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A new paradigm from the Arctic

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A Viewpoint on the Frontiers in Science Lead Article

[Safeguarding the polar regions from dangerous geoengineering:
a critical assessment of proposed concepts and future prospects](#)

Key points

- Academics, activists, and Arctic inhabitants are deeply concerned about cryosphere systems at imminent risk of collapse, and yet decades of “consequences-based” lobbying have failed to produce sufficient political will for deep decarbonization.
- There are moral imperatives to search for tools that may help stabilize polar Earth systems and to explore knowledge co-production and co-design with Arctic peoples to ensure both local and global benefits.
- We propose a “compassionate harm reduction” paradigm, whereby climate scientists prioritize the well-being of humanity and take responsibility to thoroughly understand any potential interventions that might minimize the harm from the consequences of climate change.

A new paradigm

The prevailing “consequences-based paradigm” defines the role of climate scientists as informing the public about the negative effects of climate change, assuming this will mobilize political action to reduce emissions. Under this paradigm, research into strategies other than decarbonization is often seen as counterproductive, an argument advanced by Siegert et al. (1) in their Frontiers in Science lead article, “Safeguarding the polar regions from dangerous geoengineering.” Yet after half a century of alarm-raising, this paradigm has failed to generate the political will needed for deep decarbonization.

This article uses insights from 27 academics, activists, and Arctic inhabitants to propose an alternative: a “harm-reduction paradigm.” We maintain that climate interventions research and decarbonization are not mutually exclusive. Instead of focusing solely on the problems, climate scientists should also explore all potential solutions to reduce harm to humanity. The effectiveness and risks of interventions remain uncertain, and only further

research can address these questions; research that some, including Siegert et al. (1) seek to halt. This perspective also carries implications for governance.

Stewards of the Arctic

Unlike Antarctica, the Arctic is more accessible, making it a more likely starting point for intervention field trials. It is not a global commons, and Arctic peoples must be central to any decision-making. Preference from those in the mid-latitudes are secondary. The key question is: how should decisions be made—through evidence or guesswork? Evidence includes both traditional knowledge and the scientific method, each of which has long produced valuable insights. Whether climate interventions make sense, pose risks, or are preferable to inaction remains unknown and cannot be determined without comprehensive research across legal, scientific, and technical domains.

Pirita Näkkäläjärvä, President of the Saami Parliament in Finland, states: “It is my personal opinion that we need to keep all options open and research climate interventions because of the risk of exceeding the goal of limiting global temperature rise to 1.5 degrees and the risk of crossing multiple climate tipping points” (2). Motivated by these concerns, the University of the Arctic has set up a review process for high-latitude interventions (<https://climateinterventions.org/>), led by the Saami Council and incorporating both academic and traditional knowledge perspectives (Figure 1). Gunn-Britt Retter, Head of the Arctic and Environmental Unit of the Saami Council, explains: “The Saami Council acknowledges the need to face suggested intervention ideas and initiatives that are developed or are being developed. (...) It is our position that a rights-based perspective must be the foundation in any evaluation of intervention suggestions in relation to strengths and weaknesses and benefits and co-benefits. (...) Saami Council’s participation in this project should not be interpreted as Saami Council’s endorsement or support of the intervention suggestions assessed” (private communication). Another core group interested in the future Arctic are the youth. Anni Pokela, strategic planner with Operaatio Arktis and a Gender Studies student at Helsinki University, asks: “Are we truly ready to accept the damage, the suffering that’s unavoidable without climate intervention? Or are we going to give climate repair a chance?” (private communication).

In their lead article, Siegert et al. ask: “Why would a nation such as Greenland embrace a geoengineering solution to sea level rise?”—since sea levels around Greenland’s coasts are falling as the ice disappears. A good way to find out is to ask Greenlanders. Those of us that have done so readily identified several reasons for pursuing interventions research. For example, many Greenlanders have empathy and feel a sense of solidarity with low-income communities around the world who are already experiencing the impacts of sea level rise. Furthermore, the ice itself is a global good which, if valued appropriately (3), would be highly rewarding for Greenland. Finally, declining sea levels impact Greenlanders directly, for instance through boat collisions with unmapped islets previously submerged (4).

Challenges of decarbonization

There is near-universal agreement among scientists and policymakers that decarbonization is essential. The Earth is already at 1.5°C above pre-industrial levels, and no climate intervention can work sustainably without rapid emissions cuts. Yet, glossing over the serious challenges involved is, at best, naïve.

Siegert et al. (1) describe a scenario in which global temperature is stabilized at 0.9°C above preindustrial levels; a target long since past. While we agree that this “simple vision for Antarctica is appealing,” it is also practically impossible. Even in 2020, achieving net zero required global investments in clean-energy and carbon-removal infrastructure exceeding US\$ 4 trillion annually by 2030 (5). With President Trump now actively reversing United States commitments to renewable energy, despite the United States being the world’s largest historical emitter of greenhouse gasses, the likelihood of achieving rapid global decarbonization in time to meet climate goals is becoming increasingly remote. Meanwhile, human activities continue to drive planetary warming: the most effective large-scale geoengineering experiment to date.

Governance

Moral hazard

A widely touted argument against research into climate interventions, and used by Siegert et al. (1), is that such research may reduce the likelihood of decarbonization. This is known as the “mitigation deterrence” or “moral hazard” argument. However, evidence is mixed: public attitudes show weak and variable support for this hazard, and there is equally strong evidence of the opposite effect (6): that is, the idea of interventions can motivate people to take decarbonization more seriously. Furthermore, anticipating moral hazard may limit policymakers’ options (7). Support for intervention research is strongest among those suffering the worst climate impacts, especially in the Global South and among Indigenous peoples (8).

Motives and vested interests

Opinions on geoengineering are often influenced by who funds the research and their motives. Who gains from Arctic intervention research? The fossil fuel and mineral extraction industries have clear interests in the Arctic, which holds an estimated 25% of untapped global gas reserves, 13% of oil, and large amounts of rare earth elements, such as 40% of global palladium (9). These resources become more accessible with reduced snow and ice cover or minimal sea ice, which also facilitates safer transport. Thus, resource extraction industries are unlikely to fund efforts to preserve the Arctic cryosphere intact; unless they are cynically assuming interventions will fail. Many institutions active in Arctic research, including the University of the Arctic and the University

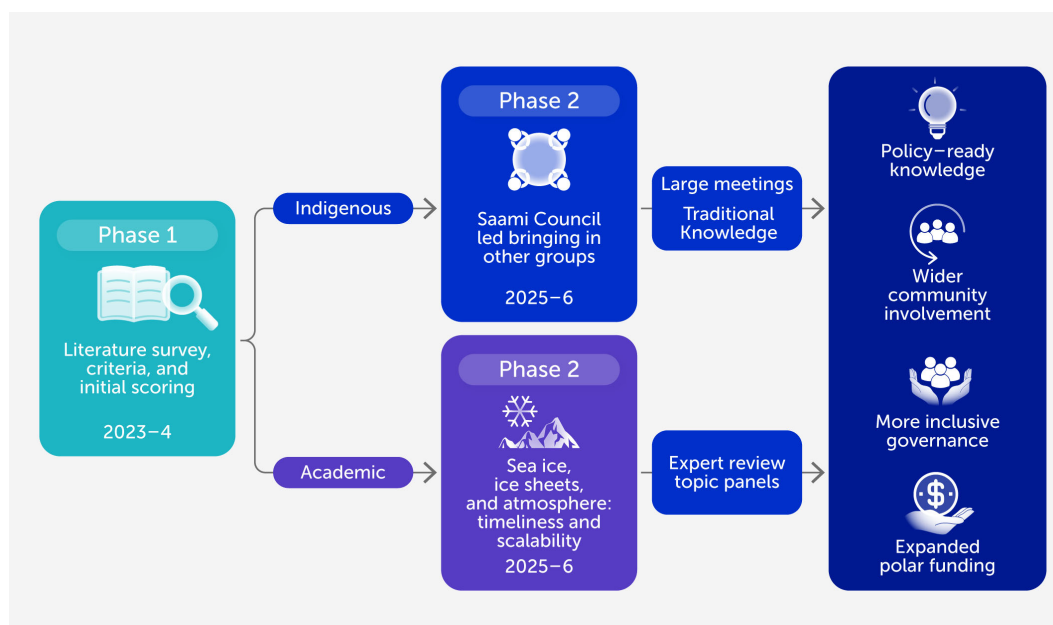


FIGURE 1

The methodology adopted by the University of the Arctic for an evaluation of intervention ideas. The Saami Council leads the indigenous knowledge stream but engages with other indigenous groups in the Arctic Council. Meetings include three distinct groups: traditional knowledge holders, indigenous politicians, and indigenous experts. The meetings take various formats, including formal workshops, town halls, and council meetings, in addition to awareness campaigns and general capacity-building activities.

of Cambridge, have published strong ethical statements rejecting support from such sources (10).

The precautionary principle

Environmental risks are often cited to oppose geoengineering research [e.g., (1)]. The precautionary approach has framed most environmental legislation over the last 30 years. Davis and Vinders (11) examine how it might apply to geoengineering. In the case of intervention field trials, environmental risks are generally very small. However, perceived risk often includes concern over a “slippery slope” toward broader deployment. Davis and Vinders (11) argue that political risk should be included when evaluating harms, but this assessment must consider both the risk of using an intervention and the risk of not using one; the “moral hazard of non-research”. This latter risk is missing in Siegert et al.’s lead article, and more broadly, for example in the European Union advisory report (12). Risks of inaction include the socio-economic damages from crossing climate tipping points, which are concentrated in the polar regions (13).

Sticky slopes, not slippery ones

Does research inevitably lead to deployment—the so-called slippery slope? Not if research is ethically guided [e.g., (14)]. There is a duty to report all findings, positive and negative, often required by funders. A roadmap to potential deployment involves

many checkpoints along the way [e.g., (15)]. So far, the slope has proven “sticky,” not slippery. For example, the Arctic Ice Project ceased sea ice albedo modification research due to toxicity concerns about hollow glass microspheres that they proposed for use (<https://srm360.org/news-reaction/arctic-ice-project-shuts-down/>). Similarly, simulations suggest that the retreat of the Sermeq Kujalleq (Jakobshavn Isbræ) glacier is unstoppable (16).

The induction fallacy

Both decarbonization and climate interventions are extraordinarily challenging. Many intervention proposals will prove unworkable due to feasibility, cost, timing, or risk. Whether this has already been demonstrated, as Siegert et al. claim, is debatable given how little research exists on most options (Figure 1). Dismissing all climate interventions because some face serious challenges is a logical error, known as the induction fallacy. Siegert et al. examine only 5 of the 61 intervention ideas identified so far for the Arctic (<https://climateinterventions.org>), with more likely to emerge in the future. Conversely, advocating a sole focus on carbon emissions reduction risks falling into “single action bias”—the tendency to favor one familiar solution while neglecting others that may also be necessary.

Risk-risk assessment

Any analysis of climate interventions must be framed as a risk-risk assessment; that is, comparing the risks and benefits of

doing something versus doing nothing. Neither the present nor a past climate state can serve as a viable baseline. We must compare against plausible future scenarios. While research is still at an early stage for many intervention ideas, the literature on stratospheric aerosol injection (SAI) is relatively mature. It generally finds that projected impacts under SAI are less severe, and crucially more equitable, than those under future greenhouse gas climate scenarios. Supporting references (see the [Supplementary Material](#)) point to economic benefits, an overwhelmingly positive cryospheric response, and net human health gains from reduced temperatures that outweigh risks from air pollution and from ozone depletion by a factor of 13 (17).

Conclusions

While scientific and public support for climate action is strong (18), the political will for large-scale emissions reductions remains insufficient. Siegert et al. frequently cite fossil fuel-funded opposition as a key barrier. While such interests have obstructed other major societal and economic changes in the past (e.g., workers' rights, environmental regulations), those changes still occurred. Hence, lack of climate action is likely not solely due to fossil fuel-funded opposition but to fossil fuels being integral to modern lifestyles [e.g., (19)].

We argue that the “consequences-based paradigm,” the belief that warning the public will generate political action, has failed. After decades of warnings, emissions remain high. Worse, fear-based messaging may even boost support for right-wing parties [e.g., (20)], which typically oppose climate action. By contrast, research into climate interventions could offer much-needed optimism and agency. Our “harm-reduction paradigm” suggests that such research may strengthen public confidence in our ability to meet climate challenges, thereby fostering solidarity, expanding empathy, and ultimately increasing political support for decarbonization.

Of course, we could be wrong, and even if we are right that climate interventions research boosts support for decarbonization, that does not necessarily mean interventions themselves are good ideas. Only more research can answer that. Yet, Siegert et al. claim that “further research into these techniques would not be an effective use of limited time and resources” (1). Arguing to shut down an entire field of scientific research is an extraordinary claim and requires extraordinary proof. Pointing to specific problems in individual techniques, as the authors do, is not sufficient. Further research may resolve those problems. The only potentially valid argument against all interventions research is political: that it might reduce motivation to decarbonize. But even setting aside the ethical concern of suppressing science for political reasons, this argument is unproven. It rests entirely on the same “consequences-based paradigm” of climate outreach. It is fair to say that the “consequences-based paradigm” has, after half a century, failed to deliver. Perhaps, it is time that we try compassionate harm reduction instead.

Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsci.2025.1657323/full#supplementary-material>

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Author contributions

JCM: Investigation, Methodology, Conceptualization, Visualization, Project administration, Writing – original draft, Writing – review & editing, Formal Analysis.

MM-F: Formal Analysis, Writing – review & editing, Conceptualization, Investigation, Methodology.

MW: Writing – review & editing, Formal Analysis, Methodology, Conceptualization, Investigation.

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