Why geoengineering is not a solution to the climate problem

This briefing addresses grave scientific concerns in relation to proposed geoengineering techniques such as solar radiation management (SRM). "Geoengineering" as used here does not refer to negative emissions technologies that remove CO_2 from the atmosphere (carbon dioxide removal or CDR) as part of the energy system or through ecosystem restoration and afforestation or reforestation. Here we specifically address the risks posed by SRM.

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Summary

Solar radiation management is not a solution to the climate problem

Solar radiation management does not address the drivers of human-induced climate change, nor does it address the full range of climate and other impacts of anthropogenic greenhouse gas and air pollutant emissions. Solar radiation management aims at limiting temperature increase by deflecting sunlight, mostly through injection of particles into the atmosphere. At best, SRM would mask warming temporarily, but more fundamentally is itself a potentially dangerous interference with the climate system.

Solar radiation management would alter the global hydrological cycle as well as fundamentally affect global circulation patterns such as monsoons. Substantial monsoon disruptions induced by SRM cannot be ruled out. SRM may not halt ocean warming around Antarctica and would fail to counteract the increasing contribution of Antarctic melt to sea level rise.

Solar radiation management does not halt, reverse or address in any other way the profound and dangerous problem of ocean acidification which threatens coral reefs and marine life as it does not reduce CO_2 emissions and hence influence atmospheric CO_2 concentration. SRM does not counter other effects of increased CO_2 concentration adversely affecting the terrestrial and marine biosphere.

SRM is unlikely to attenuate the effects of global warming on global agricultural production. Its potentially positive effect due to cooling is projected to be

counterbalanced by negative effects on crop production of reducing solar radiation at the earth's surface.

There is very high scientific uncertainty on the potential impacts of solar radiation management, and these cannot be resolved by field experiments. Most studies of solar radiation management are based on highly idealised scenarios and assumptions that differ substantially from discussed, real-world applications of solar radiation management. Results of idealised experiments should not be conflated with discussions around solar radiation management 'solutions' based on very different techniques.

Solar radiation management would undermine renewable energy potentials.
As it reduces the amount of solar radiation reaching the earth's surface, solar radiation management would greatly diminish the potential one of the biggest alternatives to fossil fuel electricity generation: solar energy.

Solar radiation management poses fundamental risks to global governance and cooperation

Solar radiation management could be undertaken unilaterally, creating massive climate risks for many others. SRM would strongly alter the climate system producing 'winners' and 'losers' in different regions and with different levels of deployment. It would therefore most likely become a source of massive conflict between nations. If not banned completely, it would put the power of triggering a climate shock into the hands of single actors.

Solar radiation management is in contradiction with the ultimate objective of the UNFCCC which is to prevent dangerous interference with the climate system. Geoengineering techniques like solar radiation management come with grave risks and themselves constitute a new, dangerous anthropogenic interference with the climate system, on top of emitting carbon dioxide and other greenhouse gases into the atmosphere.

Solar radiation management poses pivotal problems of intergenerational justice. Techniques like solar radiation management have to be continuously sustained. If disrupted, very rapid and large-scale planetary warming will occur on a timescale of months. The impacts of such a "termination shock" would be much worse than the effects of climate change it aims to avoid. As SRM does not reduce CO_2, future generations would effectively be handed highly acidic oceans which cannot be easily reversed, if at all, with large scale damages to coral reefs and other marine ecosystems.

Background

What is Geoengineering?

The term 'Geoengineering'[1,2] refers to a range of proposals and, most prominently, to 'Solar Radiation Management' (SRM) and more generally radiative forcing geoengineering (RFG)[3].

SRM techniques aim to reduce some of the effects of climate change through large-scale technological applications such as stratospheric aerosol particle injection. Here, sulphur particles, for example, are injected into the stratosphere, causing a shading effect and reducing the amount of solar radiation available to warm the lower atmosphere. It would act like a major volcanic eruption, but on a sustained basis.

Other proposed RFG techniques that are even less viable include putting mirrors in space, increasing surface reflectivity of the earth, or altering the amount or characteristics of clouds.

The IPCC's assessment

These and other considerations led the IPCC's Fifth Assessment Report (AR5) to assess that SRM techniques "*entail numerous uncertainties, side effects, risks and shortcomings*" and "*raise questions about costs, risks, governance and ethical implications of development and deployment.*"

Further, the IPCC AR5 found that: "*SRM would not prevent the CO_2 effects on ecosystems and ocean acidification that are unrelated to warming.*"[4] This assessment has been reaffirmed in the most recent IPCC Special Report on Global Warming of 1.5°C that found that SRM measures "*face large uncertainties and knowledge gaps as well as substantial risks, institutional and social constraints to deployment related to governance, ethics, and impacts on sustainable development.*"[5]

SRM and the "termination shock"

If stratospheric aerosol particle injection is stopped, the planet would abruptly warm as greenhouse gases would still have increased. The restoration of the full amount of solar radiation to the lower atmosphere would lead to an abrupt catch up warming effect. The consequences of a sudden termination of geoengineering would lead to quasi-immediate temperature increases, reaching - within five years - up to 60 - 100% of the warming projected in a non-geoengineered world of equivalent levels of CO_2 concentrations.[6]

SRM does not address ocean acidification

Apart from leading to warming, rising CO_2 concentrations are also causing serious damage to the world oceans through ocean acidification. About 30% of current anthropogenic CO_2 emissions is absorbed by the oceans, in response to higher CO_2 concentrations in the atmosphere.

According to IPCC AR5, observed rates of acidification are unprecedented in the past 65, if not 300 million years[7]. The observed decrease by 0.1pH since pre-industrial values corresponds to a 26% increase in acidity. Emissions leading to more than 4°C warming are associated with a further decrease of 0.3 to 0.32 pH, or an increase in acidity by 100 to 110%.

As a result of anthropogenic CO_2 emissions, ocean acidification over the coming centuries could be higher than at any time in the past 300 million years. The net absorption - or uptake - of CO_2 by the oceans – and hence ocean acidification - will stop when the equilibrium is restored at the ocean's surface. Coral reefs, calcifying marine organisms and fish populations are projected to be adversely affected unless ocean acidification is halted and reversed. Solar radiation management scenarios will do nothing to address this "other CO_2 problem".[8] The impacts of ocean acidification over the coming decades will leave a substantial, adverse legacy in the marine environment for centuries.[9]

Effects of SRM on agriculture, food production and the natural carbon sink

Increasing atmospheric CO_2 concentrations are found to have a fertilising effect on many plants. This has led to the assertion that SRM could be beneficial for plant growth and agricultural productivity. However, it appears that damages due to scattering sunlight caused by solar radiation management are roughly equal in magnitude to benefits from cooling[8]. SRM would therefore attenuate little of the global agricultural damage from climate change[8].

Recently there have also been attempts - misleadingly in our view - to link SRM with mitigation related concepts like carbon budgets or carbon dioxide removal[9]. Such attempts are close to being disingenuous, given that SRM does not address the problem of increasing GHG concentrations and does not provide any permanency in solving the climate problem.

Solar radiation management cannot mask the full impacts of CO_2 and other greenhouse gas emissions on the climate

SRM would substantially affect the hydrological cycle as well as the atmospheric temperature profile. It would come with serious adverse consequences and risks, including regionally-changed precipitation patterns.[10] SRM would not halt ocean warming around Antarctica and would fail to counteract the increasing contribution of Antarctic melt to sea level rise.[11] At any temperature level, a world with solar radiation management would be different and much riskier than a world without it.[Error! Bookmark not defined.]

SRM would also alter the stratospheric chemistry and may delay the recovery of the Antarctic ozone hole by decades[12]. The avoided climate impacts under an SRM regime will be strongly regionally differentiated and vary with deployment level and total warming, and SRM itself is likely to have adverse effects on climate and weather in some regions. As SRM can be deployed variably, it is therefore most likely to become a source of massive conflict between nations to 'tune' the global climate according to their national priorities. And, once deployed and not banned completely, it would put the power of triggering a climate shock into the hands of single actors.

Risk of monsoon disruption

Agricultural economies, which mainly depend on seasonal monsoon rainfall, are very sensitive to any fluctuations in the usual seasonal patterns. These rains not only play a vital role in food security and exports, but also provide essential water for the very large, and often already vulnerable, populations.

A multi-model study based on highly idealised geoengineering experiment (G1) has projected reductions in seasonal rainfall over all the monsoon regions of the world as a result of geoengineering (in East Asia it could fall by 6%, in South Africa by 5%, in North America by 7%, and in South America by 6%).[13]

SRM deployment would most likely also cause fluctuations in onset of the monsoon, which is very important in deciding the fate of the seasonal yield of a particular crop.

Status of solar radiation management modelling experiments

The scientific modelling of SRM is still at a very early stage. Most studies are stand-alone in nature and by a limited number of scientists. Most of them- particularly multi-model inter-comparisons - are based on highly idealised scenarios reducing the incoming solar radiation.[14]

For more complex experiments (e.g. with the representation of sulphate aerosols in the stratosphere) only a few studies based on individual (or a few) models are available in the literature. Those that *are* available show a much higher inter-model uncertainty related to aerosol injection than for the highly idealised solar radiation experiment[15,16]. This is in line with the state of the science as reported in the IPCC AR5 that there are still very large uncertainties in atmospheric chemistry in relation to aerosols.[17] Furthermore, there may be very different circulation responses to aerosol injection and total solar irradiance. For example, reduced tropical precipitation has been reported as a result of aerosol injection that is not present in simplified irradiance reduction experiments[18].

There need to be substantial advances in our modelling capabilities - and analysis based on multiple atmospheric chemistry climate models is required to assess the full spectrum of uncertainties and risks related to atmospheric aerosol injection. This is in particular the case for proposed discussions on 'solar radiation management governance'[19] that appear to be based on public claims about limited risks and scientific certainty that are not backed by sufficient scientific evidence.

Reduction of solar energy resources

SRM may also undermine the potential of solar energy development, especially in the developing world, shielding solar radiation from reaching the earth's surface.
A recent study has pointed towards a potential decrease in solar power output of an average of 6% over land areas, with this reduction being the highest in tropical regions.[20] Solar power has become one of the cheapest electricity sources[21], and

projected will be one of the main drivers of a transition to zero carbon energy system. SRM could undermine and/or reduce the effectiveness and uptake of this mitigation technology. This fundamentally questions the argument from proponents of SRM that it would not undermine greenhouse gas mitigation.

Solar radiation management poses fundamental risks to global governance and cooperation

SRM cannot help achieve the Paris Agreement
The ultimate objective of the UNFCCC is to prevent dangerous anthropogenic interference with the climate system. Arguably, SRM represents such a dangerous interference with the climate system in itself and can thereby not be an option to achieve the purpose of the UNFCCC nor the Paris Agreement that establishes its purpose in *"enhancing the implementation of the Convention, including its objective "*[22].

Moreover, realising the serious risks and unresolved issues associated with SRM, the 193 countries at the UN Convention on Biological Diversity (CBD) established a de facto moratorium against most forms of geoengineering including all forms of SRM[23].

SRM risks becoming a major distraction from the main task of mitigation. A discussion on deployment of SRM at this stage would divert the attention of media, civil societies, governments and other stakeholder groups away from actions and policies to reduce emissions and implement the Paris Agreement. In others words promotion of SRM as a climate solution could adversely impact the progress towards achieving the Paris goals. In Australia the government has put resources into unproven geoengineering approaches for the 'protection' of the Great Barrier Reef[24] but has not taken any substantive action to reduce emissions.

Achieving the 1.5°C temperature limit of the Paris Agreement is feasible.
A major argument presented in favour of SRM is the claim that the Paris Agreement goals to limit the global temperature rise to 1.5°C is almost impossible to achieve. However, the recent IPCC Special Report on 1.5°C has shown how limiting warming to below 1.5°C can be achieved for different scenarios of future socio-economic development and based on a broad literature base[5].

Solar radiation management poses pivotal problems of intergenerational justice. SRM has a huge potential to serve as an excuse for inaction for climate deniers as well as for the governments not willing to reduce the carbon emissions. Thereby, it is shifting the burden to future generations. Techniques like solar radiation management have to be continuously sustained. If disrupted, very rapid and large-scale planetary warming will occur on a timescale of months. The impacts of such a "termination shock" would be much worse than the effects of climate change it aims to avoid. In addition, as SRM does not reduce CO_2 future generations would be effectively passed highly acid oceans which cannot be easily reversed, if at all, with large scale damages to marine ecosystems.

Solar radiation management implies massive future deployment of carbon dioxide removal technologies

In order to be able to safely terminate SRM, future generations will certainly need to deploy large scale carbon dioxide removal at massive scale. In combination with insufficient greenhouse gas mitigation, the scale of removal required would be substantially above levels implied by Paris Agreement 1.5°C compatible pathways.

Potential for weaponisation of solar radiation management

SRM will strongly alter the climate system producing 'winners' and 'losers' in different regions and with different levels of deployment. It could therefore become a source of massive conflict between nations[25]. If not banned completely, it would put the power of triggering a climate shock into the hands of single actors. Although the main aim of proposed SRM measures is to fight climate change, there is no guarantee that it will not be used for the purposes beyond that[26]. Therefore, it can have serious repercussions for global power balance, peace and security.

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