

# Fire Ecology

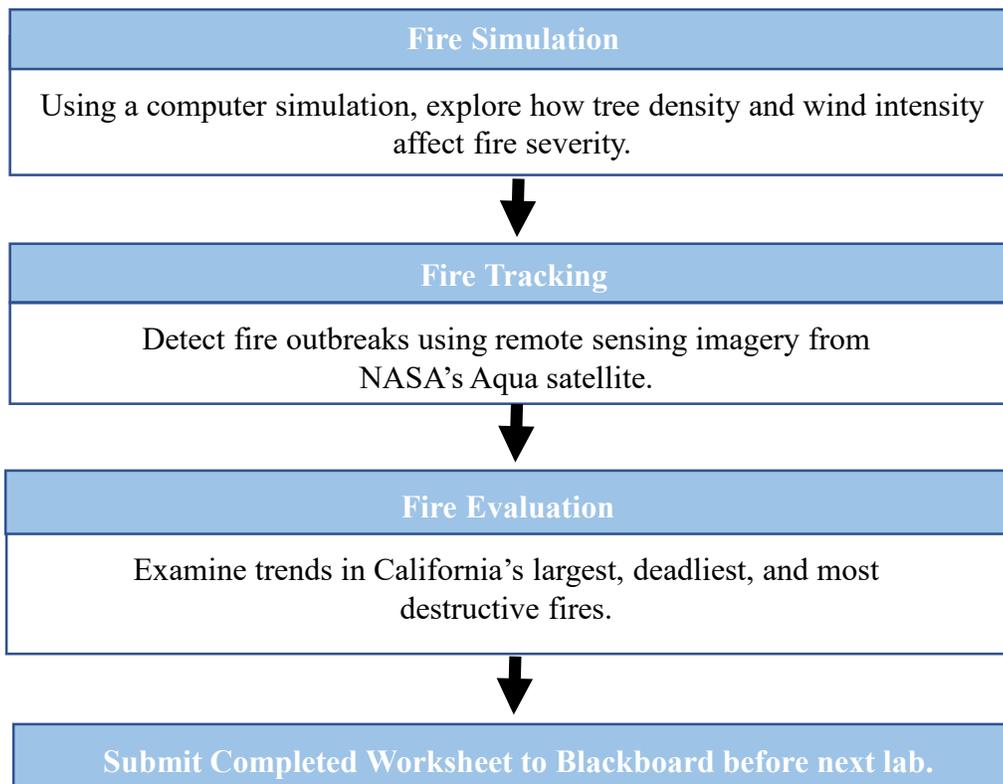
## OBJECTIVES

- Simulate how tree density and wind affect fire spread through a forest
- Work with raster data to track fires via satellite
- Calculate statistics on California fire severity and identify trends
- Understand the importance of forest management to reducing megafires

## ROADMAP

Many habitats in California are adapted to frequent, low-severity fires. However, recent decades have seen an increase in the size, destruction, and deadliness of California's yearly fire season, and climate change is likely to continue exacerbating this trend. An understanding of fire ecology and forest management is crucial to avoiding so-called "megafires" and their devastating impacts on habitats, people, and infrastructure.

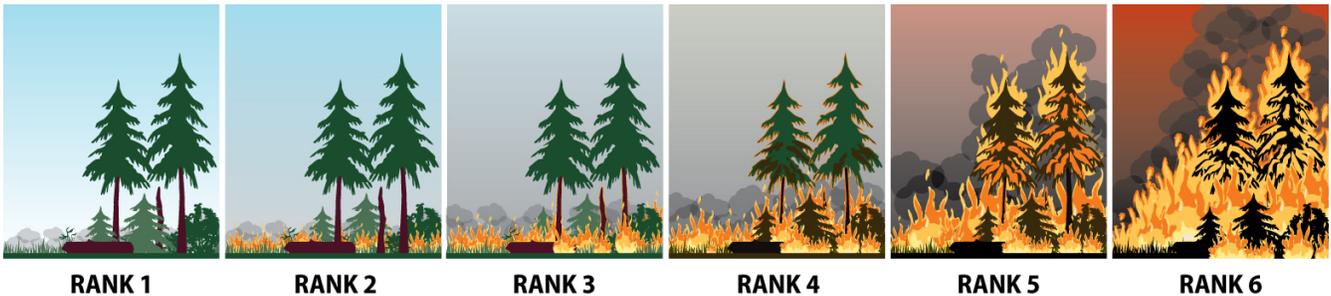
In today's lab, we'll explore several tools used to simulate, track, and evaluate the spread and severity of wildfires in California.



# Fire Simulation

## BACKGROUND

The **severity** of a wildfire, or how much damage it causes to soil and vegetation, is influenced by both climate and landscape structure. Forests with spread-out trees and open understories have low **fuel load**, enabling fire to move quickly over the ground without causing much damage. In contrast, dense forests with overgrown understories have a high fuel load and are more vulnerable to higher-severity crown fires that spread into the tree canopy. Fire severity also increases in hot, dry conditions. **Wind** plays a large role in fire spread, pushing fires to cover larger areas while also increasing the risk of embers “jumping” into the canopy or over fire breaks.

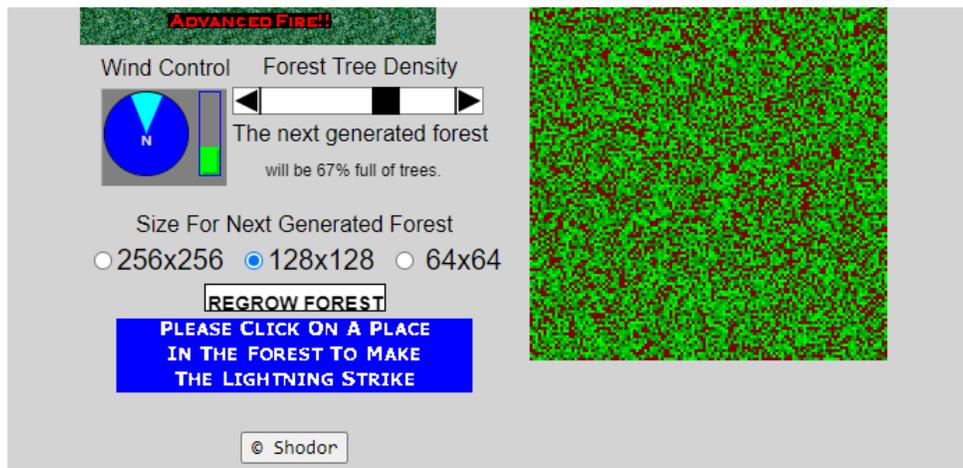


## SIMULATION

Computer simulations are a valuable tool for understanding natural processes, such as how fire spreads through a forest. By simulating fire spread under different scenarios of tree density, wind, etc., land managers can better prepare for and respond to fire outbreaks.

Open a web browser and navigate to [shodor.org/interactive/activities/ABetterFire/](http://shodor.org/interactive/activities/ABetterFire/). This website offers several ecology simulations (accessible via the “Learner” tab), but we’ll focus on the “A Better Fire!!” simulation, which allows us to examine how fire spread is influenced by tree density and wind. You should see a window similar to the screenshot below.

For forest size, we’ll stick with the default of 128x128, meaning our simulation box is 128 pixels on each side. Every green pixel in the box represents a tree in our virtual forest, while every brown pixel is a patch of dirt without a tree.



# Fire Simulation

Name:

Let's start by investigating how tree density impacts the spread of fire through our virtual forest. Find the "Forest Tree Density" slider, then click the left arrow until "The next generated forest will be 52% full of trees." Once you've selected the correct percentage value, click the "Regrow Forest," button, which generates a new forest that is 52% covered by trees in randomly generated positions.

To start a fire, click in the approximate center of the forest (the simulation lets you start a fire anywhere, but to standardize our process, we'll start all our fires in the center). You must click on a green square to start a fire, otherwise you will receive an error message. As the fire spreads, burned trees turn from green to black. Once the fire stops spreading, an output at the bottom left of the box will tell you what percent of trees were burned. Record this value in "Trial 1" of the table below.

Because simulations yield random results every time, we should perform multiple replicates to reduce the bias of any outliers. Keeping the tree density at 52%, click the "Regrow Forest" button then perform a second trial by starting a new fire. Record the results for a total of five trials for each of the density percentages in the table. Make sure to "Regrow Forest" before starting each new trial or after changing the tree density! Once you've completed your trials, calculate the average percent of trees burned for each forest density.

## Percent of Trees Burned, No Wind:

Forest Density	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
52%						
54%						
56%						
58%						
60%						
62%						
64%						

What trend do you see in percent of trees burned as forest density increases? Is this pattern gradual, or does it happen suddenly?

Within each forest density, how similar were the results of each trial? What causes this variation?

# Fire Simulation

Name:

Next, let's investigate how wind affects fire spread at different tree densities. Set tree density back to 52%. Next, inspect the "Wind Control" tool at the top left of the box. We will leave the wind direction blowing north. The bar to the right of the pie chart controls three levels of wind strength: low (green), medium (yellow), and high (red). Click the center of the bar to change wind strength to medium, which should turn the bar yellow.

At medium wind speed, fill out the table below by performing five trial fires for each of the three tree densities. As we did in the previous exercise, reset your forest after each trial and calculate the average of your trials for each density.

**Percent of Trees Burned, Medium Wind:**

Forest Density	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
52%						
58%						
64%						

Finally, change the wind intensity to high by clicking the top of the bar (should change the color to red), then repeat your simulation process to fill out the table below.

**Percent of Trees Burned, High Wind:**

Forest Density	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
52%						
58%						
64%						

For a given forest density, what effect does wind strength have on percent of trees burned? Is this pattern the same for lower forest densities as it is for higher densities?

What implications do your simulations have for managing forests to minimize wildfire spread?

# Fire Tracking

## BACKGROUND

Tracking the spread of large wildfires can be difficult to do from the ground, and plumes of smoke can obscure wide areas beyond a fire’s actively burning perimeter. For these reasons, fire monitoring often relies on **remote sensing** – observing and measuring an object without coming into contact with it.

**Satellite imagery** is a type of remote sensing. Satellites collect data in the form of **rasters**, or energy-sensing pixels arranged into a grid. A standard photograph is a raster where each pixel is programmed to detect visible light wavelengths corresponding to different colors. Many satellites are equipped to do more than simply take pictures, including sensors for environmental data such as radio waves or X-rays. FireSat is a system of 200 satellites being developed by NASA to detect wildfires via infrared energy.

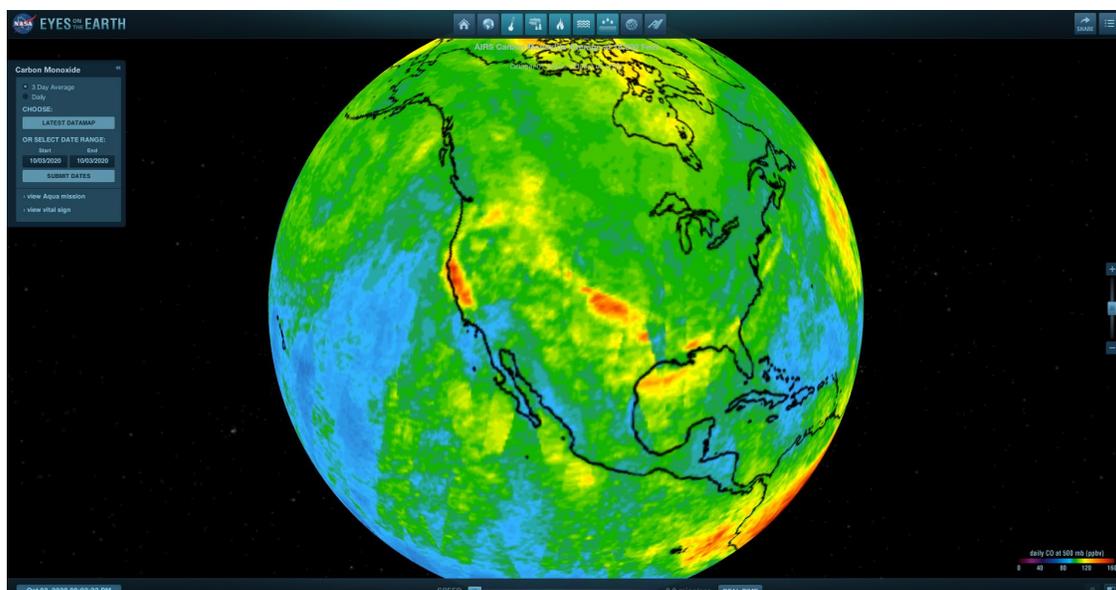
## NASA’S EYES

The NASA’s Eyes program will allow us to explore remote sensing of fires using satellite detection of carbon monoxide, a pollutant common in smoke (note: here, we are not focusing on active fire perimeter, but on smoke detection).

In your web browser, navigate to [eyes.nasa.gov](http://eyes.nasa.gov). Scroll down to “Eyes on the Earth” and download the program to your computer. Once installed, launch the program by finding its folder and double-clicking the launch icon, or select “Launch” from NASA’s website.

Eyes on the Earth will show you a 3D rendition of the planet overlaid with various satellite rasters. Start by finding the “Speed” slider on the bottom of the screen and sliding it all the way to the left, holding the Earth’s position still. Click and drag the Earth to position North America in the middle of the screen.

At the top of the screen, find the “Vital signs of the Planet” section and select “Carbon Monoxide.” The map displayed shows a three-day average of carbon monoxide (CO) levels detected by the Atmospheric Infrared Sounder (AIRS) instrument on the Aqua satellite.



# Fire Tracking

Name:

Based on carbon monoxide given off by smoke, we will attempt to detect the start dates of several historic California fires. On the left, find the Carbon Monoxide box and click “Choose Dates.” Select 5/25/13 as the start date and 6/25/13 as the end date, then click “Submit Dates.”

During this time period, the Powerhouse Fire in Los Angeles began. Hit the pause button in the Carbon Monoxide window to prevent autoplaying, then click the right arrow to advance forward frame by frame (the display date is printed in the center top of the screen in white text and may be hard to see against the bright background).

When is the first date you detect CO from the Powerhouse Fire?

Take a screenshot that shows the CO plume indicating the fire. Add it below, or upload attachment.

When is the last date you are able to see CO from this fire?

Identify the start and end dates for the following fires:

**Rim Fire, Northern California, Date Range 8/10/13 to 9/10/13**

Start Date:  End Date:

**July Complex Fire, Northern California, Date Range 7/24/14 to 8/24/14**

Start Date:  End Date:

# Fire Tracking

Name:

Depending on fire size and wind conditions, smoke can carry pollutants such as carbon monoxide far beyond the actively burning perimeter. We can track smoke spread via remote sensing.

Using the Eyes on the Earth program, let's investigate smoke spread from the devastating California wildfires in August 2020, including four of the top 20 largest wildfires ever recorded in the state. Set the date range from August 1 2020 to October 1 2020. Click the play button and watch for the smoke coming from California. Follow the plume of smoke as it moves (you may need to spin the globe a bit to keep it in sight).

Describe the approximate size and spread of smoke from the 2020 California wildfires.

Are wildfires just a "California problem"? Why or why not?

So far, we've focused on large fires that are relatively easy to detect via satellite. However, spatial resolution is important in remote sensing. If a 5x8 pixel sensor observes a 25x40 meter area, each pixel is detecting 25 (5x5) square meters of surface area. How, then, does the resolution of our imagery affect our ability to detect fires?

# Fire Evaluation

Name:

## CAL FIRE

Once a fire has been put out, the cause and damage must be evaluated. Wildfires vary in terms of ignition source, size, deadliness, and structures destroyed. We may also wish to analyze trends over time. Cal Fire maintains a public database of California wildfires, including summary statistics on several of the most severe fires in the state.

In your web browser, navigate to [fire.ca.gov/stats-events/](https://fire.ca.gov/stats-events/). A table on this page shows some basic statistics for number of fires and acres burned so far in 2020. How do the number/acres of fires in 2020 compare to the 5-year average?

The right-hand menu provides links to several summary data tables, including lists of the top 20 largest, most destructive, and deadliest California wildfires. Open each file, then count and record the total number of fires that occurred within each year interval in the table below.

Year Interval	# of Largest Fires	# of Most Destructive Fires	# of Deadliest Fires
2016-2020			
2011-2015			
2006-2010			
2001-2005			
2000 or earlier			

What was the largest fire in CA history, and when did it occur?

What was the most destructive fire in CA history, and when did it occur?

What was the deadliest fire in CA history, and when did it occur?

What trend do you see in California wildfires over time?