

mede's core to form slowly. As the core differentiated from the rest of the mixture, the moon's interior temperature would have risen to 1250 K, and iron would then start to melt. The model shows that ongoing melting and core formation could sustain a dynamo whose properties are consistent with the *Galileo* magnetic field observations.

If Ganymede could start at a low temperature and sustain a dynamo, then why don't the neighboring Jovian moons of Callisto and Europa have dynamos? Trinh and others are still working on the answer to that question, and it may have to do with, among other factors, the moons' composition and tidal heating—the frictional heat that's dissipated when the moons expand and contract as they elliptically orbit Jupiter. Callisto, for example, has rock that's

richer in water than Ganymede's and likely experienced less tidal heating, and those factors would have inhibited ongoing core formation. Answers may be forthcoming, as the European Space Agency's *Juice* (*Jupiter Icy Moons Explorer*) spacecraft, which is scheduled to enter orbit around Ganymede in 2034, will collect more observations of Jupiter and its moons.

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References

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Wildfire emissions reverse declines in US surface ozone levels

A dataset of daily ozone concentrations with high spatial resolution enables researchers to identify the reversal.

By Sarah Wells

Created by a chemical reaction between nitrogen oxides and volatile organic compounds in the presence of sunlight, ground-level ozone can harm human health and vulnerable ecosystems. Since the establishment of regulations in the Clean Air Act, surface ozone levels in the US have declined from levels as high as 400 ppb in

some areas in the 1970s to peak values of roughly 70–90 ppb today. (Current measurements represent a daily maximum ozone level recorded in an eight-hour period.) But a new analysis by Jun Wang of the University of Iowa and colleagues has shown that the trend has reversed in the past decade because of ozone produced during wildfires.¹ The researchers estimate

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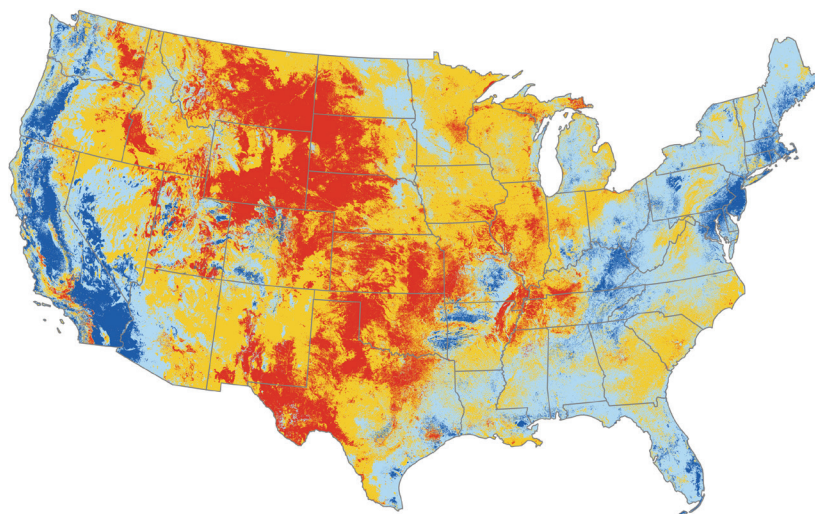
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◀ Some regions across the US have seen a decline in ozone-related air quality from 2015 to 2024 because of increased wildfire emissions, data from a deep-learning model reveal. Surface ozone (O_3) levels increased not only in the western US, where wildfires are more common, but also in the Midwest, where wildfire smoke is carried by wind. (Image courtesy of Weizhi Deng.)

■ Improving
(O_3 levels declining by > 0.50 ppb/yr)

■ Slightly declining
(O_3 levels increasing by 0 to 0.50 ppb/yr)

■ Slightly improving
(O_3 levels declining by 0.50 to 0 ppb/yr)

■ Declining
(O_3 levels increasing by > 0.50 ppb/yr)

that increasing ozone emissions from wildfires has contributed to more than 300 additional premature deaths per year from ozone-related health complications.

The Environmental Protection Agency tracks surface ozone concentrations by using more than 1000 air-quality monitoring stations across the country. Each covers approximately a 10 km radius, meaning that the stations cover only about 2% of the total US land area and 26% of the population. As a result, surface ozone data can be spatially sparse and incomplete, particularly in rural areas, and they may not fully capture nationwide trends. To create a richer dataset, Wang and colleagues used a combination of satellite and ground-station measurements and weather and air-quality models to train a deep-learning model to estimate daily surface ozone levels at 1 km resolution across the US from 2003 to 2024.

Other machine-learning models can underestimate the total number of extreme ozone events—for example, high ozone days that result from active wildfires churning out

nitrogen oxides and volatile organic compounds—because those events are underrepresented in the overall data. But high ozone days are becoming more common as a result of a warming climate, which has contributed to the increasing intensity of wildfires over the past decade and, in turn, to the growth in wildfire emissions. To address the data imbalance problem, Wang and colleagues trained their model to put additional weight on the rare but important events.

Using the new dataset, the team found that ozone levels fell at a rate of 0.65 ppb/yr from 2003 to 2015 but rose at a rate of 0.13 ppb/yr from 2015 to 2024. To isolate the impact of wildfire emissions, Wang and colleagues compared ozone-level estimates with and without those contributions and found that without the additional emissions, ozone levels would have continued to decline at a rate of 0.25 ppb/yr. And the modeling shows that wildfire emissions have affected the ozone levels not only in the western US, where the environment is more prone to fires, but also in the Midwest because of wind spread-

ing the pollutant. The figure illustrates where in the US air quality has improved or declined from 2015 to 2024 as a result of changing ozone levels. The researchers' estimate of some 300 additional premature deaths per year came from their analyzing the connections between ozone levels, wildfire emissions, and human health.

Wang says he hopes that the data can be used by public health researchers to better understand the impact of rising ozone levels on human health and to develop tools, such as high-resolution monitoring and forecast systems, to help better alert the public of their exposure to local surface ozone. Findings from the work, he says, could also potentially help in identifying sparsely monitored regions with rising ozone levels, like the Texas Panhandle, that might be included in a more robust monitoring network.

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Reference

1. W. Deng et al., "Fires reverse progress toward ozone air quality standards in the United States," *Science* **392**, 1088 (2026).