Pollution particles emitted from these smoke stacks may alter cloud properties, partially offsetting the enhanced greenhouse effect.

Cool clouds shade our view of global warming

Investigations into the effect of aerosols on cloud formation have revealed a cooling effect, previously unaccounted for in climate models, which may partly explain their tendency to overestimate global warming.

Dr Leon Rotstayn has calculated this cooling effect, using the global climate model developed at CSIRO Atmospheric Research in Melbourne.

Rotstayn says the burning of fossil fuels – as well as creating greenhouse gases – produces small pollution particles called aerosols which seem to exert a cooling effect on climate. The effect is partially offsetting warming by greenhouse gas emissions.

The impact of aerosols which has been studied most extensively is their so-called 'direct' effect: the white haze of pollution that hovers over industrial areas of the northern hemisphere, and sometimes over Melbourne and Sydney. This haze of small particles reflects some incoming sunlight back to space, and can have a significant cooling effect on climate.

In addition to this direct effect, however, aerosols can also influence the properties of clouds. This is because cloud droplets (which are like the droplets that comprise fog) prefer to form on small particles or 'nuclei', rather than in completely clean air.

Clouds that form in polluted air therefore contain more droplets than those that form in relatively clean air. So, the available water is distributed over a larger number of droplets, which are smaller than those in clouds that form in cleaner air. The climatic effect of these changes in cloud properties is called the 'indirect' aerosol effect.

Recent research has suggested that the indirect aerosol effect may exert a stronger cooling than the relatively well studied direct aerosol effect.

The first reason is simple. Clouds that form in polluted air are brighter than those that form in relatively clean air, so they reflect more sunlight back to space.

The second reason relates to the formation of rainfall in these clouds.

In clouds comprised of water droplets, rain begins to form when droplets collide and coalesce, forming larger droplets which eventually fall as drizzle or rain. In polluted air, where the droplets are smaller, more collisions are required for them to grow sufficiently large to form raindrops.

In this way pollution suppresses rain formation and causes the clouds to persist for longer, thereby further increasing the amount of sunlight reflected back to space. This is called the cloud-lifetime effect.

When Rotstayn recently used the CSIRO climate model to assess the importance of the indirect aerosol effect – including the cloud-lifetime effect. He found the indirect aerosol effect may be strong enough to be substantially offsetting the warming due to the enhanced greenhouse effect, and the sum of the two effects may even give a net cooling in some regions. His findings are in broad agreement with calculations performed independently by a German group, which published its results in 1997.

Does this mean there is no need for concern about global warming? Rotstayn says the answer is no, because the cooling effect of aerosols is largely restricted to the more polluted areas, whereas the greenhouse gases are well mixed throughout the entire atmosphere.

Also, probably the most important of the aerosols are sulfates, produced by the burning of sulfur-containing fuels such as coal. These are the same compounds that cause acid rain, which the Europeans and North Americans in particular are very concerned about. So, if they are successful in reducing their sulfur emissions in order to save the forests, a side effect could be an acceleration of global warming.

These results have important implications for the debate about whether global warming is 'really happening'. Some critics of the greenhouse theory argue that computer models overestimate the enhanced greenhouse effect, because the models suggest that the Earth should have warmed by more than the half a degree or so that has been observed during the last 100 years.

However, it now looks more likely that the reason for this difference is not that the models are too sensitive, but simply that important cooling effects such as the indirect aerosol effect have not been included. In other words, it appears that the greenhouse effect is really happening; it has just been partially masked by these cooling effects.

Nevertheless, Rotstayn says our understanding of aerosol effects on clouds, and hence on climate, is still limited. Only the effect of aerosols on low clouds comprised of water droplets has been considered so far in climate models. High cirrus clouds are comprised of small ice crystals, and aerosols are thought to affect these clouds too, although these effects are even more difficult to quantify.

There is also evidence that carbonaceous aerosols (soot) have different properties from the sulfate aerosols mentioned above, and may even reduce the brightness of clouds when cloud droplets condense on these particles. So, we can expect the debate about climate change to continue.

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