El Nino cycle has a big effect on a major greenhouse gas

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Credit: NASA

Nitrous oxide is commonly associated with laughing gas—the pleasantly benign vapor that puts patients at ease in the dentist's chair. But outside

the dentist's office, the gas plays a serious role in the planet's warming climate.

After carbon dioxide and methane, nitrous oxide is the third-largest contributor of greenhouse-gas emissions to the atmosphere. The colorless gas is also the top culprit in the depletion of ozone—the layer of the atmosphere that protects Earth from the sun's ultraviolet radiation.

The majority of nitrous oxide emissions arise naturally from soil, where microbes break down nitrogen, releasing nitrous oxide as a byproduct. However, human activities such as farming, and the use of fertilizer, in particular, have increased nitrous oxide emissions over the last 35 years—a rise that has contributed to the overall warming of the planet.

Now scientists in MIT's Center for Global Change Science have developed a highly detailed model that simulates levels of nitrous oxide emissions in different regions and ecosystems of the world. Based on local soil temperature and moisture content, some of the simulations were able to reproduce actual nitrous oxide measurements.

From their simulations, the researchers discovered a surprising pattern: Regions around the world typically experience a decrease in nitrous oxide emissions during El Niño events, which periodically create unusually warm waters in the Pacific Ocean, affecting temperature and rainfall patterns around the world. Conversely, they found that emissions rise during periods of La Niña, the opposing weather pattern, in which colder waters take over the Pacific. The findings suggest a feedback mechanism in which nitrous oxide not only contributes to global warming, but may also be affected by climate patterns.

"If more emissions are released into the atmosphere, there will be more global warming … and with higher temperatures, we would have more nitrous oxide coming out," says Eri Saikawa, who led the research as a

postdoc at MIT. "Many people may not consider the nitrogen cycle, but we do have to realize it is pretty important."

Saikawa, who is now an assistant professor of environmental studies at Emory University, collaborated with Ron Prinn, the TEPCO Professor of Atmospheric Science at MIT and director of the Center for Global Change Science, as well as principal research scientist Adam Schlosser. The group has published its results in the journal *Global Biogeochemical Cycles*.

A seesaw of emissions

To simulate nitrous oxide emissions around the world, Saikawa adapted a model of soil temperature and moisture content that is often used by hydrologists to track the movement of water through soil.

Saikawa added to this model a component that calculates how much nitrous oxide is likely emitted from a region, given variables such as soil temperature and moisture. She simulated monthly global nitrous oxide emissions from 1975 to 2008; to check that the model generated accurate calculations, Saikawa simulated nitrous oxide emissions in regions where actual nitrous oxide measurements were available, including 25 locations in the Amazon, North and Central America, Asia, Africa and Europe.

For many of the sites, the model's calculations agreed with observations, verifying its ability to accurately simulate nitrous oxide emissions. Looking at the variability of emissions from year to year, Saikawa noticed a dramatic correlation with the El Niño/La Niña climate pattern, particularly in tropical regions near the equator: Nitrous oxide emissions dipped during periods of El Niño, and spiked during La Niña events.

Saikawa says this periodic seesaw in emissions makes sense: As El Niño

warms the Pacific, rainfall increases to the east, causing flooding in parts of South America, and droughts in parts of South Asia. Saikawa points out that the largest sources of nitrous oxide emissions arise from South Asia; Saikawa observed that decreased soil moisture from El Niño led to a large dip in emissions from those regions, with the opposite effect from La Niña.

"We thought we would see some variability, but we didn't think it would be this significant," Saikawa says. "There is a need for more research to really determine what are the possible impacts from future climate change."

William Horwath, a professor of soil biogeochemistry at the University of California at Davis, says the group's model, while relatively simple, generally does a good job of predicting nitrous oxide events. However, to truly dig down to the root cause of emissions, he says the model will have to incorporate many more factors, including the presence of iron, which Horwath says is a big player in regulating microbes and nitrous oxide emissions.

"Future modeling studies stand to gain valuable information by considering iron among the regional drivers of N2O emission," Horwath says.

Modeling better fertilizer

Going forward, the team will incorporate agricultural components into the model, to simulate the effect of certain fertilizers on nitrous oxide emissions. Many types of fertilizer introduce nitrogen to the soil—an ingredient that nitrogen bacteria thrive upon. The more fertilizer nitrogen there is in soil, the more bacteria break it down, releasing nitrous oxide as a byproduct.

Prinn says that deforestation has also stirred up nitrous oxide emissions, particularly in regions such as Brazil. The Brazilian government, he says, is exploring the increased production of biofuels, fertilizing croplands in place of forests.

"Brazil and other countries are very concerned about the sustainable production of biofuels in the future," Prinn says. "What damage will it do to soil health? … Will they be making biofuels that are causing nitrous oxide and carbon dioxide emissions?"

A model like Saikawa's, he says, may help simulate the effect of biofuel production on nitrous oxide emissions, and present more sustainable methods for growing biofuel crops.

"We should think about the impact that we have from our agricultural activities," Saikawa says. "Over-fertilizing our soil could be potentially quite damaging for the climate and also for the ozone."

The paper is titled 'Global modeling of soil nitrous oxide emissions from natural processes.'

More information:
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