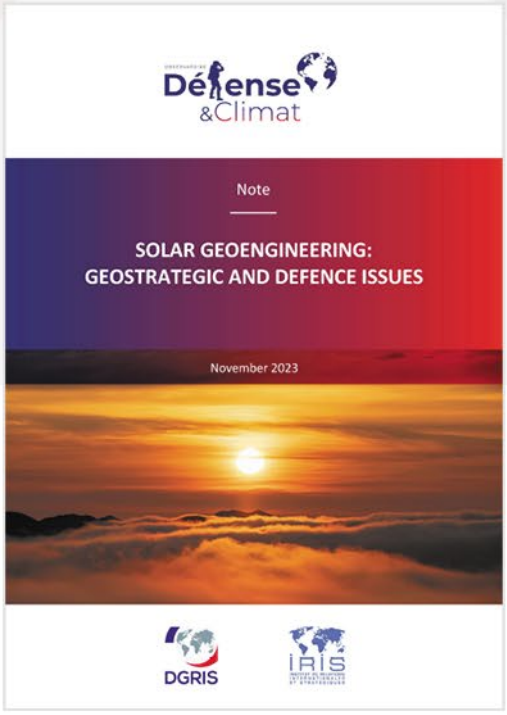
# SYNTHESIS

## SOLAR GEOENGINEERING: GEOSTRATEGIC AND DEFENCE ISSUES

November 2023



The Defence and Climate Observatory, launched in December 2016, aims to study climate-related security and defence issues.

It is coordinated by IRIS under contract to the French Ministry of Defence's Directorate General for International Relations and Strategy (DGRIS). The Observatory has a multi-disciplinary and cross-disciplinary team of researchers specialising in international relations, security, defence, migration, energy, economics, climatology and health. It is headed by Julia Tasse and François Gemenne.

The Observatory has initiated numerous collaborations with European partners (Netherlands, Luxembourg) and international partners (Australia, United States, India), international NGOs and national and international public bodies. These initiatives have strengthened cooperation on climate issues and their security implications.

The Observatoire Défense et Climat produces reports and notes, organises restricted seminars and conferences open to the public, and hosts the podcast "On the climate front".

**www.defenseclimat.fr/en**

The Ministry of Defence regularly calls on private research institutes for outsourced studies, using a geographical or sectoral approach to complement its external expertise. These contractual relationships are part of the development of the defence foresight approach, which, as emphasised in the latest White Paper on Defence and National Security, *"must be able to draw on independent, multidisciplinary and original strategic thinking, integrating university research as well as specialised institutes*".

Most of these studies are made public and available on the Ministry of Defence website. In the case of a study published in part, the Directorate General for International Relations and Strategy may be contacted for further information.

**DISCLAIMER: The Directorate General for International Relations and Strategy or the organisation leading the study cannot be held responsible for the statements made in the studies and observatories, nor do they reflect an official position of the Ministry of Defence.**

## ABOUT THE AUTHORS OF THE NOTE

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This brief addresses the **geostrategic and defence implications of solar geoengineering**. The term "solar geoengineering" covers **a range of techniques and practices designed to offset the rise in average global temperature by reducing the amount of solar radiation absorbed by the Earth**. This note is divided into four parts: **a presentation of techniques and associated natural and human risks (I)**; **an analysis of the geopolitical and strategic issues they raise (II)**; **four hypotheses and three scenarios for 2050 (III)**; **and finally, recommendations for the Ministry for Armed forces (IV)**.

## 1. Presentation of techniques and associated natural and human risks

This note focuses on solar geoengineering techniques that significantly affect atmospheric processes, and therefore raise the most important safety issues. These are two techniques on a local intervention scale - **the brightening of marine clouds**[1] and **the thinning of cirrus clouds**[2] ; one technique on a planetary intervention scale - **the injection of aerosols into the stratosphere**[3] ; and one technique on a spatial scale: the installation of **space mirrors**[4]**.** According to the existing literature, despite the large number of uncertainties that remain, each of these techniques presents its own specific risks. For example, acid rain could be caused by the injection of aerosols into the stratosphere, while thinning of cirrus clouds could have a paradoxical warming effect.

Furthermore, all these techniques present common risks. They are likely to lead to **significant disruption of the atmospheric system and photosynthesis activity,** resulting in **disruption of rainfalls** (drought in some areas, torrential rains in others), a **fall in agricultural yields** and a **weakening of ecosystem services.** Another risk common to all these techniques is that of **terminal shock**: if one of these techniques were deployed in the absence of a reduction in greenhouse gas emissions, the interruption of that technique would cause warming far too rapid for natural and human systems to adapt.

## 2. Solar geoengineering: a political object with conflict potential

An analysis of the current state of development of solar geoengineering shows that major geopolitical powers are clearly interested in these technologies, and that the United States has a clear lead in terms of funding, research and experimentation. However, there is currently no multilateral governance framework dedicated to solar geoengineering.

The deployment of solar geoengineering could be guided by particular political interests, rather than global climate objectives. In this way, solar geoengineering can be seen as 1) **a tool for preserving**

[1] The aim of marine cloud brightening is to increase the reflectivity and sometimes the lifespan of certain clouds. It involves injecting sea spray into low-lying marine clouds, which are ubiquitous in subtropical and mid-latitude oceans and play a fundamental role in reflecting the sun's rays back into space.

[2] Thinning cirrus clouds means reducing the amount of terrestrial radiation they absorb. Located in the upper troposphere, these thick clouds made up of ice crystals trap a large proportion of the Earth's radiation within the atmosphere. In this sense, their warming effect is similar to that of greenhouse gases.

[3] This method consists of diffusing reflective particles into the stratosphere by plane or balloon to create cooling conditions similar to those following major volcanic events.

[4] Some solar geoengineering projects envisage deploying reflecting devices in outer space. The preferred strategy would be to place mirrors in orbit in space, which could reflect around 2% of the Sun's rays.

**economic interests; 2) a tool for assets and population protection**; and 3) **a tool for negotiation on the international stage.**

**These technologies could fuel tensions between states**. Firstly, the deployment of solar geoengineering **could lead to extreme climate events being attributed to the intervention of a third party**. Secondly, tensions could emerge as a result of **disagreements between states over the desired effects and deployment methods.** Such disagreements could **lead to a risk of escalation,** resulting in counter-geo-engineering operations. Finally, the deployment of solar geoengineering could lead to **a militarisation of the technology**, or even be **used for hostile purposes**.

## 3. Scenarios for the future

| Scenario | Deployment of geoengineering | Geopolitical consequences, consequences for France |
|---|---|---|
| **2047 - Unilateral deployment by the United States** | Operation to inject aerosols into the stratosphere organised unilaterally by the United States. | Polarisation of relations between States. Opposition from China and Russia ; use of the threat of a counter-geo-engineering intervention. France's diplomatic efforts to find an agreement and thwart the unilateral initiative. |
| **2050 - China and the ArcticX project** | A marine cloud clearing operation organised by the United States, China and India in the Arctic. | Opposition from Russia, which destroys two ships used for the geo-engineering operation. France increases its military presence in the region. It also has to organise a HADR operation in Senegal following a devastating drought. |
| **2037 - Solar geoengineering on demand: a new consumer good** | A multitude of aerosol injection operations in the stratosphere by private individuals. | China denounces the initiative, is confirmed in its role as an ecological power, and the areas of Chinese influence are greatly extended.<br>France, which does not condemn this movement, is losing influence with developing countries. |

## 4. Recommandations

**1**

Integrate into defence strategies a reflection on solar geoengineering as a political, geostrategic and military tool, and on its geostrategic consequences.

**2**

Set up a scientific, technological and geostrategic watch to monitor developments of solar geoengineering projects. Anticipate the ability of different players to maintain a technological lead.

**3**

Assess opportunities and risks presented by solar geoengineering for France, and consider its geostrategic position on this issue in the context of international discussions.

**4**

Characterise the state of progress of the United States, China and Russia in solar geoengineering.

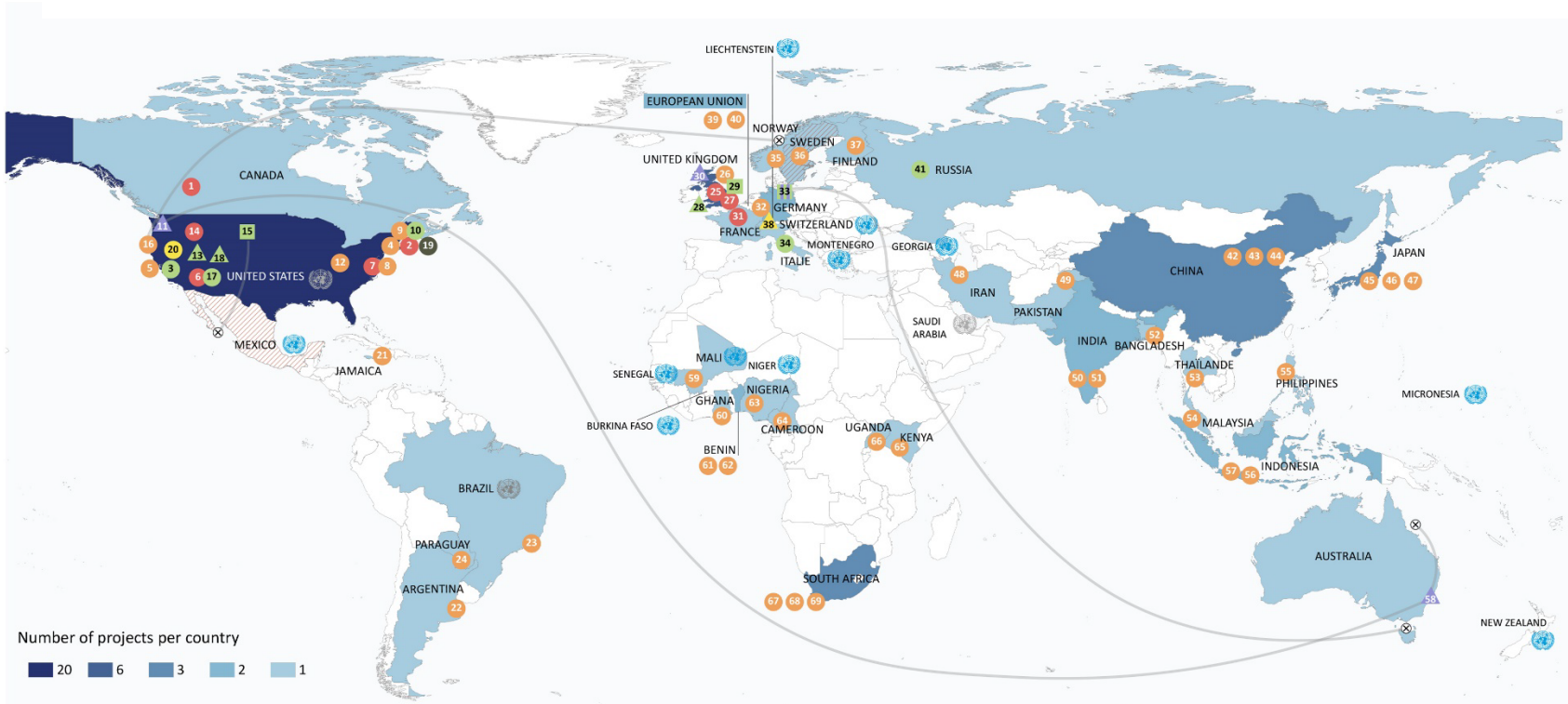
**5**

Promoting information sharing on solar geoengineering with partners and allies.

**6**

Strengthen partnerships with atmospheric science research institutes (e.g. MétéoFrance), and include research into the possible effects of solar geoengineering.

# Map: main solar geoengineering projects worldwide




Number of projects per country

20 | 6 | 3 | 2 | 1

## Type of project

- Multidisciplinary
- Marine Cloud Brightening (MCB)
- Stratospheric Aerosol Injection (SAI)
- Cirrus thinning
- Human and social sciences (ethical and governance issues)
- Space mirrors

## Stated objective of the project

- Research
- Experimentation
- Research and experimentation
- Commercialisation

## Experiments or attempted experiments

- Delocalized experiments
- Target states for experiments that have expressed opposition to deployment

## 2019 United Nations General Assembly Environment Resolution

Proposal for a resolution aimed at evaluating geoengineering techniques and its governance arrangements at the UNGA Environment

- States sponsoring the resolution
- States that have opposed the resolution

Sources : The Degrees Initiative; "Funding for Solar Geoengineering Research from 2008-2018" on geoengineering.environment.harvard.edu; map.geoengineeringmonitor.org, interactive map by ETC Group and the Heinrich Boell Foundation

Cartography : IRIS - A. Diacre, V. Pelpel, M. Verzeroli

## Name and year of the project [1] – ● *projects in progress in 2023*

**Canada**
- 1 - Geoengineering Research Governance Project | 2015 - *in progress*

**United States**
- 2- Carnegie Climate Geoengineering Governance Initiative (C2G2) |2017-2020
- 3- Collaborative Research: Evaluation of Suggestions to Geoengineer the Climate System Using Stratospheric Aerosols and Sun Shading | 2008-2013
- 4- Cornell Climate Engineering
- 5- Emmett Institute Project | 2017-2020
- 6- Exploring Democratic Governance of Solar Geoengineering Research
- 7- Forum for Climate Engineering Assessment | 2013 - *in progress*
- 8- Geoengineering Model Intercomparison Project (GeoMIP) | 2008 - *in progress*
- 9- Gordon Research Conference (GRC) | 2017 - *in progress*
- 10- Harvard's Solar Geoengineering Project (SGRP), dont Stratospheric Controlled Perturbation Experiment (SCoPEx) | 2017-2024
- 11- Marine Cloud Brightening Project (MCB) | 2016 - *in progress*
- 12- Network for Sustainable Climate Risk Management (SCRiM) | 2012-2019
- 13- Stratospheric Aerosol Geoengineering Large Ensemble (GLENS) | 2015-2017
- 14- The Ethics of Geoengineering: Investigating the Moral Challenges of Solar Radiation Management | 2010-2014
- 15- Make Sunsets | 2022 - *in progress*
- 16- Arctic Ice Project | 2018 - *in progress*
- 17- Planetary Science Institute project | 2015-2018
- 18- NOAA Earth's Radiation Budget (ERB) Initiative dont Projet SABRE
- 19- Space Bubbles | 2021 - *in progress*
- 20- Ice Cloud Size Distributions | 2006 - 2011

**Jamaica**
- 21- Caribbean agriculture under SRM: a case study in Jamaica | 2018 - *in progress* [2]

**Argentina**
- 22- Impacts of SRM on the La Plata Basin's hydroclimate in South America, | 2018 - *in progress* [2]

**Brazil**
- 23- Studying the response of Cyclones to SRM in the Southern Hemisphere | 2023 - *in progress* [2]

**Paraguay**
- 24- Tackling the effects of climate change on the Andean glaciers | 2023 - *in progress* [2]

**United Kingdom**
- 25- Climate Geoengineering Governance Project | 2012-2014
- 26- Integrated Assessment of Geoengineering Proposals (IAGP) | 2010-2015
- 27- Solar Radiation Management Governance Initiative (SRMGI) | 2010-2020
- 28- Stratospheric Particle Injection for Climate Engineering (SPICE) | 2010-2014
- 29- Stratospheric Aerosol Transport and Nucleation project (SATAN) | 2021-2022
- 30- MCB with sea water | 2006 - *in progress*

**France**
- 31- Systemic thinking on the issues and methods of environmental geoengineering | 2013-2014

**Germany**
- 32- Global Governance of Climate Engineering | 2009-2012
- 33- ISA-Iron Salt Aerosol Method | 2019 - *in progress*

**Italy**
- 34- SRM-related research at Aquila University | 2016 - *in progress*

**Norway**
- 35- Exploring the Potential and Side Effects of Climate Engineering (EXPECT)

**Sweden**
- 36- Linköping University Climate Engineering Research Programme (LUCE)

**Finland**
- 37- Aerosol Intervention Technologies to Cool the Climate: Costs, Benefits, Side Effects, and Governance (COOL) | 2011-2014

**Switzerland**
- 38- Cirrus Cloud Thinning calculations | 2016 - *in progress*

**European Union**
- 39- European Transdisciplinary Assessment of Climate Engineering (EuTRACE) | 2012-2014
- 40- Implications and Risks of Engineering Solar Radiation to Limit Climate Change (IMPLICC) | 2009-2012

**Russia**
- 41- injection d'aérosols dans la troposphère par Yuri Izraël | 2008

**China**
- 42- Geoengineering: Basic Mechanisms, Impacts and Strategies | 2013-2015
- 43- Geoengineering: Integrated approaches and impacts | 2015-2019
- 44- Project by scientists from the Northwest Institute of Eco-environment and Resources, affiliated to the Chinese Academy of Sciences

**Japan**
- 45- Integrated Climate Assessment – Risks, Uncertainties and Society (ICARUS)
- 46- SOUSEI | 2012-2016
- 47- TOUGOU | 2017-2021

**Iran**
- 48- Extreme weather events and drought in the MENA region under SRM| 2018 - *in progress* [2]

**Pakistan**
- 49- The impact of climate change and SRM on malaria in South Asia| 2023 - *in progress* [2]

**India**
- 50- Reversing Climate Change via Geoengineering: Impacts on Developing countries like India | 2017-2020
- 51- Investigating the Indian summer monsoon rainfall under SRM| 2023 - *in progress* [2]

**Bangladesh**
- 52- Assessing the impacts of SRM on hydrology in Bangladesh| 2021 - *in progress* [2]

**Thailand**
- 53- Modelling temperature and precipitation changes in lowland Thailand| 2023 - *in progress* [2]

**Malaysia**
- 54- Impact of SRM on Hydro-climatic Extremes in Malaysia | 2023 - *in progress* [2]

**Philippines**
- 55- Impacts of SRM on agriculture: the Southeast Asian case | 2021 - *in progress* [2]

**Indonesia**
- 56- Hydro-climatic extremes in Southeast Asia under SRM| 2018 - *in progress* [2]
- 57- Studying tropical cyclone-related extreme rainfall in Indonesia | 2023 - *in progress* [2]

**Australia**
- 58- MCB for the Great Barrier Reef | 2013 - *in progress*

**Mali**
- 59- Exploring whether SRM could offset droughts in West Africa| 2023 - *in progress* [2]

**Ghana**
- 60- Exploring changes to the Harmattan windy season and precipitation in southern West Africa | 2023 - *in progress* [2]

**Benin**
- 61- Effects of SRM on climate change in the northern Gulf of Guinea| 2018 - *in progress* [2]
- 62- Marine biogeochemistry and sea level in the Gulf of Guinea| 2023 - *in progress* [2]

**Nigeria**
- 63- Exploring whether SRM could offset droughts in West Africa| 2023 - *in progress* [2]

**Cameroon**
- 64- Assessing the risks of water deficit in Central Africa | 2023 - *in progress* [2]

**Kenya**
- 65- Impacts of SRM on extreme rainfall and urban floods in East Africa| 2021 - *in progress* [2]

**Uganda**
- 66- The impacts of SRM on seasonal and intra-seasonal climate variability over East Africa | 2023 - *in progress* [2]

**South Africa**
- 67- Agricultural production under SRM in Southern Africa| 2023 - *in progress* [2]
- 68- Exploring whether SRM can reduce risks to biodiversity and human health | 2023 - *in progress* [2]
- 69- Assessing the future of livestock production in Africa | 2023 - *in progress* [2]

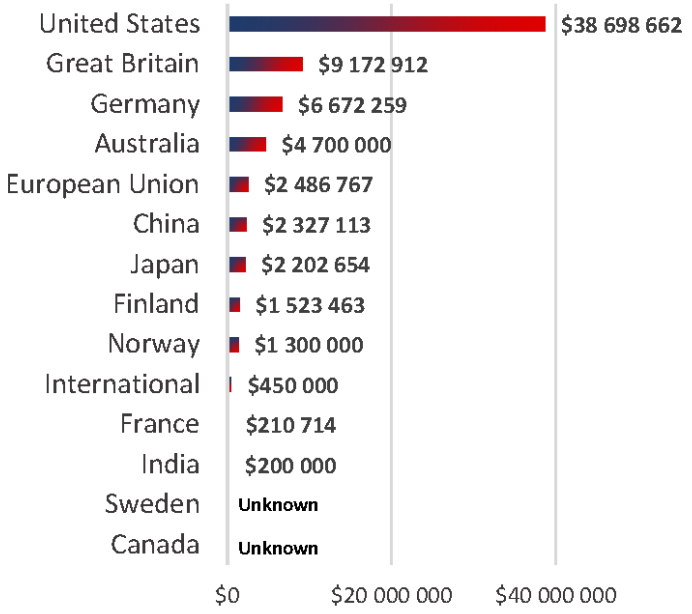
**International**
- 70- DECIMALS Fund | 2018-2020

*(1) Project dates are indicated when available*
*(2) These projects are funded by the Degrees Initiative*

# Infographics : Financial, political and security issues of geoengineering

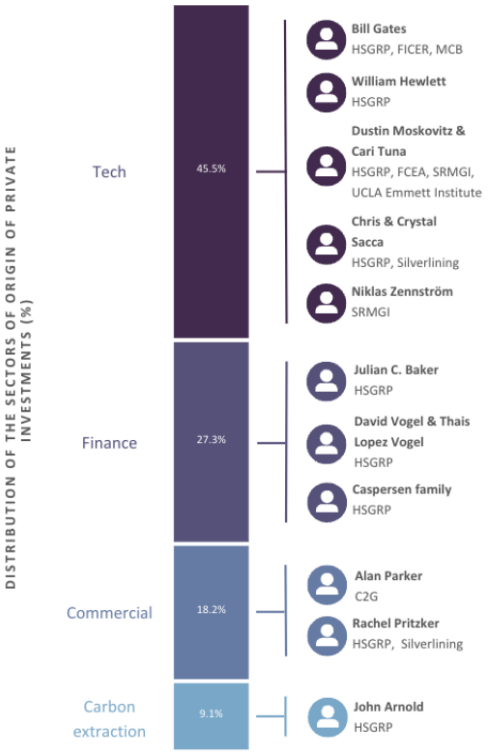
Solar geoengineering is attracting increasing attention and investment across the world. The infographic below shows the dominance of the United States in terms of investments, far ahead of Great Britain and Germany in second and third position. With investments of 210'714 and 200'000 US dollars, France and India find themselves last in the ranking. The total amount of investments from Sweden and Canada remains unknown.

## a) Sum of investments in solar geoengineering by country between 2008 and 2018.




Source : Necheles et al. 2018

## b) Distribution of the main private investors in solar geoengineering according to their sector of activity in the United States




Source : Necheles et al. 2019

## c) Solar geoengineering as a political tool

A tool to prolong lifestyles and interests dependent on fossil fuels.

A tool to protect territories and military capabilities.

A tool for negotiating on the international scene.

## d) The conflictual potential of solar geoengineering

1. Tensions due to environmental consequences and their attribution to a third party.
2. Use for hostile purposes.
3. Divergences of geopolitical interests in a specific area.
4. Suspicion of surveillance.
5. Disagreements on the effects and modalities of deployment.
6. Target during a conflict.

Beyond the possibility of using geoengineering as a tool for adaptation to climate change, the latter could also serve strategic political interests. Furthermore, the development and possible deployment of these techniques contribute to making the issue of mitigation invisible. Thus, solar geoengineering would reduce global ambition to reduce emissions. It also has a strong conflict potential.

[1] **HSGRP:** Harvard Solar Geoengineering Project; **FICER:** Fund for Innovative Climate and Energy Research; **MCB:** Marine Cloud Brightening Project; **SRMGI:** Solar Radiation Management Governance Initiative; **FCEA:** Forum for Climate Engineering Assessment; **C2G:** Carnegie Climate Geoengineering Governance Initiative.

# ANALYSIS OF SECURITY AND DEFENCE ISSUES RELATED TO CLIMATE CHANGE

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