Can human activity have led to global cooling?

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Human activity may be behind the decrease in global temperatures from 1945 to 1975, a period during which a significant increase in small particles were released into the atmosphere.

Over the last 20-30 years, anthropogenic emissions (mainly greenhouse gases) have in all likelihood resulted in global warming (IPCC, 2001). However, recent studies also show that human activity, both in the previous century and before, can actually have led to a drop in global temperatures. Govindaswamy et al. (2001) demonstrate that changes in vegetation and thus the albedo of the earth’s surface (that is, the ability of the earth to reflect solar radiation) can have resulted in the observed cooling from the year 1000 to 1900.

We recently published an article (Myhre et al., 2001) where we show that small particles in the atmosphere, known as aerosols, may have had a cooling effect on global temperatures during the mid-1900s. In this study, we looked at the development of anthropogenic radiative forcing (see textbox) from the most well known climate mechanisms in the period 1850–1995: carbon dioxide and other well mixed greenhouse gases in the atmosphere; changes in the amount of ozone both in the troposphere and the stratosphere; and the role of a number of aerosols. In addition to these anthropogenic sources, we also studied two natural radiative forcings.

Greenhouse gases

First we present the results from the various calculations of the anthropogenic radiative forcings. We calculated the radiative forcing of the greenhouse gases by using observed changes in the concentrations of these gases and combining this with what we know about their physical characteristics. The results are shown in Figure 1. Note that the radiative forcing from carbon dioxide increased throughout the entire period, except for a short decrease after 1940. The concentration of ozone varies both in time and space in the
stratosphere, and to an even greater degree in the troposphere. This leads to large regional differences in its radiative forcing. Since tropospheric ozone is mainly formed through emissions of pollutants from the ground, we used data on the relevant emissions to calculate its radiative forcing. To calculate the radiative forcing for stratospheric ozone, we used observed changes in both the stratospheric ozone and the amount of chlorine in the stratosphere from 1979 to 1995. These results are also shown in Figure 1.

![Figure 1: Radiative forcing 1850–1995 from all well-mixed greenhouse gases, for CO$_2$ alone, for tropospheric and stratospheric ozone, for direct aerosol (sulfate, soot, and organic aerosols from fossil fuel combustion and aerosols from biomass burning), for indirect aerosol, and for total anthropogenic radiative forcing.](image)

**Particles**

Anthropogenic emissions form a number of different aerosols in the atmosphere. In our study, we looked at sulfate, soot and organic carbon aerosols from fossil fuel combustion, as well as aerosols that result from burning biomass. Soot particles generally absorb solar radiation, and thus have a warming effect. All other aerosols reflect solar radiation back to space and therefore have a cooling effect. Aerosols not only reflect and absorb solar radiation – i.e., have a direct aerosol effect – they can also act as condensation nuclei for cloud droplets. This increases both the lifetime of the clouds and the extent to which they reflect solar radiation. These changes in the clouds constitute the indirect aerosol effect of the aerosols (see Kristjansson, 1999).

We calculated the change over time of the radiative forcing from the direct effect of the sulfate aerosols from global sulfur emissions back to 1850. We derived the change over time in the radiative forcing for the other aerosols in a similar manner. The radiative forcing from organic aerosols was calculated on the basis of the consumption of fossil fuel; soot originating from the consumption of coal, diesel, and oil; and aerosols from biomass burning.
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based on gross tropical deforestation. Figure 1 shows the change over time in the radiative forcing from the direct effect for all aerosol types.

The indirect aerosol effect is derived from an increase in the amount of sulfate aerosols, which has led to a change in cloud droplet size. Figure 1 shows the change over time in this radiative forcing. The radiative forcing of the indirect aerosol effect is very strong. There is great uncertainty associated with this radiative forcing, which indeed is one of the most uncertain elements in current knowledge about global climate change. We have also not taken into account a possible increase in the lifetime of clouds as a result of smaller cloud droplets, but other studies show that this can also have a significant effect. Figure 1 shows the sum of all of the anthropogenic radiative forcings calculated in our study.

![Radiative forcing from changes in solar intensity and aerosols in the stratosphere from volcanic activity.](image)

**Figure 2:** Radiative forcing from changes in solar intensity and aerosols in the stratosphere from volcanic activity.

**Natural factors**

We also looked into the natural radiative forcings from variations in radiation from the sun and stratospheric aerosols of volcanic origin (see Figure 2). The figure shows a very strong and varying radiative forcing from stratospheric aerosols. The amount of these aerosols decreases rapidly after only a few years, thus decreasing the radiative forcing and temperature response.

Figure 3 shows the total radiative forcing of the various climate mechanisms that are studied for the period 1850–1995. We found that the change over time in total radiative forcing in the 1900s can be divided into three periods: 1900–1945, 1945–1970, and 1970–1995. From 1900 to about 1945, anthropogenic contributions increase noticeably, as do natural contributions. In this period, the radiative forcing from the sun is roughly as great as that from the total anthropogenic radiative forcing. After 1945, there is a decrease in both anthropogenic and natural radiative forcings, and the negative radiative forcing from the
aerosols counteracts most of the radiative forcing from the greenhouse gases up to about 1970. In this period there was a strong increase in anthropogenic emissions, which resulted in an increase in the amount of both greenhouse gases and aerosols. The lifetime of greenhouse gases ranges from 10 years to several thousand years, but aerosols have a lifetime of only a few days. This means that current emissions govern the amount of aerosols in the atmosphere for only a short time, while the greenhouse gases we emit today will affect the climate for many years to come.

Figure 3: Total anthropogenic radiative forcing, combined total anthropogenic radiative forcing and changes in solar intensity, and combined total anthropogenic, changes in solar intensity and aerosols in the stratosphere from volcanic activity

**Anthropogenic cooling?**

Anthropogenic radiative forcing increases again after 1970, but in this period the natural radiative forcing drops. It is an interesting coincidence that in the 1900s the anthropogenic and natural radiative forcing generally followed the same trends. The one important exception, however, is the volcanic activity that resulted in significant cooling after 1960, at the same time that anthropogenic activity contributed to warming. The previous century also showed a fairly good correlation between the total radiative forcing and the global change in temperature over time. Because uncertainty is particularly great for the anthropogenic aerosols, we performed sensitivity studies, which showed that an even more powerful radiative forcing from aerosols results in an even more pronounced reduction in the total radiative forcing in the mid 1900s. We must nevertheless emphasize that we still cannot conclude that it is possible to derive a temperature profile from the total radiative forcing. The slow response of the global climate system and the fact that different radiative forcings work over different time scales make it necessary to integrate radiative forcings in a comprehensive climate model before we can draw any conclusions about temperature development. There is also great uncertainty associated with the radiative forcings discussed here, as well as
additional ones that are not considered in this study (e.g., the climate effect of mineral dust, changes in surface albedo, and contrails (condensation trails) from airplanes). Nevertheless, the results of this work indicate that the global temperature decrease from 1945 to 1975 may have resulted from human activity – and primarily from a large increase in the amount of aerosols.

The various climate mechanisms (anthropogenic and natural) act over different time scales where the overall result that human activities generally lead to global warming, but also in some periods to global cooling. With respect to future temperature changes, we should be particularly aware that significant reductions in anthropogenic emissions that lead to the formation of aerosols can lead to a more rapid increase in the total radiative forcing (and temperature) than has been the case over the last 20–30 years.

**Radiative forcing**

Radiative forcing is defined as change in the radiative power for a unit area of surface and is given in Watts per square meter (W/m²). This quantity is used to compare various mechanisms that affect the earth’s climate. These mechanisms can be natural, such as changes in solar intensity, and anthropogenic (human induced), such as increases in the concentration of carbon dioxide. When we say that radiative forcing is negative, we mean that the radiative power decreases because of increased reflection from the earth’s surface or from particles in the atmosphere. Radiative forcing is calculated at the tropopause, which separates the troposphere (the lowermost 10–17 km of the atmosphere) and the stratosphere above.

**References**