

Global status of activities relating to Solar Radiation Modification and its governance

Briefing note by the Carnegie Climate Governance Initiative (C2G)¹ summarising key insights into activities relating to solar radiation modification and its governance globally

Eighth Edition, 3 July 2023

Summary

With climate impacts intensifying and no credible pathway in place for international climate action to limit global warming below 1.5°C², increasing voices are calling for and preparing additional emergency options such as solar radiation modification (SRM)³ to keep global temperature rise in check⁴. This briefing note provides a high-level overview of the current status and developments in research, intergovernmental processes and non-governmental engagement relating to SRM and its governance globally⁵.

The latest assessment of science by the Intergovernmental Panel on Climate Change (IPCC) published in 2021-23 indicates that while SRM techniques may be theoretically effective in reducing some climate hazards, the risks or benefits they pose are poorly understood and relevant governance is weak or missing⁶. In addition to the IPCC assessment, other UN bodies have recently published (or are preparing) reports addressing SRM and its governance and over the past year public statements both supporting and objecting to more SRM-related research have increased along with private sector engagement and media interest.

In late June 2023 the White House published an SRM research plan and governance framework and the European Union announced its support for international efforts to assess the risks and uncertainties of SRM and promote discussions on a potential international framework for its governance. Earlier in April, the UN High-Level Advisory Board on Effective Multilateralism (HLAB) published a report recommending a forum on the governance of climate altering technologies. In February 2023, the UN Environment Programme (UNEP) published a rapid independent expert review of SRM research and deployment concluding on the need for robust scientific assessment, development of governance frameworks, and promotion of globally inclusive discussions. Meanwhile a US company began selling ‘cooling credits’ and launching balloons for the purpose of stratospheric aerosol injection based SRM and two international groups of scientists called for more research into SRM and its impacts. Outdoor marine cloud brightening experiments are underway in Australia while planned stratospheric aerosol injection-related experiments were recently cancelled over the US and Sweden, following objections from indigenous people and environmental groups. In early 2023, the US National Oceanic and Atmospheric Administration (NOAA) successfully completed its first stratospheric research flights over the Arctic to better assess, among other things, the potential costs and benefits of SRM climate intervention.

With an increasing number of UN and other intergovernmental processes indicating the risk of ungoverned SRM is becoming a growing cause for concern, the international discussion about SRM and its governance is now firmly emerging on the international agenda.

Status of Research and Assessments

- **SRM-related research is underway internationally.** While not yet systematically tracked, some notable examples include:
 - In 2023 the **Degrees Modelling Fund** announced an additional USD~\$1m for 15 new research projects into the impacts of SRM across Africa, Asia and South America.
 - the USD\$16.2m **Harvard Solar Geoengineering Program** which is planning the world's first outdoor experiments to advance understanding of stratospheric aerosol injection (SAI) (**SCoPEX**).
 - the USD\$1m/year **Arctic Ice Project** which is exploring ways to restore Arctic Sea ice
 - part of the AUS\$100m Australian-funded **Reef Restoration and Adaptation Program (RRAP)** which in 2020 began the **first marine cloud brightening (MCB) field tests** spraying nano-sized sea-salt particles into the air above the reef.
 - In 2021 the EUR€9m European Union-funded **GENIE project** began exploring transdisciplinary dimensions of SRM.
 - In **2020** the US government funded **Earth Radiation Budget project** received USD\$4m (and a further \$9m in both **2021** and **2022**) for SRM-related research, with the National Oceanic and Atmospheric Administration (NOAA) completing the first **SABRE project** stratospheric research **flights over the Arctic in March 2023**.
 - The **Silver Lining safe climate research initiative** is supporting physical science SRM research programmes in various US research institutions.
 - UK-based researchers **reportedly launched** an engineering proof-of-concept test of a small-scale balloon system for stratospheric aerosol deployment in September 2022.
- **Previous SRM-related research has been supported by public and private funding in Australia, Canada, China, the EU, Finland, France, Germany, India, Japan, Norway, Sweden, the UK, and the US.** Examples include⁷ (entirely or in part): China's €2m government funded geoengineering research programme (**2015-19**); the EU's €1.3m Implications and Risks of Engineering Solar Radiation to Limit Climate Change programme (IMPLICC) (**2009-2012**) and €1.3m European Trans-disciplinary Assessment of Climate Engineering (**2015**); Germany's €10.5m Climate engineering project (**2016-2019**); Norway's) \$0.6m Exploring the Potential and Side Effects of Climate Engineering project (**2014-2017**); UK's €1.7m Stratospheric Particle Injection for Climate Engineering (SPICE) programme (**2010-14**) and €1.5m Climate Geoengineering Governance project (**2012-14**); US National Science Foundation projects such as the \$0.7m Impacts of Climate Engineering Using Stratospheric Aerosols (**2016-20**); and collaborations such as The Marine Cloud Brightening Project (**2015-**).
- **SRM research and collaboration is growing, but slowly.** Published literature on the topic has been steadily increasing (e.g. **see bibliography**) and for over a decade an international collaboration of researchers (**GeoMIP**) has been comparing models to better understand expected climate effects of SRM. Other model intercomparison projects have also begin to explore potential SRM impacts, for example on agriculture (**AgMIP**). The Degrees Modelling Fund is catalysing a growing number of **papers published** by authors from the global south. Researchers continue to collaborate and share learning via e.g. journal **special issues**, **conferences** and dedicated **online fora**.

- **Support for SRM research is growing among some actors.** In June 2023 the White House Office for Science and Technology Policy published a [research plan and governance framework](#) related to SRM, focussed on improving understanding of potential impacts, rather than deployment of SRM technologies. Also in June 2023 the [European Union announced](#) its support for international efforts to assess the risks and uncertainties of climate interventions, including SRM. In February 2023, [UNEP published an expert review of SRM](#), which included recommendations for further research to inform decision-making and SRM research was also addressed a [draft report](#) for the UN Human Rights Council. Also in February, 90+ scientists published a [letter supporting more research into atmospheric aerosol-based SRM](#). During that same week another group of 80+ scientists issued a [letter calling for more balanced, insight-based deliberation, research and assessment of SRM](#). Recent statements from the [UK Meteorological Office](#) and [American Meteorological Society](#) advocate for more research into SRM to ensure any global discussions on addressing climate risk are based on a robust and broad range of evidence. In [2021](#) a US National Academies of Science report recommended USD\$100-200m for a new 5-year SRM research program and in 2022 the [US Congress](#) directed the White House's Office of Science and Technology Policy to coordinate delivery of a [five year plan](#) for a federal research assessment of rapid climate interventions including SRM.
- **Objection to SRM research is growing among some actors.** In early 2022 a group of academics launched [an initiative](#) calling for governments to ban funding for SRM experiments and development, which has since attracted 400+ signatories. In 2021, outdoor experiments planned in Sweden as part of the Harvard [SCoPEX project](#) were [halted by the Swedish Space Agency](#) following objections by [indigenous people and environmental NGOs](#).
- **Areas for future SRM research to address knowledge gaps have been identified** by various actors including: the IPCC ([2022](#); [2021](#); [2018](#)); US Council on Foreign Relations ([2022](#)) US National Academies of Science ([2021](#); [2015](#)); GESAMP ([2019](#)); C2G ([2018](#)); Parties to the Montreal Protocol ([2018](#)) and Convention on Biological Diversity ([2016](#)).
- **The need to govern SRM-related research has received some attention.** In June 2023, the [SRM research plan](#) published by the White House outlined an approach for establishing a research governance framework. Previously, the importance of robust SRM research governance has been widely emphasised, including in the US National Academies of Science report ([2021](#)). Some aspects have been initially addressed through intergovernmental processes such as the [Convention on Biological Diversity](#) and the [London Convention/Protocol](#). Some relevant tools have also been development including the [Oxford Principles](#) and the [Code of conduct for responsible geoengineering research](#). In 2023, the American Geophysical Union published a draft [ethical framework for climate intervention](#) and invited public review comments.
- **National and transnational bodies have undertaken initial assessments of SRM.** For example, the US National Academies of Science ([2021](#); [2015](#)); the Swiss Federal Office for the Environment ([2020](#)); the European Union ([2015](#)); the UK Research Council ([2013](#)), House of Commons ([2010](#)), and Royal Society ([2009](#)).
- **SRM is increasingly appearing on the radar of strategic foresight assessments.** For example, the latest US National Intelligence estimate ([2021](#)) that noted the risk of unilateral geoengineering increasing. Swiss Re Institute's latest SONAR emerging risks report included a chapter on SRM ([2023](#)) and the Geneva Science and Diplomacy

Anticipator (GESDA) foresight report has identified SRM as a key emerging topic (2022). The latest World Economic Forum Global Risks reports (2022; 2023) have also highlighted the potential risks associated with ungoverned SRM. In 2021, the Paris Peace Forum established an initiative called the **Global Commission on Governing Risks from Climate Overshoot**, that plans to publish a report in 2023 addressing SRM.

Status of Intergovernmental Processes

- **Convention on Biological Diversity (CBD)** Parties have **engaged on the topic of climate-related geoengineering (which includes SRM)** for over a decade now, including COP decisions relating to SRM, and the production of technical reports into the potential impacts and regulation of climate geoengineering in relation to the CBD (2016; 2012).
- **European Union:** In June 2023 the European Union **announced** its support for international efforts to assess the risks and uncertainties of SRM and promote discussions on a potential international framework for its governance.
- **Intergovernmental Panel on Climate Change (IPCC)** assessed the science around SRM and its governance across all three IPCC Working Group reports (2021; 2022; 2022) and the final synthesis report (2023) of its most recent **sixth assessment cycle**⁸. SRM was also assessed in the earlier Special Report on 1.5°C Global Warming (2018). The IPCC convened a first expert meeting covering SRM a decade ago (2012).
- **Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP)** produced **a report in 2019** that reviewed a wide range of proposed marine geoengineering techniques, including SRM.
- **London Protocol / London Convention (LP/LC)** Parties to the LP/LC **adopted a statement** in December 2022 identifying the need to carefully evaluate marine geoengineering techniques which may have potential for mitigating the effects of climate change but may have adverse impacts on the marine environment (including SRM).
- **Organisation for Economic Co-operation and Development (OECD)** published a **report** in October 2022 including analysis of the potential use of SRM to reduce the risk of crossing climate tipping points.
- **UN Educational, Scientific and Cultural Organization (UNESCO)** World Commission on the Ethics of Scientific Knowledge and Technology (**COMEST**) is preparing a **report on the ethics of climate engineering** expected in 2023). UNESCO previously convened the first **UN-hosted expert meeting** on geoengineering in 2010 with a **policy brief** published in 2011.
- **UN Environment Assembly (UNEA)** discussed SRM during its Fourth meeting in 2019 following the tabling of a **Swiss-led resolution** proposing that UNEP prepare an assessment of geoengineering. Following extensive discussion the proposal was **withdrawn** due to lack of consensus.
- **UN Environment Programme (UNEP)** published a **rapid independent expert review of SRM research and deployment** in February 2023 which concluded on the need for robust scientific assessment, development of governance frameworks, and promotion of globally

inclusive discussions. The report's findings were presented in briefings to UN Member States in [Nairobi in April](#) and in [New York in June 2023](#).

- **UN Framework Convention on Climate Change (UNFCCC)** has not addressed the topic directly, but SRM and its governance has begun to emerge in side events during Conference of the Parties, such as this [Silver Lining event at COP26](#) and these events by [UNESCO](#) and the [Climate Overshoot Commission](#) at COP27.
- **UN General Assembly (UNGA)** adopted [resolution 76/112 on the Protection of the atmosphere](#) in 2021, which includes legal guidelines relating to intentional large-scale modification of the atmosphere based on work undertaken by the International Law Commission. In a [2018 report](#) to the UN General Assembly, the UN Secretary-General highlighted gaps in environmental law relating to geo-engineering.
- **UN High-level Advisory Board on Effective Multilateralism (HLAB)** published its report [A Breakthrough for People and Planet](#) in April 2023 which included recommendation for a forum on the governance of climate-altering technologies.
- **UN Human Rights Council (UNHRC)** adopted resolution [48/14](#) in its 48th session in 2021 requesting the preparation of a report on the [impact of new technologies for climate protection on the enjoyment of human rights](#) to be presented during its 54th session. Member states and others [submitted contributions](#) during 2022 and a [first draft of the report](#) was shared with the Advisory Committee during its [29th Session](#) in February 2023.
- **UN Interagency Task Team on Science, Technology and Innovation (IATT)** included [SRM implications for the SDGs](#) in its 2021 report to the UN Science, Technology and Innovation Forum.
- **World Climate Research Programme (WCRP)** established a [task team on climate intervention/geoengineering](#) research in 2021 which [reported in 2022](#) and presented its recommendations during the [44th session of the Joint Scientific Committee](#) in 2023.
- **World Meteorological Organization (WMO)** The two most recent scientific assessments prepared for the Parties to the Protocol have addressed SRM ([2022](#); [2018](#)) with the latest dedicating an entire chapter to stratospheric aerosol injection (SAI) and its potential effects on the ozone layer.

Status of Non-governmental Engagement

- **Non-governmental and civil society organisations are engaged around SRM.** Some, like the [Degrees Initiative](#), [SilverLining](#), [Bright Ice Initiative](#) or [Planetary Sunshade Foundation](#) actively promote SRM-related research or cautiously call for more, like the [Union of Concerned Scientists](#) or the [American Geophysical Union](#). Some, like [Reflective Earth](#) are advocating for SRM development while others are critical or opposed, such as the [Climate Action Network International](#), the [Heinrich Böll Foundation](#), or the [ETC Group](#), or focus on specific gaps such as [Transparency International](#). In early 2022 a group of academics called for an [international non-use agreement](#) for SRM, echoing similar [concerns made by prominent international environmental campaigners](#) in 2021, and established campaigns such as [Hands off Mother Earth](#) and [Geoengineering Monitor](#). Other actors focus on promoting policy-

dialogue, like the [Council on Energy Environment and Water](#) which has convened events and briefings in India, the recently launched [Alliance for Just Deliberation on Solar Geoengineering](#) that is working towards just and inclusive deliberation about research and potential use of solar geoengineering, or the [Carnegie Climate Governance Initiative](#) that has been working over the past seven years to catalyse the creation of effective international governance.

- **Some private sector actors have begun to engage around SRM.** In January 2023, a US-based company [Make Sunsets](#) began selling ‘cooling credits’ to fund small-scale stratospheric aerosol injection interventions. Initial deployment attempts in Mexico led to [the Mexican government announcing its intention to block such activities](#) and the company consequently relocated and [reported they had made three launches from the US](#) in February 2023. In 2021, German technology group OHB and various European research institutes setup a [geoengineering network](#) for interdisciplinary cooperation.
- **SRM is gaining increasing attention in the media.** Over the past years there have been increasing numbers of articles appearing in prominent publications including, for example: [Al Jazeera](#), [Associated Press](#), [Bloomberg](#), [Forbes](#), [Foreign Policy](#), [France24](#), [The Guardian](#), [Los Tiempos](#), [Le Monde](#), [Nature](#), [The New Yorker](#), [Politico](#), [Reuters](#), [Science](#), [Thompson Reuters Foundation](#), [Time](#), [Washington Post](#), [Wired](#), [UN Dispatch](#)⁹.
- **Public statements and commentary about SRM are increasing.** For example, this recent article in [Foreign Affairs](#), advocating for the implementation of SRM (by the US), or these in [Project Syndicate](#) or [Axios](#), cautioning against it. In early 2023, this article in [Foreign Policy](#) argued how China and the US now have a mutual interest in beginning multilateral discussions about governance to constrain SRM development or deployment. Elsewhere, billionaire [George Soros considered the merits of SRM in a speech to the 2023 Munich Security Conference](#), a group of [African civil society organizations called on African Union leaders to reject SRM](#) and in the [foreword to UNEP’s new expert review](#), Executive Director, Inger Anderson highlighted the lack of evidence to make informed decisions, calling on the international community to invest in understanding the potential risks and uncertainties of SRM technologies.

For more information and learning resources see: www.c2g2.net or email: contact@c2g2.net

Publishing information

Information included in this briefing note is compiled and provided in good faith and based on sources available in the public domain at the time of publication. It is not intended to provide an exhaustive or prioritized list but rather a high-level overview of the status of activities underway relating to SRM and its governance globally. C2G gratefully acknowledges the contributions provided by readers of previous editions of this briefing note and welcome further additions and corrections in future. Please send to: contact@c2g2.net

This note is published under Creative Commons license [CC BY-NC-SA](https://creativecommons.org/licenses/by-nc-sa/4.0/) and may be reproduced in whole or in part for education or non-profit purposes without special permission, provided acknowledgement or proper referencing of the source is made.



Notes and references

- ¹ The Carnegie Climate Governance Initiative (C2G) is a small, foundation-funded initiative of the Carnegie Council for Ethics in International Affairs. C2G seeks to catalyse the creation of governance for climate-altering approaches and is impartial regarding their potential use. See: <https://www.c2g2.net/what-is-c2g/>
- ² UNEP (2022). Emissions Gap Report 2022: The Closing Window — Climate crisis calls for rapid transformation of societies. United Nations Environment Programme (UNEP). Kenya, Nairobi. Available from: <https://www.unep.org/emissions-gap-report-2022> (Accessed on 01.03.23).
- ³ Solar radiation modification (SRM) is also referred to as ‘solar radiation management’, ‘solar radiation intervention’, ‘climate intervention’, ‘climate engineering’, ‘solar geoengineering’, ‘geo-engineering’, and ‘geoengineering’.
- ⁴ UNEP (2023). One Atmosphere: An independent expert review on Solar Radiation Modification research and deployment. United Nations Environment Programme (UNEP). Kenya, Nairobi. Available from: <https://www.unep.org/resources/report/Solar-Radiation-Modification-research-deployment> (Accessed 01.03.23).
- ⁵ This briefing focusses on (but is not limited to) developments relating to two prominent SRM techniques which propose to reduce levels of warming. The first, stratospheric aerosol injection (SAI) aims to disperse reflective particles in the stratosphere, and the second, marine cloud brightening (MCB) aims to enhance and brighten ocean cloud cover.
- ⁶ See IPCC AR6 WGII report (2022) SPM and Chapter 16; WG1 report (2021) Chapter 4; and SR15 (2018) Chapter 4.
- ⁷ While there is currently no systematic international monitoring of SRM-related research, these examples are drawn from analysis undertaken by Harvard University (2008-2019) together with information shared with C2G in response to previous editions of this status update. Funding volumes are converted to EUR for ease of comparison.
- ⁸ For analysis of how SRM was addressed in the recent IPCC reports, see resources on the [IPCC page of C2G’s website](#).
- ⁹ Examples provided here are taken from English language, largely US-based publication sources but SRM is also appearing in publications in other languages and other countries.