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RESEARCH ARTICLE

Considering stratospheric aerosol injections beyond an environmental frame: The intelligible 'emergency' techno-fix and preemptive security

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Abstract

Stratospheric Aerosol Injection (SAI), is often referred to as a 'Plan B' if mitigation strategies to reduce emissions fail and the need to rapidly reduce global temperatures becomes urgent. In theory, SAI would help buy more time to bring carbon and other emissions down while also cooling or keeping the planet below the threshold for dangerous warming, though it is not a solution to the problem of climate change in itself. What little attention it has received in International Relations (IR) is usually focused on the need for governance of the technology and assumes that development and use of the technology will be driven primarily by vulnerability to climate impacts. Through an analysis of common security assumptions and preemptive security framings the article shows that while current assessments of SAI focus on the technology's environmental impact, broader political and security dynamics, particularly the desire to render climate change more intelligible as a security problem with a solution may have substantial influence on how the technology is used and by whom.

Keywords: Climate Emergency; Preemptive Security; Solar Geoengineering

Introduction

As the consequences of environmental degradation and climate change intensify, the search for potential solutions and adaptations accelerates. The political difficulties of reducing greenhouse gas emissions and keeping global temperature rise below a dangerous threshold[1] have increased interest in solar geoengineering as a technological intervention to keep global temperatures in check, particularly Stratospheric Aerosol Injection (SAI), which is the focus of this article. SAI involves spraying reflective particles into the stratosphere to partially block or reflect incoming solar radiation.[2] SAI has been posited as a 'Plan B', 'stopgap', or 'emergency' measure to buy time to

[1]Bentley B. Allan, 'Producing the climate: States, scientists, and the constitution of global governance objects', *International Organization*, 71:1 (2017), pp. 131–62, available at: {https://doi.org/10.1017/S0020818316000321}; Scott Hamilton, 'Action, technology, and the homogenisation of place: Why climate change is antithetical to political action', *Globalizations*, 13:1 (2 January 2016), pp. 62–77, available at: {https://doi.org/10.1080/14747731.2015.1040282}; Mike Hulme, *Why We Disagree About Climate Change: Understanding Controversy, Inaction and Opportunity* (Cambridge, UK: Cambridge University Press, 2009), available at: {https://doi.org/10.1017/CBO9780511841200}.

[2]Holly Jean Buck, *After Geoengineering: Climate Tragedy, Repair, and Restoration* (London, UK: Verso, 2019), p. 3; Mike Hulme, 'Climate change: Climate engineering through Stratospheric Aerosol Injection', *Progress in Physical Geography: Earth and Environment*, 36:5 (October 2012), pp. 694–705, available at: {https://doi.org/10.1177/0309133312456414}.

reduce atmospheric GHGs and complete a systemic energy transition away from fossil fuels.[3] On 25 March 2021 the United States (US) National Academies of Sciences, Engineering, and Medicine (NASEM) released their report on solar geoengineering research and research governance that recommended a $100–200 million dollar investment in the research from the US government over the next five years, which would represent a massive leap in governmental funding for such work,[4] the US Biden administration has announced a five-year research plan to study solar geoengineering,[5] and interest in the potential social and physical impacts of using SRM technologies has grown since the November 2021 United Nations Climate Change Conference (COP26) in Glasgow.[6] SRM strategies in general, and SAI technology in particular, present serious geopolitical and security challenges that demand the attention of the International Relations (IR) and security research community.

SAI and solar geoengineering technologies more broadly are currently viewed through a narrow environmental framing, which focuses on its potential effects on climate conditions. While climatological assessments of the technology are important, their domination of the literature leads to a blinkered analysis of the potential motivations and circumstances in which SAI might be used. The attention this technology has received in IR has primarily focused on the issue of governance.[7] While this work is valuable, and work by Olaf Corry, in particular, provides an excellent introduction into the under-examined security concerns that may create governance challenges for solar geoengineering,[8] I argue that there is a gap in the governance literature on the likely pathways for development and deployment of the technology that can be better filled by the insights of literature on security, particularly as it relates to emergency and preemption, and the security-technology nexus. Current literature focuses on actors that are heavily impacted by climate change as the most likely contenders to develop and use the technology;[9] I will show there is good reason to expect actors that are not necessarily experiencing the most immediate or severe climate

[3]Jeremy Baskin, *Geoengineering, the Anthropocene and the End of Nature* (Cham: Springer International Publishing, 2019), available at: {https://doi.org/10.1007/978-3-030-17359-3}; Holly Jean Buck et al., 'Evaluating the efficacy and equity of environmental stopgap measures', *Nature Sustainability*, 3:7 (July 2020), pp. 499–504, available at: {https://doi.org/10.1038/s41893-020-0497-6}; Nils Markusson et al., '"In case of emergency press here": Framing geoengineering as a response to dangerous climate change: Framing geoengineering as a response to dangerous climate change', *Wiley Interdisciplinary Reviews: Climate Change*, 5:2 (March 2014), pp. 281–90, available at: {https://doi.org/10.1002/wcc.263}.

[4]Committee on Developing a Research Agenda and Research Governance Approaches for Climate Intervention Strategies that Reflect Sunlight to Cool Earth et al., *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance* (Washington, DC: National Academies Press, 2021), available at: {https://doi.org/10.17226/25762}.

[5]Catherine Clifford, 'White House is pushing ahead research to cool Earth by reflecting back sunlight', *CNBC*, available at: {https://www.cnbc.com/2022/10/13/what-is-solar-geoengineering-sunlight-reflection-risks-and-benefits.html} accessed 20 November 2022.

[6]See, for example, the recently announced Climate Overshoot Commission, which brings together former heads of state, national ministers, and intergovernmental organisation directors to work with scientific experts to consider 'additional approaches' like solar geoengineering to bring down global temperatures. Overshoot Commission, 'Climate Overshoot Commission', available at: {https://www.overshootcommission.org} accessed 30 May 2022.

[7]Joshua B. Horton and Jesse L. Reynolds, 'The international politics of climate engineering: A review and prospectus for International Relations', *International Studies Review*, 18:3 (September 2016), pp. 438–61, available at: {https://doi.org/10.1093/isr/viv013}; Sikina Jinnah, 'Why govern climate engineering? A preliminary framework for demand-based governance', *International Studies Review*, 20:2 (1 June 2018), pp. 272–82, available at: {https://doi.org/10.1093/isr/viy022}.

[8]Olaf Corry, 'The international politics of geoengineering: The feasibility of Plan B for tackling climate change', *Security Dialogue*, 48:4 (August 2017), pp. 297–315, available at: {https://doi.org/10.1177/0967010617704142}.

[9]Felix Schenuit, Jonathan Gilligan, and Anjali Viswamohanan, 'A scenario of solar geoengineering governance: Vulnerable states demand, and act', *Futures*, 132 (September 2021), p. 102809, available at: {https://doi.org/10.1016/j.futures.2021.102809}; Zachary Dove, Joshua Horton, and Katharine Ricke, 'The middle powers roar: Exploring a minilateral solar geoengineering deployment scenario', *Futures*, 132 (1 September 2021), p. 102816, available at: {https://doi.org/10.1016/j.futures.2021.102816}; Anne Pasek et al., 'Reflections on a hypothetical decentralized grassroots deployment solar geoengineering scenario', *Futures*, 132 (1 September 2021), p. 102811, available at: {https://doi.org/10.1016/j.futures.2021.102811}; Edward A. Parson and Jesse L. Reynolds, 'Solar geoengineering governance: Insights from a scenario exercise', *Futures*, 132 (September 2021), p. 102805, available at: {https://doi.org/10.1016/j.futures.2021.102805}.

change consequences to pursue the development and use of SAI for security-political reasons. This is a planetary-level technological intervention. If experience with other planetary or extra-planetary level technologies such as nuclear weapons and the space race between the US and the Soviet Union are any indication, powerful actors may have an interest in developing the technology first and trying to assert control over its development and use.

In the article, I argue that there are under-considered political and security dynamics beyond potential climatological assessments of the technology that may enable the conditions for poorly governed SAI development and use. The first of these is that the nature of SAI as a technological intervention may help make climate change more intelligible as a political problem, which in turn may make climate change more politically actionable. This may be especially relevant for actors that have been relatively insulated from the impacts of climate change to this point. The second of these is that the increasingly common framing of climate change as an emergency may align climate interventions like SAI with preemptive security logics in which emergency measures are taken to manage threats without adequate consideration of the potential consequences, and which may involve a race to control a planetary-level technological intervention. After an overview of solar geoengineering and the risks and political challenges posed by SAI, I will examine why climate change has not triggered sustained, effective political action despite increasingly frequent and insistent 'climate emergency' framings. I will then use literature on techno-politics and path-dependencies to show how SAI can render climate change as a more politically legible and actionable problem. I will then use insights from work in security studies to explore how preemptive security framings may lead to rapid development and deployment of SAI without adequate governance measures in response to a supposed emergency situation.[10] In a preemptive security context, the efficacy and safety of SAI technology would not be integral to decisions made about its use; I will argue that the existence of the technology itself may create justification for its deployment regardless of international objections and whether any scientifically determined threshold of climate emergency is met. The key intervention of the article is an alternative assessment of the political conditions and security motivations that inform how and why the technology may be developed and deployed beyond or apart from climatological considerations.

Stratospheric Aerosol Injection: A dangerous idea whose time has come?

Geoengineering is the use of different technologies to intervene in the climate to mitigate the effects of greenhouse gas emissions and global warming. Geoengineering is usually divided into two subcategories: Carbon Dioxide Removal (CDR) and Solar Radiation Management (SRM). CDR strategies are often considered as a key part of any emissions mitigation plans but are not sufficient on their own because of the scale and time required for them to work. They are controversial in their own right due to the speculative nature of carbon capture and sequestration technologies,[11] the problem of land-use changes associated with CDR strategies such as large-scale tree planting,[12]

[10]Claudia Aradau and Rens van Munster, *Politics of Catastrophe: Genealogies of the Unknown*, PRIO New Security Studies (London, UK and New York, NY: Routledge, 2011); Marieke de Goede, Stephanie Simon, and Marijn Hoijtink, 'Performing preemption', *Security Dialogue*, 45:5 (October 2014), pp. 411–22, available at: {https://doi.org/10.1177/0967010614543585}; Marieke De Goede, 'Beyond risk: Premediation and the post-9/11 security imagination', *Security Dialogue*, 39:2–3 (April 2008), pp. 155–76, available at: {https://doi.org/10.1177/0967010608088773}; Marieke de Goede and Samuel Randalls, 'Precaution, preemption: Arts and technologies of the actionable future', *Environment and Planning D: Society and Space*, 27:5 (October 2009), pp. 859–78, available at: {https://doi.org/10.1068/d2608}; Melinda Cooper, 'Pre-empting emergence: The biological turn in the War on Terror', *Theory, Culture & Society*, 23:4 (July 2006), pp. 113–35, available at: {https://doi.org/10.1177/0263276406065121}.

[11]Thierry J. Courvoisier, European Academies Science Advisory Council, and Deutsche Akademie der Naturforscher Leopoldina (eds), *Negative Emission Technologies: What Role in Meeting Paris Agreement Targets?*, EASAC Policy Report 35 (Halle (Saale): EASAC Secretariat, Deutsche Akademie der Naturforscher Leopoldina, 2018), pp. 29–33.

[12]Duncan Brack and Richard King, 'Managing land-based CDR: BECCS, forests and carbon sequestration: Managing land-based CDR', *Global Policy* (6 September 2020), available at: {https://doi.org/10.1111/1758-5899.12827}.

and the inefficacy and potential counterproductivity of ocean fertilisation.[13] SRM strategies seek to minimise the amount of incoming solar radiation in order to mask the effect of greenhouse gas emissions and lower global temperatures.[14]

SAI, the focus of this article, is viewed as the most immediately effective geoengineering strategy for rapidly cooling global temperatures by a growing number of scientists, advocates, and policymakers,[15] and there is growing momentum around the development and use of solar geoengineering.[16] Proponents argue that SAI would help buy more time to bring carbon and other emissions down while keeping the planet below the threshold for dangerous warming.[17] Although it has long had advocates, especially in the US, SAI has moved steadily up the climate agenda since 2006 when prominent climate scientist Paul Crutzen argued that it may be necessary to consider SAI and other forms of solar geoengineering due to the lack of substantial effort to prevent further climate degradation through greenhouse gas mitigation.[18] Advocates for SAI research claim it is a relatively cheap, rapidly effective means of cooling global temperatures, thus addressing the most immediate consequence of climate change,[19] and that it may be a necessary humanitarian response to the rapidly intensifying consequences of global temperature rise.[20] The key argument is that SAI simply provides more time to engage in vital mitigation efforts, arresting the worst consequences of increasing temperatures, while fossil fuels are phased out and carbon is drawn out of the atmosphere.[21]

However, solar geoengineering has yet to be widely embraced by either scientists or policymakers because interfering with or altering the Earth's solar radiation balance is undeniably dangerous, with serious potential environmental consequences, and may be politically and socially destabilising.[22] SAI researchers sometimes minimise the expected consequences of the

[13]Phillip Williamson et al., 'Ocean fertilization for geoengineering: A review of effectiveness, environmental impacts and emerging governance', *Process Safety and Environmental Protection*, 90:6 (November 2012), pp. 475–88, available at: {https://doi.org/10.1016/j.psep.2012.10.007}.

[14]Baskin, *Geoengineering, the Anthropocene and the End of Nature*, p. 6.

[15]David Keith, 'Climate Engineering, No Longer on the Fringe | Harvard John A. Paulson School of Engineering and Applied Sciences', available at: {https://www.seas.harvard.edu/news/2015/02/climate-engineering-no-longer-fringe} accessed 26 October 2020; Douglas G. MacMartin, Katharine L. Ricke, and David W. Keith, 'Solar geoengineering as part of an overall strategy for meeting the 1.5°C Paris target', *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 376:2119 (13 May 2018), p. 20160454, available at: {https://doi.org/10.1098/rsta.2016.0454}; David Keith, *A Case for Climate Engineering* (Cambridge, MA: The MIT Press, 2013).

[16]Jeff Tollefson, 'First sun-dimming experiment will test a way to cool Earth', *Nature*, 563:7733 (27 November 2018), pp. 613–15, available at: {https://doi.org/10.1038/d41586-018-07533-4}; Peter Irvine et al., 'Halving warming with idealized solar geoengineering moderates key climate hazards', *Nature Climate Change*, 9:4 (April 2019), pp. 295–99, available at: {https://doi.org/10.1038/s41558-019-0398-8}; MacMartin, Ricke, and Keith, 'Solar geoengineering as part of an overall strategy for meeting the 1.5°C Paris target'; David G. Victor et al., 'The geoengineering option', *Foreign Affairs* (n.d.), p. 5.

[17]David W. Keith and Douglas G. MacMartin, 'A temporary, moderate and responsive scenario for solar geoengineering', *Nature Climate Change*, 5:3 (March 2015), pp. 201–6, available at: {https://doi.org/10.1038/nclimate2493}; MacMartin, Ricke, and Keith, 'Solar geoengineering as part of an overall strategy for meeting the 1.5°C Paris target'; Lee Lane, Ken Caldeira, and Stephanie Langhoff, 'Workshop Report on Managing Solar Radiation' (2007), p. 40.

[18]Paul J. Crutzen, 'Albedo enhancement by Stratospheric Sulfur Injections: A contribution to resolve a policy dilemma?', *Climatic Change*, 77:3–4 (1 September 2006), pp. 211–20, available at: {https://doi.org/10.1007/s10584-006-9101-y}.

[19]Scott Barrett, 'The incredible economics of geoengineering', *Environmental and Resource Economics*, 39:1 (January 2008), pp. 45–54, available at: {https://doi.org/10.1007/s10640-007-9174-8}.

[20]'Climate Futures Series – The Rise of Geoengineering and Its Potential Impacts for the Humanitarian Sector | The Keith Group', available at: {https://keith.seas.harvard.edu/file/812826} accessed 15 February 2021; 'The Climate Emergency, Intersectional Justice, and the Urgency of Solar Geoengineering Research', available at: {https://geoengineering.environment.harvard.edu/blog/climate-emergency-intersectional-justice-and-urgency-solar-geoengineering-research} accessed 6 April 2021.

[21]Shepherd, *Geoengineering the Climate*, p. 45; Corry, 'The international politics of geoengineering', pp. 299–300.

[22]Anna Lou Abatayo et al., 'Solar geoengineering may lead to excessive cooling and high strategic uncertainty', *Proceedings of the National Academy of Sciences*, 117:24 (16 June 2020), pp. 13393–8, available at: {https://doi.org/10.1073/pnas.1916637117}; Jennie C. Stephens and Kevin Surprise, 'The hidden injustices of advancing solar geoengineering research', *Global Sustainability*, 3 (2020), p. e2, available at: {https://doi.org/10.1017/sus.2019.28}; Alan Robock, Kirsten Jerch, and Martin Bunzl,

technology,[23] however, the historical evidence from large-scale volcanic eruptions, which are used as proof-of-concept for SAI,[24] indicate that such interventions could be massively disruptive in terms of weather patterns and food production, leading to drought, crop failures, and other problems.[25] SAI without carbon removal or emissions reduction would not address the growing problem of ocean acidification, which has a number of effects including coral bleaching and disruption or devastation of ocean-based food production and biodiversity through deoxygenation of the oceans.[26] Depending on the aerosol used for SAI, it may, in fact, exacerbate the problem of ocean acidification and contribute to increased pollution, which will in turn increase pollution related deaths and the hole in the ozone layer.[27] There are also concerns that without reduction in carbon in the atmosphere the nutritional content and quality of food will be lowered and agricultural yields will be affected,[28] rainfall patterns will be disrupted,[29] and new research indicates it may substantially increase the incidence of malaria in regions that do not currently experience high case rates.[30] In addition to these biophysical risks, if extensive SAI is undertaken without a corresponding reduction of carbon in the atmosphere through mitigation strategies, then it can never be safely stopped because of the possibility of termination shock – shooting sulfates or other compounds into the atmosphere would have to continue without interruption unless and until atmospheric carbon and other greenhouse gases were reduced.[31] Large-scale SAI termination without carbon reduction would lead to significant and rapid temperature rises it would not be possible to adapt to because of the compressed timescale.[32]

Proponents of SAI geoengineering research argue that climate models suggest that careful calibration of SAI led by scientific expertise would minimise these problems[33] but there is dispute

'20 reasons why geoengineering may be a bad idea', *Bulletin of the Atomic Scientists*, 64:2 (May 2008), pp. 14–59, available at: {https://doi.org/10.1080/00963402.2008.11461140}.

[23]Keith and MacMartin, 'A temporary, moderate and responsive scenario for solar geoengineering'; Andy Parker and Peter J. Irvine, 'The risk of termination shock from solar geoengineering', *Earth's Future*, 6:3 (March 2018), pp. 456–67, available at: {https://doi.org/10.1002/2017EF000735}.

[24]Jihong Cole-Dai, 'Volcanoes and climate: Volcanoes and climate', *Wiley Interdisciplinary Reviews: Climate Change*, 1:6 (November 2010), pp. 824–39, available at: {https://doi.org/10.1002/wcc.76}.

[25]G. D. Wood, *Tambora: The Eruption that Changed the World* (Princeton, NJ: Princeton University Press, 2014); Cole-Dai, 'Volcanoes and climate'; Robock, Jerch, and Bunzl, '20 reasons why geoengineering may be a bad idea'.

[26]Robock, Jerch, and Bunzl, '20 reasons why geoengineering may be a bad idea'.

[27]Barry Goldstein, Peter Kobos, and Patrick Brady, 'Unintended Consequences of Atmospheric Injection of Sulphate Aerosols' (1 October 2010), pp. 10–14, available at: {https://doi.org/10.2172/1000289}.

[28]Kristie L. Ebi and Irakli Loladze, 'Elevated atmospheric CO2 concentrations and climate change will affect our food's quality and quantity', *The Lancet Planetary Health*, 3:7 (July 2019), pp. e283–84, available at: {https://doi.org/10.1016/S2542-5196(19)30108-1}; Kristie L. Ebi and Lewis H. Ziska, 'Increases in atmospheric carbon dioxide: Anticipated negative effects on food quality', *PLOS Medicine*, 15:7 (3 July 2018), p. e1002600, available at: {https://doi.org/10.1371/journal.pmed.1002600}; Chunwu Zhu et al., 'Carbon dioxide (CO_2) levels this century will alter the protein, micronutrients, and vitamin content of rice grains with potential health consequences for the poorest rice-dependent countries', *Science Advances*, 4:5 (May 2018), p. eaaq1012, available at: {https://doi.org/10.1126/sciadv.aaq1012}.

[29]Jim M. Haywood et al., 'Asymmetric forcing from Stratospheric Aerosols impacts Sahelian rainfall', *Nature Climate Change*, 3:7 (July 2013), pp. 660–65, available at: {https://doi.org/10.1038/nclimate1857}.

[30]Colin J. Carlson et al., 'Solar geoengineering could redistribute malaria risk in developing countries', *Nature Communications*, 13:1 (December 2022), p. 2150, available at: {https://doi.org/10.1038/s41467-022-29613-w}.

[31]Susanne Baur, Alexander Nauels, and Carl-Friedrich Schleussner, 'Deploying Solar Radiation Modification to Limit Warming under a Current Climate Policy Scenario Results in a Multi-Century Commitment', preprint (Management of the Earth System: Engineering Responses to Climate Change, 29 April 2022), available at: {https://doi.org/10.5194/esd-2022-17}; Seth D. Baum, Timothy M. Maher, and Jacob Haqq-Misra, 'Double catastrophe: Intermittent stratospheric geoengineering induced by societal collapse', *Environment Systems & Decisions*, 33:1 (March 2013), pp. 168–80, available at: {https://doi.org/10.1007/s10669-012-9429-y}; Parker and Irvine, 'The risk of termination shock from solar geoengineering'.

[32]Florian Rabitz, 'Governing the termination problem in solar radiation management', *Environmental Politics*, 28:3 (16 April 2019), p. 503, available at: {https://doi.org/10.1080/09644016.2018.1519879}.

[33]Jesse L. Reynolds, Andy Parker, and Peter Irvine, 'Five solar geoengineering tropes that have outstayed their welcome: Five solar geoengineering tropes', *Earth's Future*, 4:12 (December 2016), pp. 562–68, available at: {https://doi.org/10.1002/2016EF000416}; Jesse L. Reynolds, *The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene*

about the accuracy of these models and the assumptions that inform them.[34] The argument that the termination problem will not happen rests on particularly shaky ground, assuming that emissions reductions will take place[35] and that the use of SAI will be carefully governed and calibrated.[36] However, the assumption that SAI would buy time to bring down emissions is itself a gamble that pays inadequate attention to the possibility of mitigation deterrence. Mitigation deterrence is the idea that promises of either carbon removal or the rapid cooling prospects of SAI could create an excuse to delay or avoid cutting emissions.[37] SAI geoengineering would rapidly cool global temperatures and therefore make the problem of global warming less of an immediate threat, which may in turn reduce structural incentives to lower emissions. The prospect of future SAI that can create rapid cooling may displace near-term emissions cuts because they are perceived as too costly and less necessary or urgent. Even optimistic assessments of SAI raise this possibility. Economist Scott Barrett, for example, argues that relative to emissions reduction or rapidly restructuring the economy away from fossil fuels, SAI provides the 'incredible economics' of an extremely cheap alternative strategy.[38] A recent assessment argues that deployment due to scenarios in which current efforts to hold warming to 1.5 degrees fail, which is likely, would entail multi-century commitments to solar geoengineering use and its exposure to its attendant risks due to decreased motivation to bring down greenhouse gas emissions.[39]

In any case, managing and constraining the risks of the technology is dependent on international political stability and effective governance, which are far from given during this period of disruption in international order that has placed stress on extant global governance regimes,[40] and created barriers to cooperation in developing new governance regimes.[41] Researchers have suggested that SAI can follow the governance map provided by arms control regimes or the UN

(1st edn, Cambridge, UK: Cambridge University Press, 2019), available at: {https://doi.org/10.1017/9781316676790}; Joshua B. Horton et al., 'Solar geoengineering and democracy', *Global Environmental Politics*, 18:3 (August 2018), pp. 5–24, available at: {https://doi.org/10.1162/glep_a_00466}.

[34]Sean Low and Matthias Honegger, 'A precautionary assessment of systemic projections and promises from sunlight reflection and carbon removal modeling', *Risk Analysis* (28 July 2020), risa.13565, available at: {https://doi.org/10.1111/risa.13565}. For examples of how ideal assumptions inform modelling outcomes, see Daniele Visioni, Douglas G. MacMartin, and Ben Kravitz, 'Is turning down the Sun a good proxy for stratospheric sulfate geoengineering?', *Journal of Geophysical Research: Atmospheres*, 126:5 (2021), p. e2020JD033952, available at: {https://doi.org/10.1029/2020JD033952}; Irvine et al., 'Halving warming with idealized solar geoengineering moderates key climate hazards'; Daniele Visioni et al., 'Seasonal injection strategies for Stratospheric Aerosol Geoengineering', *Geophysical Research Letters*, 46:13 (2019), pp. 7790–99, available at: {https://doi.org/10.1029/2019GL083680}.

[35]Douglas G. MacMartin, Ken Caldeira, and David W Keith, 'Solar geoengineering to limit the rate of temperature change', *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences* A, 372: 20140134 (2014), p. 13; Elnaz Roshan, Mohammad M. Khabbazan, and Hermann Held, 'Cost-risk trade-off of mitigation and solar geoengineering: Considering regional disparities under probabilistic climate sensitivity', *Environmental and Resource Economics*, 72:1 (January 2019), pp. 263–79, available at: {https://doi.org/10.1007/s10640-018-0261-9}.

[36]Parker and Irvine, 'The risk of termination shock from solar geoengineering'; Reynolds, Parker, and Irvine, 'Five solar geoengineering tropes that have outstayed their welcome'; Reynolds, *The Governance of Solar Geoengineering*; Low and Honegger, 'A precautionary assessment of systemic projections and promises from sunlight reflection and carbon removal modeling'; Keith and MacMartin, 'A temporary, moderate and responsive scenario for solar geoengineering'.

[37]'Carbon Removal'; Duncan McLaren, 'Mitigation deterrence and the "moral hazard" of solar radiation management: Mitigation deterrence and the moral hazard of SRM', *Earth's Future*, 4:12 (December 2016), pp. 596–602, available at: {https://doi.org/10.1002/2016EF000445}.

[38]Barrett, 'The incredible economics of geoengineering'.

[39]Baur, Nauels, and Schleussner, 'Deploying Solar Radiation Modification to Limit Warming under a Current Climate Policy Scenario Results in Multi-Century Commitment'.

[40]Stewart Patrick, 'When the system fails', *Foreign Affairs* (3 August 2020), available at: {https://www.foreignaffairs.com/articles/world/2020-06-09/when-system-fails}; Beate Jahn, 'Liberal internationalism: Historical trajectory and current prospects', *International Affairs*, 94:1 (1 January 2018), pp. 43–61, available at: {https://doi.org/10.1093/ia/iix231}; Tony Barber, 'The three clear threats to limits on nuclear arms control', *Financial Times* (14 January 2020), available at: {https://www.ft.com/content/474334fc-178c-11ea-b869-0971bffac109}.

[41]Michael C. Horowitz, 'World War AI', *Foreign Policy* (blog), available at: {https://foreignpolicy.com/2018/09/12/will-the-united-states-lose-the-artificial-intelligence-arms-race/} accessed 21 October 2020.

Security Council.[42] Yet the governance of existing and emerging technologies is under pressure and there are increasing concerns over a collapsing liberal international order,[43] while the efficacy of previous arms control regimes has been thrown into doubt on their own terms.[44] In addition, as Corry and Duncan McLaren have pointed out, the idea that coming to an international agreement on the use of geoengineering technology would somehow be easier than coming to an international agreement on mitigating emissions is difficult to support.[45]

The potential problems posed by SAI noted above present serious enough challenges in themselves, but SAI raises additional political and security issues that may make the technology as difficult to govern as emissions mitigation. For example, it has been argued that states may attribute any severe weather effects to SAI whether SAI were the cause or not, and that it would be difficult to differentiate whether SAI or climate change itself caused catastrophic weather events or other side effects like drought.[46] Actors could be led to engage in 'counter-geoengineering' to disrupt SAI in order to reverse real or perceived consequences of SAI, such as disruption to monsoon patterns, increased droughts, or flooding.[47] This could lead to a breakdown in cooperation on which both SAI and avoiding the termination problem of SAI depend. Other events or factors could lead to a dangerous disruption of SAI include wars and disasters like pandemics, earthquakes, and tsunamis that contribute to political upheaval or collapse.[48] Given the strain COVID-19 has placed on international political, social, and economic structures, such factors should not be easily dismissed.[49]

Despite these problems, there is still a reasonable case for research on and potential use of SAI. According to the Degrees Initiative, formerly the SRM Governance Initiative, 'SRM is the only known way to quickly stop or reverse the rise in global temperatures, and could be the only way to keep warming below 2°C if emissions cuts and carbon removal prove insufficient.'[50] It may be

[42]Elizabeth L. Chalecki and Lisa L. Ferrari, 'A New Security Framework for Geoengineering' (2018), p. 25; Reynolds, *The Governance of Solar Geoengineering*, pp. 209–11; Joshua Reynolds, 'The international regulation of climate engineering: Lessons from nuclear power', *Journal of Environmental Law*, 26:2 (1 July 2014), pp. 269–89, available at: {https://doi.org/10.1093/jel/equ006}.

[43]Trine Flockhart, 'Is this the end? Resilience, ontological security, and the crisis of the liberal international order', *Contemporary Security Policy*, 41:2 (2 April 2020), pp. 215–40, available at: {https://doi.org/10.1080/13523260.2020.1723966}; Jahn, 'Liberal internationalism'.

[44]'How Divergent Views on Nuclear Disarmament Threaten the NPT | Arms Control Association', available at: {https://www.armscontrol.org/act/2013-12/divergent-views-nuclear-disarmament-threaten-npt} accessed 26 October 2020; Lukasz Kulesa, 'The crisis of nuclear arms control and its impact on European Security', *EU Non-Proliferation and Disarmament Consortium*, No. 66 (January 2020), pp. 1–16.

[45]Duncan McLaren and Olaf Corry, 'Clash of geofutures and the remaking of planetary order: Faultlines underlying conflicts over geoengineering governance', *Global Policy* (23 January 2021), p. 1758-5899.12863, available at: {https://doi.org/10.1111/1758-5899.12863}; Corry, 'The international politics of geoengineering'.

[46]Corry, 'The international politics of geoengineering', p. 306; Simon Dalby, 'Geoengineering: The next era of geopolitics?: Geoengineering: The next era of geopolitics?', *Geography Compass*, 9:4 (April 2015), pp. 190–201, available at: {https://doi.org/10.111}; Paul Nightingale and Rose Cairns, 'The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure', Climate Geoengineering Governance Working Paper Series (November 2014).

[47]Abatayo et al., 'Solar geoengineering may lead to excessive cooling and high strategic uncertainty'; A. Parker, J. B. Horton, and D. W. Keith, 'Stopping solar geoengineering through technical means: A preliminary assessment of counter-geoengineering', *Earth's Future*, 6:8 (August 2018), pp. 1058–65, available at: {https://doi.org/10.1029/2018EF000864}; Muhammet A. Bas and Aseem Mahajan, 'Contesting the climate: Security implications of geoengineering', *Climatic Change*, 162:4 (October 2020), pp. 1985–2002, available at: {https://doi.org/10.1007/s10584-020-02758-7}; Scott Barrett, 'Solar geoengineering's brave new world: Thoughts on the governance of an unprecedented technology', *Review of Environmental Economics and Policy*, 8:2 (1 July 2014), p. 256, available at: {https://doi.org/10.1093/reep/reu011}; Corry, 'The international politics of geoengineering', p. 306.

[48]Baum, Maher, and Haqq-Misra, 'Double catastrophe'.

[49]Aaron Tang and Luke Kemp, 'A fate worse than warming? Stratospheric Aerosol Injection and global catastrophic risk', *Frontiers in Climate*, 3 (19 November 2021), 720312, p. 7, available at: {https://doi.org/10.3389/fclim.2021.720312}.

[50]'What Is SRM?', *The DEGREES Initiative* (blog), available at: {https://www.degrees.ngo/what-is-srm/} accessed 31 May 2022.

the case that the consequences of worsening climate change outweigh the potential risks of SAI.[51] However, to truly understand if the potential benefits of SAI outweigh the risks it is essential to have a comprehensive understanding of its risks and the conditions under which it might be used. Stumbling into SAI use as a matter of 'last resort' or 'emergency' without effective governance has the potential to lead to nightmarish unintended consequences. In the following section, I will examine how the increasingly common emergency framing of climate change contrasts with the lack of sustained, effective political action to address it, and how SAI might enable political action because it makes climate change more intelligible as a political problem. I will then turn to how preemptive security logics may shape the development and use of SAI.

Making climate change intelligible to states: Emergency framing, security, and the technopolitics of SAI

There is widespread recognition that climate change is a serious problem and the language of 'climate emergency' has become more prevalent.[52] For example, in response to a recent IPCC climate report, UN Secretary General António Guterres said 'We are on a fast track to climate disaster. Major cities under water. Unprecedented heatwaves. Terrifying storms. Widespread water shortages. The extinction of a million species of plants and animals … We are on a pathway to global warming of more than double the 1.5°C limit agreed in Paris … This is a climate emergency',[53] and referred to the report as a 'code red for humanity'.[54] Even wealthy states that have been relatively insulated from the worst impacts of climate change have embraced the emergency framing. US President Biden, in his remarks after touring the damage caused by Hurricane Ida in 2021, stated that, 'Climate change poses an existential threat to our lives, to our economy … this is Code Red; the nation and the world are in peril. And that's not hyperbole. That is a fact.'[55] In the lead up to the COP26 climate summit in Glasgow, then UK Prime Minister Boris Johnson warned, 'Humanity has long since run down the clock on climate change … It's one minute to midnight on that doomsday clock and we need to act now.'[56] Yet, despite this emergency framing, sustained and extensive efforts to address climate change at both the national and international level have been lacking. Designating a problem as a security threat is a fraught process,[57] but it is also a means of signalling the seriousness of an issue. Climate change has been identified as 'threat multiplier'[58] that intensifies or worsens other security problems such as conflict and migration that threaten

[51]Tang and Kemp, 'A fate worse than warming?', p. 13; 'No, We Shouldn't Just Block Out the Sun', Gizmodo (24 April 2020), available at: {https://gizmodo.com/no-we-shouldnt-just-block-out-the-sun-1843043812}.

[52]Mike Hulme, 'Climate Emergency Politics Is Dangerous', *Issues in Science and Technology* (blog) (9 December 2019), available at: {https://issues.org/climate-emergency-politics-is-dangerous/}; William J. Ripple et al., 'World scientists' warning of a climate emergency', *BioScience* (5 November 2019), biz088, available at: {https://doi.org/10.1093/biosci/biz088}; 'The Climate Emergency, Intersectional Justice, and the Urgency of Solar Geoengineering Research'.

[53]'Secretary-General Warns of Climate Emergency, Calling Intergovernmental Panel's Report "a File of Shame", While Saying Leaders "Are Lying", Fuelling Flames | Meetings Coverage and Press Releases', available at: {https://www.un.org/press/en/2022/sgsm21228.doc.htm} accessed 31 May 2022.

[54]United Nations Western Europe, 'Guterres: The IPCC Report Is a Code Red for Humanity' (9 August 2021), available at: {https://unric.org/en/guterres-the-ipcc-report-is-a-code-red-for-humanity/}.

[55]The White House, 'Remarks by President Biden on the Administration's Response to Hurricane Ida' (7 September 2021), available at: {https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/09/07/remarks-by-president-biden-on-the-administrations-response-to-hurricane-ida-2/}.

[56]Sam Meredith, 'Boris Johnson warns it's "one minute to midnight" to prevent climate catastrophe', CNBC (1 November 2021), available at: {https://www.cnbc.com/2021/11/01/cop26-boris-johnson-says-one-minute-to-midnight-amid-climate-crisis.html}.

[57]Maria Julia Trombetta, 'Environmental security and climate change: Analysing the discourse', *Cambridge Review of International Affairs*, 21:4 (December 2008), pp. 585–602, available at: {https://doi.org/10.1080/09557570802452920}; Maria Julia Trombetta, 'Rethinking the securitization of the environment: Old beliefs, new insights', *Securitization Theory* (London, UK: Routledge, 2010).

[58]Chad Michael Briggs, 'Climate security, risk assessment and military planning', *International Affairs*, 88:5 (September 2012), p. 1049, available at: {https://doi.org/10.1111/j.1468-2346.2012.01118.x}.

sovereign states, and there have been substantial efforts to understand climate change as a security problem, particularly from a critical perspective,[59] but there is still a struggle to mobilise political action by bringing security discourses to bear on the problem. 'Climate change represents an "avoidable catastrophe", but its sheer immensity causes distrust in political action, and hence prevents it from resulting in exceptional measures.'[60] The long temporal horizon, scale, and multifarious nature of climate change consequences has led it to be treated more as a series of risks to be managed rather than as an urgent or emergency situation.[61] This in itself is not necessarily a bad thing. Prominent security thinkers such as Daniel Deudney,[62] Simon Dalby,[63] and Jon Barnett[64] have argued strongly against approaching or thinking about environmental degradation as a security threat. This is not least because security approaches do not address the underlying causes of environmental degradation and in fact may make the problem(s) of environmental degradation worse if they promote militarised responses because of the adverse ecological impacts associated with both military operations and the development and maintenance of military capabilities.[65] In addition, security discourses tend to reproduce a sense of the primary importance of the survival of the state and the maintenance of sovereignty over the territory of the state,[66] because 'at its core, the politics of security is obsessed with the survival of the sovereign.'[67] This in turn is an obstacle to the reorganisation of political practices and relations that environmental degradation demands because environmental problems are ultimately driven by political and economic practices and problems.[68] Even ecological security approaches that are more aware and critical of human embeddedness with the environment do not adequately account for the ways that the modern political system and subjects within it contribute to environmental degradation because of the lack of attention paid to 'complex inequalities' that constitute the modern international system,[69]

[59]Matt McDonald, 'Climate change and security: Towards ecological security?', *International Theory*, 10:2 (July 2018), pp. 153–80, available at: {https://doi.org/10.1017/S1752971918000039}; Olaf Corry, 'Securitisation and "riskification": Second-order security and the politics of climate change', *Millennium: Journal of International Studies*, 40:2 (January 2012), pp. 235–58, available at: {https://doi.org/10.1177/0305829811419444}; Rita Floyd, *Security and the Environment: Securitisation Theory and US Environmental Security Policy* (Cambridge, UK: Cambridge University Press, 2010).

[60]Chris Methmann and Delf Rothe, 'Politics for the day after tomorrow: The logic of apocalypse in global climate politics', *Security Dialogue*, 43:4 (August 2012), p. 333, available at: {https://doi.org/10.1177/0967010612450746}.

[61]Ibid.

[62]See especially, Daniel Deudney, 'The case against linking environmental degradation to national security', *Millennium Journal of International Studies*, 19:3 (1990), pp. 461–76.

[63]Simon Dalby, *Security and Environmental Change* (Cambridge, UK: Polity Press, 2010).

[64]Jon Barnett, *The Meaning of Environmental Security: Ecological Politics and Policy in the New Security Era* (London, UK: Zed Books, 2001).

[65]Deudney, 'The case against linking environmental degradation to nationals security'; Oliver Belcher et al., '"Hidden carbon costs of the "everywhere war": Logistics, geopolitical ecology, and the carbon boot-print of the US military', *Transactions of the Institute of British Geographers*, 45:1 (March 2020), pp. 65–80, available at: {https://doi.org/10.1111/tran.12319}; Matthias Finger, 'Global environmental degradation and the military', in Jyrki Kakonen (ed.), *Green Security or Militarized Environment* (Aldershot, UK: Dartmouth, 1994), pp. 169–91; Maximilian Mayer, 'Chaotic climate change and security', *International Political Sociology*, 6 (2012), pp. 165–85.

[66]Madeleine Fagan, 'Security in the Anthropocene: Environment, ecology, escape', *European Journal of International Relations*, 23:2 (June 2017), pp. 292–314, available at: {https://doi.org/10.1177/1354066116639738}; John Agnew Reviewed work(s), 'The territorial trap: The geographical assumptions of International Relations theory', *Review of International Political Economy*, 1:1 (1994), pp. 53–80; Erika Cudworth and Stephen Hobden, 'Beyond environmental security: Complex systems, multiple inequalities and environmental risks', *Environmental Politics*, 20:1 (February 2011), pp. 42–59, available at: {https://doi.org/10.1080/09644016.2011.538165}; Simon Dalby, 'Rethinking geopolitics: Climate security in the Anthropocene', *Global Policy*, 5:1 (February 2014), pp. 1–9, available at: {https://doi.org/10.1111/1758-5899.12074}.

[67]François Debrix, 'Katechontic sovereignty: Security politics and the overcoming of time', *International Political Sociology*, 9:2 (June 2015), p. 143, available at: {https://doi.org/10.1111/ips.12088}.

[68]Dalby, 'Rethinking geopolitics', p. 1. See also Madeline Fagan, 'Who's afraid of the ecological apocalypse? Climate change and the production of the ethical subject', *British Journal of Politics and International Relations*, 19:2 (2017), pp. 225–44.

[69]Cudworth and Hobden, 'Beyond environmental security', p, 42. For a good exposition of ecological security, see McDonald, 'Climate change and security'.

and because, as Madeleine Fagan notes, ecological security approaches often remain 'tied to a modern, anthropocentric logic that reproduces the secondary place given to nature in its constitution of the subject',[70] meaning that nature or the environment are still treated as a backdrop against which politics unfold. Because climate change is such a multifaceted problem that unfolds over a long period of time and demands extensive, if not wholesale changes to the international system, states, and other actors struggle to recognise and effectively respond to the problem – a seeming lack of urgency that allows the problem to be continually deferred to the future. This is compounded by the fact that powerful states such as the US often have the least motivation to make significant changes in response to climate change because of their relative insulation from the most deleterious effects of climate change and because they continue to benefit from *status quo* consumption and environmental behaviour.[71]

The treatment of climate change as a serious security problem has been uneven precisely because it is complex, without a straightforward, evident solution. SAI is purported to solve the most immediate climate issue, global heating, quickly and cheaply, through the use of relatively familiar and visible means: the use of planes and balloons or other aircraft to spray reflective aerosols into the stratosphere.[72] In policymaking, problems are excluded from agendas if they have no clear solution that makes sense to a public or political audience.[73] If SAI makes *sense* as a response to policymakers and security actors it may be used regardless of whether or not it is scientifically necessary or effective. Some geoengineering proponents have argued that we need to research SAI technology because if 'intolerable damages accrue far more quickly than expected, the world may look for a panic button to push',[74] but this has the techno-politics – 'the strategic practice of designing or using technology to enact political goals'[75] – of SAI backwards. The political goal of managing the climate crisis in a visible, rapidly effective way that offers the appearance of causing minimal disruption to status quo economic and political configurations will also shape the development and use of the technology, not just climate impacts. As Julia Schubert writes:

> The career of geoengineering illustrates how quantified expertise becomes politically relevant by promising to reinstate the political capacity to act in the face of an otherwise hopelessly complex situation … measuring and modeling climate change promises to expand political agency to the natural climate; it promises to make the atmosphere politically 'legible' and therefore amenable to political control.[76]

Designations of threat and declarations of emergency are political. If SAI renders the atmosphere 'politically legible' it creates the possibility of turning climate change into something that can be understood and reacted to in an emergency/response framework. SAI technology would enable climate change to be conceptualised as an emergency from a security perspective because it creates the appearance of a discrete response available that would have rapid, discernible results in terms of quickly lowering temperatures, even though it does not actually ameliorate the underlying problems of excess greenhouse gases in the atmosphere. The efficacy of SAI is not the point – its

[70] Fagan, 'Security in the Anthropocene', p. 300.

[71] Joseph Masco, 'The crisis in crisis', *Current Anthropology*, 58:S15 (February 2017), pp. S65–76, available at: {https://doi.org/10.1086/688695}.

[72] Axel Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?', *Global Policy*, 12:S1 (April 2021), p. 123, available at: {https://doi.org/10.1111/1758-5899.12872}.

[73] Michael D. Cohen, James G. March, and Johan P. Olsen, 'A garbage can model of organizational choice', *Administrative Science Quarterly*, 17:1 (March 1972), p. 1, available at: {https://doi.org/10.2307/2392088}.

[74] Wake Smith and Claire Henly, 'Updated and outdated reservations about research into Stratospheric Aerosol Injection', *Climatic Change*, 164:3–4 (February 2021), p. 39, available at: {https://doi.org/10.1007/s10584-021-03017-z}.

[75] Gabrielle Hecht, *Entangled Geographies: Empire and Technopolitics in the Global Cold War* (Cambridge, MA: MIT Press, 2011), p. 3.

[76] Julia Schubert, 'Measuring, modelling, controlling the climate? Numerical expertise in US climate engineering politics', in Markus J. Prutsch (ed.), *Science, Numbers and Politics* (Cham: Springer International Publishing, 2019), p. 195, available at: {https://doi.org/10.1007/978-3-030-11208-0}.

intelligibility as a response is. One of the political challenges that climate change presents is that there is no clear enemy to counter; consumption patterns of wealthy people and states, the structure of modern food and transportation systems and the overall organisation of the global economy present neither a clear nor intelligible opponent. The 'identification of an enemy'[77] is a core feature of security logic but climate change as an enemy 'overburdens the capacity of human beings, and in particular that of political actors',[78] because the enemy or antagonist cannot be clearly identified, contained, or attacked. There are other transnational challenges, such as terrorism, that have a wide range of potential responses available or required but they are easily securitised because it is possible to clearly draw the friend/enemy distinction[79] by identifying the central actors and communities under threat.[80] Climate change is an indiscrete, systemic problem that has been difficult to make sense of, and therefore respond to, from a security perspective. A technology that appears to offer a fast-acting response to its most immediate and well-recognised threat, a rise in global temperatures, will help provide a clear, definable and seemingly measurable plan of action. Indeed, as Chris Methmann and Delf Rolf argue, the complex and universalised nature of climate change as a threat creates the desire for a technological 'deus ex machina' in which 'authority is transferred to the political machine of technology'.[81] The perceived climate emergency that some argue makes SAI a humanitarian necessity may be declared because of the availability of the technology to respond to that emergency, not because of particular climate realities. In other words, if your tool is SAI, the problem starts to look like it can be fixed with this tool.

Developing SAI technology renders its use more likely, which may not necessarily be connected to the climate impacts experienced by the actors interested in using it. This can be demonstrated through work on path-dependency, which has shown that the technologies we build impact our political and social understandings and behaviour and push us towards certain futures and not others.[82] This is because 'technologies substantially contribute to the coming about of actions and of decisions about how to act.'[83] Indeed, some have argued that the threat of using solar geoengineering may galvanise the development of a democratic, effective governance regime.[84] Developing the technology will create frameworks or path dependencies in which initially 'contingent … circumstances that confer an initial advantage on a particular technology' are 'followed by self-reinforcing processes' that 'become resistant to change' in turn 'constraining possibilities for the development of alternative … socio-technical configurations'.[85] As the technology emerges in the context of a climate crisis in need of a fast-acting response, it will become very difficult to imagine other possibilities, enabling conditions for its use.

The issue is not whether the technology solves the broader problem it is applied to, but if it can make sense of the problem for the actors trying to solve it. SAI is a technology that can be

[77]Methmann and Rothe, 'Politics for the day after tomorrow', p. 326.

[78]Ibid., p. 331.

[79]Carl Schmitt, *The Concept of the Political: Expanded Edition* (Chicago, IL: University of Chicago Press, 2008).

[80]Methmann and Rothe, 'Politics for the day after tomorrow', p. 328. I would like to thank the anonymous reviewer for raising the question of whether and why there is a distinction between securitising climate change and other transnational threats that have multiple responses available. As argued above, there is a distinctive element to climate change worth taking into account.

[81]Ibid., p. 333.

[82]Rose C. Cairns, 'Climate geoengineering: Issues of path-dependence and socio-technical lock-in: Climate geoengineering lock-in', *Wiley Interdisciplinary Reviews: Climate Change*, 5:5 (September 2014), pp. 649–61, available at: {https://doi.org/10.1002/wcc.296}.

[83]Peter-Paul Verbeek, 'Morality in design: Design ethics and the morality of technological artifacts', in Peter Kroes, Pieter Vermaas, Andrew Light, and Steven Moore (eds), *Philosophy and Design: from Engineering to Architecture* (Dordrecht: Springer. 2008), p. 91, available at: {https://doi.org/10.1007/978-1-4020-6591-0_7}.

[84]Jonathan Symons, *Ecomodernism: Technology, Politics and The Climate Crisis* (1st edn, Cambridge, UK: Polity, 2019), pp. 169–89.

[85]Rose C. Cairns, 'Climate geoengineering: Issues of path-dependence and socio-technical lock-in: Climate geoengineering lock-in', *Wiley Interdisciplinary Reviews: Climate Change*, 5:5 (September 2014), p. 650, available at: {https://doi.org/10.1002/wcc.296}.

deployed to control or ward off an imagined catastrophe or manage an emergency. Whether there is an actual catastrophe point scientifically may not be determinative in the calculation to use the technology.[86] The political challenges of responding to climate change and the perceived threats or dangers that it poses enhance the appeal of SAI and the likelihood of its deployment, which are not necessarily tied to its efficacy or immediate demands of the physical consequences of climate change. In the following section, I will examine how preemptive security discourse and practices may further shape the development and use of SAI beyond the consideration of direct climate impacts.

Preemptive security and prospects for unilateral deployment without governance

Governing security through the lens of preemptive uncertainty and possible catastrophe extends back to the Cold War preparations for the possibility of nuclear war.[87] Preemptive security practices of anticipating or imagining possible future catastrophes has been closely linked to potential health and environmental threats,[88] and the prospect of developing SAI technology emerged within the Cold War context of attempting to 'control the weather' or intervene in the climate for military purposes of mastery and strategic advantage against potential threats.[89] In addition, SAI parallels nuclear weapons as a technology with planetary-altering capabilities that has already sparked concerns about who will control and potentially use the technology.[90] A key element of preemptive security thinking and practice in the nuclear context during the Cold War was racing to control and secure the technology,[91] and governance of nuclear weapons technology is centralised, hierarchical, and hyper-securitised despite the open, cooperative, and science-led governance of the technology envisioned by its developers.[92] SAI governance differs technologically and historically but could encounter similar dynamics that merit more extensive consideration given already existing concerns about domination of SAI by the Global North and its potential to contribute to inter-state conflict.[93] SAI lends itself to preemptive security reasoning in a way other solutions or strategies such as emissions reductions and CDR do not, meaning that thinking about the problem is driven towards the most intelligible solution, regardless of the value or risks of that solution. The historical trajectory of nuclear governance towards hyper-securitised, exclusionary control on the basis of racial and geographic lines,[94] and the persistence of arms racing despite

[86] Markusson et al., '"In case of emergency press here"'.

[87] Aradau and Munster, *Politics of Catastrophe*, pp. 1–17.

[88] Cooper, 'Pre-empting emergence'; de Goede and Randalls, 'Precaution, preemption'; Liam P. D. Stockdale, *Taming an Uncertain Future: Temporality, Sovereignty, and the Politics of Anticipatory Governance* (London, UK: Rowman & Littlefield, 2015).

[89] Joseph Masco, 'Bad weather: On planetary crisis', *Social Studies of Science*, 40:1 (February 2010), pp. 7–40, available at: {https://doi.org/10.1177/0306312709341598}; Jürgen Scheffran, 'The entwined Cold War roots of missile defense and climate geoengineering', *Bulletin of the Atomic Scientists*, 75:5 (3 September 2019), pp. 222–8, available at: {https://doi.org/10.1080/00963402.2019.1654256}; Baskin, *Geoengineering, the Anthropocene and the End of Nature*.

[90] Bas and Mahajan, 'Contesting the climate'; Nightingale and Cairns, 'The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure'.

[91] Rens van Munster and Casper Sylvest, 'Reclaiming nuclear politics? Nuclear realism, the H-Bomb and globality', *Security Dialogue*, 45:6 (December 2014), pp. 530–47, available at: {https://doi.org/10.1177/0967010614543583}; Campbell Craig, *Glimmer of a New Leviathan: Total War in the Realism of Niebuhr, Morgenthau, and Waltz* (New York, NY: Columbia University Press, 2003).

[92] Niels Bohr, 'For an open world', *Bulletin of the Atomic Scientists*, 6:7 (1 July 1950), pp. 213–17, available at: {https://doi.org/10.1080/00963402.1950.11461268}; James Franck et al., 'Report of the Committee on Political and Social Problems', Metallurgical Laboratory, Manhattan Project (Chicago, IL: University of Chicago, 1945), pp. 1–16.

[93] Jennie C. Stephens and Kevin Surprise, 'The hidden injustices of advancing solar geoengineering research', *Global Sustainability*, 3 (2020), e2, pp. 1–6, available at: {https://doi.org/10.1017/sus.2019.28}; Muhammet Bas and Aseem Mahajan, 'Contesting the climate: Security implications of geoengineering', *Climatic Change*, 162:4 (2020), pp. 1985–2002.

[94] Shampa Biswas, '"Nuclear apartheid" as political position: Race as a postcolonial resource?', *Alternatives: Global, Local, Political*, 26:4 (October 2001), pp. 485–522, available at: {https://doi.org/10.1177/030437540102600406}.

declared commitments to disarmament[95] justifies consideration of how preemptive security logics may influence the development of SAI governance.

As explored above, the developing discourse about SAI frequently presents it as a potential emergency response,[96] creating the conditions in which a state or other actor may declare an emergency that justifies its use as a preemptive response even if that requires contravening a governance regime and regardless of the breach of actual scientific thresholds for such an emergency.[97] According to Claudia Aradau and Rens van Munster, preemptive security practices 'aim to act on threats that are unknown and recognized to be to be unknowable, yet deemed potentially catastrophic, requiring security intervention at the earliest possible stage'.[98] In securitisation theory, a distinction is usually made between threat and risk, where threats are 'existential, imminent, and clearly identifiable',[99] which justify or legitimate exceptional practices. The climate has had an uneven career as a securitised referent object because of the challenges associated with understanding it as immediate and clearly identifiable. However, as the systemic risks of climate change proliferate and intensify, the distinction between risk and threat in securitisation theory blur. As William Clapton writes:

> In a period of change, contingency, and widespread anxiety produced by the collapse of control over debounded risks and the subsequent emphasis on their catastrophic potential, exceptional behaviours on the part of states and other actors can be justified. Gone is the emergency produced by a clearly identifiable, existential, and imminent threat, replaced instead by an urgency generated by collective imaginaries of future catastrophic possibilities.[100]

Climate change presents us with an uncertain future. Preemptive security framings and practices of risk calculation are resistant to uncertainty and try to respond to a crisis before it happens. In preemptive security logics disasters are a negative outcome of failing to prevent a crisis from passing a particular threshold.[101] The notion of crisis associated with climate change is slippery, which creates room to claim that if something is not done, such as SAI, disaster will happen. This is an intelligible process to traditional security actors. As Claudia Aradau and Rens van Munster explain, 'As an object of knowledge and governance, catastrophes are made knowable and amenable to action through the deployment of particular styles of reasoning',[102] meaning that making sense of something, like climate change, as a crisis or emergency requires an available response that can be demonstrably directed at the problem.

In contemporary security logics, accuracy or efficacy of a calculation or a technology does not solely determine its application.[103] Whether something is intelligible as a response matters. SAI could easily fall under this category in a situation where an emergency or crisis is declared and a sense that 'something must be done' to respond to a potential catastrophic future emerges. Research has found that public perceptions of climate change are strongly influenced by extreme weather/

[95] Miriam Barnum and James Lo, 'Is the NPT unraveling? Evidence from text analysis of review conference statements', *Journal of Peace Research*, 57:6 (1 November 2020), pp. 740–51, available at: {https://doi.org/10.1177/0022343320960523}; Alexey Arbatov, 'Mad momentum redux? The rise and fall of nuclear arms control', *Survival*, 61:3 (May 4, 2019), pp. 7–38, available at: {https://doi.org/10.1080/00396338.2019.1614785}.

[96] Baskin, *Geoengineering, the Anthropocene and the End of Nature*, pp. 96–8; Brigitte Nerlich and Rusi Jaspal, 'Metaphors we die by? Geoengineering, metaphors, and the argument from catastrophe', *Metaphor and Symbol*, 27:2 (April 2012), pp. 131–47, available at: {https://doi.org/10.1080/10926488.2012.665795}.

[97] Markusson et al. point out that determining an actual scientific threshold for emergency would be very difficult, but that reality has little effect on the use of emergency framing to justify geoengineering. See Markusson et al., '"In Case of Emergency Press Here"'.

[98] de Goede, Simon, and Hoijtink, 'Performing preemption', p. 412.

[99] Clapton, 'The exceptionalism of risk', p. 7.

[100] Ibid.

[101] Aradau and Munster, *Politics of Catastrophe*, p. 23.

[102] Ibid., p. 30.

[103] Louise Amoore, 'Security and the incalculable', *Security Dialogue*, 45:5 (October 2014), pp. 423–39, available at: {https://doi.org/10.1177/0967010614539719}.

climate events,[104] and if a high-impact climate event like a mass wildfire, damaging storm system, or flood focuses public demands for action SAI is something that can be done (if the technology is developed), even if it does not solve the problem. In the context of preemptive security logics, decision-makers face a trap in which 'we will call to account those who confront the incalculability and say it is undecidable in advance; we will say that they failed to secure us.'[105] Security officials may be moved to act at a much lower threshold than we should be comfortable with when it comes to use of SAI. As climate change becomes further securitised through the language of 'climate emergency', the drive towards technofix solutions may merge with preemptive security frameworks because 'the notion of crisis refers not just to the actual moment of decision but includes the broader prior strategic choices and actions that move or prevent a situation from moving in the direction of the decisive moment of victory or defeat.'[106] An extreme weather event, for example, may create a call for action that leads to deployment of geoengineering to demonstrate that policymakers are responsive to the political and security demands of the public. A scenario like this was recently imagined in Kim Stanley Robinson's 2021 science-fiction work *Ministry for the Future*. The book imagines a heat wave in India that kills approximately 20 million people and spurs India to begin a unilateral SAI programme, which is largely successful in both climatological and political terms.[107] Robinson's book posits a scenario that echoes the thinking evinced in much of the literature and among investors and researchers interested in solar geoengineering that considers the conditions under which SAI might be used. Indeed, Chris Sacca, a billionaire venture capitalist heavily invested in solar geoengineering research,[108] drew on Kim Stanley Robinson's imagined scenario when he recently stated: 'The odds are 100 percent that some country pursues sunlight reflection, particularly in the wake of seeing millions of their citizens die from extreme weather', because 'The world will not stand idly by and leaders will feel compelled to take action.'[109] A serious climate event in the context of the broader climate emergency leads a vulnerable state to deploy SAI as a fast-acting response, which may help spur international cooperation and an effective, fair governance regime. This is a plausible sequence of events, but it is not the only plausible scenario, and may not be the most likely.

SAI is not especially technologically difficult to implement – 'Any country that is able to operate airports, and has access to sulphur (including from coal) could implement SAI, provided that it can procure planes able to spray aerosol'[110] – but keeping it up indefinitely would be a logistical, resource intensive challenge.[111] More importantly, managing the potential environmental and political risks of the technology in the absence of effective international governance would require strong military capabilities to both organise and protect the critical infrastructure needed[112] and resist political pressure and sanctions against unauthorised use that may or may not cause unacceptable side effects for other actors or communities. Large militarily and economically powerful actors are less likely to be hit with sanctions than smaller powers and there is currently no clear

[104] Peter D. Howe et al., 'Mapping the shadow of experience of extreme weather events', *Climatic Change*, 127:2 (November 2014), pp. 381–89, available at: {https://doi.org/10.1007/s10584-014-1253-6}; Lawrence C. Hamilton et al., 'Tracking public beliefs about anthropogenic climate change', ed. Vanesa Magar, *PLOS ONE*, 10: 9 (30 September 2015), p. e0138208, available at: {https://doi.org/10.1371/journal.pone.0138208}.

[105] Amoore, 'Security and the incalulable', p. 436.

[106] Aradau and Munster, *Politics of Catastrophe*, p. 23.

[107] Kim Stanley Robinson, *The Ministry for the Future* (New York, NY: Orbit, 2020).

[108] Kevin Surprise and J. P. Sapinski, 'Whose climate intervention? Solar geoengineering, fractions of capital, and hegemonic strategy', *Capital & Class* (2022), p. 9, available at: {https://journals.sagepub.com/doi/abs/10.1177/03098168221114386}.

[109] Clifford, 'White House is pushing ahead research to cool Earth by reflecting back sunlight'.

[110] Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?'.

[111] Nightingale and Cairns, 'The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure'.

[112] Markusson et al., '"In case of emergency press here"'; Nightingale and Cairns, 'The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure'.

sanction regime under the UNFCC in the case of unilateral use.[113] Given these considerations, a perhaps more plausible scenario might be one in which a powerful actor unilaterally deploys SAI not on their own behalf, but for ostensibly altruistic purposes, to demonstrate responsible leadership in the climate emergency.[114]

These thought exercises raise questions about which actors might be most likely to engage in unilateral SAI use, and under what conditions? There is some game theoretic[115] and scenario work[116] that considers these questions, but they do so on the assumption of perceived climatological necessity. When taking into account the influence of SAI as a politically intelligible technological response to climate change and preemptive security thinking and practice different possibilities emerge. In the following subsection, I will briefly assess two of the actors most commonly posited as having the potential to engage in unilateral SAI, India and China, through this broader lens. I will then show why a less narrow environmental framing of SAI indicates that it is worth seriously considering that an actor not primarily motivated by climate vulnerabilities is at least as likely to turn to SAI.

SAI: Means, motive, opportunity?

China, and to a lesser extent, India are frequently mentioned as actors who may be interested in SAI use, unilateral or otherwise due to their size, economic and military capacity, and relative vulnerability to climate change.[117] Although India theoretically has incentive to engage in unilateral SAI due to adverse climate impacts, research indicates that SAI will impact monsoon and rainfall patterns particularly important to the country and which make the prospect of SAI much less appealing to India than it may be for China.[118] China is concerned about climate change vulnerabilities and maintaining its development trajectory, which may make SAI an appealing intervention to extend the window for bringing down reliance on fossil fuels for growth.[119] China also has a history of engaging in large-scale engineering projects and weather modification that may arguably

[113]Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?', p. 125.

[114]Such as a possibility in briefly touched on by Tang and Kemp in relation to the common but differentiated responsibility principle in Tang and Kemp, 'A fate worse than warming?', p. 9.

[115]Gernot Wagner, *Geoengineering: The Gamble* (1st edn, Cambridge, UK and Medford, MA: Polity, 2021), pp. 15–34.

[116]Parson and Reynolds, 'Solar geoengineering governance'; Dove, Horton, and Ricke, 'The middle powers roar'; Pasek et al., 'Reflections on a hypothetical decentralized grassroots deployment solar geoengineering scenario'.

[117]See, for, example, Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?', p. 121; Bettina Bluemling, Rakhyun E. Kim, and Frank Biermann, 'Seeding the clouds to reach the sky: Will China's weather modification practices support the legitimization of climate engineering?', *Ambio*, 49:1 (January 2020), pp. 365–73, available at: {https://doi.org/10.1007/s13280-019-01180-3}; John C. Moore et al., 'Will China be the first to initiate climate engineering?: Climate engineering initiation in China', *Earth's Future*, 4:12 (December 2016), pp. 588–95, available at: {https://doi.org/10.1002/2016EF000402}; Kingsley Edney and Jonathan Symons, 'China and the blunt temptations of geo-engineering: The role of solar radiation management in China's strategic response to climate change', *The Pacific Review*, 27: 3 (27 May 2014), pp. 307–32, available at: {https://doi.org/10.1080/09512748.2013.807865}; Surat Parvatam, 'Geoengineering: Should India tread carefully or go full steam ahead?: The wire science', available at: {https://science.thewire.in/environment/geoengineering-should-india-tread-carefully-or-go-full-steam-ahead/} accessed 31 May 2022; 'Climate change: How India and China can work together on a geoengineering governance framework', *Firstpost* (28 April 2022), available at: {https://www.firstpost.com/opinion/climate-change-india-and-china-geoengineering-governance-framework-10611341.html}; Parson and Reynolds, 'Solar geoengineering governance'.

[118]'India and Atmospheric Sulfate Injection: A Double-Edged Sword', available at: {https://www.csis.org/blogs/new-perspectives-asia/india-and-atmospheric-sulfate-injection-double-edged-sword} accessed 1 June 2022; I. R. Simpson et al., 'The regional hydroclimate response to stratospheric sulfate geoengineering and the role of stratospheric heating', *Journal of Geophysical Research: Atmospheres*, 124:23 (16 December 2019), pp. 12587–616, available at: {https://doi.org/10.1029/2019JD031093}.

[119]Moore et al., 'Will China be the first to initiate climate engineering?'; Edney and Symons, 'China and the blunt temptations of geo-engineering'.

make it more comfortable with shifting into SAI deployment.[120] However, China has shown far more interest in CDR geoengineering strategies like afforestation and some reluctance to explore SRM strategies,[121] in addition to complex geopolitical challenges it would face if it engaged in SAI, particularly with India and Australia.[122] China appears to have enough internal agreement that climate change is a serious problem for it to mobilise political and scientific efforts to pursue longer-term, less immediately impactful but also less dangerous climate interventions.[123] It is certainly not impossible that China may engage in unilateral SAI in the event of a serious environmental disaster, and it fits the profile sketched above of an economically and militarily powerful country that may be able to evade or withstand sanctions if it acted preemptively and unilaterally. However, there is also a strong case to be made that the US is the actor more likely to engage in unilateral geoengineering when broader considerations beyond perceived environmental vulnerability are taken into account.

Climatological assessments of SAI discount or fail to consider US interest or motivation to use SAI because it is relatively insulated from the impacts of climate change, but this misreads or ignores US orientation to both security and technology. US international conduct is characterised by exceptionalism,[124] and lack of convergence on what desirable levels of SAI would be may not lead to lack of deployment but simply to unilateral deployment without legitimacy in the name of preventing catastrophe and/or behaving 'responsibly'.[125] Exploration of SAI is most intensive in the Global North, with US institutions driving research.[126] The US has frequently and overtly signalled that its most desirable future closely resembles its past and present in terms of the organisation of its economy and military, which are reliant on fossil fuels.[127] Fossil fuel use is deeply embedded in military and economic structures and a technology that seems to offer the possibility of putting off extensive and costly restructuring away from them will appeal most to the very states and other actors capable of developing and deploying SAI.[128] While the governance debates over SAI assume cooperative, responsible international actors, security literature and US behaviour in relation to climate change suggest a different path.

Since the end of the Cold War, the US has shifted its understanding of security and military preparedness towards a model of responding to 'emergent threats' through preemptive security framing and practices, which has only accelerated and intensified since the 9/11 terrorist attacks in 2001.[129] After the Cold War, the US reframed its security thinking away from concerns with

[120]Bluemling, Kim, and Biermann, 'Seeding the clouds to reach the sky'; Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?', p. 121.

[121]Moore et al., 'Will China be the first to initiate climate engineering?'.

[122]Michaelowa, 'Solar radiation modification: A "silver bullet" climate policy for populist and authoritarian regimes?'; Adam Lockyer and Jonathan Symons, 'The national security implications of solar geoengineering: An Australian perspective', *Australian Journal of International Affairs*, 73:5 (3 September 2019), pp. 485–503, available at: {https://doi.org/10.1080/10357718.2019.1662768}.

[123]Moore et al., 'Will China be the first to initiate climate engineering?'.

[124]David Hughes, 'Unmaking an exception: A critical genealogy of US exceptionalism', *Review of International Studies*, 41:3 (July 2015), pp. 527–51, available at: {https://doi.org/10.1017/S0260210514000229}.

[125]Tang and Kemp, 'A fate worse than warming?'.

[126]Kevin Surprise, 'Geopolitical ecology of solar geoengineering: From a "logic of multilateralism" to logics of militarization', *Journal of Political Ecology*, 27:1 (6 April 2020), pp. 213–35, available at: {https://doi.org/10.2458/v27i1.23583}; Stephens and Surprise, 'The hidden injustices of advancing solar geoengineering research'; Baskin, *Geoengineering, the Anthropocene and the End of Nature*. See also the Harvard Solar Geoengineering Research Program, perhaps the leading research institution in this space.

[127]Bush Sr, Tillerson, Trump, Obama, Biden LNG references

[128]Duncan McLaren, 'Mitigation deterrence and the "moral hazard" of solar radiation management: Mitigation deterrence and the "moral hazard" of solar radiation management', *Earth's Future*, 4:12 (December 2016), pp. 596–602, available at: {https://doi.org/10.1002/2016EF000445}; Surprise, 'Geopolitical ecology of solar geoengineering'; Clive Hamilton, *Earthmasters: The Dawn of the Age of Climate* Engineering (New Haven, CT: Yale University Press, 2013), pp. 107–38; Baskin, *Geoengineering, the Anthropocene and the End of Nature*, pp. 214–23.

[129]Cooper, 'Pre-empting emergence'; de Goede, Simon, and Hoijtink, 'Performing preemption'; De Goede, 'Beyond risk'.

mutual deterrence directed primarily at other states towards preparation for 'emerging threats' that require constant counterproliferation efforts and continuous readiness to fight a deterritorialised and disembodied 'enemy' wherever it emerges.[130] This preemptive security logic and the perils associated with it were most clearly displayed in the 2003 US invasion of Iraq in which the constraints of international governance were not enough to stop the US from pursuing the action it justified in terms anticipating risk or threat.[131] This move to preempt threats wherever they are identified or emerge accelerated after the 9/11 terrorists attack, but preemptive security framing is not limited to the problem of terrorism or the post 9/11 world – it has been associated with immigration,[132] health,[133] and the environment.[134] It is also not limited in time to the Bush administration. In general, the US displays remarkable continuity in its security and foreign policy across administrations, regardless of perceived political and ideological differences between them.[135] Indeed, although preemptive security thinking has shifted since the end of the Cold War, preemptive concerns with controlling technology and remaining on the cutting edge of technological interventions for security purposes[136] that informed the US approach to nuclear weapons[137] persists, including in the purported motive for the 2003 invasion of Iraq to dismantle Iraq's alleged weapons of mass destruction programme. The move to embrace and extend preemptive security logic and practice that is so obvious in the Bush administration after the 9/11 attacks has persisted and sometimes intensified,[138] with implications for climate security policy in general and future SAI technology.

US policy advisors seem to assume that unilateral development and deployment by the US is acceptable in a way that it would not be for any other state[139] and US-based research meant to inform US policy on geoengineering has openly opposed global governance because of the constraints it may place on the US.[140] In current US security policy, 'it is extremely unlikely that Congress would approve the development of geoengineering systems under United Nations or other international organisation's control',[141] and, as Paul Nightingale and Rose Cairns argue:

> In the security domain, perceptions of threats, which can be highly uncertain and unlikely, play important roles in policy. The perceptions that geoengineering would create a potential doomsday device, which if stopped would rapidly lead to a catastrophic 'termination effect', could easily be perceived to present a threat to US security. Under such circumstances it would

[130] Cooper, 'Pre-empting emergence', p. 124.

[131] Ibid., p. 125.

[132] Clapton, 'The exceptionalism of risk'.

[133] Cooper, 'Pre-empting emergence'; Simon Rushton, 'Global health security: Security for whom? Security from what?', *Political Studies*, 59:4 (December 2011), pp. 790–1, available at: {https://doi.org/10.1111/j.1467-9248.2011.00919.x}.

[134] de Goede and Randalls, 'Precaution, preemption'.

[135] Nikolas Gvosdev and Derek Reveron, 'Continuity in the National Interest? Assessing the Biden Administration's Interim National Security Guidance: Foreign Policy Research Institute', available at: {https://www.fpri.org/article/2021/03/continuity-in-the-national-interest-assessing-the-biden-administrations-interim-national-security-guidance/} accessed 9 May 2021; Jon Herbert, Trevor McCrisken, and Andrew Wroe, *The Ordinary Presidency of Donald J. Trump* (Cham: Palgrave Macmillan, 2019), pp. 185–214; Trevor McCrisken, 'Ten years on: Obama's war on terrorism in rhetoric and practice', *International Affairs*, 87:4 (2011), pp. 781–801, available at: {https://doi.org/10.1111/j.1468-2346.2011.01004.x}.

[136] Daniel R. McCarthy, 'Imagining the security of innovation: Technological innovation, national security, and the American way of life', *Critical Studies on Security* (10 June 2021), pp. 1–16, available at: {https://doi.org/10.1080/21624887.2021.1934640}; Baskin, *Geoengineering, the Anthropocene and the End of Nature*.

[137] Craig, *Glimmer of a New Leviathan*.

[138] David Rohde, 'The Obama doctrine', *Foreign Policy*, 192 (March/April 2012), pp. 64–9.

[139] Baskin, *Geoengineering, the Anthropocene and the End of Nature*, pp. 185–9.

[140] David Victor, *Global Warming Gridlock: Creating More Effective Strategies for Protecting the Planet* (Cambridge, UK: Cambridge University Press, 2011), pp. 165–200; Lee Lane and Eric Bickel, *Solar Radiation Management: An Evolving Climate Policy Option* (Washington, DC: American Enterprise Institute, 2013).

[141] Nightingale and Cairns, 'The Security Implications of Geoengineering: Blame, Imposed Agreement and the Security of Critical Infrastructure', p. 9.

> be reasonable to assume that there would be considerable US security interest and a desire to have it under US security control or at least subject to considerable oversight. The notion that North Korea, Iran, Russia, China or even the EU could develop a geoengineering capability without generating concern in Washington is unrealistic.[142]

The US has organised its security and foreign policy around being able to project power globally to deter potential competitors and shape global security norms,[143] particularly when it comes to the development and use of technology.[144] It is exceedingly unlikely that they will willingly cede substantial control of SAI to anyone else, regardless of environmental necessity.

Faith in a future technology that will preempt present concerns about the environment, or about other areas of social concern, has characterised US thinking for decades,[145] which aligns with the security dynamic explored above in which the complexities of climate change spur a desire for a technological escape route the make climate change more intelligible as a problem with active, preemptive solutions to which political actors can point.

Conclusion

Solar geoengineering has a lot of known and unknown consequences and it is impossible to fully research them before deployment because of issues of scale.[146] Technological capabilities and deployment may rapidly outstrip consideration of the political and social implications of SAI use without urgent attention. Governance of SAI has already been identified as a key area of concern within the social sciences and the literature on governing geoengineering and geoengineering research is rapidly proliferating.[147] However, the literature on SAI governance is largely missing the political context of environmental degradation and climate change politics including unforeseen political and social consequences, and the hierarchies that exist in international politics, with the noted exception of McLaren and Corry's on the political faultlines that will inform and present obstacles to geoengineering governance.[148] It also does not account for the politics of emergency or preemptive security practices that will be important to address as SAI develops.

The main contributions of this article have been to widen the scope for assessing SAI beyond a narrow environmental framing and offer a preliminary analysis of how technological intelligibility and preemptive security logic and practices may shape the development and use of SAI. Based on an analysis informed by more substantive political and security thinking, I have demonstrated that there is a case for more research on the political and security implications of SAI beyond its potential direct environmental impacts and those actors more immediately vulnerable to climate change. The influence of preemptive security practices, the appeal of technological responses to climate change, and the desire for responses to climate change intelligible within a more traditional problem/solution framework are all candidates for greater reflection and more research, both separately and together.

[142] Ibid.

[143] Ibid.; Daniel Immerwahr, *How to Hide an Empire: A History of the Greater United States* (repr. edn, New York, NY: Picador, 2020), pp. 355–71.

[144] Immerwahr, *How to Hide an Empire*; McCarthy, 'Imagining the security of innovation'; van Munster and Sylvest, 'Reclaiming nuclear politics?'.

[145] See, for example, White House, *Restoring the Quality of Our Environment*, p. 127.

[146] Cairns, 'Climate geoengineering'.

[147] Duncan McLaren and Olaf Corry, 'The politics and governance of research into solar geoengineering', *WIREs Climate Change* (14 March 2021), available at: {https://doi.org/10.1002/wcc.707}; Jinnah, 'Why govern climate engineering?'; Aarti Gupta and Ina Möller, 'De facto governance: How authoritative assessments construct climate engineering as an object of governance', *Environmental Politics*, 28:3 (16 April 2019), pp. 480–501, available at: {https://doi.org/10.1080/09644016.2018.1452373}; Committee on Developing a Research Agenda and Research Governance Approaches for Climate Intervention Strategies that Reflect Sunlight to Cool Earth et al., *Reflecting Sunlight*.

[148] See McLaren and Corry, 'Clash of geofutures and the remaking of planetary order'.

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