The Urgent Priority of a Healthy Climate Requires Enhanced Climate Intervention Research and Community Engagement

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 Urgency of Action

Human activities are changing the Earth's climate in ways that have and will continue to cause increasingly disruptive societal and ecological impacts as well as human suffering.[i] Deep reductions in greenhouse gas (GHG) emissions as well as global adaptation must be central to any policy response to the dangers of climate change. The likelihood that global average temperatures will overshoot the targets agreed to by the world's nations (1.5 – 2.0 degrees C) has led the Intergovernmental Panel on Climate Change (IPCC) to consider Climate Intervention (CI) in its assessment 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.[ii]

With CI approaches beginning to proliferate, substantial research and evaluation efforts are urgently needed to determine the effectiveness, risks, and opportunities of CI and inform societal decisions about possible implementation. It is imperative that the research community and policymakers consider and address the ethical implications of CI globally and fully engage communities in the decision-making process.[iii] Finally, there is a need for effective and inclusive national and global governance structures that can manage all these considerations.

Climate Intervention Approaches

CI is any "deliberate intervention in the planetary environment of a nature and scale intended to counteract anthropogenic climate change and its impacts."[iv] Such approaches can be large in scale or take the form of cumulative local interventions. The most plausible approaches to CI fall into two distinct categories: carbon dioxide removal (CDR) and solar radiation modification (SRM).

CDR, which involves the removal of carbon dioxide from the atmosphere,[v] includes both terrestrial and ocean-based approaches, such as large-scale afforestation, direct air capture, and direct ocean capture, among others.[vi] These could be deployed at a range of scales and currently vary widely in their scientific and market readiness. SRM, which involves a deliberate alteration to the Earth's surface or atmosphere, has mostly focused on the addition of reflective particles into the upper atmosphere or seeding clouds in the lower atmosphere.[vii] Localized surface albedo modification, while less studied, may also be included in this category. A third category of CI, methane removal, seeks to address the serious climate risks posed by this highly potent GHG, but is at an earlier stage of research and thus requires additional focus and funding.

Opportunities and Challenges

As climate change accelerates and causes increasingly unacceptable damage to lives, property, and ecosystems, GHG emissions reductions and adaptation actions have been insufficient. Even stopping GHG emissions now could leave Earth at levels of warming that could have devastating impacts.[viii] CI approaches could cool the climate quickly, helping to mitigate some harms while societies decarbonize. CI approaches must be researched and tested to augment emissions reductions and adaptation. Legitimate concerns exist about the scalability and side effects of some CI approaches, but such concerns do not negate the present need for research, which would shed light on the impacts of and ultimately inform decisions about any possible deployment.

Needed Actions

AGU recommends funding agencies create substantial CI research programs and foster international cooperation. Such programs should be embedded, where possible, in existing initiatives on climate science to ensure that the knowledge gleaned will improve understanding of the changing climate system. CI research should be interdisciplinary and integrated into efforts to understand socio-economic and environmental trade-offs, ethical and environmental justice considerations, and governance structures and needs. Funding from the philanthropic, public, and private sectors is essential to ensure an adequate level of research support. Regardless of funding source, all CI research must be transparent and adhere to ethical principles such as those that could be part of a research code of conduct.

Each technique will have unique research needs and may raise issues that involve different norms of transparency, peer review or intellectual property ownership, and there may be overlap between large-scale experiments and small-scale deployments. The scientific community should contribute to the development of appropriate national and international norms around CI research. Such norms should adhere to ethical scientific principles, including transparency around activities and data, and the development of a governance framework to advance safe, fair, inclusive, and equitable action.

While in many cases, much can be learned from laboratory and modelling research, robust CI research programs require controlled field experiments. All field experiments should be pursued transparently and include an assessment of potential biological and environmental impacts, including transboundary impacts. Decisions about where and how to conduct such field experiments should be made with the participation of potentially affected stakeholders, with particular attention to vulnerable populations, including Indigenous Peoples and peoples of the Global South.[ix] Effective and timely governance of CI field experiments will be necessary to avoid potential long-term social and environmental impacts and promote public trust.

Adequate governance frameworks do not yet exist. AGU recommends that governments and international bodies adopt governance frameworks prior to large-scale CI field experimentation, especially in light of the current differentiated – and hopefully future equitable– distribution of impacts and benefits.

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[i] *Society Must Address the Growing Climate Crisis Now*, AGU, November 2019.
[ii] IPCC, 2018: Summary for Policymakers. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty [Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J.B.R. Matthews, Y. Chen, X. Zhou, M.I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (eds.)]. World Meteorological Organization, Geneva, Switzerland, 32 pp.
[iii] *AGU Climate Intervention Engagement: Leading the Development of an Ethical Framework*, AGU, June 2022.
[iv] Secretariat of the Convention on Biological Diversity (2012). Geoengineering in Relation to the Convention on Biological Diversity: Technical and Regulatory Matters, Montreal, Technical Series No. 66, 152 pages. (2012).
[v] IPCC, AR6 Glossary, https://www.ipcc.ch/site/assets/uploads/2018/11/sr15_glossary.pdf
[vi] National Academies of Sciences, Engineering, and Medicine 2021. A Research Strategy for Ocean-based Carbon Dioxide Removal and Sequestration. Washington, DC: The National Academies Press. https://doi.org/10.17226/26278
[vii] National Academies of Sciences, Engineering, and Medicine 2021. Reflecting Sunlight: Recommendations for Solar Geoengineering Research and Research Governance. Washington, DC: The National Academies Press. https://doi.org/10.17226/25762. National Research Council. 2015. *Climate Intervention: Reflecting Sunlight to Cool Earth*. Washington, DC: The National Academies Press. https://doi.org/10.17226/18988.
[viii] S.Solomon, *et. al*, Irreversible climate change due to carbon dioxide emissions. *PNAS* 106 (6) 1704-1709. (2009). https://doi.org/10.1073/pnas.0812721106. Sigmond, M., Fyfe, J.C., Saenko, O.A. *et al.* Ongoing AMOC and related sea-level and temperature changes after achieving the Paris targets. *Nat. Clim. Chang.* 10, 672–677. (2020). https://doi.org/10.1038/s41558-020-0786-0. Is there warming in the pipeline? A multimodel analysis of the Zero Emissions Commitment from CO2. *Biogeosciences*, 17, 2987–3016. (2020). https://doi.org/10.5194/bg-17-2987-2020
[ix] IPCC, WGIII AR6 Summary for Policy Makers, D.1.2. https://www.ipcc.ch/report/ar6/wg3/downloads/report/IPCC_AR6_WGIII_SummaryForPolicymakers.pdf