# How Will Geoengineering Aerosols Affect Air Temperature?

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*In this guest post, Dr. Richard A. Rosen closely examines some of the assertions and assumptions made by geoengineering proponents. The complexities of how aerosols would affect climate and ecosystems are not as straightforward or predictable as they are sometimes presented, and merit close examination.*

**by Dr. Richard A. Rosen**

I. **What good are climate change models for estimating the impact of aerosols?**

First, one might ask what good are climate change models at all? This is a perfectly reasonable question to ask given how difficult it is to accurately predict the weather over a period of just a few weeks. And since the climate is just average weather over longer periods of time such as multi-year averages, one might wonder how climate scientists can model the relatively small changes in annual average temperatures or precipitation that can be attributed to human intervention in the climate-earth system. The answer is – not very well.

There are several dozen fairly well-known climate models the results of which appear in the literature on climate change on a regular basis. When these models are run for the same basic scenarios, such as a scenario representing a doubling of $CO_2$ concentrations in the atmosphere, unfortunately the models get very different results. The projected equilibrium temperature increase for such a scenario in the long run differs by approximately a factor of three, from about 1.8-5.4 degrees C, in recent analyses, or from about 1.5-4.5 degrees C in the past. From the perspective of a physicist such as myself, this is a very large difference. Similarly, model projections of regional precipitation, ice melting rates, and sea level rise also differ substantially. However, given how complex the climate/earth system is, these differences are inevitable.

Yet, if we just look at the historical record for the annual average temperature of the earth (both on land and over the oceans) we see a clear pattern of very slow increases from the early twentieth century to the late 1970s, and then fairly rapid but fluctuating increases from then until now. Relative to the average annual global temperatures in the $19^{th}$ century, we find the increase by 2020 to be about 1.2 degrees C, or 2.2 degrees F. There is generally a greater increase in higher latitudes and less near the equator, and more over land than the oceans. That temperature trend line representing the impact of humans on the climate is, then, crystal clear, so we do not need any fancy statistical tools or computer models to tell us that it exists.

That steady increase in average global temperature can also be compared to the very steady increase in the concentration of $CO_2$ in the atmosphere, the most important greenhouse gas that leads to climate change. In fact, we find that the increase in temperature closely parallels the increase in $CO_2$ emissions from 280 ppm in the $19^{th}$ century to 415 ppm now, with some recent acceleration, as one would expect from the physics of climate change. Historical measures also find that the total amount of precipitation is also increasing, ocean water temperatures are rising, sea and glacial ice is melting, and sea level is steadily rising. Thus, again, complex computer-based climate change models are not needed to tell us that climate change is occurring, and what is causing it to occur. That is simple undisputed physics, and the rate at which it is occurring from the late 1970s until today is also quite clear.

We also know from the historical record that when there have been large volcanic eruptions, the small particulates and the chemical aerosols that have been ejected into the upper atmosphere have caused the earth's average temperature to cool slightly for a couple of years. Again, we do not need complex climate models to tell us that this can happen. However, when some climate researchers have raised the question as to whether chemical aerosols could be purposely injected into the atmosphere to cool the earth enough to significantly offset climate change, scientists have attempted to address that question via the use of climate models, which have already incorporated the existing quantities of aerosols in the atmosphere when calculating climate change. The research question became, then, how many tons of aerosols and what kind would have to be injected into the upper atmosphere and where, to offset a significant amount of climate change, both temperature and precipitation changes?

## II. **What is the problem with attempting to answer these questions about the potential impact of aerosols on the climate using climate/earth system models?**

The first problem is, as we noted above, that different climate models yield very different results even for average global temperature changes. The results for regional temperature changes vary even more between models, as do the changes in regional precipitation rates. Because we do not even know which climate models are best for forecasting changes in temperature and precipitation, it is even more challenging to know which models are best for calculating the impact of purposely adding aerosols to the atmosphere on temperature and precipitation patterns. In terms of physics theory, it is relatively easy to determine how $CO_2$, water vapor, and other greenhouse gases such as methane ($CH_4$) absorb and re-radiate the sunlight falling on the earth's atmosphere in a local area with clear skies as that sunlight travels from outer space to the earth's surface.

Once sunlight warms the air, land, ice, and water those bodies radiate energy in different parts of the electromagnetic spectrum (mostly visible and infra-red light) back out towards outer space in all directions, and down to earth. However, when these beams of light of many different frequencies travel up and down from outer space to the surface of the earth, they also interact with clouds, ice, vegetation of many types, different types of land, and human settlements around the world. Sometimes clouds absorb the light hitting them and heat up, and sometimes the clouds reflect the radiation back into outer space, or back down to the earth. Again, remember that all gaseous molecules and solid surfaces reflect light in all directions, not just up and down with respect to the earth's surface, and to differing degrees, depending on the frequencies of the spectral lines involved. The aerosols themselves, such as sulfates ($H_2SO_4$), have very complex properties which make it difficult to know to what extent they will reflect or absorb light, and at which frequencies, and in which directions. Therefore, the climate/earth models are extremely complex prior to even considering the effects of aerosols in the atmosphere, and if the impact of large amounts of different kinds of aerosols need to be included, the models get even more complex.

In fact, the underlying physics of all these interactions between molecules of many types and radiation across the ultra-violet, visible, and infra-red spectrum is so complex, even though well-known, that climate models cannot actually use the correct physics equations to calculate the interactions and their impact on the earth. The models necessarily use various kinds of approximate equations the solutions to which can be much more readily calculated in a finite period of time on a computer, so that multi-year calculations can be made in order to assess climate change over decades. One reason, then, that different climate models get very different results is that they use different approximations for different physical effects based on judgements made by the different model developers. One effect not mentioned above is that more aerosols tend to create more clouds, but climate models are notoriously poor at "knowing" how and when to create clouds with or without aerosols present. This is one reason why it is difficult for climate models to accurately predict precipitation amounts from the clouds, in part because climate models cannot produce individual storms which cause precipitation.

## III. **Can we trust the results of scientific research on aerosol impacts on climate change using climate models?**

I think that the safest way to proceed through the masses of scientific literature on climate change and, in particular, studies on the impact of adding aerosols on climate change is to interpret the published results as merely suggestive of what might actually happen in whatever scenario is being analyzed. No one knows to any reasonable degree of accuracy what will actually happen in a given scenario, for example how more aerosols will affect regional air temperatures, ice or land temperatures, vegetation growth, ocean temperatures, or precipitation patterns. The latter are the least likely to be knowable, since they are not very accurately calculated by climate models even without taking the impacts of aerosols into account.

But even IPCC reports point out that it is extremely unlikely that aerosol impacts from adding aerosols regularly to the atmosphere could possibly replicate the regional patterns of climate change so that climate change could be offset everywhere, even with regard to only temperature changes. Yet, some researchers who focus on aerosol impacts seem to claim that there could be a very precise offsetting effect. There are some obvious simple physical reasons that support the conclusion that fairly precise offsetting would not be possible. The clearest example is that when the sun does not shine on the earth's surface, either at night anywhere, or in winter for months at a time in the polar regions, aerosols have no light source that they can reflect back into space in order to cool the earth's surface. Thus, the presence of more and more greenhouse gases in the atmosphere in the future will cause the warming of such regions at least half the hours of the year, in different patterns and degrees, depending on the latitude of the region under consideration. This warming will occur whether or not more aerosols are injected into the upper atmosphere so the added aerosols could not offset this warming. At the very least, then, the average difference between the low temperature for the day and the high temperature for the day in most regions of the world will decrease because aerosols are likely to cool the high daily temperatures somewhat, but would not reduce the low temperatures. This reduction in the difference between daily high and low temperatures could have important but currently unknown implications for our ecosystems and crops, and ocean temperatures. This change could also affect human comfort because people without air conditioning need cool nighttime temperatures to recover from daytime heat in the summer. Yet, aerosols will not cool nighttime temperatures as greenhouse gas-induced warming makes summers ever hotter at night.

In conclusion, when one reads research articles that seem to imply that the regular injection of aerosols into the atmosphere could at least offset the temperature impacts of climate change, please read more carefully to see if the article only describes offsetting average global temperatures on an annual basis, or whether it covers the average changes that affect human beings and ecosystems on a daily and seasonal basis. These are clearly more important, just as changes in the daily weather are what people really feel and must cope with.