New research on megafire smoke plumes clarifies what they contain, how they move and their potential impacts

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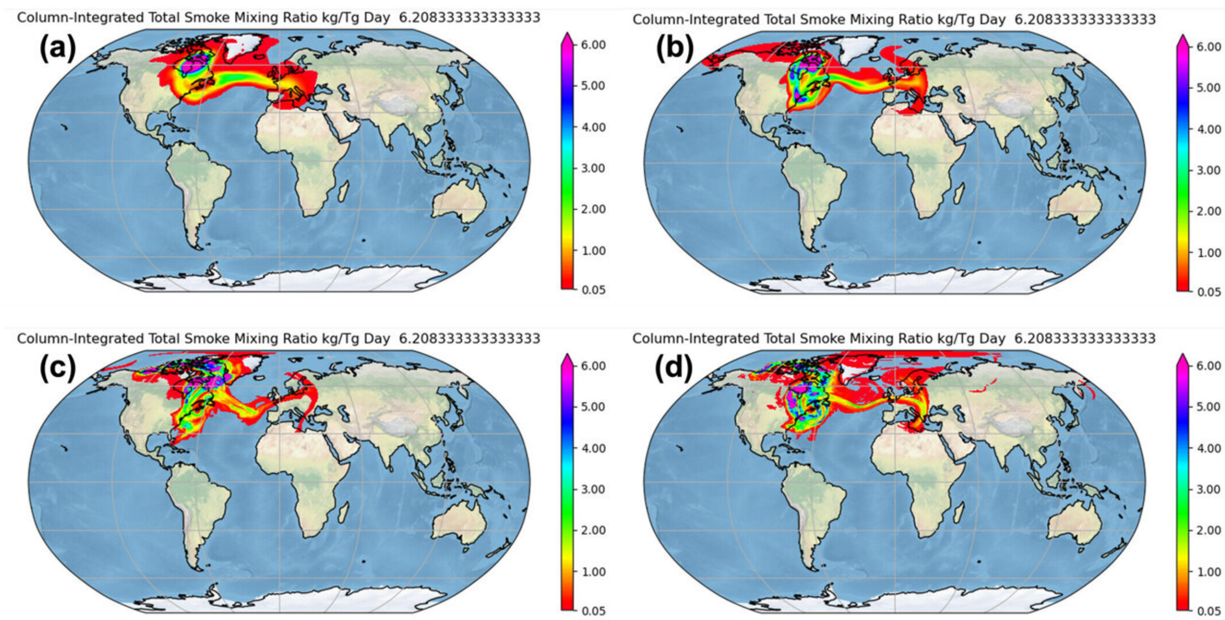

Vertically integrated total smoke mixing ratio in kg/Tg over the entire model atmosphere at 6.2 days (00:00 UTC 19 August) into the simulations for varying resolutions, (a) 2.0° (b) 1.0° (c) 0.25°, and (d) 7 km. Credit: *Journal of Advances in Modeling Earth Systems* (2023). DOI: 10.1029/2022MS003432

In recent years, large, intense wildfires, known as megafires, have increasingly caused severe damage to forests, homes, and crops. In addition to megafires fatally impacting humans and wildlife alike, they may also be impacting climate change. New research led by UMBC's Stephen Guimond provides insight into how the large smoke plumes produced by megafires can be more accurately modeled and characterized to improve our understanding of how they might impact the Earth.

Guimond, an associate research professor of physics, collaborated with scientists at the Los Alamos National Laboratory to determine the long-term effects of smoke plumes from megafires. Their findings, recently published in the *Journal of Advances in Modeling Earth Systems*, demonstrates how previous research utilized a model grid spacing that does not sample smoke plumes accurately. These inaccuracies in defining the dynamics of the problem leads to errors in interpretation of the smoke's properties, vertical and horizontal movement of the plume, and potential climatic effects.

Tracking how smoke rises

The smoke plumes from megafires are voluminous and can rise very high into the upper atmosphere. Initially, the plumes get transported upwards by convective cells and travel into the stratosphere, explains Guimond, who is also a scientist at UMBC's Goddard Earth Sciences Technology and Research (GESTAR) II (previously known as the Joint Center for Earth Systems Technology).

"Once it gets up into the stratosphere, the smoke can stay around for many months, even up to a year or more. The fact that it can stay up there so long means that you can get effects on the solar radiation reaching the surface," says Guimond. "If you have a big, dark-colored blanket of smoke up there, it's going to absorb most of the sunlight, which will lead to less sunlight reaching the surface of the Earth. Because of this, you could get, over a long period of time, a cooling that happens on the surface of the Earth," among other impacts.

For three years, scientists at Los Alamos studied the chemical properties of smoke plumes by burning objects like trees in a controlled setting to determine the percentages of carbon that the smoke emitted. The scientists evaluated atmospheric particulates, or aerosols, which have a major effect on climate. Guimond used a NASA climate model to determine the carbon characteristics of the smoke plumes, how they rise into the atmosphere, and the underlying causes of rotation within the plumes.

"The measurements we looked at included particle types, the spectrum of the particles, and their sizes," says Guimond. "We also looked at the contributions of different chemical species such as black carbon, organic carbon, and other chemical compounds that come off of burning materials."

Assessing previous smoke plume research

The color of the smoke is an important factor, Guimond notes, as different types of smoke have different radiative properties. White smoke is composed mostly of organic carbon: brightly-colored aerosol particles that in large part reflect radiation back into the atmosphere. Black smoke is composed mostly of black carbon: dark-colored aerosol particles that absorb radiation.

The researchers determined that previous models didn't accurately sample the types of carbon within smoke plumes, leading to miscalculations or incorrect assumptions about the percentage of black carbon the plumes contained.

As the black smoke absorbs solar radiation, the smoke heats up, which can create a lofting effect that pushes the smoke higher into the atmosphere. The higher the smoke rises, the longer it stays in the stratosphere. The longer it stays, the more time it has to impact the surface of the Earth. This means that inaccurate characterization of the percentage of black carbon in wildfire smoke can lead to inaccurate calculations of the lofting effect, height of the plume and stratospheric lifetime, as well as climatic effects.

Limits in how previous research represented the atmosphere also made for less accurate smoke plume simulations, Guimond said. He notes that prior smoke plume research used "coarse representation of the smoke plume in the model calculations, which has significant downstream effects on all other components of this problem, including the conclusions drawn from the research."

Guimond hopes that his research can improve understanding of the dynamics of this problem: tracking of atmospheric motion and forces in three-dimensions, and how phenomena like rotating smoke plumes form and decay.

"Scientists need to accurately simulate the dynamics in order to get more accurate answers about aerosol properties inside the smoke plumes," Guimond says, "such as how much of the smoke is black carbon, how long it is going to last in the stratosphere, how high it rises, and its effects on the radiation of the Earth."

With more accurate models and simulations, future research will be able to better inform climate policy and megafire response.

More information: S. R. Guimond et al, The Dynamics of Megafire Smoke Plumes in Climate Models: Why a Converged Solution Matters for Physical Interpretations, *Journal of Advances in Modeling Earth Systems* (2023). DOI: 10.1029/2022MS003432

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