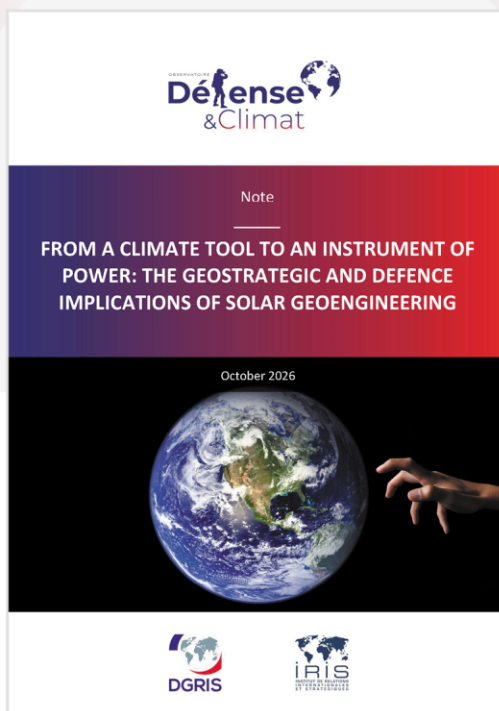


SUMMARY

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 of 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.

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 Armed Forces.

ABOUT THE AUTHOR OF THIS NOTE



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Sofia Kabbej is an independent consultant and researcher, affiliated with IRIS as part of the Climate, Environment and Security Programme. Her work focuses on the geopolitical and security implications of climate change and climate modification methods. She holds a PhD from the University of Queensland (Australia). Her thesis examined France's commitment to tackling climate change as a security issue.

DATA COLLECTION, INFOGRAPHICS AND MAPS



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In the context of accelerating climate change, scientific and political discourses 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.

This note builds on the 2023 note of the Defence and Climate Observatory on the geostrategic and defence issues of SRM (De Guglielmo et al., 2023). Like this previous note, 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 note also examines its potential to become integrated into security logics and power dynamics.

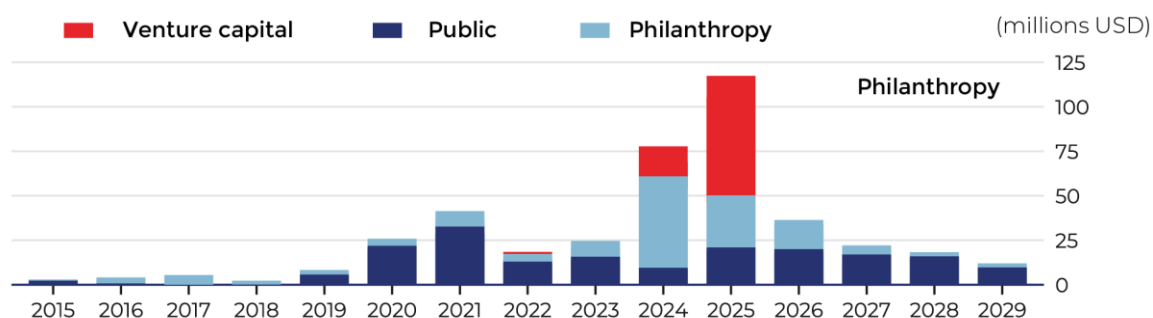
I. THE STRUCTURING OF THE SRM SECTOR AND ITS GEOPOLITICAL IMPLICATIONS

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.

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). The involvement of private actors marks a turning point in the structuring of the SRM sector and should be understood in light of economic motivations associated with the potential profits linked to the commercialisation of these technologies.

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



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

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 and allocated for SRM-related activities is heavily concentrated in developed countries, at 95% and 83%, respectively (see Map 1). The United States and the United Kingdom dominate both rankings, while the European Union (EU), and France in particular, remain absent from the leading positions. This pattern of concentration and domination is particularly evident in the gap between developed and developing countries (see Map 2).

Second, non-state actors are particularly present among the organisations funding SRM-related activities. Although this funding comes from a variety of sources, including non-governmental and philanthropic organisations, wealthy individuals, venture capital firms and investment funds, it masks a concentration in the underlying sources of funding. Moreover, the involvement of private actors makes funding data more difficult to access, as some of them refuse to disclose this information.

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

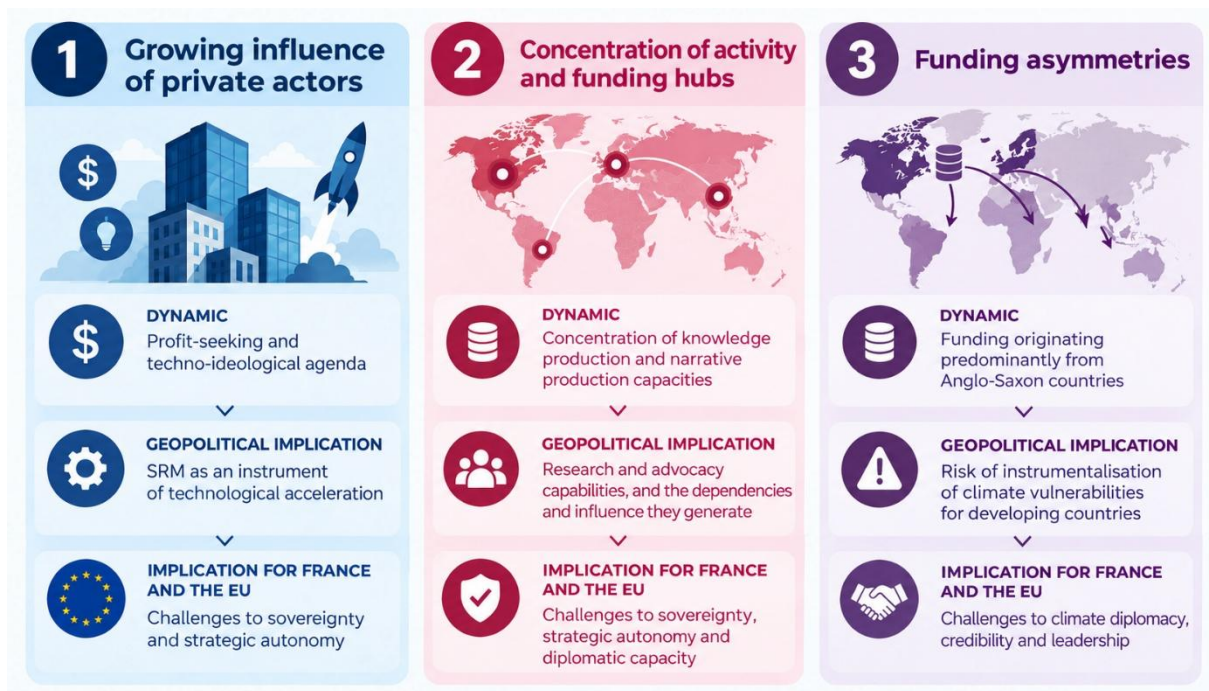
The structuring and domination dynamics described above are not merely characteristics of the SRM sector: they also have geopolitical implications. Three of these implications directly affect French and EU strategic and diplomatic interests.

First, the growing presence of private actors seeking to commercialise SRM raises significant geopolitical issues because of their ideological orientation and the narratives they promote. Mainly based in the United States, some of these actors view SRM as serving a broader civilisational project centred on technological acceleration in digital technology and artificial intelligence (AI). In this context, the development of SRM could become part of techno-industrial and ideological ecosystems from which France and the EU remain largely outside, while nevertheless being affected by their evolution. **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 also concentrates the capacity to produce knowledge and shape narratives about these emerging technologies. 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. **These knowledge and information gaps also raise questions of sovereignty also raises questions of sovereignty,** as it affects France's ability to anticipate the potential impacts of SRM on its territories and to monitor possible deployments and their effects. **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. These gaps could also weaken France and the EU's diplomatic influence by reducing their ability to put forward analyses and positions based on 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. Countries most vulnerable to climate change 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, as they risk being perceived as insufficiently engaged with the emerging challenges of climate governance.**

Figure 2: 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 is both fragmented and incomplete. No international legal framework prohibits the deployment of SRM explicitly, and no multilateral agreement is specifically devoted to its governance. **Recent initiatives to fill these governance gaps have come up against divergent approaches: a precautionary approach,** notably supported by the EU, and **a more permissive approach,** supported notably by the United States and Saudi Arabia. These divergences are part of the broader power dynamics that structure international climate negotiations. **Since 2019, there has also been growing involvement of developing countries and the scientific community in debates on SRM governance.** Finally, initiatives to regulate SRM are emerging at the national level, although driven by very different logics.

In a context marked by controversies and the failure of multilateral initiatives, numerous voluntary and informal initiatives seek to define the conditions under which SRM research may be considered as being conducted responsibly. Led by non-state actors, they pursue both normative objectives, by promoting **governance standards**, and reputational objectives, by building their legitimacy in a controversial field. As new outdoor research activities are planned, **a key challenge 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.

II. 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.

Current knowledge suggests, on the one hand, that SAI deployment at a scale sufficient to affect the functioning of the climate system 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).

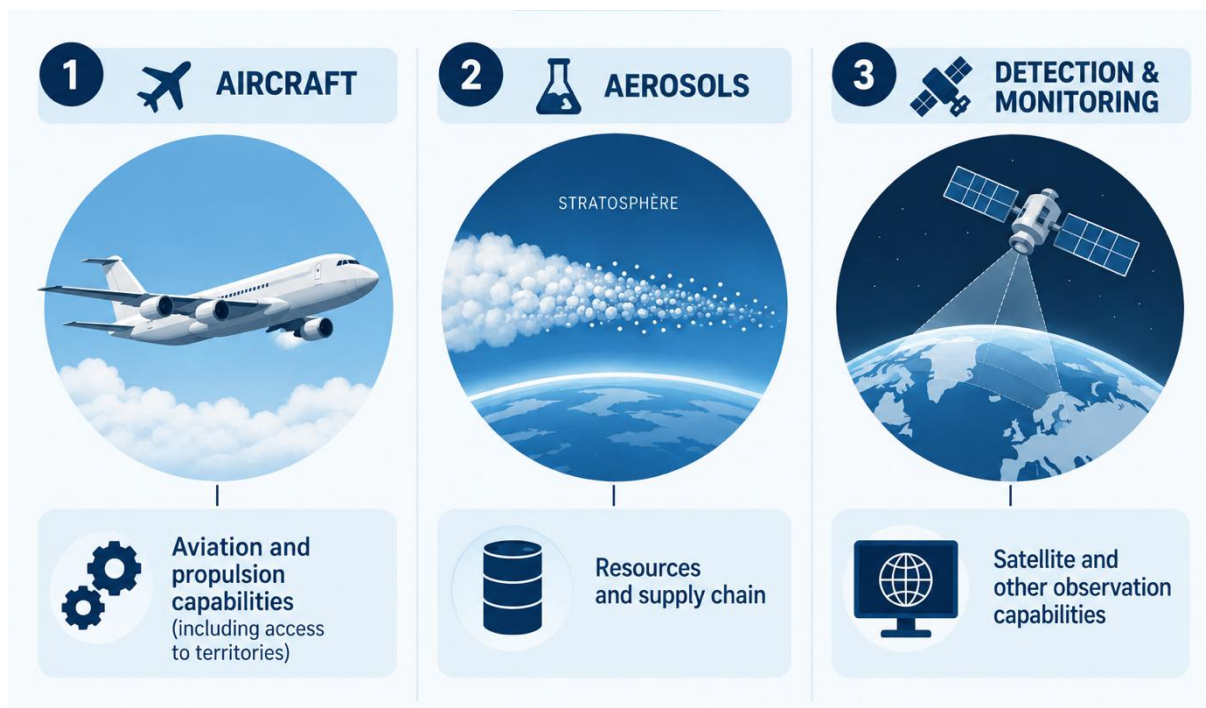
Many SAI's effects remain highly uncertain, particularly those relating to weather patterns, ecosystems, food and water systems, the ozone layer, human health, and solar energy production. One major risk is termination shock: an interruption of a significant deployment while GHG concentrations remain 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.

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 3) that are unevenly distributed among states, raising important geopolitical questions.**

Figure 3 – SAI: three capability requirements with geopolitical implications



A. The capability requirements of a technology with transboundary effects

The first capability requirement concerns the availability and suitability of aircraft, making the aeronautical and engine manufacturing industries essential to carrying out deployment activities. These activities would also depend on access to the territories and infrastructure required to launch and base aircraft, as well as on obtaining authorisation to fly through the airspace concerned

The second capability challenge 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. The use of precursors or synthetic reflective particles would raise distinct issues of resource geopolitics, relating to the control of supply chains, the associated dependencies and vulnerabilities, and their effects on markets.

The third capability requirement concerns the access to, and suitability of, systems for detecting and monitoring a possible SAI deployment. While a deployment on a scale sufficient to affect the global climate would theoretically be detectable by satellite, no country is currently able to detect an undeclared small-scale injection. Monitoring the effects of a possible deployment also presents significant capability gaps, and these capabilities are very unevenly distributed among states.

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

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. For policymakers, SAI may indeed present the attributes of a concrete, visible and politically valuable policy solution. **From this perspective, security rhetoric surrounding climate change could contribute to aligning SAI within a logic of preventive security.** This hypothesis must also be considered in light of the primacy accorded to sovereignty in security logics, which could favour non-cooperative approaches to SAI.

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. **In this context, disagreements could emerge over the objectives of deployment, which could lead to counter-geoengineering activities or diplomatic, coercive and offensive responses, including in the military domain.**

C. SAI: an object of geostrategic competition with a potential for weaponisation and instrumentalisation

SAI could be developed and used to pursue strategic and political objectives that extend well beyond the climate considerations for which this technology was initially conceived. 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).**

Figure 4 – SAI as an instrument of power



In a context of intensifying competition between states, the development of SAI tends to be part of a dynamic of competition over the mastery of a disruptive technology. From this competitive perspective, a state's interest in SAI may be driven more by **ambitions for technological superiority and the prestige associated with it** than by the technology's potential capacity to mitigate the extent of global warming.

Some of the dynamics surrounding the development and potential deployment of SAI are **conditioned by China-US rivalry**. These dynamics first speak to partisan logics but are also grounded in capability-based considerations. In this context, several scenarios can be envisaged, including a unilateral deployment led or supported by the United States or China, but also a cooperative deployment following a phase of non-coordination, or even confrontation. **These dynamics show that the technological and environmental arenas in which SAI is situated can themselves be perceived as spaces of competition.**

The threat of using or not using SAI to influence or coerce the behaviour of adversaries or partners could constitute a form of SAI weaponisation. Although this technology does not meet the objectives of spatial and temporal precision sought in military operations, it shares these characteristics with biological, chemical and nuclear weapons. **Thus, given its effects on the global climate and therefore on all territories, SAI has the potential to be used as a geopolitical lever.**

Linked to the potential for SAI weaponisation is the question of whether its development and/or potential deployment might be perceived as hostile. Such perceptions could be fuelled by the difficulty, or even impossibility, of attributing an isolated extreme weather

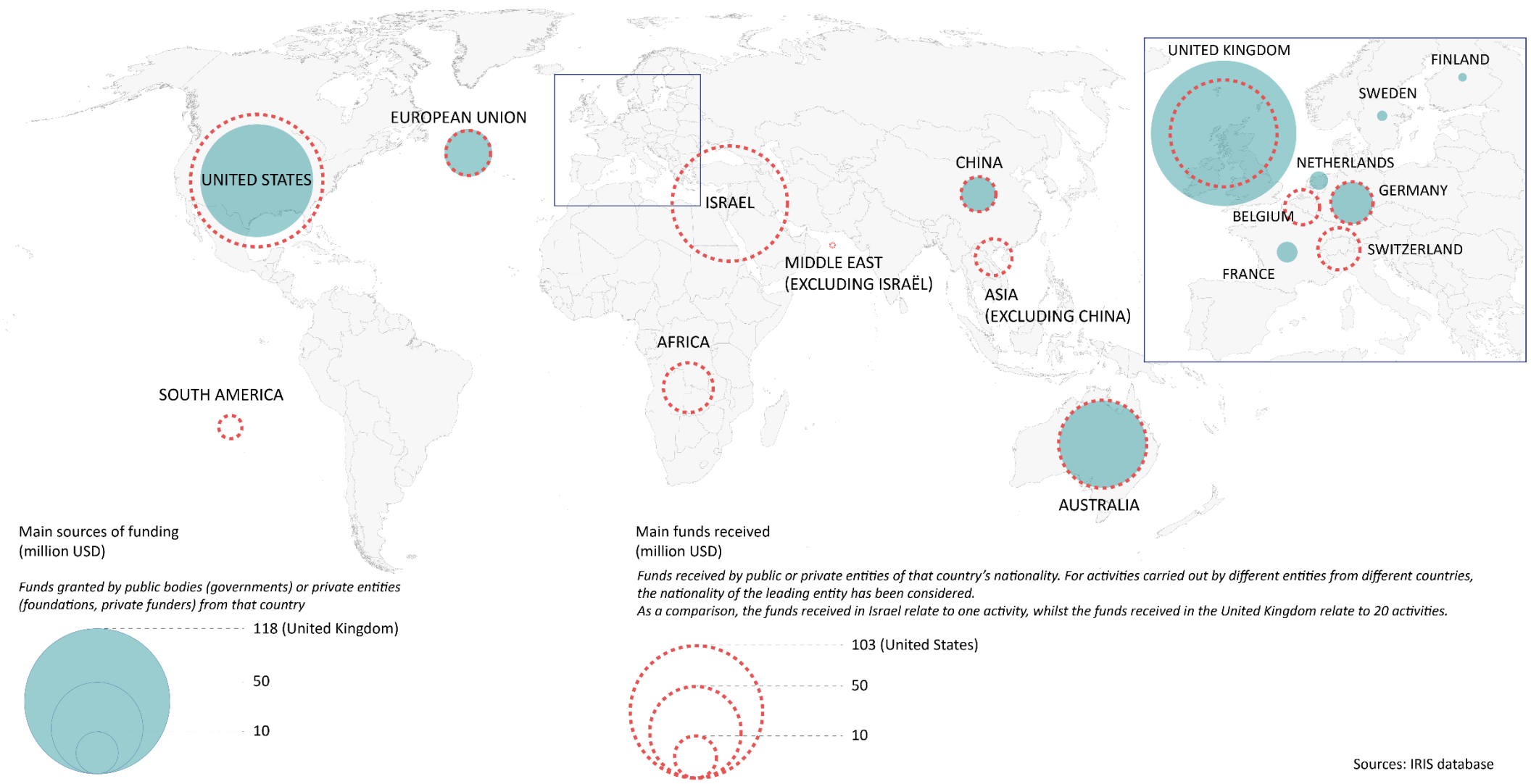
event to SAI, to ongoing climate change or to natural climate variability. **This ambiguity surrounding attribution could create favourable conditions for the instrumentalisation of SAI and its effects.** Such practices could serve various political and strategic objectives and exploit the information domain, in a context marked by the rise of cognitive warfare and the growing integration of climate change into hybrid warfare practices.

The findings of this note 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 priority, 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 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.

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

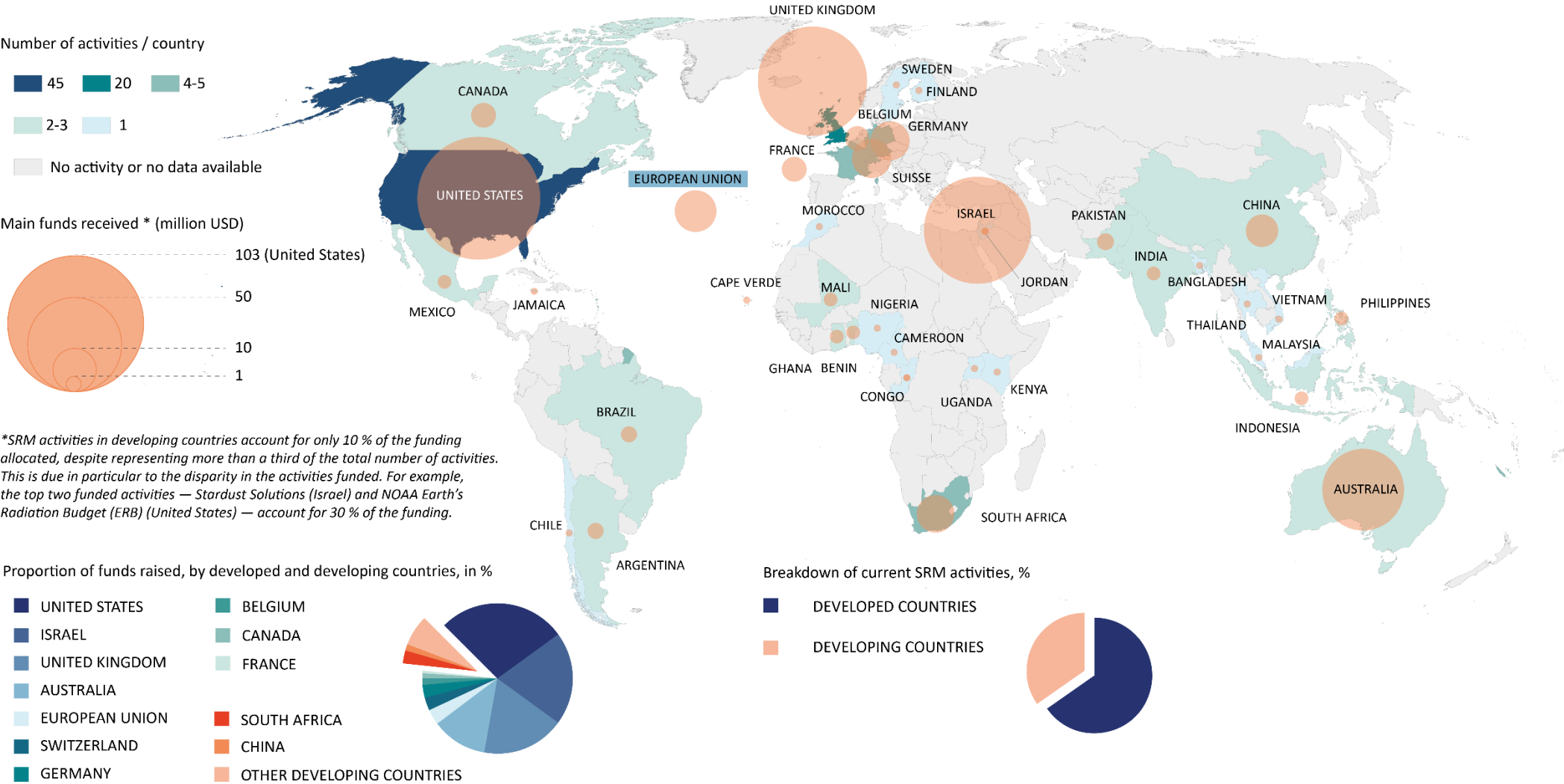
Main Regions of Donors and Recipients of Funding Relating to Ongoing Solar Radiation Modification (SRM) Activities, by Amounts Granted and Received



Sources: IRIS database

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



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