MEERTALK

KNOWN UNKNOWNS IN STRATOSPHERIC AEROSOL INJECTION (SAI) PROPOSALS

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SUMMARY

Well-mixed greenhouse gases have had a warming effect on our planet's atmosphere, leading to changes in climate. Less well recognized are the cooling effects that particulates tend to have on the atmosphere. Particulates that act as cooling agents, such as sulphur, range in their chemical effect and residence time in the atmosphere in addition to their impact on climate. One commonality, however, is that particles are absolutely critical for cloud formation. This ability of particles to seed clouds and reflect sunlight has led to considerable academic interest in creating "designer" aerosols for stratospheric injection.

While it is tempting to think of the cooling effects that the addition of these particles could have, there are considerable risks and unknown factors. One such negative effect is the tendency for particles in the stratosphere to destroy ozone. This can be mitigated to a certain extent, but any new particle that is introduced into the atmosphere is known to promote ozone loss. Current proposals to inject aerosols into the stratosphere on the order of several Teragrams per year (equivalent to the cumulative impact of 50 aircrafts worth of material every single year or a single large dust dust storm) make assumptions that have already been demonstrated to be inaccurate. For example, the tendency for an "armored surface" to form on calcium carbonate would prevent additional reactions with acids in the atmosphere, contrary to the assumptions used in geoengineering proposals. Additionally, initial assumptions that reactions would take place in an anhydrous environment also appear to be faulty.

SUMMARY CONTD

Also unclear is the amount of warming that would be offset by a given mass of material injected into the upper atmosphere. Initial models suggest that this could lead to a cooling effect of -2W/m^2, but if this scattering takes place above an existing cloud or leads to the formation of new clouds that prevent the exit of solar radiation, this figure could fall to as low as -0.9 W/m^2 of cooling. It is becoming clear that there are still major knowledge gaps that require additional study and experimentation to understand what chemical reactions are taking place in the atmosphere as well as the actual effect that aerosol injection would have on the reflection of sunlight.

Current research is investigating just that. NASA is trying to understand the complexity of the atmosphere and the effect of intense thunderstorms that punch material into the stratosphere: something that has yet to be integrated into any climate model. Stratospheric particles and chemistry are proving to be much more complex that typically acknowledged, making these experiments all the more important, since geoengineering proposals often do not capture this complexity. Understanding of the current state of the upper troposphere and stratosphere is critical for both climate change and geoengineering proposals.

STUDENT QUESTIONS

Q What governing body should oversee this research and is there such a body in place?

A: This is a very important question as this is outside of the realm of expertise of most scientists. The United Nations and associated bodies would be an obvious candidate for such governance to take place, but no such body exists. Scientists shouldn't be advocates for one particular decision or another but should just provide information.

Q How do radiative cooling and warming effects change based on altitude as well as the season at which aerosols are released?

A: Lower lying clouds in the middle and lower troposphere tend to be cooling agents, as anyone who has walked outside on a cloudy day will know. Higher altitude clouds exist very high in the troposphere and tend to absorb more terrestrial heat and radiate it downwards, acting as a blanket.

Q Does the potency of the greenhouse effect depend on emission altitude?

A: In general, CO_2 emitted at a lower altitude has more of a warming effect. That being said, essentially anything emitted in the troposphere, be it at ground level or the tropopause, has approximately the same warming effect.

Q Do you think that the CO_2 being produced in the service of injecting aerosols will have a long-term effect on global warming?

A: Any CO_2 molecule emitted in the atmosphere will have some impact on climate change. That said, the proposals that most people have put forward have been as stop gaps, which would have less of an impact due to their temporary nature.

Q Would the aerosols injected amplify stratospheric clouds?

A: Most of the clouds we have discussed have been tropospheric. That said, there are also polar stratospheric clouds and new particles that could nucleate new clouds at the poles. Additionally, any new particle in the atmosphere is known to promote ozone loss.

Q What are the effects of compounds that you create in the atmosphere and what happens when they precipitate onto the Earth's surface?

A: What goes up must come down and all of these particles will eventually fall out onto the earth's surface. Going forward, it would be beneficial to talk to an air quality expert to understand the public health ramifications that this would have.

STUDENT QUESTIONS (CONT.)

Q What are the key milestones that must be achieved before stratospheric aerosol injection can be admitted for discussion in policy circles and public discourse?

A: Two key milestones must be reached. First, the computational ability of computer models must be enhanced considerably. Second, we must increase our understanding of the underlying microphysics.

Q Given the time constraints, how should scientists approach solar radiation management, considering the danger of climate change?

A: Dr. Cziczo is a proponent of carbon sequestration, as we know more about what the climate looked like with less carbon. He is not a proponent of injecting material into the atmosphere because it leads to an atmosphere that we have no understanding of and may be entirely different from what the models predict. Land surface changes are more known, as scientists have a better understanding of the changes in surface albedo. Additionally, mitigating climate change in this way wouldn't affect ocean acidification, which will continue to worsen as long as the carbon dioxide concentration increases.

Q Are there any detriments to smog decreasing?

A: Some rise of warming may be due to the lack of offsetting cooling from air pollution. These particles have such severe health impacts that we should never consider leaving them in the atmosphere. We must have continued vigilance in places that have already cleaned their air up, and enhanced work in developing countries.

AUDIENCE QUESTIONS

Q How do we make the production circular to reclaim them?

A: There aren't any proposals he knows about for circular production. Rather, the idea is to use abundant materials that won't fall out.

Q Is there a danger you could form clouds over the arctic and prevent refreeze?

A: Models don't do cloud formation all that well and it isn't at all clear that we have a good enough understanding to know that we aren't putting particles into the polar vortex.

AUDIENCE QUESTIONS (CONT.)

Q Do you think carbon sequestration is scalable?

A: Dr. Cziczo thinks it will take a multi-pronged approach and there isn't a silver bullet. We would have to learn more about the extent to which it is feasible.

Q What has been the cloud effect of loss of forests and change in forest carbon?

A: We don't know because we don't know what clouds looked like before 1950, much less the preindustrial era.

Q What do you think about marine cloud brightening over the Arctic?

A: If a cloud is put into the troposphere, it is going to change precipitation. Additionally water that goes into the atmosphere is going to make changes that may have an impact on atmospheric circulation and other dynamic. It is impossible to decouple any of these things from changing clouds.

Q What is the effectiveness of ground based vs. Stratospheric solar radiation manipulation?

A: There is no fundamental difference, although we have a better understanding of what effects modifying surface albedo would have.

Q What is causing the larger-than-normal hailstone showers?

A: There would need to be more research into this question, but the larger hailstone size could be affected by a warmer atmosphere able to hold more water and more droplets as well as the increased particulate matter in the atmosphere, again leading to more droplets.