

Report

FROM A CLIMATE TOOL TO AN INSTRUMENT OF POWER: THE GEOSTRATEGIC AND DEFENCE IMPLICATIONS OF SOLAR GEOENGINEERING

October 2026





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

It is coordinated by IRIS as part of the contract carried out on behalf of the French Ministry of Armed Forces's Directorate General for International Relations and Strategy (DGRIS). The Observatory's multi-disciplinary team includes researchers specializing in international relations, security, defence, migration, energy, economics, climatology and health. It is directed by Mathilde Jourde 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 Climate and Defence Observatory 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 for Armed Forces regularly calls upon 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"*.

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

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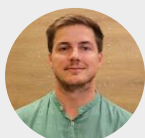
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In the context of accelerating climate change, scientific and political discourses¹ advocating research into solar geoengineering are multiplying. These methods, also referred to as "Solar Radiation Modification" (SRM), vary in complexity and aim to lower the global surface temperature by reflecting a portion of incoming sunlight back into space (Annex 1). According to these "pro-research" discourses, efforts to mitigate greenhouse gas (GHG) emissions and adapt to climate change are insufficient to contain the risks associated with rising global temperatures, particularly the risk of crossing climate tipping points² (Climate Intervention Research Letter, 2023; Gruener and Visoni, 2026; Zhao et al., 2025).

Although SRM presents numerous risks and uncertainties, contributing to strong polarisation within the scientific community³ (Collomb, 2020; Oomen, 2025), **the sector has grown steadily since 2020**. This growth is reflected in both the increasing number and diversity of actors involved and the volume of funding mobilised. Yet the dynamics that shape this expansion and their associated geopolitical implications remain largely unexplored. At the same time, several characteristics of the international political environment influence the conditions under which SRM research is conducted, its development pathways and potential deployment scenarios.

This report builds on the 2023 report of the Defence and Climate Observatory on the geostrategic and defence issues of SRM (De Guglielmo et al., 2023). **Like this previous report, it seeks to broaden the analysis of SRM beyond its geophysical effects**. It therefore looks beyond SRM's climate objectives to explore how this sector raises geopolitical issues shaped by dependencies and struggles for influence. By focusing on an SRM method with global, transboundary and uncertain effects, this report also examines its potential to become integrated into security logics and power dynamics. Its findings will be relevant to actors in defence, security and international affairs, as well as to scientific and political stakeholders in climate change governance.

The first section analyses the geopolitical implications of the structuring of the SRM sector (I). It shows that the sector's expansion is shaped by profit-driven logics and dynamics of domination (I.A), which in turn contribute to shaping the dependencies, dominant narratives

¹ In this report, the concept of discourse refers to a phenomenon of expression and communication whereby an actor formulates and conveys ideas, whose form and content are shaped by the actor's interests and the constraints to which it is subject (Bonditti and Kabbej, 2020).

² A tipping point is understood as a degree of change in a system's properties beyond which that system undergoes a reorganisation, potentially a chaotic one (IPCC, 2019). The tipping points identified by the IPCC include the melting and thawing of ice and frozen soils, major changes in global circulation patterns, and shifts in biomes (Tasse and Collet, 2025; Jourde et al., 2026).

³ This polarisation within the scientific community can be understood as a continuum, ranging from positions in favour of SRM research, including, in some cases, the development of deployment capabilities, to positions opposed to any research on SRM. Between these two poles lie numerous and varied positions, including, for example, differing views on outdoor experiments and public funding.

and struggles for influence associated with its development (I.B). These dynamics are also reflected in governance initiatives, which are shaped by divergent visions and interests (I.C).

The second section focuses on Stratospheric Aerosol Injection (SAI): the SRM method attracting most interest and presenting the lowest technical barriers. It examines the extent to which this technology could become integrated into security logics (II), particularly given the global and transboundary scale of its effects. It shows that the development and deployment of this technology would depend on capabilities that are unevenly distributed among states (II.A). It then explains how framing climate change as a security issue⁴ may encourage the appropriation of SAI as a political response, or even as a security measure (II.B). Finally, it demonstrates that SAI should be understood as an object of geostrategic competition and that this technology has the potential for weaponisation and instrumentalisation (II.C).

Scope of the report

This report does not aim to present the different methods of solar radiation modification (SRM), also known as solar geoengineering, or to provide a detailed account of the risks and uncertainties they pose to natural and social systems. An overview of these elements is nonetheless provided in the annex section: the main SRM methods are presented in Annex 1 and the main risks in Annex 2. For further information, readers may refer to the report of the Defence and Climate Observatory (de Guglielmo et al., 2023).

⁴ Framing climate change as a security issue differs from its *securitisation* in the sense used by Buzan and Wæver (1998). Securitisation refers to the process through which an issue is constructed as an existential threat to a referent object and, on this basis, justifies recourse to exceptional measures, i.e., measures that go beyond the ordinary procedures for managing that issue. From this perspective, although climate change is increasingly being framed as a security issue, the literature remains divided on whether its *securitisation* has been successful, particularly given the absence of exceptional measures that depart from the ordinary frameworks of public action.

Data collection methodology

1 – Identification of ongoing SRM activities

The data on SRM activities covers all funding operations supporting activities and organisations whose work focuses primarily on SRM research, advocacy and awareness-raising, or commercialisation, and that were known to us at the time of publication (October 2026). This data collection draws on publicly available information, including public statements, reports published by various institutions, project activity reports, and information on funding and activities available through open sources or publicised by the organisations concerned. The IRIS database identifies 140 ongoing activities.

2 – Estimating the funding associated with identified activities

The following methodology was used to assign a funding amount to each activity:

- Where the amount allocated to an identified activity was explicitly stated, that amount was recorded.
- For multi-year government funding announcements, the announced amount was recorded, even where the funds had not yet been fully disbursed by the project as of the publication date of this report (October 2026).

Where the amounts allocated to individual activities were not publicly available:

- The maximum amount that could be awarded to each project was used. In the absence of precise data on the amounts actually awarded, using the announced funding ceiling helps avoid underestimating the funding potentially associated with the identified projects.
- This approach was applied in particular to activities funded through calls for proposals, including those launched by foundations. For example, the exact amounts awarded to individual projects funded by the *Simons Foundation* are not known. However, available information indicates that funding ranges from US\$500,000 to US\$1.5 million per project. As the Foundation announced a total funding envelope of US\$50 million for these projects, the maximum amount of US\$1.5 million was assigned to each of the 19 ongoing activities funded by the *Simons Foundation*. This approach results in an estimated US\$28.5 million in potential funding associated with these 19 activities.

Given the difficulty of accessing information on all funding allocated to SRM activities and/or the exact amounts involved, **the figures presented in this note should therefore be considered as high-end estimates of funding allocated to the SRM sector.**

Throughout this note, figures derived from this data collection are followed by the reference IRIS, 2026.

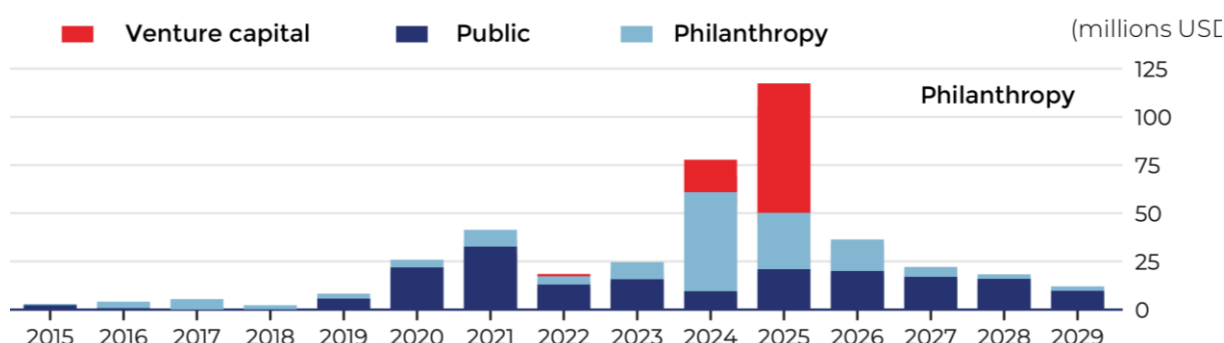
PART 1

**THE STRUCTURING OF
THE SRM SECTOR AND
ITS GEOPOLITICAL
IMPLICATIONS**

A - A rapidly expanding sector shaped by profit-driven logics and dynamics of domination

Between 2007 and 2026, USD 412 million was invested in research, advocacy and awareness-raising activities, as well as in the commercialisation of SRM. Most of this funding, some of which was provided over several years, has been allocated since 2020 (see Figure 1). This reflects growing interest in these methods, which aim to lower global temperatures.

Figure 1 – SRM funding by year of expenditure and source type, 2015–2029
(all identified projects)



The amounts shown are calculated using the methodology applied across the entire database. For multi-annual commitments, the amounts are spread over the duration of the project.

Source: IRIS database

This growth is accompanied by two significant and closely related transformations in the structure of the sector: the reconfiguration of funding sources and the emergence of start-ups (see Figure 1). Since the early 2020s, philanthropic funding has progressively overtaken public funding and is now also being challenged by investment funds and venture capital firms⁵ (SRM360, 2025b), which accounted for more than USD 142 million between 2020 and 2025 (IRIS, 2026). This diversification of funding sources has gone hand in hand with the emergence of several start-ups seeking to commercialise SRM and raise funds from these investment firms. **Together, these two transformations are orienting the SRM sector towards market-driven dynamics and the pursuit of profitability.**

The involvement of private actors, initially concentrated mainly in Silicon Valley and now extending into financial and military-industrial circles (Lazard, 2026a), marks a turning point in the structuring of the SRM sector. Their presence should therefore not be regarded as an anomaly or an isolated deviation (Surprise et al., 2025). Furthermore, links have been

⁵ Venture capital (VC) is a mode of financing for emerging companies with strong growth potential. It relies on high-risk investments, generally made by specialised funds, known as venture capital firms, which acquire equity stakes in start-ups and innovative companies.

identified between several venture capital firms funding SRM activities and the defence sector, including between *AWZ Ventures* and the Israeli Ministry of Defence, or between *Quadrature Capital* and Palantir Technologies (Bisset and Dyke, 2025). Within the SRM ecosystem, the involvement of these actors is debated (Cheng, 2025) and has attracted criticism, including from proponents of SRM research (Keith and Visoni, 2025).

The interest of private actors should be understood in light of economic motivations that are not limited to the pursuit of climate benefits. They may seek to anticipate future demand from states and position themselves as contractors by securing patents⁶ on relevant technologies (Young, 2026). **The potential profits associated with the commercialisation of these technologies may therefore incentivise these actors to promote their development and, more broadly, to foster conditions conducive to their future use.**⁷

Two models of funding and conducting SRM research: the cases of *Exploring Climate Cooling* and *Stardust Solutions*

Two recent developments have marked the SRM sector. **The first is the launch of the British project *Exploring Climate Cooling*, which represents the largest public investment in SRM research to date, with £56.8 million (approximately USD 75 million)⁸. The second is the October 2025 fundraising round of the Israeli-American start-up *Stardust Solutions*, which raised USD 75 million, representing nearly 65% of private investment in the sector (Hiar, 2025). These two initiatives nonetheless pursue distinct objectives:** whereas the British programme supports research into several SRM methods, *Stardust* focuses on commercialising a complete stratospheric aerosol injection system (see Annex 2).

Despite these differences, both initiatives have publicly stated their intention to conduct field experiments in the coming years, a prospect that has generated considerable controversy (Science Media Center, 2025). **However, they adopt different approaches to conducting these activities.** Despite the criticism it has faced, the British programme is regarded by many actors in the sector as an example of how research governance principles can be implemented⁹, notably through the establishment of an independent oversight committee (ARIA, 2025). By contrast, the start-up *Stardust* has faced extensive criticism, including from scientists who support SRM research. These criticisms relate in particular to the lack of transparency surrounding some of the company's activities, its undisclosed lobbying of US political representatives, and its links to the Israeli intelligence services and defence sector (see Figure 2) (Lazard, 2026a).

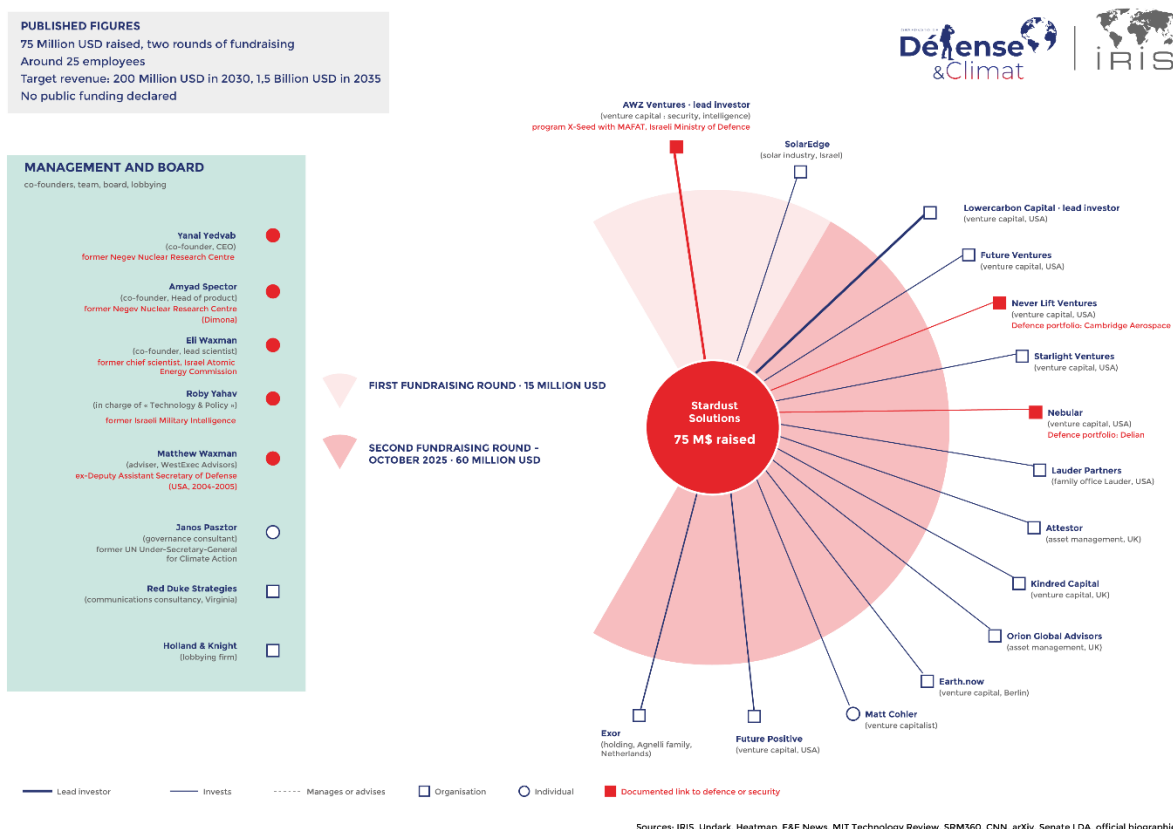
⁶ One example is the American start-up *Make Sunsets*, which sells "cooling credits" to individuals and companies, and which obtained its first patent in the United States in 2025 (Make Sunsets, 2025).

⁷ This is important to note as maintaining the climate effects sought through SRM would require deployment over several decades, or even several centuries (Royal Society, 2025).

⁸ Funded by the public agency *Advanced Research and Invention Agency* (ARIA), this project, launched in May 2025, supports 22 research teams in more than 10 countries and has sparked to considerable controversy (de Freitas, W., 2025). The British public agency ARIA, created in 2023, funds research projects described as "high risk, high reward".

⁹ Research includes modelling work, observations, as well as laboratory and field experiments.

Figure 2 – The Stardust Solutions Ecosystem: Management and Investor Networks



While the SRM sector is expanding and undergoing significant transformations, it is also characterized by dynamics of domination and marginalisation. Two trends appear particularly significant.

First, funding received for SRM-related activities¹⁰ is heavily concentrated in developed countries (approximately 95%), particularly in Anglo-Saxon countries (see Map 1). Funding is also unevenly distributed among developed countries: the United States ranks first (28%), followed by the United Kingdom and Israel (26% each) and Australia (13%). The European Union (EU), which accounts for just 5% of funding received, and France in particular, remain largely absent from the leading positions (IRIS, 2026). This pattern of concentration and domination is particularly evident in the gap between developed and developing countries (see Map 2). Between 2007 and 2024, researchers and organisations in developed countries received "more than fifty times as much funding as their counterparts" in developing countries (SRM360, 2025b).

The concentration of funding received is matched by an equally pronounced geographical concentration in the origins of that funding (see Map 1). Between 2007 and 2026, 83% of

¹⁰ This includes research, advocacy and awareness-raising, as well as commercialisation activities.

funding allocated to SRM activities originated from Anglo-Saxon countries, primarily the United States¹¹ and the United Kingdom (IRIS, 2026). The EU and its member states remain comparatively marginal, together accounting for only about one fifth of the funding originating from the United States (SRM360, 2025b). **Thus, even where funding supports actors based in other regions of the world, it originates overwhelmingly from organisations based in Anglo-Saxon countries.**¹² Funding commitments already announced for SRM activities through 2030 are expected to reinforce this trend, bringing the share of funding originating from Anglo-Saxon countries to nearly 85% (SRM360, 2025b).

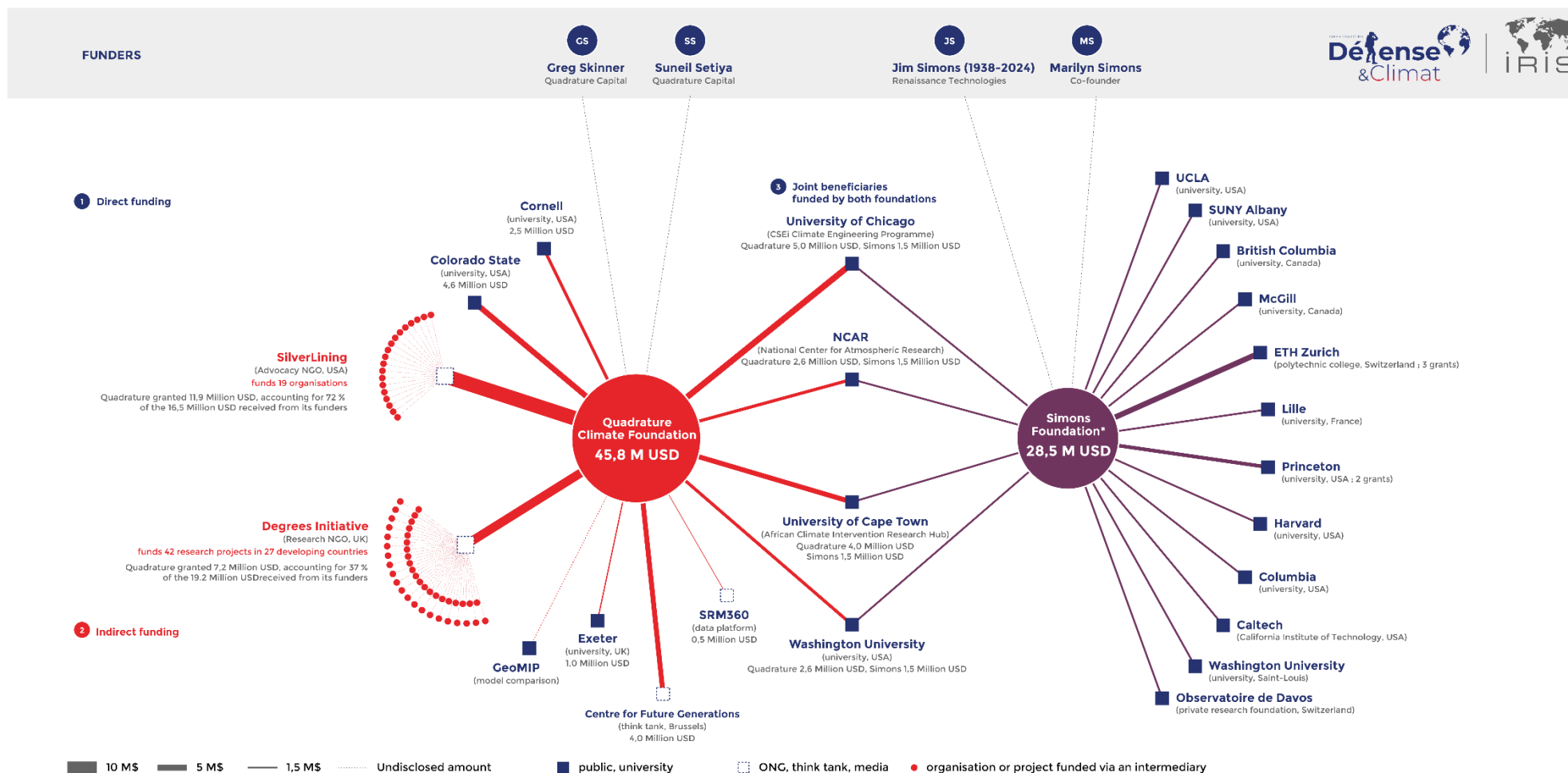
Second, this geographical concentration of funding received and awarded is accompanied by a strong presence of non-state actors among the organisations funding SRM-related activities. These funds come from a variety of sources, including non-governmental and philanthropic organisations, wealthy individuals, venture capital firms and investment funds. **This apparent diversity of funders nonetheless masks a concentration in the underlying sources of funding.** This is particularly evident in the case of some non-governmental organisations funding research or advocacy activities on SRM that are themselves dependent on philanthropic funding, often from the same donors (see Figure 3).¹³ **Moreover, the involvement of private actors makes funding data more difficult to access, as some of them refuse to disclose this information**, as is the case for the American start-up *Sunscreen* (Hiar, 2025).

¹¹ This concentration of funding in developed countries, particularly the United States, is also evident in other innovation sectors, notably Artificial Intelligence (AI) and quantum technologies (Lelièvre, 2026).

¹² The *Degrees Initiative*, based in the United Kingdom, illustrates this trend: it funds more than half of the research projects conducted in developing countries (SRM360, 2025b).

¹³ For example, *Reflective* and the *Degrees Initiative*, two actors in the sector that fund SRM research, receive funding from several of the same philanthropic donors, including the *Navigation Fund*, *Cranstar* and the *LAD Climate Fund*.

Figure 3 – Concentration of Initial Funding Sources: The Cases of the Quadrature Climate Foundation and the Simons Foundation

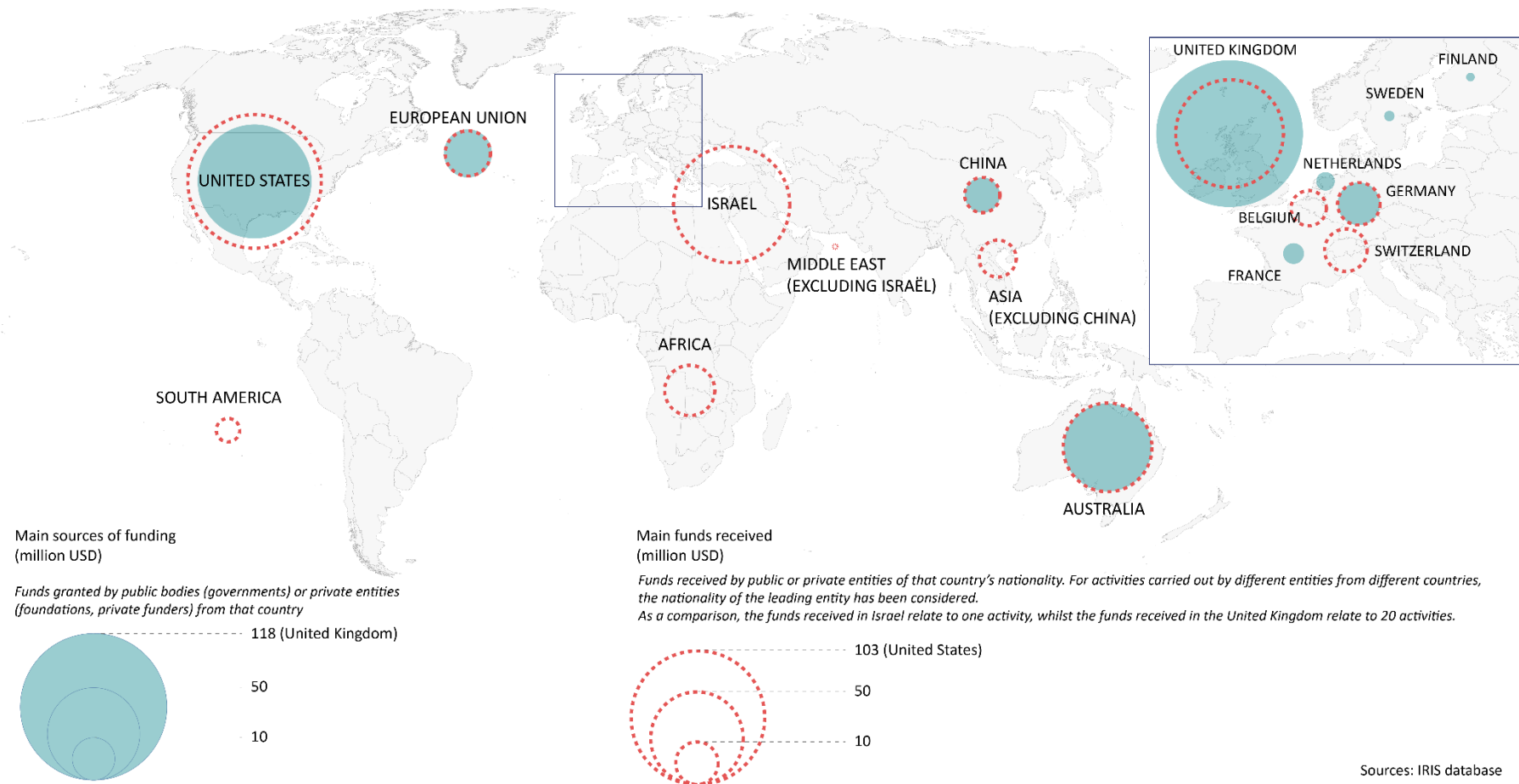


*Simons Foundation: 19 grants were allocated up to the call's funding ceiling (1.5 million USD), out of the 50 million USD announced over five years.

Sources: IRIS database, Quadrature Climate Foundation, Simons Foundations, SRM 360

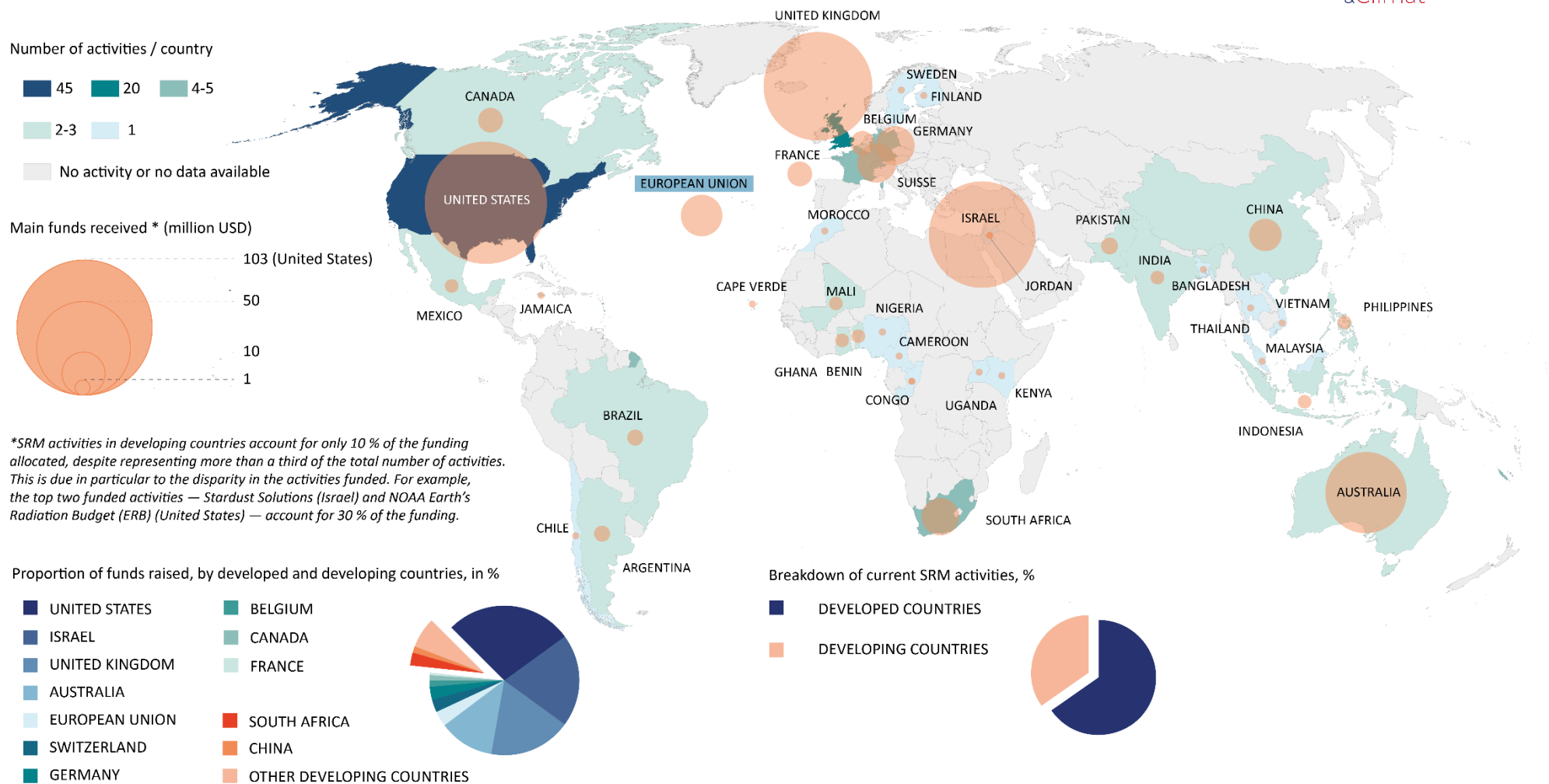
Map 1 – Main Regions of Donors and Recipients of Funding Relating to Ongoing Solar Radiation Modification (SRM) Activities, by Amounts Granted and Received

Main Regions of Donors and Recipients of Funding Relating to Ongoing Solar Radiation Modification (SRM) Activities, by Amounts Granted and Received



Map 2 – Main Ongoing Activities Relating to Solar Radiation Modification (SRM) and Associated Funding

Main Ongoing Activities Relating to Solar Radiation Modification (SRM) and Associated Funding



Source: IRIS database

B – Implications of structuring and domination dynamics for French and European interests

The structuring and domination dynamics described above are not merely characteristics of the SRM sector: they also have geopolitical implications. Three of these implications directly affect French and EU strategic and diplomatic interests.

First, the growing presence of private actors seeking to commercialise SRM raises significant geopolitical issues because of their ideological orientation and the narratives¹⁴ they promote. Some of these actors, primarily from the digital technology, biotechnology and finance sectors, view SRM as an instrument serving a broader civilisational project centred on technological acceleration in digital technology and artificial intelligence (AI). This ecosystem, located mainly in the United States, promotes a vision in which biological and planetary limits can be overcome by, and for, technological progress (Lazard, 2026a; Lazard, 2026b). In this context, SRM is viewed as a response to the growing energy demand associated with the expansion of AI.¹⁵

Investments in SRM by some actors from the technology and finance sectors are thus embedded in political and ideological agendas that extend beyond climate considerations. These dynamics are also linked to geostrategic rivalries surrounding the Fourth Industrial Revolution¹⁶ (Lazard, 2026a; see II.3). Yet France and the EU remain largely outside the techno-ideological ecosystems driving these agendas, while remaining connected to them and affected by their evolution (Benoit, 2024). **When viewed as an instrument serving technological acceleration, the development of SRM introduces a new dimension to the challenges facing French and European sovereignty and strategic autonomy in the fields of digital technology and AI.**

Second, the concentration of activity and funding hubs in a limited number of countries (see Maps 1 and 2) also concentrates the capacity to produce knowledge and to shape narratives about these emerging technologies. This configuration gives a small number of actors significant influence over research priorities and directions and, more broadly, over the narratives conveyed to the general public (Bisset and Dyke, 2025). It enables these actors to produce data and expertise that may be regarded as authoritative and, in turn, shape the narratives surrounding SRM that subsequently inform policy discussions at different levels.

¹⁴ The concept of narrative differs from that of discourse in that it designates not the expression of a particular actor, but to a representation of an issue, constructed from a set of ideas and arguments that give it a particular meaning.

¹⁵ This perceived interdependence was explicitly articulated in 2024 by Sam Altman, CEO of *OpenAI*, who presented SRM as a means of overcoming planetary limits (Bloomberg Live, 2024).

¹⁶ The fourth industrial revolution refers to a new way of organising production, that brings together the physical and digital worlds.

These efforts to exert influence are reflected in the terminology used to reframe SRM, as illustrated by the term "climate stabilisation", as well as in how SRM is presented in public debate. One example is the emerging debate within the scientific community over whether SRM should be classified as a form of adaptation to climate change.¹⁷

Influence through narratives: the case of "climate stabilisation"

Within climate governance, the objective of stabilisation has gradually evolved: initially associated with the stabilisation of greenhouse gas concentrations, it was subsequently framed in terms of stabilising the global average temperature (Buck, 2026). **Some actors are now seeking to extend this concept to SRM itself, presenting it as a tool for climate stabilisation.**

This reframing draws in particular on growing concerns about tipping points and the idea that certain interventions could help limit the risks associated with the destabilisation of the climate system (Buck, 2026). At this stage, it is driven mainly by actors outside of academia and is part of a broader effort to reframe the debate on SRM in order to overcome the taboo surrounding it. Prominent advocates of this terminology include influential figures such as Paul Gambill and Ben Lachman, who present stabilisation as a third pillar of the response to climate change, alongside mitigation and adaptation. **This reframing is explicitly presented as serving a political and strategic objective:** to encourage greater state involvement by enabling policymakers to speak about SRM "in a way that garners support from their constituents" (Gambill, 2026). **Several actors have adopted this terminology,** illustrating its influence and contributing to its wider dissemination. Examples include the NGO Ocean Visions, media outlets such as Foreign Policy, and international events such as the Global Risk and Stabilization Summit, held in Iceland in October 2026.

In this context, France and the EU's limited capacity to produce knowledge on SRM risks undermining both their independence and their ability to influence the field. They remain reliant on data mainly generated and held by actors abroad (Kabbej, 2026a). **Such reliance creates a vulnerability,** as access to this data depends on stakeholders' willingness to share information transparently. Yet some private actors have already been found to withhold information (Pasztor and Talati, 2025), while access to information remains particularly difficult in certain countries, notably China¹⁸ and Russia (de Guglielmo et al., 2023; Lazard, 2026b). **These knowledge and information gaps also raise questions of sovereignty,** as they constrain France's ability to anticipate the potential effects of SRM on both metropolitan

¹⁷ Informations gathered through informal discussions.

¹⁸ A report published in September 2026 by the US think tank *American Council for Capital Formation* indicates that China's Ministry of Science and Technology has reportedly increased its funding specifically dedicated to SRM, particularly stratospheric aerosol injection and marine cloud brightening. However, at approximately US\$6 million, this funding remains marginal compared with the amounts allocated in Anglo-Saxon countries (Bowen, 2026).

France and its overseas territories, as well as to detect and monitor potential deployments and their impacts (see II.A).

Without a sufficiently developed and recognised domestic scientific base and body of expertise, France and the EU face constraints on their ability to maintain strategic autonomy. They are more reliant on data, standards, methodologies and assessment frameworks developed by other actors, and must formulate their positions within narratives shaped elsewhere. **These gaps could also weaken France and the EU's diplomatic influence,** potentially marginalising them in international forums where SRM governance is debated. Over the medium and long term, this situation could also limit their ability to put forward analyses and positions grounded in their own scientific expertise.

Third, the heavy reliance of SRM research and advocacy activities in developing countries on funding from institutions based in developed countries (see Map 1) has fuelled considerable debate about the risk of instrumentalising these countries' climate vulnerabilities. Some civil society organisations argue that funding asymmetries help advance an agenda favourable to SRM research and potentially its deployment, including by influencing the research priorities of scholars in developing countries (Chalmin, 2024). **These criticisms are disputed by the organisations concerned** (*Degrees Initiative* and ACIRH), as well as by scientific and government representatives. They advocate an approach centred on strengthening scientific capacity in developing countries, enabling them to conduct their own research and participate actively in international debates (Degrees Initiative, 2026; ACIRH, 2026).

These competing positions reflect struggles for influence over the role that countries most vulnerable to climate change should play in international debates on SRM. These countries must navigate competing pressures: on the one hand, the pursuit of greater autonomy and scientific sovereignty; on the other, the risk of their climate vulnerabilities being instrumentalised. **These dynamics could have implications for French and European climate diplomacy,** affecting both their credibility among these countries and their ability to maintain a leading role in climate governance. As a small number of Anglo-Saxon actors dominate the sector, while countries most vulnerable to climate change are becoming increasingly involved in international debates on SRM (see I.C), **France and the EU risk being perceived as insufficiently engaged with the emerging challenges of climate governance.**

Figure 3 – Three dynamics shaping the SRM sector, three geopolitical implications for France and the EU



C – Governance initiatives shaped by divergent visions and interests

The international governance architecture for SRM remains both fragmented and incomplete (de Guglielmo et al., 2023). No international legal framework explicitly prohibits the deployment of SRM, and no multilateral agreement is specifically dedicated to its governance. Nevertheless, several existing frameworks cover, or could potentially cover, certain aspects of research into or deployment of these methods. This reflects the range of issues that SRM could affect, including the ozone layer, climate, biodiversity, human rights and international security (Ruddigkeit et al., 2025; European Parliament, 2026).

Several initiatives have sought to address these governance gaps, including Swiss resolutions discussed at the United Nations Environment Assembly (UNEA) in 2019 and 2024.¹⁹ Although unsuccessful, these initiatives illustrate the main divisions shaping debates on SRM governance (Corry and McLaren, 2025). Two approaches stand in opposition. The first, supported by a majority of countries, including the EU, favours a precautionary approach grounded in the precautionary principle, the use of existing governance frameworks and the incorporation of social science perspectives. The second, a more permissive approach,

¹⁹ The two proposals sought to produce an assessment report on carbon dioxide and SRM in 2019, and specifically on SRM in 2024.

supported notably by the United States and Saudi Arabia, holds that governance mechanisms should be developed once the scientific evidence is more firmly established. In 2024, these countries notably opposed the inclusion of social sciences in the body of knowledge used to assess SRM methods.

These diverging positions should be understood within the broader political economy of international climate negotiations. **On the one hand, some states with economic and political interests in the continued exploitation of fossil fuels** favour a more permissive approach, as illustrated by the United States and Saudi Arabia. **On the other hand, states that favour a more precautionary approach may see it as a means of exerting influence.** This may be particularly the case where climate diplomacy, including the Paris Agreement, is a cornerstone of their foreign policy, as is the case for several EU Member States, or where countries are heavily reliant on funding channelled through international climate negotiations, as is the case for small island states and many African countries.

Beyond these differences, **debates on SRM governance have evolved in two ways between 2019 and 2026. The first is the growing engagement of developing countries and states most vulnerable to climate change** (Corry and McLaren, 2025; Hassan, 2024). This is reflected in the adoption of dedicated decisions by bodies such as the African Ministerial Conference on the Environment, regional group deliberations during international discussions, notably within the African Group, and in the hosting of international conferences on SRM in countries such as South Africa and Ghana. **The second development is the growing involvement of scientific communities in putting forward proposals for SRM governance**, as illustrated by the *Solar Geoengineering Non-Use Agreement*²⁰. **This initiative, which remains controversial**, proposes to restrict SRM development by prohibiting public funding, field experiments, patents, deployment, and support for these technologies in international forums.²¹

National initiatives to regulate SRM are also emerging, driven by very different rationales. In **Mexico**, the launch of atmospheric balloons by the US start-up *Make Sunsets*, without prior consultation with the Mexican authorities (Daly *et al.*, 2025), prompted the government to announce a ban on all SRM experiments on its territory. Although the ban was never formally adopted, this episode established an important precedent in SRM governance. In the **United States**, legislative initiatives also point to growing public-sector involvement, albeit in a context largely shaped by conspiracy theories. In 2025, bills seeking to ban weather

²⁰ This initiative is supported by several hundred researchers, numerous civil society organisations and certain state representatives, including the African Union's environment ministers.

²¹ Controversies relate mainly to its opposition to public funding and to the lack of geographical representativeness in the perspectives advanced by its promoters.

modification²² and SRM activities were introduced in 22 states, three of which enacted such legislation (SRM360, 2025a). These proposals draw in part on the *chemtrails* conspiracy theory, which alleges that aircraft deliberately release toxic substances to sterilise or enslave populations. Several Republican politicians have explicitly invoked this rhetoric in support of the bills (Buck, 2025).

Against this backdrop of controversy and unsuccessful multilateral initiatives, **numerous voluntary and informal initiatives²³ seek to define the conditions under which SRM research²⁴ may be considered as being conducted responsibly** (Brent et al., 2025). Led by non-state actors, these initiatives pursue both **normative objectives**, by promoting governance standards, **and reputational objectives**, by seeking to establish their legitimacy in a controversial field. They share certain commonalities (Brent *et al.*, 2025), but also differ significantly in substance, particularly in their views on which research activities these principles should cover and the role of the public in research governance. Furthermore, **the development of these principles is largely dominated by Anglo-Saxon actors, who seek — and have to some extent succeeded — in shaping research standards at the international level.**

These voluntary initiatives for the governance of SRM research are emerging at a time when outdoor research activities are expected to expand in the coming years (SRM360, 2025d). **Yet such activities remain highly controversial** (King, 2025). Proponents of continued field research argue that it is necessary given the limitations of models and laboratory experiments. Others, however, argue that no field experiment can capture the full range of SRM's effects unless conducted at the scale of deployment. **A key challenge, therefore, is to distinguish field activities undertaken for research purposes from those that would constitute deployment.** A central question will be which criteria should be used to draw this distinction, including the intentions of the actors involved, the geophysical effects of the activities, and their social and political consequences.

²² Unlike SRM, which is still under development and could have long-term global consequences, weather modification through cloud seeding is already widely practiced in around 50 countries, despite its relatively limited effectiveness. It aims to influence the distribution of water resources by altering precipitation patterns (de Guglielmo and Jash, 2025).

²³ These initiatives include the 2021 report by the US National Academies of Sciences, Engineering, and Medicine (NASEM), the 2024 report by the American Geophysical Union (AGU), the 2025 report by the Advanced Research and Invention Agency (ARIA), and the principles published by the start-up Stardust in 2026.

²⁴ Research encompasses modelling, observations, laboratory experiments and field experiments. The latter category is the subject of the most intense controversy.

PART 2

**STRATOSPHERIC AEROSOL
INJECTION (SAI):
A TECHNOLOGY THAT COULD
BE INTEGRATED INTO
SECURITY LOGICS**

SAI: a technology with uncertain and transboundary effects

Stratospheric aerosol injection (SAI) involves injecting millions of tonnes of reflective particles into the lower stratosphere, at altitudes of approximately 10 km at high latitudes and 20 km in the tropics. The aim is to create an aerosol plume that reflects part of incoming solar radiation, thereby cooling the Earth's surface relatively rapidly. This method seeks to replicate the temporary cooling effects observed following large volcanic eruptions.²⁵

Current knowledge suggests, on the one hand, that SAI deployment at a scale sufficient to affect the functioning of the climate system²⁶ would have transboundary geophysical effects and, on the other, that these effects would alter weather patterns differently across regions (Smith et al., 2026). **The distribution of these effects would depend in particular on the objectives pursued** (temperature stabilisation or a reduction in global temperature) **and on deployment modalities**, including the type and quantity of particles injected, injection locations and timing, and duration of deployment (Pope et al., 2012; Smith et al., 2026; Duffey et al., 2025).

Many SAI's effects remain highly uncertain, particularly those relating to weather patterns, ecosystems, food and water systems, the ozone layer, human health, and solar energy production. **One major risk is termination shock**: an interruption of a significant deployment while GHG concentrations remain high would lead to very rapid warming, to which human societies and ecosystems would find extremely difficult to adapt (Académie des sciences, 2025).

Furthermore, most existing research examines SAI and its projected climate effects through idealised scenarios and modelling based on rational behaviour and climate-optimal objectives. However, these assumptions are not necessarily geopolitically plausible (Määttä et al., 2026). **As a result, these approaches do not fully capture the environmental and (geo)political consequences of deployment scenarios that are non-ideal, non-rational, non-cooperative or contested.** Moreover, despite improvements in modelling and uncertainty reduction enabled through research, the full range of consequences arising from a deployment could not be anticipated before its implementation.

The transboundary nature and uncertainty of SAI's effects give the technology significant geopolitical implications.

²⁵ For example, the 1991 eruption of Mount Pinatubo in the Philippines is estimated to have caused cooling of the order of 0.3°C to 0.5°C over a period of two to three years (Haywood and Times, 2022).

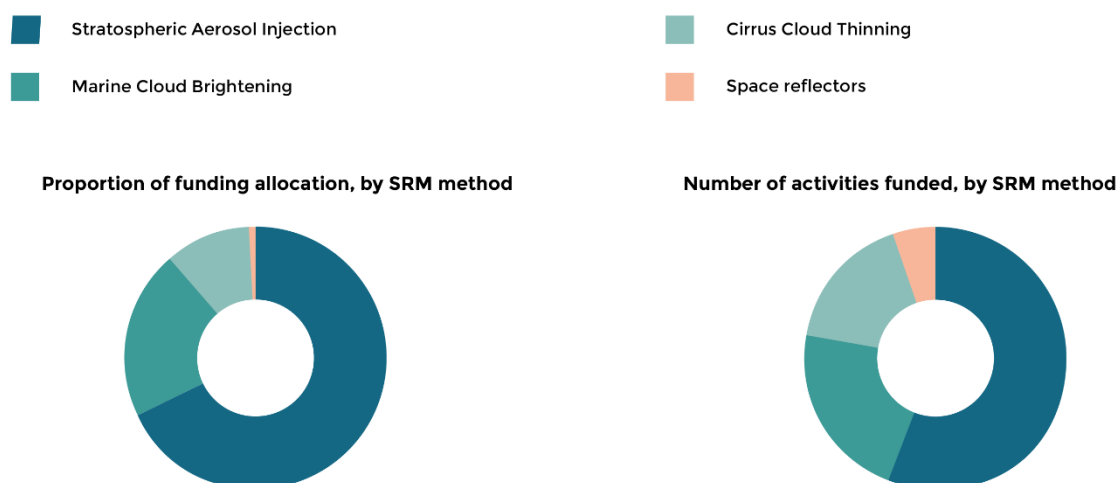
²⁶ The effects of SAI deployment, including transboundary ones, depend on the scale of the perturbation to the climate system, which depends in particular on the quantity of aerosols released.

A – The capability requirements of a technology with transboundary effects

SAI is currently the SRM method attracting the greatest interest and receiving the most funding. This interest can be explained in part by the fact that SAI presents the lowest technical barriers among the SRM methods currently under research. **Nevertheless, its development and possible deployment will depend on meeting capability requirements (see Figure 6) that are unevenly distributed among states, raising important geopolitical questions.**

Figure 5 – Identified funding by SRM method (US\$ millions; ongoing activities only)

Ongoing Activities and Identified Funding, by SRM Method

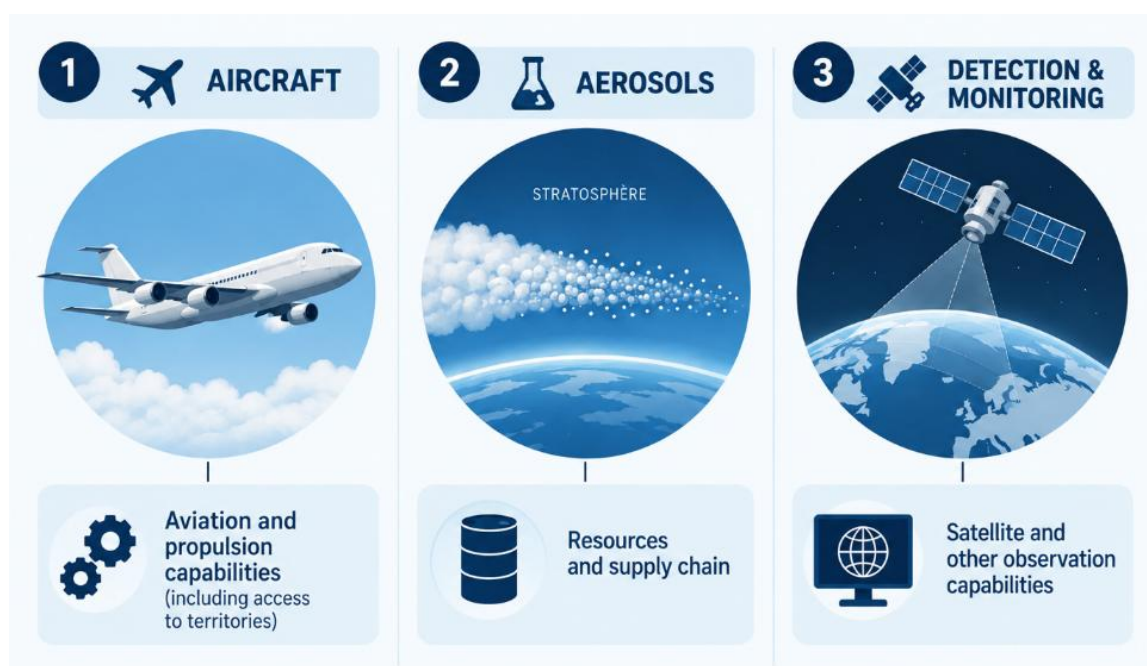


*Only activities clearly identified as focusing on a single SRM method are listed here.
82 out of 140 activities are taken into account, representing 220 million USD out of 328 million USD.

Other projects not included here relate to SRM funding activities, multidisciplinary activities (modelling, social science research) which involve the analysis of several SRM methods.

Source: IRIS database

Figure 6 – SAI: three capability requirements with geopolitical implications



1. Capability requirement 1: dependence on the aerospace and propulsion industries

The first capability requirement concerns the availability and suitability of aircraft.²⁷ The ability to deploy SAI would depend on the injection strategy, particularly the altitude and latitude at which aerosols are dispersed. **Simulations generally favour injections at high altitudes, around 18 km, and in the tropics, where they produce a greater cooling effect** (Duffey *et al.*, 2025; Zhang *et al.*, 2024). **However, existing aircraft available on the global market cannot meet these requirements:** their operational ceiling is generally around 13 km, while the few jets capable of reaching altitudes of 15.5 km cannot carry a sufficient aerosol payload to produce a significant cooling effect (Smith and Wagner, 2018; Keith and Smith, 2024).

A high-altitude deployment would therefore require the development of a fleet of around 100 aircraft capable of operating in the stratosphere near the equator, carrying substantial aerosol payloads and sustaining combustion at high altitudes for extended periods (Smith and Wagner, 2018; Horton *et al.*, 2025). Developing these aircraft and the associated infrastructure could take around two decades, at an estimated cost of several tens of billions

²⁷ Although several injection devices have been considered (rockets, atmospheric balloons), aircrafts are generally regarded as the most effective means of deployment (Horton and Irvine, 2024).

of USD per year (Smith and Wagner, 2018; Robock, 2020). **More recent research²⁸, however, suggests that these barriers could be reduced by opting for a smaller-scale deployment using remotely piloted aircraft (drones), which would require less energy and smaller payloads.** These prospects raise the possibility of SAI deployment occurring sooner and at lower cost.

To overcome these technical, temporal and economic constraints, researchers are also exploring alternative injection strategies. Some scenarios envisage seasonal injections at lower altitudes, around 13–15 km, in polar regions (60°N and 60°S). **Existing aircraft, such as the Boeing 777F, could then be adapted to carry aerosol payloads.** However, this “polar” scenario would be less effective than tropical deployment²⁹ and would entail additional risks and uncertainties, particularly regarding the exposure of populations and ecosystems to particles and the effects on precipitation (Duffey *et al.*, 2025). Some researchers present polar deployment as a **potential first step towards near-term deployment**, reducing the upfront costs and lead times associated with aircraft research and development (Reflective, 2026; Temple, 2026).

These two scenarios — tropical and polar— illustrate how deployment objectives and modalities determine both the aviation capabilities required and the timeframe within which SAI could be deployed. At present, no major technical barriers prevent small-scale experiments using existing aircraft, subject to certain modifications. Moreover, the technical barriers to achieving a deployment with a significant effect on the global climate are relatively low (Horton and Irvine, 2024).

These scenarios also show that the ability to develop and deploy SAI will depend directly on the capabilities of the aerospace and propulsion industries. The involvement of companies from these industries would be essential for adapting existing aircraft or designing new ones. **These companies are, however, concentrated in a relatively small number of countries: around a dozen states** including the United States, France, Germany, the United Kingdom, Japan, Canada, Russia, China, India and Brazil. Moreover, **companies operating in these advanced industries constitute "strategic assets" (Horton et al., 2025), notably because of their close links with defence industrial bases.** These characteristics make it unlikely that such companies would become involved in SAI-related activities without the explicit or tacit approval of government authorities.

²⁸ This research was presented in May 2026 as part of the University of Chicago's *Climate Systems Engineering initiative*, a major hub for research into the development of aircraft and aerosol dispersion systems, which remain a central capability challenge (Temple, 2026). The US company *Iris Aero*, for example, is developing an aircraft that, according to available estimates, could be built in three years at a cost of approximately US\$120 million (Levitan, 2026b).

²⁹ The cooling effectiveness of a polar deployment is estimated at between 50% and 65% of that of a tropical deployment (Duffey et al., 2025).

Deployment capabilities also depend on access to the territories and infrastructure needed to launch and base aircraft, as well as on authorisation to fly through the airspace concerned. A deployment by a private actor without the explicit or tacit backing of a government therefore appears unlikely (de Guglielmo et al., 2023). **These constraints nevertheless confer an advantage to states with industrial capabilities and territories spanning multiple latitudes,** as they have greater flexibility for determining deployment strategies and potentially pursuing unilateral deployment.³⁰ Furthermore, **operations involving the release of significant quantities of aerosols would be subject to regulatory procedures involving specific bodies³¹, which could help ensure traceability.** However, this would depend on the willingness of the actor, or actors, involved to comply with the standards governing the transport of goods by cargo (Wagner, 2026).

2. Capability requirement 2: dependence on supply chains for different types of aerosols

The second capability requirement concerns the quantities of aerosols required for a deployment at a scale sufficient to produce a significant climatic effect, as well as the supply chains needed to support such operations. For example, cooling the planet by around 1°C would require the annual injection of several tens of millions of tonnes of sulphur dioxide (SO₂) (Horton and Irvine, 2024). **This would pose major challenges in terms of particle availability, storage and transport, as well as the industrial capacity required to support these operations.**

Research into which aerosols would be most suitable for SAI is still ongoing, and there is no scientific consensus on the preferred materials. Sulphate aerosols³² are the most extensively studied option, largely because of their historical and present presence in the atmosphere and the natural analogue provided by volcanic eruptions (Visioni, 2026; Vattioni, 2025). **However, their use entails significant risks,** including stratospheric warming, ozone depletion and acid rain. **Other solid particles, such as calcite and diamond dust, are also being investigated,** while the start-up *Stardust* is exploring **the production of synthetic particles³³** (Spector et al., 2026). These solid particles introduce greater uncertainties regarding their

³⁰ The United States has a particularly favourable combination of economic, industrial and territorial capabilities in this respect to develop and, where appropriate, deploy SAI at a scale likely to have a significant climate effect. China could also have similar options in due course, notably thanks to its investments under the *Belt and Road Initiative* (Horton et al., 2025; Möller and Young, 2026).

³¹ For example, the International Air Transport Association (IATA).

³² Sulphate aerosols are tiny solid or liquid particles composed of sulphates.

³³ Published as preprints, without having been peer reviewed, Stardust's work has been criticised within the scientific community (SRM360, 2026).

behaviour in the stratosphere, their ecological interactions and the dispersion systems required³⁴ (Henry, 2026; Visoni, 2026).

The use of existing or synthetic reflective particles would raise distinct issues of resource geopolitics³⁵, relating to the control over supply chains, the dependencies and vulnerabilities they create, and their effects on markets (Hack et al., 2025).

For example, the use of sulphate aerosols would rely primarily on sulphur recovered as a by-product of oil refining and natural gas processing. This option would therefore be closely tied to the fossil fuel industry (Nwuneli, 2026). This could reinforce two risks associated with SAI. First, it could contribute to sociotechnical lock-in by helping sustain infrastructure and dependencies associated with fossil fuels. Second, it would create moral hazard by reducing incentives to address the causes of climate change through the reduction of GHG emissions. Furthermore, global demand for SO₂ continues to grow, notably for fertiliser production, while export capacity is concentrated in a few regions, notably the Middle East (Saudi Arabia and Qatar) (Hebebrand et al., 2026) and Canada. These characteristics could increase pressure on markets and create vulnerabilities in supply chains. **By contrast, the use of synthetic solid particles would require industrial capacity to be developed and coordinated across the entire value chain on a very large scale, encompassing manufacturing, storage, transport and dispersion.**

3. Capability requirement 3: dependence on detection and monitoring systems

The third capability requirement concerns the access to, and suitability of, systems for detecting and monitoring a possible SAI deployment. Several currently operational systems could, in principle, detect abnormal concentrations of stratospheric aerosols or their precursors in the atmosphere, notably the European TROPOMI instrument. **A deployment on a scale sufficient to affect the global climate would therefore be detectable by satellite, but also through the logistics associated with it** (Smith et al., 2026). Repeated take-offs and landings by large numbers of aircraft, together with the flows of aerosol precursors required to supply them, would generate logistical signatures that could be identified using existing surveillance capabilities.

³⁴ Existing mechanisms do not, at this stage, make it possible to prevent agglomeration (Visoni, 2026).

³⁵ To date, little research has examined the geographical distribution of the capacity to recover and/or produce these different materials, the countries involved, and the associated geopolitical implications. This could be explored in greater depth in a separate report.

However, current capabilities remain limited when it comes to detecting small-scale injections. Indeed, no country currently has the capabilities needed to detect an undeclared, small-scale injection (Visioni, 2026).³⁶ Yet such deployments are an essential step towards developing the capacity for large-scale deployment, as they help reduce scientific uncertainties. **Developing detection capabilities is therefore essential to identifying potentially non-transparent activities.**

Significant capability gaps also remain in monitoring the effects of a potential SAI deployment. Several monitoring systems are expected to be decommissioned in the coming years,³⁷ raising the risk of an “imminent data desert” (Salawitch *et al.*, 2025), particularly with regard to ozone layer monitoring and the detection of potential aerosol injections. Moreover, **current capabilities do not yet provide sufficiently detailed and continuous data to fully assess the effects of SAI deployment.** Strengthening monitoring capabilities could involve combining satellite-based observations with balloons and/or air campaigns (Visioni, 2026).

Finally, **detection and monitoring capabilities are currently distributed very unevenly across states.** Only a small number of satellites, primarily American, have sufficient precision to detect aerosol plumes, and even these are subject to limitations in terms of geographical coverage and temporal resolution. These limitations are particularly significant when it comes to detecting and monitoring activities in polar regions. **The concentration of detection and monitoring data in the hands of a limited number of actors, and the resulting dependencies, may have geopolitical implications.** In a context of growing challenges to trust in information and science more broadly, **this concentration of capabilities could fuel mistrust among actors regarding data on the detection and monitor SAI activities.**

B – Framing climate change as a security issue may encourage the appropriation of SAI as a political response or security measure

The preceding analysis sheds light on the capability requirements associated with SAI and their geopolitical implications. However, **it does not account for the political factors that could shape the conditions under which SAI might be deployed and the consequences of such a**

³⁶ The threshold of 0.55 tonnes of SO₂ was identified in a recent paper (Smith *et al.*, 2026).

³⁷ These are the Atmospheric Chemistry Experiment–Fourier Transform Spectrometer (ACE-FTS) on SCISAT-1 and the Microwave Limb Sounder (MLS) on NASA's Aura satellite. The Aura platform is reaching the end of its operational lifespan, while SCISAT-1 has been in service for more than 20 years.

deployment. In particular, it does not address the decision-making processes involved: who might decide to deploy SAI, for what reasons, under what procedures, and with what implications for relations between states.

Among these factors is the growing tendency to frame climate change as a security issue.³⁸ Many state and non-state actors, including some involved in SAI-related activities, describe climate change as a phenomenon that generates risks, or even threats (Gemenne et al., 2021; Climate Diplomacy, 2026; McDonald, 2024; Kabbej, 2025). **These discourses are, however, heterogeneous,**³⁹ **and translate into the promotion and implementation of different policy responses** (Vogler, 2023): GHG emissions reduction, ecosystem restoration, early warning systems, dyke construction, etc.

Despite this heterogeneity, climate security discourses in several states, including the United States, Germany and France, **have gradually shifted away from ecological considerations**⁴⁰ **towards a focus on national and international security issues** (Von Lucke, 2015; Von Lucke, 2023; Kabbej, 2025). **This shift has had concrete effects on the orientation of the policy responses adopted.** These responses have tended to favour the implementation of adaptation measures and emergency management over reducing fossil fuel consumption – even though fossil fuels are the source of the threat being addressed (Kabbej, 2025).

SAI could therefore align with policy orientations that prioritise managing the effects of climate change, including their security implications. This perspective is reinforced by the emergence of narratives within the SRM sector that present SAI as a potential means of protection, despite significant differences in how the underlying problem is characterised⁴¹ (Kabbej, 2026b). **The interplay between these two trends** – on the one hand, state-led approaches to climate security that tend to shift attention away from the causes of climate change and, on the other, the framing of SAI as a potential means of protection– **could create favourable conditions for the appropriation of SAI as a political response, or even a security measure.**

³⁸ See Introduction

³⁹ There is no consensus on what constitutes "climate security". Divergences relate in particular to the threats identified (extreme weather events, population displacement, tensions over resources, etc.), what should be protected (the state, populations, ecosystems, etc.), the responses to be favoured (reducing fossil fuel consumption, early warning systems, adapting infrastructure, etc.) and who should implement them (governments, international organisations, individuals, etc.) (McDonald, 2013).

⁴⁰ These ecological considerations include the identification of the oceans, biodiversity, and marine or terrestrial species as objects of protection.

⁴¹ As with broader debates on climate security, this framing encompasses a range of approaches, particularly regarding the nature of the threats associated with climate change, whether direct or indirect, and what should be protected: the biosphere, humanity, nation-states or the international order (Kabbej, 2026b).

For policymakers, SAI may indeed present the attributes of a concrete, visible and politically valuable policy solution (Young, 2026). Such a technology could be presented as responding to public expectations regarding climate change without addressing its underlying causes or challenging existing economic and political power structures.⁴² It would thus make it possible to demonstrate that societal expectations are being considered, including by populist and authoritarian regimes (Michaelowa, 2021). **From this perspective, security rhetoric surrounding climate change could contribute to aligning SAI within a logic of preventive security, whereby an emergency measure is adopted in the name of managing a threat, without its potential consequences being fully taken into account** (Young, 2023).

The hypothesis that SAI could be pursued as a preventive security measure must also be considered in light of the primacy accorded to sovereignty in security logics.⁴³ **In a context of increasingly security-oriented approaches to climate change, and in the absence of consensus on what should be protected, the central role given to sovereignty could favour non-cooperative approaches to SAI.** This possibility is reinforced by states' ability to reframe transnational problems in ways that enable them to exercise power. As illustrated by the response to the COVID-19 pandemic, which was marked by border controls and disputes over intellectual property rights relating to vaccines, **"SAI could thus be conceived as a way to reframe the climate problem in terms that are intelligible and compatible with the exercise of sovereignty"** (Young, 2026).

The adoption of SAI as a security measure could lead one or more states to pursue a unilateral or minilateral deployment pathway, with significant geopolitical implications. This prospect is reinforced by evolutions in the international political environment, and **by the potential for the militarisation of SAI**, understood as the involvement of human and technical military resources needed to initiate or sustain a deployment (de Guglielmo et al., 2023; Chalecki, 2026). **In this context, disagreements could emerge over the objectives of deployment, in other words, over what SAI should protect and how that protection would**

⁴² These factors may lead to SAI being considered without sufficient scientific evidence of its effectiveness (Young, 2023).

⁴³ Security logics "tend to reproduce a sense of the primary importance of the survival of the state and the maintenance of sovereignty over the territory of the state" (Young, 2023, p. 270).

be achieved. Such disagreements could lead to counter-geoengineering⁴⁴, as well as diplomatic, coercive and offensive responses, including in the military domain⁴⁵.

C – SAI: an object of geostrategic competition with the potential for weaponisation and instrumentalisation

The analyses presented so far, including those considering non-cooperative deployment, still approach SAI as a tool conceived for achieving climate-related objectives. However, **SAI could also be developed and used to pursue strategic and political objectives that extend well beyond the climate considerations for which this technology was initially conceived** (Corry et al., 2025; Young, 2023; Sovacool et al., 2023; Surprise, 2020; McLaren, 2024). By theoretically granting a state the ability to control planetary habitability through its influence on the global climate and weather patterns, **SAI has the characteristics of an instrument of power (see Figure 7)** (Möller and Young, 2026, pp. 1-3).

Figure 7: SAI as an instrument of power



⁴⁴ Two forms of counter-geoengineering have been envisaged: one aimed at neutralising or eliminating aerosols, and the other at offsetting their effects (de Guglielmo et al., 2023). The first would consist "of releasing new substances to accelerate the atmospheric deposition of the initially released products" (de Guglielmo et al., 2023, p. 30). It has recently been the subject of an efficacy study, the results of which should be treated with caution owing to the simulation conditions (Jones et al., 2026). The second would seek "to reverse the effects of these products by injecting warming agents (particles or greenhouse gases)" (de Guglielmo et al., 2023, p. 30).

⁴⁵ These responses could span a broad continuum, including the recall of ambassadors or the severing of diplomatic ties, economic and trade instruments (such as sanctions or tariffs), demands for financial compensation, or neutralisation through the destruction or sabotage of the logistical infrastructure needed for deployment (aircraft, runways, monitoring systems, etc.) (de Guglielmo et al., 2023; Kabbej, 2026a).

1. SAI as an object of geostrategic competition

The development of SAI tends to be part of a dynamic of competition over the mastery of a **disruptive technology**, rather than a cooperative endeavour (Nielsen, 2025; Möller and Young, 2026). **This competition could take shape ahead of any deployment, through the gradual building of the technical and scientific capabilities required to master the technology.** Building these capabilities could become a **strategic objective in its own right, regardless of any decision to proceed with an actual deployment. Such capabilities could be perceived as a means of preserving room for manoeuvre** in the face of changes in the climatic or geopolitical context, to reduce dependence on foreign capabilities and to gain leverage in international negotiations on SAI governance (Young, 2026).

In this competitive perspective, **a state's interest in SAI could also be driven by ambitions for technological superiority**, rather than solely to mitigate the extent of global warming. In this sense, **mastery of SAI could constitute an attribute of prestige**, enabling a state to signal its power and pre-eminence (Horton, 2026). **This technological mastery could be achieved, but it could also be claimed without being able to verify those claims in the short or medium term.** Assessing whether cooling can be attributed to SAI deployment may take several years, or even one or two decades (Henry, 2026; Baur, 2026).⁴⁶ These uncertainties, combined with the concentration of monitoring capabilities, could undermine trust in the political and scientific narratives surrounding a possible deployment and fuel mistrust.

These competitive dynamics are unfolding against the backdrop of US-China rivalry, which is already influencing dynamics surrounding the development and potential deployment of SAI (Horton et al., 2025; Nielsen, 2025). Issues relating to self-determination, strategic autonomy, and the potential for weaponisation associated with SAI have featured in reports published by several US conservative think tanks (TCCRI, 2026; ACCF, 2026; Rainey Center and Silverlining, 2026). In these reports, **SAI is framed as an instrument of power largely detached from climate concerns.** The actors behind them advocate the development of SRM capabilities under US leadership in the name of national security. Such capabilities are presented in particular as means of ensuring "weather sovereignty" in the face of perceived Chinese ambitions (Noyon, 2026), while also preserving the continued exploitation of fossil fuels (Levitan, 2026a), which is central to the US energy dominance strategy (Goeffron, 2026).

The inclusion of SAI as an instrument of power into narratives of US-China rivalry is first driven by partisan considerations but is also grounded in capability-related factors. Carrying

⁴⁶ This reflects the time required to establish with confidence whether any observed cooling can indeed be attributed to SAI deployment. The length of this period would depend on the deployment modalities.

out a large-scale deployment would depend not only on technological mastery, but also on a state's ability to impose a decision to deploy. **One possible scenario is therefore a unilateral deployment, led or supported by the United States or China** (Horton et al., 2025). Given their military, economic, political and technological capabilities, their territorial control and their climate and energy policies, **the United States would be more likely than China to resort to SAI⁴⁷** (Young, 2026). **Nevertheless, a change in Beijing's position remains conceivable**, especially if it were to identify a diplomatic opportunity to assert leadership among countries particularly vulnerable to the effects of climate change.

Cooperation between the two superpowers on SAI nonetheless remains possible. From a geophysical perspective, an ideal cooperative deployment could, in theory, help reduce the risks associated with rising temperatures in the United States and China. **However, this scenario does not account for the political dynamics that could shape decision-making, or the issue of policy coherence when these two superpowers are constructed as systemic rivals.** Some studies suggest that the United States and China might consider deploying SAI even if it were also to cause them physical harm (Möller and Young, 2026; Corry et al., 2024; Chalecki, 2026). **Cooperation on a potential deployment therefore cannot be ruled out, "but may be more likely to occur after a phase of confrontation or non-coordination"** (Young, 2026).

These scenarios illustrate how **the technological and environmental arenas in which SAI operates can themselves be approached as spaces of competition.** This approach is explicitly articulated in a 2023 Pentagon strategy, which presents these arenas as means of avoiding "direct military confrontation" (Möller and Young, 2026, p. 5). Furthermore, competition over SAI should also be understood in the context of AI development. **SAI can be viewed as one dimension of the broader US-China rivalry over technological superiority in this field** (Lazard, 2026a; Lazard, 2026b, see I.B).

2. SAI: a technology with the potential for weaponisation and instrumentalisation

A common view within the SRM sector stresses that SAI is unlikely to be used to inflict physical harm on a specific target, given its lack of precision and the unpredictability of its effects (Horton, 2024). **In this respect, SAI would not meet the requirements for spatial and temporal precision sought in military operations.** Moreover, such use would contravene the ENMOD Convention (1977), which prohibits the hostile or military use of environmental

⁴⁷ This analysis is based exclusively on open-source data collection.

modification techniques.⁴⁸ **However, the argument that SAI's imprecision and the difficulty of controlling its effects preclude its weaponisation overlooks the fact that these characteristics are also shared by biological, chemical and nuclear weapons.** Although imprecise in their temporal and spatial effects, these weapons are nonetheless used and/or subject to widely varying degrees of prohibition (Möller and Young, 2026).

Given its potential effects on the global climate and, consequently, on all territories, SAI could serve as a geopolitical lever. This possibility becomes more plausible in a context where weaponisation is increasingly understood in broader terms than the mere capacity to inflict physical harm (Möller and Young, 2026), and where environmental levers are being used in contemporary conflict dynamics (Jourde et al., 2025). **The threat of using or not using SAI to influence or coerce the behaviour of adversaries or partners could therefore constitute a form of SAI weaponisation** (Möller and Young, 2026; de Guglielmo et al., 2023). **The mere possession of deployment capabilities could thus provide a means of coercion,** regardless of whether a decision is ever taken to use them.

Linked to the potential weaponisation of SAI is the question of whether its development and/or potential deployment might be perceived as hostile (Möller and Young, 2026; Sikorsky, 2025). Such perceptions have already emerged around weather modification methods (de Guglielmo et al., 2023) and are arising in the context of SAI development. The *Palestinian Initiative for Climate Strategy* has accused the Israeli-American start-up Stardust of conducting field experiments, raising concerns that these tests may have been conducted over Gaza (2025). Although there is no evidence that these experiments actually took place, **this example illustrates how SAI can become embedded into the narratives and strategies of stakeholders involved in pre-existing conflicts** (Kabbej, 2026a).

Such perceptions of hostility could be fuelled in particular by the difficulty - even impossibility - of attributing an isolated extreme weather event to SAI, to ongoing climate change or to natural climate variability (Smith et al., 2026). **This ambiguity surrounding attribution creates fertile ground for the instrumentalisation of SAI and its effects.** Such practices could **serve a range of political and strategic objectives.** They could first be used **in the domestic sphere,** enabling authorities to deflect responsibility for how they manage the effects of climate change. They could also serve **foreign policy objectives** by creating opportunities to blame other actors to justify political or military responses (de Guglielmo et al., 2023).

⁴⁸ Several states, including France, are not party to the Convention. Moreover, its applicability would depend, among other factors, on the ability to establish that SAI had been used with hostile intent.

Finally, this ambiguity could be exploited by third parties to pursue strategic objectives, notably through disinformation or information manipulation campaigns designed to erode trust in public authorities and fuel grievances or mistrust. The use of information warfare practices to destabilise societies has already been documented in the United States and the EU. In some cases, these practices were directly associated with weather modification methods (Jourde et al., 2026; Sikorsky, 2025). **The role of information as a strategic lever in the risks associated with SAI must therefore be considered in a broader context, marked both by the rise of cognitive warfare (NATO STO, 2025) and by the growing inclusion of climate change into hybrid warfare practices (Duffau et al., 2025).**

SAI in the Arctic: understanding the interactions between climate objectives and geostrategic considerations

Climate change in the Arctic⁴⁹ is unfolding within a geopolitical environment that is itself transforming. This context is characterised, first, by the proliferation of discourses framing climate change as a threat to national and regional security (Energy News, 2025; Greaves and Gricius, 2026), including by some actors in the SRM sector (Gunnarsson, 2026; Smith et al., 2024). **Nevertheless, this framing of climate change as a security issue is not consensual:** Russia and, to a lesser extent, China have been more reluctant to frame climate-driven changes in the Arctic in terms of national or regional security (Zhou, 2017). The second Trump administration, meanwhile, denies the existence of climate change while acknowledging the environmental transformations taking place in the region and their economic and strategic implications. **Second, the Arctic is marked by strategic rivalry between Russia and NATO member states**, as reflected in growing militarisation (Foreign Policy, 2020) and the gradual erosion of "Arctic exceptionalism" (Lozier, 2022).

The region is thus characterised by the interaction of multiple actors, competing conceptions of security and differing understandings of what constitutes a threat. **This plurality of perspectives could shape the conditions in which decisions about SAI development are made, and in turn, give rise to contestation.** For Iceland, for example, which has declared the collapse of the Atlantic Meridional Overturning Circulation (AMOC) an existential security issue (Energy News, 2025), the development of SAI could be justified as a national security measure. However, such a decision "would not necessarily be accepted by the **United States**, which perceives the Arctic as a highly important strategic space. This could encourage a conservative Republican administration in the United States to invest in SAI development in order to preserve a strategic advantage and maintain a sense of primacy in the region."⁵⁰ A future Democratic administration could also justify SAI development as a means of

⁴⁹ The Arctic is warming almost three times faster than the global average, leading to glacier and sea-ice loss, permafrost thaw, and increases in precipitation and wildfires (AMAP, 2024). These changes also have global implications, particularly for albedo, sea levels and ocean circulation. For these reasons, the Arctic is frequently described in SRM research, including research on SAI, as a "great white shield" (Kornbech et al., 2024), whose preservation could help limit the risks associated with crossing multiple climate tipping points.

⁵⁰ This positioning would be consistent with the new emphasis placed in the 2025 *National Security Strategy* on the Western Hemisphere as a priority area of US influence (The White House, 2025).

restoring climate leadership. (...) For **Russia**, SAI development could be understood as a matter of status, presence, and recognition in a region that constitutes its immediate environment”.

In such an environment, SAI-related activities could take on strategic significance, potentially giving rise to suspicion and mistrust and fuelling disinformation practices (Young, 2026). Depending on the actors involved, the same activity could be interpreted as a response to climate change, or as an attempt to alter regional strategic balance, given the potential dual-use of the associated logistical infrastructure, including monitoring systems (Corry, 2024; Young, 2026).⁵¹ **These findings have implications for France and its armed forces, even in the absence of French participation in SAI development.** The emergence of SAI capabilities in the region could indeed require strengthening detection and monitoring capabilities needed to identify the activities conducted, the actors responsible for them, and their effects. It could also affect the strategic environment in which French and allied forces may have to operate in a region considered a priority area of interest.

⁵¹ Recent research has also shown that, during simulations of international negotiations on SRM, concerns about geostrategic competition quickly and overwhelmingly take precedence over climate-related considerations (Young et al., 2026).

CONCLUSION

The dynamics structuring the SRM sector raise significant geopolitical issues for France and the EU. First, the rise of private actors pursuing a political and ideological agenda combined with the concentration of SRM activity and funding hubs in a limited number of countries raises issues of sovereignty, strategic autonomy and influence. Second, debates over funding asymmetries between developing and developed countries have fuelled concerns about the potential instrumentalization of developing countries' climate vulnerabilities, with possible implications for France and the EU's credibility and climate leadership. **In this context, the capacity of France and the EU to develop their own expertise on SRM is a strategic issue,** both for understanding the scale of the geophysical and socio-political effects of these technologies and, consequently, being able to influence debates on their governance.

SAI is the SRM method attracting the greatest interest and the most funding, while also presenting the lowest technical barriers to development. Its characteristics could facilitate its integration into security logics. On one hand, the uneven distribution of the capabilities needed for its development raises geopolitical issues that remain underexplored. On the other hand, the framing of climate change as a security issue combined with the prioritisation of managing its effects rather than its causes could create favourable conditions for the appropriation of SAI as a political response, or even as a security measure. Finally, its theoretical environmental effects make it a potential instrument of power. **SAI must therefore be understood as an object of geostrategic competition, with the potential for weaponisation and instrumentalisation.**

The findings of this report reinforce the need for French and European political engagement. The absence of major technical barriers to small-scale experiments in the very short term, combined with the rise of narratives that contribute to legitimising SRM, stand in contrast to gaps in French and European research and influence capacity, as well as limitations in global detection and monitoring capabilities. **Strengthening these capabilities should therefore be a priority⁵², enabling activities, the actors responsible for them and their effects to be identified, notably within European and NATO frameworks.** For the EU, this effort also presents an opportunity for leadership and influence, by providing reliable data on the detection and monitoring of SAI, and more broadly, SRM.

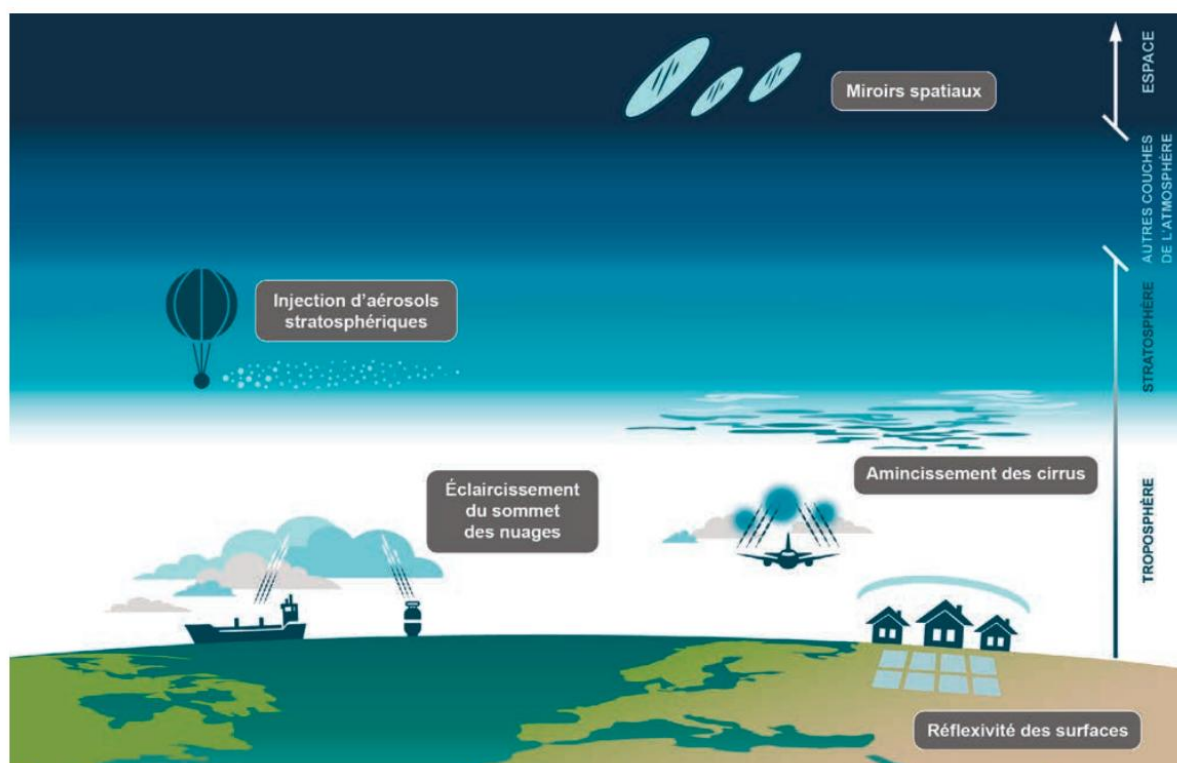
For France and the EU, the challenge is to preserve their ability to independently assess the implications of SRM and developments in this controversial sector. This is particularly important for the French armed forces: any development or deployment of SRM could alter

⁵² The European Commission recently announced €10 million in funding under Horizon Europe for research into SRM-related detection, monitoring, modelling and attribution (European Commission, 2026).

their strategic and operational environment, even in the absence of French participation in these activities. Maintaining a capacity for independent assessment requires **the ability to draw on independent expertise and dedicated resources**. This is essential to safeguarding French and European decision-making autonomy in an environment where the climate and geopolitical dimensions of these technologies could become increasingly intertwined.

ANNEX

Annex 1. The main solar radiation modification (SRM) methods



Source : Académie des Sciences. (2025). *Géo-ingénierie climatique : état des lieux scientifique, enjeux et perspectives*.

Solar geoengineering, or solar radiation modification (SRM), encompasses a range of methods that share the common objective of lowering the global mean temperature through technical and/or chemical devices designed to reflect or block part of incoming sunlight back into space. Some interventions aim to increase the reflectivity (albedo) of land and ocean surfaces, including using **white paint on urban surfaces** (roofs, roads) or **through the thickening of sea ice**. Others seek to modify the reflective properties of clouds: **cirrus cloud thinning** aims to reduce their opacity, while marine cloud brightening aims to increase their reflectivity through the injection of particles at low altitude. **Stratospheric aerosol injection (SAI)** consists in introducing reflective aerosols at high altitude in order to increase the portion of incoming solar radiation reflected back into space. Finally, some proposals aim to intervene directly in space, notably by means of **reflective devices placed in orbit between the Earth and the Sun**.

Annex 2. Natural and human risks by type of SRM methods⁵³

Technique	Risks to the Earth system	Risks to Human safety
Lightening of marine clouds	<ul style="list-style-type: none"> - Changes in rainfall and temperature (droughts in South America increased tropical rainfall) (Grisé et al., 2021). - Persistence of impacts associated with rising CO₂ - Decrease in photosynthesis impacting humidity levels, precipitation and local oxygen concentrations (Sacha, 2022). - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which ecosystems cannot adapt. 	<ul style="list-style-type: none"> - Reduction in agricultural yields⁹ (Sacha, 2022) - Reduction in primary productivity in the Amazon, and a slight increase in Africa (rainfall disruption) (Jones et al., 2009; 2011). - Loss of ecosystem services (reduced photosynthesis). - Health risks linked to temperature changes¹⁰ (Swiss Re, 2023). - Reduced air quality. - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which human societies will not be able to adapt.
Thinning cirrus clouds	<ul style="list-style-type: none"> - Disruption of precipitation (intensification of rainfall in the Sahel and of the monsoon in India) (Gasparini et al., 2020). - Amplification of global warming if techniques are carried out in areas with low cloud cover and relatively high humidity (Peters et al., 2011) or if too many particles are injected (Gasparini et al., 2020). - Persistence of impacts associated with rising CO₂ - Decrease in photosynthesis impacting humidity levels, precipitation and local oxygen concentrations (Sacha, 2022). - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which ecosystems cannot adapt. 	<ul style="list-style-type: none"> - Health risks linked to temperature changes (Swiss Re, 2023). - Loss of ecosystem services (reduced photosynthesis). - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which human societies will not be able to adapt.
Injection of stratospheric aerosols	<ul style="list-style-type: none"> - Degradation of the ozone layer (Lawrence et al., 2018). - Deterioration in rainfall (in particular, droughts in sub-Saharan Africa, the Mediterranean and India, torrential rains and floods in Brazil and Northern Europe) (Baughman et al., 2012; Jones et al., 2022; Grisé et al., 2021). - More hurricanes in the North Atlantic (Grisé et al., 2021). - Variability of effects depending on place of injection¹¹ 	<ul style="list-style-type: none"> - Reduced agricultural yields (Proctor et al. 2018)¹². - Health risks linked to released substances¹³ - Health risks linked to temperature changes. - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which human societies will not be able to adapt.

⁹ This is linked to a drop in photosynthesis by crops, but also in temperatures and rainfall.

¹⁰ Changes in temperature and precipitation patterns could cause certain diseases, such as malaria, to shift geographical zones and proliferate in new areas (Carlson et al., 2022).

¹¹ Aerosols injected into the northern hemisphere could cause severe droughts in sub-Saharan Africa and India. Injection into the southern hemisphere could lead to a collapse of the rainfall system in Brazil and an increase in hurricanes in the North Atlantic (Grisé et al., 2021).

¹² Some studies have highlighted the risk of reduced agricultural yields following stratospheric aerosol injection in regions where productivity is strongly determined by the summer monsoon system, particularly in East Asia (Robock et al., 2008; Tilmes et al., 2013).

¹³ Sulphuric acid, in particular, is extremely toxic (Lawrence et al., 2018). Sulphur could also fall back in the form of acid precipitation (Chalecki & Ferrari, 2018).

⁵³ This table was initially conceived in French.

	<ul style="list-style-type: none"> - Interference with El Niño, the North Atlantic Oscillation, the Quasi-Bienial Oscillation, the polar vortex and the Brewer-Dubson circulation (Aquila et al., 2014; Jadwiga et al., 2018; Jones et al., 2022). - Persistence of the impacts associated with the increase in the level of CO₂ and risk of cancelling out the benefits induced by the MRS due to the degradation of cloud cover under the effect of GHGs (Schneider et al., 2020). - Decrease in photosynthesis impacting humidity levels, precipitation and local oxygen concentrations (Sacha, 2022). - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which ecosystems cannot adapt. 	
Space mirrors	<ul style="list-style-type: none"> - Cascading regional variations depending on mirror positioning and shaded or unshaded regions (Sánchez & McInnes, 2015). - Climate extreme changes in terrestrial zones with temperatures and ecosystems that are strongly impacted by solar radiation (tropics and poles), leading to a cascade of the following effects: <ul style="list-style-type: none"> → Rainfall disruption (United Nations, 2023) → Reduction in the amplitude of the seasonal cycle (United Nations, 2023) → Decrease in photosynthesis impacting humidity levels, precipitation and local oxygen concentrations (Sacha, 2022) - Objects placed at L1 are relatively stable, but risk going off their axis¹⁰. Without intervention (replacement or replacement), the mirrors will come off their axis after a certain time (Siegel, 2020; European Space Agency, 2023). - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which ecosystems cannot adapt. 	<ul style="list-style-type: none"> - Reduced agricultural yields but no chemical interference with the earth's biosphere (Sacha, 2022). - Health risks linked to temperature changes. - "Terminal shock" in the event of a halt (cf. I, 2, b.): a sudden rise in temperature to which human societies will not be able to adapt.

Source: De Guglielmo et al. (2023). Solar Geoengineering: Geostrategic and Defence issues.

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