

## DGL Article

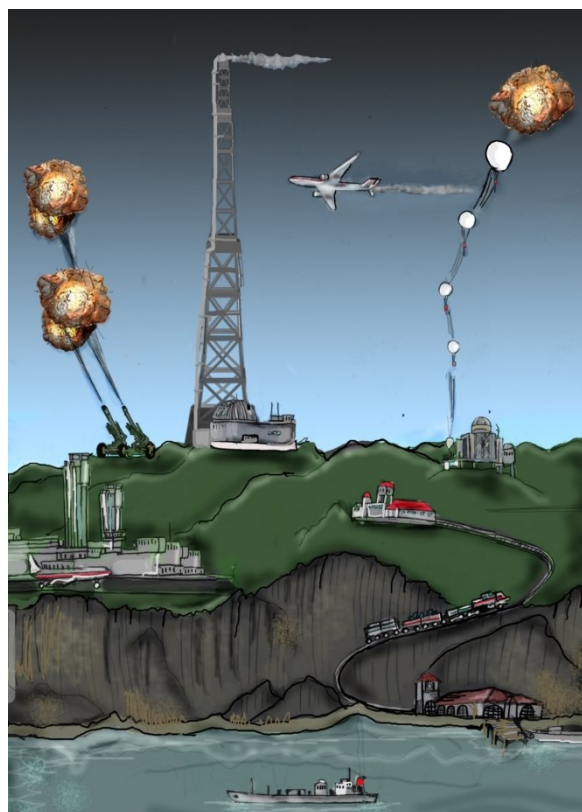
# Smoke and mirrors are not the solution to global warming

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Geoengineering is the “deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change” (1). Proposed schemes include carbon dioxide reduction (CDR) and radiation management (RM). CDR technology exists but is very expensive, and no facilities exist for doing it on a large scale. It presents very different engineering, scientific, governance, and ethical issues than RM. Here I focus on the most studied proposed RM scheme, artificial creation of stratospheric aerosol clouds. I use the term “geoengineering” to refer to that scheme (2).

Geoengineering is currently impossible. The technology does not exist, and there are serious questions as to whether it would be possible to create a cloud in the stratosphere that would have the desired effects. We can investigate the impacts of a geoengineering intervention by using analogues, in particular volcanic eruptions, to explore some of the resulting benefits and risks. We can also use climate models, that is, computer simulations that calculate the climate response to geoengineering scenarios. These are the same models that we use for weather forecasting and global warming climate simulations. They are validated with simulations of past climate, in particular the response to volcanic eruptions.

If there were a way to continuously inject  $\text{SO}_2$  into the lower stratosphere, it would create a permanent cloud there, producing global cooling, stopping melting of the ice caps, and increasing the uptake of  $\text{CO}_2$  by plants. A comparison of different proposed injection schemes, using airplanes, balloons, and artillery (Figure 1), shows that putting sulphur gases into the stratosphere would be comparatively inexpensive. But there are at least 27 reasons why stratospheric geoengineering may be a bad idea (Table 1). These include disruption of the Asian and



**Figure 1.** Proposed methods of stratospheric aerosol injection. A mountain top location would require less energy for lofting to stratosphere. Drawing by Brian West. Reprinted with permission from (5).

African summer monsoons, reducing precipitation to the food supply for billions of people; ozone depletion; no more blue skies; reduction of solar power; and rapid global warming if geoengineering stops. Furthermore, there are concerns about commercial or military control, and serious degradation of terrestrial astronomy and satellite remote sensing.

Clearly, the solution to the global warming problem is mitigation (reduction of emissions of gases and particles that cause global warming, primarily  $\text{CO}_2$ ). Society will also need to adapt to impacts that are already occurring. Whether geoengineering should ever be used will require an analysis of its benefits and risks, as compared to the risks of not implementing it. Research so far has

pointed out both benefits and risks from geoengineering and has shown that it is not a solution to the global warming problem, but at some time in the future, despite mitigation and adaptation measures, society may be tempted to try to control the climate to avoid dangerous impacts. Much more research on geoengineering is needed for society to be able to make informed decisions about the fate of Earth, the only planet in the universe known to sustain life.

The audacious idea of controlling Earth's climate brings up ethical and governance issues. The fundamental question is that of where to set the planet's thermostat. Who would decide how to carry out geoengineering? What values would be used to decide? For whose benefit would this decision be made: for those controlling the geoengineering; for the entire planet, however defined; for the benefit of those most at risk; only for humans; or taking into account the rest of the natural biosphere? These decisions are in the realms of politics and power and are different from testable scientific hypotheses. But scientific evaluations of the benefits, risks, and uncertainties of various proposals should, in an ideal world, inform decisions about implementation of geoengineering.

Ethical and governance decisions about geoengineering need to differentiate between research and deployment. As for geoengineering research, there have been many recent recommendations that it be enhanced, most recently from the U.S. National Academy of Sciences (3). But is such research ethical? Does it take resources away from other more useful pursuits? Is it yet another way for developed countries to continue to run the world to benefit themselves? Does the knowledge that this research is ongoing reduce whatever political drive there is toward mitigation because geoengineering will be seen as an easier solution to global warming? Does geoengineering research in a laboratory or a computer, with no emissions to the environment, have different ethical issues from outdoor research in which sulphur is emitted into the stratosphere? Would the existence of the technology enable hasty, politically-driven decisions to deploy? Is geoengineering research merely a smokescreen for weapons development? Or would it be unethical not to investigate a technology that may prevent widespread dangerous impacts of rising greenhouse gas concentrations? Would it be unethical not to provide policymakers with detailed information about the benefits and risks of various geoengineering proposals so that they can make informed decisions about implementation? Would it be unethical not to

develop the technology to carry out geoengineering, both so that the costs and efficacy can be determined (maybe it will prove impossible or much too expensive or dangerous), and to have the designs available so that it could be rapidly implemented if needed?

Certainly if the research itself were dangerous, directly harming the environment, this would bring up ethical concerns. To test whether there were a climate response or whether existing sulphuric acid cloud droplets would grow in response to additional emissions would require very large emissions, essentially amounting to implementation of geoengineering, and would therefore be unethical. But what about flights to spray a little SO<sub>2</sub> or other sulphur species and then observe how particles would grow or the response of ozone? Although no such governance now exists, any such outdoor experiments need to be evaluated by an organisation, like a United Nations commission, independent from the researchers, that evaluates an environmental impact statement from the researchers and determines that the environmental impact would be negligible, as is done now for emissions from the surface. Additional monitoring capabilities would be needed. There would also need to be enforcement of the limits of the original experiment, so that it would not be possible to expand the experiment in light of inconclusive results.

To make decisions about ethics requires a declaration of values, unlike in the physical sciences, where nature follows accepted laws such as conservation of energy. The above conclusions are based on the following principles: curiosity-driven indoor research cannot and should not be regulated, if it is not dangerous; emissions to the atmosphere, even for scientific purposes, should be prohibited if they are dangerous; and any results from geoengineering research need to be governed in the same way as all other dangerous human inventions, such as ozone depleting substances and nuclear weapons.

I have previously concluded that "in light of continuing global warming and dangerous impacts on humanity, indoor geoengineering research is ethical and is needed to provide information to policymakers and society so that we can make informed decisions in the future to deal with climate change... Outdoor geoengineering research, however, is not ethical unless subject to governance that protects society from potential environmental dangers" (4). Eventual decisions about deployment will need to consider the relative benefits and risks, which will be determined by research. All

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these potential benefits and risks (**Table 1**) will need to be quantified. Because some can never be quantified, I am sceptical that geoengineering will ever be deployed. Of course, real-world decisions are made without full knowledge and sometimes under pressure from extraordinary events. Much more research in stratospheric geoengineering, conducted transparently and published openly, is needed for future policy decisions to be as informed as possible.

Even at this late date, a global push to rapid decarbonisation by imposing a carbon tax will stimulate renewable energy and allow solar, wind, and newly developed energy sources to allow civilisation to prosper without using the atmosphere as a sewer for CO<sub>2</sub>. Adaptation will reduce some negative impacts of global warming. Geoengineering does not appear to be a panacea; geoengineering research should be in addition to strong efforts toward mitigation, and should not be a substitute. In fact, geoengineering may soon prove to be so unattractive that research results will strengthen the push toward mitigation.

**Table 1.** Benefits and risks of stratospheric geoengineering. The effects that are observed after volcanic eruptions are indicated by an asterisk (\*). Updated from (2).

Benefits	Risks
1. Reduce surface air temperatures*, which could reduce or reverse negative impacts of global warming, including floods, droughts, stronger storms, sea ice melting*, land-based ice sheet melting, and sea level rise*	1. Drought in Africa and Asia*
2. Increase plant productivity*	2. Perturb ecology with more diffuse radiation*
3. Increase terrestrial CO <sub>2</sub> sink*	3. Ozone depletion, with more UV at surface*
4. Beautiful red and yellow sunsets*	4. Whiter skies*
5. Unexpected benefits	5. Less solar energy generation*
	6. Degrade passive solar heating
	7. Environmental impact of implementation
	8. Rapid warming if stopped*
	9. Would not stop ice sheets from melting
	10. Cannot stop effects quickly
	11. Human error
	12. Unexpected consequences
	13. Commercial control
	14. Military control of technology
	15. Conflicts with current treaties
	16. Whose hand is on the thermostat?
	17. Degrade terrestrial optical astronomy*
	18. Affect stargazing*
	19. Affect satellite remote sensing*
	20. Societal disruption, conflict between countries
	21. Effects on airplanes flying in stratosphere*
	22. Effects on electrical properties of atmosphere
	23. More sunburn (from diffuse radiation)
	24. Continued ocean acidification
	25. Impacts on tropospheric chemistry
	26. Moral hazard – the prospect of it working would reduce drive for mitigation
	27. Moral authority – do we have the right to do this?

## Acknowledgments

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## References

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