Climate chronicles

https://doi.org/10.1038/s43017-024-00544-y

Wildfires in 2023

Crystal A. Kolden, John T. Abatzoglou, Matthew W. Jones & Piyush Jain

Wildfires burned 384 Mha of land in 2023, the highest since 2017 but 5% lower than the 2001–2022 average. These fires emitted an estimated 2,524 Tg C, 30% of which came from Canada's record fire season.

Although wildfires are a natural part of the global climate system, extreme wildfires are among one of the most striking signals of a changing climate. Fuelled by higher temperatures and drier conditions that desiccate fuels, larger wildfires are burning for longer periods across the globe[1]. Accordingly, some regions have seen substantial increases in wildfire activity, including eastern Siberia and the Pacific coast of North America, where burned area increased by 93% and 54% from 2001 to 2019, respectively[1]. Given that these locations are home to some of the densest forest carbon stores[1], they raise concerns about positive wildfire carbon cycle feedback[2], while also highlighting rising wildfire disasters at temperate latitudes[3]. At the global scale, however, burned area has actually declined owing to land use change-related reductions in frequent fire regimes across the African savannah[4].

Here, we describe the 2023 wildfire season in the context of burned area[5], fire-related carbon (C) emissions[6] and fire weather[7]. We focus on regions that exhibited extreme anomalous fire in 2023, omitting discussions of regions such as Russia and Australia that saw average burned area.

2023 at the global scale

Global area burned reached 384 Mha in 2023. This total is substantially higher than the past few years, including 2020 (351 Mha), 2021 (354 Mha) and 2022 (329 Mha) (Fig. 1a). However, the 2023 total remains 12% lower than the 2001–2010 annual average of 437 Mha, a considerably more active fire period.

Fire carbon emissions also peaked in 2023, reaching an estimated 2,524 Tg C (Fig. 1a). These emissions are the highest since the El Niño-related peak of 1998 (2,892 Tg C) and are markedly higher than 2020 (1,957 Tg C), 2021 (2,122 Tg C) and 2022 (1,617 Tg C) (Fig. 1a), despite record wildfire seasons in carbon-rich western North American forests in 2020 and 2021 (ref. 2). The substantive increase in 2023 emissions is consistent with projected higher emissions associated with longer fire seasons and increased extreme fire weather in the extratropics, particularly in carbon-dense forest ecoregions[1]. Indeed, fuelled by record Canadian wildfires and ongoing declines in savannah burned area[4], 2023 Northern Hemisphere (NH) C emissions exceeded Southern Hemisphere (SH) C emissions for only the second time since 2000[6] (Fig. 1a).

Canada goes up in smoke

Globally, Canada was the wildfire hotspot of 2023. Although large fire seasons here are not uncommon, 2023 total burned area reached 15.0 Mha (ref. 8), over seven times the annual average of 2.1 Mha and double the previous maximum of 6.7 Mha in 1989. Moreover, the single largest fire was 1.14 Mha, exceeding the previous largest wildfire of 858 kha in 1995. Relatedly, the spatial extent of fire season was also unusual, with large wildfires spanning all provinces and territories – British Columbia (2.3 Mha), Alberta (2.7 Mha), Quebec (4.3 Mha) and the Northwest Territories (3.6 Mha) all recorded their highest burned areas. Although 59% of these major wildfires were caused by lightning (lower than the normal 75%), 93% of area burned was due to lightning-ignited fires, highlighting how extreme fire weather is facilitating high fire growth rates. In addition to the spatial extent and magnitude, the season was surprising in its duration. Typically, the fire season in Canada spans mid-May through late August, since these are the snow-free months. However, in 2023, fires started in April in the central prairie provinces, continued into June in rural Quebec and the eastern provinces owing to a heat wave, and burned large areas across the continent into late September, over a month longer than normal.

The Canadian fire season also had huge environmental impacts. Collectively, the fires emitted an estimated 763 Tg C, five times the next highest year (2021; 152 Tg C) and >11 times the 1998–2022 average (67 Tg C for the entire Boreal North America region, comprising Canada and Alaska)[6]. Accordingly, Canadian fires contributed 30% of the total 2,524 Tg C emitted globally by wildfires in 2023, largely due to carbon-dense forests in British Columbia and the boreal provinces. The June–July fires in eastern Canada further produced a severe smoke event along the densely populated US eastern seaboard; New York City and other eastern North American metro areas experienced record high PM2.5 levels, with sustained PM2.5 levels above the US EPA 24-hour threshold of 35 $\mu g/m^3$ for unhealthy particulate matter.

Equally substantial social impacts were also observed. Notably, over 232,000 people spanning several provinces were evacuated[8]. These encompass over 200 evacuation orders, including for the Nova Scotia capital Halifax (16,400 people), the Northwest Territories capital, Yellowknife (21,720), Kelowna and West Kelowna in BC (29,566), and numerous smaller towns and First Nations indigenous communities. Hundreds of homes were destroyed and eight firefighters died.

Key points

- The hottest year on record facilitated destructive wildfires on six continents, with 70% of total burned area occurring in the Northern Hemisphere.
- Canada experienced its most severe fire season in the modern era (more than doubling burned area of the previous record), while extreme fire weather resulted in catastrophic fires in Hawaii, the Mediterranean, central Amazonia and central Chile.
- Extreme events produced mass fatalities, lengthy evacuations and extensive economic losses.

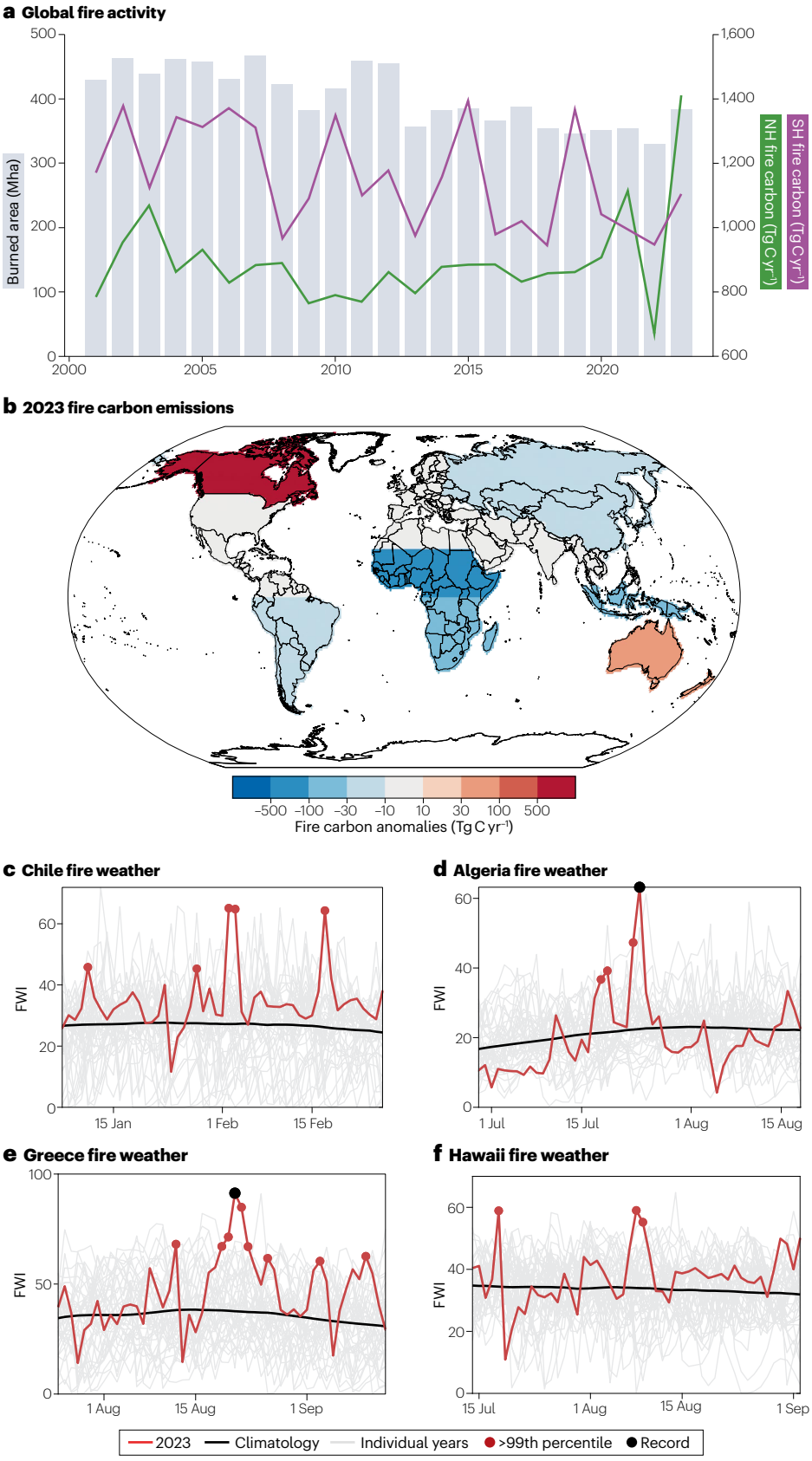

Fig. 1 | Outcomes of and contributors to global wildfire in 2023. a, Time series of burned area[5,6] (BA; grey bars), and Northern Hemisphere (NH; green) and Southern Hemisphere (SH; purple) wildfire-related carbon emissions[6]. **b**, 2023 wildfire carbon emission anomalies relative to the 2000–2022 mean across GFED regions[6]. **c**, Fire weather index (FWI)[7] values for a 0.25-degree pixel where fire occurred in central Chile from 7 January to 26 February 2023. The black line denotes climatological daily FWI over 1979–2023; grey lines, individual years; and the red line, 2023 conditions. Red and black circles indicate >99th percentile and record FWI, respectively. **d**, As in **c**, but for a 0.25-degree pixel in Algeria from 29 June to 18 August. **e**, As in **c**, but for a 0.25-degree pixel in Greece from 25 July to 13 September. **f**, As in **c**, but for a 0.25-degree pixel in Hawaii from 14 July to 2 September. A record year in Canada drove increasing C emissions and area burned globally, while local extreme fire weather drove disasters across multiple continents.

Fires offset deforestation progress

Beyond Canada, record wildfires burned Amazonian Brazil in October and November[9]. These fires consumed an estimated 462,673 ha and released 17.2 Tg C, 57% above the 2003–2022 average. These fires were driven by extreme drought conditions that gripped the area for much of 2023 (ref. 9). Smoke from these fires meant that two million residents of Manaus, the Amazon capital, experienced the worst air quality in the world in October 2023. The uptick in wildfires in primary

forest contrasts starkly with a 70% drop in deforestation fire activity following increased forest protection in 2023 under a new government.

Extreme conditions produced disasters

In addition to the extreme fires in Canada and Brazil, several other events were also observed in 2023. These events reinforce close connections to fire weather, typified by extremes in the Fire Weather Index (FWI) – a measure of potential fire intensity that integrates the influence of fuel drying over prior days to months and short-term fire weather (winds, humidity, temperature)[1,3]. Several unusual or record single events highlight how changing fire weather extremes is fundamentally altering wildfire risks to humans, particularly where factors such as land abandonment, monoculture forestry and excessive fire suppression have amplified fuel volume, and where downslope winds fan flames and entrap humans trying to evacuate[10].

In central Chile, wildfires in February burned 439,000 ha of extensive monoculture forest plantations. These human-caused fires were associated with FWI values reaching the 99th percentile (Fig. 1c), linked to a prolonged February heatwave with record temperatures, drought and downslope winds from the Andes (Puelche winds) that produced extreme fire behaviour. A total of 26 people were killed and 2,560 homes destroyed.

Extreme fire weather also spanned the Mediterranean in July and August owing to an extensive and record-breaking heatwave, fanning fires across northern Africa and southern Europe. In Algeria, for instance, the FWI reached the 100th percentile in late July (Fig. 1d), causing human-ignited fires to burn uncontrollably; burned area reached 60,900 ha and resulted in 34 fatalities. In Greece, similar 100th percentile FWI was observed in August (Fig. 1e), causing 86,000 ha to burn (the largest European Union wildfire since tracking began) and 28 fatalities.

The US state of Hawaii also experienced catastrophic fires in August that burned 1,900 ha. FWI reached the 99th percentile (Fig. 1f) owing to extreme downslope winds, drought and a high fuel load from agricultural land abandonment. The event killed 100 people (the most in a US wildfire since 1918), destroyed over 2,000 homes and displaced over 10,000 people.

Summary

Since 2000, record wildfires have occurred nearly every year despite declining global burned area[3,4]. 2023 was no exception: extreme wildfires burned on all six vegetated continents, including 4% of Canadian forests, killing hundreds. Even in regions with below-normal wildfire activity, the global effects of toxic air quality from wildfire smoke affected tens of millions.

Wildfires in 2023 reinforce the concerns that fire, air quality and carbon managers have about the impact of climate change on extreme wildfire potential and highlight the vast scale and effect of wildfires on society. The US and Canada learned of their vulnerability to toxic smoke exposure from remote wildfires in boreal forest. Longer fire seasons and increased extreme fire weather days globally, and particularly at high latitudes[1], lead to increased mortality rates from smoke and disturb stores of carbon in dense forests that serve a vital role in removing CO_2 from the atmosphere. Finally, an emergent increase in mass fatality wildfires globally will only continue with projected more extreme fire weather unless countries enact fire fatality mitigation strategies with the same systematic commitment as they do wildfire suppression.

Crystal A. Kolden [1] ✉, John T. Abatzoglou[1], Matthew W. Jones [2] & Piyush Jain[3]

[1]Department of Management of Complex Systems, University of California, Merced, Merced, CA, USA. [2]School of Environmental Science, University of East Anglia, Norwich, UK. [3]Northern Forestry Center, Canadian Forest Service, Natural Resources Canada, Edmonton, Alberta, Canada.

✉e-mail: ckolden@ucmerced.edu

Published online: 4 April 2024

References

1. Jones, M. W. et al. Global and regional trends and drivers of fire under climate change. *Rev. Geophys.* **60**, e2020RG000726 (2022).
2. Hudiburg, T. et al. Terrestrial carbon dynamics in an era of increasing wildfire. *Nat. Clim. Change* **13**, 1306–1316 (2023).
3. Bowman, D. M. J. S. et al. Human exposure and sensitivity to globally extreme wildfire events. *Nat. Ecol. Evol.* **1**, 0058 (2017).
4. Andela, N. et al. A human-driven decline in global burned area. *Science* **356**, 1356–1362 (2017).
5. Giglio, L., Boschetti, L., Roy, D. P., Humber, M. L. & Justice, C. O. The Collection 6 MODIS burned area mapping algorithm and product. *Remote Sens. Environ.* **217**, 72–85 (2018).
6. van der Werf, G. R. et al. Global fire emissions estimates during 1997–2016. *Earth Syst. Sci. Data* **9**, 697–720 (2017).
7. Vitolo, C. et al. ERA5-based global meteorological wildfire danger maps. *Sci. Data* **7**, 216 (2020).
8. Jain, P. et al. Canada Under Fire-Drivers and Impacts of the Record-Breaking 2023 Wildfire Season. Preprint at *ESS Open Archive*. https://doi.org/10.22541/essoar.170914412.27504349/v1 (2024).
9. Mataveli, G. et al. Deforestation falls but rise of wildfires continues degrading Brazilian Amazon forests. *Glob. Change Biol.* **30**, e17202 (2024).
10. Abatzoglou, J. T. et al. Downslope Wind-Driven Fires in the Western United States. *Earths Future* **11**, e2022EF003471 (2023).

Acknowledgements

C.A.K. was supported by University of California Office of the President Multicampus Research Programs and Initiatives M21PR3385. J.T.A. was supported by NSF under award number OAI-2019762. M.W.J. was supported by the UK Natural Environment Research Council (NE\V01417X\1).

Competing interests

The authors declare no competing interests.

Additional information

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.