Forest fires

Global Warming Science EPS101

Eli Tziperman

https://courses.seas.harvard.edu/climate/eli/Courses/EPS101/
CBS Sunday Journal: Apocalyptic Western wildfires, Sep 13, 2020

https://www.youtube.com/watch?v=mC_TP2Syk7s
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Workshop #1:

Observed fire trends
Over 8000 fires occur each year, & burn an average of over 2.1 million hectares. Lightning causes ~50% of all fires but accounts for ~85% of annual area burned.

https://cwfis.cfs.nrcan.gc.ca/ha/nfdb?type=poly&year=9999
Observed Forest Fire trends

\[ p=0.776143, r^2=0.00293535 \]

\[ p=0.0003904, r^2=0.366805 \]

\[ p=0.00102345, r^2=0.30604 \]

\[ p=2.29739 \times 10^{-5}, r^2=0.639923 \]

It’s complicated...
The Science Behind Forest Fires | NYTimes, May 15, 2014

https://www.youtube.com/watch?v=mj75koAJBvY
The basics

Fuel ignition dryness
It’s complicated…

Climate factors affecting fire frequency and size:
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- warming, droughts, dry weather, prior rainy season precipitation ➔ more fuel availability,
- earlier spring snow melt, strong & dry winds (Santa Ana, S. CA): dry fuels, enhance & spread fires.
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Non-climate related human effects:
95% of fire ignitions in some areas are human-caused, logging, conversion of land to and from agriculture-use, fire suppression policies & buildup of fuels, population increases (more ignitions, building in fire-prone areas & more fire damage).
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Additional factors: changes of unknown origin to composition of forests (tree type, size, density), effect of past fires on connectivity of forests & ability of fires to spread, on fuel availability in following years.
Lightning-ignited forest fires are natural, part of ecosystem dynamics.

Pre-anthropogenic past forest fires are recorded in ash layers in lake sediments, and as burn signs in tree ring records.

https://www.ncdc.noaa.gov/data-access/paleoclimatology-data/datasets/fire-history
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Lab experiments: resinous bonds between cone scales begin to break between 45°-60°C; serotinous cones touched by fire expand and allow seeds to be released.

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Notes section 14.1:

Tools:
- Vapor pressure deficit (VPD),
- Climatic water deficit (CWD),
- Fire indices - use next two slides
**Fine Fuel Moisture Code:** moisture content of litter & other cured fine fuels, indicator of relative ease of ignition & flammability.

https://cwfs.cfs.nrcan.gc.ca/background/summary/fwsi
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**Duff Moisture Code:** average moisture content of loosely compacted organic layers of moderate depth.

[Diagram of the Canadian Forest Fire Weather Index (FWI) System]

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Buildup Index: total amount of fuel available for combustion. Based on DMC and DC.

https://cwfis.cfs.nrcan.gc.ca/background/summary/fwii
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**Fire Weather Index:** fire intensity. based on ISI & BUI, used as a general index of fire danger

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**Daily Severity Rating:** difficulty of controlling fires. based on the Fire Weather Index but it more accurately reflects the expected effort required for fire suppression.

https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Fire indices use a variety of factors to predict daily fire danger. Commonly used ones: Canadian Fire Weather Index (FWI), Australian (McArthur’s) Forest Fire Danger Index (FFDI) & US Burning Index. They depend on daily weather measurements, including temperature, relative humidity, wind speed, and precipitation over the past few days. They also take into account fuel dryness/aridity, fine fuel moisture, drought, buildup of fuel and the ability of fire to spread.

https://cwfis.cfs.nrcan.gc.ca/maps/fw

https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi
Workshop #2:

**VPD as a fire danger index:**

a) Understanding VPD: Plot the saturation water vapor pressure and the water vapor partial pressure assuming an 80% relative humidity versus temperature. Plot the difference between the two curves (i.e., the VPD for a constant relative humidity) versus temperature.

b) Plot the western US VPD and area burnt versus time on the same axes. Then repeat using VPD and the $\log_{10}$ of area burnt. Calculate the correlation coefficient between the two plotted time series for each of the two cases.
Notes section 14.2
Detection of burnt area due to ACC

Ensemble model runs, chaotic behavior and sensitivity to initial conditions, weather/climate variability vs forced ACC signal (use next two slides)
Weather chaos sensitivity to initial conditions
The butterfly effect

https://upload.wikimedia.org/wikipedia/commons/8/8e/SensInitCond.gif
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Figure 14.2: Example of extraction of ACC signal from multi-model mean. Showing August temperature (K) averaged over the western US from an ensemble of climate model runs, following the RCP8.5 scenario to year 2100. Thin color lines are individual ensemble members. The black line is of ensemble member number 33, the red line is the average over all ensemble members, and the thick yellow line is the smoothed & averaged time series representing the ACC signal estimated using this model ensemble.
Workshop #3:

Separating ACC from variability: Extract the ACC signal in temperature from an ensemble of model runs for 1920–2020. Plot all ensemble time series and superimpose the estimated ACC signal.

Leave for HW, use notes’ Fig 14.2 for now if needed for workshop #4
Notes section 14.2: continued
Detection of burnt area due to ACC

Outline:
Regression between VPD and log area burnt
Extracted VPD due to ACC from model average
Predicted area due to ACC-induced change in VPD

(use following slide)
Detection of west-US burnt area due to ACC

Figures 14.1: Estimating contribution of ACC to western US forest fire area. (a) Red line: log\(_{10}\)(area burnt in 10^3 km^2). blue: standardized VPD. (b) regression between log\(_{10}\) of burnt area & VPD. Points color-coded by year, blue to red. (c) blue: VPD over western US. dash: contribution of ACC from a multi-model average. solid gray: VPD time series w/ ACC signal removed. (d) dash gray: estimated contribution to burnt area due to ACC, calculated from VPD due to ACC using the regression relation. solid gray: estimated burnt area without contribution of ACC.
Workshop #4:

Estimate the contribution of ACC to western US forest fire area (following Abatzoglou and Williams 2016):
Projection of future west-US burnt area due to ACC

**VPD vs frequency of wet days**

Both measures are good predictors of observed burnt area, but their future trajectories under warmer climate are very different ➔ difficult to know which one to use for projections of forest fires.

Observed Impacts of Anthropogenic Climate Change on Wildfire in California
A. Park Williams et al 2019
Australian fires of 2019/20: variability modes vs Anthropogenic climate change
The 2019–20 Australian bushfire season, known as Black Summer, was a period of unusually intense bushfires in many parts of Australia.
Australian fires of 2019/20 and SST variability modes

https://www.youtube.com/watch?v=wRBlvXov91E
Australian fires of 2019/20 and SST variability modes

https://www.youtube.com/watch?v=wRBlvXov91E
Memories of the Peregian fires

https://www.youtube.com/watch?v=dJpNLfD84gA
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Australia’s Angry Summer: This Is What Climate Change Looks Like

The catastrophic fires raging across the southern half of the continent are largely the result of rising temperatures.

Scientific American, By Nerilie Abram on December 31, 2019
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“Of course, unusually hot summers have happened in the past; so have bad bushfire seasons. But the link between the current extremes and anthropogenic climate change is scientifically undisputable.”
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“The current summer has presented the perfect storm for wildfire. Long-term climate warming, combined with years of drought, colliding with a set of climate patterns that deliver severe fire weather.”
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“The current summer has presented the perfect storm for wildfire. Long-term climate warming, combined with years of drought, colliding with a set of climate patterns that deliver severe fire weather.”

“The angry summer playing out in Australia right now was predictable. The scientific evidence is well known for how anthropogenic greenhouse gas emissions are causing long-term climate change and altering climate variability in ways that increase our fire risk. The role of climate change in the unprecedented fires gripping Australia is also well understood by our emergency services.”
Australia fires 2020 and La Nina/SAM/IOD

King et al 2020: “The major Australian droughts of the past 100 years have coincided with several of the longer-lasting periods when La Niña and negative IOD events did not occur. The Second World War Drought from 1935 to 1945 includes two unusually long periods when neither a La Niña nor a negative IOD event occurred, from 1934 to 1938 and 1939 to 1942.”
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Australian fires of 2019/20 and SST variability modes
Figure 14.3: Factors contributing to Australian droughts. (a) IOD. (b) NINO3.4. (c) SAM. (d) Rain over the Murray-Darling Basin in south-east Australia.
Australian fires of 2019/20 and SST variability modes
Figure 14.4: Cluster analysis results for Australian forest fires, showing the means for the five dominant clusters. (a) IOD vs rain in the Murray-Darling Basin in south-east Australia. (b) NINO3.4 vs rain. (c) SAM vs rain. The black star shows the mean conditions during 2018–2020.
Bottom line: Indian Ocean dipole, La Nina and Southern Annular Mode all contributed. Anthropogenic Climate Change may have too. In the long term: warming may very likely contribute to such fires.
Workshop #5: Role of variability modes

Calculate the averaged SAM/NINO3.4/IOD indices for rainy vs dry years (defined to be above and below one standard deviation, respectively) in south-east Australia following King et al. (2020), compare to 2018–9.
Global fire trends

(a) Fire season length

(b) Affect area

(c) Area burnt

Area burnt reduction dominated by African land use changes
Response to warming depends on current regime

Increased precipitation in currently warm areas characterized by grass and shrubs may lead to higher plant growth and thus **increased** fires. In moister areas, a precipitation increase can **reduce** fire activity.

Warmer and drier weather may **increase** fires in areas rich with available fuel (e.g., western US forests)

But: increases in potential evaporation due to atmospheric warming and drying can reduce the growth of plants **in drier areas**, thus **reducing** fire activity.

► It is therefore important to realize that temperature is not necessarily the only or even dominant factor determining fire activity in a future warmer climate.
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6. **Bottom line:** with a significant warming, some changes are unavoidable, not only fire increases, though
The End