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State Responsibility for Environmental Harm from Climate Engineering

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Abstract

Some have proposed that climate-engineering methods could be developed to offset climate change. However, whilst some of these methods, in particular a form of solar-radiation management referred to as stratospheric aerosol injection (SAI), could potentially reduce the overall degree of global warming as well as some associated risks, they are also likely to redistribute some environmental risks globally. Moreover, they could give rise to new risks, raising the issue of legal responsibility for transboundary harm

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caused. This article examines the question of international accountability of states for an increased risk of environmental harm arising from a large-scale climate intervention using SAI, and the legal consequences that would follow. Examination of the applicability of customary rules on state responsibility to SAI are useful for understanding the limitations of the existing accountability framework for climate engineering, particularly in the context of global environmental problems involving risk-risk trade-offs and large uncertainties.

Keywords

State responsibility – preventive principle – due diligence – causation – precautionary principle – climate engineering – geoengineering – stratospheric aerosol injection – termination effect

1 Introduction

The UNFCCC declares in its preamble that 'climate change and its adverse effects are a common concern of humankind'.[1] This legal concept is interpreted and widely applied in related climate agreements and policy documents to mean that all countries share in the burden of addressing climate change, subject to the principle of common but differentiated responsibilities. Unfortunately, to date, 'international climate governance represents a case of shared *ir*responsibility'.[2] The year 2014 set a new record in global CO_2 emissions,[3] and the ten warmest years on record since 1880 belong to the period 1998–2014.[4] States parties to the UNFCCC are, at the time of writing, engaged in a process under the Durban Platform for Enhanced Action to reach a new global agreement on climate change by the end of 2015. Important progress is being made in international climate diplomacy and at the national and subnational levels. However, even with immediate and decisive political action to reduce greenhouse gas emissions, the chances of limiting global warming to 2°C are low.[5]

1 1771 UNTS 107f.

2 Daniel H. Cole, 'The Problem of Shared Irresponsibility in International Climate Law' (http://ssrn.com/abstract=2291800) (2013), at 1.

3 Corinne Le Quéré et al., 'Global Carbon Budget 2014', 7(2) *Earth System Science Data Discussion* 521–610 (2014).

4 Cf. the Global Analysis of the National Oceanic and Atmospheric Administration, June 2015 (www.ncdc.noaa.gov/sotc/global/).

5 Cf. Kevin Anderson and Alice Bows, 'Beyond "Dangerous" Climate Change: Emission Scenarios for a New World', 369(1934) *Philosophical Transactions of the Royal Society* 20 (2011), at 22 f.

Some have proposed that so-called 'climate engineering' measures could be developed to supplement the existing portfolio of strategies for counteracting human-induced climate change.[6] In its Fifth Assessment Report, the IPCC defined climate engineering (or geoengineering) as 'a broad set of methods and technologies that aim to deliberately alter the climate system in order to alleviate the impacts of climate change'.[7] Climate-engineering methods fall within two categories, seeking either to reduce the amount of absorbed solar energy in the climate system (solar radiation management, SRM) or to increase net long-term carbon sinks at a scale sufficient to alter the climate (carbon-dioxide removal, CDR).[8] According to the IPCC, 'Scale and intent are of central importance'[9] as shared characteristics of all climate-engineering technologies. The IPCC also points out important concerns raised by climate-engineering measures which 'use or affect the climate system (e.g., atmosphere, land or ocean) globally or regionally and/or could have substantive unintended effects that cross national boundaries.'[10] Therefore, if carried out at scale, all proposed climate-engineering strategies could create 'winners and losers',[11] with the consequence that research into or the application of any one of them may give rise to interstate disputes.[12] Yet some climate-engineering methods have potential implications, including implications under international law that make them different from others.[13]

6 For a discussion of the implications of 'novel climate change responses' within the broader context of climate change and international environmental law, see Catherine Redgwell, 'Climate Change and International Environmental Law', in *International Law in the Era of Climate Change*, edited by Rosemary Rayfuse and Shirley V. Scott (Cheltenham, UK: Edward Elgar, 2012), at 137–145.

7 Steven J. Smith and Philip J. Rasch, 'The Long-Term Policy Context For Solar Radiation Management', 121(3) *Climatic Change* 487–497 (2013).

8 John Shepherd et al., *Geoengineering the Climate: Science, Governance and Uncertainty* (London: Royal Society, 2009), at 1.

9 Serge Planton (ed.), IPCC, 2013: Annex III: Glossary, in *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by T. F. Stocker et al. (Cambridge, UK: Cambridge University Press, 2013), at 1454.

10 Ibid.

11 Shepherd et al., supra note 8, at 51.

12 See Meinhard Doelle, 'Climate Geoengineering and Dispute Settlement under UNCLOS and the UNFCCC: Stormy Seas Ahead?', in *Climate Change Impacts on Ocean and Coastal Law: U.S. and International Perspectives*, edited by Randall S. Abate (Oxford: Oxford University Press, 2015), at 345ff.

13 Ken Caldeira, Govindasamy Bala, and Long Cao, 'The Science of Geoengineering', 41 *Annual Review of Earth and Planetary Sciences* 231–256 (2013); Gernot Klepper and Wilfried Rickels, 'The Real Economics of Climate Engineering', *Economics Research*

Currently, SAI is considered to be the most promising SRM technique in terms of its potential efficacy at cooling the climate.[14] This method entails releasing reflective aerosol particles into the middle atmosphere to increase the reflection of sunlight. Scientific understanding of SAI and its effectiveness is limited, and research to date has focused on modelling simulations. SAI could be deployed for a variety of reasons, and it is speculative to predict at this stage how it would be used.[15] If deployed at a large scale, the combination of elevated CO_2 conditions and SAI would create climatic conditions unlike those experienced in the past or those expected under unmitigated global warming, including changes in regional climate patterns. In addition, if SRM were exerting a significant cooling and were terminated for some reason, a rapid warming would follow that could give rise to substantial environmental harm. This 'termination shock' is one of the major risks of SAI, a risk shared with all other solar-radiation management techniques, and a risk that would persist during the entire period of implementation. In the event of unabated greenhouse gas emissions, in order to avoid the global increase of temperature that would follow, the intervention might have to be maintained for an indefinite amount of time. Even if mitigation were successful, it would still take hundreds, if not thousands of years for the concentration of greenhouse gases in the atmosphere to return to a level that would allow the termination of the intervention. The US National

International 1 (2012), at 20; Naomi Vaughan and Tim Lenton, 'A Review of Climate Geoengineering Proposals', 109(3–4) *Climatic Change* 1–46 (2011).

14 Olivier Boucher et al., 'Clouds and Aerosols', in *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Thomas Stocker, et al. (Cambridge, UK: Cambridge University Press, 2013), at 571–657.

15 For example, SAI has been proposed by some as a way to circumvent the failure of mitigating CO_2 or even as substituting for mitigation to some extent, since the direct costs might be very cheap compared to emission reductions. See Eric Bickel and Lee Lane, *An Analysis of Climate Engineering as a Response to Climate Change*, (http://faculty.engr.utexas.edu/bickel/Papers/AP_Climate%20Engineering_Bickel_Lane_v%205%200.pdf), at 51. Others frame it as a possible 'last resort' option or 'emergency strategy'; see David Victor et al., 'The Geoengineering Option: A Last Resort Against Global Warming?', 88(2) *Foreign Affairs* 64 (2009), at 64. Between these poles lies the possible need for a bridging technology or climate remediation method. For an overview of the different arguments raised in the debate, see Gregor Betz and Sebastian Cacean, *The Moral Controversy About Climate Engineering: An Argument Map* (version 2011-02-24; http://digbib.ubka.uni-karlsruhe.de/volltexte/1000022371).

Academy of Sciences recently coined this circumstance the 'millennial dependence risk'.[16]

Furthermore, even if SAI could be deployed as an effective means of reducing the overall physical risks of climate change globally, the salient point from an international-law perspective is that '[SAI] would introduce new risks and would shift the overall burden of risks',[17] and fundamental uncertainties would remain. Therefore, it is plausible that individual states would disagree about whether, and, if so, how SAI should be used, based on their differing views on the potential benefits, risks, and uncertainties. The situation could be exacerbated by the fact that SAI may be relatively 'fast and cheap' to use, and thus could potentially be deployed by a single state, or a small group of states acting on their own.[18] As a result, SAI could trigger international conflicts, as well as attempts to formally adjudicate such disputes. State responsibility is relevant to this problem as it relates to enforcement: it 'regulates the accountability of States under international law' and 'lies in the breach of obligations undertaken by States or imposed on them by international law'.[19]

From an international-law perspective, the idea of the use of a global technology, which may benefit some states, but harm others, without the agreement and cooperation of all, sits uncomfortably alongside (and is perhaps fundamentally incongruent with) the basic tenets of the international legal order. Classical international law was founded upon the notion of the reciprocal rights and obligations of states and their enforcement under the doctrines of sovereignty and equality.[20] The rules on state responsibility also reflect this 'bilateralist' emphasis.[21]

16 Cf. Peter Irvine, Ryan L. Sriver, and Klaus Keller, 'Tension Between Reducing Sea-Level Rise and Global Warming Through Solar-Radiation Management', 2(2) *Nature Climate Change* 97–100 (2012); US National Academy of Sciences, *Climate Intervention: Reflecting Sunlight to Cool Earth* (Washington, DC: National Academies Press, 2015), at 36.

17 Peter Irvine, Stefan Schäfer, and Mark Lawrence, 'Solar Radiation Management Could Be a Game Changer', 4(10) *Nature Climate Change* 842 (2014), at 842.

18 Shepherd et al., supra note 8, at 36, 40.

19 Patricia Birnie, Alan Boyle, and Catherine Redgwell, *International Law and the Environment* (Oxford: Oxford University Press, 2009), at 214.

20 The doctrine of the sovereignty and equality of states rests on three pillars: (1) jurisdiction over a territory, (2) the duty of non-intervention in an area in the exclusive jurisdiction of another state, and (3) the dependence of obligations arising from customary law and treaty on the consent of the obligator. See Ian Brownlie, *Principles of Public International Law* (Oxford: Clarendon Press, 1990), at 287.

21 Martti Koskenniemi, 'Doctrines of State Responsibility', in *The Law of International Responsibility,* edited by James Crawford, Alain Pallet, and Simon Olleson (Oxford: Oxford University Press, 2010), at 47–51.

This incongruity between the global conception of SAI and the mutual-rights-and-obligations paradigm of state responsibility is only one dimension examined in this article, which broadly deals with questions of the legal accountability of states for their use of climate-engineering measures. Specifically, the central questions addressed here are whether a state could be held internationally responsible for environmental harm arising from a large-scale climate intervention using SAI, and what legal consequences would flow from such a violation. State responsibility is also used here as a 'lens' through which to understand the limitations of the existing accountability framework under international law for SAI and the governance implications that arise from this analysis.[22]

In approaching these questions, we begin with a scientific overview of the potential efficacy, risks, and uncertainties associated with SAI. Following this is an analysis of the international law of state responsibility, which is a set of rules that flow from the commission of an international wrongful act by a state. State responsibility is premised on a breach of a primary norm for a state to be legally accountable under international law.[23] We focus on the possibility of a violation of the customary-law principle of prevention, while also considering the legal implications of its companion, the precautionary principle. We describe the elements of the international obligation of prevention, including the need for a foreseeable risk of significant harm to the environment of another state or to areas beyond national jurisdiction arising from a full-scale SAI deployment. Particular emphasis is placed on the legal implications of the termination effect, including in terms of the standard of care for a state to meet its due-diligence requirements. Furthermore, given the inherent complexity and natural variability of the climate system, the analysis pinpoints the legal requirement of causation, which could be fatal to the proof of a violation of the preventive principle. The article then turns to the issue of the legal consequences of a breach of the duty of prevention and the implementation of the law of state responsibility under international law. In particular, it highlights the obligation of cessation and the implications of *erga omnes* obligations owed to the international community as a whole.

22 See, generally, Jutta Brunnée, 'International Legal Accountability Through the Lens of the Law of State Responsibility', 36 *Netherlands Yearbook of International Law* 21–56 (2005).

23 International Law Commission, *Draft Articles on Responsibility of States for Internationally Wrongful Acts, With Commentaries*, II(2) Yearbook of ILC (2001), at. 32, 34, Articles 1, 2 (hereinafter ASR).

2 The Science of SAI: Perspectives, Risks, and Uncertainties

This section provides an overview of the technological and scientific principles of SAI, which are critically important to understand its potential repercussions and related risks and uncertainties.

SAI climate engineering would aim to cool the climate and thereby to reduce the risks of climate change, by introducing reflective aerosol particles into the stratosphere that would scatter light, increasing the planetary albedo, and cooling the climate.[24] Sulphate aerosols have been suggested as a likely candidate, as large explosive volcanic eruptions release millions of tons of sulphate aerosols into the stratosphere and have been observed to cause a significant, temporary cooling of the global climate. There are two main approaches that could be adopted to generate a stratospheric sulphate-aerosol cloud. First, a precursor sulphurous gas, such as sulphur dioxide, could be released in the stratosphere, which would then be oxidized over a period of days or months to form sulphuric acid, which would condense to form the aerosol particles.[25] Second, sulphuric acid could be released directly and then condense into particles promptly.[26] Solid particles of aluminium or titanium oxides, or even novel nanoparticles, are also under discussion. Beyond these common characteristics, each of these methods carries certain specific risks, as described below. Furthermore, due to effective mixing in the stratosphere, it is not possible to restrict the effects of the resulting aerosol cloud to a given region, such as within the borders of a single state.[27] As such, SAI would by its very nature entail a worldwide intervention in the global environment.

Current climate models suggest that the climate of a world with high GHG concentrations and a deployment of SAI would be more similar to that of a low-GHG world than a high-GHG world. One might therefore argue that SAI would

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24 Paul Crutzen, 'Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution To Resolve a Policy Dilemma?', 77(3) *Climatic Change* 211–220 (2006).

25 Patricia Heckendorn et al., 'The Impact of Geoengineering Aerosols on Stratospheric Temperature and Ozone', 4(4) *Environmental Research Letters* 045108 (2009).

26 Jeffrey R. Pierce et al., 'Efficient Formation of Stratospheric Aerosol for Climate Engineering by Emission of Condensable Vapour from Aircraft', 37(18) *Geophysical Research Letters* L18805 (2010).

27 Ulrike Niemeier, Hauke Schmidt, and Claudia Timmreck, 'The Dependency of Geoengineered Sulfate Aerosol on the Emission Strategy', 12(2) *Atmospheric Science Letters* 189–194 (2011); see also Alan Robock, Luke Oman, and Gregory L. Stenchikov, 'Regional Climate Responses to Geoengineering with Tropical and Arctic SO2 Injections', 113(D16) *Journal of Geophysical Research-Atmospheres* D16101 (2008).

help reduce the risks of climate change.[28] This notwithstanding, SAI also has significant limitations and undesirable consequences. There is no proof as of yet that SAI is technically feasible. Moreover, even if it turned out to be implementable at scale, it could only address some of the adverse effects of elevated GHG concentrations. It would not, for example, affect atmospheric CO_2 concentrations, which would carry the risk of ocean acidification.[29] It is also implausible that SAI could reverse all climate changes associated with rising GHG concentrations. Whilst it may be possible to restore the global mean temperature to some previous state, a deployment would likely produce a significantly altered climate state on the regional scale and affect other climate parameters which could result in environmental damage. For example, it appears that SAI would lead to a weakening of the global hydrological cycle, which could regionally exacerbate water scarcity for agricultural and human needs.[30] There are many potential impacts of SAI that are highly uncertain. Few studies have investigated the implications of SAI for the biosphere in terms of agricultural productivity or ecosystem impacts.[31] Because of the uncertainty that is related to SAI's implementation and the complexity of its interaction with a system as difficult to understand as the climate, it is questionable whether current climate models can foresee all of the implications of SAI.

Apart from changing global temperature and rainfall patterns, SAI is to some extent known to have a number of other consequences that could lead to claims of damage or the risk thereof:

- SAI will affect the chemistry of the stratosphere.[32] Such changes would have implications for the ozone layer and could lead to an increase in harmful UV

28 Ben Kravitz et al., 'Climate Model Response from the Geoengineering Model Intercomparison Project (GeoMIP)', 118(15) *Journal of Geophysical Research: Atmospheres* 8320–8332 (2013); Ulrike Niemeier et al., 'Solar Irradiance Reduction Via Climate Engineering: Impact of Different Techniques on the Energy Balance and the Hydrological Cycle', 118(21) *Journal of Geophysical Research: Atmospheres* 11905–11917 (2013).

29 See further, Global Ocean Commission, 'Climate Change, Ocean Acidification, and Geoengineering' (Policy Options Paper #2, 2013) (www.globaloceancommission.org/policies/climate-change-ocean-acidification-and-geo-engineering).

30 Angus J. Ferraro, Eleanor J. Highwood, and Andrew J. Charlton-Perez, 'Weakened Tropical Circulation and Reduced Precipitation in Response to Geoengineering', 9(1) *Environmental Research Letters* 014001 (2014).

31 Julia Pongratz et al., 'Crop Yields in a Geoengineered Climate', 2(2) *Nature Climate Change* 101–05 (2012); Elena Couce et al., 'Tropical Coral Reef Habitat in a Geoengineered, High-CO_2 World', 40(9) *Geophysical Research Letters* 1799–1804 (2013).

32 Caspar M. Ammann et al., 'Climate Engineering Through Artificial Enhancement of Natural Forcings: Magnitudes and Implied Consequences', 115(D22) *Journal of Geophysical*

radiation at the surface globally or in some regions. An increase in UV radiation could lead to an increased incidence of melanoma cancer and agricultural losses.[33]

- Similar to the effect of clouds, SAI will lead to less 'direct' light and a greater quantity of 'diffuse' light reaching the surface (i.e. the sky would appear hazier). The reduced intensity of direct sunlight would reduce the efficacy of solar-power collection, especially at concentrated solar power plants, which could result in economic losses.[34]
- The particles injected by SAI will sediment to the surface, and depending on their toxicity and other properties would cause impacts. For example, sulphate aerosols may induce acid rain and thereby harm ecosystems and human health. Fall-out of nanoparticles could similarly cause damage.

In relation to the termination effect, the IPCC has found with high confidence that 'surface temperature would increase rapidly [if SRM were terminated] to values consistent with the GHG forcing, which would stress systems sensitive to the rate of climate change'.[35] The rate and magnitude of the resultant warming would depend on how great a cooling effect SAI was exerting. If it was being conducted on a smaller scale of one- or two-tenths of a degree Celsius, the adjustment might be hard to notice given the natural variability in the global climate. If the amount of cooling exerted by SAI was larger, of the order of one or two degrees Celsius or more, large changes to climate patterns would manifest in a few years.[36] The related risks would include the full panoply of effects

Research-Atmospheres 1984–2012 (2010); Angus J. Ferraro, Eleanor J. Highwood, and Andrew J. Charlton-Perez, 'Stratospheric Heating by Potential Geoengineering Aerosols', 38(24) *Geophysical Research Letters* L24706 (2011).

33 Cf. G. Pitari et al., 'Stratospheric Ozone Response to Sulfate Geoengineering: Results from the Geoengineering Model Intercomparison Project (GeoMIP)', 119(5) *Journal of Geophysical Research: Atmospheres* 2629–53 (2014); UNEP, 'Environmental Effects of Ozone Depletion and its Interactions With Climate Change: 2014 Assessment', 14(1) *Photochemical and Photobiological Sciences* 9 (2015), (also available at: http://ozone.unep.org/Assessment_Panels/EEAP/eeap_report_2014.pdf).

34 Daniel M. Murphy, 'Effect of Stratospheric Aerosols on Direct Sunlight and Implications for Concentrating Solar Power', 43(8) *Environmental Science and Technology* 2784–86 (2009).

35 Thomas Stocker et al., 'Technical Summary', in *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Thomas Stocker et al. (Cambridge, UK: Cambridge University Press, 2013), at 98.

36 Andy Jones et al., 'The Impact of Abrupt Suspension of Solar Radiation Management (Termination Effect) in Experiment G2 of the Geoengineering Model Intercomparison Project (GeoMIP)', 118(17) *Journal of Geophysical Research: Atmospheres* 9743–52 (2013).

of global warming that SAI was intended to avoid, except that their onset would be faster, endangering individual species or entire ecosystems and causing economic, social, and political ramifications as societies struggle to adapt within a short amount of time. The impacts of termination would be exacerbated if the level of GHGs in the atmosphere continued to increase. This dependence on a sustained use of SAI is called the 'lock-in effect' of climate engineering.

Overall, it seems that SAI could have the potential to reduce, but certainly not eliminate, the risks associated with climate change. On the other hand, SAI carries substantial environmental risks (e.g. depletion of the ozone layer) and uncertainties of its own. Thus, any implementation of SAI could potentially be beneficial to some states and detrimental to others. To what extent would international law protect states from these environmental harms? Is there an international obligation that might limit or even prohibit an SAI deployment, and what would be the consequences of its breach?

3 State Responsibility Arising from a Breach of the Obligation of Prevention

A state's failure to comply with its primary obligations is governed by the customary rules of international law on state responsibility. The ILC's Articles on State Responsibility (ASR) provide a useful description of the law in this area,[37] with the caveat that in some cases the Articles would not be directly applicable to a specific issue in dispute without further proof of state practice.[38] Article 1 of the ASR declares that 'Every internationally wrongful act of a State entails the international responsibility of that State'. An act is 'wrongful' when it can be attributable to the state under international law[39] and constitutes a breach

37 Cf. ILC, supra note 23.

38 See David D. Caron, 'The ILC Articles on State Responsibility: The Paradoxical Relationship Between Form and Authority', 96(4) *American Journal of International Law* 857 (2002), at 857.

39 Article 2(a) of the ASR requires that the breach is attributable to the state. According to the Commentaries to Article 4, this requirement covers 'all the individual or collective entities which make up the organization of the state and act on its behalf'. Attribution of climate change harm to states is highly problematic. Cf. Myles Allen, 'Liability For Climate Change: Will it Ever Be Possible to Sue Anyone For Damaging the Climate?', 421(6926) *Nature* 891 (2003), at 891f. Attribution of SAI activities to the state of origin, on the other hand, is likely to be easier due to the potentially reduced group of actors involved.

of an international obligation of a state.[40] In short, legal responsibility flows from the breach of positive obligations undertaken by states or imposed on them by international law.[41] In environmental cases, responsibility typically results from the breach of a customary obligation of international law or from the breach of a treaty obligation.[42]

Although there is no treaty that specifically addresses SAI, of relevance are various provisions of multilateral environmental agreements such as the Vienna Convention for the Protection of the Ozone Layer,[43] the Convention on Long-Range Transboundary Air Pollution,[44] and the Convention on Biological Diversity.[45] Nevertheless, although several norms could be violated as a result of a SAI deployment, this section focuses on the potential breach of the customary-law obligation of prevention.

The obligation of prevention requires that states ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or of areas beyond the limits of national jurisdiction.[46] This is a

40 ASR, Article 2.

41 ASR, Articles 1–3.

42 Birnie et al., supra note 19, at 214.

43 Adopted 22 March 1985 (entered into force 22 September 1988), 1513 UNTS 293.

44 Adopted 13 November 1979 (entered into force 16 March 1983), 18 ILM 1442.

45 Adopted 5 June 1992 (entered into force 29 December 1993), 1760 UNTS 79. For an overview, see Ralph Bodle, 'Climate Law and Geoengineering', in *Climate Change and the Law*, edited by Erkki Hollo, Kati Kulovesi, and Michael Mehling (Heidelberg: Springer, 2013), at 450f.; Catherine Redgwell, 'Geoengineering the Climate: Technological Solutions to Mitigation: Failure or Continuing Carbon Addiction', 5(2) *Carbon and Climate Law Review* 178 (2011), at 181ff.

46 Declaration of the UN Conference on the Human Environment (Stockholm), UN Doc./A/CONF/48/14/Rev.1, Principle 21; Declaration of the UN Conference on Environment and Development (Rio), UN Doc./A/CONF.151/26/Rev.1, Principle 2; ILC, *Draft Articles on the Prevention of Transboundary Harm from Hazardous Activities* (hereinafter Prevention), II(2) ILC Report 148 (2001). Regarding the consideration of the obligation of prevention in international jurisprudence, cf. United States v. Canada, *Trail Smelter Arbitration*, 33 *AJIL* (1939) 182 and 35 *AJIL* (1941), at 684 (hereinafter *Trail Smelter*); ICJ, *Corfu Channel Case,* ICJ Reports 4 (1949), at 22 (hereinafter *Corfu Channel*). The duty to prevent is also referred to as the no-harm rule. Cf. Birnie et al., supra note 19, at 137. Birnie et al. prefer to call it a duty to prevent, since the obligation does not prohibit harm per se. The authors of this paper follow the view of Beyerlin and Marauhn, according to whom the no-harm rule is a coin with two sides, which includes both a prohibitive and a preventive element. Cf. Ulrich Beyerlin and Thilo Marauhn, *International Environmental Law* (Oxford: Hart, 2011), at 40. For a detailed analysis of the relationship between the prohibitive and the preventive elements and the decreasing relevance of the former, see Alexander Proelß, 'Das Urteil des Internationalen Gerichtshofs im Pulp-Mills-Fall und seine Bedeutung für die Entwicklung

general obligation of due diligence requiring that the deploying state would have to exercise due care to avoid, minimize, and reduce environmental and other damage through the use of SAI. Conditions for a breach include an increased risk of significant harm to the environment of another state or to areas beyond national jurisdiction. The degree of care expected of a deploying state is proportional to the degree of hazard involved, and the harm or risks must be foreseeable.[47] In the context of international dispute settlement processes, the burden would be on the claimant state to show a causal link between the SAI action and the increased risk of harm to the environment at the relevant evidentiary standard.[48] The scientific uncertainty associated with SAI also brings into play the closely related precautionary principle, which is relevant in instances where there is a lack of scientific certainty and a threat of serious or irreversible damage.[49] The following section provides a closer examination of a potential breach of the preventive principle from a large-scale climate intervention using SAI, while also taking into account the precautionary principle.

3.1 *Relationship Between the Principles of Prevention and Precaution*

The preventive principle applies to harm and risks that are 'known or knowable and are backed by strong scientific evidence'.[50] However, as discussed above, the science of SAI is fraught with uncertainties, including its potential to cause environmental harm. Thus, it may be difficult for a state to show a breach of the preventive principle given the requirement that it applies in instances where evidence of the risk and its linkage to the activity is substantial. On this basis, it is necessary to consider the legal relationship between the principles of prevention and precaution.

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des Umweltvölkerrechts', in *Dynamik und Nachhaltigkeit des Öffentlichen Rechts, Festschrift für M. Schröder*, edited by Matthias Ruffert (Berlin: Duncker and Humblot, 2012), at 611–625.

47 ILC, Prevention, supra note 46, at 155, para. 18.

48 The standard of proof that would be required is another area of legal uncertainty. In the *Pulp Mills* case, the ICJ required 'conclusive evidence' with respect to the preventive principle. See ICJ, *Case Concerning Pulp Mills on the River Uruguay*, Argentina v. Uruguay, ICJ Reports 14 (2010), para. 265 (hereinafter *Pulp Mills*). Regarding the standard of proof required by international courts and tribunals generally, see Separate Opinion of Vice-President Wolfrum, *The M/V 'Saga' Case,* Saint Vincent and the Grenadines v. Guinea, Judgment 4 December 1997, para. 7ff.

49 Rio Declaration, supra note 46, Principle 15.

50 ILA, Legal Principles Relating to Climate Change, Washington Conference (2014), commentaries to draft article 7 Prevention and Precaution, at 21–22, paras 1 and 2.

The legal regime of precaution is a more recent addition to international environmental law, aimed at 'adjusting the insufficiencies of the regimes of prevention' given the widespread growth and intensification of human activities and technologies, a lack of knowledge of the impact of such phenomena on ecosystems, and the need to anticipate serious or irreversible damage.[51] The close association between these related principles makes it difficult to define the dividing line between their implementation, so that 'increasingly … the two principles are treated as part of a continuum'.[52] The distinction lies in the extent of the evidence of harm from an activity. Thus the preventive principle applies where the probability of the risk can be proven scientifically, whereas the precautionary principle 'runs in advance' of prevention by calling for action to protect the environment before sufficient scientific evidence of harm can be furnished.[53] The precautionary principle has an obvious relevance to SAI since it covers circumstances where a potential risk arising from an activity can be identified, often using traditional risk analysis or scientific evaluation, but where scientific data is insufficient to demonstrate or quantify the risk or prove a cause-and-effect relationship between the activity and possible adverse effects.

Regarding the legal status of precaution in international law, ITLOS's Seabed Disputes Chamber, in its *Advisory Opinion on the Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area*, identified the precautionary principle as reflected in Principle 15 of the Rio Declaration to be 'an integral part of the due diligence of sponsoring States, which is applicable even outside the scope of the regulations', and further observed a 'trend towards making this approach part of customary international law'.[54] Presumably, then, the precautionary principle is folded into the standard of care required under the obligation of prevention, discussed below.

51 Ibid., commentaries to draft article 7, at 21–22, para. 1. See also Gerhard Hafner and Isabelle Buffard, 'Obligations of Prevention and the Precautionary Principle', in *The Law of International Responsibility,* edited by James Crawford, Alain Pallet, and Simon Olleson (Oxford: Oxford University Press 2010), at 525.

52 Cf. Hafner and Buffard, supra note 51, at 525.

53 David Freestone, 'Satya Nandan's Contribution to the Development of the Precautionary Approach in International Law', in *Peaceful Order in the World's Oceans: Essays in Honour of Satya N. Nandan,* edited by Michael W. Lodge and Myron H. Nordquist (Leiden: Brill, 2014), at 311–12; ILA, supra note 50, commentary to draft Article 7, para. 2.

54 ITLOS Seabed Disputes Chamber, *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area,* Advisory Opinion, 1 February 2011, 50 ILM 458, para. 135.

Rio's Principle 15 provides that 'Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.'[55] Thus, for the precautionary principle to be invoked, there would have to be, first, a 'threat of serious or irreversible damage', and, second, a 'lack of full scientific evidence'. ITLOS's *Advisory Opinion* on seabed mining clarifies that the relevant threshold of evidence for the application of the precautionary principle is 'plausible indications of potential risks'.[56]

Taking into account this 'theoretically sound'[57] description of the relationship between precaution and prevention, the analysis now turns to the breach of the preventive principle[58] from the creation of a risk of significant transboundary harm from the implementation of SAI.

3.2 *Risk of Significant Transboundary Harm*

What constitutes environmental harm or its risk depends upon the scope and content of the primary norm at hand. The OECD's definition of environmental harm—now commonly accepted[59]—is 'the introduction by man … of substances or energy into the environment resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems, and impair or interfere with amenities and other legitimate uses of the environment'.[60] 'Mere change' of the environment is not sufficient to constitute harm.[61] The ILC, in its commentary to its 2001 Draft Articles on Prevention of Transboundary Harm, states that 'risk of causing significant transboundary

55 See also UNFCCC, Article 3(3).

56 ITLOS Seabed Disputes Chamber, supra note 54, para. 131.

57 Arie Trouwborst, 'Prevention, Precaution, Logic and Law: The Relationship Between the Precautionary Principle and the Preventative Principle in International Law and Associated Questions', 02(02) *Erasmus Law Review* 105 (2009), at 119.

58 Cf. fn. 46.

59 Alexander Proelß, 'Raum und Umwelt im Völkerrecht', in *Völkerrecht*, 6th edition, edited by Wolfgang Graf Vitzthum and Alexander Proelß (Berlin: Walter De Gruyter, 2013), at 411.

60 OECD, Recommendation C(74)224 for the Council on Principles Concerning Transfrontier Pollution, Part A (Introduction). Another view in the legal literature defines harm as an 'emission of substances or particles to such a high degree in which it may become a danger to the health of human beings, the living resources, the ecosystem as well as the use of the environment'; see Rüdiger Wolfrum, 'Purposes and Principles of International Environmental Law', 33 *German Yearbook of International Law* 308 (1990), at 311.

61 Cf. Arie Trouwborst, *Precautionary Rights and Duties of States* (Leiden: Martinus Nijhoff, 2006), at 40; Markus Müller, *Die internationale Zuständigkeit bei grenzüberschreitenden Umweltbeeinträchtigungen* (Basel: Helbing and Lichtenhahn, 1994), at 13.

harm' refers to 'the combined effect of the probability of occurrence of an accident and the magnitude of its injurious impact'. This concept covers 'risks in the form of a high probability of causing significant transboundary harm and a low probability of causing disastrous transboundary harm'.[62] Furthermore, the risk of harm needs to meet the legally relevant threshold of 'significant',[63] meaning something more than detectable, but not necessarily serious.[64] The harm must also lead to real detrimental effects that must be measurable by factual and objective standards.[65]

Another issue is whether the environmental harm must have a transboundary element for the preventive principle to apply. The preventive principle does not cover harm that is located solely within the territory of a state within which the activity is conducted if there is no possibility of harm to any other state.[66] The question is whether it nevertheless applies to environmental harm of a global character, given that SAI entails the global modification of the global climate system and other components of the atmosphere, such as the ozone layer. The preventive principle can be traced back to the *Trail Smelter Arbitration*, a relatively simple case of bilateral transboundary air pollution.[67] This bilateral concept may not, however, be entirely apposite to global atmospheric problems. Regarding the legal status of the atmosphere, the ILC recently concluded in its First Report on the Protection of the Atmosphere that the atmosphere has the legal status of an international resource and that its protection is a common concern of humankind.[68] As a result, 'States can no longer claim that atmospheric problems are within the reserved domain of domestic jurisdiction because the issues now legitimately fall under "matters of international concern".'[69] Against this background, it could be argued, on the one hand, that the preventive principle does not apply to the global

62 ILC, Prevention, supra note 46, art 2. See also Roda Verheyen, *Climate Damage and International Law: Prevention Duties and State Responsibilities* (Leiden: Martinus Nijhoff, 2005) at 152.

63 ICJ, *Pulp Mills*, supra note 48, para. 101.

64 Cf. ILC, Prevention, supra note 46, Article 2, para. 4.

65 Cf. ibid.

66 ILC, Prevention, supra note 46, at 151.

67 Cf. *Trail Smelter*, supra note 46, at 1905–1982. See also the ILC Report on the Protection of the Atmosphere, UNGA A/CN.4/667, stating the scope of the rule derived from that case: 'The principle is recognized as customary international law as far as transboundary air pollution between adjacent countries is concerned to the extent that cause and effect can be proved with clear and convincing evidence'.

68 See further, ILC, First Report on the Protection of the Atmosphere, supra note 67, para. 90.

69 See further, ibid., para. 89.

environmental commons (i.e. shared resources), such as climate change,[70] which lack a 'true' transboundary character in the sense that the activities in one state's sovereign territory cause harm to another.[71] On the other hand, Verheyen points out that 'neither the decades of ILC debates on the issue of prevention of environmental harm nor international jurisprudence provide evidence that complex instances of environmental change are not to be covered by the general duty to prevent harm and minimise the risk thereof'.[72] Moreover, it is frequently recognized that the customary duty of prevention applies to 'areas beyond national control',[73] and may extend to cases of environmental harm from long-distance transboundary air pollution or global atmospheric pollution such as ozone depletion and climate change.[74]

At this point it can be assumed that some of the intended and unintended effects of SAI could qualify as meeting the threshold of significant transboundary harm. This may include the reduction of stratospheric ozone and the consequent increase in harmful UV radiation reaching Earth's surface, and changes to precipitation patterns that may lead to an increased occurrence of droughts and crop losses, depending on the magnitude and duration of the deployment of stratospheric SRM.

3.3 *Causation*

To recover for actual or anticipated damage under the preventive principle, there must be proof of a causal link between the activity in question and the risk of significant harm to the environment.[75] In assessing causation, scientists and lawyers focus on different aspects of the question. Whereas the scientific approach aims at the 'discovery of generalisations and the construction of

70 UNFCCC, preamble. See further, ILC, First Report on the Protection of the Atmosphere, supra note 67, paras. 86–90, Draft guideline 3(a), extending the common concern of humankind concept to the entire atmosphere.

71 See Prue Taylor, *An Ecological Approach to International Law: Responding to Challenges of Climate Change* (London: Routledge, 1998), at 56–58.

72 Verheyen, supra note 62, at 167. See further, ILA, supra note 50, commentaries to draft article 7, para. 5.

73 ICJ, Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion. 8 July 1996, ICJ Reports 226, para. 29 (hereinafter *Threat of Use of Nuclear Weapons*); cf. also Birnie et al., supra note 19, at 145.

74 ICJ, *Threat or Use of Nuclear Weapons*, supra note 70, para. 29. Cf. also Birnie et al., supra note 19, at 145. See further, Kerryn Brent, Jeffrey McGee, and Amy Maguire, 'Does the "No-Harm" Rule Have a Role in Preventing Transboundary Harm and Harm to the Global Atmospheric Commons from Geoengineering?', 5(1) *Climate Law* 35, at 49.

75 Proelß, supra note 59, para. 95; Verheyen, supra note 62, at 317–321.

general theories of causation',[76] the legal approach focuses on the construction of 'causal statements based on particulars'.[77] Narrowing down further, the requirements for legal construction are variable and uncertain,[78] such that there may be no 'specific established … requirement for determining causation in international law'.[79] However, a greater reliance on some theories by international courts and tribunals helps to shed light on the requirements for proving causation for a breach of the preventive principle from a large-scale climate intervention. Regarding legal approaches to causation, a distinction is made between factual causation (cause-in-fact) and normative causation.

A common approach used in domestic and international tribunals to determine a factual causal relationship is the 'but for test':[80] 'but for the act, there would be no loss, i.e. the act is an indispensable condition for the result'.[81] In complex cases, like climate change, general and specific factual causation are further differentiated. According to Haritz, general causation refers to the 'immediate cause of damage'.[82] In SAI deployment, the question is whether SAI in general has the abovementioned unintended effects; for example, whether an SAI deployment leads to changes in stratospheric ozone or changes in global precipitation patterns. Specific causation entails 'the more specific causal connection between the … activity in question and the particular damage'[83] or the risk thereof. A specific causal link would prove the connection

76 Verheyen, supra note 62, at 177.

77 Ibid., at 249.

78 Cf. Lucas Bergkamp, *Liability and Environment, Private and Public Law Aspects of Civil Liability for Environmental Harm in an International Context* (The Hague: Kluwer Law International, 2001), at 280.

79 Verheyen, supra note 62, at 251.

80 A different approach is the theory of contribution, according to which causation is established 'on the basis of a contribution to the problem from a specific actor, [while] the issue of how much of the damage might have been' is left to the apportioning of damage. See, in detail, Verheyen, supra note 62, at 254.

81 Ibid., at 253ff. The applicability of the but-for test is problematic in cases of cumulative or alternative cases of causation, the former referring to cases of various actors contributing to damage to the environment, without being solely responsible. Alternative causation refers to scenarios in which several activities by different actors could have caused the damage, yet uncertainty remains about which activity was actually decisive in realizing in damage.

82 Miriam Haritz, *An Inconvenient Deliberation: The Precautionary Principle's Contribution to the Uncertainties Surrounding Climate Change Liability* (Alphen aan den Rijn: Wolters Kluwer, 2011), at 177.

83 Ibid., at 178.

between the SAI deployment and a certain amount of ozone depletion over a specific region, or the specific change of precipitation; for example, an altered Indian monsoon. Second, it would be necessary to prove the connection, for instance, between the reduction in ozone and an increased incidence of skin cancer due to increased UV incidence, or the connection between the reduction in rainfall and agricultural losses due to reduced water availability.

Normative causation concerns the limits that the law places on the length of the causal chain to avoid responsibility for every condition contributing to a result of the wrongful act on the ground of fairness or proportionality.[84] Various theories exist to restrict liability in this regard.[85] For example, international tribunals have held states responsible only for the 'proximate and natural consequences of their acts'.[86] The theory of proximity aims at excluding damage that is too remote. However, the concepts and reasoning differ in the international and national contexts.[87] According to Faure and Nollkaemper, in international law, the criteria of normality and foreseeability are primarily applied to limit the scope of liability.[88] The test of normality is met whenever the 'normal and natural course of events indicates that the damage is a logical consequence of the act',[89] and that it is therefore proximate. The damage also needs to be reasonably foreseeable for the actor at the time of the conduct in question.[90]

Hence, a key question in making out a breach of the preventive principle is whether a causal link can be established between an SAI deployment and certain environmental effects, in general, or for specific harm or the risk thereof.[91] Though risks can be identified at this stage, there are uncertainties accumulating along the causal chain from general to specific that might not satisfy a given standard of proof. The next section begins with a description of the scientific methodology for proving causation-in-fact, and draws some general conclusions regarding the application of the legal tests to a hypothetical

84 Cf. Verheyen, supra note 62, at 295; Haritz, supra note 82, at 178.

85 Bergkamp, supra note 78, at 285; for a short overview of the different national normative approaches to causation see, Haritz, supra note 82, at 180 f.

86 Verheyen, supra note 62, at 297.

87 Ibid., at 297.

88 Cf. Michael Faure and André Nollkaemper, 'International Liability as an Instrument to Prevent and Compensate for Climate Change', 43A *Stanford Journal of International Law* 123 (2007), at 158; see also Haritz, supra note 82, at 183.

89 Faure and Nollkaemper, supra note 88, at 158.

90 Ibid.; see Haritz, supra note 82, at 183.

91 Alternatively, according to Haritz, causation is thought to be 'the most controversial issue in bringing a successful claim'. See Haritz, supra note 82, at 177.

SAI deployment, taking into account evidentiary issues, including the standard of proof.

3.3.1 Scientific Methodology for Establishing a Causal Link Between SAI Deployment and Increased Damage or Risk

The legal evidence for proof of a causal link entails a substantial fact-finding exercise.[92] Establishing such a link by applying the but-for test in a system as complex as the climate system requires a broad and deep understanding of the underlying science and its methodology. Thus, a general description of foundations of scientific detection and attribution is necessary to draw some conclusions on the general relationship between SAI and identified risks.

With respect to the global climate, the detection of change has been defined as 'the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense without providing a reason for that change'.[93] A change in climate is detected when the chances of a given variation arising due to short-term fluctuation alone are small.[94] Thus, a baseline must be defined that captures short-term fluctuation adequately and takes into account possible long-term trends. One difficulty with agreeing upon and describing such a baseline climate state is that Earth's climate is known to exhibit substantial variability on every timescale.[95] This means that even in well and lengthily observed regions, such as Northern Europe, standard climate conditions are difficult to define, as no time interval may be defined that is not subject to fluctuation and possibly long-term trends.[96]

92 Cf. Verheyen, supra note 62, at 249.

93 Gabriele C. Hegerl et al., 'Good Practice Guidance Paper on Detection and Attribution related to Anthropogenic Climate Change', in *Meeting Report of the Intergovernmental Panel on Climate Change Expert Meeting on Detection and Attribution of Anthropogenic Climate Change, IPCC Working Group I Technical Support Unit*, edited by Thomas Stocker et al. (Bern: University of Bern, 2010), at 2.

94 N. L. Bindoff et al., 'Detection and Attribution of Climate Change: From Global to Regional', in *Climate Change 2013: The Physical Science Basis: Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, edited by Thomas Stocker et al. (Cambridge, UK: Cambridge University Press, 2013), at 872ff.

95 Allen et al. frame it as follows: 'the first question that we would like the legal community to resolve: what is the appropriate baseline against which to quantify human influence on climate?' See Myles Allen et al., 'Scientific Challenges in the Attribution of Harm to Human Influence on Climate', 155(6) *University of Pennsylvania Law Review* 1353 (2007), at 1367.

96 See Bindoff et al., supra note 94.

Another challenge is that throughout the observational record multiple drivers of climate will have changed, including rising concentrations of GHGs, anthropogenic aerosol emissions, volcanic eruptions, land-use change, and natural variations in the solar cycle. This co-variation of different climate drivers makes it challenging to determine what the consequences of one particular driver of climate change have been. This combination of ubiquitous climate variability and the simultaneous variations of its multiple drivers means that the observation of a trend after the deployment of SAI, such as a decline in precipitation and increased intensity of droughts, would not in itself prove that SAI were to blame for the increased risk of harm.

Climate models may be used to test whether a given change in climate would have occurred if one particular factor had not been present,[97] by performing simulations in which that driver is included and others in which it is omitted, and examining which set of simulations is more consistent with observations. However, apart from the difficulty in defining a reference unperturbed baseline climate, there are two other key challenges to this approach that introduce uncertainty into all model-based attribution statements on climate change: first, the known limitations of climate models to predict and to reproduce climate phenomena; and, second, the fundamental problem that models are not reality, and that in consequence a match between model and reality does not constitute proof that it matches for the postulated reasons.

Attribution assessments would thus rely to a certain extent on expert judgment to evaluate and justify methodological assumptions, and to evaluate the significance of any potential shortcomings on the confidence level of attribution statements. However, the dependence on expert judgment opens up the potential for disagreement between experts, which may present a challenge for courts in terms of the evaluation of scientific evidence.[98]

Typically, detection and attribution studies assume that global-climate models correctly simulate the pattern of climate response for the drivers of climate change, but not their magnitude.[99] However, the detection and attribution of the effects of SAI with climate models would pose a new challenge, for it is, strictly speaking, a type of perturbation that has never occurred before.

97 See further, below, section 3.3.2, regarding the application of the but-for test to prove causation in fact.

98 See Joint Dissenting Opinion of Judges Al-Khasawneh and Simma, supra note 48, paras 2–17.

99 E.g. a simulation might predict an increase in rainfall over southern Europe combined with a decrease over northern Europe, though the magnitude of decrease and increase might be off by a factor of two.

If efforts to detect and attribute its consequences were to be made in the months and years immediately after deployment, there would be a much shorter observational record than for other attribution efforts, such as that concerning the role of GHGs in twentieth-century climate trends. In general, this would result in claims that are much less robust and confident, at least in the initial years and decades of deployment.

From the existing volcanic analogue, two main side effects may be expected to occur: ozone depletion and changes in local precipitation levels and patterns. The volcanic analogue is somewhat limited by the fact that the chemical composition of the SRM aerosol is different, and also that volcanic eruptions produce a transitory rather than a persistent climate forcing. From that point of view, qualitatively similar but quantitatively different side effects, as well as qualitatively different side effects, may be expected. Qualitatively different side effects, such as massive ozone depletion or a substantial change to the dynamics of the Asian monsoon, producing a response which is clearly outside the range of natural variability, will be relatively easy to diagnose a posteriori if they were to occur.

For quantitative changes to pre-existing phenomena, detection and attribution must be made statistically, in most cases combining observations with climate-model simulations. As a rule of thumb, the observational period required for detection, and the confidence in any attribution statement, will be inversely proportional with the intensity of the signal. In other words, the smaller the change in climate, the longer it will take to detect, and the lower the confidence in any attribution statement. However, if the expected response to a forcing has a certain 'fingerprint', such as a particular spatial or temporal pattern, which is distinct from patterns of natural variability or the fingerprint of other forcings, it may facilitate the detection and attribution of the signal. In this sense, the perturbation of stratospheric ozone in response to a major volcanic eruption (e.g. Mt Pinatubo in 1991) produces a clear fingerprint in as much as it is readily detectable as an abrupt perturbation, albeit its intensity is limited as it is comparable to the internal variability of the stratospheric ozone column on a decadal time scale. At this stage it is unclear how distinct the various responses to SAI will be. Stratospheric ozone, for instance, is known to constitute a complex system that is relatively insensitive to external changes. However, it may also be prone to abrupt changes, such as in relationship with the injection of water vapour.[100]

100 See J. G. Anderson et al., 'UV Dosage Levels in Summer: Increased Risk of Ozone Loss From Convectively Injected Water Vapour', 337(6096) *Science* 835 (2012), at 835ff., for an

Given the novel nature of any SAI deployment, the complexity of the climate system, and the limitations of climate models, projections of the response will be imperfect, and it is likely that some unexpected responses will occur. Under these circumstances, the ability to detect and attribute the responses to the deployment will be limited by a combination of the length of the observation period, the strength of the response, and by the distinctiveness of the fingerprint of the signal compared with other factors that affect the system. The diversity of the phenomena to be expected is such that their detection and attribution necessitates a case-by-case expert assessment of the appropriate approach to attribution and the degree of confidence in these assessments. The subjectivity of expert judgments in relation to the uncertainty around attributing changes in the climate system will often lead to a diminished certainty of the attribution statements that are made. It thus seems likely to lead to inconclusive or contested attribution findings in the case of fundamentally differing views, or when the expected changes are small in magnitude.[101]

However, this does not imply that no attribution statements can be made, bearing in mind the evidentiary requirements. Certain aspects of the anticipated response to SAI that are related to well-known and widely accepted scientific knowledge, or reveal a very characteristic fingerprint, are more likely to pass the but-for test:

- Climate changes: The ease of detecting and attributing changes in the climate due to SAI will depend on their magnitude. Very large changes to atmospheric circulation and precipitation patterns that are outside the range of natural variability, especially if previously observed in the context of volcanic eruptions, such as a persistent failure of the African or Indian monsoons, or a persistent drought over the Amazon, would be relatively easy to detect and attribute, possibly within one or a few years. However, more modest changes in climate, that would be harder to distinguish from natural variability, may take many decades to attribute.
- Ozone changes: The detectability and attribution of changes in the concentration of stratospheric ozone or in the quantity of UV reaching the surface would depend on how large the change is, and how clear its fingerprint is relative to natural inter-annual variability.
- Diffuse-light changes: There is a straightforward connection between SAI and a shift from direct to diffuse light, for the aerosols would scatter light

example of abrupt ozone depletion in relationship with water-vapour intrusions into the stratosphere.

101 On climate change damages, see Allen et al. supra note 95, at 1353–1400.

and such a shift should be readily detectable if the changes are large enough to give a sufficient signal-to-noise ratio relative to inter-annual variability.

- Particle deposition: The difficulty of detecting and attributing the effects of the deposition of injected particles, such as on ecosystems, would depend on the natural abundance and variability of the particles, which would be relatively high in the case of sulphates and non-existent in the case of a specially designed particle, but also on the sensitivity of the affected system to the particles.

3.3.2 Initial Conclusions Regarding the Proof of a Causal Link

There are various obstacles to establishing a causal link at the relevant evidentiary standard in order to show the risk of an SAI deployment resulting in significant transboundary environmental harm. Depending upon the circumstances, this may not always be possible, due to the complexity of the climate system, uncertainties relating to a lack of knowledge about its functioning, and the presence of a multitude of drivers that act within a system that experiences substantial natural variability on all timescales.[102]

From a legal point of view, the discussion on scientific attribution and detection of environmental risks shows that a causal link may be difficult to establish due to considerable scientific uncertainty and potentially conflicting expert opinions. It seems likely that it would require years, or even decades, to overcome the lack of observational data after an SAI deployment, which leads to the question of how a court would evaluate complex evidence that is essentially restricted to global-climate models and scientific testimony. This has already been identified as a problem with respect to climate change damages,[103] but in some respects it may be even more difficult to demonstrate causation to

102 With regard to the application of the but-for test, see René Lefeber, *Transboundary Environmental Interference and the Origin of State Liability* (The Hague: Kluwer Law International, 1997), at 90. According to Lefeber, due to the complicated physical and chemical processes involved, proving a *conditio sine qua non* is a 'tedious task'. There are different theories in domestic legal systems trying to derive 'from the "everything or nothing" notion of tort where a plaintiff will either win his case or lose it, but will normally not be able to receive partial justice'. See Verheyen, supra note 62, at 293f., for additional examples, such as the market-share theory or the German *Risikoerhöhungslehre*. Proving at least *partial causation* and attributing a certain share to a specific harm seems easier with these approaches, but until now they have not been commonly used by international courts and tribunals. Therefore, the authors will follow the but-for test as a first denominator in establishing a causal link.

103 See Allen et al. supra note 95, at 1355.

the relevant evidentiary standard for SAI, which would be partly due to the long observation periods necessary to robustly detect changes due to SAI. In their joint dissenting opinion in the *Pulp Mills* case, Judges Al-Khasawneh and Simma described the scientific analysis by the court as 'flawed methodologically' and criticized the usage of traditional rules on the burden of proof, in contrast with the use of expert assessments, which in their view was indispensable.[104] By contrast, the ICJ's treatment of the complex technical issues in the recent *Whaling in the Antarctic* case has been regarded more positively, and even hailed by some commentators as a 'model for separating scientific matters and the non-scientific agenda in other complicated disputes involving science, society and law'.[105]

Overall, under certain circumstances, general factual causation could be demonstrated for some kinds of risk. These general linkages could also be considered to be a logical consequence of the act, and thus foreseeable, such that they would also be causal in the normative sense. However, establishing proof of causation for specific risks would depend upon the relevant circumstances and would become increasingly difficult for those risks that lack a particular fingerprint, in particular, extreme weather events, such as droughts or floods.

To a certain extent the problems related to causation could be alleviated by, for example, easing the burden of proving causation or avoiding it altogether through the creation of a bespoke regulatory regime that addresses responsibility and liability for SAI, including the requisite standard of proof.[106] The

104 Cf. Judges Al-Khasawneh, Simma, Joint Dissenting Opinion, ICJ, *Pulp Mills*, supra note 48, at 1–3.

105 William de la Mare, Nick Gales, and Marc Mangel, 'Applying Scientific Principles in International Law on Whaling', 325(6201) *Science* 1125 (2014), at 1126. For a more critical perspective, see Sonia E. Rolland, 'International Convention for the Regulation of Whaling: Moratorium in the Southern Ocean Sanctuary: Scientific Evidence: Objective Assessment of Reasonable Exceptions', 108(3) *American Journal of International Law* 496 (2014), at 501.

106 For example, the Asilomar Conference called upon governments to 'clarify responsibilities for, and, when necessary, create new mechanisms for the governance and oversight of large-scale climate engineering research activities that have the potential or intent to significantly modify the environment or affect society. These mechanisms should build upon and expand existing structures and norms for governing scientific research and, in the event of damaging outcomes, establish who would bear the cost and the degree of liability and proof that are required.' Asilomar Scientific Organizing Committee, 'The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques' (Washington, DC: Climate Institute, 2010), at 9. See also Verheyen, supra note 62, at 362–63.

precautionary principle may play an important role here too. Although the ICJ in *Pulp Mills* simply states that the precautionary principle does not operate as a 'reversal of the burden of proof',[107] it may serve to lower the standard of proof to avoid all-or-nothing verdicts.[108] A change in the requirement of proof is also discussed for ultra-hazardous activities.[109] Being global in nature with regard to its effects, both intended and unintended, as well as the potential severity of some of the effects, an SAI deployment could easily fall into the category of an ultra-hazardous activity. However, state practice does not as yet seem to support a customary rule for a strict-liability regime for conducting ultra-hazardous activities[110] or for easing the shift of the burden of proof.[111]

3.4 *Standard of Care*

A wrongful act or omission occurs if the conduct of a state does not measure up to what is required of it by the obligation.[112] Thus, the determination of whether the primary obligation of prevention has been breached is not determined by secondary rules of state responsibility, but is to be judged by substantive requirements of the primary obligation itself.[113] An important question is what would be required of a state undertaking SAI in terms of its standard of

107 ICJ, *Pulp Mills*, supra note 48, para. 164.

108 Birnie et al., supra note 19, at 160; Caroline E. Foster, *Science and the Precautionary Principle in International Courts and Tribunals: Expert Evidence, Burden of Proof and Finality* (Cambridge, UK: Cambridge University Press, 2011), at 273; Miriam Haritz, supra note 82, at 306–309; Simon Marr, 'The Southern Bluefin Tuna Cases: The Precautionary Approach and Conservation and Management of Fish Resources', 11(4) *European Journal of International Law* 815 (2000), at 815.

109 Cf. Birnie et al., supra note 19, at 151.

110 With regard to the existence of a customary rule for strict liability for ultra-hazardous activities, cf. Alexandre Kiss and Dinah Shelton, *Guide to International Environmental Law* (Leiden: Martinus Nijhoff, 2007), at 28.

111 Interestingly, the Lugano Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment, 32 ILM (1993) 1228, which is not yet in force, sets up a regime where joint responsibility is imposed on the operators of a dangerous activity and where the burden of proof is put on the persons in control of the activity; cf. Kiss and Shelton, supra note 110, at 143. However, international courts have generally required 'enough evidence to establish at least a prima facie case'. See Birnie et al., supra note 19, at 158, with further references.

112 ASR, Article 12.

113 In the words of the ILC, 'It is [the primary obligation] which has to be interpreted and applied to the situation, determining thereby the substance of the conduct required, the standard to be observed, the result to be achieved, etc.'; supra note 23, at 54.

care to take 'reasonable efforts' to prevent environmental harm,[114] which is to be assessed objectively.[115] Although this analysis turns on the relevant circumstances of the case, some basic conclusions can be drawn from a hypothetical SAI deployment scenario. The preventive principle expresses the customary-law obligation of states to avoid or minimize environmental damage.[116] The obligation is one of due diligence,[117] which requires that states regulate and control activities within their territory or subject to their jurisdiction or control that pose a significant risk of environmental harm.[118] In other words, the relevant standard of care is an objective determination of the conduct expected of 'good government'.[119] The preventive principle is an obligation of conduct, and therefore does not equate with an absolute prohibition against causing environmental damage.[120] Rather, it is an obligation to take appropriate rules and measures to prevent or minimize environmental harm as much as possible.[121] The required due diligence of the state conducting the activity is proportionate to the degree of risk in the case at hand.[122] Put simply, the riskier the activity, the higher the standard of diligence. The degree of harm should be foreseeable, and the state must know, or should have known, that the activity concerned bears the risk of significant harm.[123]

Furthermore, the preventive principle is a 'compound obligation consisting of procedural and substantive duties'.[124] These procedural duties include the

114 Brunnée, supra note 22, at 27.

115 René Lefeber, 'Climate Change and State Responsibility', in *International Law in the Era of Climate Change*, edited by Rosemary Rayfuse and Shirley Scott (Cheltenham, UK: Edward Elgar, 2012), at 335.

116 The ICJ stated that this obligation 'is now part of the corpus of international law relating to the environment'. Cf. ICJ, Legality of the Threat or Use of Nuclear Weapons, supra note 73, at 242, para. 29. See also Brent et al., supra note 74, at 37f.

117 ILC, Prevention, supra note 46, Article 3 par. 8. See also ITLOS Seabed Disputes Chamber, supra note 54, para. 131; ICJ, *Pulp Mills*, supra note 48, para. 101.

118 Günther Handl, 'Transboundary Impacts', in *The Oxford Handbook of International Environmental Law*, edited by Daniel Bodansky et al. (Oxford: Oxford University Press, 2007), at 539; Beyerlin and Marauhn, supra note 46, at 40.

119 ILC, Prevention, supra note 46, Article 3 par. 17; Verheyen, supra note 62, at 174.

120 For a detailed analysis of the legal dispute on whether it is an obligation of result or conduct, cf. Brent et al., supra note 74, at 44f.

121 See ICJ, *Pulp Mills*, supra note 48, par. 197.

122 ILA, supra note 50, commentary to draft article 7A, paras 3, 10.

123 ILC, Prevention, supra note 46, Article 3, at 155.

124 Lefeber, supra note 102, at 66.

obligation to notify[125] and consult with potentially affected states, as well as to conduct an environmental impact assessment.[126] On the one hand, compliance with these procedural duties could be seen as 'evidence of diligent behaviour'.[127] On the other hand, it is to be acknowledged that 'non-compliance does not automatically entail a breach of the due diligence obligation'.[128]

The relevant standard of care is determined by the nature of the activity and is subject to the principle of proportionality.[129] For example, the ILC states in its Draft Articles on the Prevention of Transboundary Harm that

> activities which may be considered ultrahazardous require a much higher standard of care in designing policies and a much higher degree of vigour on the part of the state to enforce them. Issues such as the size of the operation; its location; special climatic conditions; materials used in the activity; and whether the conclusions drawn from the application of these factors in a specific case are reasonable, are among the factors to be considered in determining the due diligence requirement in each instance.[130]

According to the International Law Association in its commentary to its Legal Principles Relating to Climate Change, 'What is judged to be "riskier" will depend upon both the nature of the risks involved in a particular measure (for instance, geoengineering projects involving solar radiation management) and

125 Cf. ICJ, *Corfu Channel*, supra note 46, at 22, which stated that the obligation to notify is based inter alia on elementary considerations of humanity and on every state's obligation not to knowingly allow its territory to be used for acts contrary to the rights of other states.

126 Cf. ICJ, *Pulp Mills*, supra note 48, para. 204. According to the court, carrying out an EIA is to be considered 'a requirement under general international law, where there is a risk that the proposed … activity may have a significant adverse impact in a transboundary context'.

127 Lefeber, supra note 102, at 66.

128 Ibid., at 66. Interestingly, the ICJ further states in the *Pulp Mills* case that 'due diligence … would not be considered to have been exercised, if a party … did not undertake an environmental impact assessment'. Nonetheless, a breach of the obligation to notify and inform does not lead to a breach of the substantive obligation to prevent; cf. ICJ, *Pulp Mills*, supra note 48, para. 282. For a critique of the ICJ's understanding of the interplay of substantive and procedural rules in *Pulp Mills*, see Proelß, supra note 46.

129 ILC, Prevention, supra note 46, Article 3, at 155.

130 ILC, Prevention, supra note 46, Article 3, at 154.

the vulnerability to harm of affected States.'[131] It could be argued, for example, that, as an alternative, drastic mitigation strategies could be deemed more proportionate climate measures than a deployment of SAI.

Overall, many good arguments speak in favour of the highest standard of care with regard to an SAI deployment.[132] Obviously, scale and uncertainty are both factors here. Moreover, the stakes would be extremely high in undertaking a global intervention in a not-fully-understood Earth system. Given the possibility of serious or irreversible environmental harm, and notwithstanding scientific uncertainty, measures may be required that reflect 'abundant caution'.[133]

In particular, it is important to consider how the risk of a termination effect would bear upon the applicable standard of care under the duty of prevention. As stated above, some harms or risks of SAI are generally foreseeable in the sense that an objectively determinable risk can be identified at this point in time, taking into account the allowance for scientific uncertainty in line with the precautionary principle.[134] The IPCC, in the Fifth Assessment Report, assigned 'high confidence' to the prediction that, upon termination of some SRM deployment,[135] temperature, precipitation, and sea-ice cover would change considerably faster compared to rising CO_2 emissions without SRM.[136] From a socio-political standpoint, a decision to deploy reflects a certain kind of irreversibility in terms of a potential lock-in effect. Some authors suggest that 'The expectation that humankind would be able to continuously maintain a geoengineering effort at the required level for this length of time is questionable, to say the least.'[137] Given the risks associated with a termination effect,[138] including the impacts on ecosystems due to a rapid temperature increase,[139] a deploying state may be obligated to take measures to avoid this possibility by avoiding the implementation of SAI in the first place. The potential reasons for stopping an SAI deployment are, at this stage, a mere conjecture, but could

131 ILA, supra note 50, at 24.

132 ITLOS Seabed Disputes Chamber, supra note 54, para. 117. See also ILC, Prevention, supra note 46, Article 3, at 154, which suggests that activities which 'may be considered ultra-hazardous require a much higher standard of care in designing policies and a much higher degree of vigour on the part of the State to enforce them'.

133 ILC, Prevention, supra note 46, Article 3, at 155.

134 Birnie et al., supra note 19, at 153.

135 IPCC, supra note 35.

136 See Jones et al., supra note 36.

137 Ibid., at 9743–44.

138 Ibid.

139 Ibid.

include the manifestation of environmental 'surprises', a failure of the technology, or a breakdown in the governance arrangements that allowed deployment. The global nature of this technology suggests that legislative and administrative requirements, as well as appropriate enforcement mechanisms may need to be instituted at the international level. This raises the question of whether a 'good government' could ever meet the requisite standard of conduct if it deployed SAI unilaterally or 'minilaterally', without some form of general international agreement in place from the outset.

Furthermore, it is worth considering whether SAI activities would be so risky as to demand a due diligence that is so high that in effect it amounts to an absolute prohibition against a large-scale deployment.[140] In the *MOX Plant* and *Pulp Mills* cases, this kind of argument was raised, but was unsuccessful on the facts.[141] Still, it seems *a priori* possible that 'certain risks can never be rendered equitable if the costs to other states seriously outweigh the benefits to the state undertaking the project'.[142]

4 Risk-Risk Trade-Offs Relating to the Prevention of Significant Environmental Harm

As discussed, while SAI might offset some of the environmental risks of climate change, it could also give rise to new risks and uncertainties. The starting point for tackling these issues is the concession that almost all decision-making imposes risks of one kind or another,[143] and that such decisions are almost always subject to a degree of uncertainty. This includes the necessity to decide between different environmental goods or values, i.e. environment-environment trade-offs.[144] An example is the weighing of the risks of operating fossil-fuel power plants against nuclear power plants, or, in our case, the risks of climate change weighed against those of SAI. How do policy decisions involving risk-risk trade-offs manifest themselves and how can competing environmental objectives and values be reconciled under international

140 Birnie et al., supra note 19, at 150.

141 Cf. ITLOS, *MOX Plant Arbitration* (Jurisdiction and Provisional Measures) No. 10 (2001), paras 53–5; ICJ, *Pulp Mills*, supra note 48, paras 73–7.

142 Birnie et al, supra note 19, at 181.

143 Robert Hahn and Cass Sunstein, 'The Precautionary Principle as a Basis for Decision Making', 2(2) *The Economists' Voice* 2005 (also available at: http://ssrn.com/abstract=721122), at 3.

144 Cass Sunstein, 'Irreversibility', 9(3–4) *Law, Probability and Risk* 227 (2010), at 240.

law?[145] In legal terms, this balancing of environmental risks could be addressed at the stage of the breach of a primary norm, or under the secondary rules of state responsibility.

It is doubtful that the preventive principle itself provides a mechanism for weighing policy options that entail competing risk scenarios, namely, balancing the risks of climate change against SAI, which could render the potential wrongfulness of an SAI deployment lawful if shown to be outweighed by the risks of climate change. Several arguments speak against such an understanding. The ILC's Draft Articles on the Prevention of Transboundary Harm mention an equitable balancing of interests based on the principle of permanent sovereignty that states have the sovereign right to exploit their own resources.[146] However, such considerations might not apply here, since the Draft Articles do not deal with activities that are prohibited by international law.[147] This differentiation between lawful and unlawful activities and the respective balancing of interests is in line with the reasoning of special rapporteur Rao, who observed that the ILC's draft article 9, which requires states to enter into consultations with a view to achieving acceptable solutions regarding the measures to be adopted to prevent significant transboundary harm, 'was not intended to dilute the obligation of prevention enshrined in draft Article 3'.[148] Draft article 3 requires that states 'shall take all appropriate measures to prevent significant transboundary harm or at any event to minimize the risk thereof'. It has been deemed inappropriate to 'condition the threshold of significant harm to considerations of equitable sharing'.[149]

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145 Risk-risk trade-offs can be defined as 'cases where measures implemented to mitigate one risk to human health or the environment knowingly or unintentionally [create] another new risk equally or more problematic than the original risk.' See Steffen Hansen et al., 'The Precautionary Principle and Risk-Risk Trade-Offs', 11(4) *Journal of Risk Research* 423 (2008), at 424.

146 Draft Article 9 indicates that the states concerned shall enter into consultations with a view to achieving acceptable solutions regarding measures to be adopted in order to prevent significant transboundary harm. In particular, 'The States concerned shall seek solutions based on an equitable balance of interests in the light of article 10.' Draft Article 10 provides a non-exhaustive list of some relevant factors to be taken into account in this balancing exercise, including the degree of risk, the availability of means of preventing such harm, and the importance of the activity for the state of origin in relation to the potential harm for the state likely to be affected.

147 Cf. ILC, Prevention, supra note 46, Article 9, para. 2.

148 P. S. Rao, *Third Report on International Liability for Injurious Consequences Arising Out of Acts Not Prohibited by International Law*, UN Doc. A/CN4/510 (9 June 2000), at 11, para. 21. See also Handl, supra note 118, at 537.

149 Cf. Beyerlin and Marauhn, supra note 46, at 42, fn. 15.

Risk-risk trade-offs are also often discussed within the context of the precautionary principle. This principle has a clear relevance as a primary norm within the legal framework of prevention for balancing climate risks against the risks of individual climate measures like SAI, since any decision on deployment would surely involve uncertainty. However, the precautionary principle offers only limited guidance on how to navigate this weighing-up exercise. Even if some harm cannot be quantified, or some cause-effect relationships not fully demonstrated, it is widely recognized that a large-scale use of SAI could cause serious or irreversible damage to the environment, including through disruptions to the hydrological cycle, ozone layer, and biological productivity.[150] Under a conservative reading of the precautionary principle, a lack of full scientific certainty would not preclude a deploying state from taking measures to avoid, minimize, and reduce environmental damage from a large-scale climate intervention using SAI. However, SAI could also be presented as a precautionary measure with regard to the possible damage from climate change. Therefore, the principle 'embodies the core arguments for and against geoengineering'.[151] Views differ greatly with regard to its potential to guide decision-making in risk-risk situations. Being criticized as merely stating a truism,[152] or generally not being suited for trade-off situations, the precautionary principle can at least provide a framework by incorporating the criteria of adequacy and proportionality for taking policy action under conditions of uncertainty.[153] On balance, however, it is an open question whether the principle provides a 'sufficient legal tool for making essentially political decisions about conflicting objectives and managing risks'.[154]

Alternative approaches to risk-risk trade-offs such as conducting a cost-benefit analysis, which is also a consideration regarding the application of

150 See above section 2 and also Shepherd et. al., supra note 8, at 29 ff.

151 Bodle, supra note 45, at 460.

152 Cf., with further references, Gregory Mandel and James Gathii, 'Cost-Benefit Analysis Versus the Precautionary Principle: Beyond Cass Sunstein's Laws of Fear', 2006(5) *University of Illinois Law Review* 1037 (2006), at 1039.

153 Haritz, supra note 82, at 118; Douglas A. Kysar, 'It Might Have Been: Risk, Precaution, and Opportunity Costs', *Cornell Law Faculty Publications* (2006), (http://scholarship.law.cornell.edu/lsrp_papers/50), at 8 ff.

154 Bodle, supra note 45, at 460. See, on the other hand, Alexander Proelß, 'International Environmental Law and the Challenge of Climate Change', 66(53) *German Yearbook of International Law* 65 (2010), at 76ff., who proposes a multi-faceted operationalization of the precautionary principle to counteract the fragmentation of international environmental law. Instead of reducing it to the status of a norm of prohibition or obligation, the precautionary principle could be utilized as a procedural balancing mechanism to resolve norm conflicts between different environmental regimes.

precautionary measures,[155] reach their limits in complex cases like climate change. In such cases, acquiring the necessary amount of data presents a 'likely impossible task',[156] and due to the remaining level of uncertainty renders 'any such analysis statistically insignificant'.[157]

Another way in which the differing environmental objectives and values of states regarding the risks of SAI versus the risks climate change could be expressed is through a conflict of laws. This could occur with the invocation of conflicting norms of international law in dispute-settlement proceedings (e.g. conflicts between the rights and obligations contained in two different treaties or customary rules that apply between the same states).[158] For example, an interstate dispute could arise in which an injured state could claim a breach of the preventive principle due to SAI as laid down in one treaty, and, in response, a deploying state would claim that they had a conflicting obligation read within the context of the object and purposes of a different treaty to avoid or minimize the risks of climate change. It is likely that a full-scale SAI intervention into the global climate system could fall within the regulatory scope of most environmental treaties. By way of another example, one state could claim that it has an obligation to avoid dangerous climate change under the UNFCCC.[159] At the same time, another state could claim a breach of an obligation arising from SAI deployment relating to the duty to protect human health and the environment against the adverse effects of human activities that modify the ozone layer under the Vienna Convention on the Protection of the Ozone Layer.[160]

In general, international law does not prohibit conflicting obligations for states, nor does it preclude conflicting breaches by them.[161] Furthermore, aside

155 See European Commission, Communication from the Commission on the Precautionary Principle, COM(2000)1 (2 February 2001), at 19.

156 Mandel and Gathii, supra note 152, at 1045.

157 Ibid.

158 See Gabrielle Marceau, 'Conflicts of Norms and Conflicts of Jurisdiction', 35(6) *Journal of World Trade* 1081 (2001), at 1082.

159 Regarding the interpretation of the UNFCCC and climate engineering, see Bodle, supra note 45, at 456.

160 See Vienna Convention on the Protection of the Ozone Layer, Article 2. Cf. Rüdiger Wolfrum and Nele Matz, *Conflicts in International Environmental Law* (Berlin: Springer, 2003), at 11.

161 See further, James Crawford and Penelope Nevill, 'Relations Between International Courts and Tribunals: The Regime Problem', in *Regime Interaction in International Law: Facing Fragmentation*, edited by Margaret Young (Cambridge, UK: Cambridge University Press, 2012), at 236.

from interpretive techniques set out in articles 31 to 33 of the VCLT, there are no international conflict rules for resolving norm conflicts.[162] Beyond this, 'the rather frail way we resolve conflict is to remit it to the black box of State responsibility: in effect, conflict becomes a matter of remedies or reconciliation of "competing breaches" through circumstances precluding wrongfulness or through the vagaries of availability of remedies'.[163]

Turning then to the secondary rules under the state responsibility regime, could an SAI deployment, if considered a breach, be justified on the basis of a risk-risk trade-off? A breach of an international obligation is not considered wrongful if justified. Probably the most relevant circumstance precluding wrongfulness in the case of an SAI activity would be necessity, as set out in ASR article 25. According to article 25(1)(a), the defence of necessity can be invoked only if it is the only means for the state to safeguard an essential interest against a grave and imminent peril, and does not seriously impair an essential interest of the state or states towards which the obligation exists, or of the international community as a whole. The burden of proof would, according to general rules, rest on the deploying state. Furthermore, the deploying state could not invoke this defence if it has contributed to the situation of necessity.[164] Bearing in mind that the root problem is human-induced global warming, an environmental crisis that is caused by the entire state community, a deploying state might not be able to invoke necessity as a circumstance precluding wrongfulness under an SAI deployment scenario.[165]

Hence, it seems that there is no clear-cut answer regarding how to deal with risk-risk situations under international law. Dramatic climate change might call for an SAI deployment, while, at the same time, the same legal norm argues for a very cautious approach that avoids highly risky, global-scale interventions in the climate system. Guidance from customary international law is given by incorporating the criteria of adequacy and proportionality. Yet, as an alternative to a potentially precarious enforcement action under the regime of state

162 Wolfrum and Matz, supra note 160, at 147 ff., 210.

163 Crawford and Nevill, supra note 161, at 236–37.

164 ASR, Article 26(2)(b).

165 Cf. Bodle, supra note 45, at 461. The ICJ, in the *Gabčíkovo-Nagymaros Project Case*, considered that Hungary could not rely on preclusion of wrongfulness since it had 'helped, by act or omission to bring about' the situation of alleged necessity. Cf. ICJ, *Case Concerning the Gabčíkovo-Nagymaros Project*, Hungary v. Slovakia, Judgment, ICJ Reports 7 (1997), at 46, para. 57. However, perils that might prove to be imminent could be: loss of the Great Barrier Reef, permafrost thaw, ecosystem losses, the shift from seasonal to perennial pest species as winter frosts disappear, etc.

responsibility, if a global technology like SAI is ever used, the equitable balancing of interests and risks involved should be done through the general agreement of states. Also in this vein, coordination concerning a conflict of laws can best be achieved 'if a forum would be established that provides for a respective harmonization of either interpreting particular rules or coordinat[ing] implementation'.[166] In other words, the issues raised by risk-risk trade-offs of a global character speak against a state taking matters into its own hands via a unilateral deployment, and are better settled through appropriate regulatory supervision in advance through an internationally agreed mechanism.

5 Legal Consequences

In the absence of any specific provisions, the general rules of state responsibility determine the legal consequences that arise by virtue of the commission of an internationally wrongful act.[167] As a result of a breach of a primary norm, a new legal relationship arises between the responsible state and those states to whom the duty is owed that gives rise to new obligations under general international law.[168] The main legal consequences of an internationally wrongful act are the obligations of the responsible state to cease the wrongful act, to offer appropriate assurances and guarantees of non-repetition, if appropriate,[169] and to make full reparation for the injury caused by the internationally wrongful act.[170] The general obligation to make reparations concerns the remedies of restitution, compensation, and satisfaction.[171] However, in dispute-settlement proceedings, cessation is often a central issue of the dispute. Given this priority, this section focuses on the legal implications of the remedy of cessation in relation to a deployment of SAI.

State responsibility aims, above all, at restoring the legal relationship that has been affected by the wrongful act.[172] It seeks to rectify the situation in two ways. First, notwithstanding the breach, the previous primary obligation

166 Wolfrum and Matz, supra note 160, at 211.

167 Birnie et al., supra note 19, at 225.

168 These new legal relations arise without any condition of invocation by the injured stated. See ILC, supra note 23, at 88.

169 ASR, Article 30.

170 ASR, Article 31.

171 ASR, Article 34. See also Yann Kerbrat, 'Interaction Between the Forms of Reparation', in *The Law of International Responsibility*, edited by James Crawford, Allain Pellet, and Simon Olleson (Oxford: Oxford University Press, 2010), at 573.

172 ILC, supra note 23, at 88, para. 1.

remains intact, and thus the responsible state is under a continued duty to perform the obligation breached.[173] Second, the responsible state is under an obligation to cease the wrongful act or omission, if it is of a continuing character.[174] Generally, the cessation of wrongful acts is regarded as an 'essential obligation', the fulfilment of which is regarded to be 'in the interest of a wider community of States' in preservation of the rule of law under the international legal system.[175] The purpose of the remedy of cessation thus is to '[put] an end to a violation of international law and to safeguard the continuing validity and effectiveness of the underlying primary rule'.[176] Moreover, as discussed further below, cessation is not only an obligation that can be invoked by an injured state, but also by non-injured states or international organizations for claims made on behalf of the international community as a whole.[177]

Several important questions arise with regard to the legal consequences of a breach of duty of prevention from a large-scale intervention in the climate system using SAI, particularly given the possibility of a termination effect. Since aerosol particles would have to be continually injected into the stratosphere to maintain a global cooling effect for as long as GHG concentrations are elevated, SAI could be regarded as a continuing activity or one that entails repeated violations.[178] The primary legal consequence of a continuing breach of an international norm is the obligation to cease the activity,[179] and, in principle, as a remedy that applies to future events 'Cessation unlike restitution is always possible'.[180] However, cessation could result in a further risk of

173 ASR, Article 29.

174 ASR, Article 30.

175 Oliver Corten, 'The Obligation of Cessation', in *The Law of State Responsibility*, edited by James Crawford, Allain Pellet, and Simon Olleson (Oxford: Oxford University Press, 2010), at 546 f.

176 ILC, supra note 23, at 89, par. 5.

177 Ibid., at 89, paras 4–5.

178 Ibid., at 89, para. 3.

179 Cf. Corten, supra note 175, at 546; Marina Spinedi, 'Les conséquences juridiques d'un fait internationalement illicite causant un dommage à l'environnement', in *International Responsibility for Environmental Harm*, edited by Franscesco Francioni and Tullio Scovazzi (London: Graham and Trotham, 1991), at 86; Karl Zemanek, 'State Responsibility and Liability', in *Environmental Protection and International Law*, edited by Winfried Lang, Hanspeter Neuhold, and Karl Zemanek (London: Graham and Trotman, 1991), at 193; John Lammers, 'International Responsibility and Liability for Damage Caused by Environmental Interferences', 31(1) *Environmental Policy and Law* 42 (2001), at 45.

180 Corten, supra note 175, at 548. Regarding the distinction in law between the remedies of cessation and restitution, see ILC, Commentaries to ASR at 89, paras 7–8.

significant environmental damage in some locations, if it triggers a termination effect. A quick stoppage would produce an outcome that on the face of it runs counter to the very purpose of the preventive principle to not cause damage to the environment of other states or to areas beyond the limits of national jurisdiction. A slower termination would in principle allow ecosystems and human societies that are dependent upon them to adapt. On the other hand, continuation of SAI could lead to an unfair result by perpetuating the damage to the territory of the injured state, and may serve to undermine the fundamental principle of *pacta sunt servanda* in international law.[181] The question then becomes how the obligation of cessation would be interpreted if the wrongful act relating to the SAI deployment and a possible termination shock could not be precluded under one of the available defences (e.g. *force majeure*) by the deploying state.[182]

6 Implementation of State Responsibility

As signalled by the declaratory language of ASR article 1, state responsibility 'flows immediately from the commission of an international wrongful act without any need for action on the part of any injured state or entity'.[183] Nonetheless, the ASR also deal with the implementation of international responsibility, including the enforcement of claims asserted by states or the commencement of proceedings before an international court or tribunal.[184] This concerns the right of injured and non-injured states to take actions to invoke state responsibility and the forms of reparation available in such cases.

The law of state responsibility was originally premised on the classical bilateral right-duty formulation of interstate relations.[185] Traditionally, legal standing to bring international claims was restricted to injured states, which is dealt with in ASR article 42. This requirement does not likely present much of a barrier to the invocation of responsibility in interstate environmental disputes,

181 See Corten, supra note 175, at 546. The issue of the legality of the intervention would also turn upon developments in state practice over time.

182 Ibid.

183 James Crawford, 'Overview of Part Three on the Articles of State Responsibility', in *The Law of State Responsibility*, edited by James Crawford, Allain Pellet, and Simon Olleson (Oxford: Oxford University Press, 2010), at 935.

184 ASR, Part III.

185 Cf. James Crawford, *Third Report on State Responsibility*, UN Doc. A/CN.4 (507) 2000, at 25.

including arguably from the intentional modification of the global climate system using SAI.[186]

Breaches of international environmental law that affect only the global commons or collective state interests are considered 'more problematic'.[187] The traditional rules have had to accommodate a growing number of primary environmental obligations of a multilateral character, which aim at the protection of the collective common interests.[188] The use of SAI which alters the composition of the global atmosphere would without a doubt touch upon international community interests.

The issue is whether any state would have standing to hold a deploying state legally accountable for a breach of an international obligation arising from a large-scale climate intervention using SAI. In certain situations, international law recognizes the invocation of responsibility by states other than an injured state to seek enforcement for a violation of an international obligation owed to the international community as a whole.[189] ASR article 48 recognizes that a non-injured state can invoke the responsibility of another state if the obligation is owed to a group of states, including that state, and is for the protection of the collective interests of that group (*erga omnes partes*), or the obligation owed is to the international community as a whole (*erga omnes*).[190]

However, this category of public-interest standing reflected in article 48 is only partly developed, and is subject to certain limits under international law. For example, the ILC recently noted in its First Report on the Protection of the Atmosphere that it may be too early to interpret the concept of common concern as giving all states an interest in the legal enforcement of substantive obligations related to the protection of the atmosphere, given the lack of appropriate procedural law to implement such a requirement.[191] Furthermore, the ASR limit the remedies available to non-injured states to a requirement of cessation of the wrongful act, assurances and guarantees of non-repetition, and the performance of the obligation in reparation of the injured state or the beneficiaries of the obligation breached.[192] These restrictions could, for example, preclude recovery for harm to the global commons in the form of

186 See Birnie et al., supra note 19, at 232.

187 Ibid., at 233.

188 Ibid.

189 ICJ, Case concerning the *Barcelona Traction, Light and Power Company, Limited*, Belgium v. Spain, Judgment, 5 February 1970, ICJ Reports 3 (1970), at 32, para. 33. See also Brunnée, supra note 22, at 26.

190 ASR, Article 48.

191 ILC, supra note 23, at 89.

192 ASR, Article 49(2).

compensation. Furthermore, the implementation of state responsibility in dispute-settlement proceedings could be complicated by a larger number of litigants, for example if a claim was launched by a group of states or against another group of states which carried out the SAI deployment.[193]

In principle, if the obligation of prevention constitutes an obligation *erga omnes*, any state could have a cause of action against a deploying state, by claiming that it had breached its duty of prevention to enforce the collective interests of the international community as a whole. As such, it is possible that any state may have legal standing and require cessation on behalf of the international community as a whole.

7 Conclusions and Outlook

The prospect that SAI will create 'winners and losers'—a global technology that would entail a redistribution of the benefits, risks, and uncertainties of climate change—does not easily map onto the classical view of the international legal system. Grounded in a decentralized legal order concerning the reciprocal rights and obligations of sovereign states, the international rules on state responsibility were fashioned in a very different historical and legal context than the relations of the 'Brave New World' of deliberate, planetary-scale, climate interventions in the face of severe human-induced global warming.[194] Nevertheless, state responsibility still remains the 'paradigm form of responsibility on the international plane'.[195] As such, the regime provides a useful tool and the starting point for examining whether existing international law ensures effective accountability for environmental harm from large-scale climate-engineering measures such as SAI. This examination showed that although it is not entirely hopeless, there would be several hurdles in ensuring legal accountability for the risk of environmental harm from SAI under international law.

First, international responsibility flows from an internationally wrongful act of a state. Thus, if the applicable primary obligations are somehow lacking in terms of the protection of the environment, then the secondary rules on state accountability would not be triggered. This article focused on the possible

193 See Crawford, supra note 183, at 935–36.

194 See Scott Barrett, 'Solar Geoengineering's Brave New World: Thoughts on the Governance of an Unprecedented Technology', 8(2) *Review of Environmental Economics and Policy* 249 (2014).

195 Brunnée, supra note 21, at 55.

breach of the customary obligation of prevention, which requires that states ensure that activities within their jurisdiction or control do not cause damage to the environment of other states or to areas beyond their jurisdiction. International law sets a high bar for any state wishing to engage in a large-scale intervention in the climate system. The mere possibility that an SAI deployment would pose the risk of serious or irreversible harm argues in favour of a high standard of care for a state in meeting its obligation of due diligence. Moreover, a deploying state would also have to comply with its procedural obligations to conduct an environmental impact assessment, and to notify and consult potentially affected states. However, the requirement to show a causal link between the SAI intervention and the harm or risk thereof may be difficult to establish to the relevant evidentiary standard.

There are also deficiencies in the secondary rules.[196] One issue that arises regarding legal consequences concerns the obligation of cessation in view of the termination effect attributed to a rapid shut-down of SAI. Another challenge relates to the handling of multiparty international disputes[197] and the enforcement of obligations owed to the international community as a whole.[198] There is a strong case to be made that SAI touches upon such collective community interests, including the protection of the atmosphere as a common concern of humankind. However, whether there is effective procedural law to support the enforcement of *erga omnes* obligations relating to the atmosphere remains an outstanding issue.

Overall, it is questionable whether state responsibly as a 'backward-looking' enforcement mechanism is entirely appropriate for ensuring legal accountability for any large-scale climate intervention using SAI.[199] Any real-world deployment would be 'experimental' in the sense that it would be predominately based on the risks predicted in climate models and may entail limited controllability and unforeseen and irreversible harms.[200] The regime for state responsibility mainly aims at the 'protection of the legal order … the enforcement of international obligations [and] to physically restore the *status quo*

196 See further, ibid., at 53 f.

197 André Nollkaemper and Dov Jacobs, 'Shared Responsibility in International Law: A Conceptual Framework', 34(2) *Michigan Journal of International Law* 359 (2013), at 432.

198 Cf. Brunnée, supra note 22, at 30 ff.

199 James Crawford and Simon Olleson, 'The Nature and Forms of International Responsibility', in: *International Law, 3rd edition*, edited by Malcom Evans (Oxford: Oxford University Press, 2010), at 463.

200 Alan Robock et al., 'A Test for Geoengineering', 327(5965) *Science* 530 (2010), at 531f.

ante'.[201] Hence it may not be effective at facilitating legal accountability and safeguarding the rule of law in the face of deliberate environmental modification that cannot easily be reversed environmentally, and that could result in political lock-in. In other words, reliance upon the state-responsibility regime merely 'complements, but does not displace, the need for a system of regulatory supervision'.[202] The most important conclusion here is that, well before any such activities actually take place, further clarification is needed of legal responsibility and the creation is recommended of bespoke mechanisms of regulation and oversight of climate-engineering activities that would alter the climate system.[203]

201 C. Hoss, 'State Responsibility, Liability and Environmental Protection', in *Environmental Liability in International Law: Towards a Coherent Conception*, edited by Rüdiger Wolfrum, Christine Langenfeld, Petra Minnerop (Heidelberg: Max Planck Institute for Comparative Public Law and International Law, 2005), at 455.

202 Birnie et al., supra note 19, at 237.

203 Asilomar Scientific Organizing Committee, supra note 106, at 9.