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Thunderstorms Helping Bring Ozone Down to Earth

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Ozone is a bit of a shape-shifting chemical. High in the stratosphere, ozone acts as an ultraviolet-blocking shield around Earth (which is why the ozone hole is such a problem). At ground level, it's a pollutant that can cause serious respiratory problems. And if it finds its way into the troposphere — the lowest level of the atmosphere — ozone serves as a potent greenhouse gas that warms the planet.

A supercell thunderstorm over Great Bend, Kan. Credit: Lane Pearman/Flickr

It ends up in the troposphere through a variety of processes including human pollution. It also finds its way there by trickling down from the stratosphere. In the past, scientists have attributed the trickle between the atmosphere's different layers to large-scale patterns, such as shifts in the jet stream or air moving from the tropics toward the poles.

But for the first time, research has definitively shown that it's not just these large-scale movements that lure ozone down from the stratosphere, it's also smaller-scale events like thunderstorms.

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"The convective-scale events like thunderstorms are smaller. They're not explained well in global climate models but we know they're important," scientist Laura Pan, the lead author of the new research published in Geophysical Research Letters, said.

Pan's findings could be important to climate modelers looking to get a better handle on just how greenhouse gases end up in the troposphere and where they go once they get there.

Some research has projected that severe storms — or at least the conditions favorable for their formation — could increase by 40 percent over the U.S. by 2100 during the height of severe storm season if our carbon dioxide emissions continue unabated. The new research could be a warning about a potentially unexplored feedback loop that could futher warm the planet, with more storms bringing more warming ozone to the lower levels of the atmosphere.

Pan, who works on atmospheric chemistry at the National Center for Atmospheric Research in Boulder, Colo., found that as thunderheads rise to heights up to 50,000 feet above the Earth's surface, they cause ripples in the boundary between the troposphere — the lowest layer of the atmosphere — and the stratosphere — the next layer above it. Those ripples can actually tear a gap in the boundary layer on the front of the storm, allowing ozone-rich stratospheric air to pour down to the troposphere.

Understanding this new process has implications for our understanding of the current climate as well as future ramifications.

"If you have a weather pattern change, say your storms get more intense and bigger storms happen more often, our models need to reflect the chemical changes (such as ozone) as well," Pan said.

Those changes could in turn lead to feedbacks, generating larger storms that drive more ozone into the atmosphere.

Current weather models have an easier time capturing thunderstorm dynamics than climate models, which have a fuzzier view of these small-scale processes.

Michael Prather, an atmospheric chemist at University of California-Irvine who has modeled this process, said the new study is a "nice piece of work that clearly shows the process" of how thunderstorms can facilitate the movement of ozone between the stratosphere and the troposphere.

The reason Pan's work has such a clear view of the process is because she got up close and personal with thunderstorms. Pan flew in and around storms aboard the National Science Foudnation's Gulfstream V research aircraft outfitted with special equipment to monitor ozone and other chemicals in the atmosphere in a number of field studies. She considers airborne studies to be the key to many of the new findings, particularly their outer workings.

The Gulfstream V research aircraft operated by NCAR and the National Science Foundation.
Credit: NASA

"People who study storms have focused mostly on the inside of the storms. There is not much information on the flow pattern around the cloud," Pan said.

Measurements taken during the flight show that ozone concentrations on the front of the storm were more than double that of the surrounding air, dropping to 5 miles above the Earth's surface and spreading more than 60 miles ahead of the storm.

Pan said further research needs to be done to ensure the information is useable in climate models. She suggested moving forward by both monitoring other storms to understand the process and working closely with weather modelers to quantify exactly how much ozone is leaking down from the stratosphere and where it goes afterward.

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