Liability for Solar Geoengineering: Historical Precedents, Contemporary Innovations, and Governance Possibilities

LIABILITY FOR SOLAR GEOENGINEERING: HISTORICAL PRECEDENTS, CONTEMPORARY INNOVATIONS, AND GOVERNANCE POSSIBILITIES

JOSHUA B. HORTON, ANDREW PARKER, AND DAVID KEITH*

TABLE OF CONTENTS

INTRODUCTION

The prospect of geoengineering, or the "deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change," carries with it a varied set of technical challenges.[1] Yet it is the governance challenges associated with geoengineering that are likely to be far more difficult to overcome if deployment, or even large-scale experimentation, is ever seriously contemplated by the international community. Questions about decision making, political legitimacy, policy objectives, risk management, and other

* We would like to thank our colleagues at the Harvard Kennedy School Belfer Center for Science and International Affairs for their valuable insights and feedback on earlier versions of this article. We would also like to thank the staff of the *New York University Environmental Law Journal*, whose considerable efforts helped refine both the manuscript and our overall thinking on the topic.

1 *See* THE ROYAL SOC'Y, GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY 1 (2009).

governance dilemmas have been raised with respect to both solar radiation management (SRM) and carbon dioxide removal (CDR) geoengineering methods. One particularly difficult challenge raised by commentators on geoengineering is the problem of liability; that is, how would international society deal with a climate engineering intervention gone wrong?[2] In general, liability concerns are more novel and potentially more acute for SRM methods than for CDR techniques: carbon dioxide removal and storage present significant but relatively conventional liability problems related to carbon leakage and environmental impacts, whereas modifying planetary albedo introduces a range of possible side effects not previously encountered for which no direct governance precedents exist.

Stratospheric aerosol injection (SAI), a fast-acting SRM technique that would introduce aerosol particles to the upper atmosphere to reflect a small amount of solar radiation away from Earth and thereby decrease temperatures, has received particular attention from the geoengineering research community, and much of this attention has focused on the governance challenges posed by questions of liability. If a country were damaged by negative effects from SAI, should that country be compensated for its loss? If so, by what mechanism? Could such effects be persuasively linked to SAI? Who should pay for damages, and how much should they pay? The extraordinary difficulties presented by this issue have led some observers to conclude that building a just and effective system of liability and compensation for SAI would be virtually impossible.[3] In the absence of a credible liability system available as recourse in the event of miscalculation or accident, the international community would (arguably) be unlikely to agree to

---

2 *E.g.,* SOLAR RADIATION MANAGEMENT GOVERNANCE INITIATIVE, SOLAR RADIATION MANAGEMENT: THE GOVERNANCE OF RESEARCH 44 (2011); Adam D.K. Abelkop & Jonathan C. Carlson, *Reining in Phaethon's Chariot: Principles for the Governance of Geoengineering*, 21 TRANSNAT'L L. & CONTEMP. PROBS. 763, 799–801 (2013); Daniel Bodansky, *May We Engineer the Climate?*, 33 CLIMATIC CHANGE 309, 319 (1996); Lisa Dilling & Rachel Hauser, *Governing Geoengineering Research: Why, When, and How?*, 121 CLIMATIC CHANGE 553, 560–61 (2013); David W. Keith, *Geoengineering the Climate: History and Prospect*, 25 ANN. REV. ENERGY & ENV'T, 245, 275–76 (2000).

3 *E.g.,* Alan Robock, *Will Geoengineering With Solar Radiation Management Ever Be Used?*, 15 ETHICS POL'Y & ENV'T 202, 203 (2012); Bronislaw Szerszynski et al., *Why Solar Radiation Management and Democracy Won't Mix*, 45 ENV'T & PLAN. A 2809, 2811–12 (2013).

any form of SAI implementation.[4] Thus, future SAI geoengineering may be contingent on, among other things, solving the liability problem.

Yet liability for stratospheric aerosol geoengineering is not necessarily as intractable as some suggest. Historical antecedents and contemporary methodological and legal innovations provide a strong basis for constructing a liability regime. Certainly, designing a liability regime would be no easy task, and any regime will be limited in both the risks it covers and its enforceability. However, there are more tools at hand to address SAI liability than it might initially appear. The world may decide at some point in the future that SAI is or is not desirable, but liability itself is unlikely to pose an insuperable obstacle to its implementation. We have chosen to focus on SAI in this Article for the sake of specificity; however, most of these arguments about liability and compensation should apply to other forms of SRM as well.

Section I provides an overview of the concept of liability and its historical development at the international level. Section II examines the variety of potential harms stemming from SAI that any system of liability would need to contend with. Sections III and IV take a detailed look at how international liability and compensation have been addressed in the context of the Space Liability Convention and oil spill regime, respectively. Finally, Section V considers scientific and legal aspects of causal attribution in the global climate system, and Section VI takes up a number of additional issues related to SAI liability in a discussion Section.

Two caveats should be noted here. First, any discussion of liability threatens to reduce the multitude of real damages suffered by victims to straightforward, simple monetary terms. This is true with respect to geoengineering as it is for all other fields, and it is important that researchers and practitioners bear in mind the full range of non-monetary losses that damages may incur, including emotional, spiritual, cultural, aesthetic, artistic, historical, and religious losses. However, it is also important to acknowledge that financial compensation for liability is widely accepted as the principal means of reparation in modern settings, and no functional replacement is readily available. As such, meaningful, policy-

4 *See* Edward A. Parson & Lia N. Ernst, *International Governance of Climate Engineering*, 14 THEORETICAL INQUIRIES L. 307, 327 (2013).

relevant discussions of liability are unavoidably conducted on the basis of financial redress.

Second, we are aware that research on geoengineering liability may be viewed as enabling a wider sociotechnical project grounded in particular conceptions of society, nature, technology, and humanity.[5] We recognize that this research may add discursive momentum to the articulation of a geoengineering "imaginary."[6] We remain agnostic about the ultimate role and value of this imaginary.

I. THE EVOLUTION OF INTERNATIONAL LEGAL LIABILITY

The concept of legal liability originates in domestic law.[7] Liability was developed to help alleviate the tension between the belief that parties should not be made to bear the costs of activities carried out by others, and a societal judgment that certain activities, while inherently risky, ought nevertheless to be encouraged for the sake of the public interest.[8] Legal liability held that such activities, for example, industrial production, ought to be permitted, however, third parties incurring damages as a result should be compensated by those who conduct and/or benefit from the activities in question. A system of liability serves not only to make restitution to victims of harmful activities in cases of accident, error, or negligence, but also fulfills a "preventative" function by encouraging those who engage in dangerous activities to exercise caution and adopt safe practices, in order to avoid the potential cost of reparations.[9]

Initially, the normal standard for legal liability was based on fault;[10] that is, liability was contingent on demonstrating both (1) a

---

5 *See* A. Rip & R. Kemp, *Technological Change*, *in* 2 HUMAN CHOICES AND CLIMATE CHANGE: RESOURCES AND TECHNOLOGY, 327, 348 (S. Rayner & E.L. Malone eds., 1998).

6 *See* Nils Markusson, *Tensions in Framings of Geoengineering: Constitutive Diversity and Ambivalence* 6 (Climate Geoengineering Governance, Working Paper No. 003, 2013).

7 *See* U.N Secretariat, *Survey on Liability Regimes Relevant to the Topic International Liability for Injurious Consequences Arising Out of Acts Not Prohibited by International Law,* [1995] 2 Y.B. Int'l L. Comm'n 60, 66–73, Int'l L. Comm'n, U.N. Doc. A/CN.4/471 [hereinafter *Survey on Liability Regimes*].

8 *See id.* at 67.

9 *See* PHILIPPE SANDS ET AL., PRINCIPLES OF INTERNATIONAL ENVIRONMENTAL LAW 700 (3d ed. 2012).

10 *See Survey on Liability Regimes*, *supra* note 7, at 67.

causal link between the act or omission alleged to have caused damage and the actual loss suffered, and (2) negligence or culpability on the part of the defendant. Causal linkage, and hence attribution of specific damage to a specific wrongful act or omission, was established by showing an uninterrupted chain of cause-effect relationships, none of which would have occurred but for the preceding relationship. As particularly hazardous ("ultrahazardous") yet socially beneficial activities—such as keeping wild animals and using explosives—became more common, the competing standard of strict liability emerged, according to which only causation and not culpability was required to hold a party liable for damages.[11] Strict liability effectively lightened claimants' burden of proof relative to fault-based liability. The proliferation of hazardous activities with impacts that reached across international borders, and the concomitant risks of transboundary damage, brought the issue of liability to international law. The precedent of international legal liability was set by landmark cases such as the *Trail Smelter* dispute[12] and the *Corfu Channel* case.[13] As international legal liability arose in the context of hazardous activities posing disproportionately high cross-border environmental risks, subsequent development of international mechanisms for assessing and resolving liability was concentrated on environmental topics.[14] Some of the more prominent issue-areas include marine oil pollution, transboundary movements of hazardous waste, nuclear accidents, Antarctic environmental protection, and biosafety related to living modified organisms.[15] Strict liability, requiring no need to establish fault, emerged as the accepted standard in international law, for several important reasons: it avoided the difficult task of defining standards of care; it lessened the burden of proof for plaintiffs in complex, technical fields; and most of the activities initially covered were viewed as ultrahazardous.[16] Since any system of

11 *See id.* at 67–69.

12 Trail Smelter Case (U.S. v. Can.), 3 R.I.A.A. 1905 (1941).

13 Corfu Channel Case (U.K. v. Alb.), 1949 I.C.J. 4 (Apr. 9).

14 *See Survey on Liability Regimes*, *supra* note 7, at 65.

15 *See* Table 1 for an overview of selected international liability and compensation regimes.

16 *See* RUDIGER WOLFRUM & CHRISTINE LANGENFELD, ENVIRONMENTAL PROTECTION BY MEANS OF INTERNATIONAL LIABILITY LAW 398 (1999); A.E. Boyle, *Globalising Environmental Liability: The Interplay of National and International Law*, 17 J. ENVTL. L. 3, 13 (2005).

liability rests on a means of establishing causation, in those issue-areas where demonstrating causal relationships has proven especially problematic, such as climate change, liability mechanisms have played little role.[17]

Table 1: Selected International Liability and Compensation Regimes

Regime	Instrument	Date of Adoption	Date of Entry into Force	Number of States	Notes
Aircraft accidents	Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface (Rome Convention)	10/7/52	4/1/68	49	Compulsory insurance/ financial security
Nuclear accidents	Convention on Third Party Liability in the Field of Nuclear Energy (Paris Convention)	7/29/60	4/1/68	15	Multiple compensation tiers
	Vienna Convention on Civil Liability for Nuclear Damage	5/1/63	11/12/77	38	
	Supplementary Convention to the Convention on Third Party Liability in the Field of Nuclear Energy	1/31/63	12/4/74	12	

17 *See* Jutta Brunnée et al., *Overview of Legal Issues Relevant to Climate Change*, *in* CLIMATE CHANGE LIABILITY: TRANSNATIONAL LAW AND PRACTICE 23, 33–34 (Richard Lord et al. eds., 2012) (discussing problems related to climate change, causation, and liability).

Oil spills	International Convention on Civil Liability for Oil Pollution Damage (CLC 69)	11/29/69	6/19/75	35 (74 denunciations linked to CLC 92)	Multilateral compensation funds partially financed by mandatory levies; compulsory insurance; flexible institutional structure; industry integration
	International Convention on the Establishment of an International Fund for Compensation of Oil Pollution Damage (1971 Fund Convention)	12/18/71	10/16/78	18 (59 denunciations linked to 1992 Fund Convention)	
	International Convention on Civil Liability for Oil Pollution Damage (CLC 92)	11/27/92	5/30/96	130	
	International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1992 Fund Convention)	11/27/92	5/30/96	111	
	Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (Supplementary Fund Convention)	5/16/03	3/3/05	29	
Space objects	Convention on International Liability for Damage Caused by Space Objects (Space Liability Convention)	11/29/71	9/1/72	88	Only state liability regime

Dangerous activities relating to the environment	Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment (Lugano Convention)	6/21/93	Not in force	9	Compensation for damage to environment per se
Hazardous substances at sea	International Convention on Liability and Compensation for Damage in Connection With the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention)	5/3/96	Not in force	8	Modeled on oil spill regime
Hazardous wastes	Basel Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and Their Disposal	12/10/99	Not in force	11	Liability determined by transport phase
Bunker oil pollution	International Convention on Civil Liability for Bunker Oil Pollution Damage (Bunkers Convention)	3/23/01	11/1/08	68	Modeled on CLC 69
Antarctic Treaty System	Annex VI to the Protocol on Environmental Protection to the Antarctic Treaty: Liability Arising from Environmental Emergencies	6/14/05	Not in force	6	Applies to public and private actors
Biosafety	Nagoya-Kuala Lumpur Supplementary Protocol on Liability and Redress to the Cartagena Protocol on Biosafety	10/15/10	Not in force	9	Nested within biodiversity regime

Note: For instruments in force, "Number of States" refers to number of contracting parties. For instruments not in force, "Number of States" refers to number of ratifications and accessions.

International liability regimes vary along multiple dimensions. One fundamental distinction is between civil and state liability regimes. Most transboundary hazardous activities that have been subjected to international liability rules have been commercial in nature, carried out by firms or other private entities.[18] Most of these regimes, in turn, have been based on civil liability, in which private parties are held accountable for damages occurring beyond national borders. As in domestic law, international civil liability

18 For example, of the thirty-four multilateral instruments cited by the International Law Commission (ILC) in its comprehensive global survey of liability regimes, only one agreement (the Convention on International Liability for Damage Caused by Space Objects) is primarily non-commercial in character. *See Survey on Liability Regimes*, *supra* note 7, at 63–64.

frameworks are generally premised on the polluter pays principle (although the degree to which it is achieved in practice varies greatly). For example, the regime covering maritime bunker fuel pollution, the 2001 International Convention on Civil Liability for Bunker Oil Pollution Damage (Bunkers Convention), assigns liability for damages exclusively to shipowners.[19] Similarly, the regime covering civilian nuclear accidents, based on the 1960 Paris Convention on Third Party Liability in the Field of Nuclear Energy[20] and the 1963 Vienna Convention on Civil Liability for Nuclear Damage[21], holds owners of nuclear installations legally liable for transboundary damages resulting from nuclear accidents. Assigning liability to private owners and operators under civil liability systems is referred to as "channeling."[22] Provision is typically made for joint and several liability in cases of multiple defendants.[23] Under civil liability regimes, claims for compensation are adjudicated in domestic courts, with states agreeing to mutual recognition and enforcement of judgments—in this way, civil regimes ultimately rely on state action to function effectively.

By contrast, under a state liability regime, sovereign states are held liable for damages or injuries occurring outside respective areas of national jurisdiction or control. State liability has been accepted and codified only for activities that are primarily non-commercial in character. Indeed, the 1972 Convention on International Liability for Damage Caused by Space Objects (Space Liability Convention)[24] is the only instance of an

19 International Convention on Civil Liability for Bunker Oil Pollution Damage art. 3, Mar. 23, 2001, 973 U.N.T.S. 3.

20 Convention on Third Party Liability in the Field of Nuclear Energy, July 29, 1960, 956 U.N.T.S. 251.

21 Vienna Convention on Civil Liability for Nuclear Damage, May 21, 1963, 1063 U.N.T.S. 265.

22 *See* JULIO BARBOZA, THE ENVIRONMENT, RISK AND LIABILITY IN INTERNATIONAL LAW 32–33 (2010).

23 Under joint and several liability, a claimant may pursue all claims tied to multiple defendants against a single defendant. If damages are awarded, defendants must jointly arrange for compensation to the claimant. *See* WARREN FREEDMAN, JOINT AND SEVERAL LIABILITY: ALLOCATION OF RISK AND APPORTIONMENT OF DAMAGES 3 (1987).

24 Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187 [hereinafter Space Liability Convention].

international liability mechanism based entirely on state liability.[25] State liability differs from the related concept of state responsibility.[26] State responsibility, on the one hand, is invoked when states fail to uphold their international legal obligations.[27] If a state fails to exercise due diligence as required by international law, for example, then it is considered to be in breach of its legal commitments and thus responsible for any damages that ensue. State liability, on the other hand, arises when damages occur as a result of lawful activities undertaken by states.[28] If a state exercises due diligence yet injurious consequences still result, that state may be liable for damages. Again, liability applies to situations in which lawful activity gives rise to collateral damages. Under state liability, disputes are resolved through negotiation, mediation, or arbitration.[29] In a world of sovereign states, settlements reached using these processes are not legally enforceable. This defining feature of international relations means that settling damage claims under a system of state liability is ultimately a political rather than a legal issue.

Parties, whether state or private, are typically excluded from liability under certain conditions. Defendants normally are exonerated in the event of armed conflict, hostilities, civil war, or insurrection.[30] Exemptions are provided where damage is due to natural phenomena of "exceptional, inevitable and irresistible character" (acts of God or *force majeure*).[31] Exclusions are also granted where injuries are traceable to acts or omissions of a third party, or of the claimant.[32] In addition, regimes provide exemptions for situations specific to particular issue-areas. For example, under the 1996 International Convention on Liability and Compensation for Damage in Connection With the Carriage of Hazardous and Noxious Substances by Sea (HNS Convention), shipowners are excluded from liability in cases where responsible

25 *See* WOLFRUM & LANGENFELD, *supra* note 16, at 411.

26 *See* Frans G. von der Dunk, *Liability Versus Responsibility in Space Law: Misconception or Misconstruction?*, PROCEEDINGS 34TH COLLOQUIUM ON L. OUTER SPACE 363, 363–65 (1991) (discussing the distinction between state liability and state responsibility).

27 *See* BARBOZA, *supra* note 22, at 21–22.

28 *See id*.

29 *See Survey on Liability Regimes*, *supra* note 7, at 109–10.

30 *See id*. at 93–95.

31 *See id*.

32 *See id*. at 94–95.

states or other parties fail in their duty to provide coastal lights and other navigational aids.[33] In addition to such exonerations, international liability agreements also normally prescribe a statute of limitations to restrict claims to a defined period of time.[34] Importantly, international law does not provide exclusions in cases where defendants claim to have acted to prevent pre-existing harms; likewise, affirmative defenses based on this argument are not available in domestic legal settings.[35]

Compensation for damages usually takes the form of monetary payments. International liability regimes award compensation for traditional harms such as loss of life, personal injury, loss of or damage to property, and economic loss.[36] To prove economic loss, a claimant must make the case that future earnings would have materialized if not for the event in question.[37] Compensation for economic loss is available, for instance, for damages to fishing and tourism industries under the oil spill regime, founded on the 1971 International Convention on the Establishment of an International Fund for Compensation of Oil Pollution Damage (1971 Fund Convention).[38] Many regimes also entail compensation for preventive measures as well as reasonable steps taken to reinstate the environment.[39] The 1993 Convention on Civil Liability for Damage Resulting from Activities Dangerous

33 International Convention on Liability and Compensation for Damage in Connection With the Carriage of Hazardous and Noxious Substances by Sea, May 3, 1996, 35 I.L.M. 1406.

34 *See Survey on Liability Regimes, supra* note 7, at 111–14.

35 There is no exhaustive list of defenses to tort liability with which to demonstrate this. However, there is a widely accepted principle permitting an actor to cause injury to another, without the consent of the other, in order to prevent a different harm. This principle only applies in situations where (1) it is an emergency where the actor does not have the opportunity to obtain consent and (2) the actor has no reason to believe the other would decline consent. RESTATEMENT (SECOND) OF TORTS § 892D (1979). The corollary principle is that an actor is liable in a situation where there was an opportunity for consent to be given regardless of the harm that might be prevented. *See* Mohr v. Williams, 104 N.W. 12, 16 (Minn. 1905) (finding civil liability for assault and battery where a surgeon had consent to operate only on the right ear, but during surgery instead operated on the left ear as it was in worse condition).

36 *See Survey on Liability Regimes*, *supra* note 7 at 98–100.

37 *See* Giuseppe Dari-Mattiacci & Hans Bernd-Schafer, *The Core of Pure Economic Loss*, 27 INT'L REV. L. & ECON. 8, 8 (2007).

38 International Convention on the Establishment of an International Fund for Compensation of Oil Pollution Damage, Dec. 18, 1971, 1110 U.N.T.S. 57 [hereinafter 1971 Fund Convention].

39 *See Survey on Liability Regimes*, *supra* note 7, 98–99.

to the Environment (Lugano Convention) provides a rare example of compensation for damage to the environment per se, regardless of impacts on socioeconomic use.[40]

The predominance of strict liability in international law has been matched by widespread limits on compensation for liable parties.[41] Another common feature of international liability mechanisms is compulsory insurance schemes, which are intended to ensure that those found liable have resources sufficient to meet their compensatory obligations. Typically, signatory states that license, register, or issue permits to owners or operators must require such parties to maintain adequate insurance or other financial security as a condition of operation. Under terms of the 1952 Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface (Rome Convention), for example, aircraft operators must carry insurance or provide other security adequate to cover damages resulting from liability.[42]

Quantitative caps on defendant liability have led to the creation of additional tiers of compensation within some liability regimes in order to ensure full redress for victims. For instance, the 1963 Supplementary Convention to the Convention on Third Party Liability in the Field of Nuclear Energy established three layers of compensation for nuclear accidents in Europe: a first tier provided by operators of nuclear installations, who are protected by limited liability; a second tier provided by states on whose territory compromised installations are located, again with a specified cap; and a third tier based on contributions to a compensation fund made by all contracting parties.[43]

The best-known liability compensation funds are the International Oil Pollution Compensation (IOPC) Funds, established beginning with the 1971 Fund Convention.[44] The IOPC Funds are financed by mandatory levies on public and private

40 Convention on Civil Liability for Damage Resulting from Activities Dangerous to the Environment, June 21, 1993, E.T.S. No. 150.

41 *See Survey on Liability Regimes*, *supra* note 7, 105–07.

42 Convention on Damage Caused by Foreign Aircraft to Third Parties on the Surface, Oct. 7, 1952, 310 U.N.T.S. 181.

43 Supplementary Convention to the Convention on Third Party Liability in the Field of Nuclear Energy, Jan. 31, 1963, 1041 U.N.T.S. 374.

44 *See, e.g.,* Jutta Brunnee, *Of Sense and Sensibility: Reflections on International Liability Regimes as Tools for Environmental Protection*, 53 INT'L & COMP. L.Q. 351, 357–58 (2004).

entities that import oil.[45] The purpose of such funds is to serve as a supplementary compensatory backstop in cases where liability limits have been reached, insurance was not maintained, defendants are insolvent, or no parties qualify as liable.[46] Fund contributions may be mandatory or voluntary, and may derive from public or private entities.[47]

As this discussion makes clear, existing liability mechanisms are closely tailored to the specific needs and features of the issue-areas they are designed to help manage. Every potentially hazardous transboundary activity is distinguished by a unique risk profile, characterized by a set of variably likely, variably severe possible impacts. While SAI remains at the conceptual stage of development, researchers have already devoted considerable attention to potential hazards associated with this climate engineering technique. The following Section takes stock of current knowledge about possible losses and damages connected to SAI, and points toward some institutional elements that might be particularly suited to a future stratospheric aerosol liability regime.

II. POSSIBLE SAI DAMAGES, POSSIBLE LIABILITY SOLUTIONS

SAI, like other forms of SRM, is intended to reflect away a small fraction of the sunlight reaching the planet, thereby reducing climate changes that would otherwise occur as a result of the accumulation of anthropogenic greenhouse gas (GHG) emissions. SAI would accomplish this by introducing aerosols to the stratosphere. Most research and analysis has focused on the use of sulfuric acid aerosols created by the injection of sulfur dioxide.[48]

Researchers have identified a number of significant damages that could potentially result from large-scale SAI experimentation and/or deployment. These harms fall into three distinct categories.[49] First, there are a handful of risks directly related to the specific technology employed to carry out SAI. These risks pertain primarily to the unintended chemical effects of aerosols introduced

45 *See* INT'L OIL POLLUTION COMPENSATION FUNDS, THE INTERNATIONAL REGIME FOR COMPENSATION FOR OIL POLLUTION DAMAGE: EXPLANATORY NOTE, 4–7 (2014).

46 *See id.* at 3.

47 *See id.* at 4.

48 *See, e.g.,* SOLAR RADIATION MGMT. GOVERNANCE INITIATIVE, SOLAR RADIATION MANAGEMENT: THE GOVERNANCE OF RESEARCH 14–15 (2011).

49 *See* Table 2.

into the stratosphere. The use of sulfate aerosols in particular would lead to an increase in acid rain (although the small quantities and distributed delivery of sulfur typically proposed would be likely to substantially reduce the magnitude of this harm).[50] And recovery of the stratospheric ozone layer might be slowed as a result of aerosol injection, as aerosols can shift chlorine from inactive reservoir species to the species that catalytically destroy ozone.[51] Any ozone effects would likely be concentrated at the poles.[52] In both of these cases, SAI technology carries the risk of independently intensifying existing environmental problems. Other, previously unidentified health, safety, or environmental risks might also materialize in the course of SAI operations.

50 *See* B. Kravitz et al., *Sulfuric Acid Deposition from Stratospheric Geoengineering With Sulfate Aerosols*, 114 J. GEOPHYSICAL RES.-ATMOSPHERES D14109 (2009).

51 *See* S. Tilmes et al., *The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes*, 320 SCIENCE 1201, 1201 (2008).

52 *See id.*

Table 2: Possible Harms Associated with SAI

Harm Category	SAI Impact	Probability	Magnitude
Technology risks	Increased acid rain	Certain	Very low
	Increased ozone depletion, UV radiation (polar regions)	High	Low
Climate response damages	Uneven regional climate effects (temperature and precipitation)	Certain	Unknown, potentially high
	Disruptions to Asian, African monsoons	Unknown	High
	Reduced soil moisture in tropics	Medium	Unknown, potentially high
	Enhanced ocean acidification (due to reduced sea surface temperature)	Low	Low
	Reduced effectiveness of solar power generation	Medium	Low
	Whiter skies, altered sunsets	High	Unknown (aesthetic)
Opportunity costs	Loss of potential climate change benefits	Varies	Varies

The second category of impacts arises from climate responses to SAI. The potential magnitude of climate response damages is typically larger than what characterizes more limited technology risks. To begin with, global climate change will produce a specific regional distribution of climate changes with largely negative impacts.[53] Current modeling studies suggest that injecting an artificial layer of aerosols into the stratosphere on top of projected climate change would reduce negative impacts of climate change overall. On average, the evidence available to date indicates that local weather patterns across the planet would more closely resemble preindustrial conditions if a globally warmer world implemented SAI than if no SAI were deployed—in this sense, global net utility would be higher with SAI than without. But SAI is also expected to redistribute some negative climate effects locally. As a consequence, a minority of regions might suffer greater losses in a climate-changed, geoengineered world than they would in a climate-changed world where geoengineering was not implemented.[54]

At a planetary level, implementing SAI could cause exaggerated cooling in the tropics and amplified warming at high latitudes relative to preindustrial conditions.[55] Modeling indicates that some regional precipitation patterns could shift.[56] If stratospheric aerosols were used to completely offset the increase

53 *See generally* Intergovernmental Panel on Climate Change, *Technical Summary*, *in* CLIMATE CHANGE 2014: IMPACTS, ADAPTATION AND VULNERABILITY 2 (Field, C.B., et al., eds., 2014), *available at* http://www.ipcc.ch/report/ar5/wg2/ (summarizing likely regional impacts of global climate change).

54 *See* K. Caldeira & L. Wood, *Global and Arctic Climate Engineering: Numerical Model Studies*, 366 PHIL. TRANSACTIONS ROYAL SOC'Y A 4039, 4042 (2008) (demonstrating that a minority of regions would suffer increased disruption due to precipitation changes under SRM compared to no SRM); H.D. Matthews & K. Caldeira, *Transient Climate-Carbon Simulations of Planetary Geoengineering*, 104 PROC. NAT'L ACAD. SCI. U.S. 9949, 9950 (2007) (demonstrating that a minority of regions would suffer increased disruption due to precipitation changes under SRM compared to no SRM); J. Pongratz et al., *Crop Yields in a Geoengineered Climate*, 2 NATURE CLIMATE CHANGE 101, 103 (2012) (demonstrating that individual local areas may exhibit larger changes in agricultural yields under SRM compared to no SRM); K.L. Ricke et al., *Regional Climate Response to Solar Radiation Management*, 3 NATURE GEOSCIENCES 537, 537 (2010) (showing that in most regions and seasons SRM reduces disruptions due to precipitation changes compared to no SRM); H. Schmidt et al., *Solar Irradiance Reduction to Counteract Radiative Forcing from a Quadrupling of CO_2: Climate Responses Simulated by Four Earth System Models*, 3 EARTH SYS. DYNAMICS 63, 74 (2012) (showing differentiated regional responses to SRM).

55 *See* B. Kravitz et al., *Climate Model Response from the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 J. GEOPHYSICAL RES.: ATMOSPHERES 8320, 8323 (2013); H. Schmidt et al., *supra* note 54, at 72.

56 *See* Simone Tilmes et al., *The Hydrological Impact of Geoengineering in the Geoengineering Model Intercomparison Project (GeoMIP)*, 118 J. GEOPHYSICAL RES.: ATMOSPHERES 11,036, 11,036 (2013).

in global mean temperature caused by anthropogenic CO_2, then global average precipitation would be reduced (relative to the projected increase from a warming world).[57] (Modeling also indicates that changes in regional precipitation would be *even greater* in a warmer world *without* SRM.[58]) Particular concerns have been raised over possible disruptions to Asian and African monsoon systems.[59] (But again, current modeling indicates that monsoon disruptions would be *more severe* in a warmer world *without* SRM.[60]) In addition, evidence suggests that soil moisture levels in the tropics could be reduced.[61]

The use of stratospheric aerosols poses other climate response risks distinct from uneven regional climate effects. Ocean acidification is already occurring as a result of excess atmospheric CO_2, but could be additionally enhanced by SAI as lower sea surface temperatures promote increased oceanic uptake of CO_2 (although net effects on ocean pH would likely be negligible).[62] Researchers have speculated that solar power generation might be negatively affected due to changes in light quality.[63] Lastly, research indicates that SAI would likely result in whiter skies and more colorful sunsets.[64] As in the case of possible damages resulting directly from SAI operations, other, unanticipated climate responses to stratospheric aerosol interventions may lead to significant unforeseen losses.

57 *See id.* at 11,044–47.

58 *See id.* at 11,050.

59 *See* Alan Robock et al., *Regional Climate Responses to Geoengineering with Tropical and Arctic SO_2 Injections*, 113 J. GEOPHYSICAL RES. D16101, D16101 (2008). *But see* Juan B. Moreno-Cruz et al., *A Simple Model to Account for Regional Inequalities in the Effectiveness of Solar Radiation Management*, 110 CLIMATIC CHANGE 649, 661 (2012).

60 *See* Tilmes et al., *supra* note 56, at 11,047–53.

61 *See* G. Bala et al., *Albedo Enhancement of Marine Clouds to Counteract Global Warming: Impacts on Hydrological Cycle*, 37 CLIMATE DYNAMICS 915, 921 (2011).

62 H. Damon Matthews et al., *Sensitivity of Ocean Acidification to Geoengineered Climate Stabilization*, 36 GEOPHYSICAL RES. LETTERS L10706 (2009); Phillip Williamson & Carol Turley, *Ocean Acidification in a Geoengineering Context*, 370 PHIL. TRANSACTIONS ROYAL SOC'Y A 4317, 4317 (2012).

63 Daniel M. Murphy, *Effect of Stratospheric Aerosols on Direct Sunlight and Implications for Concentrating Solar Power*, 43 ENVTL. SCI. & TECH. 2784, 2784 (2009).

64 Ben Kravitz et al., *Geoengineering: Whiter Skies?*, 39 GEOPHYSICAL RES. LETTERS L11801 (2012).

A third category of potential harms includes opportunity costs stemming from climate change benefits that do not occur because of SAI deployment. Opportunity costs, in this sense, are equivalent to economic losses caused by economic opportunities foreclosed. For example, successful SAI deployment would be expected to reduce, halt, or even reverse the regional thawing currently underway in the Arctic. Yet a multiplicity of actors has already invested in expanded oil and gas exploration opportunities made possible by climate change above the Arctic Circle.[65] Arresting the Arctic thaw would both diminish the value of investments made to date in regional hydrocarbon extraction, and cut off the expected future revenue streams on which such investments are based. Expanded Arctic shipping and improved agricultural productivity in boreal zones represent other potential opportunity costs of SAI, since solar geoengineering would counteract the warming on which these activities depend. The probability and magnitude of harms resulting from lost benefits of climate change would vary widely depending on the potential benefit in question.

The risks described above are characterized by different degrees of likelihood, different orders of severity, and, above all, high levels of uncertainty. The probability, magnitude, and location of potential harms are likely to vary in unpredictable ways based on the rate, size, and point of intervention. These risks could be at least partially mitigated through wise choices about, for example, temperature targets, spatial distribution, particle type, quantity, and rate of release. However, the possibility of such losses likely cannot be completely eliminated, and would need to be addressed by any prospective SAI liability mechanism. Furthermore, the threat of "unknown unknowns" would accompany any SAI implementation; since these cannot be anticipated prior to deployment, a post-factum liability system would be the only way to manage risks of this type.

From the perspective of liability and compensation, two aspects of these potential hazards stand out. First is the potentially high magnitude of damages that attend several of these known risks (regardless of the probability of their occurring). In particular, regional threats to the hydrological cycle, whether in the form of localized flooding or droughts, interference with

65 *See, e.g.,* Scott Borgerson, *The Coming Arctic Boom: As the Ice Melts, the Region Heats Up*, 92 FOREIGN AFF. 76, 80 (2013).

monsoons, or reduced soil moisture, constitute a significant potential source of loss caused by SAI implementation. Large-scale disruptions to water supplies and agriculture could pose serious risks to sizeable populations. We make the working assumption that the damages from SAI—for the worst affected regions—would be of the same order of magnitude as damages expected from climate change.[66] In this case, total SAI damages could amount to roughly one percent of gross domestic product (GDP). This would equate to monetary damages of approximately $10 billion for a country the size of Indonesia, or $100 billion for a country the size of China. All things being equal, larger interventions would likely cause more severe damages and hence larger liabilities. A well-structured, all-inclusive international liability mechanism designed to ascertain damage, allocate loss, and award compensation for hydrological and other possible hazards might well be a precondition for any widespread, multilateral political decision to move forward with stratospheric aerosol deployment.

Second, as is often the case in international relations, a North-South political dynamic infuses many of these hazards, particularly those that are potentially most severe, such as hydrological disruptions. Within the emerging discourse on geoengineering, one dominant strain holds that climate interventions such as SAI represent a political project of the global North. According to this view, the benefits of climate engineering would accrue disproportionately to the developed world, while the costs would fall primarily on developing countries.[67] The opposing view seems more credible as climate risks are well known to be more severe in the global South because there is less adaptive capacity.[68]

66 The following calculations are made based on the approximately one percent GDP climate damage estimate used by the Dynamic Integrated Climate-Economy (DICE) model and the IPCC, and current national GDP estimates provided by the World Bank. *See* WILLIAM NORDHAUS & PAUL SZTORC, DICE 2013R: INTRODUCTION AND USER'S MANUAL 11–12 (2d ed. 2013) (indicating one percent GDP estimate).

67 *See, e.g.,* ETC GROUP, GEOPIRACY: THE CASE AGAINST GEOENGINEERING 3 (2010), *available at* http://www.etcgroup.org/sites/www.etcgroup.org/files/publication/pdf_file/ETC_geopiracy_4web.pdf.

68 *See, e.g.,* Climate Change Secretariat of the U.N. Framework Convention on Climate Change (UNFCCC), *Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries* 5 (2007) (noting that "[d]eveloping countries are the most vulnerable to climate change impacts because they have fewer resources to adapt: socially, technologically and financially").

Nevertheless, a narrative of exploitation has gained traction.[69] As with climate change more broadly, SRM and its possible effects have become inextricably linked to ongoing arguments about Northern responsibility, Southern victimhood, rights to develop, and climate justice,[70] and a successful liability mechanism must take these political realities into account.

With these characteristics in mind, how do possible hazards associated with SAI map onto the historical development of liability and compensation at the international level? As a starting point, it is necessary to recognize that strict liability (as opposed to fault-based) has become the standard in international law, and would almost certainly apply to any SAI liability regime.[71] The reasons for this are both practical and political. Once established, norms such as strict liability in international law are very difficult to dislodge.[72] Some risks from SAI and other forms of SRM, such as changes in regional precipitation patterns, are potentially very costly, for which strict, no-fault liability is regarded as appropriate. Demonstrating fault is notoriously problematic in international legal proceedings.[73] And the standard of strict liability eases the burden of proof for claimants, a condition that would almost certainly be insisted upon by any major power uninvolved in the deployment of SRM.

The purpose of SAI, as discussed, would be to counteract some of the potential damages stemming from climate change. It might be argued that this preventative character makes harms

---

69 *See* Jonas Anshelm & Anders Hansson, *Battling Promethean Dreams and Trojan Horses: Revealing the Critical Discourses of Geoengineering*, 2 ENERGY RES. & SOC. SCI. 135, 142 (2014).

70 *See, e.g.,* AFRICAN ACADEMY OF SCIENCES AND THE SOLAR RADIATION MANAGEMENT GOVERNANCE INITIATIVE, GOVERNANCE OF RESEARCH ON SOLAR GEOENGINEERING: AFRICAN PERSPECTIVES 20–27 (2013); Mulugeta M. Ayalew & Florent Gasc, *Managing Climate Risks in Africa: The Role of Geoengineering*, GEOENGINEERING OUR CLIMATE?, July 2013, *available at* http://geoengineeringourclimate.com/2013/07/23/managing-climate-risks-in-africa-the-role-of-geoengineering-opinion-article/.

71 It is conceivable that, depending on institutional arrangements, strict liability for SAI geoengineering could create such powerful disincentives for individual states to carry out deployment that SAI would not be provided, even if there is universal agreement on its desirability. Such a free rider problem theoretically could be overcome by enhancing the scope and credibility of exemptions from liability.

72 *See* ALEXANDER WENDT, SOCIAL THEORY OF INTERNATIONAL POLITICS 310–12 (1999).

73 *See* Boyle, *supra* note 16, at 13.

caused by solar geoengineering ethically distinct from more conventional harms, and hence SAI liability claims ought to be restricted in their admissibility if not disallowed in their entirety. As noted above, however, no legal precedent exists for negating liability on this basis, and it is extremely unlikely that such a defense would be accepted in practice.[74]

Beyond these points, institutional and conceptual developments in the field of international legal liability lead to three distinct conclusions when viewed through the lens of stratospheric aerosol geoengineering. First, the manner in which SAI would likely be conducted suggests that state, rather than civil, liability is the appropriate basis on which to construct a liability regime. Second, the potentially enormous costs that might result from certain negative impacts (however unlikely they may be) recommend use of a compensation fund to spread the burden of compensation as well as to reassure potential victims that reparations will be paid. Third, and most challenging, the necessity of being able to establish causation in any liability regime (whether strict or fault-based), combined with the difficulty of demonstrating causality with respect to any climate intervention, warrants a fresh look at issues of legal causation in the climate context. The next Sections address these three topics in turn.

III. STATE LIABILITY AND THE SPACE LIABILITY CONVENTION

As noted earlier, a key question for the design of any liability regime is whether the activity in question is commercial or non-commercial in nature. In general, commercial transboundary hazardous activities have been subject to civil liability regimes, while state liability has been assigned to activities where markets play little role.[75] SRM, including its stratospheric aerosol variant, would likely constitute an archetypal public activity, for which a regime of state liability would be appropriate. Atmospheric manipulation via stratospheric aerosol injection would act upon the quintessential global commons. There is no current market for SRM, and few incentives exist for private firms to engage in solar geoengineering without strong (inter)governmental leadership. Indeed, the very liability risks discussed in the preceding Section would serve as powerful and probably insurmountable obstacles to

74 *See supra* note 35 and accompanying text.
75 *See Survey on Liability Regimes*, *supra* note 7, at 107.

organizing SRM as a primarily commercial enterprise, even if there were a market for it, since adequate insurance likely would be impossible for corporations to obtain.

Even if SAI could be successfully commercialized, a privatized system of stratospheric SRM would probably be politically unacceptable. The notion of commercial or corporate control over SRM is highly controversial and subject to intense debate within the geoengineering community.[76] While many potential stakeholders are open to the possibility of corporate participation in SAI, for example, as contractors or vendors,[77] little (if any) support has been voiced for operational decision making by private, commercial entities. Even those interests most sympathetic toward market solutions to public policy problems, who advocate at least a partial substitution of SRM in place of emissions mitigation, view states as the essential players in any organized stratospheric aerosol effort.[78] For political, practical, and principled reasons, therefore, it is necessary to approach SAI as a non-commercial endeavor best suited to a system of state liability.

The only liability regime based solely on state liability, as noted above, is the Convention on International Liability for Damage Caused by Space Objects, also known as the Space Liability Convention, which was both signed and entered into force in 1972.[79] This convention was in effect an elaboration of the principle of state liability for damages in outer space as set down in the foundational 1967 Outer Space Treaty.[80] Specifically, according to Article VII of the Treaty:

> Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory

76 *See, e.g.,* KELSI BRACMORT & RICHARD K. LATTANZIO, CONG. RESEARCH SERV., R41371, GEOENGINEERING: GOVERNANCE AND TECHNOLOGY POLICY 5 (2013); THE ROYAL SOC'Y, *supra* note 1, at 5.

77 *See* Steve Rayner et al., *The Oxford Principles* 26–27 (Climate Geoengineering Governance, Working Paper No. 1, 2013).

78 *E.g.*, James Erick Bickel & Lee Lane, *Challenge Paper: Climate Change, Climate Engineering R&D*, Copenhagen Consensus 2012, *available at* http://www.copenhagenconsensus.com/sites/default/files/Climate%2BChange%2BEngineering%2BR%2526D.pdf (advocating a government-run SRM research and development program).

79 Space Liability Convention, *supra* note 24.

80 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies, Jan. 27, 1967, 18 U.S.T. 2410, 610 U.N.T.S. 205.

> or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such object or its component parts on the Earth, in airspace or in outer space, including the moon and other celestial bodies.[81]

The institutional machinery for actualizing state liability in outer space was spelled out five years later in the Space Liability Convention.

The Convention was intended to facilitate the launching of spacecraft, satellites, and other "space objects" into outer space for purposes of exploration and responsible use, while at the same time protecting the interests of those who might be negatively affected by accidental impacts or collisions caused by those space objects.[82] Only states may present and answer claims for compensation.[83] Private parties, either victims or accused, must be represented by national governments.[84] Where more than one state is involved in a space launch, the Convention provides for joint and several liability.[85] Exoneration is available in cases of contributory negligence on the part of victim states.[86]

The Space Liability Convention lays out a two-stage claims procedure for settling disputes over damage from space objects. The first step requires the claimant state(s) to present its claim to the alleged launching state(s), and for the parties to attempt to reach a settlement through "diplomatic channels."[87] In the event a mutually acceptable settlement cannot be reached, the Convention provides for the convening of a three-person "Claims

81 *Id.* art. VII.

82 Space Liability Convention, *supra* note 24, pmbl.

83 *Id.* art. IX.

84 *Id.* art. VIII.

85 *Id.* art. V.

86 The Convention remains exceptional in that it establishes two separate standards of liability based upon where damage occurs. For impacts on the surface of the Earth and collisions with aircraft, strict ("absolute") liability was assigned to "launching states." But for collisions in orbit and otherwise above the atmosphere, fault liability was assigned to responsible launching states. Fault-based liability in cases of space object collision in outer space was premised on the idea that only major "space powers" would be likely to suffer such damage, these powers were of equivalent stature, and launching states were fully cognizant of the risks entailed in placing satellites and other objects into outer space. *See* BRUCE A. HURWITZ, STATE LIABILITY FOR OUTER SPACE ACTIVITIES IN ACCORDANCE WITH THE 1972 CONVENTION ON INTERNATIONAL LIABILITY FOR DAMAGE CAUSED BY SPACE OBJECTS 34 (1992).

87 Space Liability Convention, *supra* note 24, art. IX.

Commission," composed of one individual appointed by each side as well as a third member jointly agreed upon.[88] Decisions of the Claims Commission "shall be final and binding if the parties have so agreed; otherwise the Commission shall render a final and recommendatory award, which the parties shall consider in good faith."[89] Compensation for damage should aim "to provide such reparation . . . as will restore the person, natural or juridical, State or international organization on whose behalf the claim is presented to the condition which would have existed if the damage had not occurred" (i.e., status quo ante).[90] There is no limit to liability or cap on compensation.[91] The entire claims process can take no more than four years to complete.[92]

To date, the Convention has been invoked only once.[93] In 1978, Cosmos 954, a Soviet nuclear-powered satellite, malfunctioned and fell from orbit, scattering approximately one hundred kilograms of largely radioactive debris over a broad swathe of northern Canada.[94] Due to the remoteness of the deposition area, the small amount of debris, and the short half-lives of radioactive materials involved, the crash was determined to pose no significant hazards to people or the environment.[95] Recovery and analysis of the debris, however, cost the Canadian government approximately CAD$14 million.[96]

In January 1979, the Canadian government presented a surface-based strict liability claim to the Soviet Union for damages stemming from the Cosmos 954 incident, grounded in the Space Liability Convention, to which both states were party.[97] Specifically, Canada requested approximately CAD$6 million in compensation for the "incremental costs" incurred in the course of search, recovery, technical analysis, and storage activities related

---

88 *Id.* art. XIV–XV.

89 *Id.* art. XIX, ¶ 2.

90 *Id.* art. XII.

91 *Id.*

92 *Id.* art. X.

93 *See* SANDS ET AL., *supra* note 9, at 728.

94 *See* GOV'T OF CAN., DEP'T OF EXTERNAL AFF., NOTE FROM THE SECRETARY OF STATE FOR EXTERNAL AFFAIRS, TO THE SOVIET AMBASSADOR, 23 JANUARY 1979; ANNEX A: STATEMENT OF CLAIM 924 (1979).

95 *See* W.K. GUMMER ET AL., CAN. ATOMIC ENERGY CONTROL BD., COSMOS 954: THE OCCURRENCE AND NATURE OF RECOVERED DEBRIS 33–35 (1980).

96 *Id.* at 36.

97 GOV'T OF CAN., *supra* note 94 at 899.

to debris from Cosmos 954.[98] (Canada did not seek the additional CAD$8 million incurred in the cleanup because the Soviets had signaled their refusal to pay for "fixed costs" such as administrative expenditures, which in their view were not properly recoverable.[99]) Canada's claim was presented in accordance with the first, negotiation stage of the claims procedure laid out by the Convention. A series of bilateral negotiating sessions (notably conducted against the politically charged background of the 1979 Soviet invasion of Afghanistan) ended in April 1981 with an agreement by the Soviets to pay CAD$3 million to the Canadian government for damages caused by the disintegration of Cosmos 954, a sum accepted in full and without qualification by Canada.[100] Indeed, in the context of contemporary Cold War relations, many Western observers were pleasantly surprised by how much the Soviets were willing to pay.[101] Many legal scholars and other observers regarded the Cosmos 954 settlement as a success for the Convention.[102] However, the fact that Canada, a developed country and close ally of the United States, ultimately received less than a quarter of the amount originally spent on cleanup, even though the source of the damage was unambiguous, also supports an interpretation of the incident as a case where liability payments were insufficient.

Several modest yet important insights derive from consideration of the Space Liability Convention and its application in the case of Cosmos 954. First and most simply, the existence of an operative state-based international liability mechanism for damage caused by space objects shows that many of the structures that would be needed for a SAI liability regime, in particular a state-based standard, are possible. To be sure, the harms potentially caused by SAI could dwarf those associated with incidents such as Cosmos 954. In current U.S. dollars, the Cosmos 954 settlement was approximately $6 million, compared to the $10–$100 billion SAI damage estimate noted above. Second, the Cosmos 954 incident demonstrates that a state-based mechanism is in fact workable. After incurring cleanup costs associated with

98 *See* HURWITZ, *supra* note 86, at 118.

99 *See* Alexander F. Cohen, *Cosmos 954 and the International Law of Satellite Accidents*, 10 YALE J. INT'L L. 78, 85–86 (1984).

100 *See* HURWITZ, *supra* note 86, at 125.

101 *See* Cohen, *supra* note 99, at 87–89.

102 *See, e.g.*, HURWITZ, *supra* note 86, at 128–29.

radioactive debris from a foreign satellite, the Canadian government presented a claim for damages to its Soviet counterpart, and subsequent negotiations produced a settlement acceptable to both states. Of course, this episode represents only a single case under a single convention, and it would be wholly inappropriate to extrapolate wider lessons for other areas based on the specifics of the Cosmos 954 affair. Nevertheless, its occurrence and amicable resolution underline the practical potential of liability regimes built on sovereign state claimants and defendants.

Third, legal scholars regard the Space Liability Convention as a well-designed, effective instrument with features worthy of emulation by other regimes. Hurwitz, for example, concludes that "The Liability Convention . . . provides a solid basis for the creation of new liability regimes. [T]he Convention is an effective and useful instrument for the development of international law . . . ."[103] Lastly, some singular aspects of the Convention may be especially significant for issues related to SAI liability. In particular, the role of "launching states" as potentially liable parties under the Convention may serve as a helpful analog for states which in the future might deliver stratospheric aerosols or precursor gases, providing important conceptual, definitional, and legal foundations for a system of liability and compensation focused on SAI deployment.

IV. COMPENSATION AND THE OIL SPILL REGIME

Given a rough estimate of \$10–\$100 billion in possible damages resulting from SAI deployment, any politically acceptable SAI liability regime would need to have the capacity (if not the resources) to provide indemnification on this scale to affected parties. The most developed and highly capitalized system for international compensation is found in the liability provisions and industry funds that together make up the international oil spill regime.[104] The origin and evolution of the oil spill regime offers many lessons potentially applicable to a future liability regime for stratospheric aerosols.

Accidental oil pollution at sea, or oil spills, became an urgent

103 *Id*. at 209.

104 *See, e.g.*, Anne Daniel, *Civil Liability Regimes as a Complement to Multilateral Environmental Agreements: Sound International Policy or False Comfort?*, 12 RECIEL 225, 227 (2003).

international issue with the advent of the supertanker in the 1960s.[105] The rapidly expanding scale of potential spills, combined with the highly complex, transnational nature of shipping oil by sea (with shipowners, operators, insurers, cargo owners, charterers, and other interests based in different countries and subject to multiple jurisdictions exercised by flag states, coastal states, and port states), created powerful incentives for systematizing and rationalizing a uniform approach to settling disputes and compensating for damages.[106] The need for such a regime was brought home in dramatic fashion by the 1967 wreck of the Torrey Canyon just outside British territorial waters. The tanker was owned by a Bermudan company and registered in Liberia, had been chartered by U.S. oil major Unocal then sub-chartered to British Petroleum, and the 32 million gallons of crude oil it spilled fouled coastlines in Britain as well as France.[107] The ensuing legal morass (eventually settled[108]) convinced governments and industry that a more orderly system was required.

Diplomatic conferences quickly produced a pair of linked conventions that spread the burden of compensation between shipowners and oil companies. The first of these was the 1969 International Convention on Civil Liability for Oil Pollution Damage.[109] CLC 69, as it is known, assigned primary liability for oil spills to the shipping industry.[110] The treaty was based on strict, no-fault liability, and executed through the civil courts of contracting parties.[111] Liability was channeled to tanker owners, who were required to compensate governments and private parties alike for losses stemming from "pollution damage" (including preventive measures) affecting coastlines and territorial seas.[112]

---

105 *See* Samuel Bergman, *No Fault Liability for Oil Pollution Damage*, 5 J. MAR. L. & COM. 1, 5–6 (1973).

106 *See* ALAN KHEE-JIN TAN, VESSEL-SOURCE MARINE POLLUTION: THE LAW AND POLITICS OF INTERNATIONAL REGULATION 288–89 (2006).

107 *See* COLIN DE LA RUE & CHARLES B. ANDERSON, SHIPPING AND THE ENVIRONMENT: LAW AND PRACTICE 11 (2d ed. 2009).

108 *See* Patrick Griggs, *"Torrey Canyon," 45 Years On: Have We Solved All the Problems?*, *in* POLLUTION AT SEA: LAW AND LIABILITY 3, 5 (Baris Soyer & Andrew Tettenborn eds., 2012).

109 International Convention on Civil Liability for Oil Pollution Damage, Nov. 29, 1969, 973 U.N.T.S. 3 [hereinafter CLC 69].

110 *Id*. art. III.

111 *Id*.

112 *Id.* art. II.

Owner liability was limited to a maximum 210 million francs Poincare (equivalent to approximately $3 million in 2014 dollars[113]), although liability could be suspended under certain exculpatory circumstances such as acts of war.[114] In order to ensure availability of adequate funds, shipowners were required to carry compulsory insurance certificates issued by flag states and subject to inspection by all states party to the convention.[115] Claimants were entitled to take direct legal action against insurers.[116] In all cases, a six-year statute of limitations applied to spill incidents.[117]

Governments signed CLC 69 with the explicit understanding that it would be followed by a second convention affixing an additional layer of liability to the oil industry.[118] This came at the insistence of tanker owners, marine insurance providers (so-called protection and indemnity insurance or "P&I Clubs"), and maritime states, who demanded that the burden of compensation for oil spill liability be shared by those who owned and profited from the oil in question.[119] The 1971 Fund Convention fulfilled this demand by setting up a new fund ("Fund 71") to pay for pollution damages in the event CLC 69 liability limits were reached (or victims otherwise went uncompensated).[120] This second tier of compensation was financed by annual contributions from major oil companies.[121] For any one incident, aggregate compensation paid by CLC 69 and Fund 71 together was capped at 450 million francs Poincare ($6 million).[122] Fund 71 was structured as an intergovernmental organization complete with a voting Assembly

---

113 Calculated by the authors using historical exchange rate and contemporary inflation calculators.

114 The franc Poincare (similar to the French franc) was formerly the standard unit of account used in international liability instruments, but has since been replaced by the International Monetary Fund special drawing right. U.S. dollar equivalents for both francs Poincare and special drawing rights provided subsequently in the text are approximations in 2014 dollars. *See generally* JOSEPH GOLD, SDRS, CURRENCIES, AND GOLD: SEVENTH SURVEY OF NEW LEGAL DEVELOPMENTS (1987) (discussing francs Poincare and special drawing rights).

115 CLC 69, *supra* note 109, art. VII.

116 *Id*.

117 *Id*. art. VIII.

118 *See* DE LA RUE & ANDERSON, *supra* note 107, at 17.

119 *See* TAN, *supra* note 106, at 295.

120 1971 Fund Convention, *supra* note 38.

121 *Id*. art. X.

122 *Id*. art IV.

and international Secretariat.[123]

CLC 69 entered into force in 1975 and the 1971 Fund Convention in 1978.[124] In order to fill the regulatory void during the ratification process, and to stave off more aggressive unilateral actions by coastal states, the oil majors led in the creation of two voluntary industry arrangements designed to serve as interim liability measures.[125] The Tanker Owners Voluntary Agreement Concerning Liability for Oil Pollution (TOVALOP) provided for shipowner liability in much the same way as CLC 69, while the Contract Regarding an Interim Supplement to Tanker Liability for Oil Pollution (CRISTAL) assigned secondary liability to oil company cargo owners using a mechanism similar to Fund 71.[126] Tanker owners that joined TOVALOP gained access to inexpensive insurance and advantageous claims settlement procedures,[127] and oil companies that joined CRISTAL benefited from its affiliated fund that assumed member liabilities exceeding specified ceilings.[128] TOVALOP took effect in 1969 and CRISTAL in 1971.[129]

Even as these industry initiatives became operative, followed by CLC 69 and Fund 71, a series of devastating incidents, notably the 1978 Amoco Cadiz[130] and 1980 Tanio[131] spills off France, exposed the inadequacy of existing liability limits to cover the full range of losses resulting from major spills. For this and other reasons, the United States refused to ratify either CLC 69 or the 1971 Fund Convention, leaving the world's leading oil importer outside the emerging international regulatory framework.[132] To address these problems, contracting parties drafted two protocols

123 *Id*. art. XVI.

124 *See* TAN, *supra* note 106, at 309.

125 *See id.* at 291.

126 *See* DE LA RUE & ANDERSON, *supra* note 107, at 13–14, 17.

127 *See* R. MICHAEL M'GONIGLE & MARK W. ZACHER, POLLUTION, POLITICS, AND INTERNATIONAL LAW: TANKERS AT SEA 159 (1981); Michael Faure & Wang Hui, *The International Regimes for the Compensation of Oil-Pollution Damage: Are They Effective?*, 12 REV. EUR. COMP. & INT'L L. 242, 245 (2003).

128 *See* Susan Bloodworth, *Death on the High Seas: The Demise of TOVALOP and CRISTAL*, 13 J. LAND USE & ENVTL. L. 443, 446–48 (1998).

129 *See* TAN, *supra* note 106, at 292, 301.

130 *See id.* at 311.

131 *See id.* at 312.

132 *See id.* at 318–19.

to the conventions in 1984.[133] The first protocol revised shipowner liability upward. Ships less than 5,000 tons were liable up to 3 million International Monetary Fund (IMF) special drawing rights (SDRs) ($7 million).[134] For each additional ton beyond this, ships were liable for 420 SDRs, up to a maximum 59.7 million SDRs ($140 million) per incident.[135] The second protocol increased the maximum aggregate CLC 69 and Fund 71 compensation to 135 million SDRs ($310 million), thereby expanding oil industry liability.[136]

By the early 1990s, faced with continuing U.S. intransigence, states party to the conventions adopted two new agreements.[137] The 1992 International Convention on Civil Liability for Oil Pollution Damage (CLC 92)[138] effectively superseded the original CLC 69 with the higher shipowner liabilities specified in the first 1984 protocol. Similarly, the 1992 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage (1992 Fund Convention)[139] established a new Fund 92 in accordance with the higher financial limits laid out in the second 1984 protocol.[140] The 1992 conventions came into force in 1996, and Fund 71 began winding up in 2002.[141] Such episodes exemplify the sort of institutional flexibility that a liability regime

133 *See id.* at 313.

134 The SDR is a currency basket that serves as the unit of account for the IMF. *See generally* GOLD, *supra* note 114 (discussing special drawing rights).

135 *See* WANG HUI, CIVIL LIABILITY FOR MARINE OIL POLLUTION DAMAGE: A COMPARATIVE AND ECONOMIC STUDY OF THE INTERNATIONAL, U.S. AND CHINESE COMPENSATION REGIME 140 (2011).

136 *See id.*

137 Before the 1984 protocols took effect, the 1989 Exxon Valdez spill occurred off Alaska, subsequently driving the U.S. Congress to pass the Oil Pollution Act of 1990 (OPA-90). This legislation instituted liability limits even higher than those envisioned by the 1984 protocols, with the result that the United States again refused to ratify CLC 69 and the 1971 Fund Convention. Oil Pollution Act of 1990, 33 U.S.C. § 2701 (2012).

138 International Convention on Civil Liability for Oil Pollution Damage, Nov. 27, 1992, 973 U.N.T.S. 3 [hereinafter CLC 92].

139 International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, Nov. 27, 1992, 973 U.N.T.S. 3 [hereinafter 1992 Fund Convention].

140 *Id.* art IV. Both instruments extended coverage for oil spill damage to parties' exclusive economic zones consistent with the 1982 United Nations Convention on the Law of the Sea. United Nations Convention on the Law of the Sea, Dec. 10, 1982, 1833 U.N.T.S. 397.

141 *See* TAN, *supra* note 106, at 329–30.

for SAI will likely require. TOVALOP and CRISTAL, having undergone multiple revisions over the years to keep pace with regulatory developments, were formally terminated in 1997.[142]

By the turn of the century, new accidents such as the 1999 Erika spill off France[143] and the 2002 Prestige spill off Spain[144] made clear that even the enhanced 1992 compensation levels were insufficient to compensate for losses from oil spills. In response, contracting parties crafted another package of liability upgrades. In 2000, governments amended CLC 92 so that ships are liable up to 89,770,000 SDRs ($165 million) per incident.[145] Likewise, the maximum aggregate compensation under the 1992 Fund Convention was raised to 203 million SDRs ($375 million).[146] These changes amounted to a two-thirds increase relative to 1992 liability levels. Both amendments came into force in 2003.[147] That same year, yet another instrument was signed, the 2003 Supplementary Fund Convention.[148] This optional protocol established a third tier Supplementary Fund for interested states, for whom the maximum aggregate compensation available from CLC 92 and Fund 92 (both as amended) together with the new Supplementary Fund (the "IOPC Funds") would be 750 million SDRs ($1.3 billion).[149] Additionally, to address concerns that liability burdens had become unbalanced to the detriment of the oil industry, the shipping industry consented to another set of voluntary agreements obliging P&I Clubs to partially indemnify the IOPC Funds.[150] The Small Tanker Oil Pollution Indemnification Agreement (STOPIA) applied to Fund 92, while the Tanker Oil Pollution Indemnity Agreement (TOPIA) applied to

142 *See* Bloodworth, *supra* note 128, at 444.

143 *See* Luc Grellet, *Avoiding International Legal Regimes: The Erika Experience*, *in* POLLUTION AT SEA: LAW AND LIABILITY 141, 141 (Baris Soyer & Andrew Tettenborn eds., 2012).

144 *See* TAN, *supra* note 106, at 331.

145 CLC 92, *supra* note 138, art. V.

146 1992 Fund Convention, *supra* note 139, art. IV.

147 *See* INT'L OIL POLLUTION COMP. FUNDS, LIABILITY AND COMPENSATION FOR OIL POLLUTION DAMAGE: TEXTS OF THE 1992 CIVIL LIABILITY CONVENTION, THE 1992 FUND CONVENTION AND THE SUPPLEMENTARY FUND PROTOCOL 3 (2011).

148 Protocol of 2003 to the International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage, 1992, May 16, 2003, 973 U.N.T.S. 3.

149 *See id.* art. IV.

150 *See* HUI, *supra* note 135, at 182–83.

the Supplementary Fund.[151] Both shipping industry schemes took effect in 2006.[152]

The history of the oil spill regime has been characterized overall by continually increasing liability limits; accreting layers of additional compensation; balancing of burdens between shipowners and oil interests; and supplementing intergovernmental arrangements with industry initiatives. This evolution has been driven to a large degree by a series of major oil spills beginning with the Torrey Canyon in 1967, but in terms of number of incidents, quantity spilt, and other key measures, there has been a remarkable decline in accidental oil spills since the 1960s: "the volume of oil spilt from tankers demonstrates a significant improvement through the decades. Consistent with the reduction in the number of oil spills from tankers, the volume of oil spilt also shows a marked reduction."[153] While large spills have been the impetus for institutional changes, their frequency and resulting damages have declined markedly over time.

There are indications that compensation payments under the oil spill regime have had a "deterrent effect" by encouraging industry to take preventative safety measures.[154] The regime is generally viewed as effective in providing satisfactory compensation to public and private victims of oil spills: "features such as strict liability, compulsory insurance, limitation funds, direct action against insurers and cargo-financed supplemental funds have all benefited pollution victims immensely."[155] In the vast majority of cases, claims for oil spill damages brought under the regime have been settled out of court.[156] The most recent available data indicate that, since Fund 71 first became operational, the IOPC Funds collectively have distributed a total £569 million ($896 million) in compensation to the victims of 147

151 *See* DE LA RUE & ANDERSON, *supra* note 107, at 172–75 (describing STOPIA and TOPIA).

152 *See* HUI, *supra* note 135, at 183.

153 INT'L TANKER OWNERS POLLUTION FED'N LTD., OIL TANKER SPILL STATISTICS 2012 6 (2013).

154 *See* Michael Faure & Wang Hui, *Economic Analysis of Compensation for Oil Pollution Damage*, 37 J. MAR. L. & COM. 179, 215 (2006).

155 TAN, *supra* note 106, at 342.

156 *See* INT'L OIL POLLUTION COMP. FUNDS, ANNUAL REPORT 2013 4 (2013), *available at* http://www.iopcfunds.org/uploads/tx_iopcpublications/annualreport2013_e.pdf.

separate incidents.[157] As noted above, a rough calculation of potential damages from SAI is in the range of $10–$100 billion. While the IOPC Funds do not approach this level, they are more comparable than the relatively small amount involved in the Cosmos 954 settlement under the Space Liability Convention.

Several aspects of the oil spill regime policy architecture are noteworthy in the context of stratospheric aerosol liability. First is the fact that compensation levels marshaled by the regime to date have been adequate to satisfy damage claims brought by public and private parties: "The strict liability systems of compensation established by the Civil Liability and Fund Conventions, and by U.S. domestic legislation, have ensured that in practice compensation has nearly always been available for payment of claims resulting from an oil pollution incident."[158] While the lack of U.S. participation in the conventions has undercut the drive for global uniformity in oil spill liability rules, this refusal to ratify has been motivated not by any interest in dodging liability, but rather by a belief that regime coverage should be even greater than it is.[159]

Second, the ongoing adequacy of compensation levels reflects the impressive institutional flexibility of the regime. Flexibility mechanisms such as amendment and protocol procedures are hardly unique to the oil spill regime, yet the adaptability they enable has been a key factor in the success of the Conventions and Funds. By using these mechanisms, parties to the regime have been able to enhance compensation levels over time to take account of increasing tanker tonnages; expanding categories of losses recognized by civil courts; the entry of new litigants; accelerating coastal development; intensified fishing and aquaculture; and general price inflation.[160] Such flexibility has allowed the regime to accommodate unforeseen technological, economic, and legal developments. A liability regime for SAI geoengineering would almost certainly encounter similarly unanticipated occurrences, and require a comparable capacity for adaptability.

Third, the fund structure pioneered by the oil spill regime

157 *See id.* at 4, 16.
158 DE LA RUE & ANDERSON, *supra* note 107, at 355.
159 *See* TAN, *supra* note 106, at 287.
160 *See id.* at 288–89.

offers a number of advantages that would benefit efforts to address SAI liability. By collecting levies prior to actual incidents, the IOPC Funds reassure potential victims that a pool of liquid capital will be available for disbursement if an accident occurs. Freestanding, pre-existing bodies like the IOPC Funds can help expedite delivery of compensation to claimants, through institutionalized payment mechanisms and rights of subrogation spelled out in the Conventions.[161] Since SAI would likely be based on state liability, restoring losses through a compensation fund would perform a particularly useful diplomatic function insofar as it would replace direct state-to-state legal action with a less politicized claims process in which damages would be recovered from a neutral international organization such as the IOPC Assembly. IOPC financing arrangements, based on annual contributions by oil companies, also present a unique approach to raising funds for compensation from private sources regarded (at least politically) as ultimately liable for environmental damages. In the SRM context, oil companies and other core constituents of the fossil fuel industry might conceivably be compelled to provide funds for collective liability coverage.[162]

Lastly, the critical role played by oil interests in financing the IOPC Funds exemplifies the key importance of industry involvement in the success of the oil spill regime. From the outset, the oil and shipping industries collaborated closely with each other, with their maritime state backers, and with coastal and port states to design and implement a liability system that would balance the immense economic benefits of shipping oil by sea against the need to provide satisfactory reparations to those who might suffer damage from the accidents such commerce would inevitably cause. While the actions of oil majors, independent tankers, and P&I Clubs were clearly motivated by a desire to shape the agenda, influence deliberations, protect commercial interests, and maintain some degree of control over the evolving regulatory framework, the net result was a liability and compensation system generally regarded as having benefited victims of oil pollution

161 Rights of subrogation allow for payment of claims by third parties (in this case, the IOPC Funds), who then assume rights to compensation from responsible parties (insured shipowners). CLC 92, *supra* note 138, art. III.

162 How this would align with other emerging contributory climate funds such as the Green Climate Fund and Adaptation Fund is unclear; the issue is outside the scope of this article.

enormously.[163] Insurance payments for shipowner liability and oil company contributions to the IOPC Funds, mechanisms that were influenced and consented to by these same actors, together constitute the entirety of compensation payments under the regime. And voluntary schemes wholly conceived by industry such as TOVALOP and CRISTAL served as valuable interim measures offering relief to victims during periods of ratification, accession, and revision to the primary intergovernmental instruments.[164]

One element of market engagement in the oil spill regime, however, would not be applicable to a liability system for stratospheric aerosol deployment. Compulsory liability insurance, a particularly innovative provision of the Conventions, is a device used in civil proceedings and designed to ensure victims receive adequate compensation for damages inflicted.[165] Doctrines of sovereign and state immunity protect states from civil actions brought by non-state actors at home or abroad, so that governments are not subject to civil liability claims and cannot be sued for injuries.[166] As previously discussed, where government operators are held to cause recoverable damages, liability and compensation are addressed outside civil courts in a state liability regime (such as the Space Liability Convention). In a state liability setting populated exclusively by sovereigns settling disputes through negotiation or arbitration, such as would likely characterize SAI, liability insurance has no role to play, since it is premised on rules that do not apply. Other types of insurance, however, may conceivably perform useful functions; for example, joint funds could be channeled to support sovereign disaster risk insurance for potential victims of SRM.[167]

V. THE PROBLEM OF ATTRIBUTION

When considering liability in the context of stratospheric aerosol geoengineering, an especially problematic issue relates to the difficulty of demonstrating causal attribution. Traditionally,

163 *See, e.g.,* TAN, *supra* note 106, at 342.

164 *See generally* Gordon L. Becker, *A Short Cruise on the Good Ships TOVALOP and CRISTAL*, 5 J. MAR. L. & COM. 609, 626–32 (1974) (discussing TOVALOP and CRISTAL).

165 *See* HUI, *supra* note 135, at 95.

166 *See* JULIE A. DAVIES & PAUL T. HAYDEN, GLOBAL ISSUES IN TORT LAW 141 (2008).

167 This is discussed below. *See infra* text accompanying notes 205–209.

establishing legal liability has required showing a direct cause-effect relationship between an action committed by an alleged wrongdoer, and damages suffered by the victim.[168] In law, such deterministic causation is referred to as the "but for" test: but for factor X, would harm Y have occurred?[169] If the answer is no, X is considered to have caused Y, liability is established, and compensation may be awarded. If the answer is yes, Y cannot be attributed to X, liability is not proven, and damage claims will not be satisfied.

Determining responsibility for a fallen satellite or an oil spill is relatively unproblematic. But establishing an unambiguous direct causal connection between a stratospheric aerosol intervention and damages alleged to have occurred as a result is impossible due to the highly complex nature of the climate system.[170] Indeed, the very concept of "climate" itself, that is, "the average weather, or more rigorously, . . . the statistical description in terms of the mean and variability of relevant quantities over a period of time," is fundamentally probabilistic in nature.[171] Strictly speaking, climate science is incapable of producing deterministic statements describing empirical causal chains that run from initial cause to final effect; instead, climate science is limited to statements about the probability of events occurring under different conditions.[172] While climate science shares this fundamental epistemological character with all other sciences, it is distinguished by a very high degree of complexity and large uncertainties that render traditional deterministic, but-for causal statements about climate effects particularly problematic.

168 *See* Richard W. Wright, *Causation in Tort Law*, 73 CAL. L. REV. 1735, 1775 (1985).

169 *See generally* Antony Honore, *Causation in the Law*, STAN. ENCYCLOPEDIA PHIL., http://plato.stanford.edu/entries/causation-law/ (last updated Nov. 17, 2010) (discussing legal causation and the "but for" test).

170 *See* Pak-Hang Wong et al., *Compensation for Geoengineering Harms and No-Fault Climate Change Compensation* 13 (Climate Geoengineering Governance, Working Paper No. 008, 2014), *available at* http://geoengineering-governance-research.org/perch/resources/workingpaper8wongdouglassavulescu compensationfinal-.pdf.

171 Intergovernmental Panel on Climate Change, *The Physical Science Basis*, *in* CLIMATE CHANGE 2013 1450 (Stocker, T.F., et al., eds., 2014), *available at* http://www.ipcc.ch/report/ar5/wg1/#.UwTh6vaprig.

172 *See* Myles Allen, *The Scientific Basis for Climate Change Liability*, *in* CLIMATE CHANGE LIABILITY: TRANSNATIONAL LAW AND PRACTICE 8, 10–17 (Richard Lord et al. eds., 2012).

Since liability systems generally assume that damages can be traced back directly to wrongful acts, efforts to address liability in the weather and climate field have been unsuccessful to date. Early attempts at cross-border regulation of weather modification activities foundered on the apparent impossibility of awarding compensation based on nondeterministic causal statements.[173] Likewise, current efforts to address issues of "loss and damage" within the UNFCCC are hampered by (among other things) controversy over attribution of specific damaging weather events to specific emissions of CO_2 and other GHGs.[174] Future attempts to assign causal responsibility for particular harms to particular SAI interventions might, at first sight, appear unlikely to succeed for similar reasons. Opportunistic behavior in the context of liability for SRM is conceivable; for example, a country might take advantage of liability mechanisms by making damage claims based on disputable evidence that is nevertheless impossible to disprove due to methodological limitations.

Contemporary advances in both computer modeling and legal reasoning, however, are providing possible ways around the attribution impasse. Climate scientists have been developing a number of methods to enhance the strength of claims made using probabilistic event attribution.[175] The most prominent of these methods is a technique known as Fraction Attributable Risk (FAR).[176] In essence, FAR allows researchers to quantify the

173 *See* Edith Brown Weiss, *International Liability for Weather Modification*, 1 CLIMATIC CHANGE 267, 279 (1978); *see also* Lance D. Wood, *The Status of Weather Modification Activities Under United States and International Law*, 10 NAT. RES. L. 367, 379 (1977) (explaining that the science of 1977 was not yet capable of determining what damages resulted from weather modification activities).

174 *See* United Nations Framework Convention on Climate Change (UNFCCC), *Current Knowledge on Relevant Methodologies and Data Requirements as Well as Lessons Learned and Gaps Identified at Different Levels, in Assessing the Risk of Loss and Damage Associated with the Adverse Effects of Climate Change: Technical Paper*, ¶112, U.N. Doc. FCCC/TP/2012/1 (May 10, 2012).

175 *See generally* 94 BULL. AM. METEOROLOGICAL SOC'Y (SPECIAL SUPP.) (2013) (discussing weather event attribution methods).

176 To calculate a fraction of attributable risk, models and observations are used to simulate the probability distribution of a particular climate event (such as a drought) in the current climate, and to simulate the probability distribution of the same event in a climate with a particular driver (for example, increased greenhouse gases or stratospheric aerosols). The change in the event's probability between the two models shows the increase or decrease in likelihood

relative probabilities of a particular weather event occurring under two different climate scenarios. Models and observations are first used to simulate the probability distribution of a particular climate variable under known climate conditions. Model runs then simulate the probability distribution of that same variable under a climate characterized by an additional driver, typically increased GHG levels. Comparing these two distributions allows researchers to calculate the probabilities that the variable will exceed a specific weather threshold under the two different scenarios, and this in turn enables calculation of the increased likelihood that this threshold will be surpassed with the additional driver present.[177]

Using FAR or similar methods, scientists have demonstrated probabilistic causal attribution for a growing number of discrete weather events, including flooding in the United Kingdom in 2000, the European heat wave of 2003, and drought in East Africa in 2011.[178] These and other studies show statistically significant increases in the likelihood that such extreme weather events occurred as a result of anthropogenic GHG emissions.[179] In practice, a liability regime for stratospheric aerosols would be concerned with precisely these sorts of extreme events and resulting damages.

At the same time as new statistical methods are increasing the power of causal explanations based on probability distributions, the use of statistical evidence is gaining wider acceptance in many national legal systems, supplementing the traditional reliance on but-for causation. English law has demonstrated a willingness to rely on probabilistic evidence to settle liability claims.[180] In cases

that is attributable to the driver in question. *See* Myles Allen, *Liability for Climate Change*, 421 NATURE 891, 891 (2003).

177 *See* Peter A. Stott et al., *Attribution of Weather and Climate-Related Extreme Events*, *in* CLIMATE SCIENCE FOR SERVING SOCIETY: RESEARCH, MODELING AND PREDICTION PRIORITIES 307, 315–18 (G.R. Asrar & J.W. Hurrell eds., 2013).

178 *See* Chris Funk, *Exceptional Warming in the Western Pacific-Indian Ocean Warm Pool Has Contributed to More Frequent Droughts in Eastern Africa*, 93 BULL. AM. METEOROLOGICAL SOC'Y 1049, 1051 (2012); Pardeep Pall et al., *Anthropogenic Greenhouse Gas Contribution to Flood Risk in England and Wales in Autumn 2000*, 470 NATURE 382, 382 (2011); Stefan Rahmstorf & Dim Coumou, *Increase of Extreme Events in a Warming World*, 108 PROC. NAT'L ACAD. SCI. U.S. 17905 (2011); Peter A. Stott et al., *Human Contribution to the European Heatwave of 2003*, 432 NATURE 610, 610 (2004).

179 *See* Allen, *supra* note 172, at 17.

180 *See* Silke Goldberg & Richard Lord, *England*, *in* CLIMATE CHANGE

such as *Novartis Grimsby v. Cookson*,[181] *Ministry of Defence v. AB*,[182] and *Sienciewicz v. Greif*,[183] English courts have accepted that, if the risk of a given event is more than doubled by a particular factor (or driver), that factor can be said to have caused the event.[184] In *Fairchild v. Glenhaven* (a mesothelioma case), the House of Lords ruled that causation is demonstrated if a factor can be shown to have created a "material increase in risk" of an event happening;[185] the court did not define "material increase in risk" in quantitative terms, but instead specified that the risk in question must be "not insignificant" and the allegedly tortious act must have "contributed substantially to the risk."[186]

In Australia, statistical evidence has formed the basis of decisions on liability in cases such as *Seltsam Pty Ltd v. McGuiness*,[187] and "material contribution" arguments have been accepted in cases such as *Henville v. Walker*.[188] South African courts have accepted that, if there is a greater than 50 percent probability that damage resulted from a particular act, that act may be regarded as tortious and the perpetrator held liable.[189] Japanese courts have, as in the Minamata disease case, pioneered the practice of awarding compensation in proportion to the degree of probability that an act caused harm.[190] In the United States, probabilistic evidence derived from statistical models has long served as the basis for findings of liability and damage awards in

LIABILITY: TRANSNATIONAL LAW AND PRACTICE 445, 465–70 (Richard Lord et al. eds., 2012).

181 Novartis Grimsby Ltd. v. John Cookson, [2007] EWCA (Civ) 1261, [74] (Eng.).

182 Ministry of Defence v. AB & Ors, [2010] EWCA (Civ) 1317, [151] (Eng.).

183 Sienkiewicz v. Greif (UK) Ltd., [2011] UKSC 10, [222] (appeal taken from Eng.).

184 *See* Goldberg & Lord, *supra* note 180, at 465–70.

185 Fairchild v. Glenhaven Funeral Services Ltd. & Ors, [2002] UKHL 22, [67] (Lord Hoffman).

186 *See* GIEDRE KAMINSKAITE-SALTERS, CONSTRUCTING A PRIVATE CLIMATE CHANGE LAWSUIT UNDER ENGLISH LAW 171–72 (2010) (quoting Fairchild v. Glenhaven Funeral Services Ltd. & Ors, [2002] UKHL 22, [42] (Lord Nicholls), [47] (Lord Hoffman)).

187 *Seltsam Pty. Ltd. v. McGuiness* [2000] NSWCA 29 (Austl.).

188 *Henville v. Walker* (2001) 206 CLR 459, 493, 510–11 (Austl.).

189 *See* FRANCOIS DU BOIS ET AL., WILLE'S PRINCIPLES OF SOUTH AFRICAN LAW 1120 (9th ed. 2007).

190 *See* Goldberg & Lord, *supra* note 180, at 230 (discussing a Tokyo district court case on Minamata disease).

fields such as tobacco litigation, "toxic torts" (including pharmaceuticals), and radiation exposure.[191]

While not always presented as such, the standard of proof for civil cases in most courts is a greater than 50 percent likelihood.[192] This general rule of thumb derives from the widely held principle that a "preponderance of evidence" is necessary to prove damage in a civil case, which is commonly interpreted to mean "more probable than not," or greater than 50 percent.[193] In modeling terms, this conventional standard is equivalent to a FAR greater than 0.5. Significantly, a number of the weather attribution modeling studies that have been conducted to date have demonstrated FARs greater than 0.5.[194]

Taken together, methodological advances in climate science and the growing acceptance of statistical evidence in national courts suggest that reliance on probabilistic reasoning as proof of cause may offer a potential way forward in addressing the problem of liability attribution, both for SAI geoengineering and for climate policy more broadly. These converging trends point in the direction of an emerging, substantive alternative to conventional but-for, deterministic causation in cases of damage related to the effects of climate change. Such an alternative would allow for more definitive assessments of damage claims, as well as strengthen the ability to identify and dismiss opportunistic claims.

Yet serious obstacles stand between these promising scientific and legal developments, on the one hand, and a fully realized climate attribution system based on probabilistic methods, on the other. Some critics express skepticism that model-based techniques will ever be able to convincingly demonstrate causation.[195] It would undoubtedly prove challenging to gain wide scientific consensus on the robustness of a climate attribution system, which would seem a likely prerequisite for political consensus. It would probably be even more challenging to gain international political

---

191 *See* THE EVOLVING ROLE OF STATISTICAL ASSESSMENTS AS EVIDENCE IN THE COURTS 6–9, 124, 128, 133 (Stephen E. Fienberg ed., 1989).

192 *See* Eyal Zamir & Ilana Ritov, *Loss Aversion, Omission Bias, and the Burden of Proof in Civil Litigation*, 41 J. LEGAL STUD. 165, 165–66 (2012).

193 *See* CHRISTOPHER B. MUELLER & LAIRD C. KIRKPATRICK, EVIDENCE: PRACTICE UNDER THE RULES 113–15 (4th ed. 2012).

194 *See* Stott et al., *supra* note 178, at 612.

195 *See*, *e.g.*, Mike Hulme, *The Case for and Against Climate Engineering*, OXFORD MARTIN SCHOOL (Dec. 2013), http://www.oxfordmartin.ox.ac.uk/videos/view/334.

consensus. A government opposed to an attribution apparatus would likely have little difficulty finding scientific experts to question the accuracy and reliability of such a system. Since an effective attribution system would encompass all climate damages, whether caused by climate change or solar geoengineering, political objections to liability for conventional climate loss and damage may prevent acceptance of an attribution scheme intended for SAI. These and other issues would need to be overcome in order for a SAI liability regime based on statistical models to be adopted and implemented. However, in light of progress to date, the problem of attribution does not necessarily appear to present an insurmountable barrier to crafting a workable regime.

If such a regime could be built, it is likely that the larger the SAI intervention, the easier attribution by FAR or similar methods would be, since (all things being equal) a larger intervention will create a louder signal relative to background climate noise. This has implications for the form an intervention might take. An "emergency" SAI intervention entailing a relatively large pulse of stratospheric aerosols, for example, would likely generate a higher signal-to-noise ratio than a more gradual ramping up, or "peak shaving," approach to aerosol injection. An emergency intervention might therefore be more tractable from a liability perspective, but also more damaging, whereas peak shaving might cause less damage but elude efforts to assign attribution.

VI. DISCUSSION

So far, we have shown that there are a number of precedents on which a liability and compensation system for SAI could draw. Treaty systems such as the Space Liability Convention and the oil spill regime demonstrate that institutional mechanisms can be developed to effectively address some of the unavoidable risks that accompany internationally accepted hazardous cross-border activities. Furthermore, methodological and legal innovations offer a possible path forward for probabilistic attribution in the field of climate liability; these same innovations would be equally applicable to questions of causation with respect to stratospheric aerosol liability.

These considerations raise a number of additional issues. As noted in the previous Section, the science of weather attribution, as embodied in FAR and other probabilistic attribution methods, is primarily focused on extreme weather events.[196] In the context of SAI geoengineering, these events correspond to harms of potentially high magnitude as denoted in Table 2 above. Given the current understanding of SAI geoengineering, these possibly extreme, potentially attributable damages consist of extraordinary temperature and precipitation events such as heat waves, cold waves, floods, droughts, and severe storms. Conceivably, a party responsible for SAI could be held liable for opportunity costs if related environmental changes can be causally attributed to an aerosol intervention using probabilistic methods. Returning to the example of Arctic hydrocarbons used earlier, if computer models were able to demonstrate convincingly that changes in the Arctic (relative to a global warming scenario) were likely caused by SAI, grounds would exist for damage claims based on economic opportunities denied by Arctic refreezing. Proving the claim and obtaining compensation, however, would depend on separate judgments regarding the foresight and reasonableness involved in Arctic oil and gas investments prior to SAI deployment, as well as prior political agreement that compensation could be awarded for lost opportunities.

The essential role of attribution in liability regimes, combined with the critical part played by computer modeling in emerging climate and weather attribution methods, means that any system of liability and compensation for SAI geoengineering would lean heavily on the performance and credibility of climate models. Most obviously, models must be capable of demonstrating causation probabilistically using FAR or similar techniques in a methodologically rigorous and scientifically sound manner. This is of paramount importance from a technical point of view, and at least as important from a political perspective. Ultimately, in order for a stratospheric aerosol liability regime to work, scientists, policymakers, politicians, civil society, and global publics would all need to regard its foundational modeling system as reliable, accurate, independent, apolitical, and above all, legitimate. This is a tall order, and poses a significant challenge for any effort to build a liability system for SAI.

An important function of SAI liability would be to encourage appropriate precaution among those involved in its implementation. An effective, well-executed regime creates

196 *See supra* text accompanying notes 178–179.

expectations of a durable, well-functioning governance structure among all parties to an agreement. Such expectations encourage actors to internalize norms of compliance and cooperation, and to develop behaviors that support and complement larger institutional purposes.[197] In the case of a liability regime, expectations that unsafe or reckless behavior will result in significant penalties in the form of reparations can induce actors to take measures that minimize the chances of such costly outcomes. In the oil spill regime, for example, decades of effective operation have instilled oil and shipping interests, and their national backers, with the expectation that those responsible for oil spills will be held liable and forced to pay compensation; evidence suggests that, partly as a result, oil and shipping companies have made constant improvements to tanker design, oil containment systems, safety protocols, and response capabilities.[198] A liability system for stratospheric aerosols would aim to produce a similar preventative effect (although achieving it via incremental regime improvements may be substantially more problematic in a higher-stakes geoengineering context).

Enforcement presents a serious challenge to a possible future SAI liability regime. If liability is established, and compensation awarded, how would a regime function to enforce compliance with such a determination? In other words, what would force a guilty party to pay? The problem of enforcement is hardly unique to geoengineering; it applies to any cooperative endeavor between states in the anarchic international system.[199] With no global monopoly on the use of force to police the behavior of states and other actors, compliance with international norms and decisions can only be achieved through the exercise of power, the pursuit of interest, or the influence of institutions, or some combination of these factors.[200]

197 *See* John Gerard Ruggie, *International Regimes, Transactions, and Change: Embedded Liberalism in the Postwar Economic Order*, *in* INTERNATIONAL REGIMES 195, 220 (Stephen D. Krasner ed., 1983).

198 *See* Faure & Hui, *supra* note 154, at 215.

199 *See generally* KENNETH A. OYE, COOPERATION UNDER ANARCHY (1986) (discussing problems of cooperation and enforcement under conditions of anarchy).

200 *See generally* MICHAEL W. DOYLE, WAYS OF WAR AND PEACE: REALISM, LIBERALISM, AND SOCIALISM (1997) (summarizing leading theories of international relations).

The innovative design of the IOPC Funds discussed above,[201] in particular their intergovernmental legal status, suggests one possible way to resolve the enforcement problem for SAI liability. The disincentive of a guilty party to pay compensation in the absence of third party enforcement is obvious, but if an independent body authorized and funded by a multilateral group were made responsible for making reparations instead, the disincentive to pay and consequent need for enforcement would likely be considerably less. Indeed, lack of enforcement has been a nonfactor in the functioning of the oil spill regime[202], which as described above is widely regarded as an effective system for delivering compensation to spill victims. By spreading the burden of compensation across the international community, and shifting decisions about the release of funds from national governments and finance ministries to neutral international officials insulated from national interests, the IOPC Funds have in effect depoliticized the transfer of compensation from culprit to victim.

Theoretically, this logic could be extended to findings of liability itself. That is, if the decision to deploy were taken by a multilateral body, then it rather than individual states could be assigned any liability for negative side effects of the deployment. No precedent exists for assigning legal liability to a multilateral organization, as historically all liability regimes with the exception of the state-oriented Space Liability Convention have been based on civil liability.[203] But the principle of international legal personality and related concepts would seem to provide at least a minimal basis for constructing a regime based on multilateral liability. As with compensation via intergovernmental body, locating legal liability with a multilateral organization would be likely to dampen the sorts of diplomatic and political tensions that can accompany accusations of wrongdoing and demands for reparations.[204]

A further aspect of SAI liability with potential for institutional innovation is the form of compensation awarded to victims. Traditionally, compensation for international legal liability has

201 *See supra* Part IV.

202 *See* TAN, *supra* note 106, at 342.

203 *See supra* text accompanying notes 24–25.

204 *See generally* C.F. AMERASINGHE, PRINCIPLES OF THE INSTITUTIONAL LAW OF INTERNATIONAL ORGANIZATIONS (2d ed. 2005) (discussing legal frameworks of international organizations).

taken the form of monetary payments made by those responsible for damage to those suffering loss.[205] The resolution of the Cosmos 954 affair exemplifies this standard means of restitution.[206] Conventional monetary payments also typify the oil spill regime, yet compulsory insurance for shipowners first introduced under CLC 69 represented a departure from past practice, and its success has been emulated by other liability systems.[207] Although liability insurance is inapplicable to sovereign states (as discussed above), other novel insurance mechanisms currently being proposed for managing climate risks hold promise for transferring sovereign risks to insurance and reinsurance markets.[208] Regime funds could be used to finance sovereign disaster risk insurance policies, for individual countries or groups of countries; in the event of loss attributable to SAI deployment, compensation would be paid by private insurance firms with potential support from multilateral development banks. Non-insurance mechanisms such as environmental assurance bonding might also be adapted to provide coverage for potential victims of SRM implementation.[209] These and other innovative financial instruments could help to spread risk and reduce costs, particularly useful functions given the uncertain scale of damages that might result from SAI.

Such instruments might also help to depoliticize the liability and compensation process, which as noted above could also be a potential advantage of both multilateral liability and multilateral compensation designs. However, in all likelihood considerations of SAI risks, harms, and restitution will remain a highly political undertaking. Some countries might be encouraged to claim damages from SAI even in the absence of compelling evidence. Conversely, other countries might display unwarranted levels of

---

205 *See Survey on Liability Regimes*, *supra* note 7, at 103–04.

206 *See id*. at 104.

207 *See* Int'l Oil Pollution Compensation Funds, *supra* note 156, at 16 (giving amount of monetary compensation paid by IOPC Funds).

208 *See* U.N. Framework Convention on Climate Change (UNFCCC), *Mechanisms to Manage Financial Risks from Direct Impacts of Climate Change in Developing Countries*, 75–82, U.N. Doc. FCCC/TP/2008/9 (Nov. 21, 2008), *available at* http://unfccc.int/resource/docs/2008/tp/09.pdf; J. DAVID CUMMINS & OLIVIER MAHUL, CATASTROPHE RISK FINANCING IN DEVELOPING COUNTRIES: PRINCIPLES FOR PUBLIC INTERVENTION 20–25 (2009).

209 *See* Bidisha Banerjee, *The Limitations of Geoengineering Governance in a World of Uncertainty*, 4 STAN. J.L. SCI. & POL'Y 15, 33–35, *available at* http://journals.law.stanford.edu/sites/default/files/stanford-journal-law-science-policy-sjlsp/print/2011/05/61_banerjee_final.pdf.

skepticism and resistance toward SAI damage claims. Disputes over liability would likely place even greater stress on attribution modeling systems, which as noted above would already be subject to considerable technical and political strains.

The politics of SAI liability would, in the end, largely reflect the underlying ethical commitments embedded within any institutional framework. The ethics of SAI liability and compensation would ultimately revolve around questions of who pays, who gets paid, and how much.[210] Should the "polluter" pay, as is normally assumed in liability regimes, or should this obligation fall instead on those who benefit most from SAI, or alternatively on those most able to pay for damage from SAI? Should victims include parties harmed directly by SAI, parties who are harmed by SAI but benefit in net climate terms, or parties suffering opportunity costs or economic loss from reduced climate change? Should compensation be based on preindustrial, contemporary, or hypothesized future conditions? Answers to these questions are not self-evident, and can only be decided at the intersection of ethics, law, and power.

Reaching political agreement on these ethical issues will be enormously challenging. Questions of fault and responsibility bedevil current negotiations on mitigation and adaptation under the UNFCCC. Coming to a consensus on which set of historical actors should be liable for damages from solar geoengineering, either inside or outside established negotiating tracks, will be immensely difficult given the significant moral and material implications of the question. Agreeing on eligibility for compensation will require resolving sensitive distributional issues between countries (developed versus developing), within countries (central government versus local victims), and between generations (immediate payout versus long-term trust fund). And agreeing on a formula for compensation will lay bare the potentially huge financial stakes of a stratospheric aerosol liability regime. Whose damage estimates will be accepted? Should compensation take into account separate spending on mitigation and adaptation? Should private flows count as compensation? These and other ethico-political controversies will present serious obstacles to

210 *See* Tony Svoboda & Peter J. Irvine, *Ethical and Technical Challenges in Compensating Harm Due to Solar Radiation Management Geoengineering* 17 ETHICS, POL'Y & ENV'T 157, 162 http://www.tandfonline.com/doi/pdf/10.1080/21550085.2014.927962.

constructing an effective SAI liability regime. While liability is not an insurmountable problem for solar geoengineering, neither is it a problem that is easily solvable.

CONCLUSION

This Article has examined multiple, overlapping aspects of liability and compensation as they relate to possible stratospheric aerosol geoengineering: law and practice, causation and attribution, institutional design, and sociopolitical context. The purpose of this analysis has not been to recommend any particular approach to liability (although we have identified several promising structural elements). Rather, the goal has been to demonstrate that there is considerable precedent for managing international liability of the kind that would arise from SRM intervention; and that there is evidence that the system of international liability law is now evolving in ways that should make it still more applicable. In sum, historical precedents and contemporary innovations combine to suggest workable governance possibilities for addressing the difficult problem of liability for solar geoengineering.

Experiences in other spheres have shown that the community of states can construct and operate instruments to address damages stemming from otherwise acceptable cross-border activities. Cases such as the Space Liability Convention and oil spill regime show that such arrangements can function with a large measure of success. State-based liability mechanisms, compensation funds, and other innovations such as compulsory insurance have helped resolve disputes between states and other international actors in ways that redress grievances while allowing beneficial but hazardous activities to continue. Some of these structures might prove useful in the design of a liability system for SRM deployment or large-scale research. The issue of attributing climate damages to human drivers (whether GHGs or stratospheric aerosols) will be of central importance to a liability system. Methodological advances such as FAR, and innovations in legal reasoning such as probabilistic causation, show great potential for addressing the attribution problem, but significant technical and political challenges remain to be overcome before an effective attribution apparatus can be adopted internationally.

We have shown that there is precedent with respect to legal structures. One might concede that such structures exist, but argue that the potential magnitude of SRM damages exceeds previous compensation amounts to such a degree that our analogy is false. It is impossible to provide precise estimates of SRM damages given the high uncertainties and unknown factors involved, but we have calculated \$10–\$100 billion as a rough approximation based on current modeling of expected damages from climate change. This estimate far exceeds the \$6 million paid out under the Space Liability Convention, and is significantly higher than the \$700 million paid out by the IOPC Funds to date. Yet the total aggregate compensation now available under the oil spill regime is \$1.3 billion. By further comparison, the largest claim so far approved by the dispute settlement mechanism of the World Trade Organization, an intergovernmental body whose (non-liability) damage claim decisions are binding, is valued at more than \$5 billion, a sum that is arguably comparable to our lowest SAI damage estimate.[211] We conclude that while SAI involves potentially larger damages, SAI damages for all but the largest countries—who we presume would likely be members of any SAI regime—are within an order of magnitude of those amounts contemplated and delivered by current international compensation regimes. Given that compensation levels under these regimes continue to increase, it is not unreasonable to imagine that an effective SAI liability regime could be created.

In the end, questions about SAI liability will be secondary to more fundamental questions about whether SAI should be deployed, and whether geoengineering is desirable in the first place. These more basic questions are inherently political, and cannot be reduced to issues of jurisprudence or scientific understanding. To the extent that the possibility of a credible liability mechanism enhances the probability that broad political agreement can be reached, however, relatively narrow questions of liability and more general political and diplomatic questions about the desirability of geoengineering are inextricably bound to each other, and responses to them are likely to develop in tandem. For this reason, further research into various aspects of liability raised here and elsewhere promises to contribute to both the present,

211 This decision ruled affirmatively on allegations of illegal subsidies for aircraft manufacturing made by the European Union against the United States. Appellate Body Report, *United States—Measures Affecting Trade in Large Civil Aircraft (Second Complaint)*, WT/DS353/AB/R, 11 (Mar. 3, 2012).

more limited discussion as well as wider attempts to reach a global consensus on climate change and geoengineering.