Cooling effect of preindustrial fires on climate underestimated

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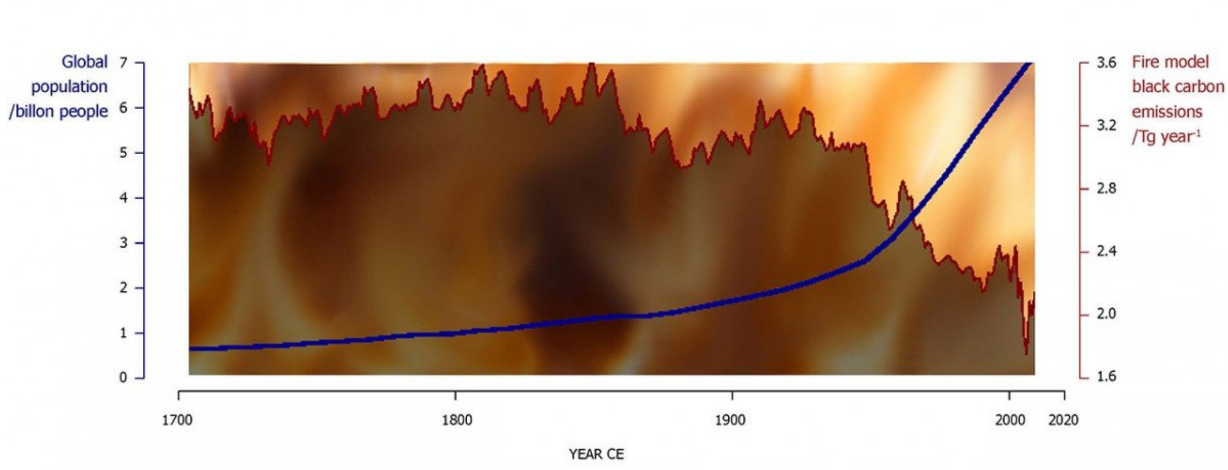

This graphic shows the decline of black carbon emissions from fire activity from 1700 to the present, contrasted with the rise in global population. Credit: Atkinson Center for a Sustainable Future

The Industrial Revolution brought about many things: the steam engine, the factory system, mass production.

But not, apparently, more wildfires. Actually, the opposite.

A new study, "Reassessment of Pre-Industrial Fire Emissions Strongly Affects Anthropogenic Aerosol Forcing," by a Cornell University postdoctoral researcher, published in August in *Nature Communications*, finds that emissions from fire activity were significantly greater in the preindustrial era, which began around 1750, than previously thought. As a result, scientists have underestimated the cooling effect the aerosol particles produced by these fires had on the past climate.

As fire burns, tiny particles—aerosols—are released into the atmosphere, where they can increase the brightness of clouds and reflect sunlight back into space, cooling the planet in the process (also known as indirect radiative forcing). This cooling can help offset increased warming caused by anthropogenic greenhouse gases like carbon dioxide.

"Most people are probably very familiar with the idea of greenhouse gas warming but are less aware that human activities can also create a cooling at the same time, through changes to cloud properties via emissions of aerosols and their pre-cursor gases," said lead author Douglas Hamilton, postdoctoral researcher in earth and atmospheric sciences. "You don't see the full impact of the warming from the greenhouse gases at any point because you also have these aerosols. It's really important for us to understand the cooling effect from these aerosols in order to understand the overall impact human activity has on climate."

To gain a clearer picture of aerosols' historical impact, Hamilton examined fire proxy records, such as ice cores, that hold black carbon emitted from preindustrial fires; charcoal depositions in lake and marine sediments; and scarring in tree rings, along with present-day satellite data documenting the decline in the burnt area caused by fires in recent decades. These paleoenvironmental archives show that fire occurrences worldwide peaked around 1850 and fire emissions have dropped between 45 to 70 percent globally since the Industrial Revolution.

While common sense might suggest fires would rise as human density increased around the planet, in actuality, the establishment of cities, fire departments and local infrastructure, plus the reduction of forests for agricultural purposes, have all curtailed the spread of wildfires, Hamilton said.

Climate change and land-management practices, however, may be reversing that trend. Recent years have seen an increase in the amount of fires in the U.S., for example.

"In some regions we're now starting to see an increase in the amount of fires, and it's projected to continue," Hamilton said. "But where the fires are and where they will increase in the future is not the same as where they were in the past."

The paper concludes that preindustrial fire emissions are the single largest source of uncertainty when it comes to understanding the magnitude of climate warming caused by manmade forms of combustion.

Black carbon: friend or foe?

That sense of uncertainty around aerosol impacts on the climate also informs a separate paper Hamilton recently coauthored, "Black Carbon Radiative Effects Highly Sensitive to Emitted Particle Size When Resolving Mixing-State Diversity," also published in *Nature Communications* in August. That study—led by Hitoshi Matsui, a former visiting scholar at Cornell and now at Nagoya University in Japan—finds that better measurements of the size of black carbon particles, and the ways these particles mix with other aerosol compositions in climate models, is more important than previously thought to understanding black carbon's heating effect in the present day, and how it could change in a future with potentially more wildfires and less fossil-fuel burning.

Black carbon is formed by incomplete combustion of fossil fuels, biofuels and wildfires. Because of its dark color, it absorbs sunlight and warms the planet. The strength of this warming is determined by a particle's size and how diluted it is by other aerosols—such as clearer, organic carbon—or by the condensation of gases that then mix with it.

The researchers developed a more detailed model of black carbon than is currently used. The model factors in a wide range of particle sizes and the different ways black carbon can mix with other atmospheric constituents to show just how nuanced these atmospheric interactions can be. Understanding these interactions is particularly important because one proposed way of mitigating the human impact on the climate is actively reducing only black carbon aerosols while not eliminating others.

"Properly describing the particle size of black carbon particles and their mixing with other aerosol components is very important to understand the contribution of black carbon to the current climate and its future changes," Matsui said.

"What we're showing here in this new advanced model is that, as fires increase in the future, the additional warming that was predicted in more basic models could be an actual cooling relative to present day, because we resolve the size and composition of black carbon in more detail, combined with what is going on with other aerosol and gases that are also co-emitted with the fires," Hamilton said.

Both of these studies add nuances to how effective reducing black carbon to improve air quality and reduce climate change will be, according to Natalie Mahowald, the Irving Porter Church Professor of Engineering and Atkinson Center for a Sustainable Future faculty director for the environment, who coauthored the particle-size paper.

"We really need to understand more about preindustrial fires and how we're changing the size distribution of the black carbon emissions. That's the bottom line," Mahowald said. "As we try to move forward and solve problems with air quality and the climate, we need answers to these questions."

More information: D. S. Hamilton et al, Reassessment of pre-industrial fire emissions strongly affects anthropogenic aerosol forcing, *Nature Communications* (2018). DOI: 10.1038/s41467-018-05592-9

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