Wildfires in 2021 emitted a record-breaking amount of carbon dioxide

UC Irvine-led study found northern-latitude forest fires to be the highest source
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Steven Davis, UCI professor of Earth system science, led a study of carbon dioxide emissions from forest fires in recent decades. In a paper in the journal Science, he and his colleagues shared some shocking findings. “According to our measurements, boreal fires in 2021 shattered previous records. These fires are two decades of rapid warming and extreme drought in Northern Canada and Siberia coming to roost, and unfortunately even this new record may not stand for long,” he says.

Picture Credit:
Steve Zylius / UCI

Irvine, Calif., March 2, 2023 — Carbon dioxide emissions from wildfires, which have been gradually increasing since 2000, spiked drastically to a record high in 2021, according to an international team of researchers led by Earth system scientists at the University of California, Irvine.

Nearly half a gigaton of carbon (or 1.76 billion tons of CO_2) was released from burning boreal forests in North America and Eurasia in 2021, 150 percent higher than annual mean CO_2 emissions between 2000 and 2020, the scientists reported in a paper in *Science*.

“According to our measurements, boreal fires in 2021 shattered previous records,” said senior co-author Steven Davis, UCI professor of Earth system science. “These fires are two decades of rapid warming and extreme drought in Northern Canada and Siberia coming to roost, and unfortunately even this new record may not stand for long.”

The researchers said that the worsening fires are part of a climate-fire feedback in which carbon dioxide emissions warm the planet, creating conditions that lead to more fires and more emissions.

“The escalation of wildfires in the boreal region is anticipated to accelerate the release of the large carbon storage in the permafrost soil layer, as well as contribute to the northward expansion of shrubs,” said co-author Yang Chen, a UCI research scientist in Earth system science. “These factors could potentially lead to further warming and create a more favorable climate for the occurrence of wildfires.”

Davis added, “Boreal fires released nearly twice as much CO_2 as global aviation in 2021. If this scale of emissions from unmanaged lands becomes a new normal, stabilizing Earth’s climate will be even more challenging than we thought.”

Analyzing the amount of carbon dioxide released during wildfires is difficult for Earth system scientists for a variety of reasons. Rugged, smoke-enshrouded terrain hampers satellite observations during a combustion event, and space-based measurements are not at a sufficiently fine resolution to reveal details of CO_2 emissions. Models used to simulate fuel load, fuel consumption and fire efficiency work well under ordinary circumstances but are not robust enough to represent extreme wildfires, according to the researchers.

And there is another roadblock of our own creation. “Earth’s atmosphere already contains large amounts of carbon dioxide from human fossil fuel burning, and the existing greenhouse gas is difficult to distinguish from that produced by forest fires,” said Chen.

The team found a way around these hurdles by studying carbon monoxide expelled into the atmosphere during blazes. Combining CO readings from MOPITT – the Measurements Of Pollution In The Troposphere satellite instrument – with existing fire emissions and wind speed datasets, the team reconstructed changes in global fire CO_2 emissions from 2000-2021. Carbon monoxide has a shorter lifespan in the atmosphere than CO_2, so if scientists detect an anomalous abundance of CO, that provides evidence of fires.

The researchers independently confirmed the occurrence of extreme fires in 2021 with data sets provided by NASA’s Moderate Resolution Imaging Spectroradiometer aboard the Terra and Aqua satellites.

“The inversion approach employed in this study is a complementary method to the conventional bottom-up approach, which is based on estimating the burned area, fuel load, and combustion completeness,” Chen said. “Combining these approaches can result in a more comprehensive understanding of wildfire patterns and their impacts.”

The researchers said their data analysis revealed links between extensive boreal fires and climate drivers, especially increased annual mean temperatures and short-lived heat waves. They found that higher northern latitudes and areas with larger tree cover fractions were especially vulnerable.

“Wildfire carbon emissions globally were relatively stable at about 2 gigatons per year for the first two decades of the 21st century, but 2021 was the year when emissions really took off,” David said. “About 80 percent of these CO_2 emissions will be recovered through vegetation regrowth, but 20 percent are lost to the atmosphere in an almost irreversible way, so humans are going to have to find some way to remove that carbon from the air or substantially cut our own production of atmospheric carbon dioxide.”

Joining UCI’s Davis and Chen on this project was an international team of researchers from Tsinghua University in Shenzhen, China; China’s State Environmental Protection Key Laboratory of Sources and Control of Air Pollution

Complex in Beijing; the University of Paris-Saclay; Germany's Max Planck Institute for Biogeochemistry; the Netherlands Institute for Space Research; Vrije University in Amsterdam; Harbin Institute of Technology in China.

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