Silver Lining in the Clouds: Will the US Geoengineer?

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Once denounced by former United States (US) Vice President Al Gore as “delusional in the extreme”, solar geoengineering is receiving greater attention from American scientists and policymakers. Increasingly pessimistic as to the prospects of existing strategies for addressing climate change and mindful of America’s acute vulnerability to its effects, these voices are challenging taboos by exploring alternative solutions to global warming. Solar geoengineering (SG) is a category of climate interventions which would mask the effects of global warming by reflecting incoming solar radiation. Amongst these interventions, the technology attracting the most attention is stratospheric aerosol injections (SAI), which mimic the cooling impact of volcanoes by injecting reflective aerosol particles into the stratosphere. In recent years, however, marine cloud brightening (MCB) has emerged as a credible alternative to SAI (increasingly considered a blunt and unwieldy environmental tool). Deployed at scale, MCB would alter the energy balance of Earth by seeding seawater aerosol above the ocean to produce more reflective clouds.

To its critics, SG is an unhelpful distraction from climate mitigation which risks unintended and uneven global effects and a dangerous securitisation of the environment. However, in light of the continued failure of climate mitigation and America’s tradition of scientific leadership and self-professed “exceptionalism”, this article explores the circumstances in which the US would deploy MCB to mask the impact of global warming in the coming decades. Whilst MCB appears practically feasible for a state with America’s resources, it is unclear whether there will be sufficient domestic support for its deployment, and the response of the international community is contingent upon its perceived impacts which are presently difficult to predict. This article identifies three conditions for a sustained US deployment of MCB and considers the circumstances in which they may each be met, outlined in turn below.

The first condition to the US deployment of MCB is the emergence of a consensus that it could reduce US exposure to climate change more quickly and at a lower cost than conventional mitigation or adaptation. Because the debate on SG has outpaced practical research on the subject, evaluations of SG’s environmental impact and technical feasibility are usually premised upon the climate impact of historic volcanic eruptions, with the cooling effect of the 1991 eruption of Mount Pinatubo serving as the preeminent case-study for SAI. Natural analogues for MCB are harder to find, but the warming impact of reduced maritime emissions since 2020 has helped demonstrate the principle that increasing cloud-cover over the ocean reduces global temperatures by reflecting solar radiation. Although further research on MCB is required, existing research identifies four conclusions relevant to US assessment of its feasibility.

Applied at scale, SG (including MCB) would materially reduce the temperature of Earth within months of deployment, overcoming the collective action problems of climate mitigation without the time-lag inherent to adaptation. However, most studies also indicate that SG could interfere with Earth’s hydrological cycles, reducing net global rainfall while increasing the frequency of heavy precipitation events. Depending on where these effects were experienced, SG could therefore exacerbate the western states’ vulnerability to droughts, or increase the frequency of severe flooding in the south-east of the country. Further, since SG does nothing to reduce the concentration of greenhouse gases (GHGs) in the atmosphere, the abrupt cessation of SG without the development of negative emissions technology would trigger a “termination effect” as Earth’s energy balance returns to pre-deployment levels. SG would therefore pose an increasing security threat until carbon capture reduces the concentration of atmospheric GHGs, which may take many decades. At the outset, therefore, SG therefore provides US policymakers with an imperfect and incomplete solution to global warming.

MCB has several potential advantages over other forms of SG. Because the lifespan of seawater aerosol is measured in days, MCB deployment could be ceased without any material time-lag, increasing America's ability to control the intervention. This contrasts with SAI, where sulphur particles would remain in the stratosphere for around two years from release. Further, whereas the global impact of SAI prevents localized deployment, MCB could theoretically be applied forensically in vulnerable regions to prevent the occurrence of a climate tipping point. Whilst localized deployment may not materially reduce global temperature increases, an MCB intervention to reduce ice melt in the Arctic, for example, could slow sea level rises currently threatening the coastlines of Florida, New York and Louisiana in particular. Finally, research has suggested that MCB deployments could be used to disrupt the formation of cyclones. This could, in theory, mitigate against the risk of Atlantic hurricanes, which have cost the US economy USD 1.3 trillion since 1980. MCB therefore potentially provides a greater degree of controllability than other SG interventions, and may allow US policymakers to tailor the deployment to meet the country's evolving vulnerabilities.

The deployment of MCB may be relatively straightforward from a technical perspective. As noted by Salter the most appropriate delivery mechanism for MCB would be sea vessels spraying into the air a plume of fine saltwater to augment and whiten marine clouds. Although there remains some doubt as to the preferred size and quantity of these particles, nascent research from April 2024 indicates that this spray could be produced by a form of micro-fabrication lithography, which creates droplets by forcing saltwater through tiny-nozzled sprayers. These sprayers could be mounted onto conventional maritime shipping or bespoke unmanned vessels powered by wind-propelled "Flettner rotors". Calculations of the efficacy of these sprayers are usually premised upon the achievement of a radiative forcing sufficient to offset a doubling of atmospheric Co2, which would reduce global temperatures by 1.5-3°C. Studies suggest that this effect could be achieved by thousands of sprayers attached to 2,000 vessels navigating the Pacific and Atlantic oceans with 10 kilometre spacing.

The estimated annual cost of this scale of MCB deployment ranges from USD 5 billion (McNutt, 2015) to USD 40 billion – roughly equivalent to the estimated annual cost of SAI deployment. Despite the proliferation of American billionaire advocates of SG, this cost likely places MCB beyond the reach of private individuals. However, it constitutes a fraction of total US government expenditure in 2023 (USD 6.13 trillion) and less than 5% of the America's annual defence budget. Even as an ongoing cost, it is also vastly smaller than the US's estimated financial exposure to global warming in the next 50 years (USD 14.5 trillion), and at least 1,000 times cheaper than the estimated cost of carbon dioxide removal required to achieve the same cooling effect. Significantly, it is also a fraction of the USD 332 billion of oil and gas revenue earned by the US in 2022, which would need to plummet if the country's response to climate change was limited solely to climate mitigation. Although suggestions of the involvement of the military in SG deployment has alarmed some critics, the US Navy likely has significant capacity to coordinate and deploy MCB. Further, with open access to the world's two largest oceans and a huge military-industrial complex, the US is well-positioned geographically and structurally to undertake the intervention. Therefore, whilst further research on MCB is required, feasibility alone is unlikely to be a barrier to deployment, which may be significantly more affordable than alternative responses to climate change.

The second condition to the US deployment of MCB is a sufficient level of domestic support for the intervention. Of course, popular support is neither a necessary nor a sufficient condition for the making of policy, even in representative democracies. Nevertheless, empirical studies reveal that public opinion strongly influences policy, especially where the salience of an issue is high, and politicians are often responsive to public demands on climate change. In the case of MCB, the unprecedented nature of the deployment, together with its significant financial cost, is likely to heighten the salience of the public debate. Further, because MCB would need to be maintained in perpetuity until the atmospheric concentrations of GHGs can be reduced, its deployment would likely span several decades and need to survive repeated swings between Republican and Democratic administrations. Authorising the deployment of MCB would also likely require a filibuster-proof majority in the US Senate. Taken together, these factors indicate that sustained MCB deployment by the US would require a significant coalition of bipartisan support.

In a period of intense political polarisation, the achievement of a consensus over an issue as potentially divisive as SG appears challenging. Positions on climate are amongst the strongest indicators of political identity in the US which, along with guns and abortion, reflect "two Americas divided along ideological lines". Indeed, a significant

proportion of Republicans currently deny the very existence of anthropogenic climate change – usually considered a pre-requisite to support for SG. Moreover, since climate change is a subtle phenomenon to observe in abstract, populations rely upon second-hand information to understand its causes and effects. Given that the country's political polarisation is increasingly reflected in bifurcated news consumption, the very existence of support for SG from one party could feed suspicion from the other.

Although public awareness of SG within the US is currently low two factors may complicate this model of climate polarisation. Firstly, "left/right" polarisation may be less important in determining views on SG than a divide between "Prometheans" confident of humanity's ability to control nature and "Soterians" who are instinctively suspicious of "unnatural technological solutions and the hubris of mastery projects". In this political environment, conservative Republicans doubtful of mankind's contribution towards climate change may form an unlikely coalition with environmental activists who view SG as a dangerous distraction from climate change mitigation. Conversely, pragmatic Democrats eager to "buy time" for long-term climate solutions may align with corporatist Republicans who see in SG an opportunity to maintain existing economic structures. Indeed, a coalition in support of MCB deployment could include such diverse voices as former Republican House Speaker Newt Gingrich, who made the conservative case for SG deployment in 2008, and Democratic President Joe Biden, who authorized a report on SG in 2022. It is therefore possible that the politics of SG may transcend traditional political polarisation, enabling a wider potential coalition of support for MCB deployment.

Public support for SG may evolve considerably as the impacts of climate change are felt throughout the US. Significantly, while studies suggest that the risks from climate change are highly heterogenous across the US, Republican-dominated states such as Florida, Louisiana and Texas are amongst the most vulnerable to global warming in the coming decades. America's wealth will, of course, permit higher degrees of adaptation than is available in poorer countries. However, climate change will inevitably increase social and economic stresses across the south of the US, particularly amongst non-college educated voters who increasingly dominate the Republican coalition. Growing internal and external climate migration northwards could also significantly increase the salience of the climate debate in regions less directly impacted by global warming. If these developments contribute towards a heightened threat appraisal of climate change, protection motivation theory suggests that individuals will be more likely to support SG. Further, in the coming years, SG may be seen as a more palatable alternative to a dramatic programme of decarbonisation which may more directly impact day-to-day life. However, whilst stresses caused by extreme weather may increase climate risk perception in the US, widespread suspicion of central government and rejection of scientific authority may limit support for MCB deployment. A pathway to bipartisan support for MCB therefore exists, but is contingent upon a major shift in existing dynamics of climate policy.

The third and final condition to US deployment of MCB is the existence of a degree of support from the international community. This is not because the implementation costs of MCB require burden-sharing with other states: as we have seen, the US could likely deploy MCB for a fraction of its defence budget. Nor is it because there are significant legal barriers to the US's unilateral deployment of MCB. Emerging scholarship has persuasively demonstrated that SG deployment likely falls outside of existing international treaties and customary law, and the US could use its permanent seat on the United Nations Security Council to veto any resolution prohibiting MCB. Instead, MCB deployment would likely require some international support because, unlike other forms of SG such as SAI (which could be deployed from within the US itself), MCB requires the deployment of thousands of unmanned vessels across international waters, making it acutely vulnerable to attack.

Although scholars of international relations are underrepresented in the SG debate, observers have noted the potential for the unilateral deployment to heighten tensions between countries, or even spark war. Conversely, other scholars have suggested that SG could allow for minilateral cooperation between states with similar climate vulnerabilities. In either case, the international response to an American MCB deployment would likely depend on its perceived impact upon local environments around the world. If, as a number of studies suggest, MCB reduces precipitation in South America or Africa, it may generate coalitions opposing the intervention who may resort to extreme measures if their concerns are not addressed. On the other hand, if MCB reduces the frequency of heatwaves in China or India, the intervention may receive tacit support from those states. Crucially, however, uncertainty about causation could fuel accusations of responsibility for climate disasters regardless of whether they

were in fact caused by MCB.

Given the quasi-hegemonic power of the US military, it is arguable that an MCB deployment could initially be protected by the US without international partners. However, the continued protection of 2,000 unmanned vessels across a region spanning 50% of Earth's oceans would likely pose an unprecedented logistical challenge to a naval power already stretched between competing interests the Middle East, Asia and Europe. Sinking a Flettner rotor ship would be within the capabilities of most international militaries and many non-state actors, who may be able to disguise their actions or deny responsibility. Since the ships are expected to be unmanned, the question of defending MCB vessels or punishing interference would also test normative standards of the use of force and require US policymakers to confront difficult pathways to escalation. Continuously defending these assets from opposing states or non-state actors presents a profound challenge which may fundamentally change the cost assessment of the MCB deployment.

Support from traditional allies such as the UK may be sufficient to protect a more limited MCB deployment confined, for example, to the Arctic Sea. However, to sustain a prolonged deployment in the Pacific, the US would likely need to demonstrate responsible governance of the intervention to third powers such as China and India. This could involve, for example, the establishment of an independent authority to assess the global impact of MCB and make recommendations on the location and intensity of deployment. In canvassing international support for MCB, the US may also seek to deploy MCB's potential secondary function of MCB to prevent to disrupt cyclones off the coasts of vulnerable states. Successful deployment for these purposes would, however, accelerate attempts by other states to generate an independent MCB capability, threatening America's ability to control the climate unilaterally. As a result, the sustained deployment of MCB appears fraught with uncertainty and risk on the world stage, and may only prove possible if the US is willing to compromise a degree of its control over the technology in order to achieve international support.

In conclusion, despite growing calls for further research in SG, it remains taboo in many climate policy circles and lacks mainstream support in the US and abroad. Even amongst its advocates, SG continues to be implicitly envisaged as an act of multilateral decision-making, with much of the debate focused upon an audit of its uncertain global impacts. But as mitigation efforts continue to disappoint and predictions of warming pathways grow increasingly alarming, calls for the US to use its resources to unilaterally embark upon a programme of SG are likely to grow louder in coming decades. Given its potential advantages over other forms of SG, MCB may become increasingly central to this debate. However, as this article has explained, a sustained US deployment of MCB would require three conditions will need to be met. Firstly, research must demonstrate the practical feasibility of MCB and its ability to address America's primary climate vulnerabilities. Secondly, the emergence of a bipartisan political coalition in favour of MCB will be needed to maintain the deployment beyond one political cycle. Finally, a globalized MCB deployment would require acquiescence from key international stakeholders, whose opposition to the intervention would risk escalating the cost of MCB and exacerbating America's security challenges. Whilst the achievement of these conditions appears challenging in today's environment, further studies of MCB may fundamentally alter this balance as the impact of global warming becomes increasingly apparent.

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