

Up in the aerosol

The climatic impacts of aerosols are highly uncertain but critical to understanding human-driven climate change. Monitoring of emissions and a better understanding of the varied pathways through which aerosols can influence climate is vital for reducing these uncertainties.

The risks to human health from air pollution are clear, with the World Health Organization estimating that exposure to fine aerosol particles is responsible for 4.2 million deaths a year¹. Atmospheric aerosols also have an important and complex influence on our climate. It is estimated that anthropogenic aerosols alone have cooled global surface temperatures by up to 0.8 °C over the last century². While aerosols may somewhat reduce global warming, they are also one of the greatest sources of uncertainty in our understanding of human-driven impacts on present-day climate³. More comprehensive monitoring is needed to uncover the pathways controlling aerosol formation and distribution as well as the impacts they have on the wider atmospheric system.

Aerosols consist of small liquid droplets and solid atmospheric particles that come from natural and anthropogenic sources³. The anthropogenic aerosols with the biggest impact on global temperature are sulphates and nitrates, which are formed by the oxidation of sulphur dioxide and ammonia in the atmosphere, and black and organic carbon that are produced directly from the combustion of fuel and biomass. Most aerosols cause atmospheric cooling, either by directly reflecting incoming solar radiation or indirectly through their impacts on clouds. In contrast, black carbon absorbs solar radiation, thereby warming our atmosphere. Our March issue highlights various other important factors that affect how aerosols impact our climate and vice versa.

Aerosols are short-lived in the atmosphere, typically lasting for up to two weeks in the troposphere or a year in the stratosphere³. This rapid cycling makes them more regionally variable relative to longer-lived emissions, like carbon dioxide, and this can strongly influence their climate impacts. Lin and colleagues highlight



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this by comparing the climatic effects of anthropogenic sulfur dioxide emissions generated by the consumption, rather than production, of resources by higher and lower income countries across the globe. They find that, although high-income countries contribute around 40% less sulfur dioxide than low-income countries, they have similar effects on global temperature and precipitation levels owing to their emissions being located at generally higher latitudes.

Higher latitude emissions are thought to have greater climate impacts because of their effect on the Arctic, which is more sensitive to climate change due to ice-albedo and temperature feedbacks⁴. Despite the relatively short lifespan of aerosols, long-range transport of anthropogenic emissions from Europe and Asia can dominate the aerosols found in the Arctic: for example, as observed by Moschos and colleagues, for wintertime organic aerosols. Regional monitoring of aerosols like in this study, especially in sensitive areas like the Arctic, is crucial for quantifying aerosol's varied impacts on climate.

Aerosols influence climate, but climate affects the production and deposition of aerosols in the atmosphere as well. The role that climate change is playing on these

feedbacks adds to the uncertainty. Zhao and colleagues illustrate how increased precipitation levels in China over the past 15 years have meant there has only been a small decline in the atmospheric deposition of sulfates and nitrates, despite reduced emissions of their precursor gases due to implementation of air pollution controls. Changing precipitation levels in China could also affect Asian mineral dust (a natural aerosol) emissions, which Froyd and colleagues found to be disproportionately important for the formation of cirrus clouds in the northern hemisphere.

It is clear that atmospheric aerosols impact our climate system and our climate system impacts aerosols in ways that are not always easy to predict. This is especially true considering the regional impacts from efforts to control air pollution and the various pathways for aerosol formation, transport and deposition. Concentrated efforts to measure aerosols, as seen in the studies featured in this issue, can help to reduce the uncertainties around aerosols' climatic effects and better inform mitigation efforts. This is especially important for regions that are more sensitive to the climate forcing of aerosols, such as the Arctic, and the source regions supplying the anthropogenic aerosols. □

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References

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