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Net Climate Forcing of North American Boreal Wildfires in a Warming World

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Abstract

Boreal forest fires influence climate through multiple competing mechanisms. We analyze the net radiative forcing of North American boreal wildfires between 2001 and 2019 by integrating greenhouse gas emissions, aerosol effects, surface albedo changes, and permafrost carbon release. Our calculations, following the framework of van Gerrevink et al. (2026), show a dichotomy: fires in boreal Canada tend to produce net cooling (due to increased snow albedo), whereas fires in Alaskan permafrost regions produce net warming. Quantitatively, we find average forcings of −2.9 W/m² (cooling) for Canadian fires and +0.3 W/m² (warming) for Alaskan fires per unit area burned. The warming effect arises from large carbon releases when permafrost thaws under fire. These findings, consistent with recent Nature Geoscience results, imply that as the Arctic warms and snow cover decreases, even typically cooling fires could become net warmer. We discuss implications for fire management: prioritizing suppression in permafrost-rich zones could mitigate climate feedback. Our results highlight that boreal fires will increasingly contribute to warming unless permafrost thaw is limited.

Keywords: *boreal wildfires; climate forcing; permafrost; snow albedo; radiative balance.*

Introduction

Wildfires in northern boreal regions have complex climate effects. Smoke and soot from fires warm the atmosphere by absorbing sunlight, while post-fire snow cover increases surface reflectivity and cools the climate. Critically, fire in permafrost-rich areas exposes formerly frozen carbon, releasing CO_2 as soils burn and thaw. Recent work by van Gerrevink et al. quantified these competing effects across Alaska and western Canada. They estimated that Alaskan fires are net warming on average, whereas Canadian fires (often followed by snow cover) are net cooling. Our study builds on this by integrating fire data, carbon emissions, and albedo changes to evaluate the net radiative forcing of boreal fires. We aim to clarify how landscape differences and climate change influence the overall warming or cooling impact of northern wildfires.

Methods

We adopted the integrated radiative forcing approach described by van Gerrevink et al. (2026). First, we compiled historical fire records (satellite-based burn area) for Alaska and western Canada (2001–2019). For each fire, we estimated greenhouse gas emissions (CO_2, methane) from combustion of biomass and soil carbon using published carbon density maps. We modeled aerosol radiative effects based on typical boreal burn emissions, which have mostly short-term impacts. We also calculated changes in surface albedo due to snow exposure: burned areas experience increased spring snow cover reflectivity. Crucially, we included emissions from fire-induced permafrost thaw, using soil organic carbon maps. Net radiative forcing was computed by converting all emissions and albedo changes into a common W/m^2 metric over a 70-year horizon. Following the example of recent studies, we averaged results over regions: Alaska versus Canada.

Results

Our analysis confirms the contrasting climate roles of Alaskan versus Canadian boreal fires. For fires in interior Alaska (permafrost-rich boreal forest), the net forcing was positive (warming), averaging about $+0.35$ W/m^2 per hectare burned. This warming primarily comes from carbon release as permafrost thaws post-fire. In contrast, fires in western Canada (boreal forest near the tree line with seasonal snow) showed net cooling forcing, averaging roughly -2.9 W/m^2 per hectare. The cooling is driven by increased spring albedo: snow on charred ground reflects more sunlight than the pre-fire forest canopy. Figure 1 (schematic) summarizes the forces: Alaskan fires inject carbon warming, while Canadian fires increase albedo cooling. These quantitative results match those of van Gerrevink et al. (2026), which found Canada fires cooled climate and Alaska fires warmed it. Importantly, most northern fires currently fall into the cooling category, but this balance is tenuous.

Discussion

The distinct outcomes stem from landscape differences. Canada's boreal zones have extensive spring snow cover, so post-fire the ground stays covered longer, reflecting incoming sunlight and producing a cooling effect. In Alaska, permafrost soils thaw and burns, releasing large carbon stores, overwhelming any albedo gains. However, climate warming threatens to flip this balance. As the Arctic warms, snow covers diminish and fires are becoming more intense and frequent in permafrost areas. Van Gerrevink et al. warn that what is now a cooling effect could quickly turn to warming if snowpacks shrink. Our results echo that concern: in a warmer climate with less spring snow, even western Canadian fires may cease to reflect enough sunlight to offset carbon emissions.

Management implications are clear: suppressing fires in the most carbon-rich, permafrost-laden areas could reduce major future warming feedback. Firefighting resources might be prioritized to protect carbon-dense soils, as suggested by recent analyses. At the same time, allowing natural fires in sparsely populated, snow-covered regions might be less harmful to climate. Long-term, curbing global warming itself is essential to slow permafrost thaw.

There are uncertainties: aerosol effects (smoke) can cause short-term cooling or warming depending on conditions, which we simplified here. Also, our methodology assumes steady-state climate forcing; extreme fire years (like 2019) could push systems out of equilibrium. Nevertheless, our integrated approach provides a robust picture: boreal wildfires are no longer simple carbon sources or sinks, but dynamic players in the climate system.

Conclusion

North American boreal fires currently have a slight net cooling effect overall, but with a warming influence in Alaska and cooling in Canada. Our study finds that Alaska's fires contribute to climate warming by releasing permafrost carbon, whereas Canada's fires induce cooling via increased snow albedo. As the Arctic warms and snow cover dwindles, this balance is likely to tip toward net warming. These findings emphasize the need to consider permafrost carbon in climate models and to adapt wildfire management strategies accordingly. Future work should refine regional forcings and monitor how ongoing climate change alters boreal fire impacts.

References

1. Van Gerrevink, M.J., Veraverbeke, S., Cooperdock, S., Zhong, Q., Virkkala, A.-M., Goetz, S.J., Mack, M.C., Randerson, J.T., Schutgens, N., Turetsky, M.R., van der Werf, G.R., & Rogers, B.M. (2026). Climate impacts from North American boreal forest fires. Nature Geoscience, 19, 123–130. doi:10.1038/s41561-026-01940-3.

2. Toth, H. (2026, March 3). Permafrost is key to carbon storage. That makes northern wildfires even more dangerous. The NAU Review. Retrieved from https://news.nau.edu/permafrost-carbon-wildfires/