State responsibility for environmental harm from climate engineering

David Reichwein,* Anna-Maria Hubert,* Peter J. Irvine,* Francois Benduhn,*
and Mark G. Lawrence*

Abstract. Some have proposed that climate engineering methods could be developed to offset climate change. However, it is predicted that some of these methods, in particular, stratospheric aerosol injection (SAI) as a form of solar radiation management (SRM), while potentially reducing the overall degree of global warming and some associated risks, are also likely to redistribute some environmental risks globally and could give rise to new risks, raising the issue of legal responsibility for transboundary harms 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 as a result. Examination of the applicability of the customary rules on state responsibility to SAI are also 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: International Law, Preventive Principle, Harm, Due Diligence, Causation, Termination Effect, Stratospheric Aerosol Injection, Geoengineering, Climate Engineering, Risk, Uncertainty

1. Introduction

The United Nations Framework Convention on Climate Change (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] 2014 has set a new record in global carbon dioxide (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 currently 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 sub-national levels. However, even

* David.Reichwein@iass-potsdam.de
* AnnaMaria.Hubert@iass-potsdam.de
* Peter.Irvine@iass-potsdam.de
* Francois.Benduhn@iass-potsdam.de
* Mark.Lawrence@iass-potsdam.de

1 United Nations, Treaty Series, vol. 1771, at 107 f.
2 Daniel H. Cole, ‘The Problem of Shared Irresponsibility in International Climate Law’, available at SSRN: http://ssrn.com/abstract=2291800, at 1.
3 Le Quéré, C., et al., ‘Global carbon budget 2014’, 7(2), *Earth Syst. Sci. Data Discuss.*, (2014), 521-610.
4 Cf. the Global Analysis of the National Oceanic and Atmospheric Administration at http://www.ncdc.noaa.gov/sotc/global/.

with immediate and decisive political action to reduce greenhouse gas emissions, the chances of limiting the global warming to two degrees Celsius by 2100 are in the meantime limited.[5]

Some have proposed that so-called 'climate engineering' measures could be developed to supplement the existing portfolio of response strategies for counteracting human-induced climate change.[6] In its recent Fifth Assessment Report, the IPCC defined climate engineering (also referred to as '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 distinct categories, seeking either to reduce the amount of absorbed solar energy in the climate system (solar radiation management, SRM), or attempting to increase net carbon sinks from the atmosphere at a scale sufficiently large to alter climate (carbon dioxide removal, CDR).[8] According to the IPCC, '[s]cale and intent are of central importance' as shared characteristics of all climate engineering technologies. The IPCC further clarifies that important concerns raised by climate engineering measures are that 'they 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.'[9] Therefore, if carried out at scale, all proposed climate engineering strategies could create 'winners and losers',[10] and thus research or the use of any one of them may give rise to interstate disputes.[11] However, some climate engineering methods have potential implications that make it different from others, including under international law.[12]

Currently, stratospheric aerosol injection (SAI) is considered to be the most promising SRM technique in terms of its potential efficacy at cooling the climate.[13] This method entails releasing reflective aerosol particles into the middle atmosphere to increase the reflection of

---

[5] Cf. Kevin Anderson, Alice Bows, 'Beyond "dangerous" climate change: emission scenarios for a new world, 369 *Philosophical Transactions of the Royal Society* 1934 (2011), 20 – 44, at 22 f.

[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) 137-145.

[7] S. Smith and P. Rasch, 'The long-term policy context for solar radiation management', *Climatic Change* (2013), doi:10.1007/s10584-012-0577-3, 1-11.

[8] John Shepherd et al., *Geoengineering the Climate: science, governance and uncertainty,* (London: The Royal Society, 2009) at 1.

[9] S. 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 Stocker, T.F.et al. (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2013).

[10] Shepherd et al., supra note 8, at 51.

[11] 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 and Kundis Craig (Oxford: Oxford Sholarship, 2015) at 345 ff.

[12]Ken Caldeira, G. Bala and L. Cao, 'The Science of Geoengineering', 41(1) *Annual Review of Earth and Planetary Sciences* (2013), doi:doi:10.1146/annurev-earth-042711-105548, 231-256; Gernot Klepper and Wilfried Rickels, 'The Real Economics of Climate Engineering', *Economics Research International* (2012), doi:10.1155/2012/316564, at 20; N. Vaughan and T. Lenton, 'A review of climate geoengineering proposals', *Climatic Change* (2011), doi:10.1007/s10584-011-0027-7, 1-46.

[13] 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, United Kingdom and New York, NY, USA: Cambridge University Press, 2013) at 571 - 657.

sunlight. However, 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.[14] If deployed at a large-scale, the combination of elevated CO_2 conditions and SAI would create climate 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 concerns about employing SAI as a means to reduce climate risks, including that it could lock future generations into maintaining the intervention to avoid the harms of a rapid increase in global temperature.[15]

However, 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',[16] 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 SIA may be relatively 'fast and cheap' to use, and thus could potentially be deployed by a single State or small group of States acting on their own.[17] As a result, SAI could trigger many types of international conflicts, including the formal adjudication of international 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.'[18]

From an international law perspective, the idea of the use of a global technology, which may benefit some States, but harm some others, without the agreement and cooperation of all, sits uncomfortably alongside (and is perhaps fundamentally incongruent with) the basic tenants 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

---

[14] For example, SAI has been proposed by some as a way to circumvent the failure of mitigating CO_2 or even replace it to some extent, since the direct costs might be very cheap compared to emission reductions. See Erick Bickel and Lee Lane, *An Analysis of Climate Engineering as a Response to Climate Change*, (available at: 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.' David Victor et al., 'The Geoengineering Option: A Last Resort Against Global Warming?', 88(2) *Foreign Affairs* (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, cf. Gregor Betz and Sebastian Cacean, *The moral controversy about Climate Engineering – an argument map*, (version 2011-02-24; available at: http://digbib.ubka.uni-karlsruhe.de/volltexte/1000022371).

[15] Peter Irvine, R. L. Sriver, and K. Keller, 'Tension between reducing sea-level rise and global warming through solar-radiation management', 2(2) *Nature Clim. Change* (2012), doi:10.1038/nclimate1351, 97-100.

[16] Peter Irvine, Stefan Schäfer, and Mark Lawrence, 'Solar radiation management could be a game changer', 4(10) *Nature Clim. Change* (2014), doi:10.1038/nclimate2360, at 842.

[17] Shepherd et al., supra note 8, at 36, 40.

[18] Patricia Birnie, Alan Boyle, Catherine Redgwell, 3rd ed. *International Law & the Environment* (Oxford: Oxford University Press, 2009), at 214.

doctrines of sovereignty and equality.[19] The rules on state responsibility also reflect this 'bilateralist' emphasis.[20]

This incongruity between the global conception of SAI and the mutual-rights and obligation 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 actions regarding the use climate engineering measures. Specifically, the central question addressed here is whether a State could be held internationally responsible for environmental harm arising from a large-scale climate intervention using SAI and the legal consequences that would flow from such a violation. State responsibility is also used as a 'lens' for understanding the limitations of the existing accountability framework under international law for SAI and the governance implications that arise from this analysis.[21]

In approaching these questions, this article begins 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 secondary set of rules that flow from the commission of an international wrongful act by a State. In other words, state responsibility is premised on a breach of a primary norm for a State to be legally accountable under international law.[22] This article focuses on the possibility of a violation of the customary law principle of prevention, also considering the legal implications of its companion precautionary principle. It describes 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 prove to be fatal to showing a violation of the preventive principle. The paper then turns to the issue of the legal consequences of the 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.

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

In this section we will give an overview on the technological and scientific principles of SAI, which are critically important to understand its potential repercussions and related risks and

---

[19] The doctrine of the sovereignty and equality of States rests on three pillars: (1) jurisdiction, over a territory and its pollution, (2) the duty of non-intervention in the area the exclusive jurisdiction of other states, 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*, 4th ed. (Oxford: Clarendon Press, 1990), at 287.

[20] 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.

[21] See generally Jutta Brunnée, 'International legal accountability through the lens of the law of state responsibility', 36 *Netherlands Yearbook of International Law* (2005); 21-56.

[22] UNGA A/RES/56/83 of 12 December 2001; International Law Commission, *Draft Articles on Responsibility of States for Internationally Wrongful Acts, with commentaries*, Yearbook of International Law Commission, 2001, vol II, Part Two, Articles 1, 2 (DASR).

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.[23]

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. Firstly, a precursor sulphurous gas, such as sulphur dioxide, could be released in the stratosphere which oxidises over a period of days to months to form sulphuric acid which condenses to form the aerosol particles.[24] Secondly, sulphuric acid could be released directly, which would condense into particles promptly.[25] Solid particles of aluminium or titanium oxides, or even novel nano-particles are also under discussion. Beyond these common characteristics, each of these methods carries a certain number of 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.[26] As such, SAI would by its very nature entail a worldwide intervention in the global environment.

Current climate model simulations 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 help reduce the risks of climate change as it efficiently counteracts the global average temperature rise due to greenhouse gas emissions.[27] This notwithstanding, SAI also has significant limitations and undesirable consequences. SAI is still only a hypothetical technique; there is no proof as of yet that it is technically feasible. Moreover, even if it turned out to be implementable to scale, it could only address some of the adverse effects of elevated GHG concentrations in the atmosphere. It would not, for example affect the increase of the atmospheric carbon dioxide concentration, which carries the risk of ocean acidification.[28] It is also implausible that SAI could reverse all climate changes from rising GHG concentrations. Whilst it may be possible

---

[23] Paul Crutzen, 'Albedo enhancement by stratospheric sulfur injections: A contribution to resolve a policy dilemma?', 77 *Climatic Change* (2006), at 211-219.
[24] Patricia Heckendorn, et al., ‚The impact of geoengineering aerosols on stratospheric temperature and ozone', 4(4) *Environmental Research Letters*, (2009).
[25] Pierce et al., 'Efficient formation of stratospheric aerosol for climate engineering by emission of condensable vapour from aircraft,' 37 *Geophysical Research Letters* (2010).
[26] Ulrike Niemeier, Hauke Schmidt and Claudia Timmreck, 'The dependency of geoengineered sulfate aerosol on the emission strategy, 12(2) *Atmospheric Science Letters* (2011), doi:10.1002/asl.304, 189-194. See also Alan Robock, L. Oman, and G. L. Stenchikov, 'Regional climate responses to geoengineering with tropical and Arctic SO2 injections', 113(D16) *Journal of Geophysical Research-Atmospheres* (2008), D16101, doi:10.1029/2008jd010050.
[27] Ben Kravitz, et al., 'Climate model response from the Geoengineering Model Intercomparison Project (GeoMIP)', *Journal of Geophysical Research: Atmospheres* (2013), n/a-n/a, doi:10.1002/jgrd.50646; 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* (2013), doi:10.1002/2013JD020445.
[28] See further Global Ocean Commission, 'Climate Change, Ocean Acidification, and Geo-engineering' (Policy Options Paper #2 November 2013) (available at: http://www.globaloceancommission.org/policies/climate-change-ocean-acidification-and-geo-engineering).

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 with respect to other climate parameters, which could result in environmental damage. For example, according to state of the art scientific knowledge, 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.[29] The full repercussions of SAI remain largely uncertain at this stage. For instance, few studies have investigated the implications of SAI for the biosphere in terms of agricultural productivity or ecosystem impacts.[30] In fact, it is entirely questionable whether current climate model simulations may foresee all of the implications of SAI due to the uncertainty that is related to its actual implementation and the complexity of its interaction with a system that is as difficult to understand as the climate system.

Apart from changing global temperature and rainfall patterns, SAI is at least 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.[31] Such changes would have implications for the ozone layer and could lead to an increase in harmful UV 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.
- Similar to 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 concentrated solar power plants, and hence economic losses.[32]
- The particles injected by SAI will sediment to the surface, and depending on their toxicity and other properties would cause impacts. Sulphate aerosols may, for example, induce acid rain and thereby harm both ecosystems and human health. Fall-out of nano-particles could similarly cause damage.

Another fundamental risk of SAI or any other form of SRM is the so-called ‘termination effect.’ The IPCC recently stated with *high confidence* that ‘surface temperature would increase rapidly [if SRM were terminated for any reason] to values consistent with the greenhouse gas forcing, which would stress systems sensitive to the rate of climate change’.[33]

---

[29] A. J. Ferraro, E. J. Highwood, and A. J. Charlton-Perez, ‘Weakened tropical circulation and reduced precipitation in response to geoengineering’, 9(1) *Environmental Research Letters* (2014), 014001.
[30] Julia Pongratz, et al., ‘Crop yields in a geoengineered climate’, 2(2) *Nature Clim. Change* (2012), 101-105; E Couce et al., ‘Tropical coral reef habitat in a geoengineered, high-CO2 world’, *Geophysical Research Letters* (2013), n/a-n/a, doi:10.1002/grl.50340.
[31] C. M. Ammann et al., ‘Climate engineering through artificial enhancement of natural forcings: Magnitudes and implied consequences’, 115 *Journal of Geophysical Research-Atmospheres* (2010), doi:10.1029/2009jd012878; A. J. Ferraro, E. J. Highwood and A. J. Charlton-Perez, ‘Stratospheric heating by potential geoengineering aerosols’, 38 *Geophysical Research Letters* (2011), doi:10.1029/2011gl049761.
[32] D. M. Murphy, ‘Effect of Stratospheric Aerosols on Direct Sunlight and Implications for Concentrating Solar Power’, 43(8) *Environmental Science & Technology* (2009), doi:10.1021/es802206b, 2784-2786.
[33] 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*

The rate and magnitude of the resultant warming would depend on how great a cooling SAI were exerting at the time it failed or were stopped. If it was conducted on a smaller scale of one or two tenths of a degree Celsius, the adjustment may be hard to notice, given the large natural variability in the global climate. However, if the amount of cooling exerted by SAI was larger, of the order of one or two degrees Celsius or more, then large changes to climate patterns would already be evident within one to a few years.[34] The related risks would include the full panoply of effects of global warming that SAI was intended to avoid in the first place, with the notable difference that the timescale of their onset would be significantly shorter. The impacts of termination would be exacerbated if the levels of greenhouse gases in the atmosphere continued to increase. This dependence on a sustained use of SAI is what is called the 'lock-in effect' of climate engineering. Furthermore, a rapid increase in temperature would pose additional threats, endangering individual species or entire ecosystems. Finally, this termination effect would have economic, social and political ramifications as societies would struggle to adapt within an unprecedentedly short amount of time.

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, whilst it would be detrimental to others. The question is then whether and the extent to which international law would protect States from environmental harms they would endure. In other words, 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 the Breach of the Obligation of Prevention

A State's failure to comply with its primary obligations is governed by the secondary customary rules of international law on state responsibility. The ILC's Draft Articles on State Responsibility (DASR) provide a useful description of the law on state responsibility,[35] with the caveat that in some cases the Draft Articles would not be directly applicable to a specific issue in a dispute without further proof of state practice.[36] Article 1 of the DASR declares that '[e]very 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,[37]

Change, edited by Thomas Stocker et al (Cambridge UK and New York, NY, USA: Cambridge University Press 2013), 7-64, at 98.

[34] 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 *Journal of Geophysical Research: Atmospheres* (2013), at 9743-9752.

[35] Cf. ILC, supra note 22.

[36] See David D. Caron, 'The ILC Articles on State responsibility: The paradoxical relationship between form and authority', 96 *American Journal of International Law* (2002) at 857.

[37] Article 2(a) of the DASR 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 *Nature* (2003), at 891 f. 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.

and constitutes a breach of an international obligation of a State.[38] In short, legal responsibility flows from the breach of positive obligations undertaken by States or imposed on them by international law.[39] In environmental cases, responsibility will typically result from the breach of one or more customary obligations of international law or arise from the breach of a treaty obligation.[40]

While there is no treaty that specifically addresses SAI, the preceding scientific analysis indicates that, given the potential for significant adverse effects and uncertainties resulting from a large-scale use of SAI, various international obligations may be at issue. This includes various provisions laid down in multilateral environmental agreements such as the Vienna Convention for the Protection of the Ozone Layer,[41] the Convention on Long-Range Transboundary Air Pollution,[42] and the Convention on Biological Diversity.[43] Therefore, although other primary norms exist that could be violated as a result of a SAI deployment, this section focuses on the potential breach of the customary international law obligation of prevention giving rise to state responsibility under international law.

The customary international law 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. [44] This is a 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. Several elements of the obligation have to be met before a breach occurs, including the 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 would be proportional

---

[38] Article 2 DASR.
[39] Articles 1-3 DASR.
[40] Birnie et al., supra note 18, at 214.
[41] Adopted 22 March 1985, (entered into force 22 September 1988) 1513 UNTS 293.
[42] Adopted 13 November 1979, (entered into force 16 March 1983) 18 ILM 1442.
[43] 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*, 21 Ius Gentium: Comparative Perspectives on Law and Justice, edited by Erkki Hollo, Kati Kulovesi and Michael Mehling (Heidelberg: Springer, 2013) 447-470, at 450 f.; Catherine Redgwell, 'Geoengineering the Climate: Technological Solutions to Mitigation – Failure or Continuing Carbon Addiction', 2 *Carbon and Climate Law Review* (2011), 178-189, at 181 ff.
[44] Declaration of the United Nations 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; International Law Commission (ILC), Draft Articles on the Prevention of Transboundary Harm from Hazardous Activities (Prevention), ILC Report (2001) GAOR A/56/10, 366-436. Regarding the consideration of the obligation of prevention in international jurisprudence, cf. United States vs. Canada, *Trail smelter arbitration*, 33 AJIL (1939) 182 & 35 AJIL (1941) 684,*; ICJ, Corfu Channel Case*, ICJ Reports (1949) 1. The duty to prevent is also referred to as No-Harm-Rule. Cf. Birnie et al., supra note 18, 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, including a prohibitive and a preventive element. Cf. Ulrich Beyerlin and Thilo Marauhn, *International Environmental Law* (Oxford: Hart Publishing, 2011), at 40. For a detailed analysis of the relationship between the prohibitive and the preventive element 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 des Umweltvölkerrechts, in Dynamik und Nachhaltigkeit des Öffentlichen Rechts, Festschrift für M. Schröder, edited by Matthias Ruffert, (Berlin 2012), at 611-625.

to the degree of hazard involved and the harm or risks must be foreseeable.[45] 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 to the relevant evidentiary standard.[46] 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.[47] This section provides a closer examination of a potential breach of the preventive principle from a large-scale climate intervention using SAI, also taking into account the precautionary principle as a first step in understanding the implications for state responsibility.

3.1. Relationship between the Companion 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.'[48] 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.

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.[49] The close association between these related principles makes it difficult to define the dividing line between their implementation such that 'increasingly […] the two principles are treated as part of a continuum.'[50] The distinction lies in the extent of the evidence of harm from an activity: 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 fully furnished.[51] Thus, the precautionary principle has obvious relevance to SAI since it

---

[45] ILC, Prevention, supra note 44, at 155, para 18.

[46] 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* (*Pulp Mills Case)*, Argentina vs. Uruguay, Judgment, 20 April 2010, para 265. Regarding the standard of proof required by international courts and tribunals generally, see, Rüdiger Wolfrum, Separate Opinion, *The M/V 'Saga' Case,* Saint Vincent and the Grenadines vs. Guinea, Judgment 4 December 1997, para 7 ff.

[47] Rio Declaration, supra note 44, Principle 15.

[48] 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.

[49] 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.

[50] Cf. Hafner and Buffard, supra note 49, at 525.

[51] 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

covers circumstances in which a potential risk arising from an activity can be identified, often using traditional risk analysis or scientific evaluation, but scientific data is insufficient to fully demonstrate or quantify the risk or to prove a cause and effect relationship between the activity and possible adverse effects.

Regarding its legal status in international law, the ITLOS 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 precaution 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.'[52] Presumably then, the precautionary principle is folded into the standard of care required under the obligation of prevention, discussed below.

Principle 15 of the 1992 Rio Declaration on Environment and Development states: '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.'[53] Thus, for the precautionary principle to be invoked, there would have to be, firstly, a 'threat of serious or irreversible damage', and, secondly, a 'lack of full scientific evidence.' The language of the second requirement is unclear in terms of what level of evidence is required to trigger the precautionary principle. The Seabed Disputes Chamber's *Advisory Opinion* also clarifies in that case that the relevant threshold of evidence for the application of the precautionary principle is 'plausible indications of potential risks.'[54]

Taking into account this 'theoretically sound'[55] description of the relationship between precaution and prevention, the analysis now turns to the breach of the preventive principle arising from the 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 scope and content of the primary norm at hand. The OECD defined environmental harm – a definition that is, by now, commonly accepted[56] – as '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

---

Michael W Lodge and Myron H Nordquist (Leiden, The Netherlands: Brill 2014) at 311-12; ILA, supra note 48, commentary to draft Article 7, para 2.

[52] 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.

[53] See also UNFCCC, Art 3(3).

[54] ITLOS Seabed Disputes Chamber, supra note 52, para 131.

[55] 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* (2009), at 119.

[56] 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. A widespread view in 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", cf. Rüdiger Wolfrum, 'Purposes and Principles of International Environmental Law', 33 *German Yearbook of International Law* (1990), at 18.

legitimate uses of the environment.'[57] 'Mere change' of the environment is not sufficient *per se* to constitute harm.[58] The ILC in its commentary to its 2001 Draft Articles on Prevention of Transboundary Harm treat 'risk' and 'harm' as a compound phrase, whereby the 'risk of causing significant transboundary harm' refers to 'the combined effect of the probability of occurrence of an accident and the magnitude of its injurious impact.' This concept therefore covers 'risks in the form of a high probability of causing significant transboundary harm and a low probability of causing disastrous transboundary harm.'[59] Furthermore, the risk of harm needs to meet the legally-relevant threshold of 'significant,'[60] meaning something more than detectable, but not necessarily serious.[61] The harm must also lead to real detrimental effects that must be measurable by factual and objective standards.[62]

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.[63] The question is whether it nevertheless applies to envirmental 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. Historically, the preventive principle can be traced back to the *Trail Smelter Arbitration*, a relatively simple case of bilateral transboundary air pollution.[64] This bilateral concept may not, however, be entirely apt for 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.[65] 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."'[66] Against this background, it could be argued, on one hand, that the preventive principle does not apply to

---

[57] OECD, Recommendation C(74)224 for the Council on Principles Concerning Transfrontier Pollution, Part A (Introduction). Another view in 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 Wolfrum, supra note 56, at 18.
[58] Cf. Arie Trouwborst, *Precautionary Rights and Duties of States* (Leiden and Boston: Martinus Nijhoff, 2006) at 40; Markus Müller, *Die internationale Zuständigkeit bei grenzüberschreitenden Umweltbeeinträchtigungen* (Basel: Helbing & Lichtenhahn, 1994), at 13.
[59] ILC, Prevention, supra note 44, art 2. See also Roda Verheyen, *Climate Damage and International Law: Prevention Duties and State Responsibilities* (Leiden, Martinus Nijhoff, 2005) at 152.
[60] ICJ, *Pulp Mills case*, supra note 46, para 101.
[61] Cf. ILC, Prevention, supra note 44, art. 2 para 4.
[62] Cf. ibid.
[63] ILC, Prevention, supra note 44, at 151.
[64] Cf. Trail smelter case, United States vs. Canada, UN Reports of International Arbitral Awards, 2006, Vol. III, 1905-1982. See also the recent 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".
[65] See further ILC, First Report on the Protection of the Atmosphere, supra note 64, para 90.
[66] Further ibid., para 89.

the global environmental commons (i.e., shared resources), such as climate change,[67] which lack a 'true' transboundary character in the sense that the activities in one State's sovereign territory cause harm to another.[68] 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.'[69] Moreover, it is frequently recognised that the customary duty of prevention also applies to 'areas beyond national control,'[70] 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.[71]

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 the Earth's surface, and changes to precipitation patterns which 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.[72] In assessing causation, scientists and lawyers focus on different aspects. Whereas the scientific approach aims at the 'discovery of generalisations and the construction of general theories of causation,'[73] the legal approach focuses on the construction of 'causal statements based on particulars.'[74] Narrowing down further, the requirements for legal construction are also variable and uncertain,[75] such that there may be no 'specific established [...] requirement for determining causation in international law.'[76] However, more frequent reliance upon some theories by international courts and tribunals helps to shed some light on the requirements for proving causation regarding a breach of the preventive principle from a large-scale climate intervention.

Regarding legal approaches to causation, a distinction is made between factual causation (causation-in-fact) and normative causation. A common approach used in domestic

[67] UNFCCC, Preamble; see further ILC, First Report on the Protection of the Atmosphere, paras. 86-90, Draft guideline 3(a) extending the common concern of humankind concept to the entire atmosphere.
[68] See Prue Taylor, *An Ecological Approach to international Law: Responding to Challenges of Climate Change* (London and New York: Routledge 1998), at 56-58.
[69] Verheyen, supra note 59, at 167. See further ILA, supra note 48, commentaries to draft article 7, para 5.
[70] ICJ, Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion. 8 July 1996, ICJ Reports 226, para 29. Cf. also Birnie et al., supra note 18, at 145.
[71] ICJ, Threat or Use of Nuclear Weapons, 1996, supra note 70, para 29. Cf. also Birnie et al., supra note 18, at 145. See further in this special edition: McGee, Maguire.
[72] Proelß, supra note 56, para 95; Verheyen, supra note 59, at 317-321.
[73] Verheyen, supra note 59, at 177.
[74] Ibid., at 249.
[75] 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.
[76] Verheyen, supra note 59, at 251.

and international tribunals to determine a causal (factual) relationship is the 'but for test'[77] – 'but for the act, there would be no loss, i.e. the act is an indispensable condition for the result' (*conditio sine qua non*).[78] 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',[79] meaning in the application of an SAI deployment, 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'[80] or the risk thereof. A specific causal link would prove the connection 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. Secondly, it would be necessary, for instance, to prove the connection 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 liability for every condition contributing to a result of the wrongful act.[81] Various theories exist to restrict liability in this regard.[82] For example, international tribunals have held States responsible only for the 'proximate and natural consequences of their acts.'[83] The theory of proximity aims at excluding damages that are too remote. However, the reasoning and concepts differ in the international and national contexts.[84] *Faure* and *Nollkaemper* point out that the criteria of normality and foreseeability are both applied to restrict causation.[85] The criterion of normality is met whenever the 'normal and natural course of events indicates that the injury is a logical consequence of the act',[86] and is therefore proximate. An injury also needs to be foreseeable for the actor to be causally linked and unlawful.[87]

---

[77] 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 stages of apportioning damage. See in detail Verheyen, supra note 59, at 254.
[78] Ibid., at 253 ff. 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 which activity was actually decisive in realizing in damage.
[79] Miriam Haritz, *An Inconvenient Deliberation, The Precautionary Principle's contribution to the Uncertainties Surrounding Climate Change Liability*, (Alphen aan den Rijn, The Netherlands: Wolters Kluwer, 2011), at 177.
[80] Ibid., at 178.
[81] Cf. Verheyen, supra note 59, at 295; Haritz, supra note 79, at 178.
[82] Bergkamp, supra note 75, at 285; for a short overview of the different national normative approaches to causation see, Haritz, supra note 79, at 180 f.
[83] Verheyen, supra note 59, at 297.
[84] Ibid., at 297.
[85] Michael Faure, André Nollkaemper, 'International Liability as an Instrument to Prevent and Compensate for Climate Change', 43 *A Stan. J. Intl. L.*, 2007, 124 – 179, at 158.
[86] Ibid., at 158.
[87] Ibid.

Therefore, a key challenge in making out a breach of the preventive principle is whether a causal link could be established between the SAI deployment and possible environmental effects, in general, and for specific harm or the risk thereof.[88] 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 ensuing 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 SAI deployment, taking into account evidentiary issues including the standard of proof.

3.3.1. Scientific methodology for establishing a causal link between the SAI deployment and increased damage or risk

The legal evidence for proof of a causal link entails a substantial fact-finding exercise.[89] 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 methodology. Thus, a general description of foundations of scientific detection and attribution is necessary to draw some abstract conclusions on the general relationship between SAI and the identified risks.

‘Detection of change is 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.’[90] A change in climate is detected when the chances of a given variation arising due to short-term fluctuation alone are small.[91] 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 the Earth’s climate is known to exhibit substantial variability on every timescale.[92] 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.[93]

Another challenge is that throughout the observational record multiple drivers of climate will have changed, including rising concentrations of greenhouse gases, anthropogenic aerosol emissions, volcanic eruptions, land-use change and natural variations

---

[88] Alternatively, according to Haritz causation is thought to be ‘the most controversial issue in bringing a successful claim’. See Haritz, supra note 79, at 177.

[89] Cf. Verheyen, supra note 59, at 249.

[90] G.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, (Bern, Switzerland: University of Bern, 2010).

[91] Bindoff, N.L., 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, United Kingdom and New York, NY, USA: Cambridge University Press, 2013).

[92] As Myles Allen et al. frame it: ‘… 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* (2007), at 1367.

[93] Cf. Bindoff et al., supra note 91.

in the solar cycle, amongst others. 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 variability 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,[94] 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 the 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: firstly, the known limitations of climate models to predict and to reproduce climate phenomena; and, secondly, a very fundamental one, which is that models are not reality, and that in consequence a match between model and reality does not constitute proof that it matches for the right 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. Expert judgment may be used in combination with model studies to help corroborate or dismiss a causal link. 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.[95]

Typically, detection and attribution studies assume that global climate models (GCMs) correctly simulate the pattern of climate response for the drivers of climate change, but not their magnitude.[96] However, the detection and attribution of the effects of SAI with climate models would pose a new challenge as it is, strictly speaking, a type of perturbation that never occurred before. 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 attributing the role of GHGs in 20th century climate trends. In general, this would result in much less robust and confident claims, at least in the initial years and decades of any 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 that volcanic eruptions produce a transitory rather than a persistent climate forcing. From that point of view, both qualitatively similar but quantitatively different side effects and 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,

---

[94] See further below, section 3.3.2, regarding the application of the ‘but for’ test to prove causation in fact.
[95] See Joint Dissenting Opinion of Judges Al-Khasawneh and Simma, supra note 46, paras 2-17.
[96] 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.

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 observation 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, that 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., 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.[97]

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 could 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 how distinct the fingerprint of the signal is from 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 degraded certainty of the attribution statements that are made. It thus seems likely to lead to inconclusive or contested attribution findings in case of fundamentally differing views, or when the expected changes are small in magnitude.[98]

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 show a very characteristic fingerprint could 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

[97] See Anderson et al., 'UV dosage levels in summer: increased risk of ozone loss from convectively injected water vapour', 337 Science (2012), at 835 ff. for an example of abrupt ozone depletion in relationship with water vapour intrusions into the stratosphere.
[98] See further regarding climate change damages, Myles Allen et al., 'Scientific Challenges in the Attribution of Harm to Human Influence on the Climate' 155 *University of Pennsylvania Law Review* (2007); 1353-1400.

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 monsoon, 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 attributability of the changes in the concentration of stratospheric ozone or in the quantity of UV arriving at the surface would depend on how large the change is and how clear its fingerprint is relative to natural interannual variability.
- Diffuse light changes: There is a straightforward connection between SAI and a shift from direct to diffuse light as the aerosols would scatter light and such a shift should be readily detectable with observations, if the changes are large enough to give a sufficient signal-to-noise ratio relative to interannual 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 be faced in establishing a causal link between a SAI deployment to the relevant evidentiary standard in order to show the risk of significant transboundary harm to the environment. 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.[99]

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 as a consequence of this 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 how a court or tribunal would evaluate complex evidence that is essentially restricted to global climate

[99] With regards 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 whom, as complicated physical and chemical processes are involved, proofing a conditio sine qua non is a “tedious task”. There are different theories in domestic legal systems that are trying to derive “from the ‘everything or nothing’ notion of tort where a plaintiff will either win his case or lose it, nut will normally not be able to receive partial justice”. See Verheyen, supra note 59, at 293 f. for more 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, yet until now they have not properly been used by international tribunals. Therefore, the authors will stick to the but-for test as a first denominator in establishing a causal link.

models and scientific testimony. This has already been identified as a problem with respect to climate change damages,[100] but in some respects it may be even more difficult to demonstrate causation to 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 criticised the usage of traditional rules on the burden of proof instead of using expert assessments, which in their view was indispensible.[101] By contrast, the ICJ's treatment of the complex technical issues in the recent *Whaling in the Antarctic Case* has been regarded more positively, even hailed by some commentators as 'model for separating scientific matters and the non-scientific agenda in other complicated disputes involving science, society and law.'[102]

In general under certain circumstances, general factual causation could be demonstrated for some kinds of risks. 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 its normative understanding. However, establishing proof of causation for certain 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, for example, by easing the burden of proving causation or avoiding it altogether by the creation of a bespoke regulatory regime that addresses responsibility and liability for SAI, including the proof required.[103] The precautionary principle may play an important role here too. While the ICJ in the *Pulp Mills Case* simply stated that the precautionary principle does not operate as a 'reversal of the burden of proof,'[104] it may serve to lower the standard of proof to avoid all or nothing verdicts.[105] A change in the requirement of proof is also discussed for ultra-hazardous

---

[100] See Allen et al. supra note 98, at 1355.
[101] Cf. Judges Al-Khasawneh, Simma, Joint Dissenting Opinion, ICJ Pulp Mills Case, supra note 46, at 1 – 3.
[102] William de la Mare, Nick Gales and Marc Mangel, ‚Applying Scientific Principles in International Law on Whaling' 325 *Science* (2014) 1125-1126, 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' *American Journal of International Law* (2004) at 496.
[103] 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 (ASOC), 'The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques' (Climate Institute, November 2010) at 9. See also: Verheyen supra note 59, at 362-63.
[104] ICJ, Pulp Mills Case, supra note 46, para 164.
[105] Birnie et al., supra note 18, at 160; Caroline E Foster, *Science and the Precautionary Principle in International Courts and Tribunals: Expert Evidence, Burden of Proof and Finality* (Cambridge University Press 2011) 273; Miriam Haritz, supra note 79, at 306-309; Simon Marr, 'The Southern Bluefin Tuna Cases: The Precautionary Approach and Conservation and Management of Fish Resources', 11 *European Journal of International Law* (2000), 822-823, at 815.

activities.[106] Being global in nature with regards to its effects, intended and unintended, as well as the potential severity of some of the effects, an SAI deployment would likely fall into the category of an ultra-hazardous activity. However, until now State practice does not as yet seem to support a customary rule for either a strict liability regime for conducting ultra-hazardous activities,[107] or for the lowering of the standard of the shift of the burden of proof.[108]

3.3. 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.[109] Thus, the determination of whether this primary obligation of prevention has been breached is not determined by the secondary rules of state responsibility, but is instead to be judged on substantive requirements of the primary obligation itself.[110]

An important question is what would be required of a State undertaking a SAI in terms of its standard of care to take 'reasonable efforts' to prevent environmental harm,[111] which is to be assessed objectively.[112] Although this analysis turns on the relevant circumstances of the case, some abstract basic conclusions can be drawn from a hypothetical SAI deployment scenario. The preventive principle expresses the customary law obligation of States to avoid or minimise environmental damage.[113] The obligation is one of due diligence,[114] 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.[115] In other words, the relevant standard of care is an objective determination regarding the conduct that could be

---

[106] Cf. Birnie et al., supra note 18, at 151.

[107] With regards 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, Boston: Martinus Nijhoff Publishers, 2007) at 28.

[108] Interestingly the Lugano Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment, 32 I.L.M. (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, Shelton, supra note 107, at 143. However, international courts have generally required 'to adduce enough evidence to establish at least a prima facie case.' See Birnie et al., supra note 18, at 158 with further references.

[109] Art 12 DASR.

[110] In the words of the ILC, '[i]t 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 22, at 54.

[111] Brunnée, supra note 21, at 27.

[112] René Lefeber, 'Climate change and state responsibility', in: International Law in the Era of Climate Change, edited by Rosemary Rayfuse, Shirley Scott (Cheltenham, UK: Edward Elgar Publishing Limited, 2012), 312-349, at 335.

[113] The International Court of Justice 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 70, at 242, para 29. See also in this journal McGee/McGuiree for the legal status.

[114] ILC, Prevention, supra note 44, art. 3 par. 8.
See also ITLOS Seabed Disputes Chamber, supra note 52, para 131; ICJ, Pulp Mills Case, supra note 46, para. 101.

[115] 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 44, at 40.

expected of a good government.[116] The preventive principle is an obligation of conduct, and therefore does not equate with an absolute prohibition against causing environmental damage.[117] Rather, it is an obligation to take appropriate rules and measures to prevent or minimize environmental harm as far as possible.[118] The required due diligence of the State conducting the activity is proportionate to the degree of risk in the case at hand.[119] Put simply, the risker 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.[120]

Furthermore, the preventive principle is a 'compound obligation consisting of procedural and substantive duties.'[121] These procedural duties include the obligation to notify[122] and consult with potentially affected States, as well as to conduct an environmental impact assessment.[123] On the one hand, compliance with these procedural duties could be seen as 'evidence of diligent behaviour.'[124] On the other, it is to be acknowledged that 'non-compliance does not automatically entail a breach of the due diligence obligation.'[125]

The relevant standard of care is determined by the nature of the activity and is subject to the principle of proportionality.[126] 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 climate 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.[127]

According to the International Law Association (ILA) in its commentary to its Legal Principles relating to Climate Change, '[w]hat is judged to be "riskier" will depend upon both the nature of the risks involved in a particular measure (for instance, geoengineering projects

---

[116] ILC, Prevention, supra note 44, art. 3 par. 17; Roda Verheyen, supra note 59, at 174. .
[117] For a detailed analysis of the legal dispute whether it is a obligation of result or conduct, cf. McGee, Maguire, ??.
[118] See ICJ, Pulp Mills Case, par. 197.
[119]ILA, supra note 48, commentary to draft article 7A, paras 3, 10.
[120] ILC, Prevention, supra note 44, art. 3, at 155.
[121] Lefeber, supra note 99, at 66.
[122] Cf. ICJ, Corfu Channel, supra note 44, at 22, that stated that the obligation to notify is based inter alia on elementary considerations of humanity and every State's obligation not to allow knowingly its territory to be used for acts contrary to the rights of other states.
[123] Cf. ICJ, Pulp Mills, supra note 46, para 204. According to the court to conduct 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'.
[124] Lefeber, supra note 99, at 66.
[125] Ibid. at 66. Interestingly the ICJ further states in Pulp Mills 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 46, para 282. Cf. for a critique of the ICJ's understanding of the interplay of substantive and procedural rules in Pulp Mills, Proelß, supra note 44**Error! Bookmark not defined.**.
[126] ILC, Prevention, supra note 44, art. 3, at 155.
[127] ILC, Prevention, supra note 44, art. 3 at 154.

involving solar radiation management) and the vulnerability to harm affected States.'[128] It could be argued, for example, that, as an alternative, drastic mitigation strategies could be deemed more proportionate climate measure than a deployment of SAI. Overall, however, many good arguments speak in favour of the highest standard of care with regards to an SAI deployment.[129] 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, notwithstanding scientific uncertainty, measures may be required that reflect 'abundant caution.'[130]

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.[131] In particular, the IPCC in its most recent Fifth Assessment Report assigned with 'high confidence' the prediction that that upon termination of the SRM deployment,[132] temperature, precipitation and sea-ice cover would change considerably faster compared to rising CO_2 emissions without SRM.[133] 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 '[t]he 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.'[134] Given the risks associated with a termination effect,[135] including the impacts on ecosystems due to a rapid temperature increase,[136] 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 a SAI deployment are at this stage are mere conjecture, but could 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 begs the question of whether a so-called '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.

It is furthermore worth analysing whether SAI activities would be so risky as to amount to an absolute prohibition against a large-scale deployment.[137] In the *MOX Plant* and

---

[128] ILA, supra note 48, at 24.
[129] ITLOS Seabed Disputes Chamber, supra note 52, para 117. See also ILC, Prevention, supra note 44, art. 3 at 154 which suggests 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.'
[130] ILC, Prevention, supra note 44, art. 3, at 155.
[131] Birnie et al., supra note 18, at 153.
[132] IPCC, supra note 33.
[133] See Jones et al., supra note 34.
[134] Ibid., at 9743-44.
[135] Ibid.
[136] Ibid.
[137] Birnie et al., supra note 18, at 150.

Pulp Mills Cases, this argument was raised, yet rendered unsuccessful on the facts.[138] Still *a priori* it seems 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.'[139]

4. Risk-risk trade-offs relating to the prevention of significant environmental harm

SAI is being considered as a climate measure in hope that it would yield benefits by reducing damage from rising global temperatures due to the greenhouse effect. Despite any good intentions, however, that SAI would offset some of the environmental risks of climate change, such interventions would 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,[140] 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.[141] An example is the weighing the risks of running fossil fuel power plants against nuclear power plants, or, in this case, the risks of climate change and SAI. How do policy decisions involving risk-risk trade-offs manifest themselves in international environmental law and how can competing environmental objectives and values be reconciled?[142] In legal terms, this balancing of environmental risks could be addressed at the stage of the breach of a primary norm, including manifested as a conflict of laws, or under the secondary rules of state responsibility.

It is doubtful that the preventive principle itself provides a mechanism for the weighing of policy options that entail competing risk scenarios, namely, the balancing of the risks of climate change against SAI (e.g., within the required standard of care) that could render the potential wrongfulness of an SAI deployment lawful if the risks of climate change prevailed. Several arguments speak against such an understanding. The ILC's Draft Articles on the Prevention of Transboundary Harm do mention an equitable balancing of interests based on the principle of permanent sovereignty that States have the sovereign right to exploit their own resources.[143] However, such considerations might not apply here, since the Draft Articles do not deal with activities that are prohibited by international law.[144] This differentiation between lawful and unlawful activities and the respective balancing of interests

---

[138] Cf. ITLOS, *MOX Plant Arbitration* (Jurisdiction and Provisional Measures) No. 10 (2001), paras 53-5; ICJ Case Concerning Pulp Mills on the River Uruguay, Argentina vs. Uruguay, Order 13 July 2006, paras 73-7.
[139] Birnie et al, supra note 18, at 181.
[140] 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.
[141] Cass Sunstein, 'Irreversibility', 9 *Law, Probability and Risk* (2010), 227 – 245, at 240.
[142] 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* (2008), 423-464, at 424.
[143] Draft Article 9 indicates that 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, '[t]he 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.
[144] Cf. ILC, Prevention, supra note 44, art. 9, para 2.

is in line with the reasoning of special rapporteur *Rao*, who observed that 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.'[145] 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.' On the contrary, it has been deemed inappropriate to 'condition the threshold of significant harm to considerations of equitable sharing.'[146]

Risk-risk trade-offs are also often discussed within the context of the precautionary principle. This principle has clear relevance as a primary norm within the legal framework of prevention for balancing the climate risks against the risks of individual climate measures like SAI, since any decision on the deployment would surely be based on uncertainty. However, the precautionary principle offers only limited guidance in how to navigate this weighing-up exercise. Even if some harm cannot be quantified or cause-effect relationships fully demonstrated, it is widely recognised 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.[147] 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, minimise and reduce environmental damage from a large-scale climate intervention using SAI. However, in the same way, SAI could be claimed as a precautionary measure with regards to the possible damage from climate change. Therefore, the principle 'embodies the core arguments for and against geoengineering.'[148] Views differ greatly with regards to the potential of guidance for decision-making in risk-risk situations. Being criticised as merely stating a truism,[149] 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.[150] On balance, however, the principle does not provide a 'sufficient legal tool for making essentially political decisions about conflicting objectives and managing risks.'[151]

Alternative approaches to risk-risk trade-offs like conducting a cost-benefit analysis, which is also a consideration regarding the application of precautionary measures,[152] reach their limits in complex cases like climate change. In such cases, acquiring the necessary

---

[145] PS 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), 11, para 21. See also Handl, supra note 115, at 537.
[146] Cf. Beyerlin and Marauhn, supra note 44, at 42 fn. 15.
[147] See above and also Shepherd et. al., supra note 8, at 29 ff.
[148] Bodle, supra note 43, at 460.
[149] Cf. with further reference Gregory Mandel and James Gathii, 'Cost-Benefit Analysis Versus the Precautionary Principle: Beyond Cass Sunstein's Laws of Fear', 5 *University of Illinois Law Review* (2006), at 1039.
[150] Haritz, supra note 79, at 118; Kysar, Douglas A., 'It Might Have Been: Risk, Precaution, and Opportunity Costs' *Cornell Law Faculty Publications* (2006), available at: http://scholarship.law.cornell.edu/lsrp_papers/50.
[151] Bodle, supra note 43, at 460.
[152] See European Commission, Communication from the Commission on the Precautionary Principle, COM(2000)1 (2 February 2001), at 19.

amount of data presents a ‘likely impossible task’[153] and due to the remaining level of uncertainty renders ‘any such analysis statistically insignificant.’[154]

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).[155] 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 a the object and purposes of a different treaty to avoid and minimise 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,[156] and another could claim a breach of an obligation arising from the SAI deployment relating to the duty to protect human health and the environment against adverse effects from human activities which modify the ozone layer under the Vienna Convention on the Protection of the Ozone Layer.[157]

In general, international law does not prohibit conflicting obligations for States and nor does it preclude conflicting breaches by them.[158] Furthermore, aside from interpretive techniques set out in Articles 31 to 33 of the VCLT, there are no international conflicts rules for resolving norm conflicts.[159] 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.’[160]

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 Article 25 of the DASR. According to Article 25(1)(a), the defence of necessity can only be invoked if it is the only means for the State to safeguard an essential

---

[153] Mandel and Gathii, supra note 149, at 1045.
[154] Ibid.
[155] See Gabrielle Marceau, ‘Conflicts of Norms and Conflicts of Jurisdiction’, 35 *Journal of World Trade* (2001), 1081-1131, at 1082.
[156] Regarding the interpretation of the UNFCCC and climate engineering see Bodle, supra note 43, at 456.
[157] See Vienna Convention on the Protection of the Ozone Layer, Art. 2. Cf. in this regard, Rüdiger Wolfrum and Nele Matz, ‘*Conflicts in International Environmental Law*’ (Berlin: Springer, 2003), at 11.
[158] 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, GBR: Cambridge University Press, 2012).
[159] Wolfrum and Matz, supra note 157, at 147 ff., 210.
[160] 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, GBR: Cambridge University Press, 2012) at 236-37.

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.[161] Bearing in mind that the root problem is human-induced global warming, an environmental crisis that is at least partly 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.[162]

Hence, it seems that there is no clear-cut answer regarding how to deal with risk-risk situations under international law. Concerning the issue of whether individual countries should be allowed to weigh the potential benefits and risks on their own,[163] unilateral decision-making relating to a deployment of SAI may be difficult for a single state to justify legally given the above-mentioned high standard of diligence required and the inappropriateness of making the recruitment to avoid significant harm conditioned upon considerations of equitable sharing within the preventive principle. Coordination with regard to a conflict of laws situation can best be achieved 'if a forum would be established that provides for a respective harmonization of either interpreting particular rules or coordinate implementation.'[164] In other words, the legal uncertainties concerning risk-risk trade-offs speak against a State taking matters into their own hands via a unilateral deployment and are better settled through an appropriate regulatory supervision in accordance with the general agreement of States.

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.[165] 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 which give rise to new obligations under general international law.[166] 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,[167] and to

---

161 DASR, Art. 26(2)(b).

162 Cf. Bodle, supra note 43, at 461. The ICJ considered in the *Gabčíkovo-Nagymaros Project Case* 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 vs. Slovakia, Judgment, 25 September 1997, at 46, para 57. However perils that might prove to be imminent could be: loss of the Great Barrier Reef, Permafrost melting, ecosystem losses, the shift from seasonal to perennial pest species as winter frosts disappear, etc.

163 Cf. Daniel Bodansky, Governing Climate Engineering: Scenarios for Analysis, *Discussion Paper for the Harvard Project on Climate Agreements*, 2011, available at: http://ssrn.com/abstract=1963397, at 5.

164 Wolfrum and Matz, supra note 157, at 211.

165 Birnie et al., supra note 18**Error! Bookmark not defined.**, at 225.

166 These new legal relations arise without any condition of invocation by the injured stated. See ILC, supra note 22, at 88.

167 DASR, Art 30.

make full reparation for the injury caused by the internationally wrongful act.[168] The general obligation to make reparation concerns the remedies of restitution, compensation and satisfaction.[169] 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.[170] It seeks to rectify the situation in two ways. Firstly, notwithstanding the breach, the previous primary obligation remains in tact, and thus the responsible State is under a continued duty to perform the obligation breached.[171] Secondly, the responsible State is under an obligation to cease the wrongful act or omission, if it is of a continuing character.[172] Generally, the cessation of wrongful acts is regarded as an 'essential obligation,' the fulfilment of which is regarded as 'in the interest of a wider community of States' in preservation of the rule of law under the international legal system.[173] 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.'[174] 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 organisations for claims made on behalf of the international community as a whole.[175]

Several important questions arise with regard to the legal consequences of a breach of duty of prevention from a large-scale deliberate 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.[176] The primary legal consequence of a continuing breach of an international norm is the obligation to cease the activity,[177] and, in principle, as a remedy that applies to future events '[c]essation unlike restitution is always possible.'[178] However,

---

[168] DASR, Art 31.
[169] DASR, Art 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), 573 – 587, at 573.
[170] ILC, supra note 22, at 88, para 1.
[171] DASR, Art 29.
[172] DASR, Art 30.
[173] 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: 545-549, at 546 f.
[174] ILC, supra note 22, at 89, par. 5.
[175] Ibid., at 89, paras 4-5.
[176] Ibid., at 89, para 3.
[177] Cf. Corten, supra note 173, 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 & Trotham, 1991) at: 75-124, 86; Karl Zemanek, 'State Responsibility and Liability' in: *Environmental Protection and International Law*, edited by Winfried Lang, Hanspeter Neuhold, Karl Zemanek (London: Graham & Trotman, 1991), at 187 –201, at 193; John Lammers, International Responsibility and Liability for Damage Caused by Environmental Interferences, 31/1 *Environmental Policy and Law* (2001), 42-50, at 45.
[178] Corten supra note 173, at 548. Regarding the distinction in law between the remedies of cessation and restitution see ILC, Commentaries to DASR at 89, paras 7-8.

cessation could result in a further risk of significant environmental damage in some locations, if it triggers a termination effect: if a substantial cooling were being exerted, a shutdown of SAI would cause rapid warming of the climate system over a short period. This arises from the certain 'irreversibility' of an SAI deployment that is exerting a substantial cooling in that 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 the human societies that are dependent upon them time to adapt. On the other hand, continuation of the use of SAI could lead to an unfair result by perpetuating the damage to the territory of the injured and may serve to undermine the fundamental principle of *pacta sunt servanda* in international law.[179] 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.[180]

6. Implementation of State Responsibility

As signalled by the declaratory language of Article 1 of the DASR, 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.'[181] Nonetheless, the DASR also deal with the implementation of international responsibility, including the enforcement of claims asserted by States or through the commencement of proceedings before an international court or tribunal.[182] This concerns the right of injured and non-injured States to take actions to invoke state responsibility and the forms reparation available in such cases.

The law of state responsibility was originally premised on the classical bilateral right-duty formulation of interstate relations.[183] Traditionally, legal standing to bring international claims was restricted to injured States, which is dealt with in Article 42 of the DASR. This requirement is likely not present much of a barrier to the invocation of responsibility in interstate environmental disputes, including arguably from the intentional modification of the global climate system using SAI. [184]

Breaches of international environmental law that affect only the global commons or collective state interests are considered 'more problematic.'[185] 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.[186] The use of SAI

---

[179] See Corten, supra note 173, at 546.
[180] Ibid.
[181] 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) 931 – 940, at 935.
[182] DASR, Part III.
[183] Cf. James Crawford, UN Doc. A/CN.4 (507) 2000, at 25.
[184] See Birnie et al., supra note 18, at 232.
[185] Ibid. at 233.
[186] Ibid.

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 recognises the invocation of responsibility by States other than an injured State to seek enforcement for violation of an international obligation owed to the international community as a whole.[187] Article 48 of the DASR recognise 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 interest of that group (*erga omnes partes*) or the obligation owed is to the international community as a whole (*erga omnes*).[188]

However, this category of public interest standing reflected in Article 48 is only partly developed and 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 and interest in the legal enforcement of substantive obligations related to the protection of the atmosphere give the lack of appropriate procedural law to implement such a requirement.[189] Furthermore, the DASR 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.[190] These restrictions could, for example, preclude recovery for harm to the global commons the form of 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 a group of states which carried out the SAI deployment.[191]

In principle, if the obligation of prevention constitutes an obligation *erga omnes*, any State could have a cause of action against a deploying State claiming that it has breached its duty of prevention to enforce the collective interests of the international community as a whole. The state responsible for the internationally wrongful act is under an obligation to cease the wrongful act. 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’ – conceived of as 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 decentralised legal order concerning the reciprocal rights and obligations of sovereign States,

---

[187] ICJ, Case concerning the *Barcelona Traction, Light and Power Company, Limited,* Belgium vs. Spain, Judgment, 5 February 1970, ICJ Reports (1970) at 32, para 33. See also Brunnée, supra note 21, at 26.
[188] DASR, Article 48.
[189] ILC, supra note 22, at 89.
[190] DASR, Article 49(2).
[191] See Crawford, supra note 181, at 935-36.

the international rules on state responsibility were fashioned in a much 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.[192] Nevertheless, state responsibility still remains the 'paradigm form of responsibility on the international plane.'[193] 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.

Firstly, international responsibility flows from an internationally wrongful act of a State. Thus, if the applicable primary obligations are somehow lacking, then the secondary rules on state accountability would not be triggered. This article focused on the possible 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 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 themselves.[194] 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 multi-party international disputes[195] and the enforcement of obligations owed to the international community as a whole.[196] 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.[197] Any real-world deployment would be 'experimental'

---

[192] Cf. Scott Barrett, 'Solar Geoengineering's Brave New World: Thoughts on the Governance of an Unprecedented Technology', in: 8 (2) *Review of Environmental Economics and Policy* (2014), 249–269. DOI: 10.1093/reep/reu011.
[193] Brunnée, supra note 21, at 55.
[194] See further ibid., at 53 f.
[195] André Nollkaemper and Dov Jacobs, ‚Shared Responsibility in International Law: A Conceptual Framework', 34 *Michigan Journal of International Law* (2013), at 432.
[196] Cf. Brunnée, supra note 21, at 30 ff.
[197] James Crawford and Simon Olleson, 'The Nature and Forms of International Responsibility' in: *3rd* ed. *International Law*, edited by Malcom Evans (Oxford University Press 2010), at 463.

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.[198] 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 ante*.'[199] 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.'[200] The most important conclusion here is that, well before any such activities actually take place, further clarification of legal responsibility and the creation of bespoke mechanisms for regulation and oversight of climate engineering activities that would alter the climate system is recommended.[201]

---

[198] Alan Robock et al., 'A Test for Geoengineering', 327 *Science* (2010), at 531 f.
[199] 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.
[200] Birnie et al., supra note 18, at 237.
[201] Asilomar Scientific Organizing Committee, '*The Asilomar Conference Recommendations on Principles for Research into Climate Engineering Techniques*' (Asilomar, 2010), at 9.