Aerosols from coniferous forests no longer cool the climate as much

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Emissions of greenhouse gases have a warming effect on the climate, whereas small airborne particles in the atmosphere, aerosols, act as a cooling mechanism. That is the received wisdom in any case. However,

new research from Lund University in Sweden can now show that the tiniest aerosols are increasing at the expense of the normal sized and slightly larger aerosols—and it is only the latter that have a cooling effect.

The air is full of small airborne particles—aerosols. Some are naturally produced, while others are caused by humankind's combustion of fuel. Some are harmful to our health, while others reflect sunlight.

One of the important natural sources of aerosols is the fragrant terpenes from coniferous forests. For example, the boreal coniferous forest area "the taiga" that stretches like a ribbon across the whole world, accounts for 14 percent of the world's vegetation coverage, and is thus the world's largest coherent land ecosystem.

Through chemical reactions with the ozone in the atmosphere, the terpenes are transformed into highly oxygenated organic molecules which stick to aerosol particles that are already in the air. This leads to more cloud droplets, as each cloud droplet is formed through steam condensing on a sufficiently large aerosol particle. More cloud droplets lead to denser clouds and reduced insolation.

However, the new study published in *Nature Communications* shows that this "coniferous forest effect" has diminished due to industrialization.

Emissions of ammonia from agriculture and sulfur dioxide from fossil fuels change the rules of the game: the terpenes as well as other organic molecules are instead divided into many more, but smaller, aerosol particles. As the diameter of very tiny aerosols is smaller than the wavelength of light, the particles are unable to reflect light.

Although sulphur dioxide and ammonia are gases, they generate new particles via chemical reactions in the atmosphere.

"Paradoxically, a larger number of aerosol particles can lead to the cooling effect from the organic molecules released from the forests being reduced or even eliminated," says Pontus Roldin, researcher in nuclear physics at Lund University in Sweden and first author of the article.

Together with an international research team he developed a model that for the first time reveals the process behind new particle formation of these aerosols.

"The heavily oxidized organic molecules have a significant cooling effect on the climate. With a warmer climate it's expected that forests will release more terpenes and thus create more cooling organic aerosols. However, the extent of that effect also depends on the emission volumes of sulphur dioxide and ammonia in the future. It's very clear, though, that this increase in organic aerosols cannot by any means compensate for the warming of the climate caused by our emissions of greenhouse gases," says Pontus Roldin.

This study can help to reduce uncertainty surrounding aerosol particles' effect on clouds and the climate.

There has already been a considerable reduction of sulfur dioxide emissions in Europe and U.S. since the 1980s and steps in the right direction have now also been noted in China.

"Relatively simple technical solutions are required to reduce sulfur dioxide, for example, cleaning of exhaust gases from ships and coal-fired power plants etc. It's much harder to reduce ammonia, as it's released directly from animals and when soil is fertilized," says Pontus Roldin.

It is estimated that in the future, global meat production will rise

considerably as prosperity in poor countries, mainly in Asia, increases. Today, it is not known what the consequences of these changes will be, but to make an estimate requires the use of detailed models like the one that has now been developed.

In the next few years, Pontus Roldin will work within a research project that will contribute knowledge to next generation climate models, such as EC-Earth.

"We already know that the forest is a significant carbon sink. However, other factors, such as the cooling effect of aerosols, types of vegetation and emissions, affect the climate. Hopefully, our results can contribute to a more complete understanding of how forests and climate interact," concludes Pontus Roldin.

More information: Pontus Roldin et al. The role of highly oxygenated organic molecules in the Boreal aerosol-cloud-climate system, *Nature Communications* (2019). DOI: 10.1038/s41467-019-12338-8

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