Emissions versus climate change

Climate change is likely to offset some of the improvements in air quality expected from reductions in pollutant emissions. A comprehensive analysis of future air quality over North America suggests that, on balance, the air will still be cleaner in coming decades.

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Meteorology and emissions are key drivers in controlling ambient levels of air pollution. How the air we breathe may evolve as climate and emissions change over the coming century has been intensely studied over the past decade[1,2]. Although emissions of greenhouse gases are projected to rise further as the twenty-first century unfolds, emissions that lead to the formation of atmospheric pollutants such as ozone and particulate matter are expected to decline in places such as North America. These developments are thought to have compensating effects on air quality, such as the smog over New York City shown in Fig. 1. Writing in Atmospheric Chemistry and Physics, Kelly and colleagues[3] present an analysis of the combined effects of climate change and declining precursor emissions over North America, using a combination of global and regional climate and air-quality models. They conclude that the health and ecosystem benefits from controlling pollutant emissions are likely to outweigh the negative impacts of climate change.

Climate change can affect air quality in a number of ways. First, warmer temperatures generally make chemical reactions faster. Therefore in a warmer world, emissions from sources such as traffic or power plants are turned into pollutants such as ozone more quickly. Second, climate change is likely to affect regional weather conditions as well as the atmospheric circulation; both will both affect the transport, and hence distribution, of pollutants around the globe. Natural emissions of pollutant precursors, for example from plants, can also be influenced by climate conditions, and climate change effects on cloudiness can alter photochemical reaction rates.

Based on earlier studies for shorter time periods and over smaller geographic domains, the combined result of these various influences of a warming climate is likely to be a deterioration of future air quality, particularly with respect to ozone levels[1,2]. However, this deterioration can be counteracted by reductions in emissions, for example of NO_x and SO_2, that lead to the formation of ozone and fine particulate matter ($PM_{2.5}$). The climate change effect on air quality can thus be thought of as a climate penalty[4]: even though future reductions in the emissions of NO_x and SO_2 are expected to improve air quality, these improvements would probably be larger in the absence of climate change.

To investigate how changes in both regional climate and emissions may affect pollutant concentrations over North America, Kelly et al.[3] used a combination of global and regional climate and air- quality models. They also developed a detailed estimate of future emissions over North America, in line with the global representative concentration pathway 6.0 (RCP6) scenario[5] that was generated for the Intergovernmental Panel on Climate Change. This RCP6 scenario is characterized by substantial reductions in anthropogenic precursor emissions by 2050, compared with present-day levels.

Kelly and colleagues first performed simulations to assess the air-quality impacts of climate change alone over ten summers and then assessed the impacts of changes in both climate and emissions over the same ten summers. The results of this study largely confirm earlier findings that reductions in precursor emissions overcompensate climate change effects on the concentrations of both ozone and $PM_{2.5}$ in North American summers.

Furthermore, the researchers provide a thorough analysis of the implications of these changes to human health and ecosystem damage. Here, they used a multi-pollutant air-quality health index[6] that provides an aggregate measure of acute responses to ozone, NO_2 and $PM_{2.5}$ exposure. Again, climate change alone would result in a potential increase in mortality associated with air pollution in a warmer climate. However, the expected reductions in precursor emissions under the RCP6 scenario are projected to more than offset this increase in mortality, leading to an overall reduction of the health burden caused by air quality in the future climate and emissions scenario considered here.

Kelly and colleagues also calculated the amount of total sulphur and nitrogen transferred from the atmosphere to the surface through pollutants dissolved in precipitation and dry deposition of gases to estimate the impacts on ecosystems. They found that climate change alone had only small effects on both sulphur and nitrogen deposition. However, the scenario with both climate warming and reductions in precursor emissions yields significantly lower amounts of sulphur deposition. Furthermore, this scenario also shows a substantial decrease in ozone deposition, likely decreasing foliage damage in crops and thus increasing crop yields. The findings are more complex for the total deposition of nitrogen, where the directionality of change varies regionally in response to expected increases in ammonia emissions from livestock. Thus, although the findings for sulphur and ozone indicate an improvement in ecosystem health, the nitrate results suggest the possibility of a local degradation. However, different ecosystems could be affected by these changes in different ways.

As ever, some uncertainties remain. First, the model simulations were performed for one specific climate and emissions scenario. The direction of changes in air quality should hold true for other scenarios as well, but their magnitude and spatial patterns may well differ under another set of plausible assumptions. Second, changes in air quality elsewhere may affect North American air quality[7,8] by altering background concentrations and through intercontinental transport. Furthermore, the simulations were performed for summers only, yet the full impact of climate and emission changes on future air quality can only be assessed with year-round simulations. Finally, the modelling system used in this study — as well as other regional-scale studies over North America so far — does not account for interactions between air quality and climate change such as feedbacks from the simulated aerosol concentrations on radiation and clouds.

Nevertheless, Kelly et al.[3] make substantial contributions to our understanding of the joint evolution of climate and emissions change, and its potential impacts on air quality, human health and ecosystems. It will be for even more comprehensive assessments — including more feedback effects and a larger range of scenarios — to tease out the finer quantitative details of how air quality will respond to the multiple influences from human action.

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Figure 1. Smog over New York City. Kelly and colleagues[3] use climate simulations, emissions scenarios and air-quality models to assess the joint effect of climate warming and future reductions of pollutant emissions on air quality, human health and ecosystems over North America. They find that the well- being of humans and ecosystems is expected to deteriorate in response to climate change alone, but that this deterioration can be more than compensated for by reductions in smog-forming emissions.