Pollution teams with thunderclouds to warm atmosphere

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Pollution is warming the atmosphere through summer thunderstorm clouds, according to a computational study published May 10 in *Geophysical Research Letters*. How much the warming effect of these clouds offsets the cooling that other clouds provide is not yet clear. To find out, researchers need to incorporate this new-found warming into global climate models.

Pollution strengthens thunderstorm clouds, causing their anvil-shaped tops to spread out high in the atmosphere and capture heat -- especially at night, said lead author and climate researcher Jiwen Fan of the Department of Energy's Pacific Northwest National Laboratory.

"Global climate models don't see this effect because thunderstorm clouds simulated in those models do not include enough detail," said Fan. "The large amount of heat trapped by the pollution-enhanced clouds could potentially impact regional circulation and modify weather systems."

Clouds are one of the most poorly understood components of Earth's climate system. Called deep convective clouds, thunderstorm clouds reflect a lot of the sun's energy back into space, trap heat that rises from the surface, and return evaporated water back to the surface as rain, making them an important part of the climate cycle.

To more realistically model clouds on a small scale, such as in this study, researchers use the physics of temperature, water, gases and aerosols --

tiny particles in the air such as pollution, salt or dust on which cloud droplets form.

In large-scale models that look at regions or the entire globe, researchers substitute a stand-in called a parameterization to account for deep convective clouds. The size of the grid in global models can be a hundred times bigger than an actual thunderhead, making a substitute necessary.

However, thunderheads are complicated, dynamic clouds. Coming up with an accurate parameterization is important but has been difficult due to their dynamic nature.

Inside a thunderstorm cloud, warm air rises in updrafts, pushing tiny aerosols from pollution or other particles upwards. Higher up, water vapor cools and condenses onto the aerosols to form droplets, building the cloud. At the same time, cold air falls, creating a convective cycle. Generally, the top of the cloud spreads out like an anvil.

Previous work showed that when it's not too windy, pollution leads to bigger clouds . This occurs because more pollution particles divide up the available water for droplets, leading to a higher number of smaller droplets that are too small to rain. Instead of raining, the small droplets ride the updrafts higher, where they freeze and absorb more water vapor. Collectively, these events lead to bigger, more vigorous convective clouds that live longer.

Now, researchers from PNNL, Hebrew University in Jerusalem and the University of Maryland took to high-performance computing to study the invigoration effect on a regional scale.

To find out which factors contribute the most to the invigoration, Fan and colleagues set up computer simulations for two different types of storm systems: warm summer thunderstorms in southeastern China and cool, windy frontal systems on the Great Plains of Oklahoma. The data used for the study was collected by different DOE Atmospheric Radiation Measurement facilities.

The simulations had a resolution that was high enough to allow the team to see the clouds develop. The researchers then varied conditions such as wind speed and air pollution.

Fan and colleagues found that for the warm summer thunderstorms, pollution led to stronger storms with larger anvils. Compared to the cloud anvils that developed in clean air, the larger anvils both warmed more -- by trapping more heat -- and cooled more -- by reflecting additional sunlight back to space. On average, however, the warming effect dominated.

The springtime frontal clouds did not have a similarly significant warming effect. Also, increasing the wind speed in the summer clouds dampened the invigoration by aerosols and led to less warming.

This is the first time researchers showed that pollution increased warming by enlarging thunderstorm clouds. The warming was surprisingly strong at the top of the atmosphere during the day when the storms occurred. The pollution-enhanced anvils also trapped more heat at night, leading to warmer nights.

"Those numbers for the warming are very big," said Fan, "but they are calculated only for the exact day when the thunderstorms occur. Over a longer time-scale such as a month or a season, the average amount of warming would be less because those clouds would not appear everyday."

Next, the researchers will look into these effects on longer time scales.

They will also try to incorporate the invigoration effect in global climate models.

More information: Jiwen Fan, Daniel Rosenfeld, Yanni Ding, L. Ruby Leung, and Zhanqing Li, 2012. Potential Aerosol Indirect Effects on Atmospheric Circulation and Radiative Forcing through Deep Convection, *Geophys. Res. Lett.* May 10, DOI 10.1029/2012GL051851

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