CENTRE FOR THE STUDY OF
EXISTENTIAL RISK

Report of a workshop on Managing the contribution of Solar Radiation Modification and Climate Change to Global Catastrophic Risk

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Summary

This report presents key findings from a workshop on managing the contribution of Solar Radiation Modification (SRM) and Climate Change to Global Catastrophic Risk (GCR) that was hosted by Gideon Futerman and SJ Beard at the Centre for the Study of Existential Risk on March 28th and 29th 2023. The workshop was informed by a participatory futures exercise using the ParEvo technique that explored futures for SRM and SRM governance between 2030 and 2050, which some workshop participants took part in. Initial results of the exercise were shared with workshop participants and full results will be published separately.

- **Participants emphasised that SRM can both contribute to and mitigate GCR**. However, at present, high levels of uncertainty make it difficult to perform a complete assessment of risk and so this report will not attempt to assess whether the research and deployment of SRM will raise or lower this risk. Instead, it focuses on participants' exploration of the different pathways to global catastrophes and the role SRM might play in them, the factors they saw as influencing the interaction between SRM and GCR, and their proposals for improving the governance of SRM and SRM research.

- Whilst in most cases it doesn't appear to, participants noted that **reducing GCR could sometimes conflict with other priorities.** For example, downplaying the importance of SRM and avoiding its politicisation could be important for reducing GCR, but also obscures issues of power and reduces democratic control over SRM. Therefore SRM-relevant actions may interact with GCR in many ways; not just contributing or mitigating risk but also changing its nature.

- Participants identified **many ways in which SRM may interact with GCR**. Discussions of **possible pathways towards global catastrophe typically involved interstate conflict, termination shock, or catastrophic climate impacts,** while discussion of **pathways away from global catastrophe involved the reduction of climate damages by SRM deployment.**

- Many other factors were seen as influencing SRM's interaction with GCR. These included the type of deployment and governance, the perception of SRM's impacts and importance among politicians and publics, securitisation and militarisation, geopolitics, extreme weather, knowledge networks, wealthy individuals and corporations, and developments in artificial intelligence. Whether these interactions are net contributors or mitigators of GCR will depend on how these factors evolve and interact, as summarised in Figure 1.

- **All these factors are contingent on human actions, perceptions, and behaviour**. Ultimately, social, political, and geopolitical systems will be as important as physical systems in determining whether SRM reduces or increases GCR.

- While it was generally felt that the current knowledge network around SRM has limited influence, participants also believed that there were **actions that could be taken to reliably reduce GCR** and that this ought to be a consideration in research and policy.

Below are some proposals to improve SRM research, policy, and governance. These were written by the authors and, whilst informed by the discussions at the workshop, they are not necessarily endorsed by the workshop attendees. **Further work is necessary to refine the workshop's risk identification and come up with more robust research and governance ideas**. These recommendations are targeted at those individuals and institutions who may be interested in their actions related to SRM reducing (or not increasing) GCR.

PROPOSALS TO IMPROVE POLICY AND GOVERNANCE

- If governance frameworks are to reduce GCR (whether they allow or prohibit SRM deployment) they are likely to **require widespread, sustained buy-in. Establishing the legitimacy of, and interest in, such frameworks ought to be a high priority** and should include a strong diversity of voices to allow for the broadest legitimacy of any decisions. Governance frameworks that minimise the potential for unproductive geopolitical competition over the technology and its outcomes are highly desirable.

- **SRM research can and should be used to foster multilateralism**, including voices from around the world. Unilateralism, including with very large research projects, may be dangerous as it likely increases the probability of conflict or termination by reducing trust and increasing competition. **Building bridges and trust around SRM through joint research initiatives, such as between the USA and China, could help to encourage multilateralism.**

- Researchers should seek to **lower the barriers** to a wider range of stakeholders participating in discussions on SRM, both from groups and states supportive and opposed to SRM, to promote more equitable discourse.

- **Actors in the space should be careful not to overstate the importance, impacts and controllability of SRM**. Narrative shaping can help to encourage policymakers to perceive SRM as a limited tool over which no individual state can exert total control and over which loss of some power may be of only limited significance.

- **Securitisation and militarisation of SRM may be particularly risky**. To avoid this national security establishments ought to refrain from attempting to securitise SRM and militaries commit to playing no role in SRM research. Actions by the knowledge network around SRM, such as narrative shaping,

activism or policy advice may have a role in reducing this risk, albeit a limited one.

- While there may be good arguments for bringing discussions around SRM into the political realm, this may also have dangerous consequences in promoting geopolitical competition over SRM. Actors engaging in political discourse over SRM should be mindful of this danger.

PROPOSALS FOR FURTHER RESEARCH

- **Foresight activities focused on possible consequences of actions related to SRM** (both in terms of suppressing and promoting it) may help bring about positive futures, as would better understanding of whether and how those interested in reduced GCR can steer such actions away from some of the GCR pathways identified here.

- **More modelling of plausible 'wild' deployment scenarios is needed.** Whilst workshop participants noted that there had been a start at this, better modelling, including of regional impacts and impacts on critical systems, would give more realistic implications about these scenarios, including constantly changing SAI deployment patterns, uncoordinated regional MCB, or overcooling; however, considerable refinement and exploration of the possibility space will be essential before such research is undertaken. This modelling should consider not just the median but also the plausible worst-case impacts of these scenarios.

- **More research and modelling are needed to explore the impacts, on both Earth and human systems and their interactions, of termination scenarios**, and how we might adapt to them. This should include explicit attempts to understand the worst-case scenarios.

- **More research is needed on the plausible worst-case scenarios of climate change** in a range of warming scenarios to carry out a more complete risk analysis of the interaction of SRM and GCR.

- **Exploration of cascading impacts** in the above sets of scenarios and other complex risk pathways, should be engaged in. This will likely involve methodologies beyond conventional climate and economic modelling and may require methodological innovation.

- Researchers should work with social and behavioural scientists to understand what public responses and attitudes towards SRM might be, especially the **potential for sudden dynamic shifts in public attitudes**, which workshop participants noted could be especially dangerous.

- Researchers should work with political scientists and international relations experts **to understand the geopolitical escalation dynamics that may lead**

disagreements over SRM to lead to conflict. These experts, together with legal and policy experts, may also help us to understand the full range of governance mechanisms available for SRM, including how frameworks that could develop around the regional deployment of SRM may be scaled up.

- Attention should be given to the **potential, and limits, of attribution** studies for assessing the impacts of SRM (using existing attribution work in climate change as case studies). This may help mitigate risks associated with perceptions of SRMs impacts, although whether such science could be developed before SRM deployment is unclear, as is the extent to which this would impact perceptions.

Introduction

Climate change is a growing issue of global concern, with rising impacts projected to have serious negative economic, social, and environmental impacts on large swathes of the global population. The probability of keeping warming below 1.5°C is rapidly diminishing (UNEP 2022), whilst the impacts of climate change are already being felt by millions around the world. Against this background, the possibility of carrying out Solar Radiation Modification (SRM) - techniques to cool the planet by blocking out a small amount of the incoming solar radiation - is being increasingly discussed. Research into SRM has been increasing over the last 20 years- (Ricke et al 2023), as has its political salience (NASAM 2021, The White House 2022). Nonetheless, many uncertainties and unknowns remain (NASAM 2021). This technology would not merely be of climatic but also of geopolitical importance. To bring about a more positive future, we need to understand the full range of potential impacts from SRM.

Global Catastrophic Risk (GCR) concerns some of the worst-case scenarios facing humanity. Bostrom and Ćirković (2008) define it as the risk of a catastrophe with 'the potential to inflict serious damage to human well-being on a global scale'. Some have suggested this is equivalent to >10% of global population loss (Cotton-Barratt et al 2016), although others reject such narrow criteria, instead suggesting it is the risk of an 'extraordinary, widespread disaster beyond the collective capacities of national and international governments and the private sector to control' (Schoch-Spana et al 2017), or the risk of pushing a system critical to human survival beyond its safety bounds, that spreads globally and affects the majority of the human population (Avin et al 2018). GCR has often been linked with risks of societal collapse or even human extinction, and whilst a precise definition may be elusive, it can be conceptualised as the general class of the most severe risks that humanity could face on a global scale. The current level of this risk may be uncertain, but it cannot be ignored. This report hopes to support emerging discussions on how to assess the contributions of SRM (Baum et al 2013, Halstead 2018, Tang and Kemp 2021) and climate change (Richards et al 2021, Beard et al 2021, Halstead 2022, Kemp et al 2022) to GCR.

On 27th-28th March 2023, the Centre for the Study of Existential Risk (CSER) hosted a workshop on “Managing the Contribution of Solar Radiation Modification and Climate Change to Global Catastrophic Risk” at Homerton College, University of Cambridge. This workshop was informed by a participatory exercise on futures for SRM and SRM governance, that had been undertaken using the ParEvo technique (Davies et al 2023) from November 2022-January 2023. The workshop included many of the participants in this exercise and also others whose expertise was judged to be helpful in evaluating, and building on, its key findings (both participant lists are included in the Appendix). The ParEvo scenario exercise involved the generation of narrative scenarios involving SRM deployment and governance from 2030-2050, with participants being actively encouraged to focus on those scenarios involving a heightened level of GCR. A full write up, and further exploration, of the ParEvo exercise will be published in future work, and the scenarios that were developed are available on request. This workshop involved primarily small group-based discussions focused on further developing and evaluating these scenarios, with the aim of further improving both their plausibility and relevance to GCR, identifying and discussing key themes and actors, and discussing our approach and possible future directions of exploration of SRM and GCR.

This report summarises key points from these discussions, focusing on the overall topic of the workshop: Managing the Contribution of SRM to Global Catastrophic Risk. Notetakers were present in each discussion group and, following the workshop, Gideon Futerman used their notes to write this report. There were a wide variety of views expressed at the

workshop, and not every attendee will agree with the claims made in this report. However, the claims made here were all, to the best knowledge of the authors, supported by at least one of the discussions at the workshop.

Letters are placed beside claims made, which reference specific discussion groups during the workshop. While the people within each group will be kept anonymous, we hope that this provides some indication of the diversity of these discussions and helps to highlight points of convergence and divergence between them. Individuals switched groups between discussion sessions, so each person was in multiple groups. K-O refer to discussion groups for the first session on “The creation and evaluation of governance scenarios for SRM”, A-D and J refer to groups in the second session on “Exploring future effects of SRM and Climate Change on Global Catastrophic Risk”, E-H refers to groups in the third session on “Agents of Change and Inflection Points”, and I refers to the final group discussions in the plenary.

Where a group is cited, the explanation in the text refers to the opinions presented in those discussions. The purpose of the report is to primarily present the discussions of the workshop rather than the opinion of the authors or CSER. Nonetheless, as the notes sometimes underdetermined key points and were open for interpretation, it is inevitable that this will not be an unvarnished description of the points made but hopes to be as truthful as possible. Concepts grounded in specific discussions will have the letters noting which group the ideas came from. Where statements in this report are not supported by discussions during the workshop (for example, in cases where further explanation seemed required to support points in the workshop) or when certain 'factual' statements needed evidentiary support, this was provided by the authors using the appropriate literature .

Primarily, the focus of the workshop was on SRM, and therefore this report focuses on scenarios where actions related to SRM contribute to GCR. This is not to suggest that SRM is a likely net contributor to GCR. Rather, whether SRM Is an overall contributor or mitigator of GCR is largely contingent on a number of undetermined facts about climate change, SRM, and the state of human systems. Both SRM and Climate Change contribute to GCR via interactions between Earth and human systems, and neither has been explored sufficiently for a full GCR risk assessment to be taken. Nonetheless, GCR should be considered as part of any risk assessment of SRM and climate change that is carried out.

There will be some discussions of ‘likelihood’ in this report, and certainly this will be necessary to carry out a more complete risk analysis of actions relating to SRM. However, the primary focus of the ParEvo exercise and workshop was on plausible, catastrophic scenarios, rather than likely ones. The conceptual distinction is fuzzy, and the participants were not given criteria for plausibility, to allow them freedom to negotiate this by themselves. Nonetheless, an indicative definition will be given here. Plausible futures refer to those futures composed of elements that are sufficiently grounded in what participants consider to be 'real' (Wiek et al 2013). This is bounded by what is theoretically possible given current knowledge, and enhanced by analogy to other events; however, due to the unprecedented nature of many GCR considerations, such analogies often have to be quite loose. Given the highly uncertain knowledge base, and the contingency of much of the scenarios on human decision making, this option space may be much larger than what is considered 'likely'; after all, many unlikely events do occur, allowing for the grounding of plausible scenarios in reality. Much of what is considered plausible is an illustration of the intuitive judgement of the group, and so can be seen as much as a reflection of the group as a reflection of reality.

In what follows, we have organised points arising from these discussions in relation to 14 key themes that describe different ways in which SRM may interact with GCR, combining discussion on SRM and climate scenarios, governance possibilities, and agents of change, where relevant, into each of these. These key themes are loosely arranged into groups, with preamble which summarises the section and links to some practical recommendations by the authors inspired by the discussions.

Key themes of the interaction of SRM with GCR

A variety of factors were explored in the discussions around SRM, Climate Change and GCR. Based on an analysis of discussions around these factors and the connections between them, the authors identified key themes, which are discussed in the following sections. The separation of these interacting and overlapping themes is purely of practical necessity and doesn't necessarily reflect a perception that these are fundamentally separate. To illustrate this, the authors also identified some of the causal connections between themes, which are summarised at the end of each section and illustrated in the following diagram. The arrows show a potential causal relationship of interest, where relevant events, trends, or issues relating to one factor may impact others, although they do not imply anything about the strength or nature of this relationship. Numbers in brackets refer to the page number in this report where discussion of each factor can be found. Given the complexity of these interrelationships we recommend that a broad range of foresight tools are used to better understand the broad range of possible consequences from actions relating to SRM.

All plausible scenarios where SRM-related actions impact global catastrophe discussed included one of the following: i) catastrophic climate impacts, ii) termination shock and iii) interstate conflict and rising tensions. This, however, needn't suggest that these are the most important factors to focus on, given the high levels of interdependence between other factors. It also doesn't preclude the existence of other pathways to global catastrophe in which SRM plays an important role independently of these factors; however, these may be 'boring apocalypses' (Liu et al 2018), that are hard to identify.

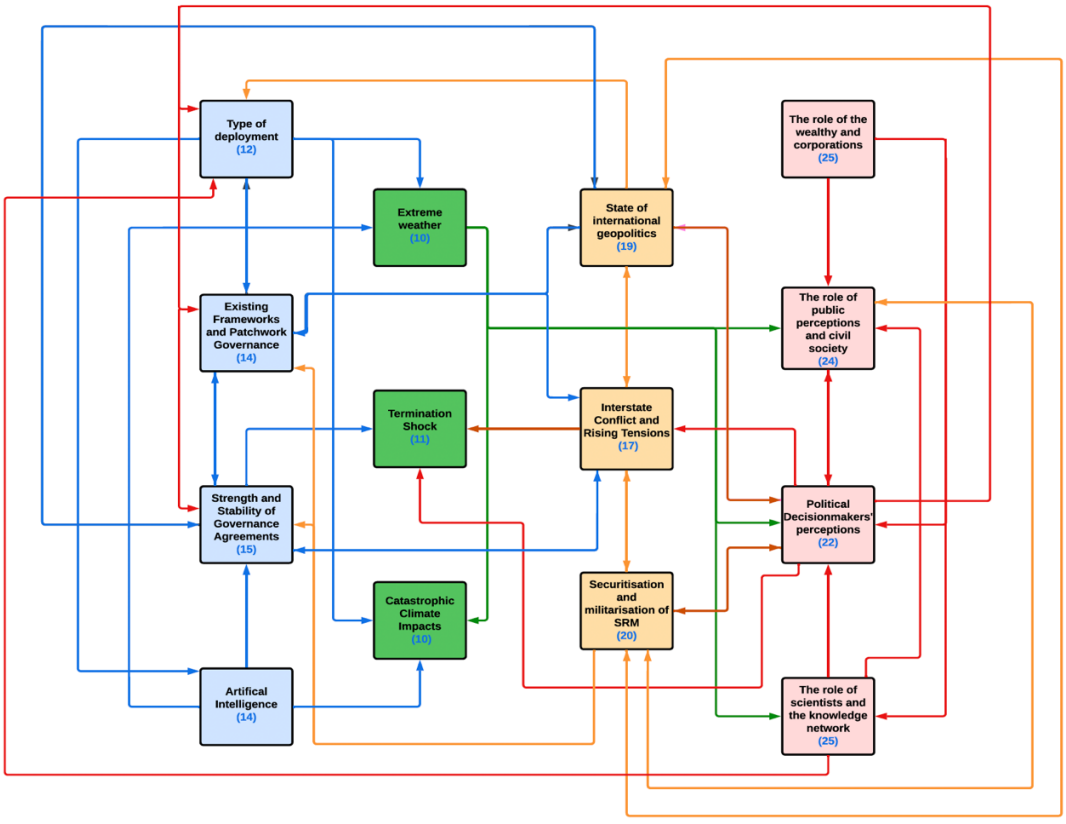

Figure 1: The interconnection of key themes of the interaction of SRM and GCR, arranged in columns corresponding to their groupings. The colour of the arrow corresponds to which grouping the arrow originated from (for double headed arrows, it is the further left grouping)

Extreme Weather and Climate

In this section we summarise participants' discussions about the importance of climate and weather, whether this be prior to (or in the absence of) SRM deployment, post deployment, or following the termination of SRM deployment. As noted above, all plausible scenarios producing a global catastrophe that were discussed by participants involved at least one of the following: catastrophic climate change; termination shock; or conflict. For catastrophic climate change and termination shock, there was little specific discussion of how these scenarios would lead to global catastrophe. We believe that this was partially a result of limited research into the plausibility of global catastrophe from either phenomenon, and recommend further research is needed, especially into their cascading impacts. However, participants also stressed that the ways in which climate and weather were perceived and interpreted, especially by political leaders and the public, may be as important as the underlying realities (discussed further in the section on agents, perceptions, narratives, and power).

CATASTROPHIC CLIMATE IMPACTS

Participants saw SRM's potential to **reduce many climatic impacts of rising greenhouse gas levels as the key way it could mitigate GCR** [I]. Impacts from climate change have been explored as contributors to GCR, particularly due to cascades from climate impacts (Beard et al 2021). Therefore, not only large amounts of warming (Ord 2020) but even lower levels of warming are being considered as potentially important for GCR (Kemp et al 2022); in either case SRM would be able to reduce the warming and many associated climate impacts (Irvine et al 2019, Felgenhauer et al 2022). **The lack of attention given to this within this report does not indicate that this is less important than other factors; indeed, some participants felt the moderation of climate hazards may be the dominant impact of SRM on GCR [I]**. However, the literature around climate change and GCR is still highly uncertain (Kemp et al 2022), and the focus of the workshop on SRM and GCR meant this theme was focused on less in discussions.

Some deemed it feasible that 'wild' deployment scenarios (see *Types of Deployment*) [I] could potentially increase negative climate effects in certain key regions [O], Others questioned whether there was any evidence that suggested this could [L,O], although the possibility of cascading impacts from negative regional impacts was raised [L]. Unforeseen climatic issues from SRM, may be important [D], although these may be less likely under SRM deployment than under climate change scenarios without SRM.

EXTREME WEATHER

Extreme weather events are the most visceral aspects of climate change and are often **how people perceive climate**. As such, extreme weather was seen as important in determining the perception of climate change and SRM, especially by political decisionmakers and publics [C, N],

Extreme weather was seen as a potentially triggering an imperative for rapid SRM deployment [L]. Participants also suggested events, such as ice sheet collapse, that could be seen as marking or giving early warning of hitting Earth system tipping points, could have similar effects [L]. However, some participants were also concerned that narratives

around extreme weather events could be manipulated to provide an excuse to carry out SRM, rather than being the primary motivation for it [A]. Some, however, questioned whether climate politics would indeed follow climate impacts [N], as this had not been perceived to be the case so far.

Participants also saw **extreme weather events as potentially triggering (rapid and extreme) shifts in attitude towards SRM post deployment** [H]. Such extreme weather events may be inflection points, where states' policies rapidly change, demanding compensation or termination, or acting as a pretext for conflict, with heatwaves been the most frequently discussed example [L,O].

Extreme weather is a key hazard of *catastrophic climatic change*. It also contributes to the perceptions of *publics* and *civil society,* although its impact is modulated by *the role of scientists and the knowledge network*; these connections are further explored in their respective sections.

TERMINATION SHOCK

Termination shock refers to the rapid changes to Earth systems that may occur in the event of a sudden termination of SRM; this has been proposed as a key pathway by which SRM may contribute to GCR (Baum et al 2013, Tang and Kemp 2021). The exact pathways via which termination shock could cause a global catastrophe were not discussed, in part because there has been little investigation of plausible consequences of termination shock, particularly cascading impacts. However, given that termination shock would involve rapid global warming, work thus far on the potential for climate change to contribute to GCR may demonstrate the potential severity of this risk (e.g. Richards et al 2021). Participants did not believe that all scenarios involving termination of SRM would be catastrophic [C], but the literature suggests that scenarios with rapid, sustained termination of a large forcing would be worse (Parker and Irvine 2018). Given that the termination pathways explored often involve international tensions and a breakdown of cooperation, political systems vulnerability to climate-related shocks may be worse than in other climate change scenarios.

Termination shock was perceived as a plausible scenario [A,B,C]. One scenario that was discussed involved a large scale SRM scheme occurring with broad global tolerance when a major power, originally not opposed to SRM (perhaps even supportive), changes its policy to be strongly in favour of SRM termination, for instance due to domestic pressure. One trigger for such a policy change could be an extreme weather event that is blamed on SRM [C], but it could also come from the rise of religious and extremist groups, anti-SRM populists (akin to anti-vaxxers) [H] or worries of the weaponisation of SRM. In this scenario, **the major power might then threaten conflict unless SRM termination occurs** [A] and other states might see this as a credible threat and perceive the risk of termination as, rightly or wrongly, less than the risk of conflict [C].

The possibility of a termination scenario where a prominent (or unilateral) deployer of SRM changes policy due to elections, particularly in the USA [B,C] was also discussed. However, the shortness of the election cycle means this may not signal a long-term shift in national policy, and short-lived terminations may not persist for long enough for the very worst effects to occur [G]. Nonetheless, the changing and breaking down of alliances, often a result of electoral changes, was considered sufficient by some to risk dangerous terminations [B], as the requisite political support to peacefully maintain SRM deployment may have been lost.

SRM Deployment and Governance

In this section we summarise discussions about the different ways in which SRM could be deployed and governed. Discussions about SRM often revolve around global perspectives and ideal assumptions about the way that technologies are used. However, in reality, deployment will be affected by a large number of factors and could occur in many different ways. Plausible scenarios of SRM in the wild could involve different actors deploying different technologies for different purposes and may interact with other emerging technologies, like Artificial Intelligence. We recommend that more research, both modelling and particularly non-modelling work, is undertaken to study the impacts of such scenarios on the combined physical-human system. Similarly, SRM governance will not emerge in a political vacuum but is likely to be strongly related to, and dependent upon, existing political arrangements, leading to patchwork governance initiatives that rely on delicately balanced coalitions, which may make achieving any kind of strong and stable governance very challenging. If strong and stable governance is to be achieved, we recommend that establishing the legitimacy of SRM governance is an important priority. Participants also discussed the ways in which these realities could impact on the state of geopolitics and the risk of interstate conflict.

TYPES OF DEPLOYMENTS

The type of SRM deployment (such as including the technology and distribution of deployment) was influential in a number of catastrophe pathways. In general, deployment was considered more dependent on political than scientific processes [A,H] and was especially contingent on the governance frameworks that deployment occurs within. This led to support among workshop participants for exploring a wider range of potential deployment schemes than those currently simulated in Earth System Models [G,J,I], and it was felt those **deployment scenarios that appear 'irrational' from an impartial, utility maximising, perspective may be more likely than generally thought when politics is taken into account [A].** There was however some worry [J] in the interest taken in these scenarios from those in national security establishment, and thus some warned that exploration of wild scenarios could increase securitisation (See *Securitisation and Militarisation*).

The ability for different types of deployment to cause differential benefits and damages, either deliberately or not, was seen as a potential motivator for conflict and tensions, as discussed below. A number of more 'wild' scenarios that may be feasible were explored, which could increase extreme weather relative to safer deployment and alter people's perception of SRM's impacts and importance contributing to termination risk and conflict. Moreover, catastrophic climate impacts may follow directly from a number of wild deployment scenarios (e.g. Haywood et al. (2013) explored some impacts that may approach near catastrophic severity for the affected region), and whilst the plausibility of those scenarios that could lead to (near) catastrophic impacts explored in the literature was not assessed, their existence may indicate that a wider range of wild deployment scenarios could result in catastrophic climate impacts, including some that are more plausible. Below, we describe four examples of possible scenarios, drawn primarily from the ParEvo scenarios rather than the workshop discussions, which, while not fully representing the breadth of those discussions, provided more detailed specification of how deployment might take place, giving some examples of what 'wild' deployment could look like.

Regional MCB scaleup. Proposals for Marine Cloud Brightening (MCB) to alter regional climates seem politically attractive [L], due to the perceived 'naturalness' and the perceived (although not necessarily real) ability to contain their most significant impacts from extending to the global scale. Thus, one 'wild' deployment scenario would involve large scale (subcontinental) regional MCB being carried out in a variety of regions around the world, with the aims primarily being to reduce sub-continental rather than global warming, but in an uncoordinated fashion [I]. The impacts of this regional deployment on regional climates, both those near to the deployment zone or linked through teleconnections, would be particularly important for the risk of conflict.

Changing distribution and deployment patterns [I]. Rather than advocating for termination, it may be possible that states opposed to SRM, irrespective of the method, make demands that affect the distribution of SRM deployment, perhaps substantially. Alternatively, if one governance regime is replaced with another, deployment distribution could change significantly. Whilst the mechanism for this to occur may seem more plausible with types of SRM that can be deployed regionally such as MCB and Cirrus Cloud Thinning (CCT), it may be possible for this to occur with global SRM technologies, like Stratospheric Aerosol Injection (SAI), such as demands to not inject over a specific latitude [J]. Even if such demands seem scientifically suspect, they may be politically attractive. Some of these changes in distribution and injection amount may be of minimal significance, whilst others may have large impacts on regional climate.

Deploying different kinds of SRM . Two different deployers or groups of deployers, not collaborating, could carry out different approaches to SRM, such as MCB and SAI [I]. While a similar scenario was proposed in Lockley et al (2022), the difference here is that the two deployment schemes may not be 'working in concert', rather, they could be independent deployment schemes [L,O] that may be attempting to outdo one other, vying for which has 'true control' over the global climate. This may lead to significant overcooling, or to large variations as deployment amounts change. Moreover, SAI may be used to try to suppress perceived regional variation in MCB impacts, or MCB to ameliorate perceived regional impacts of SAI.

Overcooling. States, either in an effort to compete for control over the deployment (due to 'free driver' incentives to try and achieve their optimal climate) or for other reasons, may overcool the climate [D]. This could cause significantly adverse effects, although it is unclear how these would compare to the alternative of climate change without SRM.

There was also significant discussion about the use of regional geoengineering, including MCB and also non-SRM techniques such as glacier stabilisation [L,M]. One set of ParEvo scenarios presented local geoengineering as a legitimising and galvanising force, allowing the build-up of governance frameworks and international support for SRM. The plausibility of a galvanising effect from regional geoengineering was divisive; some participants felt that the legitimation that it could give may make large interventions more likely [L,M], whilst others felt it would reduce the perceived necessity of SRM or may be too remote from many to have global political effects [L]. It was often considered that such regional actions may not be as responsive to international pressures as global SRM, and **would be more likely to be deployed unilaterally** [L,O], as they could be within the jurisdiction of a single state. However, it was not felt this

unilateralism would necessarily have the same direct negative consequences as unilateralism over more global interventions [L]. It was also suggested that governance agreements over the regional geoengineering could be easier than global interventions, and thus could lay the groundwork for patchwork governance [L].

The type of SRM deployment is connected with many other themes. It may contribute significantly to the possibility, and mitigation, of *catastrophic climate impacts* and *extreme weather*. The application of *Artificial Intelligence* may only be possible or desirable under certain deployment types with greater degrees of freedom. The type of deployment available may impact which *pre-existing governance frameworks SRM could fit within, and what forms of patchwork governance are feasible*; for example, if MCB is technically feasible, the possibility space of governance is increased, whilst other frameworks require regional geoengineering.

THE APPLICATION OF ARTIFICIAL INTELLIGENCE IN SRM DEPLOYMENT

Given their rapid development and increasing integration into society, AI systems were seen as a potential part of pathways to GCR [D]. Some saw automation as a way that countries could 'depoliticise' SRM and, by obviating responsibility, forestall some pathways to conflict by reducing the perception that power can be asserted through SRM (whether this perception is accurate is not necessarily of significance).

AI also impacts the type and manner of deployment [D]. The capacity for AI systems to assist in the observation, calibration, and control of SRM deployment schemes could both contribute to and mitigate GCR. This may make it easier to achieve more 'optimal' SRM deployments, reducing climate damages and opening up more conflict-avoiding options. However, it may also increase the capacity for conflict by increasing the range of options to potentially dispute over, suspicion around the possible weaponisation of the programme due to more 'precise' control, and public distrust in systems they can't understand.

Finally, AI systems may make 'wild deployment' more likely, if too much trust is put into AI systems, particularly for deployment schemes with more degrees of freedom of deployment design [D]. AI systems often do things their creators don't expect, particularly when operating outside of the conditions they were trained on. Thus, giving algorithms power over deployment runs the risk of 'irrational' and unexplainable deployment schemes that could have significant material effects or damage public trust in these schemes. This may be more likely if algorithms are having to interact with each other, or with human run deployment schemes. While these AI systems could be changed, this may not happen if there is a significant political cost to changing them. Whether there exist deployment schemes with enough degrees of freedom for this to be a problem was, however, not assessed, which may Impact the plausibility of this concern.

AI, by impacting technical characteristics of how deployment works, would impact both extreme weather and *catastrophic climate impacts*. The depoliticising tendency of AI could impact on the *strength and stability of governance frameworks*.

EXISTING GOVERNANCE FRAMEWORKS AND PATCHWORK GOVERNANCE

Many participants found it more likely that state and non-state actors would **attempt to fit SRM into existing governance frameworks** than to create wholly new frameworks around it [L,K,O]. It was suggested that, if multilateral governance were to happen, it would be situated within the UN system; although this would be unlikely to be under the auspices of the UNFCCC, especially given the lack of discussion thus far in that venue [K]. Others [K,N] felt that **a patchwork approach, where a variety of different, incomplete, governance frameworks developed around SRM, was plausible.** It was felt that this could happen because the creation of truly global and inclusive governance structures would be deeply unattractive to the most powerful and would be likely met with a veto if it were to happen at the UN

General Assembly [N]. Thus, settings where governance is less global, and either allows for more great power dominance, or can bypass objectors, was considered more plausible [N]. Moreover, such sub-global governance could come about more slowly, where states 'sleep-walk' into patchwork governance; although this could also lay stepping stones for more unified global governance to be constructed later [L]. Participants were generally more pessimistic about the plausibility of effective, unified, global governance than the plausibility of incomplete patchworks [O].

This may make forms of SRM that can be perceived as 'regional', such as MCB or CCT, more attractive, although the inherent global effects of any SRM schemes limit how plausible such regional deployment may actually be [K]. A variety of different governance regimes could contribute to the patchwork, although how such a patchwork would function is an area where further study is needed.

The scenarios laid out a number of possible patchworks, with each of the following considered plausible by different groups. Some centred around regional deployment of MCB under existing international law [K], with some then expanding these to involve either loose SRM specific coordination or SAI carried out under a different, tailored agreement simultaneously. Another set of scenarios saw SRM beginning in the Arctic under the auspices of the Arctic Council, then at the Antarctic with collaboration with the Antarctic Treaty System, and then global deployment subject to a variety of different international governance frameworks that were not specifically SRM tailored but are nonetheless relevant (e.g. Montreal Protocol) [N]. Meanwhile, other scenarios involved the creation of competing mini-lateral deployment frameworks, either centred around the USA and China, or following a rough 'Global North' and 'Global South' split [N]. These frameworks, and the workshop's assessment of their plausibility, will be further expanded upon in future works presenting the scenarios, but have been presented here for some reference.

The exact nature of the governance framework is likely to significantly impact, as well as be impacted by, the *state of geopolitics* and the *possibility of interstate conflict and rising tensions*. Similarly, the *type of deployments* available and considered to be attractive will both dictate what sorts of governance frameworks are feasible and desirable; and their desirability and support may be impacted by the frameworks considered possible or desirable. The *strength and stability of governance frameworks* will be impacted by the exact configuration of these framework, and therefore the nature of patchworks and whether pre-existing frameworks are used could be profoundly important.

STRENGTH AND STABILITY OF INTERNATIONAL GOVERNANCE

Partially as a result of this, the possible international governance frameworks that were considered during the discussions were often seen as resulting from delicately held together coalitions, and thus it was felt that the sorts of **strong and sustainable governance frameworks that are often seen as most desirable were either implausible or would collapse** [O]. Global consensus was considered very difficult to achieve on an issue as contentious as SRM [L,O], particularly given how the power dynamics and rivalry between countries would impact SRM [M] or how SRM could become a method for assertion of power [A]. Even if technical details were resolved, **issues of control may be significant enough to make multilateral agreements very contentious** [A]. Such failures of multilateralism were considered as likely precursors to conflict [A].

Participants felt that scenarios, both those presented at the workshop and those typically conceived in SRM discussions, normally underplay the impact of division in international governance [B,M]. **Historical issues between countries would significantly impact trust in any governance scheme [L]**, hindering the establishment of inclusive governance. The inherent transboundary impacts of SRM led some to conclude that it was unlikely that states would be willing to be junior partners in quasi-unilateral governance regimes [N]; although others questioned whether states would have the option to adequately counter such deployment [O].

SRM DEPLOYMENT AND GOVERNANCE

While scenarios often conceptualised states acting in traditional blocs, it was felt that the unique issues around SRM may lead to divisions within these. For instance, there may be fundamentally different perspectives between 'Global North' and 'Global South' countries on SRM as well as substantial disagreements within the 'Global South'; which it was felt both the ParEvo scenarios and discussions in the field in general underplay [L]. Moreover, if changes in public opinion and politicisation of SRM cause rapid changes in state policy towards SRM, trust in its governance institutions may weaken, meaning that even if there were strong governance institutions in the shorter term, these may break down [H]; a possibility that would be particularly dangerous in an untrusting geopolitical landscape.

The strength and stability of international governance directly impacts, and is impacted by, *interstate conflict and rising tensions*; stronger governance frameworks would allow for dispute resolution without conflict. Moreover, weak and unstable governance frameworks were seen as risk factors for *termination shock* to occur. The possibility of patchwork governance and the use of existing frameworks impacts the strength and stability of governance frameworks; and are impacted by it by weaker and stronger governance frameworks shaping the governance space, allowing room for certain possibilities and crowding out others. Not only is the strength and stability of governance frameworks shaped by the state of *geopolitics*, but if SRM were to be considered important enough, the strength of governance frameworks could impact geopolitics.

Conflict, Security, and Geopolitics

Participants felt that interstate conflict, especially but not exclusively if this involved the use of nuclear weapons, was one of the main ways in which SRM might contribute to GCR. However, there the relationship between these two things was seen as quite complicated and uncertain with many possible mechanisms involved (including great power rivalries, lesser power aspirations, different perceptions of SRM harms, and miscommunication of red-lines) and uncertainty over whether SRM would make such conflict more or less likely. However, it was also felt that the perception of SRM's impacts and importance would be more significant, even than the underlying realities. Even if interstate conflict were not directly impacted by SRM, SRM would, by similar processes, have effects on international tensions which have also been seen as important impacts on GCR. Other aspects of geopolitics were also seen as important by some participants, including the potential for SRM to be used as a way of gaining national prestige, leading to worse and/or competing deployment strategies or governance frameworks. We recommend that more research is undertaken to understand the geopolitical escalation dynamics that may lead disagreements over SRM to lead to conflict. We also suggest that researchers should seek to foster multilateralism and avoid overstating the geopolitical importance of SRM as steps towards reducing the risk of conflict in the future.

Several participants noted that the risk of conflict may be increased were SRM to be securitised in certain ways (particularly if it is brought into a limited discourse and entrenched policy establishment that has built up around different aspects of national security) and/or militarisation (i.e. adopted by military establishments), although it is important to recognise that these are not the same thing. To counter this, we recommend that national security establishments ought to refrain from attempting to securitise SRM and that militaries commit to playing no role in SRM research.

INTERSTATE CONFLICT AND RISING TENSIONS

This was amongst the most commonly discussed factors involved in pathways to catastrophe [A,C,F,H].

Of particular relevance to GCR, **the escalation of conflict related to SRM all the way to a nuclear conflict was deemed to be possible** [A, F]. However, some felt that escalation from tensions (which were either made more or less likely by SRM) all the way to nuclear war was unlikely [C], while others thought that **the escalation pathways involved would potentially be slow, increasing opportunities for de-escalation** [M]. Others, however, saw the breakdown of trust, heightening brinksmanship, and potential speed of escalation as making de-escalation unlikely, thus allowing for military and possibly nuclear conflict to occur [J]. Escalation may occur specifically due to military intervention against SRM [L], such as destruction of infrastructure used for carrying out SRM [J], which, while justified by the attacking country as protecting against SRM that it sees as a military threat in itself [M], may be considered an attack by the state carrying out SRM, escalating to full scale conflict. In addition, SRM may increase the risk of nuclear conflict indirectly, by contributing to broader geopolitical tensions, with some seeing this as the more significant way that SRM could contribute to nuclear risk [A]. The possibility of SRM reducing the risk of conflict, including nuclear conflict was also discussed by some [G]. Climate hazards have been proposed in the literature as a contributor to conflict by increasing the probability of conflict over scarce resources, and impacting mediating factors and acting as a stressor in certain

conditions (Koubi 2019), although the strength of these linkages are highly uncertain and even less is known about the link between climate change and the risk of nuclear conflict specifically. By reducing climate stresses, SRM would reduce the climate-driven contribution to conflict [A,E], which may reduce the risk of nuclear conflict overall.

However, it is not only via its impact on nuclear risk that SRM induced conflict might contribute to GCR. Rising tensions and a reduction of global cooperation have been seen as increasing humanity's vulnerability and exposure to many other hazards (Liu et al 2018, Ord 2020), and conventional conflict could compromise a number of critical global systems (Avin 2018) or contribute to societal collapse through cascades (Richards et al 2021), providing further contributions to GCR.

A number of pathways involving rising tensions and interstate conflict were discussed [A,B,C,E,F,H]. Some of the most important of these are listed below. It should be noted that even if these pathways do not escalate all the way to conflict as presented, they still would significantly contribute to rising tensions and thus GCR.

SRM could be conceptualised as an arena for great power competition, increasing tensions as states vie for influence [A,M]. If SRM was perceived to give countries a global strategic advantage, then losing control over SRM deployment may be considered a large enough threat to their influence that they would be willing to risk tensions and conflict over it [A]. While there was often pessimism about the possibility of a sustainable global agreement, there was also a suggestion that superpowers would see unilateral deployment as such a threat to their security that they simply would not allow it [C]. Participants suggested even if such a superpower competition may be deescalated by other means (economic or diplomatic), escalation to armed conflict cannot be ruled out. This is because under race dynamics and geopolitical competition, decision-making becomes increasingly concerned with saving face and asserting power while involving misperceptions of others behaviour, intentions, and interests, as well as general 'irrationality' [A].

SRM could be used as a means for weaker powers to assert themselves [A]. Some suggested SRM may be used by these powers to combat the existential threat they may perceive climate to pose for them, or as a means of gaining a global strategic advantage [L]. Moreover, the threat of unilateral deployment used to force more powerful countries into concessions, including a multilateral deployment programme, may be taken as an alarming threat to these great powers' hegemony. This may then cause great powers to take different sides, pre-empting any governance regime that could build up, and causing an expansion of SRM deployment, which individual powers alone might not have taken. While it was generally considered that hegemonic states (e.g. the USA) would be more likely to be the initiators of deployment, it was also considered that other states deploying SRM could be seen as such a threat to their hegemony that they would be willing to risk conflict over it [A].

Tensions over perceived damages from SRM [A,C,M,J]. While climate impacts have thus far failed to regularly cause interstate conflict, the ability for blame to be assigned at a single country, or coalition of countries, for deploying SRM may make this more likely. This could happen via climatic events, such as a cold snap or failed harvest, being perceived as a direct result of other countries' actions or

even as acts of aggression, and creating the impression of a general enemy who can be targeted or of whom remedial action can be demanded [J]. If such remedial action is not taken, or the SRM is perceived to have breached countries' red lines, conflict may occur.

Misperception over SRM red lines [A,J]. States, be they great powers or weaker countries, may misperceive how other states perceive them and their actions, and so what is an acceptable action to one state may be escalatory to another. It was felt that conflict may occur by one state perceiving that they had the right to deploy SRM, while another saw this as a red line and thus might take a variety of actions to attempt to stop it [A]. Other misperceptions may involve incorrectly pre-empting other states actions [J], causing a race to deployment where the states may take increasingly escalatory actions, similar to the various arms races during the Cold War.

It was also stressed by some participants that, while emerging technologies like SRM don't always lead to disruptions by themselves, **there are factors, such as a reduction in the power of arms control agreements, an increased willingness to threaten military conflict or the use of nuclear weapons, and a broadening conception of what constitutes a military attack, that can increase the vulnerability to the presence of such technologies and make conflict more likely** [A].

Although most discussions focused on SRM leading to additional conflict in the world, some felt that conflicts that could be triggered due to SRM might happen anyway due to another trigger [E]. Others highlighted the capacity of SRM to reduce conflict risk by reducing the impacts of climate change [A,E], although those discussions were mostly seen as beyond the scope of the workshop.

Rising tensions and the threat of interstate conflict were critical components for many pathways to *termination shock*. Conflict and tensions are both impacted by the *state of geopolitics* and have the potential to reconfigure geopolitics as well. The strength and stability of governance frameworks could be impacted and undermined by *rising tensions and interstate conflict*. SRM *securitisation and militarisation* are also both impacted and impacts interstate conflict and rising tensions; for example as tensions grow, SRM may become more securitised as the actions of rivals become perceived as threats to the existence of states.

THE STATE OF GEOPOLITICS

Geopolitics was seen to be a key mediator in pathways to catastrophe by many groups [A,B,H,I,M]. In these discussions and the ParEvo scenarios that informed them, the state of geopolitics was sometimes approximated as 'already set', with events and perceptions of SRM happening against a pre-existing and entrenched global system, whilst in others it was significantly altered by SRM and the discussions around it. However, it was felt by some that the importance of SRM and climate change in geopolitics is often overestimated [A]. A number of facets of geopolitics were seen as potentially important contributors to these pathways to catastrophe. The drive for national prestige, perhaps driven by domestic politics; **low trust; othering of certain states and their exclusion from the science and governance of SRM (e.g. excluding China from 'Western' SRM efforts); and a continued breakdown of multilateralism were seen as worrying** possibilities that made the scenarios where SRM contributes to GCR more likely [A]. The exclusion of states based on other geopolitical priorities, such as Russian exclusion over Ukraine, was seen as likely [M].

Unilateralism in SRM, particularly in its deployment, was seen as very dangerous [A,B,I]. It was also seen as highly possible, particularly in hegemonic states like the US, and potentially China) [A,B,M]. In a bipolar world, where a narrative

of SRM as a purely rational climate focused technology failed to take hold, this may be unstable and cause competition or conflict [A,M,N]

Geopolitics is clearly related to conflict but also other key factors. For instance, confusion around states objectives for SRM deployment, red lines, and changing state policy were seen as further contributors to geopolitical destabilisation [A]. Moreover, even if there were governance agreements around SRM, their breakdown would be made both more likely and more dangerous in an untrusting geopolitical environment.

Therefore, as explained, geopolitics both impacts as is impacted by *interstate conflict and rising tensions*, the *strength and stability of governance agreements* and *patchwork governance and existing frameworks*. While impacted by the decisions of political leaders (and so by extension their perceptions), it also impacts these perceptions by providing the frame by which leaders interact with other states' leaders and perceive their actions around SRM. *Securitisation and militarisation*, similarly, are impacted by the nature of the geopolitical landscape, and how this impacts the perceptions and actions of securitising actors. Finally, the nature of geopolitics may dictate which *types of deployment* are feasible and desirable, as different deployment types may be perceived to carry different geopolitical consequences.

SECURITISATION AND MILITARISATION OF SRM

Several participants were concerned about SRM become part of securitised politics [A,M]. This would involve moving SRM into a limited policy discourse focused on matters of security. Securitisation is not concerned with what is objectively the greatest threat; rather it is intersubjective, involving the successful carrying out of a process where an authority designates something an (existential) threat to the state or another important object, which justifies or requires the carrying out of exceptional measures to combat it (Buzan et al 1998). This could lead to precautionary principles being replaced by emergency principle [M], where the quick-fix nature of SRM and a desire to be seen as 'doing something' may dominate. Whilst there was discussion of the SRM as a security measure against the existential threat of climate change to smaller states [L], most of the discussion of concerns around securitisation centred around **SRM being subject to traditional military-political national security logics and entrenched policy establishments within powerful states** [A,M,N]. It was suggested many in the field studying SRM underestimated the influence that the security establishment may have over SRM in the future [N].

Securitisation of SRM was seen as an important condition for conflict [A,M]. Thus, the pathways and considerations discussed in *Interstate Conflict and Rising Tensions* would involve, or lead to, SRM becoming part of securitised politics, even if this language was not always used at the workshop. Collaboration between states, and especially great powers, on SRM, and even communication between them, may reduce significantly once SRM is brought into securitised politics, with competition, blame and suspicion becoming more prevalent [A,M]. Secrecy resulting from this could further erode trust and the capability of governance regimes to adequately function [B]. States may become the only actors seen as having legitimacy to engage with SRM, with the influence of civil society diminished as SRM moves out of the realm of normal politics [M]. Securitisation could lead to too much weight being put on national differences in SRM research and deployment, for example, discussions of SRM in the US security context are less likely to be inclusive of China, and are more likely to see Chinese efforts as 'rogue' deployment, in opposition to 'legitimate' Western deployment [A] Here**, political and national narratives may be put ahead of evidence-based policymaking** [A,N]. Counter-geoengineering was seen as also a plausible security tool, to be used to threaten actors using SRM during disagreements [M].

Militarisation involves the adoption of a technology by military establishments. This may follow from securitisation, with SRM deployment being carried out by military infrastructure or military engagement with SRM related actions being significant [L,M]. It was felt that such militarisation may promote military capture, in which military establishments seek to monopolise a technology with policies to limit or prohibit 'civilian use' [L], which may also impact the types of

infrastructure that are built or developed for technologies with dual-use capabilities [M]. Moreover, if SRM infrastructure fell under the control of militaries, the perception that SRM poses a significant threat may be more likely, leading to securitisation and encouraging pathways to escalation of tensions and conflict [M]. Transparency and multilateralism would likely be significantly hampered by militarisation.

Securitisation and militarisation thus both contribute to *conflict and rising tensions* directly and affect the perceptions, of SRM's importance and impacts by *political decisionmakers and publics*. Moreover, securitisation will affect the importance and logics by which SRM is governed, profoundly affecting the *state of geopolitics* and all aspects of governance, including their *strength and stability*, and the possibility of p*atchwork governance and the use of pre-existing frameworks*.

Agents, Perceptions, Narratives, and Power

Decisions about SRM deployment, termination, and governance will be substantially impacted by different actors, including political decisionmakers, publics, civil society, wealthy individuals, corporations, and scientists. These actors will also have influence over emerging conflicts and geopolitical tensions that may arise from, or have influence over, SRM. Participants therefore gave considerable attention to how these agents might perceive, interpret, impact and respond to the prospect of SRM. A key point of these discussions is that different perceptions and narratives around both the impacts and importance of SRM could greatly influence decision making and that there would be differences both between and within states and across time. As a result, political leaders are likely to be both responsive to wider perceptions while also seeking to influence them in order to navigate domestic politics and promote their state's interests on the world stage. This highlights the need for better understanding of public perceptions and the factors that can lead them to shift suddenly. Participants also highlighted the role of attribution of harms, from both climate change and SRM, mediated through a variety of narratives, might play in influencing wider debates and we thus recommend that scientific attribution studies are undertaken carefully and used reflectively by researchers.

In general participants were less concerned about the role of wealthy individuals and corporations, at least where they are operating on their own rather than via collaboration with, or capture of, state infrastructures. However, there was concern about any source of significant public influence, including religious authorities and conspiracy theorists. Participants felt that the present knowledge network around SRM had only limited influence, and that this was likely to reduce as the technology became better known. Nevertheless, as this is a community more likely to pay attention to this specific report, we also make a number of recommendations for how this network might increase its influence and use it to reduce GCR: such as lowering the barriers for a wider range of stakeholders to enter and engage with this network and thinking carefully about the ways that our work might be politicised in future.

POLITICAL DECISIONMAKERS' PERCEPTIONS

As discussed above, the **perception of SRM's impacts by political decisionmakers, particularly political leaders, was seen as important in many pathways to conflict and termination [A,D],** as well as many other factors. Moreover, as the actions of these decisionmakers may be so consequential, understanding what impacts their perceptions may be keenly important.

There are a number of ways in which these perceptions could differ significantly between states. This could be because **the 'real' impacts of SRM differ** [L]. The relative changes in benefits and power that may result from heterogenous regional impacts were considered dangerous enough that destabilisation of the international order, and thus tensions and conflict, may occur [A,J].

However, it is also possible for the perceived impacts of SRM to be considerably more heterogenous than these impacts themselves. **Policy is often not based on the best scientific evidence and modelling, [H] while perception and lived experience of climate do not reflect model outputs,** particularly when looking at global or even regional averages [B]. Indeed, long lead times (for many proposed deployment schemes) and opaque effects mean that perceived impacts of

AGENTS, PERCEPTIONS, NARRATIVES, AND POWER

SRM may be determined more by narratives than science [M]. Several discussions focussed on the potential of attribution of extreme weather and other climatic events to SRM, and it was felt that **SRM may be blamed for very damaging extreme weather events** [C, L], either cynically or sincerely. The ability of attribution science to confidently attribute an event to SRM was seen as questionable [C] but it was also felt that attempts to temper blame discourses would require public trust in the scientific community to be high [H]. Extreme weather events already get blamed on climate change with limited evidence, and it seems likely that such would continue with SRM [C].

Even where policy is supposedly evidence based; **evidence may be cherrypicked, scientific consensus can diverge between communities and nations, and extra-scientific narratives may guide the interpretation of the science** [C]. Perceptions of SRM's impacts may be informed by trust or mistrust in the deployment system, attitudes towards the SRM in general, or the power of other public narratives (discussed below); either way, **the 'scientific' perception of SRM's perceived impacts may be rather different to that which informs policy** [C,I].

Many pathways to catastrophe are contingent on the perception that control over SRM, its deployment, and termination is of sufficient importance that states are willing to risk catastrophe to ensure this control. Thus, the perceived importance of SRM and its impacts is of profound importance, not just the valence of said impacts.

Political perceptions may understate or overstate the desirability or undesirability of SRM. Damages from climate change may be perceived as so strong that political decisionmakers believe they have a moral duty to carry out SRM, and that stopping this is a direct affront to the continued existence of their states and populations [L]. Others may **interpret the impacts of SRM as an existential threat to their citizens** [A] and may interpret extreme weather events as harbingers of extreme damage to come. Here, SRM may be become seen as a matter of desperate emergency response, which could translate into unreasonable support [M]. Similarly, if the climate is surprisingly stable (due to natural variation) in the years following deployment, this may further bolster support for SRM [L]. A silver bullet narrative may develop, where SRM is touted as a saviour and its importance exaggerated, whilst also leading to dangerous mitigation deterrence [B]. Finally, **termination may be interpreted as so much of an existential threat** that it shouldn't be countenanced, and maybe even conflict would be preferable, [A] although the scientific basis of this claim was contested by some at the workshop [C].

Moreover, this perceived importance doesn't have to be solely climatic. Participants suggested that leaders may see controlling the 'global thermostat' as a vital part of continued power on the international stage and thus **the loss of control over the global thermostat as a vitally important threat to their state's power** [J]. Political decisionmakers are very unlikely to trust countries they perceive as their rivals [A], further heightening this importance. Tapping into pre-existing narratives of power and control may heighten the importance of SRM. The inequalities generated during deployment (even if, on balance, everyone benefits) may further heighten the perceived importance of control over SRM [A,L].

Political decisionmakers' perceptions may be key to all themes discussed that require political decisions, including the *types of deployment*, the *strength and stability of governance frameworks*, the *use of Artificial Intelligence*, *patchwork governance and existing frameworks*, *rising tensions and interstate conflict*, and *termination shock*. The discursive power of political decisionmakers, and their securitising authority, would impact the s*ecuritisation and militarisation of SRM*, as well as *public perceptions* of SRM. These decisions and discursive impacts will in turn impact the *state of geopolitics*.

THE ROLE OF PUBLICS AND CIVIL SOCIETY

The public can play a variety of roles in shaping narratives, including extreme narratives, around SRM and may provide a key impetus for changing policy; as discussed below, **domestic politics will likely be a key driver of international politics around SRM [M]**, and thus understanding the role of the public and civil society may be very important. As above, particular focus will be on what may impact the perceptions of publics and why these may diverge or change between publics.

Discussions highlighted many groups that impact on public perceptions and support for SRM. Typically, the knowledge-network around SRM has been the focus of discussion (and we discuss this below); however, while this may be important at present, if SRM gains political salience, the role of this community would likely decrease [N]. The media, who act to frame and highlight certain aspects of the SRM debate, will likely continue to gain importance [B,F], although the role of social media and other algorithmically mediated platforms may be even more vital - increasing the influence of both the platform users and the platform owners, such as social media companies [F,H]. Thinktanks and NGOs help to promote and legitimise certain narratives [E,F], as do religious groups and conspiracy theorists [H]. Some participants, however, saw civil society as likely more divided, and its power more limited, particularly in the face of elite or state power or the ability of powerful actors to shape narratives [A].

Discussions identified many different kinds of narrative that could shape the future development of SRM. If SRM becomes more politicised, different political groupings may contest narratives around it. This may be important, as the changing fortunes of political factions could cause rapid changes in government policies, reducing the stability of any governance regime [B,E]. If SRM is seen as a 'silver bullet' to the climate crisis [B], this may buoy public support, although such simplistic thinking may allow SRM to easily be blamed for negative events [L] or lead to mitigation deterrence [B]. Other narratives may **frame SRM as a humanitarian intervention** [A,N], while the current opposition of climate justice advocates to SRM may also continue and grow in strength. **SRM may be framed as a matter of national pride and security [A]**, as an anti-migration measure [E], or as a tool of colonialism [M]. Thus, the importance of history on public perceptions may be important [L]. Similarly, narratives of security might be bolstered by the public, thinktanks, and the media, impacting securitisation. Of particular concern may be the **narratives shaped by conspiracy theorists [M]**, including narratives around mind-control, deliberate causing of droughts, and other antagonistic possibilities; some of these narratives are already linked to discussions around SRM (such the chem-trails conspiracy), while the COVID pandemic highlighted how impactful conspiratorial thinking can become. Religious narratives, such as seeing SRM as an unnatural affront to God, may also shape public and political opinion [M].

These perceptions can inform policy in various ways**. Political decisionmakers may be responsive to public sentiment towards SRM, or towards the attitudes of special interest groups** [H]. SRM may be a useful scapegoat for other issues, a distraction, or a simple techno-fix for climate change [B]. Political groupings with strong attitudes towards SRM may gain control of the levers of power, or political leaders keen to win over constituencies may change policies towards SRM [H]. Moreover, politicians and policymakers are embedded in society, making public narratives likely to sway them as individuals as well. Nonetheless, others discussed the power of lobbyists or others working directly on elite power shaping [A,L] (see *Role of Wealthy Individuals and Corporations*) as potentially reducing the importance of public narratives.

Thus, public perception and the role of civil society can impact *political decisionmakers' perceptions*, and the dominance or challenging of narratives around security may be able to impact *securitisation and militarisation*.

THE ROLE OF WEALTHY INDIVIDUALS AND CORPORATIONS

There was much discussion about the role of the wealthy, particularly in the formation of governance frameworks [L,M]. The prospect of wealthy individuals and corporations directly and explicitly capturing SRM politics and deployment, including a 'greenfinger' scenario (in which a single wealthy individual attempts to unilaterally deploy SRM), were generally seen as implausible [L,M]. However, their ability **to promote SRM by harnessing the voices of others** was seen as potentially more significant, such as by funding NGOs and scientists they agree with [K]. Direct lobbying of governments may also be plausible, although it was considered to be most effective if a broad coalition was raised in support [L]. The motivation of such interventions was seen as being more likely philanthropic than profit-seeking, which would continue a similar mode of involvement of the wealthy in SRM today [L].

While some of the ParEvo scenarios explored the direct corporate capture of SRM governance, workshop participants generally felt this was implausible and it was felt that **nation states would remain the backbone of deployment** [K,M,O]. Corporate actors would likely require states backing to make profits from SRM [O], and ultimately international governance systems will likely be based on nation states too [K].

Wealthy individuals are most likely to exert discursive authority, and therefore to impact the perception by other actors, namely *publics* and political decisionmakers. One way this could be done is by wealthy individuals shaping the *role of scientists and the knowledge network* through funding, and this effect could also impact intra-network discourses and perceptions as well.

THE ROLE OF SCIENTISTS AND THE KNOWLEDGE NETWORK

Given one of the purposes of the workshop was to inform action among researchers on topics relevant to SRM, identifying the role that the current knowledge network around SRM played in determining how SRM may interact with GCR was seen as important by participants. However, the importance of **the knowledge network was considered minor compared to more powerful actors, such as politicians** [L, N], although not insignificant.

One aspect of this role was in **affecting public discourse and political narratives** [H]. Scientists are, in general, trusted (although the COVID pandemic highlighted the limits of this), which may allow them to play some role in shaping public discourse. This may be important in reducing extreme perceptions of SRM's impact. Attribution science may also be able to influence the perception of extreme weather events [C] and may be able to dispel worries around deliberate manipulation, although the blaming today of climate change for extreme weather events by before attribution has been able to happen may indicate such studies will only be of limited importance [C].

Some hoped that scientific advice to policymakers may also **be able to warn them away from dangerous deployment** schemes [H] or termination, by highlighting the dangers involved. Others, however, pointed to how scientists had often been cut out of the loop in military decisions, and suggested the same thing may happen with SRM [N]. Scientists also have a role in constructing the options presented as possible to policymakers and the public [H], including highlighting the risks of reliance on a single approach [E]. However, given the central importance of socio-political considerations and extra-scientific narratives, and the plausibility of deployment that would be 'irrational' from an Earth systems perspective [A], the scientific influence may be limited in setting possible options.

Therefore, scientists and the knowledge network were seen as affecting perceptions from both *political decisionmakers* and *publics*, and directing advice on the *type of deployment* - and via this advice, also affecting the possibility of *catastrophic climate impacts* and *termination shock*).

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STATEMENT OF AUTHORSHIP

Gideon Futerman conceptualised the work, prepared the initial draft of this report and revised the draft in response to feedback from reviewers.

SJ Beard reviewed and edited the manuscript and assisted with its conceptualisation and formulating the recommendations.

Appendix: List of Participants

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Daniele Visioni

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