Debate 10: Solar Radiation Management

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Solar Geoengineering Could Be Consistent with International Law

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Introduction

Although climate change is arguably the most pressing environmental issue, preventing it through reducing greenhouse gas emissions and carbon-dioxide removal (CDR) will be insufficient to prevent dangerous impacts on humans, other species, and ecosystems. Adaptation can further lessen harm, but it too faces limitations of capacity and feasibility.

Besides emissions reductions, CDR, and adaptation, the only remaining means to limit climate change impacts is solar geoengineering.[1] While it could greatly reduce climate change, including in ways that the other responses cannot, solar geoengineering also poses serious environmental risks and social challenges. For these reasons it has been controversial, including with respect to international law.

The topic of debate in this and the next chapter is whether the global testing or deployment of solar geoengineering (henceforth 'solar geoengineering', unless otherwise specified) could be consistent with international law. I advocate a forceful case that solar geoengineering could be consistent with international law.[2] I secondarily argue that international law even encourages it. To be clear, the fact that solar geoengineering *could* be consistent with international law does not mean that it necessarily *would* be. Like all other activities of significant scale, it could be conducted in ways that would be contrary to international law. In the

[1] Note that these four categories of responses to climate change are not sharply distinct and instead partially overlap.

[2] See Jesse L Reynolds, *The Governance of Solar Geoengineering: Managing Climate Change in the Anthropocene* (Cambridge University Press 2019).

next part of this debate, Kerryn Brent counters that there can be no legal justification for solar geoengineering at scale. In keeping with this volume's theme, we aim to make strong cases, which necessitates not considering subtleties and caveats that are otherwise warranted.

Solar Geoengineering

Solar geoengineering (elsewhere solar radiation management, solar radiation modification, SRM, or albedo modification) would block or reflect a small portion of incoming sunlight to cool the planet.[3] The leading feasible technology would mimic a volcanic eruption's natural-cooling effect by injecting a fine aerosol mist into the stratosphere – an upper layer of the atmosphere.[4] Another would brighten marine clouds by spraying a fine mist of seawater into the lower atmosphere. The suspended salt particles that remained after evaporation would serve as cloud condensation nuclei.[5] Finally, cirrus clouds – the high feathery ones, which appear to have a natural warming effect – could be dispersed by injecting certain salts or aerosols at high altitudes.[6] Although 'cirrus-cloud thinning' would not block or reflect incoming sunlight, its means of operation, expected impacts, governance needs, and legal implications are similar enough to solar geoengineering that it is best categorized as such.

Some other solar-geoengineering technologies have been proposed, such as placing objects in space and increasing surface reflectivity, but these have limited capacity, are expensive, or are infeasible.

Solar geoengineering appears able to effectively cool the planet. Current evidence is that it – especially stratospheric aerosol injection – could do so more-or-less globally (with some latitudinal variation possible),[7] rapidly (within months), reversibly in its direct climatic

[3] National Research Council, *Climate Intervention: Reflecting Sunlight to Cool Earth* (National Academies Press 2015).

[4] Ibid. 66–101; Peter J Irvine and David W Keith, 'Halving Warming with Stratospheric Aerosol Geoengineering Moderates Policy-Relevant Climate Hazards' (2020) 15 *Environmental Research Letters* 044011.

[5] National Research Council (n. 3) 101–27; Hannah M Horowitz and others, 'Effects of Sea Salt Aerosol Emissions for Marine Cloud Brightening on Atmospheric Chemistry: Implications for Radiative Forcing' (2020) 47 *Geophysical Research Letters* e2019GL085838.

[6] National Research Council (n. 3) 130–2; Blaž Gasparini and others, 'To What Extent Can Cirrus Cloud Seeding Counteract Global Warming?' (2020) 15 *Environmental Research Letters* 054002.

[7] Simone Tilmes and others, 'Reaching 1.5°C and 2.0°C Global Surface Temperature Targets Using Stratospheric Aerosol Geoengineering' (2020) 11 *Earth Systems Dynamics* 579.

effects,[8] and inexpensively (with annual direct deployment costs of a few billion US dollars, which is a fraction of the cost of aggressive emission reductions or of climate change impacts).[9] For example, a 2018 report of the Intergovernmental Panel on Climate Change concludes that stratospheric aerosol injection 'is the most-researched SRM method, with *high agreement* that it could limit warming to below 1.5°C' – a very ambitious global warming goal.[10] Furthermore, at least some solar-geoengineering technologies seem technically feasible.

Solar geoengineering would pose multiple environmental risks. First, it would imperfectly reduce climate change. Specifically, solar geoengineering would more effectively reduce warming from climate change than changes to precipitation. Anomalously warm, cool, dry, and wet areas would remain.[11] A globally uniform implementation of solar geoengineering would be more effective near the tropics than at the poles, although this imbalance could largely be countered.[12] Second, some materials used for stratospheric aerosol injection could catalyse the destruction of stratospheric ozone, delaying its recovery.[13] Third, some materials could also contribute to acid rain.[14] Finally, solar geoengineering would not directly reduce atmospheric greenhouse gas concentrations (even though it would indirectly do so).[15] The oceans would continue to acidify, but not as a direct consequence of solar geoengineering.[16] If used suboptimally, these risks would be greater, and more serious ones could arise.

Likewise, solar geoengineering could present social, political, and economic challenges. The most widespread concern is that its consideration,

[8] Kelly E McCusker and others, 'Rapid and Extensive Warming Following Cessation of Solar Radiation Management' (2014) 9 *Environmental Research Letters* 024005.
[9] Wake Smith and Gernot Wagner, 'Stratospheric Aerosol Injection Tactics and Costs in the First 15 Years of Deployment' (2018) 13 *Environmental Research Letters* 124001.
[10] Heleen de Coninck and others, 'Strengthening and Implementing the Global Response' in Valérie Masson-Delmotte and others (eds.), *Global Warming of 1.5°C: An IPCC Special Report* (IPCC 2019) 350, emphasis in original.
[11] National Research Council (n. 3) 66–101; Irvine and Keith (n. 4).
[12] Tilmes and others (n. 7).
[13] Jadwiga H Richter and others, 'Stratospheric Dynamical Response and Ozone Feedbacks in the Presence of SO_2 Injections' (2017) 122 *JGR Atmospheres* 12557.
[14] Ben Kravitz and others, 'Sulfuric Acid Deposition from Stratospheric Geoengineering with Sulfate Aerosols' (2009) 114 *JGR Atmosphere* D14109.
[15] David W Keith, Gernot Wagner, and Claire L Zabel, 'Solar Geoengineering Reduces Atmospheric Carbon Burden' (2017) 7 *Nature Climate Change* 617.
[16] H Damon Matthews, Long Cao, and Ken Caldeira, 'Sensitivity of Ocean Acidification to Geoengineered Climate Stabilization' (2009) 36 *Geophysical Research Letters* L10706.

research, and development would undermine necessary emission reductions. Solar geoengineering's combination of effectiveness, global impact, relatively low cost, and technical feasibility means that one or a few actors – likely but not necessarily states – could implement it regardless of any international consensus. Furthermore, solar geoengineering's reversibility and speed mean that if it were used at a substantial magnitude, suddenly stopped, and not resumed, the previously suppressed climate change would manifest rapidly and hence more dangerously. Some observers worry that early decisions might cause 'lock-in' or a 'slippery slope' towards improper solar geoengineering, while others object to solar geoengineering on ethical grounds.

International Law

As in other legal domains, the default in international law is permissive: a state may act unless it has obligations otherwise, typically including respecting another state's legal right.[17] Indeed, sovereignty – supreme authority within a territory – and statehood are ontologically interrelated. A state conducting solar geoengineering itself or allowing a non-state actor to do so would be exercising state sovereignty.

Because a common objection to solar geoengineering is that it would be 'messing with nature',[18] it is worth asking about the relative degrees to which international environmental law emphasizes humans' interests or the protection of the natural world. With rare exceptions, international law is anthropocentric, not ecocentric. A leading textbook says that 'almost all justifications for international environmental protection are predominantly and in some sense anthropocentric'.[19] In fact, one finds many prioritizations of protecting human interests and few admonitions against intervening in nature. For example, the first principle of the UN Framework Convention on Climate Change (UNFCCC) is that 'The Parties should protect the climate system for the benefit of present and future generations of humankind.'[20]

[17] *Lotus Case (France* v. *Turkey)* (Judgment) PCIJ Ser A No 10 (1927).

[18] Adam Corner and others, 'Messing with Nature? Exploring Public Perceptions of Geoengineering in the UK' (2013) 23 *Global Environmental Change* 938.

[19] Patricia Birnie, Alan Boyle, and Catherine Redgwell, *International Law and the Environment* (3rd ed., Oxford University Press 2009) 7.

[20] UN Framework Convention on Climate Change (adopted 9 May 1992, EIF 21 March 1994) 1771 UNTS 107, art. 3(1).

Customary International Law

Solar geoengineering would entail the use of territory and natural resources. A state's sovereignty over its territory is arguably the foundation of international law.[21] States also have permanent sovereignty over their natural resources. This has been expressed in multiple UN General Assembly resolutions[22] and confirmed as a rule of customary international law by the International Court of Justice (ICJ).[23]

Sovereignty is not absolute: states are constrained by international legal obligations. Solar geoengineering would affect other states' environments. The foundational Stockholm and Rio Declarations couple states' 'sovereign right to exploit their own resources pursuant to their own environmental and developmental policies' with their obligations regarding harm that would be transboundary (that is, to other states or to areas beyond national jurisdiction).[24] The ICJ has recognized at least some of these obligations as customary international law,[25] although the individual rules' precise contours and legal status are for the most part somewhat unclear. Regardless, pursuant to these, the source state need not prevent all transboundary environmental harm but instead must comply with various, mostly procedural duties, such as prior risk assessment, notification of and (if requested) consultation with potentially affected states, and take appropriate substantive measures to prevent or minimize risks.[26] None of these duties preclude solar geoengineering. Ultimately, a state may undertake or approve an action that causes

[21] *Island of Palmas Case (or Miangas) (Netherlands/US)* (Award) (1928) 2 RIAA 829.

[22] See, e.g., UNGA Resolutions 523(VI) (1952) (on Integrated Economic Development and Commercial Agreements); 626 (VII) (1952) (on the Right to Exploit Freely Natural Wealth and Resources); 1803 (XVII) (1962) (on Permanent Sovereignty over Natural Resources); 3201 (S-VI) (1974) (on the Declaration on the Establishment of a New International Economic Order); and 3281 (XXIX) (1974) (on the Charter of Economic Rights and Duties of States).

[23] *Armed Activities on the Territory of the Congo (Democratic Republic of the Congo* v. *Uganda)* (Judgment, Merits) [2005] ICJ Rep 168, 251–2 [244].

[24] Declaration of the UN Conference on the Human Environment (16 June 1972) UN Doc A/Conf.48/14/Rev. 1, (1972) 11 ILM 1416, Principle 21; Rio Declaration on Environment and Development, UN Doc A/CONF.151/26 (vol. I) 31 ILM 874 (1992) Principle 2.

[25] *Legality of the Threat or Use of Nuclear Weapons* (Advisory Opinion) [1996] ICJ Rep 226; *Pulp Mills on the River Uruguay (Argentina* v. *Uruguay)* (Judgment) [2010] ICJ Rep 14.

[26] ILC, Draft articles on Prevention of Transboundary Harm from Hazardous Activities, in Report of the ILC on its 53rd Session, UN Doc A/56/10 (2001) 148; *Pulp Mills* (n. 25); *Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica* v. *Nicaragua) and Construction of a Road in Costa Rica Along the San Juan River (Nicaragua* v. *Costa Rica)* (Judgment) [2015] ICJ Rep 665.

transboundary risks or certain negative impacts on other states. In fact, such actions occur regularly.[27]

The International Law Commission (ILC), which codifies and helps develop international law, has drafted a set of Guidelines on the Protection of the Atmosphere. The ILC intends that these reflect state practice and, to some degree, customary international law. One of the guidelines is, 'Activities aimed at intentional large-scale modification of the atmosphere should be conducted with prudence and caution, subject to any applicable rules of international law.'[28] The accompanying commentary makes clear that this is meant to include solar geoengineering.[29] If solar geoengineering were contrary to international law, the ILC would have said so in these guidelines.

The UN Climate Change Regime

States' more specific legal rights and obligations are found in treaties. Although these are binding on only those states that have ratified them, for the sake of argument I will assume that the solar-geoengineering state has done so.

The seemingly most relevant set of treaties are the UNFCCC and its two related agreements. The UNFCCC's objective is worth quoting at length:

> The ultimate objective . . . is to achieve . . . stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.[30]

In an initial reading of this, solar geoengineering does not fall within this scope, as it would not directly affect atmospheric greenhouse gas concentrations.

[27] Take the example of nuclear installations, which are disproportionately near international borders. Arne Kaijser and Jan-Henrik Meyer, 'Nuclear Installations at the Border. Transnational Connections and International Implications. An Introduction' (2018) 3 *J History Envt & Soc'y* 1.

[28] 'Text of the Draft Guidelines on the Protection of the Atmosphere, Together with Preamble, Adopted by the Commission on First Reading' in Report of the ILC on its 70th Session, UN Doc A/73/10 (2018) 158 [77], 160 (guideline 7).

[29] Ibid. 182 (Commentary on guideline 7[3]).

[30] UNFCCC (n. 20) art. 2.

Regardless of the UNFCCC's objective, its lack of explicit provisions on the matter indicates that it would not prevent solar geoengineering as an exercise of state sovereignty. If anything, the climate change regime actually encourages it, for five reasons. First, current evidence suggests that solar geoengineering would *indirectly* reduce atmospheric concentrations of carbon dioxide, the leading greenhouse gas.[31] This is expected to occur largely by preventing some of the positive CO_2-releasing feedbacks that global warming will cause. States' commitments in the UNFCCC, Kyoto Protocol, and Paris Agreement to enhance sinks and reservoirs of greenhouse gases could thus apply also to solar geoengineering.[32]

Second, while the UNFCCC's objective does not specify the levels at which atmospheric concentrations of greenhouse gases should be stabilized, it provides a constraint on the level ('prevent[ing] dangerous anthropogenic interference with the climate system') and three constraints on the time frame of their stabilization ('allow[ing] ecosystems to adapt . . ., ensur[ing] food production . . ., and . . . enabl[ing] sustainable economic development to proceed'). Solar geoengineering, as part of a diverse portfolio of responses, appears able to increase the level at which greenhouse gases' atmospheric concentrations would constitute dangerous interference with the climate system as well as to allow more time for their stabilization.

Third, solar geoengineering could reasonably be considered a form of adaptation, for which the climate change agreements contain multiple commitments. Though these treaties do not define adaptation, the UNFCCC institutions often refer to a definition developed by the Intergovernmental Panel on Climate Change (IPCC): 'Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change.'[33] Solar geoengineering would be a change in practices to moderate potential damages from climate change. If it were so included, parties' commitments in the

[31] Keith, Wagner and Zabel (n. 15).

[32] UNFCCC (n. 20) art. 4(1)(d); Kyoto Protocol to the UNFCCC (adopted 11 December 1997, EIF 16 February 2005) 2303 UNTS 162, art. 2(1)(a)(ii); Paris Agreement Paris Agreement (adopted 12 December 2015, EIF 4 November 2016) (2016) 55 ILM 740, art. 5(1).

[33] UNFCCC, 'What Do Adaptation to Climate Change and Climate Resilience Mean?' <unfccc.int/topics/adaptation-and-resilience/the-big-picture/what-do-adaptation-to-climate-change-and-climate-resilience-mean>.

UNFCCC[34] and the Paris Agreement[35] to take adaptive steps could include solar geoengineering.

Fourth, one of the UNFCCC's foundational principles is precaution:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost.[36]

Solar geoengineering could be a precautionary response to climate change.[37] It could mitigate many of its adverse effects. Furthermore, if one were to understand climate change as the product of an anthropogenic alteration of Earth's radiative energy balance, solar geoengineering could prevent or minimize its cause. Although full scientific certainty is still lacking, this should not be used as a reason for postponing solar geoengineering, according to this legal principle. And because solar geoengineering appears to have low direct costs, it might be cost-effective.[38] The precautionary approach is found in other relevant multilateral environmental statements and agreements, but these do not substantially differ from that of the UNFCCC.[39]

Fifth and finally, the Paris Agreement establishes a temperature goal, in which parties seek to keep global warming well below 2°C and 'pursue efforts' to limit it to 1.5°C.[40] Solar geoengineering could contribute to achieving this objective, and the Agreement contains no prohibitions or restrictions on parties using solar geoengineering.

34 UNFCCC (n. 20) arts. 4(1)(b), 4(1)(e), (f), 4(4).

35 Paris Agreement (n. 32) arts. 2(1)(b), 7.

36 UNFCCC (n. 20) art. 3(3).

37 Jesse L Reynolds and Floor Fleurke, 'Climate Engineering Research: A Precautionary Response to Climate Change?' (2013) 2013 *CCLR* 101.

38 J Eric Bickel and Lee Lane, 'Climate Engineering' in Bjorn Lomborg (ed.), *Smart Solutions to Climate Change: Comparing Costs and Benefits* (Cambridge University Press 2010).

39 Rio Declaration (n. 24) Principle 15; Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on Further Reduction of Sulphur Emissions (adopted 14 June 1994, EIF 5 August 1998) 2030 UNTS 122, recitals 3–4; Convention on Biological Diversity (adopted 5 June 1992, EIF 29 December 1993) 1760 UNTS 79, recital 9; 1996 Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972 (adopted 7 November 1996, EIF 24 March 2006) (1997) 36 ILM 7 (London Protocol), art. 3.1.

40 Paris Agreement (n. 32) art. 2.1(a).

My opponent and others assert that solar geoengineering could cause the very dangerous anthropogenic interference with the climate system that the UNFCCC aims to prevent.[41] This is based on a misreading of the Convention. Its objective is not to prevent such interference but instead to stabilize the atmospheric concentration of greenhouse gases at levels that would do so. The difference is subtle but important. Although solar geoengineering would indeed constitute anthropogenic interference in the climate system, by enabling an increase in the concentration levels at which dangerous interference from anthropogenic greenhouse gases would begin to occur, it could be consistent with – not contrary to – the UNFCCC's objective.

Other Atmospheric Agreements

Because most solar-geoengineering technologies would be undertaken in the atmosphere, multilateral agreements that govern activities that would take place in or affect the atmosphere are salient. None of these prohibit solar geoengineering.

The most prominent proposed solar-geoengineering technology – stratospheric aerosol injection – might catalyse the destruction of protective stratospheric ozone. The Vienna Convention for the Protection of the Ozone Layer and its Montreal Protocol regulate states' production and emissions of diverse ozone-depleting substances. If adverse effects resulting from modification of the ozone layer by stratospheric aerosol injection were likely, then the parties would be committed to adopt policies to control, limit, reduce, or prevent these activities.[42] However, stratospheric aerosol injection's risks to stratospheric ozone appear modest, and it might even be able to help the ozone layer recover.[43] Even if adverse effects were likely, the deploying or authorizing state could merely regulate and limit the activity in order to balance the competing environmental threats. Though the Montreal Protocol requires states to

[41] See, e.g., Albert Lin, 'The Missing Pieces of Geoengineering Research Governance' (2016) 100 *Minnesota Law Review* 2509, 2523.

[42] Vienna Convention for the Protection of the Ozone Layer (adopted 22 March 1985, EIF 22 September 1988) 1513 UNTS 293, art. 2(2)(b).

[43] Peer Johannes Nowack and others, 'Stratospheric Ozone Changes under Solar Geoengineering: Implications for UV Exposure and Air Quality' (2016) 16 *Atmospheric Chemistry and Physics* 4191; David W Keith and others, 'Stratospheric Solar Geoengineering Without Ozone Loss' (2016) 113 *Proceedings of the National Academy of Sciences* 14910.

phase out listed ozone-depleting substances, none of the materials considered for stratospheric aerosol injection are presently so listed.[44]

The most-researched materials for potential stratospheric aerosol injection are various precursors to sulphur dioxide, as this is what volcanic eruptions emit. In the atmosphere, these would oxidize to sulfuric acid that would eventually precipitate as acidic rain. Environmentally, this is not a major concern, as the amount would be small and widely dispersed relative to traditional anthropogenic sources.[45]

Most European and North American countries (and a few beyond) are parties to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) as well as some or all of its protocols. Parties to the framework CLRTAP 'shall endeavour to limit and, as far as possible, gradually reduce and prevent air pollution'.[46] The term 'air pollution' is defined as: 'the introduction by man, directly or indirectly, of substances or energy into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment'.[47] This definition of air pollution implicitly includes greenhouse gases, global warming, and any substances used for atmospheric solar geoengineering whose harm satisfies the given threshold.[48] Given that, if successful, solar geoengineering would reduce global warming and indirectly reduce atmospheric carbon-dioxide concentrations, and that it might (or might not) result in deleterious effects, states' obligations regarding solar geoengineering under the CLRTAP are uncertain. If solar geoengineering were believed to offer 'the best available technology which is economically feasible and low- and non-waste' to reduce harm from air pollution – including from greenhouse gases or global warming – then parties should incorporate it into their policies and strategies, including air-quality-management systems.[49]

44 UNEP, 'The Montreal Protocol on Substances That Deplete the Ozone Layer: Summary of Control Measures under the Montreal Protocol' <ozone.unep.org/treaties/montreal-protocol/summary-control-measures-under-montreal-protocol>.

45 Kravitz and others (n. 14).

46 Convention on Long-Range Transboundary Air Pollution (adopted 13 November 1979, EIF 16 March 1983) 1302 UNTS 217, art. 2.

47 Ibid. art. 1(a).

48 See Philippe Sands and Jacqueline Peel, *Principles of International Environmental Law* (Cambridge University Press 2012) 247; UN Convention on the Law of the Sea (adopted 10 December 1982, EIF 16 November 1994) 1833 UNTS 3 and the London Protocol (n. 39) use similar definitions.

49 CLRTAP (n. 46) art. 6.

Three of CLRTAP's protocols (the Helsinki, Oslo, and Gothenburg Protocols) obligate their parties to regulate and reduce sulphate emissions to within certain limits.[50] At most, if these states sought to use sulphur for stratospheric aerosol injection at full scale, in order to remain in compliance, they would need to distribute the injections among themselves or perform them in areas beyond national jurisdiction.

The Marine Environment

Some proposed solar-geoengineering technologies, such as marine-cloud brightening, would take place at sea, while others, such as stratospheric aerosol injection, could. Most of them would affect the marine environment.

The UN Convention on the Law of the Sea (UNCLOS) is a comprehensive multilateral agreement that governs, among other things, states' activities that occur in, or may affect, the marine environment. That latter phrase is undefined but is widely interpreted as encompassing the oceans and seas, the atmosphere above them, and the subsoil below them.[51] The high seas – the marine areas beyond states' territorial seas and exclusive economic zones (that is, more than 200 nautical miles from their coasts) – are open to all states for peaceful purposes, which solar geoengineering would be.[52] They need only to act with due regard for other states' interests and rights.

Parties to UNCLOS have obligations concerning the protection of the marine environment.[53] In particular, they are to prevent, reduce, and control pollution of the marine environment from any source, including land-based ones.[54] As in CLRTAP, 'pollution' is defined in a way that would include greenhouse gases, global warming, and solar geoengineering if it would be likely to harm humans or marine life.[55] And again, the implications for solar geoengineering of these and related obligations in UNCLOS

[50] Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at least 30 Per Cent (adopted 8 July 1985, EIF 2 September 1987) 1480 UNTS 215 (Helsinki Protocol); Oslo Protocol (n. 39); Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification Eutrophication and Ground-Level Ozone (adopted 30 November 1999, EIF 17 May 2005) 2319 UNTS 81 (Gothenburg Protocol).

[51] Veronica Frank, *The European Community and Marine Environmental Protection in the International Law of the Sea: Implementing Global Obligations at the Regional Level* (Nijhoff 2007) 12.

[52] UNCLOS (n. 48) arts. 86–8, 257.

[53] Ibid. art. 192.

[54] Ibid. arts. 194, 207.

[55] Ibid. art. 1(1)(4).

are unclear and would ultimately depend on the scientific evidence. At the moment, it appears that solar geoengineering could substantially prevent, reduce, and control climate change, and its judicious use would not be likely to harm the marine environment.

One could argue that the forms of solar geoengineering, such as stratospheric aerosol injection and cirrus-cloud thinning, which could involve injecting material into the marine environment, would be a kind of dumping, which is a practice regulated by UNCLOS, the London Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, and the London Protocol. However, this would not be the case. It is true that the definition of dumping in UNCLOS and the London Convention speak of the disposal *at* sea – not only into marine waters – which could include disposal into the marine atmosphere.[56] Yet in both agreements, dumping has an exception for 'placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of this Convention'.[57] Because the purpose of solar geoengineering would not be mere disposal, states' international legal obligations regarding dumping provisions would not apply.

The parties to the London Protocol have approved an amendment that addresses marine geoengineering (Resolution 4(8)). This is independent of the London Protocol's focus on dumping and instead advances its broader objective to 'protect and preserve the marine environment from all sources of pollution'.[58] The amendment would regulate 'deliberate intervention[s] in the marine environment to manipulate natural processes, including to counteract anthropogenic climate change and/or its impacts, and that has the potential to result in deleterious effects', which could include solar geoengineering conducted at sea.[59] The amendment would do so through a list of specific marine geoengineering activities that would be either prohibited or

[56] Ibid. art. 1(1)(5); Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (adopted 29 December 1972, EIF 30 August 1975) 1046 UNTS 120 (London Convention) art. III.1. In contrast, the London Protocol (n. 39) art. 1(4)(1) speaks of 'disposal *into* the sea' (emphasis added).

[57] UNCLOS (n. 48) art. 1(1)(5)(b)(2); London Convention, art. III.1(b)(2).

[58] London Protocol (n. 39) art. 2.

[59] Amendment to the 1996 Protocol to the London Convention to Regulate Marine Geoengineering (adopted 18 October 2013, not yet in force) new art. 1(*5bis*), in Report of the Thirty-Fifth Consultative Meeting and the Eighth Meeting of Contracting Parties, UN Doc LC 35/15 (2013).

approved by states on a case-by-case basis.[60] Regardless, this amendment would presently not apply to solar geoengineering. One reason is that, seven years after its approval, the amendment has been ratified by only three countries of the thirty-six that are needed for it to come into force.[61] Another reason is that the parties would need to add specific solar geoengineering technology(-ies) to the list of prohibited or regulated marine-geoengineering activities. Presently, only ocean fertilization – a CDR technique – is listed.

Other Multilateral Agreements

Both stratospheric aerosol injection and cirrus-cloud thinning would probably involve high-altitude injection of materials into the atmosphere via aircraft. The Chicago Convention on International Civil Aviation is the central multilateral agreement in this domain. Its first article is that parties have exclusive sovereignty over their airspace.[62] This means that states would not be precluded from conducting atmospheric solar geoengineering in their own airspace under the international law of civil aviation. States are to allow non-scheduled flights through their airspace unless the foreign aircraft is military, customs, or police aircraft or the aircraft operates with a purpose inconsistent with the Convention's aims.[63] These aims include to develop 'international civil aviation . . . in a safe and orderly manner and [to establish] international air transport services . . . on the basis of equality of opportunity and operated soundly and economically' – aims with which solar geoengineering could be consistent.[64] The Chicago Convention contains no explicit provisions against a foreign aircraft injecting material into the atmosphere of another state; aircraft-pollution regulations need only be enforced without distinction to the aircraft's country of registration.[65] This implies that one country's conduct of atmospheric solar geoengineering in another state's airspace could be consistent with international aviation law. Above

[60] Ibid. new art. 6*bis*.

[61] Romany M Webb, Korey Silverman-Roati and Michael B Gerrard, *Removing Carbon Dioxide Through Ocean Alkalinity Enhancement and Seaweed Cultivation: Legal Challenges and Opportunities* <https://climate.law.columbia.edu/content/removing-carbon-dioxide-through-ocean-alkalinity-enhancement-and-seaweed-cultivation-legal>.

[62] Convention on International Civil Aviation (adopted 7 December 1944, EIF 4 April 1947) 15 UNTS 295 (Chicago Convention) art. 1.

[63] Ibid. art. 5.

[64] Ibid. arts. 3, 5, and recital 3.

[65] Ibid. art. 11.

the oceans, UNCLOS also governs overflight, which is an explicit right of states beyond other states' coastal waters.[66]

The Convention on Biological Diversity (CBD) is a wide-ranging multilateral environmental agreement that seeks to, among other things, conserve biological diversity. To the extent that solar geoengineering would reduce climate change – which poses a severe threat to biodiversity – it could help conserve it.[67] Parties to the CBD are to 'Develop national strategies, plans or programmes for the conservation and sustainable use of biological diversity or adapt for this purpose existing strategies, plans or programmes'.[68] Solar geoengineering could be part of a programme for the conservation of biological diversity. Additionally, the CBD parties have addressed geoengineering in decisions at their Conferences of Parties (COPs). A 2010 CBD COP decision calls on states to prevent 'climate-related geo-engineering activities that may affect biodiversity' from taking place until such time as 'science based, global, transparent and effective control and regulatory mechanisms' have been developed and there is 'an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts'.[69] This is widely misrepresented as a moratorium.[70] For one thing, COP decisions are non-binding; for another, the statement is advisory: 'The Conference of the Parties . . . Invites Parties and other Governments . . . to consider the guidance below'. Furthermore, it is 'in accordance with . . . Article 14 of the Convention', to make clear that the hortation is limited to geoengineering activities that would have significant adverse impacts on biodiversity. Although solar geoengineering could have such impacts, this would depend on the specific technology and how it was employed. For example, while excessive stratospheric aerosol injection or any use of large reflective sheets on the land would be harmful, moderate stratospheric aerosol injection or marine-cloud brightening could offer net biodiversity benefits by reducing climate change.

66 UNCLOS (n. 46) arts. 58(1), 87(1)(b).

67 P Williamson and R Bodle, 'Update on Climate Geoengineering in Relation to the Convention on Biological Diversity: Potential Impacts and Regulatory Framework' (Secretariat of the Convention on Biological Diversity 2016).

68 CBD (n. 39) art. 6(a).

69 CBD Decision X/33(2010) [8(w)], in UN Doc UNEP/CBD/COP/ DEC/X/33.

70 See, e.g., Anna-Maria Hubert, 'A Code of Conduct for Responsible Geoengineering Research' (2020) *Global Policy* (doi: 10.1111/1758-5899.12845).

The Convention on the Prohibition of Military or any Other Hostile Use of Environmental Modification Techniques (ENMOD) aims to do what its title explicates. 'Environmental modification' is defined in a way that solar geoengineering would be included.[71] The agreement bans only the 'military or any other hostile use of environmental modification techniques having widespread, long-lasting or severe effects as the means of destruction, damage or injury'.[72] ENMOD also states that 'The provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes', which solar geoengineering would be.[73] The treaty's preamble emphasizes anthropocentricity by 'Realizing that the use of environmental modification techniques for peaceful purposes could improve the interrelationship of man and nature and contribute to the preservation and improvement of the environment for the benefit of present and future generations.'[74] Moreover, parties that are able to do so 'shall contribute, alone or together with other States or international organizations, to international economic and scientific co-operation in the preservation, improvement, and peaceful utilization of the environment'.[75] Thus, not only does ENMOD not prohibit non-hostile solar geoengineering, its parties have an obligation to internationally cooperate towards it.

Solar geoengineering could – at least in principle – be done in outer space by placing objects in orbit or at the L1 Lagrangian point between Earth and the sun. States' rights and obligations in outer space are given by the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (Outer Space Treaty) and its related agreements. The Outer Space Treaty's parties are to conduct space activities 'for the benefit and in the interests of all countries . . . in accordance with international law . . . in the interest of maintaining international peace and security and promoting international cooperation and understanding' and 'with due regard to the corresponding interests of all other States Parties'.[76] The first of these passages was *not* intended to require unanimous

[71] Convention on the prohibition of military or any other hostile use of environmental modification techniques (adopted 10 December 1976, EIF 5 October 1978) 1108 UNTS 151, art. II.
[72] Ibid. art. I.1.
[73] Ibid. art. III.1.
[74] Ibid. recital 5.
[75] Ibid. art. III.2.
[76] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (adopted 27 January 1967, EIF 10 October 1967) 610 UNTS 205, arts. I, III, IX.

approval for space activities.[77] Space-based solar geoengineering would not be prohibited under space law, provided that the state in question complies with these and other obligations.

Necessity

If a state that conducts geoengineering were to be accused by another of acting in breach of its international legal obligations, the accused state may invoke circumstances in which the customary international law of state responsibility precludes an act from being wrongful. The most pertinent of these is necessity, in which the act that would otherwise be contrary to international law 'is the only way for the State to safeguard an essential interest against a grave and imminent peril', according to the ILC's Draft Articles.[78] Climate change will threaten some states' essential interests, including the very existence of low-lying island states. A state could assert that solar geoengineering is the only way for it to safeguard such an essential interest, despite any possible ways in which the activities might be contrary to international law.

Conclusion

The large-scale outdoor testing and deployment of solar geoengineering could be consistent with international law. This is because the legal order's default is permissive and grounded in sovereignty and because there are no existing legal rules that preclude solar geoengineering. There is a handful of modest constraints. Under the customary international law of transboundary harm, the acting state would need to act with due diligence and satisfy mostly procedural duties, such as prior impact assessment, notification, and consultation. Solar geoengineering may not be for hostile purposes. In the marine environment, it would need to be done in ways that ultimately prevent, reduce, and control pollution. And on the high seas and in outer space, the solar geoengineering state must act with due regard for other states' rights and interests. A reasonably well-designed field test or use of solar geoengineering to reduce climate change risks should be able to satisfy these constraints.

[77] Francis Lyall and Paul B Larsen, *Space Law: A Treatise* (Ashgate 2009) 63–4; N Jasentuliyana, 'Article I of the Outer Space Treaty Revisited' (1989) 17 *J Space L* 129.

[78] ILC, Draft Articles on the Responsibility of States for Internationally Wrongful Acts, with commentaries, in Report of the ILC on its 53rd Session, UN Doc A/56/10 (2001) 80 (art. 25).

Furthermore, in some ways international law tilts favourably towards solar geoengineering. ENMOD requires its parties to cooperate in peaceful environmental modification, such as solar geoengineering. And, more importantly, the UN climate regime may be read as encouraging solar geoengineering for several reasons, among which is that it could be a precautionary response to climate change.