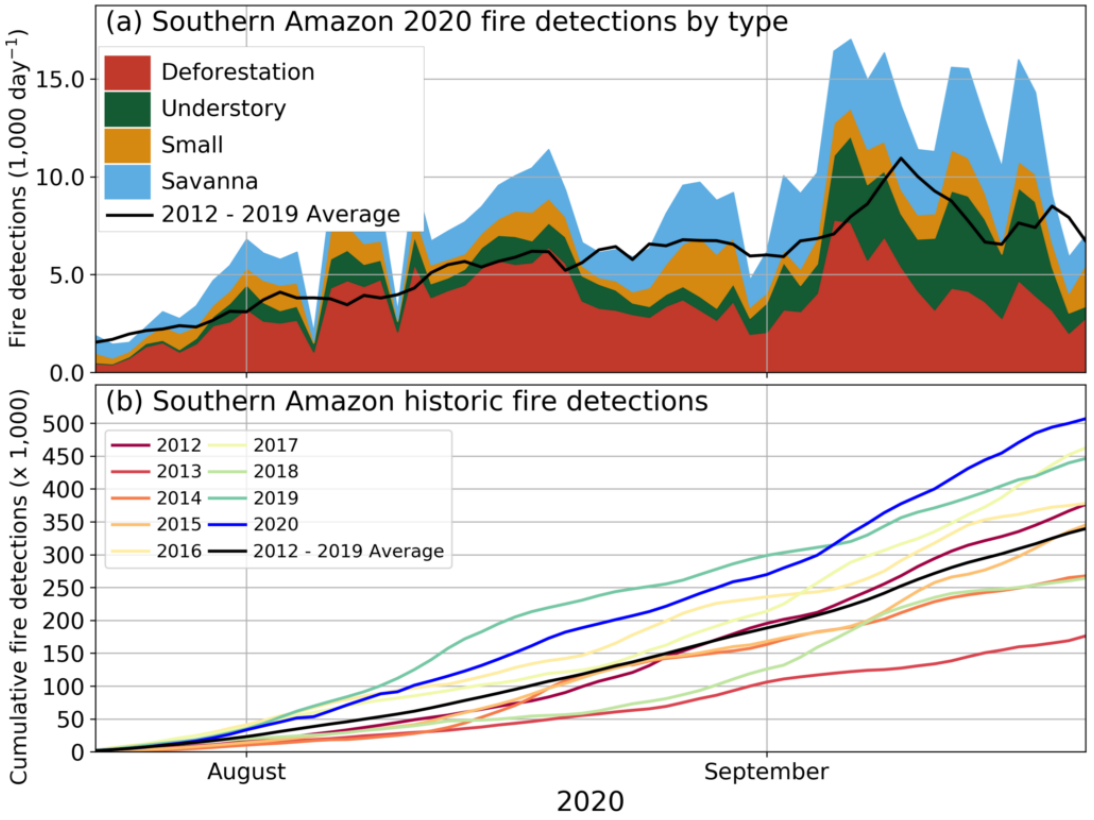
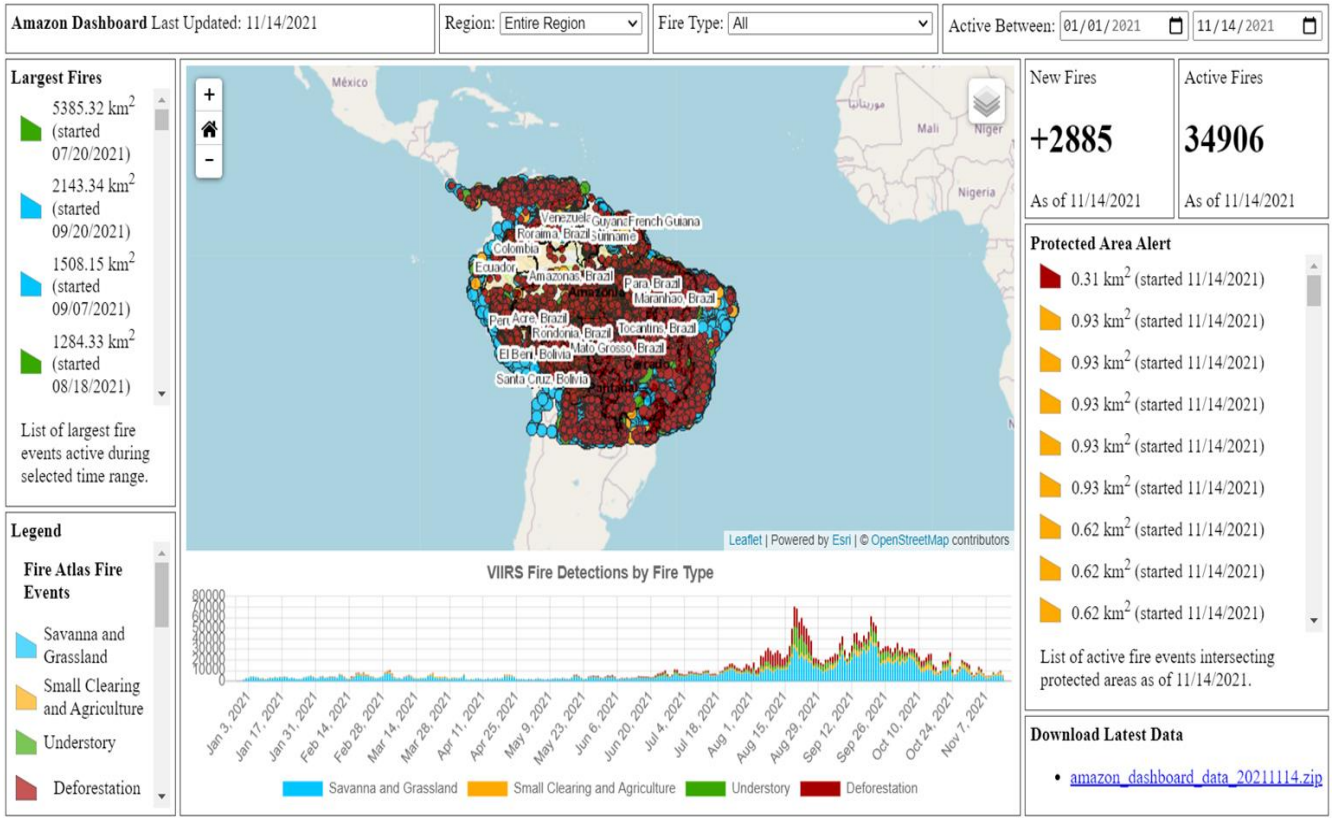


Image Credit: Global Fire Data

GFED Amazon Dashboard

http://globalfiredata.org/pages/amazon-dashboard/

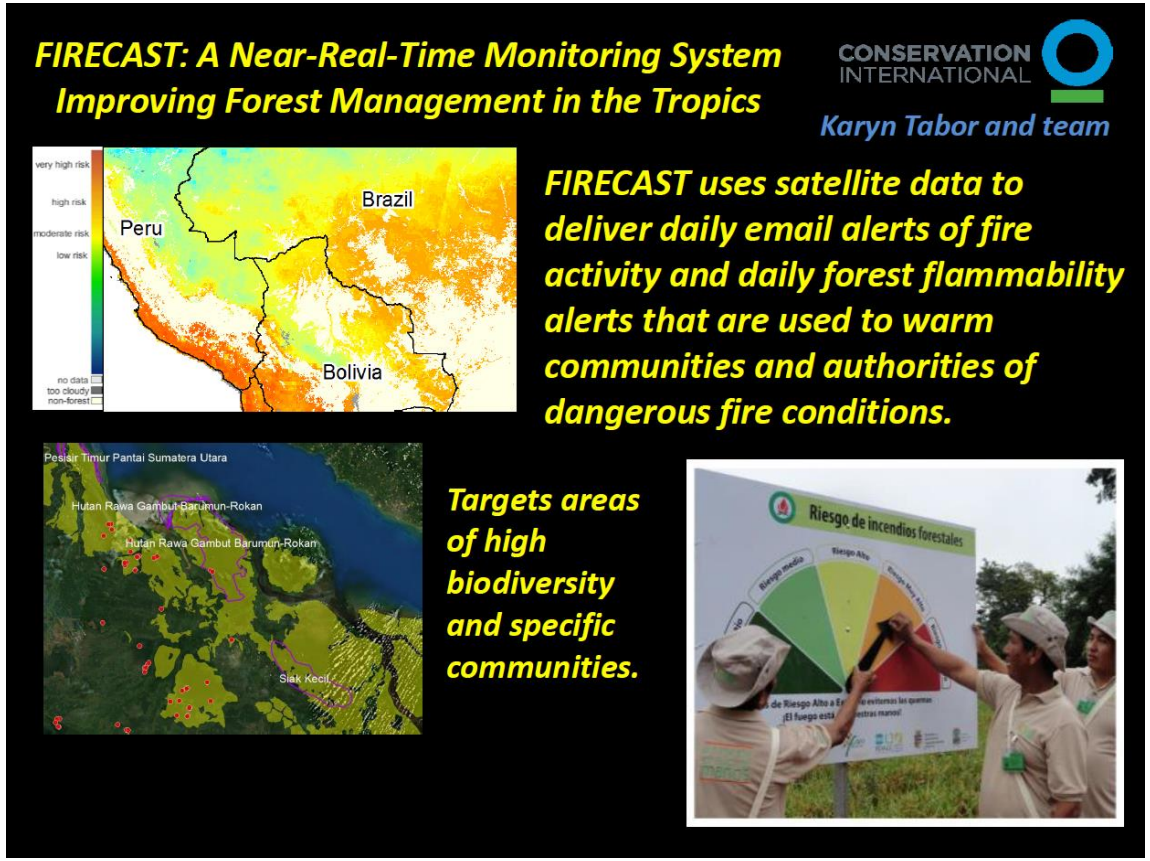


Contact: Helen Parache, hbb0009@uah.edu

- **Goal:** "Track individual fires in the Amazon region using a new approach to cluster and classify VIIRS active fire detections by fire type." Fire types include Savanna and Grassland, Small Clearing and Agriculture, and Deforestation.
- **Methods:** Uses VIIRS and MODIS detections as input to a clustering algorithm that tracks daily burned areas and spread. Also uses external data sets to characterize fire type.
- **Data:**
  - Fire Location
  - Fire Areas
  - Intensity
  - Duration, Start/End Day
  - Spread Rate

FIRECAST

- Analysis and alert system that delivers near real-time (NRT) monitoring products via email to users. Alerts include:
  - Risk of fire within a user's specified area of interest (i.e., protected areas, different vegetation and land cover types, or user-defined regions)
  - Map images depicting the locations of fires or risk of fires and KMLs for data import into Google Earth
- The system currently operates in many South American countries, Indonesia, and Madagascar



Link: https://firecast.conservation.org/

Summary

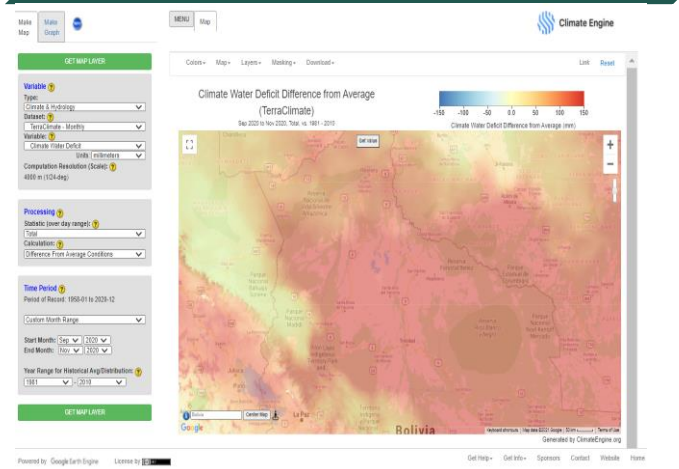
- There are MANY factors that can contribute to fire risk including climate (precipitation, temperature, soil moisture, etc.) and landscape characteristics (topography and vegetation conditions).
- Fire Danger rating systems can be simple or complex and often vary regionally.
- There are multiple tools for analyzing pre-fire conditions including:
  - Climate Engine
  - The Global Wildfire Information System (GWIS)
  - Regional webtools such as the Amazon Dashboard

Resources

- Climate Engine: https://climateengine.com/
- Natural Resources Canada: https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
- Global Wildfire Information System (GWIS): https://gwis.jrc.ec.europa.eu/
- NASA Global Fire Weather Database: https://data.giss.nasa.gov/impacts/gfwed/
- National Wildfire Coordination Group Fire Weather Information: https://www.nwcg.gov/publications/pms437/cffdrs/fire-weather-index-system
- Canada's Record-Breaking Heatwave: https://airs.jpl.nasa.gov/resources/228/nasas-airs-tracks-record-breaking-heat-wave-in-pacific-northwest/
- SERVIR Amazon Dashboard: https://globalfiredata.org/pages/amazon-dashboard/
- CNN Article about the Lytton Fire: https://www.cnn.com/2021/07/08/americas/canada-lytton-wildfire-climate-change-indigenous-intl-cmd/index.html
- Earth Observatory Article about the Bolivian Fire outbreak: https://earthobservatory.nasa.gov/images/147408/fierce-fires-in-bolivia

Interactive Training Portion

Exercise



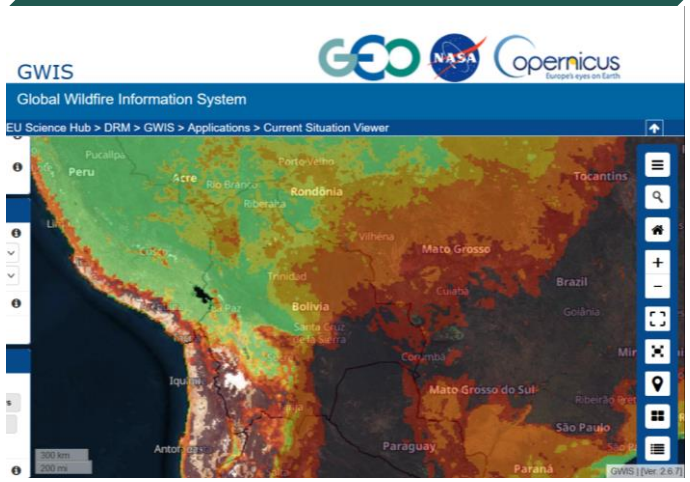
We will step through one of the hands-on exercises together

Questions

Please enter your questions in the Q&A box.

We will post the Q&A to the training website following the conclusion of the webinar.

Lab Time



The trainers will remain online as you work through the exercises.

We will answer questions related to the exercise and/or share our screen to talk through common issues.

Contacts

Follow us on Twitter
@NASAARSET

- Trainers:
  - Amber Jean McCullum: AmberJean.McCullum@nasa.gov
  - Juan Torres-Pérez: juan.l.torresperez@nasa.gov
- Training Webpage:
  - https://appliedsciences.nasa.gov/join-mission/training/english/arset-using-earth-observations-pre-and-post-fire-monitoring
- ARSET Webpage:
  - https://appliedsciences.nasa.gov/what-we-do/capacity-building/arset

Hands-On Exercise: Monitoring Pre-Fire Conditions


APPLIED REMOTE SENSING TRAINING PROGRAM
TRAIN - EMPOWER - ADVANCE

Thank You!