Overview

Description of approach

A brief description of the proposed approach to slow the loss of Arctic sea ice and relevant background information.

Description of what it does mechanistically

A brief description of the physical process of the approach and its intended impact(s).

Spatial extent (size)

The spatial size proposed for application of the approach. When possible, this is provided in terms of area (km^2).

Where applied – vertically

A description of where the approach would be applied in terms of the vertical dimension (e.g., stratosphere, troposphere, sea surface, etc.). For atmospheric approaches, the altitude of application is provided in km.

Where applied – geographically (local vs regional vs global application, is it targeting the Arctic?)

A description of where the approach would be applied spatially, indicating if application would be global or would be applied in a specific region or location, and if the approach would be applied within the Arctic region.

When effective? (summer, winter, all year)

A description of when in time the approach would produce its desired result.

Potential

Impact on:

Albedo

A description of the approach's potential impact on albedo - the fraction of light reflected by a surface. Albedo ranges from 0 (no reflectance) to 1 (total reflectance). The impact on albedo will refer to that of sea ice, ocean, land surfaces or for clouds in the atmosphere depending on the approach.

Temperature

Global

A description of the approach's potential impact on global mean surface temperature (°C).

Arctic Region

A description of the approach's potential impact on temperature within the Arctic region (°C).

Radiation budget

Global

A description of the approach's potential impact on global radiative forcing (Wm^{-2}). For some approaches, this will be in regard to the surface radiative forcing. For atmospheric approaches, this will be in regard to the top of atmosphere (TOA) radiative forcing. For context, the global energy imbalance from human activities at the top of the atmosphere is 0.90 ±0.15 Wm^{-2} (Trenberth and Cheng 2022).

Arctic Region

A description of the approach's potential impact on radiative forcing in the Arctic (Wm^{-2}). For some approaches, this will be in regard to the surface radiative forcing. For atmospheric approaches, this will be in regard to the top of atmosphere radiative forcing. For context, the global energy imbalance from human activities at the top of the atmosphere is 0.90 ±0.15 Wm^{-2} (Trenberth and Cheng 2022).

Sea ice

Direct or indirect impact on sea ice?

This describes if the approach has a direct effect on sea ice or if the approach impacts sea ice indirectly through an impact on another aspect of the climate system, such as temperature.

New or old ice?

Approaches may impact sea ice via the formation of new ice, the reinforcement of older existing ice, or both.

Impact on sea ice

A description of the approach's potential impact on sea ice in terms of sea ice extent (m^2 or km^2), area (m^2 or km^2), thickness, or volume (m^3), dependent on what is reported in the scientific literature.

Scalability

Spatial scalability

Ability to replicate and expand the approach to the appropriate spatial scale to have an impact.

Efficiency

Here we define efficiency as the ratio of impact on radiative forcing to the amount of energy required for the approach ($(Wm^{-2})J^{-1}$).

Timeline to scalability

The estimated time until this approach could be scalable for deployment.

Timeline to local impact (must be within 20 yrs)

The estimated time until this approach could have an impact on sea ice in the Arctic. Consistently ice-free conditions in September are expected by mid-century, with daily ice-free conditions expected ~4 years earlier (Jahn et al. 2024). Therefore, having a timeline to impact within 20 years might prevent ice-free conditions.

Timeline to global impact (must be within 20 yrs)

The estimated time until this approach could have a global impact on climate change in terms of temperature or radiative forcing. Consistently ice-free conditions in September are expected by mid-century, with daily ice-free conditions expected ~4 years earlier (Jahn et al. 2024). Therefore, having a timeline to impact within 20 years might prevent ice-free conditions.

Cost

Economic cost

The estimated cost of applying this approach ($USD) per relevant metric for the approach when available (e.g., $USD per 1°C temperature decrease).

CO_2 footprint

The estimated energy required to apply this approach (CO_2(t)) per relevant metric for the approach when available (e.g., CO_2(t) per 1°C temperature decrease).

Technology Readiness

TRL

Technology readiness level as defined by the National Oceanic and Atmospheric Administration (https://orta.research.noaa.gov/support/readiness-levels/).

Technical feasibility within 10 yrs

Estimation of whether this approach could be technically feasible (i.e., a demonstration project would be possible) within 10 years based on best available knowledge. Technical feasibility does not imply scalability.

Socio-ecological co-benefits and risks

Physical and chemical changes

Co-benefits

Potential beneficial impacts to the physical or chemical domain due to application of the approach.

Risks

Potential negative impacts to the physical or chemical domain due to application of the approach.

Impacts on species

Co-benefits

Potential beneficial impacts to species due to application of the approach.

Risks

Potential negative impacts to species due to application of the approach.

Impacts on ecosystems

Co-benefits

Potential beneficial impacts to ecosystems due to application of the approach.

Risks

Potential negative impacts to ecosystems due to application of the approach.

Impacts on society

Co-benefits

Potential beneficial impacts to society (human communities) due to application of the approach.

Risks

Potential negative impacts to society (human communities) due to application of the approach.

Ease of reversibility

The ability of the environment and/or climate to revert to a state without application of the approach once an approach is stopped. While this section focuses on reversibility of the environment and/or climate impact, there is also mention of constraints on reversibility due to infrastructure related to the approach.

Risk of termination shock

An estimate of the outcome(s) for the environment and/or climate if an approach were to be abruptly stopped.

Governance considerations

Here we define governance as the actions that steer or influence how decisions about approaches to slow the loss of Arctic sea ice are made, based on the definition by The Alliance for Just Deliberation on Solar Geoengineering (DSG).

International vs national jurisdiction

A description of whether the approach would be subject to international or national jurisdiction for decisions or regulations related to research activities.

Existing governance

A description of existing treaties, laws, and regulations as well as codes of conduct and recommendations that might guide research into the approach. When available, descriptions will delineate existing governance for research versus deployment.

Justice

Here we define justice related to approaches to slow the loss of Arctic ice through distributive justice, procedural justice, and restorative justice. Following COMEST 2023, we consider questions of ethics through a justice lens.

Distributive justice

Distributive justice is the protection of basic rights and the fair distribution of benefits and burdens across a society. This section answers the question, "are the benefits and costs of research or potential deployment of the approach distributed fairly while protecting the basic rights of the most vulnerable?" (DSG)

Procedural justice

Procedural justice is the equal opportunity to influence the deliberations of governance structures to whom one is subject. It is also genuine accountability for those who exercise power in order to prevent domination or exploitation. This section answers the question, "Do all those affected have an opportunity to participate and have a say in how the approach will be researched, deployed, and governed?" (DSG)

Restorative justice

Restorative justice is atonement for contemporary wrongdoing and reparations for historical injustice. This section answers the question, "Are there plans for those who could be harmed by the approach to be compensated, rehabilitated, or restored?" (DSG)

Public engagement and perception

Public engagement describes ways in which "researchers, funding institutions, and decision-making bodies aim to inform, understand, draw input from, and empower publics and stakeholders" (definition from DSG). This section describes how people have been engaged in research for a given approach, as well as capacity building efforts to build knowledge around science and governance. This section also provides information on public perception when available.

Engagement with Indigenous communities

This section describes how Indigenous peoples and communities have been engaged in research for a given approach, as well as capacity building efforts to build knowledge around science and governance.

Knowledge gaps

Information about the approach that is unknown that would advance understanding about the approach so that society could make an informed decision about whether or not to pursue the approach.

First-order Priorities

The most important ambitious yet tractable actions or research needs based on the knowledge gaps.

References for glossary (appear as hyperlinks)

COMEST. 2023. Report of the World Commission on the Ethics of Scientific Knowledge and Technology (COMEST) on the ethics of climate engineering. https://unesdoc.unesco.org/ark:/48223/pf0000386677

DSG. 2024. https://sgdeliberation.org/resources/definitions/#justice

Jahn et al. 2024. Projections of an ice-free Arctic Ocean. Nature Reviews Earth and Environment https://doi.org/10.1038/s43017-023-00515-9

Trenberth and Cheng. 2022. A perspective on climate change from Earth's energy imbalance. Environmental Research Climate https://iopscience.iop.org/article/10.1088/2752-5295/ac6f74