Zygon®: Journal of RELIGION & SCIENCE

Williams, Billy M., Mark Shimamoto, and Lisa J. Graumlich. 2024. "An Ethical Framework for Climate Intervention Research: What It Is and Why You Should Care." *Zygon: Journal of Religion and Science* 59 (1): 82–96. DOI: https://doi.org/10.16995/zygon.15389

Open Library of Humanities

An Ethical Framework for Climate Intervention Research: What It Is and Why You Should Care

Billy M. Williams, American Geophysical Union, Washington, DC, USA, bwilliams@agu.org

Mark Shimamoto, American Geophysical Union, Washington, DC, USA, mshimamoto@agu.org

Lisa J. Graumlich, American Geophysical Union, Washington, DC, USA, graumlic@uw.edu

Climate change poses significant threats to ecosystems, human health, and global stability. Despite international efforts to reduce greenhouse gas emissions, the Earth's climate continues to warm, leading to extreme weather events, rising sea levels, and other detrimental impacts. In response to this crisis, scientists have begun exploring various strategies to mitigate climate change through geoengineering, which involves deliberate interventions in the Earth's climate system. This article provides an overview of climate geoengineering research, focusing on key techniques, challenges, and ethical considerations, including actions being taken by the American Geophysical Union (AGU), a nonprofit professional scientific society, to develop an ethical framework to help guide research in this important area. AGU also is driving global engagement on this topic, including with leaders and members of faith communities.

The Case for Change

Our planet is at risk. The urgency and impact of global warming is bad and is getting worse. Increasingly severe harmful impacts in many forms can be seen across the globe, including human suffering, societal disruption, and reduced ecological health. Impacts such as record-high global temperatures, more severe storms, increased drought, a warming and rising ocean, more health risks, increased poverty, and displacement are all reported in authoritative reports by global climate scientists (United Nations, n.d.-a).

One hope for reversing this trend was the 2016 Paris Agreement, a legally binding international treaty on climate change. It was adopted by 196 parties (independent countries) at the Twenty-First Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in Paris, France, in December 2015 and entered into force in November 2016.

The overarching goal of the Paris Agreement was to "hold the increase in the global average temperature to well below 2°C above pre-industrial levels" and pursue efforts "to limit the temperature increase to 1.5°C above pre-industrial levels" (United Nations, n.d.-b.). However, in recent years, world leaders have stressed the need to limit global warming to 1.5°C by the end of this century. This is because the United Nation's Intergovernmental Panel on Climate Change indicates that crossing the 1.5°C threshold risks unleashing far more severe climate change impacts, including more frequent and severe droughts, heatwaves, and rainfall. To limit global warming to 1.5°C, greenhouse gas emissions must peak before 2025 at the latest, decline 43 percent by 2030, and target reaching net-zero emissions by 2050. The agreement also called for each country to establish and report goals for reducing its annual greenhouse gas emissions (United Nations, n.d.-a).

The climate action urgency is this: emission-reduction goals are not being met; in fact, global greenhouse gas emissions are actually increasing! There is now general scientific agreement that dramatic reductions in global CO_2 emissions combined with the active removal of CO_2 from the atmosphere may be needed (IPCC 2023). This consensus has resulted in an expansion of climate intervention research. The likelihood that global average temperatures will overshoot the targets agreed to by the world's nations (1.5–2.0 degrees Celsius) has led the Intergovernmental Panel on Climate Change to consider climate intervention as a potential pathway to reduce, remove, or offset some of the effects of climate change, with risks and trade-offs that need to be better understood. In some cases, limited outdoor testing is already underway and growing—attracting much attention—but in many cases without ethical guidelines (National Academies of Sciences, Engineering, and Medicine 2021).

What Is Climate Intervention and Why the Concern?

Climate intervention and climate geoengineering are used interchangeably in this article. Climate geoengineering refers to large-scale schemes for intervention in

the Earth's oceans, soils, and atmosphere with the aim of reducing the effects of climate change, usually temporarily (Grantham Research Institute 2018). While some argue that climate intervention should be a last resort, others argue that Earth is rapidly approaching a climate emergency, requiring the consideration of all options (Robock 2020). The *Sixth Assessment Report* of the Intergovernmental Panel on Climate Change stated that the risk of reaching climate tipping points becomes high by around 2°C above preindustrial temperatures and very high between 2.5°C to 4°C (IPCC 2023).

The two primary techniques of climate intervention being researched are solar radiation modification (SRM) and carbon dioxide removal. SRM aims to reduce the amount of sunlight reaching the Earth's surface, thereby counteracting global warming. One proposed method involves injecting aerosols into the stratosphere to reflect sunlight back into space, mimicking the cooling effect of volcanic eruptions. Research suggests that SRM could effectively lower global temperatures and offset some of the effects of greenhouse gas emissions.

> Solar radiation modification (SRM) is a deliberate and large-scale intervention in the Earth's climatic system, with the aim of reducing global warming. It attempts to offset the effects of greenhouse gases by causing the Earth to absorb less solar radiation. The idea that the climate could be artificially cooled emerged in the 1960s at the same time as the potential risks of climate change were first being taken seriously. SRM is an umbrella term for proposed technologies that would reflect more sunlight back into space, or allow more infrared radiation to escape into space, thereby creating a net cooling effect on the earth's climate. SRM technology options include stratospheric aerosol interventions (SAI — the most studied option), marine cloud brightening (MCB), ground-based albedo modifications (GBAM), ocean albedo change (OAC) and cirrus cloud thinning (CCT). Modeling studies have shown SRM could potentially offset some climate change risks, including the increase in frequency and intensity of extremes of temperature and precipitation. However, it could also introduce a range of new risks related to the change of global weather pattern. (European Commission 2023)

Carbon dioxide removal techniques seek to remove CO_2 from the atmosphere and store it in various reservoirs, such as oceans, forests, or geological formations. Examples of carbon dioxide removal methods include afforestation/reforestation, ocean fertilization, direct air capture, enhanced weathering, and direct ocean capture, among others. These potentially could be deployed at a range of scales and currently vary widely in their scientific and market readiness.

While these approaches hold promise for reducing atmospheric CO_2 concentrations, they present technical, economic, and environmental challenges (Kulkarni 2022).

While carbon dioxide removal research and testing are more advanced than for SRM, many other climate geoengineering techniques remain largely theoretical or untested at scale. Implementing large-scale interventions could have unforeseen consequences and unintended side effects on ecosystems and weather patterns. Additionally, the long-term effectiveness of these strategies is uncertain, as they may only provide temporary relief from climate change. More research is needed.

The governance of climate geoengineering also poses significant challenges due to its global scale and potential geopolitical implications. The lack of international agreements and regulations governing geoengineering research and deployment raises concerns about accountability, equity, and unintended consequences. Balancing the need for innovation with ethical considerations remains a critical issue in the field of climate geoengineering.

Proponents of geoengineering state that:

> [t]he primary challenges of geoengineering are conducting field experiments to accurately assess potential consequences and developing international agreements to safely deploy and monitor geoengineering technologies. If geoengineering were adopted, a combination of techniques would be used depending on cost, regional conditions, and the climate's response. Different methods may have local or global effects, so regulatory policies need to be agreed upon by the international community. Therefore, many scientists have called for the creation of regulatory agencies to advise the United Nations and lay out plans for how geoengineering methods should be prioritized. Geoengineering could help us reverse climate change in a more controlled manner, buying us time to make our society more sustainable. (Kulkarni 2022)

The Role of a Professional Society: American Geophysical Union Action

In 2022, the American Geophysical Union (AGU)[1] board of directors authorized an ethical framework initiative to advance research progress on these climate intervention-related topics. The context for AGU action to help address the growing climate crisis is summarized in below passage from a 2022 AGU white paper titled "AGU Climate Intervention Engagement: Leading the Development of an Ethical Framework." The white paper defines the needs and outline plans for AGU (2022) actions:

> Current technologies for active removal of carbon dioxide and other greenhouse gases from the atmosphere are not nearly at the scale needed to reach net zero emissions. Significant questions, both practical and ethical, remain as to the long-term storage of removed CO_2. As a result, other potential climate intervention technologies to mitigate warming are being researched and discussed in both

> the public and private sectors, including a variety of approaches known as "geoengineering." These methods (including SRM and Other Climate Altering Technologies) are largely untested and pose significant risks if implemented at scale. They should not move forward for deployment without an international ethical governance structure to allow globally acceptable risk-controlled testing.

An AGU (2023a) position statement on climate geoengineering states:

> Given the likelihood that the world will overshoot global average temperature targets, Climate Intervention (CI) measures such as carbon dioxide removal and solar radiation management may be part of a comprehensive risk-management strategy. CI measures cannot substitute for deep cuts in emissions or adaptation. That said, research aimed at understanding the benefits and impacts of CI measures is necessary and must consider global transparency, ethical, and inclusion practices and be subject to robust governance and oversight structures. CI research must be part of a broader climate solutions package that, given the urgency of addressing climate change, should be funded at a level matching the enormous scale of the space programs of an earlier era.

The governance of climate intervention is not straightforward. Many scientific reports call for dramatic intervention to avoid catastrophic climate tipping points, and research and small-scale tests are already in progress. However, the unintended consequences (or what engineers call 'revenge effects') of large-scale climate intervention are not fully understood. There is evidence that some large-scale climate interventions may have significant negative local and regional consequences. For instance, modeling studies of solar radiation modification suggest such an approach could alter the South Asian monsoon season and reduce precipitation in India—affecting food security for more than a billion people (Bala and Gupta 2019). As a result, some have called for a total ban on such research and approaches (Solar Geoengineering Non-Use Agreement 2022).

Ethical and Social Implications

Climate geoengineering raises complex ethical dilemmas regarding responsibility, justice, and intergenerational equity. Critics argue that deploying geoengineering technologies could undermine efforts to reduce greenhouse gas emissions and promote sustainable development. Furthermore, geoengineering interventions may disproportionately impact vulnerable communities and exacerbate existing social inequalities.

The challenges around the potential to engage in climate engineering are multifaceted and often controversial, inviting a need for broad conversations and deeper understanding. Many of the questions are ethical and do not have

quick or easy answers. For example, more than 1,500 people signed a 2022 international petition calling for a halt to climate geoengineering research (Solar Geoengineering Non-Use Agreement 2022). Similarly, in 2023, more than 100 scientists signed an open letter supporting the need for climate intervention research (An Open Letter Regarding Research on Reflecting Sunlight to Reduce the Risks of Climate Change 2023).

In this context, AGU has proposed that climate engineering research, policy, governance, and potential scaling discussions should first require directly addressing the ethical issues and ethical dilemmas involved. AGU proposed the development and use of broadly held ethical principles to help navigate this territory based on definitions of ethical issues and ethical dilemmas (AGU 2023b):

- "Ethical issues" are the difficult social questions that involve some level of controversy over the right thing to do. Environmental protection is an example of a commonly discussed ethical issue, because there can be trade-offs between environmental, societal, and economic risk factors.
- "Ethical dilemmas" are situations in which it is difficult for an individual to make decisions either because the right course of action is unclear or because it carries some potential negative consequences for the person or people involved.

AGU leadership's views are that professional societies are critical for establishing ethical standards on important geoethics issues. AGU recognizes that while professional societies do not have the same enforcement strength as nation states, the larger professional societies with global membership have the potential to offer consistent ethical standards across national borders.

Following its white paper, AGU has proposed a set of preliminary Ethical Framework Principles for climate intervention research, experimentation, and outdoor scaling. These principles are the result of extensive, diverse insights collected through workshops, summits, surveys, and outreach discussions with participants around the world, including in regions most affected by the consequences of climate change.

American Geophysical Union Internal Process for Developing Climate Intervention Research Principles

To directly address the ethical issues and ethical dilemmas around climate intervention research and potential scaling, in 2022 the AGU undertook an initiative to facilitate voluntary ethical principles towards advancing needed discussion and governance policy. AGU does not advocate for climate intervention; however, it believes that the urgent priority of a healthy climate requires enhanced climate intervention research and community engagement, and that ethical guidance is needed. Internally, AGU adopted the following engagement principles to guide this work (AGU 2022):

We are committed to:

- ensuring that research about climate intervention strategies is done in ways that are inclusive, representative, and just;
- ensuring that research about climate intervention strategies is done in ways that do not make deployment inevitable;
- ensuring that research about climate intervention strategies does not undermined efforts to reduce carbon emissions; and
- assuring public participation and consultation in the development of ethical framework decision-making mechanisms and processes.

In their white paper, AGU details why it was positioned to lead efforts to develop an ethical framework:

- AGU science and scientists represent a deep resource of knowledge necessary for proper climate intervention assessments.
- For more than 100 years, AGU has been a trusted and respected voice in science policy, scientific ethics and scientific publications. AGU also has unique global scientific convening expertise that can be used to forge partnerships and calls to action to proactively address and coordinate scientific attention and ethical climate actions.
- The AGU Strategic Plan makes an imperative call for AGU to (1) catalyze discovery and solutions to scientific challenges, (2) promote and exemplify an inclusive scientific culture, and (3) partner broadly with other organizations and sectors to address scientific and societal challenges. One of the most pressing science-related societal challenges needing action is global climate change.
- Building on existing programs, AGU is uniquely positioned to lead in bringing inclusive scientific outreach to local communities globally and to assure attraction and development of early-career and next-generation scientists in this space to proactively address the climate change crisis around the world in both policy and ethical practice strategies over the next 30 years.
- Because of the urgency of this growing crisis, bold and sustained action by AGU to help lead and address research about climate intervention strategies and implementation is both an ethical and moral organizational obligation.
- AGU has used its convening power to assemble a global advisory body of more than 40 ethicists, scientists, policy makers and other experts to help guide this work. (AGU 2022)

Further, AGU's engagement principles were developed with the understanding that climate intervention research, if tested at large scale, could have impact not only within national jurisdictions (land and territorial seas) but also outside national jurisdictions (the atmosphere, space, the high seas, Antarctica).

Balancing Caution with Urgency: Integrating Climate Justice Issues

Based on the urgency of rapidly increasing negative impacts of climate change, AGU leadership invested the direct resources and organizational expertise necessary to partner and co-lead with other organizations and governing bodies to support the voluntary ethical principles and adopt an associated governance framework to help guide climate intervention research. Importantly, the 2023 Intergovernmental Panel on Climate Change synthesis report states that approximately 3.3 billion to 3.6 billion people—almost half of the world's total population—are among the most vulnerable to the negative impacts of global climate change, with people in the developing world hit hardest (IPCC 2023). Also, between 2010 and 2020, human mortality from floods, droughts, and storms was fifteen times higher in highly vulnerable regions compared to regions with very low vulnerability (IPCC 2023). Thus, there is a need to balance caution with urgency and proactively address issues around climate justice. AGU has declared that an ethical governance framework for climate intervention research and potential scaling "must proactively address the following issues":

- distributive justice (who benefits and who is harmed)
- procedural justice (who decides/how will geoengineering decisions be made)
- local right of refusal versus global impact of refusal
- capacity to conduct research not being equitably distributed
- measurements and reporting:
  - land use and ocean issues.
  - slippery slope and moral hazard hypotheses (and how to evaluate those hypotheses) (Tang 2023)
  - levels or maturity matrix for various phases of research and field experiments or deployment. (AGU 2022)

AGU is acting to assure that its proposed ethical framework principles proactively address climate justice as a priority (AGU 2023b).

Climate Intervention Attitudes Survey

AGU also sponsored a survey of attitudes on geoengineering. In closely interrelated work, Professor Joel Cutcher-Gershenfeld[2] of Brandeis University reports that:

> [a] survey of 156 experienced geoscientists and a series of five expert-invited workshops provide in initial look at this complex landscape. While some respondents say we should just focus on reducing carbon emissions, 95% of geoscientists surveyed see ethical standards as important for geoengineering

> research. There is near universal (97%) agreement on ethical standards for large-scale "outdoor" research and very high agreement (85%) for small-scale studies. Just 63% say ethical standards are important for lab and simulation studies, raising the challenge of connecting "upstream" lab/simulation research with "downstream" small- and large-scale research. Over 90% of geoscientists responding support voluntary compliance and monitoring, but over 80% say it will be hard to do. Ensuring shared governance of ethical standards, principles and guidelines for climate intervention research and deployment—across nations, public organizations, and the private sector—is seen as important by 92% of respondents, but is seen as hard to do by 88%. Additionally, 91% see it as important that ethical standards apply equally to commercial enterprises. 80% of respondents call for the approach to ethical standards to be inclusive and 86% call for special attention to vulnerable populations. Early career geoscientists and geoscientists from the Global South have stronger views on most issues, pointing to the importance of lifting up their voices. These data provide a window into the complex landscape that must be navigated to advance ethical standards for geoengineering. (Joel Cutcher-Gershenfeld, pers. comm.; manuscript in progress)

Building on Prior Work: Five Ethical Framework Principles for Guiding Climate Intervention Research

In developing the proposed ethical principles framework, AGU looked to other voluntary and compulsory national and international governance structures that have been developed over the past two decades to address new and emerging technologies that present huge potential human, global health, or environmental risk. Four recent examples are (1) human cloning, (2) the development of genetically modified crops, (3) the advancement and application of nanotechnology, and (4) the emergence of CRISPR gene-altering technology.[3]

Building on previous geoengineering ethical principles such as the Oxford Principles (Oxford Geoengineering Programme 2009), the Asilomar Principles (Asilomar Scientific Organizing Committee 2010), and the 2019 Tollgate Principles (Gardiner and Fragnière 2018), AGU has now published draft proposed ethical principles for guiding climate intervention research (AGU 2023b).

These five principles have been developed through an ongoing outreach process designed to invite broader views beyond those scientists and engineering organizations directly involved in the research. For this work, AGU has sponsored workshops, summits, surveys, open comment periods, and other mechanisms to helps assure greater representation is considered by researchers and those sponsoring field experiments towards climate interventions technologies. The

proposed ethical principles for climate intervention research, experimentation, and potential scaling are now more fully developed, with extensive detail around each (AGU 2023b):

1. **Societal interest/public participation**: Ensuring open and transparent communication with the public and the creation of engagement guidelines for feedback.
    - The public should be provided with timely information about climate intervention research, especially outdoor experiments, and communities in the vicinity of any planned outdoor experiments should be given notice in advance, with the opportunity to comment.
    - Care should be taken to identify and invite public comment from regions where the experiments are being conducted, as well as those who may be impacted.
    - Project plans for climate intervention experiments should include plans for post project monitoring (publicly communicated), including monitoring for potential adverse impacts.
    - Any planned outdoor experiments should exhibit due diligence to prevent and mitigate potential environmental harm.
    - Engagement with vulnerable and marginalized populations should be based on norms and procedures co-developed with the involved communities.
2. **Environmental justice:** Discourse with the relevant, diverse, indigenous communities impacted by climate change and to be impacted by climate interventions with particular consideration of their equity and inclusion in the process as a whole.
    - Concepts and values advancing environmental justice are determined through discourse with relevant, diverse communities.
    - The ways in which environmental justice are to be realized are designed with explicit attention to historical injustices.
    - Consideration of transparency, inclusion, fairness, equity or social issues within or beyond direct impacts of climate intervention experiments should be addressed in advance with relevant impacted communities.
    - Project sponsors should understand, anticipate and be prepared to address five forms of environment justice:
        - Distributive justice
        - Intergenerational justice
        - Procedural justice
        - Corrective justice
        - Ecological justice

3. **Data principles/transparency:** Ensuring climate intervention research creates data in compliance with FAIR (**F**indable, **A**ccessible, **I**nteroperable and **R**eusable) principles (FAIR Principles n.d.).
   - Climate intervention data should be properly preserved in discipline-specific or generalist trusted repositories to ensure compliance with FAIR principles, i.e., data are Findable, Accessible, Interoperable, and Reusable.
   - Climate intervention outdoor scaling experiments should publicly reveal funding sources.
   - Information about the context in which the climate intervention data was generated should be made explicit when sharing data, including from indoor experiments and simulation models, so that relevant values and perspectives represented in the scientific process for generating the data can be known and acknowledged.
   - Provide pre-registration for outdoor experiments and share negative results.
4. **Scaling:** Ensuring that field experiments abide by local, regional, and international laws and regulations, and facilitating the creation of increased oversight and reporting requirements depending on the scale of proposed work.
   - All outdoor scaling experiments would abide by local, regional, and international governance laws and requirements.
   - All anticipated climate intervention experiments should address risk assessment requirements and review standards to be applied at various stages of potential testing or deployment.
   - All outdoor experiments or scaling will be covered by an independent review board (to be determined) before deployment.
5. **Governance and monitoring:** Abiding by guidance for planning, coordination, and registering of field experiments; and ensuring validated monitoring, reporting and verification procedures are in place.
   - Researchers and project sponsors should apply an incremental, proportional, step- by-step approach to the design of outdoor experiments that employ leading scientific methods and that anticipate adverse im- pacts and to include plans for monitoring for potential adverse impacts in pre- and post-outdoor trials.
   - Researchers and project sponsors should identify the appropriate local or regional or international governing bodies for its work in advance of outdoor scaling.
   - Mechanisms should be established to register climate intervention experiments in advance of outdoor trials and to monitor outdoor experiments where there is not voluntary registration.

- Researchers, project sponsors, and their home institutions share the responsibility to ensure that outdoor experiments, pilot stage scaling or implementation trials meet the Ethical Framework requirements as outlined either in these modules, the Asilomar Principles, the Oxford Principles or the Tollgate principles, plus any established local regional, national or international requirements, including institutional review boards, prior to deployment.

These five general ethical framework principles for climate intervention research, as facilitated by AGU, are still receiving public comments as of this writing and are subject to additional modifications and clarifications. Global outreach and engagement on these principles remain in progress across various global stakeholder groups, including in United Nations climate conferences. This important work is in its infancy. Ongoing global engagement and education around climate intervention research and the related ethical issues are anticipated over the next decade.

Conclusion

Climate geoengineering research represents a complex and interdisciplinary field that offers potential solutions to mitigate the impacts of climate change. However, significant challenges and uncertainties remain, including technical feasibility, governance, and ethical considerations. Continued research and international collaboration are essential to better understand the risks and benefits of climate geoengineering and to develop responsible approaches to addressing the climate crisis.

The economic implications of climate geoengineering are multifaceted. While geoengineering interventions may offer cost-effective solutions to mitigate the impacts of climate change, they also entail significant financial risks and uncertainties. Moreover, the potential commodification of geoengineering technologies raises concerns about equity and access, particularly for developing countries that may lack the resources to participate in or benefit from these interventions.

Potential geoengineering interventions also raise fundamental questions about humanity's relationship with nature and the ethical boundaries of technological manipulation of the environment. Some critics argue that geoengineering represents a hubristic attempt to control and engineer the Earth's natural systems, which could have unforeseen consequences and undermine the intrinsic value of biodiversity and ecosystems. Cultural and ethical values play a crucial role in shaping societal attitudes towards geoengineering research and deployment.

The acceptance of climate geoengineering interventions among the general public and stakeholders is influenced by various factors, including perceived effectiveness, trust in governance institutions, and cultural attitudes towards technology and risk. Public perceptions of geoengineering may vary widely, ranging from skepticism and mistrust to cautious optimism. Understanding and addressing public concerns and values are essential for achieving social acceptance and legitimacy for geoengineering research and deployment efforts. The role and views of faith-based and religious communities are important in these ongoing discussions, and AGU has helped facilitate this ongoing engagement through participation in conferences organized by the Institute on Religion in an Age of Science (https://www.iras.org/), as well as others.

AGU has contributed proposed ethical principles through a facilitated process the authors believe will benefit researchers, policymakers, and the general public. The aforementioned factors coupled with the urgency of the climate crisis suggest more research and public engagement are needed. AGU envisions its facilitated ethical principles for climate intervention research, experimentation, and potential scaling as a living document to be updated as technology, policy, and societal needs evolve around climate change-related issues.

Acknowledgments

This article derives from a presentation given at the sixty-eighth annual summer conference of the Institute on Religion in an Age of Science (IRAS) entitled "The Wizards of Climate Change: How Can Technology Serve Hope and Justice?" at Star Island, New Hampshire, from June 25 to July 2, 2023.

Notes

[1] The American Geophysical Union is the world's largest organization of Earth and space scientists. Headquartered in Washington, DC, AGU has a global membership of >60,000 from 147 countries. AGU publishes 25 peer reviewed scientific journals.

[2] Joel Cutcher-Gershenfeld is a professor and the Florence G. Heller Chair of the Heller School for Social Policy and Management at Brandeis University.

[3] CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a gene editing technology that can modify the genomes of living organisms (National Human Genome Research Institute 2024).

References

AGU (American Geophysical Union). 2022. "AGU Climate Intervention Engagement: Leading the Development of an Ethical Framework." White Paper. Washington, DC: AGU.

———. 2023a. "The Urgent Priority of a Healthy Climate Requires Enhanced Climate Intervention Research and Community Engagement." Position statement. https://www.agu.org/share-and-advocate/share/policymakers/position-statements/climate-intervention-requirements.

———. 2023b. "Ethical Framework Principles for Climate Intervention Research." Draft principles. https://www.agu.org/learn-about-agu/about-agu/ethics/ethical-framework-for-climate-intervention.

Asilomar Scientific Organizing Committee. 2010. *The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques*. Washington, DC: Climate Institute.

Bala, G., and Akhilesh Gupta. 2019. "Solar Geoengineering Research in India." *Bulletin of the American Meteorological Society* 100 (1): 23–30. https://www.jstor.org/stable/26639248. DOI: https://doi.org/10.1175/BAMS-D-18-0122.1.

European Commission. 2023. *Scoping Paper: Solar Radiation Modification*. https://research-and-innovation.ec.europa.eu/system/files/2023-08/Scoping_paper_SRM.pdf.

FAIR Principles. n.d. Accessed January 7, 2024. https://www.go-fair.org/fair-principles/.

Gardiner, Stephen M., and Augustin Fragnière. 2018. "The Tollgate Principles for Governance of Geoengineering: Moving beyond the Oxford Principles to an Ethically More Robust Approach." *Ethics, Policy and Environment* 21 (2): 143–74. DOI: https://doi.org/10.1080/21550085.2018.1509472.

Grantham Research Institute. 2018. "What Is Geoengineering and How Could It Help Tackle Climate Change?" Explainer. May 3, 2018. https://www.lse.ac.uk/granthaminstitute/explainers/what-is-geoengineering-and-how-could-it-help-tackle-climate-change/.

IPCC (Intergovernmental Panel on Climate Change). 2023. *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by Hoesung Lee and Jose Romero. Geneva: IPCC. DOI: https://doi.org/10.59327/IPCC/AR6-9789291691647.

Kulkarni, Sanjana. 2022. "Reversing Climate Change with Geoengineering." *Science in the News* (blog). January 3, 2002. https://sitn.hms.harvard.edu/flash/2022/reversing-climate-change-with-geoengineering/.

National Academies of Sciences, Engineering, and Medicine. 2021. *Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance*. Washington, DC: The National Academies Press. DOI: https://doi.org/10.17226/25762.

National Human Genome Research Institute. 2024. "CRISPR." https://www.genome.gov/genetics-glossary/CRISPR.

An Open Letter Regarding Research on Reflecting Sunlight to Reduce the Risks of Climate Change. 2023. https://climate-intervention-research-letter.org.

Oxford Geoengineering Programme. 2009. "The Principles." https://www.geoengineering.ox.ac.uk/www.geoengineering.ox.ac.uk/oxford-principles/principles.

Robock, Alan. 2020. "Benefits and Risks of Stratospheric Solar Radiation Management for Climate Intervention (Geoengineering)." *The Bridge* 50 (1): 59–67.

Solar Geoengineering Non-Use Agreement. 2022. https://www.solargeoeng.org/.

Tang, Aaron. 2023. "The Slippery Slopes of Climate Engineering Research." *Global Environmental Change* Volume 80:102674. DOI: https://doi.org/10.1016/j.gloenvcha.2023.102674.

United Nations. n.d.-a. "Causes and Effects of Climate Change." United Nations Climate Action. Accessed February 7, 2024. https://www.un.org/en/climatechange/science/causes-effects-climate-change.

———. n.d.-b. "The Paris Agreement." United Nations Climate Action. Accessed January 4, 2024. https://unfccc.int/process-and-meetings/the-paris-agreement.