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International Law in the Anthropocene: Responding to the Geoengineering Challenge

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INTERNATIONAL LAW IN THE ANTHROPOCENE: RESPONDING TO THE GEOENGINEERING CHALLENGE

*Karen N. Scott**

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[K]nowing the force and the actions of fire, water, air, the stars, the heavens, and all other bodies that surround us, just as distinctly as we know the various skills of our craftsmen, we might be able, in the same way, to use them for all the purposes for which they are appropriate, and thus render ourselves, as it were, masters and possessors of nature.

René Descartes, *Discourse on Method*, Part VI (1637)¹

INTRODUCTION

From *The Odyssey* to *The Tempest* and beyond, the control and deliberate manipulation of the weather constitutes an enduring and universal theme in myth and literature.² In the twenty-first century, it is scientists and engineers rather than authors and artists who dream of weather and climate control, and their story, as described by James Rodger Fleming, “is not, in essence, a heroic saga about new scientific discoveries that can save the planet, as many of the participants claim, but a tragicomedy of overreaching, hubris, and self-delusion.”³ This notwithstanding, the argument that we should deliberately manipulate earth systems and natural processes (referred to as geoengineering) to mitigate the impact of inevitable climate change has moved from the fringes to the mainstream of scientific and policy debate. Almost as many scientific and policy papers have been published on geoengineering during the last three years as in the preceding thirty years. The 2009 Royal Society report entitled *Geoengineering the Climate: Science, Governance and Uncertainty*⁴ provided the catalyst for a series of government reports in both the United Kingdom⁵ and the United States⁶ ex-

1. RENÉ DESCARTES, DISCOURSE ON METHOD AND MEDITATIONS ON FIRST PHILOSOPHY 35 (Donald A. Cress trans., Hackett Publ'g 3d ed. 1998) (1637 & 1641).

2. See Stephen H. Schneider, *Geoengineering: Could—or Should—We Do It?*, 33 CLIMATIC CHANGE 291, 291 (1996).

3. JAMES RODGER FLEMING, *FIXING THE SKY: THE CHECKERED HISTORY OF WEATHER AND CLIMATE CONTROL* 2 (2010).

4. THE ROYAL SOC'Y, *GEOENGINEERING THE CLIMATE: SCIENCE, GOVERNANCE AND UNCERTAINTY* (2009) [hereinafter 2009 ROYAL SOCIETY REPORT ON GEOENGINEERING] available at http://royalsociety.org/uploadedFiles/Royal_Society_Content/policy/publications/2009/8693.pdf.

5. See DEPARTMENT OF ENERGY AND CLIMATE CHANGE, *GOVERNMENT RESPONSE TO THE HOUSE OF COMMONS SCIENCE AND TECHNOLOGY COMMITTEE 5TH REPORT OF SESSION 2009–10: THE REGULATION OF GEOENGINEERING*, 2010, Cm. 7936 (U.K.); SCIENCE AND TECHNOLOGY COMMITTEE, *THE REGULATION OF GEOENGINEERING*, 2009–10, H.C. 221, at 6 (U.K.); INNOVATION, UNIVERSITIES, SCIENCE AND SKILLS COMMITTEE, *ENGINEERING: TURNING IDEAS INTO REALITY: GOVERNMENT RESPONSE TO THE COMMITTEE'S FOURTH REPORT*, 2008–9, H.C. 759, at 11 (U.K.); INNOVATION, UNIVERSITIES, SCIENCE AND SKILLS COMMITTEE, *ENGINEERING: TURNING IDEAS INTO REALITY*, 2008–9, H.C. 50-I, ¶ 195 (U.K.).

6. See KELSIE BRACMORT ET AL., CONG. RESEARCH SERV., RL 41371, *GEOENGINEERING: GOVERNANCE AND TECHNOLOGY POLICY* 2, n.11 (2011); STAFF OF H. COMM. ON SCI. & TECH., 111TH CONG., *ENGINEERING THE CLIMATE: RESEARCH NEEDS AND STRATEGIES FOR*

ploring technological and governance issues associated with geoengineering for climate change mitigation purposes, as well as focusing media attention on these proposals. At the international level, geoengineering has reached the agendas of the European Parliament,⁷ as well as meetings of parties to the 1996 Protocol to the 1972 London Convention⁸ and the 1992 Biodiversity Convention.⁹ Noted in a mere paragraph in the 2007 Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report¹⁰ (and ignored in the *Stern Review Report on the Economics of Climate Change* released by the British government in 2006¹¹), geoengineering is slated for serious consideration in a designated chapter in the IPCC's Fifth Assessment Report due to be published in 2013–2014. In contrast to other climate change mitigation measures—such as CO₂ sequestration—geoengineering features regularly in the mainstream media and has provided the subject matter for several popular science books.¹²

That geoengineering has become a serious contender for inclusion within the climate change mitigation toolbox is hardly surprising given the context of the debate: the abject failure of states to reduce their emissions of CO₂ and other greenhouse gases despite clear and increasingly irrefutable evidence of actual and predicted serious environmental harm resulting from climate change. Once framed as (simply) an environmental problem, climate change today is as often as not explored through the lenses of morality,¹³

INTERNATIONAL COORDINATION, at ii–iii (Comm. Print 2010) [hereinafter ENGINEERING THE CLIMATE].

7. See Resolution on Developing a Common EU Position Ahead of the United Nations Conference on Sustainable Development (Rio+20), P7_TA(2011)0430, ¶ 90 (Sept. 29, 2011) (“[The European Parliament] expresses its opposition to proposals for large scale geo-engineering.”).

8. See Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, Nov. 14, 1996, 36 I.L.M. 7 [hereinafter 1996 Protocol to the London Convention]; *infra* Parts III–IV.

9. Convention on Biological Diversity, June 5, 1992, 1760 U.N.T.S. 143 [hereinafter CBD]; see *infra* Parts III–IV.

10. Terry Barker et al., *Mitigation from a Cross-Sectoral Perspective*, in CLIMATE CHANGE 2007: WORKING GROUP III CONTRIBUTION TO THE FOURTH ASSESSMENT REPORT OF THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE 619, 624–25 (Bert Metz et al. eds., 2007).

11. NICHOLAS STERN, CABINET OFFICE—HM TREASURY, *THE ECONOMICS OF CLIMATE CHANGE: THE STERN REVIEW* (2007).

12. See JEFF GOODELL, *HOW TO COOL THE PLANET: GEOENGINEERING AND THE AUDACIOUS QUEST TO FIX EARTH'S CLIMATE* (2010); ELI KINTISCH, *HACK THE PLANET: SCIENCE'S BEST HOPE—OR WORST NIGHTMARE—FOR AVERTING CLIMATE CATASTROPHE* 151, 171 (2010); ROBERT KUNZIG & WALLACE BROECKER, *FIXING CLIMATE: THE STORY OF CLIMATE SCIENCE AND HOW TO STOP GLOBAL WARMING* 84–85 (2009).

13. Jean-François Mouhot, *Past Connections and Present Similarities in Slave Ownership and Fossil Fuel Usage*, 105 CLIMATIC CHANGE 329, 329–30 (2011), controversially compares the current attitude of most states and individuals toward fossil fuels with the attitudes of slave owners in the eighteenth and nineteenth centuries. For a response to this thesis,

justice,¹⁴ or security.¹⁵ Some scientists and historians would go so far as to assert that our (inadvertent) modification of the climate is so great as to warrant the end of the Holocene and the beginning of the Anthropocene.¹⁶ But labels and metaphors represent more than a mere rhetorical device and are by no means confined to the academe. The “climate as catastrophe” discourse, as developed by Mike Hulme,¹⁷ creates a common or “global enemy”¹⁸ and, thus framed, permits the development of initiatives such as the introduction of climate change as a topic for debate in the U.N. Security Council in 2007.¹⁹ The securitization of climate change serves an important function in recognizing its more diffuse impacts on the political and economic stability of nations but, more pragmatically, also provides a mechanism for demanding immediate attention from decision makers and the mobilization of additional resources.²⁰ The declaration of “war” on climate change and the deployment of other military metaphors serves a similar function and, moreover, can be used to justify more ambitious or risky measures designed to defeat climate change.²¹ While geoengineering—and its associated risks and other hazards (including moral hazard)—is arguably ill suited to address the environmental impacts of a warmer climate, it is by no means clear that it cannot be justified in order to maintain the security of states engaged in a war on climate change in the new era of the Anthropocene.

see Joshua P. Howe, *History and Climate: A Road Map to Humanistic Scholarship on Climate Change*, 105 CLIMATIC CHANGE 357, 357–58 (2011).

14. See PAUL G. HARRIS, WORLD ETHICS AND CLIMATE CHANGE: FROM INTERNATIONAL TO GLOBAL JUSTICE 74 (2010); Tim Hayward, *Human Rights Versus Emissions Rights: Climate Justice and the Equitable Distribution of Ecological Space*, 21 ETHICS & INT’L AFF. 431, 432; ERIC POSNER & DAVID WEISBACH, CLIMATE CHANGE JUSTICE 73 (2010).

15. See Michael T. Klare, *Global Warming Battlefields: How Climate Change Threatens Security*, 106 CURRENT HIST. 355, 355–56 (2007); John Podesta & Peter Ogdon, *The Security Implications of Climate Change*, WASH. Q., Winter 2007–08, at 115, 115–16.

16. See Will Steffen et al., *The Anthropocene: Conceptual and Historical Perspectives*, 369 PHIL. TRANSACTIONS ROYAL SOC’Y (ser. A) 842, 843 (2011); *infra* notes 26–61 and accompanying text.

17. Mike Hulme, *The Conquering of Climate: Discourses of Fear and Their Dissolution*, 174 GEOGRAPHICAL J. 5, 7 (2008); see also MIKE HULME, WHY WE DISAGREE ABOUT CLIMATE CHANGE: UNDERSTANDING CONTROVERSY, INACTION AND OPPORTUNITY 180 (2009).

18. Timothy Doyle & Sanjay Chaturvedi, *Climate Territories: A Global Soul for the Global South?*, 15 GEOPOLITICS 516, 520 (2010).

19. Margaret Beckett, the then U.K. Foreign Secretary who chaired the debate in the Security Council, argued that climate change affects “our collective security in a fragile and increasingly interdependent world.” Nicole Detraz & Michele M. Betsill, *Climate Change and Environmental Security: For Whom the Discourse Shifts*, 10 INT’L STUD. PERSP. 303, 303 (2009).

20. *Id.*

21. See Maurie J. Cohen, *Is the UK Preparing for “War”? Military Metaphors, Personal Carbon Allowances, and Consumption Rationing in Historical Perspective*, 104 CLIMATIC CHANGE 199, 207 (2011).

Among scientists and in the popular media, there is a perception that geoengineering currently operates in a regulatory Wild West. While there are few (if any) binding instruments of explicit application to geoengineering,²² activities posing a serious risk to the global environment are subject to the principles and obligations of international environmental law.

It is a matter of some debate whether a coherent discipline of international environmental law exists as distinct from international law more generally.²³ The term—international environmental law—is commonly used as shorthand to refer to the treaties, customs, and principles applied in the context of environmental protection and conservation.²⁴ However, this Article will argue that international environmental law not only refers to an area of international regulation, but also comprises a distinct set of norms and principles applicable to states in a situation where the global environment is at risk of serious or irreversible harm. Geoengineering provides an ideal case study through which to assess the extent and the limits of international environmental law as a discipline: geoengineering creates a clear risk of serious harm to the transboundary and global environment; it utilizes common spaces such as the high seas, atmosphere, or outer space; and it has yet to be addressed (with one limited exception) in any regulatory forum. This Article argues that there are seven principles that impose obligations on states and comprise the essential parameters of international environmental law and, consequently, are applicable to geoengineering activities. The principles are the prevention of harm; prevention of pollution; protection of vulnerable ecosystems; the precautionary principle; principles associated with information exchange, notification, and environmental impact assessment; the principle of due regard for other users; and principles associated with responsibility and liability.

However, while these principles establish an essential framework within which some control can be exercised over geoengineering activities, this Article recognizes the obvious limitations of international environmental law as it currently stands. As a case study for exploring options for the future, this Article critically assesses the regulatory regime currently being developed by the parties to the 1996 Protocol to the London Convention with respect to scientific research on ocean iron fertilization and the extent to which a precedent has been set for the regulation of other geoengineering activities.²⁵ In particular, the merits of developing an assessment framework in order to facilitate fertilization research, without first providing a forum for a broader discussion as to the policy and moral implications of

22. See *infra* Part III.A.

23. PATRICIA BIRNIE ET AL., *INTERNATIONAL LAW AND THE ENVIRONMENT* 2 (3d ed. 2009).

24. See, e.g., *THE OXFORD HANDBOOK OF INTERNATIONAL ENVIRONMENTAL LAW* (Daniel Bodansky et al. eds., 2007); *RESEARCH HANDBOOK ON INTERNATIONAL ENVIRONMENTAL LAW* (Malgosia Fitzmaurice et al. eds., 2010).

25. See *infra* Part IV.

these activities, will be addressed. This Article will conclude with the development of a proposal for a regulatory framework designed to govern geoengineering in the Anthropocene.

I. CLIMATE CHANGE AND THE CREATION OF THE ANTHROPOCENE

The IPCC in its 2007 Fourth Assessment Report described the warming of the climate system as “unequivocal.”²⁶ Atmospheric concentrations of CO₂ have increased from 280 parts per million (ppm) in the 1700s, prior to the onset of the Industrial Revolution, to 380 ppm in 2005.²⁷ By 2008, atmospheric concentration of CO₂ had increased further to 385 ppm, higher than at any point in the last eight hundred thousand years and potentially higher than at any point in the last three to twenty million years.²⁸ At the same time, land and ocean sinks, which play a valuable role in absorbing CO₂, have weakened,²⁹ and it is estimated that the percentage of emissions absorbed by these sinks has decreased from sixty to fifty-five percent over the last fifty years.³⁰ The predicted consequences of climate change—including, but not limited to, warmer temperatures, rising sea levels, loss of ice in the Antarctic and the Arctic, increased frequency of extreme-weather events, and ocean acidification—have been well documented elsewhere.³¹ Despite agreement by 195 states to stabilize “greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” under Article 2 of the 1992 United Nations Framework Convention on Climate Change (UNFCCC)³² and the

26. INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2007: SYNTHESIS REPORT 30, 72 (2008), available at http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf.

27. Michael R. Raupach et al., *Global and Regional Drivers of Accelerating CO₂ Emissions*, 104 PNAS 10,288, 10,288 (2007).

28. IAN ALLISON ET AL., THE COPENHAGEN DIAGNOSIS: UPDATING THE WORLD ON THE LATEST CLIMATE SCIENCE 9 (2009), available at http://www.cerc.unsw.edu.au/Copenhagen/Copenhagen_Diagnosis_LOW.pdf.

29. *Id.* at 10; see also Dave Reay et al., *Spring-Time for Sinks*, 446 NATURE 727, 727–28 (2007) (speculating that climate change may lead to the weakening of ocean sinks in the future).

30. ALLISON ET AL., *supra* note 28, at 10.

31. See *id.* at 7, 15–36; Gerald A. Meehl et al., *Global Climate Projections*, in CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS 747, 749–50 (Susan Solomon et al. eds., 2007); see also SECRETARIAT OF THE CBD, SCIENTIFIC SYNTHESIS OF THE IMPACTS OF OCEAN ACIDIFICATION ON MARINE BIODIVERSITY 9, 16, 23–24, 28, 53 (CBD Technical Series No. 46, 2009), available at <http://www.cbd.int/doc/publications/cbd-ts-46-en.pdf> (reporting on the impact of climate change on ocean acidification and marine biodiversity); Scott C. Doney et al., *Ocean Acidification: A Critical Emerging Problem for the Oceans*, OCEANOGRAPHY, Dec. 2009, at 16, 16–17 (discussing the effects of human CO₂ emissions on increased ocean acidification).

32. U.N. Framework Convention on Climate Change, May 9, 1992, 1771 U.N.T.S. 107 [hereinafter 1992 UNFCCC]; *Status of the United Nations Framework Convention on Climate Change*, UNITED NATIONS TREATY COLLECTION, <http://treaties.un.org/pages/>

more specific targets applied to developed states under the 1997 Kyoto Protocol,³³ CO₂ emissions from fossil fuels were forty percent higher in 2008 than in 1990.³⁴ In a business-as-usual scenario, it is predicted that temperatures will rise between four and seven degrees Celsius by 2100.³⁵

The extent to which humankind has and is continuing to alter natural processes and earth systems should arguably be categorized as a difference in *kind* as opposed to simply *degree* when compared to the preindustrial era. While attention has understandably focused on man's impact on the climate and carbon cycle,³⁶ humans have also significantly altered biogeochemical cycles including nitrogen, phosphorus, and sulfur;³⁷ modified terrestrial ecosystems through agriculture; transformed the freshwater cycle through changes in river flow;³⁸ increased the levels of CO₂ and nitrogen in the oceans;³⁹ and are in the process of driving what has been described as the Sixth Extinction.⁴⁰ In essence, "humankind has become a global geological force in its own right."⁴¹

In 2000, Paul Crutzen and Eugene Stoemer created the term "Anthropocene" to describe a new geological epoch: an epoch dominated by humans.⁴² The date on which we moved from the Holocene to the Anthropocene remains necessarily arbitrary. Paul Crutzen and Will Steffen suggest 1784, the year James Watt invented the steam engine.⁴³ William Ruddiman, on the other hand, argues that the Anthropocene began five to eight thousand years ago with the development of agriculture, the clear-cutting of forests, and the cultivation of rice.⁴⁴ What is agreed upon is that the Anthropocene openly

ViewDetailsIII.aspx?&src=TREATY&mtdsg_no=XXVII-7&chapter=27&Temp=mtdsg3&lang=en (last visited Jan. 16, 2013) (listing 195 participant states).

33. See Kyoto Protocol to the United Nations Framework Convention on Climate Change, Dec. 11, 1997, 2303 U.N.T.S. 162 [hereinafter Kyoto Protocol].

34. ALLISON ET AL., *supra* note 28, at 7.

35. *Id.* at 49.

36. See Michael R. Raupach & Josep G. Canadell, *Carbon and the Anthropocene*, 2 CURRENT OPINION ENVTL. SUSTAINABILITY 210, 210-18 (2010).

37. Steffen et al., *supra* note 16, at 843.

38. *Id.*

39. Toby Tyrrell, *Anthropogenic Modification of the Oceans*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y (ser. A) 887, 887-89, 901-02 (2011).

40. Steffen et al., *supra* note 16, at 843. See generally RICHARD LEAKEY & ROGER LEWIN, *THE SIXTH EXTINCTION: BIODIVERSITY AND ITS SURVIVAL* (1996) (providing detailed account of prior and ongoing events that the authors state may lead to the Sixth Extinction).

41. Steffen et al., *supra* note 16, at 843; see also Will Steffen et al., *The Anthropocene: Are Humans Now Overwhelming the Great Forces of Nature?*, 36 AMBIO 614, 614-21 (2007).

42. Paul Crutzen & Eugene F. Stoemer, *The "Anthropocene,"* GLOBAL CHANGE NEWSL. (Int'l Geosphere-Biosphere Programme, Stockholm, Swed.), May 2000, at 17-18.

43. Paul J. Crutzen & Will Steffen, *How Long Have We Been in the Anthropocene Era?*, 61 CLIMATIC CHANGE 251, 251-52 (2003).

44. William F. Ruddiman, *The Anthropogenic Greenhouse Era Began Thousands of Years Ago*, 61 CLIMATIC CHANGE 261, 261 (2003); see also WILLIAM F. RUDDIMAN, *PLOWS, PLAGUES AND PETROLEUM: HOW HUMANS TOOK CONTROL OF THE CLIMATE* 12 (2005).

challenges the assumption “of an environment outside or separate from human existence”⁴⁵ and forces us to confront the fact that earth system characteristics “are neither ‘human’ nor ‘natural,’ but are in fact highly integrated composites of both.”⁴⁶ Geoengineering—defined as “the intentional large-scale manipulation of the environment”⁴⁷—is arguably the poster child of the Anthropocene. Although there are individuals who challenge the notion of a new geological era and question whether it is useful to formalize the relationship between humankind and the environment in such a way,⁴⁸ recognizing the Anthropocene serves a potentially important policy purpose: it is as much about the future as the past.⁴⁹ It challenges us to think more critically about governance and law and forces us to ask whether international environmental law is capable of responding to the challenges of the Anthropocene.⁵⁰

The climate change regime, as it currently stands, is arguably ill suited to respond to the environmental impacts of climate change, let alone the greater challenges posed by the Anthropocene. The 1992 UNFCCC and the 1997 Kyoto Protocol together establish a framework designed to support a reduction in the emission of greenhouse gases in order to stabilize “greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.”⁵¹ However, David Victor has perspicaciously observed that “[t]he politics of actually stopping global climate change by mitigating emissions are nasty, brutish

45. Simon Dalby, *Anthropocene Geopolitics: Globalisation, Empire, Environment and Critique*, 1 GEOGRAPHY COMPASS 103, 111 (2007).

46. Brad Allenby, *The Anthropocene As Media: Information Systems and the Creation of the Human Earth*, 52 AM. BEHAV. SCIENTIST 107, 110 (2008) (citing BRADEN ALLENBY, RECONSTRUCTING EARTH: TECHNOLOGY AND ENVIRONMENT IN THE AGE OF HUMANS (2005)). This observation is perhaps no better illustrated by the creation of synthetic life. See Daniel G. Gibson et al., *Creation of a Bacterial Cell Controlled by a Chemically Synthesized Genome*, 328 SCIENCE 52, 52–56 (2010).

47. David W. Keith, *Geoengineering the Climate: History and Prospect*, 25 ANN. REV. ENERGY & ENV'T 245, 247 (2000).

48. See, e.g., Jan Zalasiewicz et al., *The Anthropocene: A New Epoch of Geological Time?*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y (ser. A) 835, 837–38 (2011).

49. See Libby Robin & Will Steffen, *History for the Anthropocene*, 5 HIST. COMPASS 1694, 1699 (2007).

50. See Eva Lövbrand et al., *Earth System Governmentality: Reflections on Science in the Anthropocene*, 19 GLOBAL ENVTL. CHANGE 7, 7 (2009). Few international lawyers have to date begun incorporating notions of the Anthropocene into their analyses of environmental governance. One notable exception is Davor Vidas in relation to the law of the sea. See Davor Vidas, *The Anthropocene and the International Law of the Sea*, 369 PHIL. TRANSACTIONS ROYAL SOC'Y (ser. A) 909, 909 (2011); Davor Vidas, *Responsibility for the Seas*, in LAW, TECHNOLOGY AND SCIENCE FOR OCEANS IN GLOBALISATION 3, 3–40 (Davor Vidas ed., 2010); see also Rosemary Rayfuse, *The Anthropocene: Autopoiesis and the Disingenuousness of the Genuine Link: Addressing Enforcement Gaps in the Legal Regime for Areas Beyond National Jurisdiction*, in THE LEGAL REGIME OF AREAS BEYOND NATIONAL JURISDICTION: CURRENT PRINCIPLES AND FRAMEWORKS AND FUTURE DIRECTIONS 165, 165–68 (E.J. Molennar & A.G. Oude Elferink eds., 2010).

51. 1992 UNFCCC, *supra* note 32, art. 2.

and endless,”⁵² and the Kyoto Protocol has been criticized more specifically for establishing an ineffective target for the reduction of emissions⁵³ that is not universally applied⁵⁴ and will not, in any case, be achieved by the target date of 2012.⁵⁵ Although the parties to the Kyoto Protocol decided in 2011 to launch a process to develop a further protocol or another instrument with legal force to provide for further emissions reductions, it is not envisaged that this instrument will come into effect before 2020.⁵⁶ In the meantime, while the parties have formally recognized that action must be taken in order to prevent an increase in the global temperature of more than two degrees Celsius,⁵⁷ only nine states in addition to the twenty-seven members of the European Union have agreed to extend their commitments to

52. David G. Victor, *On the Regulation of Geoengineering*, 24 OXFORD REV. ECON. POL’Y 322, 323–24 (2008).

53. Article 3 of the Kyoto Protocol calls for an aggregate reduction of five percent in emissions below 1990 levels during the commitment period from 2008 to 2012. Kyoto Protocol, *supra* note 33, art. 3.

54. Only—developed—states listed in Annex I are bound by emissions targets as set out in the Kyoto Protocol. Kyoto Protocol, *supra* note 33, art. 3. Dieter Helm has highlighted the contradiction in devising an instrument that focuses on a reduction in the production rather than the consumption of emissions while simultaneously excluding a large number of states from those production targets. See Dieter Helm, *Climate-Change Policy: Why Has So Little Been Achieved?*, 24 OXFORD REV. ECON. POL’Y 211, 211–14 (2008).

55. For a critique of the climate change regime, see Scott Barrett, *Climate Treaties and the Imperative of Enforcement*, 24 OXFORD REV. ECON. POL’Y 239, 239 (2008); Helm, *supra* note 54, at 211–14; Rafael Leal-Arcas, *Kyoto and the COPS: Lessons Learned and Looking Ahead*, HAGUE Y.B. INT’L L. 17, 17 (2010).

56. Establishment of an Ad Hoc Working Group on the Durban Platform for Enhanced Action, in U.N. Climate Change Conference, Durban, S. Afr., Nov. 28–Dec. 11, 2011, *Report of the Conference of the Parties on Its Seventeenth Session*, U.N. Doc. FCCC/CP/2011/9/Add.1, at 2 (Mar. 15, 2012).

57. The 2009 Copenhagen Accord stipulated:

To achieve the ultimate objective of the Convention to stabilize greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system, we shall, recognizing the scientific view that the increase in global temperature should be below 2 degrees Celsius, on the basis of equity and in the context of sustainable development, enhance our long-term cooperative action to combat climate change. . . . We agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity.

Copenhagen Accord, in U.N. Climate Change Conference, Copenhagen, Den., Dec. 7–19, 2009, *Report of the Conference of the Parties on Its Fifteenth Session*, ¶¶ 1–2, U.N. Doc. FCCC/CP/2009/11/Add.1, at 5 (Mar. 30, 2010). This commitment was reiterated and reinforced at the Eighteenth Conference of the Parties in Cancun in 2010. See The Cancun Agreements: Outcome of the Work of the Ad Hoc Working Group on Long-Term Cooperative Action Under the Convention, in U.N. Climate Change Conference, Cancun, Mex., Nov. 29–Dec. 10, 2010, *Report of the Conference of the Parties on Its Sixteenth Session*, U.N. Doc. FCCC/CP/2010/7/Add.1, at 2 (Mar. 15, 2011) [hereinafter The Cancun Agreements].

reduce greenhouse gas emissions post-2012.⁵⁸ Given that the largest polluters (including China, the United States, India, Russia, and Japan⁵⁹) have not agreed to binding emissions targets post-2012, and Canada has announced its formal withdrawal from the Kyoto Protocol,⁶⁰ the two-degree target appears ambitious at best and hopelessly idealistic at worst.⁶¹ It is consequently hardly surprising that individuals and—increasingly—states, deeply concerned about the consequences of climate change, are beginning to explore other mitigation strategies in combination with, or even as an alternative to, emissions reductions. The most radical of those alternatives, symbolic of the Anthropocene, is geoengineering.

II. GEOENGINEERING AS A CLIMATE CHANGE MITIGATION MEASURE

Changing technologies always seems easier than changing people or challenging power.

—Clive Hamilton, *Requiem for a Species: Why We Resist the Truth About Climate Change*⁶²

“Geoengineering” as a term of art was first coined and connected with climate change mitigation by Cesare Marchetti in 1977.⁶³ It is defined as

58. The thirty-six states have agreed to support an aggregate reduction in emissions by twenty-five to forty percent below 1990 levels by 2020. The second commitment period will begin in January 2013 and ends either in 2020 or in 2017 depending on a decision of the Ad Hoc Working Group. Australia and New Zealand are prepared to consider submitting information on emissions during this period but have not committed to reducing their emissions further. Canada, Japan, and Russia have formally indicated that they will not be participating in the second commitment period. See Outcome of the Work of the Ad Hoc Working Group on Further Commitments for Annex I Parties Under the Kyoto Protocol at Its Sixteenth Session, in U.N. Climate Change Conference, Durban, S. Afr., Nov. 28–Dec. 11, 2011, *Report of the Conference of the Parties Serving As the Meeting of the Parties Under the Kyoto Protocol on Its Seventh Session*, U.N. Doc. FCCC/KP/CMP/2011/10/Add.1, at 2 (Mar. 15, 2012).

59. Information on individual country emissions can be found on the U.S. Energy Information Administration’s website. *International Energy Statistics*, U.S. ENERGY INFO. ADMIN., <http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=90&pid=44&aid=8> (last visited Jan. 16, 2013).

60. *Statement by Minister Kent*, ENV’T CAN. (Dec. 12, 2011), <http://www.ec.gc.ca/default.asp?lang=En&n=FFE36B6D-1&news=6B04014B-54FC-4739-B22C-F9CD9A840800> (announcing Canada’s withdrawal from the Kyoto Protocol).

61. It is worth noting that the two-degree-Celsius target itself has been challenged as an arbitrary limit unsupported by science. See Chris Shaw, *The Dangerous Limits of Dangerous Limits: Climate Change and the Precautionary Principle*, SOC. REV., Dec. 2010, at 103, 112. For a more general criticism of approaches to defining “dangerous anthropogenic interference with the climate system,” see generally Timothy M. Lenton et al., *Tipping Elements in the Earth’s Climate System*, 105 PNAS 1786 (2008); D. Moellendorf, *A Normative Account of Dangerous Climate Change*, 108 CLIMATIC CHANGE 57 (2011).

62. CLIVE HAMILTON, *REQUIEM FOR A SPECIES: WHY WE RESIST THE TRUTH ABOUT CLIMATE CHANGE* 180 (2010).

63. See Cesare Marchetti, *On Geoengineering and the CO₂ Problem*, 1 CLIMATIC CHANGE 59, 59 (1977).

“the intentional large-scale manipulation of the environment”⁶⁴ and, as David Keith has pointed out, both “[s]cale and intent play central roles in the definition.”⁶⁵ Consequently, while the origins of geoengineering undoubtedly lie in the weather modification of the nineteenth and twentieth centuries, its scale sets it apart from those activities.⁶⁶ Moreover, although we have undoubtedly intervened in the climate on a large scale, this intervention has thus far been unintentional or at least an indirect byproduct of other activities.⁶⁷ In both scientific and popular contexts, the term geoengineering has serious negative connotations, and it is unsurprising that climate change mitigation measures such as reforestation, which constitute an intentional large-scale manipulation of the environment, tend not to be classified as such. As David Keith concludes, “we are moving down the continuum toward acceptance of actions that have the character of geoengineering (as defined here) though they no longer bear the name.”⁶⁸ Moreover, scientists, policy makers, and other commentators have sought to distance their proposals from “geoengineering” by employing terms such as “climate engineering”⁶⁹ or “climate remediation.”⁷⁰ However, these labels fail to capture the full spectrum of options under discussion, such as increasing the alkalinity of the oceans in order to counter ocean acidification.⁷¹ Geoengineering skeptics use similar rhetorical techniques and describe these options in rather more inflammatory terms, such as “geopiracy”⁷² or “planet hacking.”⁷³

Geoengineering—in concept if not in name—was identified as a possible response (indeed the only response) to the deleterious impacts of climate change in the first high-level government policy assessment of climate change, presented to U.S. President Lyndon B. Johnson in 1965.⁷⁴ But the

64. Keith, *supra* note 47, at 247.

65. *Id.*

66. FLEMING, *supra* note 3.

67. Brian P. Flannery et al., *Geoengineering Climate*, in *ENGINEERING RESPONSE TO GLOBAL CLIMATE CHANGE: PLANNING A RESEARCH AND DEVELOPMENT AGENDA* 379, 381 (Robert G. Watts ed., 1997).

68. Keith, *supra* note 47, at 280.

69. See *ENGINEERING THE CLIMATE*, *supra* note 6; J. Eric Bickel & Lee Lane, *Climate Engineering*, in *SMART SOLUTIONS TO CLIMATE CHANGE: COMPARING COSTS AND BENEFITS* 9 (Bjørn Lomborg ed., 2010).

70. BIPARTISAN POLICY CTR.’S TASK FORCE ON CLIMATE REMEDIATION RESEARCH, *GEOENGINEERING: A NATIONAL STRATEGIC PLAN FOR RESEARCH ON THE POTENTIAL EFFECTIVENESS, FEASIBILITY, AND CONSEQUENCES OF CLIMATE REMEDIATION TECHNOLOGIES* 3 (2011).

71. See *infra* notes 122–128 and accompanying text.

72. See ACTION GRP. ON EROSION TECH. & CONCENTRATION, *GEOPIRACY: THE CASE AGAINST GEOENGINEERING* 1–2 (2010).

73. See KINTISCH, *supra* note 12, at 3.

74. Keith, *supra* note 47, at 254. The sole focus on engineering solutions to climate change in this report is unsurprising given President Johnson’s open support for science and technology and his significant interest in weather modification both domestically and as an instrument of foreign policy. See Ronald E. Doel & Kristine C. Harper, *Prometheus*

modern debate on geoengineering was arguably initiated by a controversial article published by Nobel laureate Paul Crutzen in 2006, advocating the injection of sulfur into the stratosphere in order to reflect sunlight and thus cool the planet.⁷⁵ Over the last five years a plethora of articles have been published in serious scientific journals advocating and castigating geoengineering options,⁷⁶ and, as a technological solution to climate change, geoengineering has been explored in a series of high-profile reports published by the Royal Society and the U.K. and U.S. governments.⁷⁷

Geoengineering's journey from the fringes to the mainstream of the scientific and policy debate on climate change is in part a consequence of the perceived failure of the climate change regime and the current policy focusing on emissions reductions.⁷⁸ However, the attraction of geoengineering also lies in the arguments of its proponents that these options are "conceptually straightforward,"⁷⁹ do not require the unpalatable but inevitable lifestyle changes associated with emissions reductions, and, most significantly from a political perspective, are apparently economical. Scott Barrett has described the economics of geoengineering as "incredible";⁸⁰ moreover, Thomas C. Schelling argues that "the economics of geoengineering compared with CO₂ abatement . . . transforms the greenhouse issue from an exceedingly complicated regulatory regime to a simple—not necessarily easy, but simple—problem in international cost sharing."⁸¹ On the other hand, research published to date has yet to prove the feasibility and effectiveness of geoengineering as a climate change mitigation measure,⁸² and

Unleashed: Science As a Diplomatic Weapon in the Lyndon B. Johnson Administration, 21 OSIRIS 66, 66 (2006).

75. Paul J. Crutzen, *Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?*, 77 CLIMATIC CHANGE 211, 211 (2006). This idea was neither new nor Crutzen's own. Moreover, geoengineering as a climate change mitigation measure had been explored in at least two U.S. official reports (in 1983 and 1992), see Keith, *supra* note 47, at 255–56, and provided the subject for a (considerably less controversial) symposium in *Climatic Change* a decade earlier in 1996, see Symposium, 33 CLIMATIC CHANGE 275 (1996). However, Paul Crutzen was, and arguably remains, the most eminent serious scientist to advocate geoengineering as a solution to climate change. For an entertaining description of the controversy associated with the actual publication of Crutzen's 2006 article, see KINTISCH, *supra* note 12, at 55–57.

76. See FLEMING, *supra* note 3, at 227; 2009 ROYAL SOCIETY REPORT ON GEOENGINEERING, *supra* note 4, at 1.

77. See *supra* notes 4–6 and accompanying text.

78. See *supra* Part I.

79. Timothy A. Fox & Lee Chapman, *Review: Engineering Geo-engineering*, 18 METEOROLOGICAL APPLICATIONS 1, 2 (2011).

80. Scott Barrett, *The Incredible Economics of Geoengineering*, 39 ENVTL. & RESOURCE ECON. 45, 49 (2008).

81. Thomas C. Schelling, *The Economic Diplomacy of Geoengineering*, 33 CLIMATIC CHANGE 303, 305 (1996).

82. For comparative assessments of various geoengineering options, see 2009 ROYAL SOCIETY REPORT ON GEOENGINEERING, *supra* note 4, at ix, xi, xii; Philip W. Boyd, *Commentary, Ranking Geo-engineering Schemes*, 1 NATURE GEOSCI. 722, 724 (2008); Fox &

few proposals have been “demonstrated or costed.”⁸³ In a rare attempt to quantify the direct, indirect, and transactional costs associated with geoengineering, J. Eric Bickel and Lee Lane conclude that estimates at this stage are “speculative.”⁸⁴ David Victor notes that “the claim that geoengineering is remarkably cheap is based on simple assessments of silver-bullet geoengineering. In practice, however, the geoengineering cocktails that are likely to be deployed will not be cheap.”⁸⁵ More importantly, the environmental impacts of geoengineering—on the climate, the ozone layer, the oceans, the hydrological cycle, and the terrestrial biosphere—are essentially unknown. In contrast to emissions reductions, geoengineering relies to a much greater extent on climate modeling,⁸⁶ and the scope for controlled laboratory experimentation is limited.⁸⁷ In short, geoengineering could result in a “cure worse than the disease.”⁸⁸

A. Geoengineering Techniques and Technologies

Geoengineering techniques⁸⁹ are divided into two categories: carbon dioxide removal (CDR) and solar radiation management (SRM). Whereas CDR techniques seek to reduce atmospheric concentrations of greenhouse gases through the enhancement or manipulation of natural or artificial carbon sinks, including the oceans and the terrestrial biosphere, SRM is designed to reduce the surface temperatures of the earth through albedo enhancement—increasing the reflectivity of the planet—or by redirecting solar radiation away from the earth.

1. Carbon Dioxide Removal Techniques

The least controversial and most politically acceptable geoengineering technique seeks to reduce atmospheric concentrations of CO₂ through afforestation and reforestation strategies. It is estimated that the world’s forest estate contains “roughly 3.9 billion [hectares] of forestland and 1

Chapman, *supra* note 79, at 2, 6; T.M. Lenton & N.E. Vaughan, *The Radiative Forcing Potential of Different Climate Geoengineering Options*, 9 *ATMOSPHERIC CHEMISTRY & PHYSICS* 5539, 5539, 5556 (2009).

83. Fox & Chapman, *supra* note 79, at 6; accord Barrett, *supra* note 80, at 45–46.

84. Bickel & Lane, *supra* note 69, at 46; see also Roger A. Pielke, Jr., *Climate Engineering: Alternative Perspective*, in *SMART SOLUTIONS TO CLIMATE CHANGE: COMPARING COSTS AND BENEFITS*, *supra* note 69, at 52.

85. Victor, *supra* note 52, at 327.

86. H. Damon Matthews & Ken Caldeira, *Transient Climate-Carbon Simulations of Planetary Geoengineering*, 104 *PNAS* 9949, 9953 (2007).

87. G. Bala, *Problems with Geoengineering Schemes to Combat Climate Change*, 96 *CURRENT SCI.* 41, 44 (2009).

88. Schneider, *supra* note 2, at 299.

89. For an overview of, and introduction to, geoengineering technologies, see Flannery et al., *supra* note 67; Keith, *supra* note 47, at 247; Naomi E. Vaughan & Timothy M. Lenton, *A Review of Climate Geoengineering Proposals*, 109 *CLIMATIC CHANGE* 745, 745–48 (2011).

trillion tons of CO₂” and that deforestation contributes approximately seventeen percent of global carbon emissions.⁹⁰ Although there are limits to the effectiveness of this option—afforestation in temperate regions, for example, is largely futile because the decrease in albedo as a consequence of increased forest cover cancels out the additional sequestration of CO₂—many scientists argue that afforestation and reforestation are valuable climate change mitigation measures.⁹¹ Massimo Tavoni, Brent Sohngen, and Valentina Bosetti, for example, estimate that “forest sinks can contribute to one-third of total abatement [of CO₂] by 2050.”⁹² Often excluded from popular conceptions of what constitutes geoengineering, the enhancement of forest sinks is expressly recognized as counting toward a state’s commitment to reduce greenhouse gases in Article 3(3) of the 1997 Kyoto Protocol.⁹³ Decisions adopted at the UNFCCC Conference of the Parties in Cancun (2010) and Durban (2011) created new incentives to reduce emissions from deforestation and forest degradation in developing countries⁹⁴ and have initiated a work program in order to facilitate a wider range of land use, land-use change, and forestry activities to be considered for eligibility under the Clean Development Mechanism.⁹⁵ Other terrestrial options not yet endorsed by the Kyoto Protocol include soil-carbon sequestration (otherwise known as biochar),⁹⁶ the use of algae—which naturally absorbs CO₂—on building surfaces,⁹⁷ and the capture and removal of atmospheric CO₂ by artificial “trees.”⁹⁸

90. Brent Sohngen, *Forestry Carbon Sequestration*, in SMART SOLUTIONS TO CLIMATE CHANGE: COMPARING COSTS AND BENEFITS, *supra* note 69, at 114, 114.

91. See Josep G. Canadell & Michael R. Raupach, *Managing Forests for Climate Change Mitigation*, 320 SCIENCE 1456, 1456–57 (2008); Leonard Ornstein et al., *Irrigated Afforestation of the Sahara and Australian Outback to End Global Warming*, 97 CLIMATIC CHANGE 409, 410 (2009); Kenneth R. Richards & Carrie Stokes, *A Review of Forest Carbon Sequestration Cost Strategies: A Dozen Years of Research*, 63 CLIMATIC CHANGE 24, 25 (2004).

92. Massimo Tavoni, Brent Sohngen & Valentina Bosetti, *Forestry and the Carbon Market Response to Stabilize Climate*, 35 ENERGY POL’Y 5346, 5346 (2007).

93. Kyoto Protocol, *supra* note 33, art. 3(3).

94. The Cancun Agreements, *supra* note 57, pt. III.C.

95. Land Use, Land-Use Change and Forestry, in U.N. Climate Change Conference, Durban, S. Afr., Nov. 28–Dec. 11, 2011, *Report of the Conference of the Parties Serving As the Meeting of the Parties to the Kyoto Protocol on Its Seventh Session*, U.N. Doc. FCCC/KP/CMP/2011/10/Add.1, at 11 (Mar. 15, 2012).

96. See Raj K. Shrestha & Rattan Lal, *Ecosystem Carbon Budgeting and Soil Carbon Sequestration in Reclaimed Mine Soil*, 32 ENV’T INT’L 781, 782 (2006).

97. See Eduardo Jacob-Lobes et al., *Rates of CO₂ Removal by Aphanothece Microscopic Nägeli in Tubular Photobioreactors*, 47 CHEMICAL ENGINEERING & PROCESSING 1365, 1372 (2008).

98. See K.S. Lackner, *Capture of Carbon Dioxide from Ambient Air*, EUR. PHYSICAL J. SPECIAL TOPICS, Sept. 2009, at 93, 106. For an engaging introduction to “Lackner’s Trees,” see KUNZIG & BROECKER, *supra* note 12, at 230–47.

The oceans constitute the largest natural reservoir of carbon dioxide, storing approximately twenty times more CO₂ than the terrestrial biosphere, and have accumulated almost a third of the anthropogenic CO₂ emitted from 1750 to the present.⁹⁹ Considerable and controversial research has been undertaken over the last decade or so into how the drawdown of CO₂ into the oceans can be increased through an enhancement of the biological and solubility pumps, which are key to transferring CO₂ from the atmosphere to the ocean's surface and ultimately to its depths.¹⁰⁰

Phytoplankton are essential to the effective operation of the biological pump, but parts of the oceans such as the North and Equatorial Pacific and the Southern Ocean are characterized by low plankton biomass owing to missing key nutrients such as iron.¹⁰¹ This led scientist John Martin to suggest in 1990 that the addition of iron dust to such infertile regions would stimulate algal blooms, leading to an increased uptake in CO₂ that would ultimately be transported into the deep ocean and sequestered for hundreds of years.¹⁰² Thirteen small-scale iron fertilization experiments have been carried out to date,¹⁰³ and while all have enhanced the growth of phytoplankton,¹⁰⁴ the effectiveness of fertilization as a climate change mitigation measure is yet unproven.¹⁰⁵ Infertility in the Southern Ocean and

99. SECRETARIAT OF THE CBD, SCIENTIFIC SYNTHESIS OF THE IMPACTS OF OCEAN FERTILIZATION ON MARINE BIODIVERSITY 9 (CBD Technical Series No. 45, 2009) [hereinafter CBD FERTILIZATION SYNTHESIS], available at <http://www.cbd.int/doc/publications/cbd-ts-45-en.pdf>.

100. See MARK DENNY, *HOW THE OCEAN WORKS: AN INTRODUCTION TO OCEANOGRAPHY* 251 (2008).

101. See H.J.W. de Baar & P.W. Boyd, *The Role of Iron in Plankton Ecology and Carbon Dioxide Transfer of the Global Oceans*, in *THE CHANGING OCEAN CARBON CYCLE: A MIDTERM SYNTHESIS OF THE JOINT GLOBAL OCEAN FLUX STUDY* 61, 107 (Roger B. Hansen et al. eds., 2000); Robert A. Duce & Neil W. Tindale, *Atmospheric Transport of Iron and Its Deposition in the Ocean*, 36 *LIMNOLOGY & OCEANOGRAPHY* 1715, 1715 (1991); T. John Hart, *On the Phytoplankton of the South-West Atlantic and the Bellingshausen Sea 1929–1931*, 8 *DISCOVERY REP.* 3, 159, 186 (1934).

102. John H. Martin, *Glacial-Interglacial CO₂ Change: The Iron Hypothesis*, 5 *PALEOCEANOGRAPHY* 1, 2, 8–10 (1990); see also P.W. Boyd et al., *Mesoscale Iron Enrichment Experiments 1993–2005: Synthesis and Future Directions*, 315 *SCIENCE* 612, 612–17 (2007) (discussing recent experiments where the Iron Hypothesis was applied in an attempt to increase oceanic productivity); Nicolas Cassar et al., *The Southern Ocean Biological Response to Aeolian Iron Deposition*, 317 *SCIENCE* 1067, 1067–70 (2007) (discussing more recent scientific evidence that supports the Iron Hypothesis).

103. DOUG WALLACE ET AL., *OCEAN FERTILIZATION: A SCIENTIFIC SUMMARY FOR POLICY MAKERS* 3 (2010).

104. R.S. Lampitt et al., *Ocean Fertilization: A Potential Means of Geoengineering?*, 366 *PHIL. TRANSACTIONS ROYAL SOC'Y (SER. A)* 3919, 3928 (2008).

105. For a discussion of the results of the key experiments to date, see Stéphane Blain et al., *Effect of Natural Iron Fertilization on Carbon Sequestration in the Southern Ocean*, 446 *NATURE* 1070, 1070 (2007); Philip Boyd et al., *A Mesoscale Phytoplankton Bloom in the Polar Southern Ocean Stimulated by Iron Fertilization*, 407 *NATURE* 695, 695 (2000); Ken O. Bueseler et al., *The Effects of Iron Fertilization on Carbon Sequestration in the Southern Ocean*, 304 *SCIENCE* 414, 414–17 (2004); Raymond T. Pollard et al., *Southern Ocean Deep-Water*

Pacific regions may well be caused by factors other than a lack of iron, including limited light,¹⁰⁶ seasonality, oxygen production,¹⁰⁷ grazing by microzooplankton,¹⁰⁸ and the presence of invasive species.¹⁰⁹ Moreover, there is little evidence that any of the CO₂ drawn down to the surface of the ocean has actually been transported to, and sequestered within, the deep ocean,¹¹⁰ and there are no agreed-upon means by which to verify any such sequestration.¹¹¹ The biological and chemical responses to fertilization have been described as “variable and difficult to predict,”¹¹² but possible effects include increased ocean acidification, the disruption of marine ecosystems,¹¹³ eutrophication and anoxia,¹¹⁴ the creation of toxic harmful algal blooms,¹¹⁵ the generation of an increase in the emission of other

Carbon Export Enhanced by Natural Iron Fertilization, 457 NATURE 577, 577 (2009); R.E. Zeebe & D. Archer, *Feasibility of Ocean Fertilization and Its Impact on Future Atmospheric CO₂ Levels*, 32 GEOPHYSICAL RES. LETTERS, May 2005, at 1–5.

106. See B. Greg Mitchell et al., *Light Limitation of Phytoplankton Biomass and Macro-nutrient Utilization in the Southern Ocean*, 36 LIMNOLOGY & OCEANOGRAPHY 1662, 1662 (1991); see also Konstantin Zahariev et al., *Preindustrial, Historical, and Fertilization Simulations Using a Global Ocean Carbon Model with New Parameterizations or Iron Limitation, Calcification and N₂ Fixation*, 77 PROGRESS OCEANOGRAPHY 56, 78 (2008) (describing how light limitation decreases nutrient drawdown, which affects phytoplankton fertility).

107. See Tsung Hung Peng & Wallace S. Broecker, *Factors Limiting the Reduction of Atmospheric CO₂ by Iron Fertilization*, 36 LIMNOLOGY & OCEANOGRAPHY 1919, 1919–20 (1991).

108. Francisco P. Chavez et al., *Growth Rates, Grazing, Sinking, and Iron Limitation of Equatorial Pacific Phytoplankton*, 36 LIMNOLOGY & OCEANOGRAPHY 1816, 1816 (1991); Bruce W. Frost, *The Role of Grazing in Nutrient-Rich Areas of the Open Sea*, 36 LIMNOLOGY & OCEANOGRAPHY 1616, 1616 (1991).

109. John T. Lehman, *Interacting Growth and Loss Rates: The Balance of Top-Down and Bottom-Up Controls in Plankton Communities*, 36 LIMNOLOGY & OCEANOGRAPHY 1546, 1546 (1991).

110. See Hein J.W. de Baar et al., *Efficiency of Carbon Removal per Added Iron in Ocean Iron Fertilization*, 364 MARINE ECOLOGY PROGRESS SERIES 269, 270–71 (2008); Anand Gnanadesikan & Irina Marinov, *Export Is Not Enough: Nutrient Cycling and Carbon Sequestration*, 364 MARINE ECOLOGY PROGRESS SERIES 289, 289 (2008).

111. See John J. Cullen & Phillip W. Boyd, *Predicting and Verifying the Intended and Unintended Consequences of Large-Scale Ocean Iron Fertilization*, 364 MARINE ECOLOGY PROGRESS SERIES 295, 296 (2008).

112. WALLACE ET AL., *supra* note 103, at 7. For an overview of the measured side effects from the thirteen experiments to date, see CBD FERTILIZATION SYNTHESIS, *supra* note 99, at 23. V Smetacek and S.W.A. Naqvi, scientists involved in the controversial LohaFEX joint German and Indian fertilization experiment in 2009, argue that the suggested side effects are overstated and based on worst-case scenarios. See V Smetacek & S.W.A. Naqvi, *The Next Generation of Iron Fertilization Experiments in the Southern Ocean*, 366 PHIL. TRANSACTIONS ROYAL SOC’Y (ser. A) 3947, 3947 (2008).

113. Aaron Strong et al., *Ocean Fertilization: Time To Move On*, 461 NATURE 347, 347 (2009); see also Kenneth L. Denman, *Climate Change, Ocean Processes and Ocean Iron Fertilization*, 364 MARINE ECOLOGY PROGRESS SERIES 219, 223 (2008).

114. Lampitt et al., *supra* note 104, at 3930.

115. Charles G. Trick et al., *Iron Enrichment Stimulates Toxic Diatom Production in High-Nitrate, Low-Chlorophyll Areas*, 107 PNAS 5887, 5887 (2010).

greenhouse gases such as nitrous oxide,¹¹⁶ and a decrease in the effectiveness of the Southern Ocean methyl bromide sink leading to a delay in the recovery of the ozone layer.¹¹⁷ Although research has concentrated on iron fertilization to date, alternative options include the use of volcanic ash,¹¹⁸ phosphate,¹¹⁹ and urea.¹²⁰ Furthermore, some scientists, including James Lovelock and Chris Rapley, support the deployment of vertical ocean pipes designed to pump nutrient-rich deep waters to the surface and to effectively fertilize the oceans from the resources of their depths.¹²¹

An alternative or, possibly, an additional group of options are designed to enhance the ocean's solubility pump, which transports carbon-rich cold water into the deep ocean in areas of low temperature and high salinity.¹²² Cesare Marchetti, the originator of the term "geoengineering," suggested adding carbon to existing down-welling currents in 1977.¹²³ This is not considered to be economically viable today,¹²⁴ although the costs associated with techniques designed to increase down-welling currents—including the use of water, air, and ice—are almost as unattractive.¹²⁵ More promising is the option of increasing the alkalinity of the ocean through the addition of limestone powder or soda ash.¹²⁶ Known as weathering, this option purports

116. See C.S. Law, *Predicting and Monitoring the Effects of Large-Scale Ocean Iron Fertilization on Marine Trace Gas Emissions*, 364 MARINE ECOLOGY PROGRESS SERIES 283, 284–86 (2008); see also Jed A. Fuhrman & Douglas G. Capone, *Possible Biogeochemical Consequences of Ocean Fertilization*, 36 LIMNOLOGY & OCEANOGRAPHY 1951, 1954–57 (1991); Mark G. Lawrence, *Side Effects of Oceanic Iron Fertilization*, 297 SCIENCE 1993, 1993 (2002).

117. Oliver W. Wingenter et al., *Changing Concentrations of CO, CH₄, C₂H₆, CH₃Br, CH₃I, and Dimethyl Sulphide During the Southern Ocean Iron Enrichment Experiments*, 101 PNAS 8537, 8540 (2004).

118. Svend Duggen et al., *Subduction Zone Volcanic Ash Can Fertilize the Surface Ocean and Stimulate Phytoplankton Growth: Evidence from Biogeochemical Experiments and Satellite Data*, 34 GEOPHYSICAL RES. LETTERS, Jan. 2007, at 1–2.

119. See Lampitt et al., *supra* note 104, at 3923–24.

120. Julia Mayo-Ramsay, *Environmental, Legal and Social Implications of Ocean Urea Fertilization: Sulu Sea Example*, 34 MARINE POL'Y 831, 831 (2010).

121. James E. Lovelock & Chris G. Rapley, Correspondence, *Ocean Pipes Could Help the Earth to Cure Itself*, 449 NATURE 403 (2007); see also Andrew Yool et al., *Low Efficiency of Nutrient Translocation for Enhancing Oceanic Uptake of Carbon Dioxide*, J. GEOPHYSICAL RES., Aug. 21, 2009, at 1; Research Highlights, *Ocean Beating*, 463 NATURE 713, 713 (2010).

122. S. Zhou & P.C. Flynn, *Geoengineering Downwelling Ocean Currents: A Cost Assessment*, 71 CLIMATIC CHANGE 203, 204 (2005).

123. See Marchetti, *supra* note 63, at 59.

124. Zhou & Flynn, *supra* note 122, at 206.

125. *Id.* at 214; see also 2009 ROYAL SOCIETY REPORT ON GEOENGINEERING, *supra* note 4, at 20.

126. L.D.D. Harvey, *Mitigating the Atmospheric CO₂ Increase and Ocean Acidification by Adding Limestone Powder to Upwelling Regions*, J. GEOPHYSICAL RES., Apr. 23, 2008, at 1, 3, 15, 20. See generally Haroon S. Khesghi, *Sequestering Atmospheric Carbon Dioxide by Increasing Ocean Alkalinity*, 20 ENERGY 915, 915 (1995). An alternative method seeks to increase alkalinity through electrochemical acceleration. See Kurt Zenz House et al.,

to both increase the oceans' capacity to absorb, and thus reduce atmospheric concentrations of, CO₂ while simultaneously reducing the effects of ocean acidification.¹²⁷ However, as Jennie Stephens and David Keith point out, "[t]he manipulation of ocean chemistry is controversial as the implications and disruptions to marine systems are complex and potentially severe."¹²⁸

2. Solar Radiation Management Techniques

SRM techniques seek to address the negative impacts of climate change by lowering earth surface temperatures through increasing the planet's albedo or by deflecting solar radiation. It has been estimated that a deflection of approximately 1.8% of solar radiation would offset the global mean temperature effects of a doubling of atmospheric concentrations of CO₂.¹²⁹ Techniques that are categorized as SRM include albedo enhancement of urban environments, natural environments, and the oceans; stratospheric aerosol injections; marine cloud brightening; and the deflection of solar radiation using strategically placed mirrors in space. Unlike CDR, SRM is specifically designed to decouple atmospheric concentrations of greenhouse gases from the earth's surface temperatures. The consequences of such a radical change in this relationship cannot be predicted.¹³⁰ Moreover, while SRM seeks to mitigate the impacts of surface-temperature increases resulting from climate change, it does not ameliorate ocean acidification. Finally, SRM techniques do not address the causes of climate change—excessive emissions of greenhouse gases—and consequently, should they prove unsuccessful or be terminated for any reason, atmospheric concentrations of CO₂ and other greenhouse gases—and global temperatures—are likely to be significantly higher than prior to their deployment.

The only geoengineering option that is apparently risk free is urban albedo enhancement: the utilization of white or reflective materials in urban environments to reflect greater amounts of solar radiation and cool global temperatures.¹³¹ Unfortunately, although a whiter urban environment may reduce local temperatures—and consequently energy use in warm climates¹³²—urban albedo enhancement is capable of making only a negligible

Electrochemical Acceleration of Chemical Weathering As an Energetically Feasible Approach to Mitigating Anthropogenic Climate Change, 41 ENVTL. SCI. & TECH. 8464, 8464 (2007).

127. Jennie C. Stephens & David W. Keith, *Assessing Geochemical Carbon Management*, 90 CLIMATIC CHANGE 217, 222–23, 228 (2008).

128. *Id.* at 232.

129. Ken Caldeira & Lowell Wood, *Global and Arctic Climate Engineering: Numerical Model Studies*, 366 PHIL. TRANSACTIONS ROYAL SOC'Y (ser. A) 4039, 4040 (2008).

130. Matthews & Caldeira, *supra* note 86, at 9952.

131. See Hashem Akbari et al., *Global Cooling: Increasing World-Wide Urban Albedos to Offset CO₂*, 94 CLIMATIC CHANGE 275, 277 (2009); Robert M. Hamwey, *Active Amplification of the Terrestrial Albedo to Mitigate Climate Change: An Exploratory Study*, 12 MITIGATION & ADAPTATION STRATEGIES FOR GLOBAL CHANGE 419, 420–21 (2007).

132. See Fox & Chapman, *supra* note 79, at 4. An additional positive by-product of these techniques is an improvement in local air quality. See Haider Taha, *Urban Surface Modifica-*

contribution to lowering global temperatures.¹³³ Similar reservations have been expressed regarding proposals to enhance terrestrial albedo by increasing grasslands¹³⁴ or by selecting varieties of crops and trees that maximize solar reflectivity.¹³⁵ Proposals to enhance ocean albedo are considerably less well developed, and the potential negative environmental impacts of deploying floating reflectors¹³⁶ or the creation of microbubbles¹³⁷ would appear to be potentially significant.¹³⁸

Whitening the clouds—or more accurately, the stratosphere—with injections of sulfate aerosols provided the subject for Paul Crutzen's 2006 article in the journal *Climatic Change*, which is credited with moving geoengineering from the fringes to the mainstream of serious scientific debate.¹³⁹ Drawing on evidence from the Mount Pinatubo eruption in June 1991—which injected ten teragrams of sulfur into the atmosphere, enhancing solar radiation and apparently cooling surface temperatures by an average of 0.5 degrees Celsius in 1992¹⁴⁰—and research carried out by Russian scientist Mikhail Ivanovitch Budyko in the 1960s,¹⁴¹ Crutzen argued that deliberate injections of sulfate aerosols into the stratosphere provide a last-resort solution to drastic climate heating.¹⁴² Although the first field trial took place in Russia in 2009 and was apparently successful,¹⁴³ Crutzen and

tion As a Potential Ozone Air-Quality Improvement Strategy in California: A Mesoscale Modelling Study, 127 BOUNDARY-LAYER METEOROLOGY 219, 220, 236–37 (2008).

133. 2009 ROYAL SOCIETY REPORT ON GEOENGINEERING, *supra* note 4, at 34.

134. See Hamwey, *supra* note 131, at 435–36.

135. See Andy Ridgwell et al., *Tackling Regional Climate Change by Leaf Albedo Bio-geoengineering*, 19 CURRENT BIOLOGY 146, 149 (2009).

136. See generally Michael C. MacCracken, *On the Possible Use of Geoengineering to Moderate Specific Climate Change Impacts*, 4 ENVTL. RES. LETTERS, Oct.–Dec. 2009, at 1.

137. Russell Seitz, *Bright Water: Hydrosols, Water Conservation and Climate Change*, 105 CLIMATIC CHANGE 365, 365 (2011).

138. See MacCracken, *supra* note 136, at 5; Seitz, *supra* note 137, at 376–78.

139. Crutzen, *supra* note 75, at 212.

140. *Id.*

141. FLEMING, *supra* note 3, at 236–37.

142. Crutzen, *supra* note 75, at 216; see Robert E. Dickinson, *Climate Engineering: A Review of Aerosol Approaches to Changing the Global Energy Balance*, 33 CLIMATIC CHANGE 279, 286 (1996); Philip J. Rasch et al., *An Overview of Geoengineering of Climate Using Stratospheric Sulphate Aerosols*, 366 PHIL. TRANSACTIONS ROYAL SOC'Y (ser. A) 4007, 4033 (2008); Alan Robock et al., *Regional Climate Responses to Geoengineering with Tropical and Arctic SO₂ Injections*, J. GEOPHYSICAL RES., Aug. 16, 2008, at 1; A.F. Tuck et al., *On Geoengineering with Sulphate Aerosols in the Tropical Upper Troposphere and Lower Stratosphere*, 90 CLIMATIC CHANGE 315, 328–29 (2008).

143. See Yu.A. Izrael et al., *Field Experiment on Studying Solar Radiation Passing Through Aerosol Layers*, 34 RUSS. METEOROLOGY & HYDROLOGY 265, 272 (2009). A proposed experiment to pump water a kilometer into the atmosphere in the United Kingdom as part of the Stratospheric Particle Injection for Climate Engineering (SPICE) project in October 2011 was suspended owing to public opposition. See Sarah Fecht, *U.K. Engineering Tests Delayed Until Spring*, SCI. AM. OBSERVATIONS BLOG (Oct. 7, 2011), <http://blogs.scientificamerican.com/observations/2011/10/07/geoengineering-tests-delayed-until-spring/>;

other supporters of stratospheric sulfate aerosol injections have been criticized for failing to take into account different latitudinal and seasonal patterns when predicting temperature responses.¹⁴⁴ Moreover, the injection of sulfate aerosols into the stratosphere is highly likely to increase the depletion of the ozone layer¹⁴⁵ and has the potential to affect rainfall and monsoon patterns with consequences for food and water supplies for people in Africa and Asia.¹⁴⁶ The delivery of sulfate aerosols has been described as a “formidable task” requiring millions of flights of a four-hour duration every year,¹⁴⁷ and in a broader review of aerosol engineering, Goes, Tuana, and Keller conclude that it is simply not economic as a climate change mitigation measure.¹⁴⁸ Nevertheless, at the 2011 International Scientific Conference on Problems of Adaptation to Climate Change¹⁴⁹—attended by almost seven hundred delegates—stratospheric sulfate aerosol injection was ranked as the preferred geoengineering option.¹⁵⁰

The third-ranked option at the conference was marine cloud brightening.¹⁵¹ A significantly less risky option than aerosol engineering, marine cloud brightening seeks to increase the albedo of low-level maritime clouds through seeding those clouds with salt.¹⁵² Although Salter, Sortino, and Latham have developed a design for wind-driven, remotely controlled spray vessels for the purpose of delivering salt to low-level maritime clouds,¹⁵³ it is unclear how many such vessels would be required and whether this overall technology would, in any case, be effective.¹⁵⁴

Sarah Fecht, *U.K. Researchers to Test “Artificial Volcano” for Geoengineering the Climate*, SCI. AM. (Sept. 14, 2011), <http://www.scientificamerican.com/article.cfm?id=uk-researchers-to-test-artificial-volcano-for-geoengineering-the-climate>.

144. See Michael C. MacCracken, *Geoengineering: Worthy of Cautious Evaluation?*, 77 CLIMATIC CHANGE 235, 240 (2006).

145. Simone Tilmes et al., *The Sensitivity of Polar Ozone Depletion to Proposed Geoengineering Schemes*, 320 SCIENCE 1201, 1204 (2008); see Rasch et al., *supra* note 142, at 4031.

146. Robock et al., *supra* note 142, at 1.

147. Rasch et al., *supra* note 142, at 4030–31.

148. Marlos Goes, Nancy Tuana & Klaus Keller, *The Economics (or Lack Thereof) of Aerosol Geoengineering*, 109 CLIMATIC CHANGE 719, 720 (2011).

149. Sponsored by the Russian Academy of Sciences together with the World Meteorological Association, the U.N. Environment Programme, and the U.N. Educational, Scientific and Cultural Organization.

150. See A. Frolov, Summary of the Chairman of the International Scientific Conference: “Problems of Adaptation to Climate Change” (Nov. 7–9, 2011) (on file with author).

151. See *id.*

152. John Latham et al., *Global Temperature Stabilization via Controlled Albedo Enhancement of Low-Level Maritime Clouds*, 366 PHIL. TRANSACTIONS ROYAL SOC’Y (ser. A) 3969, 3969 (2008); see Crutzen, *supra* note 75, at 211–12.

153. Stephen Salter, Graham Sortino & John Latham, *Sea-Going Hardware for the Cloud Albedo Method of Reversing Global Warming*, 366 PHIL. TRANSACTIONS ROYAL SOC’Y (ser. A) 3989, 3989 (2008).

154. Latham et al., *supra* note 152, at 3984–85.

The final group of options might be derived directly from science fiction: the deflection of solar radiation using space mirrors, so-called sunshade geoengineering.¹⁵⁵ Options include the placement of mirrors or sunshade discs between the earth and the sun or in orbit around the earth.¹⁵⁶ Other options include an artificial equatorial ring of passive particles¹⁵⁷ or the deployment of a “cloud” of reflective spacecraft.¹⁵⁸ Although technically feasible,¹⁵⁹ the known and unknown risks are significant: overcompensation could lead to excessive global cooling, and a large number of orbiting objects is likely to result in high quantities of space debris. In any case, the economics of space-based geoengineering are not viable,¹⁶⁰ with the U.S. House of Representatives Committee on Space and Technology recently noting that “due to high projected costs, technological infeasibility and unacceptable environmental and political risks, the solar radiation management . . . strategy of space-based mirrors should be a low priority consideration for research.”¹⁶¹

III. THE CURRENT REGULATORY FRAMEWORK FOR GEOENGINEERING

With three or four notable exceptions, geoengineering has yet to capture the attention of international lawyers.¹⁶² Indeed, the application of

155. See D.J. Lunt et al., *Sunshade World: A Fully Coupled CGM Evaluation of the Climatic Impacts of Geoengineering*, 35 GEOPHYSICAL RES. LETTERS, June 2008, at 1.

156. Takanobu Kosugi, *Role of Sunshades in Space As a Climate Control Option*, 67 ACTA ASTRONAUTICA 241, 242 (2010); see also James T. Early, *Space-Based Solar Shield to Offset Greenhouse Effect*, 42 J. BRIT. INTERPLANETARY SOC'Y 567, 567 (1989); C.R. McInnes, *Space-Based Geoengineering: Challenges and Requirements*, 224 J. MECHANICAL ENGINEERING SCI. 571, 573 (2010).

157. Jerome Pearson et al., *Earth Rings for Planetary Environment Control*, 58 ACTA ASTRONAUTICA 44, 46 (2006). However, while this option would cool the tropics, it might also warm high-latitude regions. Lunt et al., *supra* note 155, at 1.

158. Roger Angel, *Feasibility of Cooling the Earth with a Cloud of Small Spacecraft Near the Inner Lagrange Point (L1)*, 103 PNAS 17,184, 17,184 (2006).

159. See Kosugi, *supra* note 156, at 243.

160. *Id.*

161. ENGINEERING THE CLIMATE, *supra* note 6, at 42.

162. See Daniel Bodansky, *May We Engineer the Climate?*, 33 CLIMATIC CHANGE 309 (1996); William C.G. Burns, *Climate Geoengineering: Solar Radiation Management and Its Implications for Intergenerational Equity*, 4 STAN. J.L. SCI. & POL'Y 38, 38 (2011); Victor, *supra* note 52, at 322; John Virgoe, *International Governance of a Possible Geoengineering Intervention to Combat Climate Change*, 95 CLIMATIC CHANGE 103, 103 (2009); see also Alan Carlin, *Global Climate Change Control: Is There a Better Strategy than Reducing Greenhouse Gas Emissions?*, 155 U. PA. L. REV. 1401, 1401 (2007); William Daniel Davis, *What Does “Green” Mean? Anthropogenic Climate Change, Geoengineering and International Environmental Law*, 43 GA. L. REV. 901, 950 (2009); Jay Michaelson, *Geoengineering: A Climate Change Manhattan Project*, 17 STAN. ENVTL. L.J. 73, 139 (1998). Ocean fertilization and the law of the sea has benefited from rather more in-depth discussion. See *infra* notes 283–284 and accompanying text.

international law to geoengineering tends to be treated dismissively or, in the words of John Virgoe, as an “aside.”¹⁶³ With the exception of reforestation and afforestation¹⁶⁴ and ocean fertilization for scientific research purposes,¹⁶⁵ there are few legal instruments explicitly applicable to geoengineering; however, as an activity that creates a significant risk of serious harm to the environment, geoengineering is subject to the obligations and principles of international environmental law more generally. In fact, geoengineering provides an ideal case study to prove the extent, limits, and the very existence of international environmental law as a coherent discipline distinct from, albeit part of, international law more generally. Seven principles or (in two cases) categories of principles comprise the basic parameters of international environmental law and impose obligations on states: the prevention of harm; the prevention of pollution; the obligation to protect vulnerable ecosystems and species; the precautionary principle; principles of cooperation, information exchange, and environmental impact assessment; the principle of due regard for other users; and the principle of state responsibility. These principles are derived from an aggregate of customary and treaty obligations and are sufficiently extensive in their scope and nature of application to constrain at least some of the proposed techniques of geoengineering. In many cases, individual states are subject to a greater level of constraint owing to the application of more specific treaty commitments. Although far from perfect,¹⁶⁶ the applicability of international environmental law as a discipline to activities creating a significant risk of serious environmental harm proves that geoengineering does not take place in a regulatory Wild West or a legal black hole.

A. Specialized Rules Applicable to Geoengineering

Although geoengineering solutions are being designed for the purpose of climate change mitigation, these technologies—with the exception of reforestation and afforestation—are not specifically addressed by the 1992 UNFCCC or the 1997 Kyoto Protocol. The ultimate goal of the climate change regime, the “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system,”¹⁶⁷ does not *prima facie* preclude the deployment of CDR technologies, although it would appear to be incompatible with SRM techniques that do not seek to reduce atmospheric concentrations of CO₂. Both the 1992 UNFCCC and the 1997 Kyoto Proto-

163. Virgoe, *supra* note 162, at 109.

164. This issue warrants additional discussion but, for the sake of concision, is not considered in this Article.

165. See *infra* text accompanying notes 176, 284–287.

166. See discussion *infra* Part V (discussing limits of current regime and peculiar challenges associated with geoengineering).

167. 1992 UNFCCC, *supra* note 32, art. 2.

col call on parties to promote the enhancement of CO₂ sinks and reservoirs including biomass, forests, and oceans,¹⁶⁸ but at this stage, only afforestation and reforestation can be used in the calculation of a state's greenhouse gas emissions.¹⁶⁹ The Kyoto Protocol calls on states to promote research into and use of "advanced and innovative environmentally sound technologies,"¹⁷⁰ but the qualification embedded within that same article would exclude many geoengineering technologies that are demonstrably environmentally unsound.

The 1976 U.N. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques (the ENMOD Convention)¹⁷¹ is probably the instrument most closely related to geoengineering in terms of subject matter. However, although the definition of "environmental modification" under Article II of the ENMOD Convention is undoubtedly broad enough to include geoengineering,¹⁷² Article I of ENMOD limits the prohibition of environmental modification to situations where it is used for military or hostile purposes.¹⁷³ Moreover, Article III(1) of the ENMOD Convention stipulates that "[t]he provisions of this Convention shall not hinder the use of environmental modification techniques for peaceful purposes and shall

168. *Id.* art. 4(d); Kyoto Protocol, *supra* note 33, art. 2(1)(a)(ii).

169. Kyoto Protocol, *supra* note 33, art. 3(3).

170. *Id.* art. 2(1)(a)(iv).

171. 1976 U.N. Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques, *opened for signature* May 18, 1977, 31 U.S.T. 333, 1108 U.N.T.S. 151 [hereinafter 1976 ENMOD Convention]. *See generally* Jozef Goldblat, *The Environmental Modification Convention of 1977: An Analysis*, in ENVIRONMENTAL WARFARE: A TECHNICAL, LEGAL AND POLICY APPRAISAL 53, 53–56, 58 (Arthur H. Westing ed., 1984) (discussing the scope of the 1976 ENMOD Convention).

172. Article II of the 1976 ENMOD Convention defines "environmental modification techniques" as "any technique for changing—through the deliberate manipulation of natural processes—the dynamics, composition or structure of the Earth, including its biota, lithosphere, hydrosphere and atmosphere, or of outer space." 1976 ENMOD Convention, *supra* note 171, art. II. By contrast, the definition of "weather modification" in the 1980 U.N. Environment Program guidelines entitled *Provisions for Co-operation Between States in Weather Modification* (Decision 8/7) focuses on activities designed to change the patterns of rainfall, cloud coverage, and fog that are on too small a scale to be categorized as geoengineering. *See* U.N. Env't Program Governing Council, *Provisions for Co-operation Between States in Weather Modification*, U.N. Doc. UNEP/GC/8/7/A (Apr. 29, 1980).

173. 1976 ENMOD Convention, *supra* note 171, art. II. Interestingly, earlier drafts of ENMOD had a broader application and sought to outlaw environmental modification, including climate modification, for military and other purposes incompatible with the "maintenance of international security, human well being and health." Lawrence Juda, *Negotiating a Treaty on Environmental Modification Warfare: The Convention on Environmental Warfare and Its Impact on Arms Control Negotiations*, 32 INT'L ORG. 975, 978 (1978) (quoting First Comm. of the Gen. Assembly, *Draft Resolution on the Prohibition of Action to Influence the Environment and Climate for Military and Other Purposes Incompatible with the Maintenance of International Security, Human Well-Being and Health*, Submitted by Union of Soviet Socialist Republics, U.N. Doc. A/C.1/L.675 (Sept. 24, 1974)). This earlier draft was developed by the then Soviet Union but narrowed at the behest of the United States. *See id.* at 979.

be without prejudice to the generally recognized principles and applicable rules of international law concerning such use.”¹⁷⁴ The ENMOD Convention does set out a number of obligations relating to cooperation and notification applicable to the seventy-six state parties.¹⁷⁵

More specifically, the states party to the 1992 Biodiversity Convention adopted Decision X/33 in 2010, calling on states to

[e]nsure . . . in the absence of science based, global, transparent and effective control and regulatory mechanisms for geo-engineering, and in accordance with the precautionary approach and Article 14 of the Convention, that no climate-related geo-engineering activities that may affect biodiversity take place, until there is an adequate scientific basis on which to justify such activities and appropriate consideration of the associated risks for the environment and biodiversity and associated social, economic and cultural impacts, with the exception of small scale scientific research studies that would be conducted in a controlled setting in accordance with Article 3 of the Convention, and only if they are justified by the need to gather specific scientific data and are subject to a thorough prior assessment of the potential impacts on the environment.¹⁷⁶

Sometimes incorrectly referred to as establishing a moratorium, this Decision, while persuasive, is not legally binding. Decision IX/16, which was adopted by the parties to the Biodiversity Convention in 2008, called on parties

to ensure that ocean fertilization activities do not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks, and a global, transparent and effective control and regulatory mechanism is in place for these activities; with the exception of small scale scientific research studies within coastal waters.¹⁷⁷

The decision is similarly nonbinding and, moreover, uses only hortatory language. Also in 2008, the parties to the 1972 London Convention and Protocol adopted mandatory terminology in Resolution LC-LP.1, which declares ocean fertilization activities other than legitimate scientific research to be contrary to the aims of both instruments.¹⁷⁸ Despite the language, how-

174. 1976 ENMOD Convention, *supra* note 171, art. III(1).

175. See discussion *infra* Part III.F.

176. Conference of the Parties to the CBD at Its Tenth Meeting, Nagoya, Japan, Oct. 18–29, 2010, *X/33 Biodiversity and Climate Change*, ¶ 8(w), UNEP/CBD/COP/DEC/X/33 (Oct. 29, 2010).

177. Conference of the Parties to the CBD at Its Ninth Meeting, Bonn, Ger., May 19–20, 2008, *IX/16 Biodiversity and Climate Change*, ¶ C.4, UNEP/CBD/COP/9/29 (Oct. 9, 2008).

178. London Convention and Protocol [LC-LP], *Resolution LC-LP.1(2008) on the Regulation of Ocean Fertilization*, ¶ 8, LC 30/16 (Oct. 31, 2008) [hereinafter LC-LP Resolution LC-LP.1 (2008)].

ever, the resolution itself is not legally binding.¹⁷⁹ However, these instruments are highly persuasive and, moreover, rely on more general principles of international environmental law that *are* independently binding and applicable to all states.

B. *The Obligation to Prevent Harm*

International environmental law is arguably founded on the obligation to ensure that activities within the jurisdiction or under the control of a state do not cause harm to the environment of other states or to areas beyond national jurisdiction. The no-harm principle forms “part of the corpus of international law,” which has been confirmed by the International Court of Justice (ICJ) on several occasions.¹⁸⁰ This principle is central to a number of declarations of principles relating to the environment, including the 1972 Stockholm Declaration,¹⁸¹ the 1992 Rio Declaration,¹⁸² and the 2001 International Law Commission’s Draft Articles on Transboundary Harm.¹⁸³ Moreover, this principle has been incorporated into and confirmed by a number of environmental treaties of general application. Of particular relevance to marine-focused geoengineering are Articles 192 and 193 of the 1982 U.N. Convention on the Law of the Sea (LOSC), which impose a general obligation to protect and preserve the marine environment and operate as constraints on activities such as ocean fertilization or weathering where there is a significant risk of environmental harm.¹⁸⁴ It is worth noting that the obligation to prevent harm to the marine environment under Part XII of the LOSC also applies to scientific research activities according to Part XIII of the Convention.¹⁸⁵ While the LOSC itself is not universally applicable,

179. See Int’l Mar. Org. [IMO], *Rep. of the Thirty-Second Consultative Meeting and the Fifth Meeting of the Contracting Parties*, ¶ 4.16, LC 32/15 (Nov. 9, 2010).

180. Legality of the Threat or Use of Nuclear Weapons, Advisory Opinion, 1996 I.C.J. 226, ¶ 29 (July 8); *accord*, e.g., Gabčíkovo-Nagymaros Project (Hung./Slovk.), Judgment, 1997 I.C.J. 7, ¶ 140 (Sept. 25).

181. U.N. Conference on the Human Environment, Stockholm, Swed., June 5–16, 1972, *Declaration of the U.N. Conference on the Human Environment*, princ. 21, U.N. Doc. A/CONF.48/14/Rev. 1 (1973).

182. U.N. Conference on Environment and Development, Rio de Janeiro, Braz., June 3–14, 1992, *Rio Declaration on Environment and Development*, princ. 2, U.N. Doc. A/CONF.151/26/Rev.1 (Vol. I), Annex I (Aug. 12, 1992) [hereinafter *Rio Declaration on Environment and Development*].

183. Draft Articles on Transboundary Harm from Hazardous Activities, in *Report of the International Law Commission on the Work of Its Fifty-Third Session*, 56 U.N. GAOR Supp. No. 10, at 370, U.N. Doc. A/56/10 (2001) [hereinafter *Draft Articles on Transboundary Harm*], reprinted in [2001] 2 Y.B. Int’l L. Comm’n 146, ¶ 97, art. 3, U.N. Doc. A/CN.4/SER.A/2001/Add.1 (Part 2).

184. U.N. Convention on the Law of the Sea arts. 192, 193, Dec. 10, 1982, 1833 U.N.T.S. 3 [hereinafter 1982 LOSC].

185. *Id.* art. 240(d).

Parts XII and XIII are generally considered to be part of customary international law and, consequently, binding on all states.¹⁸⁶

A more stringent obligation to prevent harm to the environment can be found in Article 3 of the 1991 Protocol to the 1959 Antarctic Treaty, which requires that states party to the Protocol plan activities within the Antarctic Treaty area so as to limit adverse impacts on the Antarctic environment and its dependent and associated ecosystems, including climate or weather patterns, water quality, and the marine environment.¹⁸⁷ These obligations are again of particular relevance to ocean fertilization activities taking place within the Southern Ocean¹⁸⁸ involving vessels and personnel based in states party to the Protocol.

Cloud whitening or stratospheric aerosol injections are similarly subject to the constraints of the widely ratified 1985 Vienna Convention for the Protection of the Ozone Layer, which requires parties to take measures to "protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer."¹⁸⁹ Article III of the 1967 Outer Space Treaty requires parties to comply with international law when carrying out activities in outer space;¹⁹⁰ this reference is arguably broad enough to encompass the prevention-of-harm principle.

The principle of prevention of harm is an *erga omnes* norm and consequently can be invoked by any state affected by or likely to be affected by environmental harm resulting from geoengineering activities. As articulated as a general principle within the treaties and declarations noted above, and as a general principle of international environmental law, the threshold of harm at which the principle becomes operational is unspecified. This notwithstanding, a reasonable interpretation of this principle would require its application in situations where the environmental harm is irreversible or serious. While small-scale geoengineering experiments may not create a risk of irreversible or serious harm, the risks associated with almost every option of large-scale geoengineering (other than urban albedo enhancement and reforestation) would appear to be potentially serious. Nevertheless, one important factor to bear in mind is that the purpose of geoengineering is to *avoid* or *mitigate* the harmful consequences of climate change; consequent-

186. R.R. CHURCHILL & A.V. LOWE, *THE LAW OF THE SEA* 24 (3rd ed. 1999).

187. 1991 Protocol to the Antarctic Treaty on Environmental Protection art. 3, Oct. 4, 1991, 30 I.L.M. 1461 [hereinafter 1991 Environmental Protocol].

188. Although the 1991 Environmental Protocol ostensibly applies to the area south of 60° South, the reference to "dependent and associated ecosystems" in Articles 2 and 3 of the Protocol potentially broaden its scope to parts of the Southern Ocean north of 60° South, particularly where activities also take place within the Antarctic Treaty area. *Id.* arts. 2, 3.

189. Convention for the Protection of the Ozone Layer art. 2(1), Mar. 22, 1985, T.I.A.S. No. 11,097, 1513 U.N.T.S. 293; see also *id.* art. 2(2)(b).

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

ly, the risk of harm associated with climate change is an important factor in evaluating the risk of harm posed by geoengineering.

C. *The Obligation to Prevent Pollution*

The obligation to prevent pollution is arguably part of the broader obligation to prevent harm, discussed above. However, this obligation is primarily treaty based, and, consequently, the extent to which states are constrained by this principle depends on the application of the treaty in question. Nevertheless, several treaties relating to certain geoengineering technologies are universally, or at least widely, applicable.

Although no instrument explicitly prohibits the release of sulfate aerosols or even salt into the atmosphere, one regional instrument—the 1979 Convention on Long-Range Transboundary Air Pollution (LRTAP)¹⁹¹—requires contracting parties “to protect man and his environment against air pollution” and to “endeavour to limit and, as far as possible, gradually reduce and prevent air pollution including long-range transboundary air pollution.”¹⁹² Air pollution is broadly defined as

the introduction by man, directly or indirectly, of substances or energy into the air resulting in deleterious effects of such a nature as to endanger human health, harm living resources and ecosystems and material property and impair or interfere with amenities and other legitimate uses of the environment.¹⁹³

The predicted negative impacts resulting from the release of sulfate aerosols undoubtedly possess the potential to constitute a deleterious effect on health and other living resources, and, consequently, it might be argued that large-scale geoengineering using such cloud-whitening techniques should be considered contrary to the aims and objectives of LRTAP. The deployment of salt designed to brighten marine clouds, on the other hand, is much less likely to contravene LRTAP. Although ostensibly a regional convention, LRTAP is applicable to fifty-one states including the members of the European Union, Russia, much of Eastern Europe, and the United States.¹⁹⁴

The principles prohibiting pollution of the marine environment as set out under the 1982 LOSC are universally applicable.¹⁹⁵ Pollution is defined under the Convention as

191. Convention on Long-Range Transboundary Air Pollution, Nov. 13, 1979, T.I.A.S. No. 10,541, 1302 U.N.T.S. 217.

192. *Id.* art. 2.

193. *Id.* art. 1(a).

194. *Status of the Convention on Long-Range Transboundary Air Pollution*, UNITED NATIONS TREATY COLLECTION, http://treaties.un.org/pages/ViewDetails.aspx?src=TREATY&mdsg_no=XXVII-1&chapter=27&lang=en (last visited Jan. 16, 2013).

195. See 1982 LOSC, *supra* note 184, pmbl.

the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities.¹⁹⁶

As noted by Philomene Verlaan, this definition focuses on the *effects* rather than the *nature* of the substance or energy in question.¹⁹⁷ As described above, many of the geoengineering technologies and techniques designed to be deployed in or otherwise manipulate the marine environment, such as iron fertilization or weathering, have the potential to result in deleterious effects, including impacts on ocean chemistry, biodiversity, and ecosystems.¹⁹⁸ It is nevertheless worth noting that not all marine geoengineering constitutes, or will inevitably lead to, pollution. For example, the deployment of vertical ocean pipes, which facilitate the transfer of nutrients from an ocean's depths to its surface, cannot be themselves described as substance or energy or even a means of introduction of a substance or energy likely to result in deleterious effects. However, Article 194 of the LOSC, which obliges states to take all measures necessary to prevent, reduce, and control pollution from *any* source, is applicable to the majority of geoengineering techniques.¹⁹⁹ Moreover, Article 196 specifically requires states to control pollution from the use of technologies under their jurisdiction and control.²⁰⁰ Significantly, under Article 195 of the LOSC, parties, "[i]n taking measures to prevent, reduce and control pollution of the marine environment . . . shall act as not to transfer, directly or indirectly, damage or hazards from one area to another or transform one type of pollution into another."²⁰¹ This has important implications for techniques designed to decrease atmospheric concentrations of CO₂ and commensurately increase ocean concentrations of CO₂, leading to ocean acidification. As noted above, the obligations to prevent, reduce, and mitigate pollution are applicable to research activities as well as to full-scale geoengineering.

Where substances such as iron, calcium hydroxide (lime), or calcium carbonate are introduced into the ocean, the dumping regime comprising the 1972 London Convention and 1996 Protocol are directly applicable.²⁰²

196. *Id.* art. 1(4).

197. Philomene Verlaan, *Geo-engineering, the Law of the Sea, and Climate Change*, 2009 CARBON & CLIMATE L. REV. 446, 449.

198. *See supra* Part II; *see also* Verlaan, *supra* note 197, at 448–49.

199. 1982 LOSC, *supra* note 184, art. 194(1).

200. *Id.* art. 196.

201. *Id.* art. 195(1).

202. *See* Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter art. III(1), Dec. 29, 1972, 26 U.S.T. 2403, 1046 U.N.T.S. 120 [hereinafter 1972 London Convention]; 1996 Protocol to the London Convention, *supra* note 8, art. 1.4.

Although, as discussed above, LC-LP Resolution 1 (2008) stipulates that fertilization for purposes other than legitimate scientific research is deemed to be contrary to the aims and objectives of the Convention and Protocol, the Resolution does not address other geoengineering techniques such as weathering.²⁰³ Dumping is defined under both the London Convention and Protocol as “any deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms or other man-made structures at sea.”²⁰⁴ While iron, calcium hydroxide, and calcium carbonate undoubtedly constitute “other matter,” it is open to debate whether they are “disposed of” given that their purpose in the marine environment is to create an algal bloom or to enhance the solubility pump. Moreover, both the London Convention and Protocol deliberately exclude from the definition of dumping “placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims” of the Convention or Protocol.²⁰⁵ It is this exception that is currently being relied on to permit fertilization for legitimate scientific purposes.²⁰⁶

The large-scale execution of fertilization or weathering for the purpose of mitigating climate change might be characterized as “placement of matter for a purpose other than the mere disposal thereof,” but it must also be compatible with the aims of the Convention and Protocol. Both the London Convention and Protocol indicate that their aims are the effective control of all sources of pollution of the marine environment.²⁰⁷ To the extent that geoengineering leads to marine pollution, it might be considered incompatible with the aims of the London Convention and Protocol and therefore fall outside the exception. In this situation, the introduction of iron, calcium hydroxide, or calcium carbonate would be considered “dumping” and subject to the controls under the London Convention and Protocol.

Under the 1972 London Convention, substances listed in Annex I may not be dumped, while Annex II substances *may* be dumped subject to special permission.²⁰⁸ All other substances may be dumped in accordance with a general permit.²⁰⁹ As of 2012, iron, calcium hydroxide, and calcium carbonate do not appear to be listed in either Annexes I or II.²¹⁰ Annex II includes scrap metal,²¹¹ but this is unlikely to include iron filings, which are

203. LC-LP Resolution LC-LP.1 (2008), *supra* note 178.

204. 1972 London Convention, *supra* note 202, art. III(1)(a); 1996 Protocol to the London Convention, *supra* note 8, art. 1.4.1.

205. 1972 London Convention, *supra* note 202, art. III(1)(b); 1996 Protocol to the London Convention, *supra* note 8, art. 1.4.2.

206. *See infra* notes 285–287.

207. 1972 London Convention, *supra* note 202, art. I; 1996 Protocol to the London Convention, *supra* note 8, art. 2.

208. *See* 1972 London Convention, *supra* note 202, art. IV.

209. *Id.*

210. *See id.* annexes I, II.

211. *Id.* annex II.

used for iron fertilization. Annex II also includes materials “which, though of a non-toxic nature, may become harmful due to the quantities in which they are dumped, or which are liable to seriously reduce amenities.”²¹² It might be argued that the quantities of iron, calcium hydroxide, and calcium carbonate needed for climate change mitigation render them harmful, in which case a special permit must be sought prior to dumping. Otherwise, it would appear that these materials fall outside Annexes I and II and would only require a general permit under Article IV(1)(c) of the London Convention. The 1996 Protocol introduces a reverse-listing approach to dumping and permits only those substances listed in its Annex I to be dumped subject to a special permit.²¹³ There is a provision in Annex I for the dumping of bulky items comprising iron,²¹⁴ but again, this provision is very unlikely to be considered applicable to the iron filings used in iron fertilization. Annex I also permits “inert, inorganic geological material” to be dumped (subject to a permit);²¹⁵ the key question here is the definition of “inert.” The Convention Guidelines require materials categorized as inert to be essentially chemically unreactive.²¹⁶ There is in fact little scientific consensus as to the definition of inert, and different disciplines take different approaches. While chemists generally take a strict approach—there must be no possibility of a chemical reaction—other scientists focus on the toxicity of the substance and assess inertness in a relative sense.²¹⁷ The Convention Guidelines appear to support the latter approach and stipulate that

[k]ey factors in determining if a proposed material is inert are knowledge of the material’s constituents, including any potential contaminants, and what, if any, reactions might occur following the material’s exposure to physical, chemical, or biological processes in the marine environment. Material that may result in acute or chronic toxicity, or in bioaccumulation of any of its constituents, should not be considered inert.²¹⁸

The final sentence would appear to introduce a damage threshold into the definition of inert material. Although chemists would not regard any of the proposed substances that are designed to manipulate either the solubility or the biological pump in the marine environment as inert, calcium carbonate may be considered inert according to the Convention Guidelines owing to its

212. *Id.*

213. 1996 Protocol to the London Convention, *supra* note 8, art. 4.1.

214. *Id.* annex I.

215. *Id.*

216. See IMO, GUIDELINES ON THE CONVENTION ON THE PREVENTION OF MARINE POLLUTION BY DUMPING OF WASTES AND OTHER MATTER, 1972, at 109, ¶ 13, IMO Sales No. 1531E (2006 ed.) [hereinafter DUMPING GUIDELINES].

217. I am grateful to Dr. Ian Shaw, Professor of Toxicology, University of Canterbury, for helpful information on the approach of chemists and other scientists to the question of inertness.

218. DUMPING GUIDELINES, *supra* note 216, at 109, ¶ 14.

very low toxicity. It is nevertheless unlikely that either iron or calcium hydroxide would be considered inert, particularly since they are specifically designed to interact with and change the chemistry of the oceans.

The 1996 Protocol entered into force in 2006 and has been ratified by forty-two states including the United Kingdom, China, and New Zealand.²¹⁹ Neither Russia nor the United States has ratified the Protocol. The 1982 LOSC requires “states [to] adopt laws and regulations to prevent, reduce and control pollution . . . by dumping”²²⁰ and imposes obligations on flag states as well as coastal, port, and loading²²¹ states to comply with global rules and standards.²²² Those global rules and standards, while not specified in the LOSC, are traditionally considered to equate to the provisions of the 1972 London Convention.²²³ There is no procedure within the 1982 LOSC to replace these standards with those agreed to under the 1996 Protocol, and it is unclear at what point this will take place. Nevertheless, the general application of the 1972 London Convention to marine geoengineering demonstrates that for activities that constitute dumping at sea, a permit must be sought, and the applicant must justify the proposed activity. In the case where placement is for a purpose other than disposal, that placement must nevertheless be consistent with the broader aims and objectives of the 1972 London Convention in relation to the prevention of marine pollution.

D. *The Obligation to Protect Vulnerable Ecosystems and Species*

The third principle in the international environmental law canon is the obligation to protect vulnerable ecosystems and species. Such an obligation can be found in a number of international treaties including Article 8 of the 1992 Biodiversity Convention²²⁴ and Annex V of the 1991 Protocol to the 1959 Antarctic Treaty.²²⁵ Given the global nature of many of the proposed options for geoengineering, it may prove difficult to apply this basic principle as a particular constraint. However, this is not necessarily the case for technologies and techniques designed to manipulate the marine environment.

219. 1996 Protocol to the London Convention 1972: Overview of Contracting States, INT’L MAR. ORG., http://www.imo.org/blast/blastData.asp?doc_id=7541&type=body (last updated May 28, 2012). By contrast, the 1972 Convention has eighty-seven state parties. IMO, *Status of the London Convention and Protocol: Rep. of the Secretary-General on the Status of the London Convention 1972*, ¶ 2, LC 34/2 (July 19, 2012). Scientists based in or collaborating with those in New Zealand have been quite active in connection with research into ocean fertilization and weathering.

220. 1982 LOSC, *supra* note 184, art. 210. Dumping is defined in very similar terms to the 1972 London Convention in Article 1(5) of the 1982 LOSC. Compare 1972 London Convention, *supra* note 202, art. III(1)(a), with 1982 LOSC, *supra* note 184, art. 1(5).

221. 1982 LOSC, *supra* note 184, art. 216.

222. *Id.* arts. 210(6), 216(1).

223. CHURCHILL & LOWE, *supra* note 186, at 369–70.

224. CBD, *supra* note 9, art. 8.

225. 1991 Environmental Protocol, *supra* note 187, annex V.

Article 194(5) of the 1982 LOSC stipulates that “[t]he measures taken in accordance with this Part shall include those necessary to protect and preserve rare or fragile ecosystems as well as the habitat of depleted, threatened or endangered species and other forms of marine life.”²²⁶ Where protected areas or special measures have been established, these are likely to operate as constraints on activities designed to manipulate ocean chemistry or precipitate an algal bloom. Coastal states may establish marine protected areas within their maritime zones and are able to regulate activities such as the release of iron or calcium hydroxide within their waters for climate change mitigation or for research purposes.²²⁷ The development of high-seas marine protected areas (MPAs) is an emerging field of international regulation. The first—and so far, only—network of high-seas MPAs was recently established by the parties to the 1992 Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR Convention).²²⁸ Six high-seas protected areas were designated within the OSPAR maritime area in 2010, and it is notable that the 2008 OSPAR Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area²²⁹ requires a higher level of protection when activities are carried out within OSPAR MPAs.²³⁰ The Ad Hoc Open-Ended Informal Working Group to study issues relating to the conservation and sustainable use of marine biological diversity beyond areas of national jurisdiction, established in 2004 by the U.N. General Assembly,²³¹ recommended in 2011 that the General Assembly initiate a process

226. 1982 LOSC, *supra* note 184, art. 194(5).

227. See *id.* art. 56 (giving coastal states exclusive jurisdiction to protect and preserve the marine environment within their exclusive economic zones [EEZs] as well as to regulate research activities). They are also able to regulate research activities, and, while normally coastal states should give their consent to research taking place within their EEZs, consent can be withheld where the research involves the introduction of harmful substances into the marine environment. *Id.* art. 246(5)(b).

228. Convention for the Protection of the Marine Environment of the North-East Atlantic, *opened for signature* Sept. 22, 1992, 2354 U.N.T.S. 67. The network of high-seas MPAs were established pursuant to Annex V of the Protection and Conservation of the Ecosystems and Biological Diversity of the Maritime Area to the 1992 OSPAR Convention (as amended). *Id.* annex V, art. 3; Meeting of the OSPAR Commission, Bremen, Ger., June 23–27, 2003, *Recommendation 2003/3 on a Network of Marine Protected Areas*, pmbl., para. 2, OSPAR 03/17/1-E, Annex 9 (June 27, 2003); see OSPAR Comm’n, *Strategy of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic 2010–2020*, pt. II, ¶ 4.2f(i), OSPAR Comm’n Agreement 2010-03 (Sept. 24, 2010) [hereinafter *OSPAR North-East Atlantic Strategy*].

229. OSPAR Comm’n, *2008 OSPAR Code of Conduct for Responsible Marine Research in the Deep Seas and High Seas of the OSPAR Maritime Area*, ¶¶ 15–16, OSPAR 08/24/1, Annex 6 (Jan. 2008) [hereinafter *2008 OSPAR Code of Conduct*]; see *OSPAR North-East Atlantic Strategy*, *supra* note 228, pt. II, ¶ 4.2f.

230. *2008 OSPAR Code of Conduct*, *supra* note 229, ¶ 15.

231. Oceans and the Law of the Sea, G.A. Res. 59/49a, ¶ 73, U.N. Doc. A/RES/59/24 (Nov. 17, 2004).

with a view to ensuring that the legal framework for the conservation and sustainable use of marine biodiversity in areas beyond national jurisdiction effectively addresses those issues by identifying gaps and ways forward, including through the implementation of existing instruments and the possible development of a multilateral agreement under the [LOSC].²³²

The Working Group noted that MPAs constitute an important tool for the protection and conservation of marine biological diversity beyond national jurisdiction.²³³

Although the obligation to adopt higher levels of protection and a more cautious attitude toward environmental risk within protected areas is of relatively limited applicability to global geoengineering activities at the moment, it should be recognized that this is a principle of increasing significance within international environmental law. As the network of MPAs both within and beyond national jurisdiction develops, this principle will inevitably operate as a growing constraint on activities associated with both research into and the deployment of geoengineering for climate change mitigation.

E. *The Precautionary Principle*

The precautionary principle or approach is not only an integral component of modern international environmental law but is of particularly apposite application to geoengineering. The most common articulation of the precautionary approach can be found in Principle 15 of the 1992 Rio Declaration: "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."²³⁴

In essence, the precautionary approach, which comprises both a substantive and a procedural obligation, requires a more cautious approach to the authorization of activities in situations where there are threats of serious environmental harm. As a matter of procedure, scientific uncertainty must be explicitly considered as part of the decision-making process and must not be used as justification to authorize activities that pose a risk of serious harm to the environment or to postpone cost-effective measures designed to prevent such harm. The terms "principle" and "approach" are commonly used, but there is no substantive difference between the two with respect to

232. Co-Chairs of the Ad Hoc Open-Ended Informal Working Group, Letter dated June 30, 2011 from the Co-Chairs of the Ad Hoc Open-Ended Informal Working Group to the President of the General Assembly, ¶ 1, U.N. Doc. A/66/119, Annex (June 30, 2011).

233. *Id.* ¶ 23.

234. *Rio Declaration on Environment and Development*, *supra* note 182, princ. 15.

the nature or extent of the obligation imposed.²³⁵ Both the nature and extent of the precautionary approach are contextually dependent upon the particular articulation of the level of harm, the degree or nature of scientific uncertainty within a treaty, and, importantly, whether the burden of proving harm and uncertainty is reversed.²³⁶ Nevertheless, the widespread application of the precautionary approach in situations where there is a risk of serious harm to the environment is such that it can be considered part of international environmental law.²³⁷ This has been recently, albeit indirectly, confirmed by the ICJ in the *Pulp Mills on the River Uruguay* case, where the Court accepted that the “precautionary approach may be relevant in the interpretation and application of the provisions of the Statute” in dispute between Uruguay and Argentina.²³⁸ The Court’s implicit reference to Article 31(3)(c) of the 1969 Vienna Convention on the Law of Treaties²³⁹ implies that it regards the precautionary approach as a relevant rule of international law applicable to both Uruguay and Argentina. This interpretation of the ICJ’s conclusion was confirmed in early 2011 by the Seabed Disputes Chamber of the International Tribunal for the Law of the Sea in Advisory Opinion No. 17.²⁴⁰ In that case, the Chamber noted that

the precautionary approach has been incorporated into a growing number of international treaties and other instruments, many of which reflect the formulation of Principle 15 of the Rio Declaration. In the view of the Chamber, this has initiated a trend towards making this approach part of customary international law.²⁴¹

235. The “precautionary approach” is the term commonly employed in international treaties, whereas European treaties and European Union law more regularly refer to the “precautionary principle.” See BIRNIE ET AL., *supra* note 23, at 155; see also SIMON MARR, *THE PRECAUTIONARY PRINCIPLE IN THE LAW OF THE SEA: MODERN DECISION MAKING IN INTERNATIONAL LAW* 17–21 (Vaughan Lowe ed., 2003); ARIE TROUWBORST, *PRECAUTIONARY RIGHTS AND DUTIES OF STATES* 11 (2006).

236. BIRNIE ET AL., *supra* note 23, at 162–63.

237. Birnie, Boyle & Redgwell suggest that the precautionary approach constitutes a binding legal obligation by virtue of its status as a general principle of law. *Id.* at 162–63. Other commentators conclude that it is a principle of customary international law. *E.g.*, TROUWBORST, *supra* note 235, at 295–96.

238. *Pulp Mills on the River Uruguay* (Arg. v. Uru.), Judgment, 2010 I.C.J. 71, ¶ 164 (Apr. 10).

239. *Id.*; see Vienna Convention on the Law of Treaties, May 23, 1969, 1155 U.N.T.S. 331.

240. Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area, Case No. 17, Advisory Opinion of Feb. 1, 2011, 50 I.L.M. 458 (2011), available at http://www.itlos.org/fileadmin/itlos/documents/cases/case_no_17/adv_op_010211.pdf. For commentary on this opinion, see David Freestone, *Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area*, 105 AM. J. INT’L L. 755, 755–60 (2011).

241. *Responsibilities and Obligations of States*, Case No. 17, ¶ 135.

Most geoengineering techniques and technologies pose a risk, in some cases a significant risk, to the environment. Moreover, the extent and nature of the risks involved are largely unknown. With respect to geoengineering in the marine environment, the obligations of states to prevent pollution under the LOSC must be interpreted to incorporate the precautionary approach relying on Articles 31(3)(b) and 31(3)(c) of the 1969 Vienna Convention.²⁴² Strategies that involve the dumping or placement of substances into the marine environment must be justified by their proponents under the dumping regime, which in practice reverses the burden of proof in its application of the precautionary principle.²⁴³ Furthermore, as a general principle, or possibly as a principle of customary international law, the precautionary approach requires the risk of serious harm to the environment and the degree of scientific uncertainty to be explicitly considered by decision makers charged with authorizing *any* geoengineering-related activity. However, unless specified under an applicable regime, the precautionary approach does not automatically reverse the burden of proving the harmful (or otherwise) nature of an activity.²⁴⁴

The nature, and indeed the extent, of the environmental risks associated with geoengineering could potentially justify a moratorium on the deployment of, or even research into, these techniques and technologies. However, as noted above, geoengineering constitutes a response to, and an attempt to mitigate, a serious risk of environmental harm: climate change. A moratorium on geoengineering would inevitably stifle research and innovation and, in the context of climate change, might itself be regarded as contrary to Article 3(3) of the 1992 UNFCCC.²⁴⁵ Decision makers therefore need to consider the environmental risks associated with climate change as

242. See Vienna Convention on the Law of Treaties, *supra* note 239, art. 31(3)(b)–(c). This interpretation relies on the recognition by the International Court of Justice and the Seabed Disputes Chamber of the International Tribunal for the Law of the Sea that the precautionary approach constitutes a relevant rule of international law applicable in the relations between the parties. See *supra* notes 238–241 and accompanying text. The precautionary approach to marine environmental protection has been endorsed in numerous declarations and documents including Chapter 17 of Agenda 21. U.N. Dep’t of Econ. & Soc. Affairs, Div. for Sustainable Dev., *Earth Summit: Agenda 21*, ch. 17 (Apr. 23, 1993), available at <http://www.un.org/esa/dsd/agenda21>.

243. See 1972 London Convention, *supra* note 202, art. IV; 1996 Protocol to the London Convention, *supra* note 8, art. 4.

244. *Pulp Mills on the River Uruguay* (Arg. v. Uru.), Judgment, 2010 I.C.J. 71, ¶ 163 (Apr. 10).

245. See 1992 UNFCCC, *supra* note 32, art. 3(3). The UNFCCC requires parties to

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

Id.

well as the risks associated with geoengineering. This is far from a straightforward task, and cultural attitudes to risk, climate change, and technology will inevitably influence an evaluation of the environmental risks associated with geoengineering. Without a specific framework to guide the application of the precautionary approach to geoengineering, it is almost inevitable that some states will conclude that the risks associated with geoengineering are justified in the context of the greater risks posed by climate change and that other states will disagree. This represents a serious predicament because geoengineering deployed as a climate change mitigation measure will affect *all* states.

F. *Obligations to Cooperate, Exchange Information, and Assess Environmental Impacts*

The fifth principle, or more accurately, category of principles, is procedural in nature and focuses on the obligations associated with cooperation, information exchange, and environmental impact assessment. All of these obligations are provided for under numerous environmental and other treaties and, arguably, are now part of the corpus of international environmental law more generally.

Obligations to cooperate and exchange information connected to research, the deployment of geoengineering technologies, or environmental emergencies associated with geoengineering activities can be derived from broadly phrased commitments set out in Article 4(1)(h) of the 1992 UNFCCC,²⁴⁶ Article 14(1)(c) of the 1992 Biodiversity Convention,²⁴⁷ Article 18 of the 1992 Rio Declaration,²⁴⁸ and Articles 4 and 8 of the 2001 Draft Articles on the Prevention of Transboundary Harm.²⁴⁹ More specific obligations can be found in the 1976 ENMOD Convention, under which over seventy states have undertaken to fully exchange information on, and cooperate in relation to, environmental modification for peaceful purposes.²⁵⁰ In connection with marine geoengineering, the 1982 LOSC imposes an obligation on states to cooperate on a global or regional basis for the protection of the marine environment²⁵¹ and sets out various obligations associated with notification in an environmental emergency,²⁵² as well as obligations with respect to cooperation and dissemination of information arising from scientific research.²⁵³ Similar, although less well-developed, principles apply to

246. *Id.* art. 4(1)(h).

247. *See* CBD, *supra* note 9, art. 14(1)(c).

248. *See* Rio Declaration on Environment and Development, *supra* note 182, princ. 18.

249. *See* Draft Articles on Transboundary Harm, *supra* note 183, ¶ 97, arts. 4, 8.

250. 1976 ENMOD Convention, *supra* note 171, arts. III(3), V(1).

251. *See* 1982 LOSC, *supra* note 184, art. 197; The MOX Plant Case (Ir. v. U.K.), Case No. 10, Order of Dec. 3, 2001, 5 ITLOS Rep. 95, ¶ 82, available at http://www.itlos.org/fileadmin/itlos/documents/cases/case_no_10/Order.03.12.01.E.pdf.

252. 1982 LOSC, *supra* note 184, arts. 198, 200.

253. *Id.* art. 244(2).

space-based geoengineering as a consequence of Articles IX and XI of the 1967 Outer Space Treaty.²⁵⁴ The 1967 Outer Space Treaty is widely ratified with the United States, Russia, the United Kingdom, and China among its parties.²⁵⁵

The principle of environmental impact assessment is now so widely applied that it has recently been recognized by the ICJ as a general principle of international environmental law applicable where the impacts of an activity have transboundary²⁵⁶ or commons implications.²⁵⁷ Geoengineering methods that involve the release of sulfate aerosols, seek to create algal blooms, or involve the deployment of space sunshades indubitably raise the possibility (or even inevitability) of transboundary or commons impacts and, consequently, are subject to environmental impact assessment obligations. More specifically, where an activity may have significant adverse effects on biological diversity, environmental impact assessments must be carried out with respect to such activities taking place in the territory, or under the control of, states party to the 1992 Biodiversity Convention.²⁵⁸ With the notable exception of the United States, the Biodiversity Convention is almost universally

254. Outer Space Treaty, *supra* note 190, arts. IX, XI. It is also worth noting that the 1975 Convention on Registration of Objects Launched into Outer Space requires states to register space objects launched into the earth's orbit or beyond. Convention on Registration of Objects Launched into Outer Space art. II(1), Nov. 12, 1974, 28 U.S.T. 695, 1023 U.N.T.S. 15; *see also* Recommendations on Enhancing the Practice of States and International Intergovernmental Organizations in Registering Space Objects, G.A. Res. 62/101, ¶¶ 209–215, U.N. Doc. A/RES/62/101 (Jan. 10, 2008).

255. As of January 1, 2012, the Outer Space Treaty had 101 parties. *Status of International Agreements Relating to Activities in Outer Space*, UNITED NATIONS OFF. FOR OUTER SPACE AFF., <http://www.oosa.unvienna.org/oosa/SpaceLaw/treatystatus/index.html> (last visited Jan. 16, 2013).

256. *Pulp Mills on the River Uruguay (Arg. v. Uru.)*, Judgment, 2010 I.C.J. 71, ¶ 204 (Apr. 10); *see also* *Gabčíkovo-Nagymaros Project (Hung./Slovk.)*, Judgment, 1997 I.C.J. 7, ¶ 141 (Sept. 25).

257. Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area, Case No. 17, Advisory Opinion of Feb. 1, 2011, 50 I.L.M. 458, ¶¶ 145, 148 (2011), *available at* http://www.itlos.org/fileadmin/itlos/documents/cases/case_no_17/adv_op_010211.pdf.

258. CBD, *supra* note 9, art. 14; *see also* Conference of the Parties to the CBD at Its Eighth Meeting, Curitiba, Braz., Mar. 20–31, 2006, *Impact Assessment: Voluntary Guidelines on Biodiversity—Inclusive Impact Assessment*, ¶ 5, UNEP/CBD/COP/DEC/VIII/28 (June 15, 2006) (establishing voluntary guidelines for addressing biodiversity-related concerns when conducting environmental impact assessments). The parties to the CBD are also in the process of developing voluntary guidance for the implementation of environmental impact assessments in areas beyond national jurisdiction. *See* Expert Workshop on Scientific and Technical Aspects Relevant to Environmental Impact Assessment in Marine Areas Beyond National Jurisdiction, Manila, Phil., Nov. 18–20, 2009, *Report of the Expert Workshop on Scientific and Technical Aspects Relevant to Environmental Impact Assessment in Marine Areas Beyond National Jurisdiction*, ¶¶ 1–3, UNEP/CBD/EW-EIAMA/2 (Nov. 20, 2009); Conference of the Parties to the CBD, Nagoya, Japan, Oct. 18–29, 2010, *Marine and Coastal Biodiversity*, ¶ 13(c), UNEP/CBD/COP/DEC/X/29 (Oct. 29, 2010).

applicable.²⁵⁹ Environmental impact assessment requirements are also provided for under the 1982 LOSC²⁶⁰ and have been strongly endorsed by the International Tribunal for the Law of the Sea as an important tool for marine environmental protection.²⁶¹ Additionally, many regional instruments provide for detailed environmental impact assessment obligations: Article 8 of the 1991 Environmental Protocol to the 1959 Antarctic Treaty, for example, subjects activities (including scientific research) likely to have more than a minor or a transitory impact on the environment to a process of comprehensive environmental evaluation.²⁶² It is almost inconceivable that any geoengineering option other than urban albedo enhancement and perhaps reforestation could take place without first being subject to some form of environmental impact assessment. Indeed, impact assessment is integral to the implementation of the precautionary principle.

G. The Obligation to Act with Due Regard to Other States

The penultimate principle of international environmental law, the obligation to act with due regard to other users and other states (essentially good neighborliness), underpins but goes beyond several of the principles outlined above. While not immediately associated with international environmental law, due regard plays an important role in the context of oceans governance and the management of international water courses. With respect to geoengineering, the principle of due regard operates as an important regulatory constraint in connection with marine and space-based technologies and is of particular significance where the technology in question cannot be categorized as constituting, or leading to, pollution. For example, while scientific research is a high-seas freedom,²⁶³ it must be exercised with “due regard for the interests of other States.”²⁶⁴ Objects placed in the ocean—such as vertical pipes or reflective particles—must not excessively hinder navigation or the freedom to fish or lay cables and pipelines.

The principle of due regard is generally applicable to the oceans and is consequently of relevance to all geoengineering activities irrespective of their purpose. A rather more basic obligation is applicable to space-based activities under the 1967 Outer Space Treaty, which requires parties to con-

259. See *List of Parties*, CONVENTION ON BIOLOGICAL DIVERSITY, <http://www.cbd.int/information/parties.shtml> (last visited Jan. 16, 2013).

260. 1982 LOSC, *supra* note 184, art. 206.

261. See *Land Reclamation by Singapore in and Around the Straits of Johor* (Malay. v. Sing.), Case No. 12, Order of Oct. 8, 2003, http://www.itlos.org/fileadmin/itlos/documents/cases/case_no_12/Order.08.10.03.E.pdf; *Responsibilities and Obligations of States*, Case No. 17.

262. 1991 Environmental Protocol, *supra* note 187. For further details, see *id.* annex I.

263. 1982 LOSC, *supra* note 184, art. 87(1)(f).

264. See *id.* art. 87(2).

duct their interests with due regard to the corresponding interests of all other state parties.²⁶⁵

H. Responsibility for Environmental Harm

The final principle of international environmental law is state responsibility. By no means confined to the context of environmental harm, state responsibility is nevertheless a fundamental component of the discipline of international environmental law. Article 1 of the 2001 Draft Articles on State Responsibility codifies the principle that “[e]very internationally wrongful act of a State entails the international responsibility of that State.”²⁶⁶ To the extent that geoengineering harms or pollutes the environment of another state or otherwise interferes with the rights of another state, the state that carried out or authorized the geoengineering may be held responsible under international law. Many if not all of the obligations identified as part of the corpus of international environmental law are *erga omnes* and thus owed to the international community as a whole.²⁶⁷

In this context, the wrongful act must be attributed to the state alleged to be responsible, and, consequently, a state is not automatically held responsible for damage caused by private individuals unless that state authorized or was legally responsible for authorizing those activities. Responsibility under international law is not absolute, and in the case of all of the principles identified above, the test is that of due diligence.²⁶⁸ Consequently, responsibility is dependent upon fault. Issues in relation to causation are likely to arise in connection with environmental harm alleged to result from geoengineering that are similar to those that complicate any attempt to hold states responsible for environmental harm associated with climate change. In practice, it may prove challenging to demonstrate that changes in monsoon patterns are a result of stratospheric sulfate aerosol injections, or that ozone depletion is caused by the weakening of the Southern Ocean methyl bromide sink, which is in turn a consequence of ocean iron fertilization.²⁶⁹ Finally, it is worth noting that wrongful conduct may be excused under international law

265. Outer Space Treaty, *supra* note 190, art. IX.

266. Draft Articles on the Responsibility of States for Intentionally Wrongful Acts, in *Report of the International Law Commission on the Work of Its Fifty-Third Session*, 56 U.N. GAOR Supp. No. 10, at 43, U.N. Doc. A/56/10 [hereinafter 2001 Draft Articles], *reprinted in* [2001] 2 Y.B. Int'l L. Comm'n 26, ¶ 76, art. 1, U.N. Doc. A/CN.4/SER.A/2001/Add.1 (Part 2).

267. *See supra* Part III.

268. *See* BIRNIE ET AL., *supra* note 23, at 214–16.

269. Issues of responsibility and liability arising from the manipulation of weather and climate are not in fact new, and an early discussion of liability arising from rainmaking can be found in the 1949 *Stanford Law Review*. *See* Note, *Artificial Rainmaking*, 1 STAN. L. REV. 508, 531–37 (1949). For an early discussion of other legal issues associated with the early experiments in rainmaking, *see* Note, *Who Owns the Clouds?*, 1 STAN. L. REV. 43, 43 (1948).

if one or more of a narrow range of defenses—such as *force majeure*²⁷⁰ or necessity²⁷¹—applies.

In addition to the general rules on state responsibility, individual treaty regimes may also set out the consequences arising from a wrongful breach. For example, Article 235(1) of the 1982 LOSC stipulates that parties are “responsible for the fulfillment of their international obligations concerning the protection and preservation of the marine environment [and] shall be liable in accordance with international law.”²⁷² Similarly, states party to the 1967 Outer Space Treaty are deemed to bear responsibility for national activities in outer space and, notably, are also responsible for the activities of nongovernmental entities in space.²⁷³ On a regional basis, it should be noted that while Annex VI to the 1991 Environmental Protocol to the 1959 Antarctic Treaty is not yet in force, it will ultimately address responsibility and liability of operators in connection with accidental events leading to environmental harm.²⁷⁴

Identifying who is entitled to invoke responsibility for harm resulting from geoengineering under international law is as important as identifying the state (or states) responsible for that harm. Although the various obligations to prevent harm, protect vulnerable ecosystems, and carry out environmental impact assessments can be characterized as *erga omnes* and owed to the international community as a whole, this does not inevitably mean that *any* state is entitled to take action.²⁷⁵ States that have suffered damage and are individually affected by a breach of international law may invoke the doctrine of state responsibility,²⁷⁶ and where the breach “is of such a character as radically to change the position of all the other States to which the obligation is owed with respect to the further performance of the obligation,”²⁷⁷ any state to which the obligation is owed may invoke respon-

270. 2001 Draft Articles, *supra* note 266, ¶ 76, art. 23.

271. *Id.* ¶ 76, art. 25. In reality it would seem very unlikely that a defense of necessity would succeed. A breach of international law can only be justified under necessity if the breach constitutes the only means of safeguarding an essential interest against grave and imminent peril. *Id.* ¶ 77, art. 25, cmt. 1. It is unlikely that the urgency requirement embedded in the defense would be met by the impacts of climate change. It is also worth noting that necessity cannot be used as a defense if the state seeking to rely on necessity contributed to the situation of necessity. *Id.* ¶ 77, art. 25, cmt. 20. Arguably, this requirement would preclude the United States, western Europe, Russia, and Australia from relying on the defense of necessity.

272. 1982 LOSC, *supra* note 184, art. 235(1).

273. Outer Space Treaty, *supra* note 190, art. VI. The Outer Space Treaty imposes absolute liability on the launching state for damage caused to another state by an object launched into space. However, this provision, which is complemented by the Convention on International Liability for Damage Caused by Space Objects, Mar. 29, 1972, 24 U.S.T. 2389, 961 U.N.T.S. 187, is focused on the physical damage caused by the object rather than the indirect harm resulting from the deployment of that object.

274. See 1991 Environmental Protocol, *supra* note 187, art. 16, annex VI.

275. See, e.g., *East Timor (Port. v. Austl.)*, Judgment, 1995 I.C.J. 90, ¶ 29 (June 30).

276. 2001 Draft Articles, *supra* note 266, ¶ 76, art. 42(b)(i).

277. *Id.* ¶ 76, art. 42(b)(ii).

sibility. It is not clear, however, that any state would have standing to hold another state responsible for damage to the global commons. Moreover, state responsibility is temporally static and does not easily address the interests and claims that future generations may have as a result of the geoengineering decisions taken today. Just as the impacts of climate change are likely to more significantly affect future as opposed to present generations, the impacts and more general consequences of geoengineering will inevitably affect future generations of humankind.

Intergenerational equity is an emerging principle of international environmental law that requires states to consider the impacts of their decisions on future generations.²⁷⁸ It is relevant when implementing obligations to prevent harm and to act cautiously where there is a risk of significant harm to the environment, but it is also part of the broader question of responsibility. Intergenerational equity is at the heart of the notion of sustainable development and in essence describes the obligation to balance the interests and needs of present generations with those of future generations. The interests of future generations are acknowledged in numerous environmental instruments including the 1992 UNFCCC, which calls for the protection of the climate system for the benefit of present and future generations of humankind.²⁷⁹ There is no process under current international environmental law for formally incorporating the interests of future generations into decision making, and there is little guidance on how the benefits and burdens of environmental protection should be shared between generations.²⁸⁰ However, Edith Brown Weiss has argued that intergenerational equity comprises the following principles: conservation of options, conservation of environmental quality, and conservation of access to resources.²⁸¹ Geoengineering deployed today has the undoubted potential to compromise both environmental quality and access to environmental resources in the future but, more significantly, may also reduce or eliminate options available to future generations to mitigate climate change. William Burns has recently argued that the deployment of SRM techniques, in particular, would violate the principle of intergenerational equity, since such techniques would have to be maintained indefinitely, and, at some point, the option of emissions reductions to mitigate climate change will become practically impossible.²⁸² The question of state responsibility is therefore not simply confined to the here

278. Burns, *supra* note 162, at 38, 42–43.

279. 1992 UNFCCC, *supra* note 32, pmb., para. 23.

280. BIRNIE ET AL., *supra* note 23, at 122; see SCI. & ENVTL. HEALTH NETWORK & THE INT'L HUMAN RIGHTS CLINIC AT HARVARD LAW SCH., *MODELS FOR PROTECTING THE ENVIRONMENT FOR FUTURE GENERATIONS* 1–3 (2008).

281. Edith Brown Weiss, *Our Rights and Obligations to Future Generations for the Environment*, 84 AM. J. INT'L L. 198, 201–02 (1990); see also EDITH BROWN WEISS, *IN FAIRNESS TO FUTURE GENERATIONS: INTERNATIONAL LAW, COMMON PATRIMONY AND INTERGENERATIONAL EQUITY* 38 (1989).

282. Burns, *supra* note 162, at 45–49.

and now but must also be considered in the context of future generations of humankind.

I. *Geoengineering and International Environmental Law As a Discipline*

As an activity that creates a real risk of significant harm to the environment, geoengineering can be used as a case study to demonstrate the existence of international environmental law as a discrete body of generally applicable principles and norms. Notwithstanding the absence of a regulatory regime particularly applicable to geoengineering, states engaging in or authorizing geoengineering activities are constrained by their obligations to prevent serious harm and pollution, to protect vulnerable ecosystems, to act with precaution, to carry out environmental impact assessments, to cooperate in connection with information exchange, and to act with due regard to other users. If they fail to comply with these obligations, which are owed to the international community generally, they may be held responsible for this failure under international law. However, geoengineering also demonstrates the limits of international environmental law as a discipline. In the absence of a specific regulatory framework, the application and implementation of these principles may vary according to the values states attach to the risks of geoengineering compared with the risks associated with climate change itself. Moreover, although states must consider the interests and needs of future generations, there is no mechanism through which those interests and needs can be formally factored into decision making, and, again, the implementation of intergenerational equity is likely to be variable according to the values placed on present and future risks. Consequently, international environmental law as a discipline represents the start but not the end of the regulatory framework for geoengineering.

IV. THE EVOLVING REGULATORY REGIME FOR OCEAN FERTILIZATION: A PRECEDENT?

Thus far, the only geoengineering strategy that policy makers and regulators have given serious consideration is ocean fertilization.²⁸³ As noted

283. Similarly, ocean fertilization has been subject to serious critical consideration by commentators. See Christine Bertram, *Ocean Iron Fertilization in the Context of the Kyoto Protocol and the Post-Kyoto Process*, 38 ENERGY POL'Y 1130, 1138–39 (2010); David Freestone & Rosemary Rayfuse, *Ocean Iron Fertilization and International Law*, 364 MARINE ECOLOGY PROGRESS SERIES 227, 227 (2008); Kerstin Güssow et al., *Ocean Iron Fertilization: Why Further Research is Needed*, 34 MARINE POL'Y 911, 911 (2010); Rosemary Rayfuse, *Drowning Our Sorrows to Create a Carbon Free Future? Some International Legal Considerations Relating to Sequestering Carbon by Fertilizing the Oceans*, 14 U. N.S.W. L.J. 54, 58 (2008); Rosemary Rayfuse et al., *Ocean Fertilisation and Climate Change: The Need to Regulate Emerging High Seas Uses*, 23 INT'L J. MARINE & COASTAL L. 297, 324–25 (2008); Philomène Verlaan, *Current Legal Developments: London Convention and London Protocol*, 26 INT'L J. MARINE & COASTAL L. 185, 186 (2011); Verlaan, *supra* note 197, at 455; Robin

above, ocean fertilization for nonscientific purposes has been deemed subject to, and, at the moment, contrary to, the 1972 London Convention and 1996 Protocol.²⁸⁴ Ocean fertilization for legitimate scientific research purposes is permitted on the basis that it constitutes placement for a purpose other than mere disposal under Article III.1(b)(ii) of the 1972 London Convention²⁸⁵ and Article 1.4.2.2 of the 1996 Protocol,²⁸⁶ provided that it is carried out in accordance with the Assessment Framework agreed to by the Convention and Protocol parties in 2010.²⁸⁷

The Assessment Framework “provides a tool for assessing proposed activities on a case-by-case basis [in order] to determine” their compatibility with the Convention and Protocol.²⁸⁸ Pursuant to the Framework, parties must carry out an initial assessment in order to determine whether the activity proposed constitutes an ocean fertilization experiment. Parties must then undertake a full environmental assessment of the activity, including consideration of the site of the proposed experiment, the likely environmental impact of the experiment, and the risks (both known and unknown) associated with it.²⁸⁹ Where experiments are authorized, the Assessment Framework requires parties to put in place procedures to permit monitoring and, where appropriate, facilitate adaptive management with respect to the experiment. Significantly, the Assessment Framework requires parties to act with caution and stipulates that where adverse effects are predicted, projects should be abandoned.²⁹⁰ The Assessment Framework is a model of precautionary and adaptive management and compares favorably with other instruments providing for environmental impact assessments such as the 1991 Environmental Protocol to the 1959 Antarctic Treaty.²⁹¹ Nevertheless, Resolution LC-LP 2 (2010) is not in and of itself binding, and it remains to be seen how the Assessment Framework will be implemented by parties with respect to individual proposed activities.

Warner, *Marine Snow Storms: Assessing the Environmental Risks of Ocean Fertilization*, 2009 CARBON & CLIMATE L. REV. 426, 426–27; Robin Warner, *Preserving a Balanced Ocean: Regulating Climate Change Mitigation Activities in Marine Areas Beyond National Jurisdiction*, 14 AUSTL. INT’L L.J. 99, 103 (2007); see also Jennie Dean, *Iron Fertilization: A Scientific Review with International Policy Recommendations*, 32 ENVIRONS ENVTL. L. & POL’Y J. 321, 322 (2009); Harald Ginzky, *Ocean Fertilization As Climate Change Mitigation Measure—Consideration Under International Law*, 7 J. EUR. ENVTL. & PLANNING L. 57, 57 (2010); James Edward Peterson, *Can Algae Save Civilization? A Look at Technology, Law, and Policy Regarding Iron Fertilization of the Ocean to Counteract the Greenhouse Effect*, 6 COLO. J. INT’L ENVTL. L. & POL’Y 61, 62–64 (1995).

284. LC-LP Resolution LC-LP.1 (2008), *supra* note 178, ¶ 8.

285. See 1972 London Convention, *supra* note 202, art III(1)(b)(ii).

286. 1996 Protocol to the London Convention, *supra* note 8, art. 1.4.2.2.

287. LC-LP, *Resolution LC-LP.2(2010) on the Assessment Framework for Scientific Research Involving Ocean Fertilization*, ¶ 1.2, LC 32/15 (Oct. 14, 2010); see *id.* § 1.

288. *Id.* ¶ 1.2.

289. *Id.* ¶ 1.3.

290. *Id.* ¶ 1.2.

291. 1991 Environmental Protocol, *supra* note 187, pmb1.

The process of developing a regulatory framework for ocean fertilization was initiated in 2008, and, at the beginning of 2012, four regulatory options were under serious consideration by the parties to the 1972 London Convention and 1996 Protocol. The first option comprises an amendment to the 1996 Protocol adding one additional annex designed to regulate ocean fertilization.²⁹² The second option consists of an amendment to the 1996 Protocol adding two additional annexes that would separate out the principles permitting or prohibiting ocean fertilization from the Assessment Framework, the latter being located in the second annex.²⁹³ The adoption of a resolution interpreting the 1972 London Convention and 1996 Protocol so that it applies to ocean fertilization represents the third option, although it is unclear whether this would be a binding or nonbinding resolution.²⁹⁴ The final option comprises the implementation of, and gathering experience from, the Ocean Fertilization Assessment Framework without the adoption of further regulatory steps.²⁹⁵ At the 2011 meeting, a number of delegations declared themselves in favor of options one or two,²⁹⁶ while the United States indicated that it endorsed option four;²⁹⁷ ultimately, no consensus as to a preferred option was achieved. The terms of reference of the Intersessional Working Group on Ocean Fertilization were consequently revived and revised, and the question of regulation will be revisited in 2012.²⁹⁸

In light of the active interest in ocean fertilization by not only scientists but by private, for-profit operators such as Planktos and Climos,²⁹⁹ binding regulations as opposed to self-regulation are to be preferred. Moreover, despite the presence of Resolution LC-LP.1 (2008), which asserts that ocean fertilization falls within the scope of the dumping regulatory framework,³⁰⁰ it would be desirable to amend these instruments to formally reflect this position. However, options one and two identified by the parties focus on amending the 1996 Protocol rather than the 1972 London Convention and

292. See Thirty-Third Consultative Meeting of Contracting Parties to the London Convention & Sixth Meeting of Parties to the London Protocol, Montréal, Can., Oct. 17–21, 2011, *Report of the 3rd Meeting of the Intersessional Working Group on Ocean Fertilization*, ¶ 4.1, LC 33/4 (June 20, 2011).

293. *Id.* ¶ 4.2.

294. See *id.* ¶¶ 4.11, 4.13–15.

295. *Id.* ¶ 4.12.

296. See Thirty-Third Consultative Meeting of Contracting Parties to the London Convention & Sixth Meeting of Parties to the London Protocol, Montréal, Canada, Oct. 17–21, 2011, *Report of the Thirty-Third Consultative Meeting of Contracting Parties to the London Convention and the Sixth Meeting of Parties to the London Protocol*, ¶ 4.11, LC 33/15 (Nov. 8, 2011).

297. *Id.* ¶ 4.18, annex 2.

298. *Id.* ¶ 4.23.

299. Marc Gunther, *Dumping Iron*, FORTUNE (Apr. 16, 2008, 8:24 AM), <http://money.cnn.com/2008/04/15/technology/climos.fortune/index.htm>.

300. LC-LP Resolution LC-LP.1 (2008), *supra* note 178, ¶ 1.

Protocol. While an amended 1996 Protocol will bind the forty-one states party to that Protocol, the majority of states, including the United States, will not be bound by the ocean fertilization regulatory regime. As discussed above, the international standards referred to in Article 210 of the LOSC comprise those set out under the 1972 London Convention, and it is not clear at what stage the 1996 Protocol will be treated as superseding the 1972 London Convention for the purposes of the LOSC.³⁰¹ Furthermore, the obligations imposed on states under Articles 210 and 216 of the 1982 LOSC apply to *dumping* activities rather than to activities constituting *placement* for a purpose other than dumping.³⁰²

More generally, the approach of the parties to the 1972 London Convention and 1996 Protocol in separating ocean fertilization research from ocean fertilization deployment is open to criticism. While such research may be undertaken to improve our understanding of ocean circulation and the carbon cycle, the majority of experiments to date have sought to demonstrate the effectiveness (or otherwise) of ocean fertilization as a climate change mitigation measure. These experiments use resources that could be deployed elsewhere and arguably encourage the view that ocean fertilization represents a viable climate change mitigation measure.³⁰³ The parties to the 1972 London Convention and 1996 Protocol have not debated seriously the merits of ocean fertilization or geoengineering more generally in the context of climate change mitigation, and arguably the dumping regime is not an appropriate forum for such a debate. While the Assessment Framework is entirely commendable on its own terms, it assumes without question that scientific research into ocean fertilization as a climate change mitigation measure is a meritorious activity. Given that this debate has yet to take place, this conclusion seems somewhat premature. In short, states need to address the ethical and moral issues associated with climate change mitigation in the Anthropocene *before* attempting to devise detailed regulations authorizing specific activities such as ocean fertilization research.

V. REGULATING GEOENGINEERING IN THE ANTHROPOCENE: A PROPOSAL

International environmental law provides a basic regulatory framework for geoengineering and serves a valuable function in constraining proposals for large-scale deployment that risk significant environmental harm. More specifically, the Assessment Framework designed to control and facilitate ocean fertilization research activities provides a model example of precautionary and adaptive management. However, neither the emerging regulatory

301. See *supra* notes 219–223 and accompanying text.

302. 1982 LOSC, *supra* note 184, arts. 210, 216.

303. See Stephen M. Gardiner, *Is “Arming the Future” with Geoengineering Really the Lesser Evil?*, in CLIMATE ETHICS: ESSENTIAL READINGS 284, 289–90 (Stephen Gardiner et al. eds., 2010).

framework for ocean fertilization nor international environmental law more generally provide a suitable forum or framework within which key ethical, policy, and legal questions associated with geoengineering for climate change mitigation can be addressed.

Geoengineering is qualitatively different from other mechanisms intended to mitigate or adapt to climate change. Geoengineering technologies and techniques are designed to lower surface temperatures or deliberately alter the carbon cycle on a *global* scale; all states and all peoples are likely to be affected. However, unlike emissions reductions and adaptation, which inherently require collective action in order to succeed, geoengineering technologies can potentially be deployed by a small number of states or even unilaterally by one powerful state acting in what it perceives to be the best interests of *all* states.³⁰⁴ Moreover, these technologies are such that companies or even wealthy individuals might choose—out of altruism or for profit—to mitigate climate change through geoengineering. There has been not-insignificant private sector interest in ocean fertilization thus far,³⁰⁵ and Bill Gates is currently providing \$1.5 million per year to study geoengineering options.³⁰⁶ Furthermore, without an appropriate forum to facilitate debate and discussion, the relationship between geoengineering and other mitigation or adaptation mechanisms remains unclear. While no state and few commentators advocate geoengineering as the sole solution to climate change, these technologies arguably present a moral hazard; simply knowing that they are available may cause states and individuals to abandon the costly but necessary emissions reductions required to reduce atmospheric concentrations of greenhouse gases. Finally, the cumulative environmental and political risks associated with geoengineering technologies are potentially on a scale akin to nuclear disaster. Without an appropriate forum to consider these options collectively, in the context of mitigation and adaptation more generally, the international community risks unleashing a twenty-first century version of the Legend of Phaethon.

304. Victor, *supra* note 52, at 324. Not all commentators see this as a particular risk. Joshua Horton argues that the risk of unilateral deployment of geoengineering technologies is in fact a myth because the collective constraints on deployment are likely to operate as an effective deterrent. See Joshua B. Horton, *Geoengineering and the Myth of Unilateralism: Pressures and Prospects for International Cooperation*, 4 STAN. J.L. SCI. & POL'Y 56, 59 (2011).

305. KINTISCH, *supra* note 12, at 129. Climos, Planktos Science, the Ocean Nourishment Corporation, and Atmocean are companies that have, to varying degrees, initiated and participated in ocean fertilization activities over the last decade. For an entertaining description of the activities of Climos and Planktos, see *id.*; see also Margaret Leinen, *Building Relationships Between Scientists and Business in Ocean Iron Fertilization*, 364 MARINE ECOLOGY PROGRESS SERIES 251, 252–54 (2008); Aaron L. Strong et al., *Ocean Fertilization: Science, Policy and Commerce*, 22 OCEANOGRAPHY 236, 237–38, 246–47 (2009).

306. KINTISCH, *supra* note 12, at 8–9.

In light of the particular challenges posed by geoengineering, self-regulation—whether through an active collaborative research program³⁰⁷ or through the convening of a scientific conference designed to develop suitable principles of governance³⁰⁸—does not represent an appropriate governance mechanism. While there is some scope for institutional collaboration between existing regimes and international bodies with respect to geoengineering,³⁰⁹ the creation of a designated forum for debate and regulatory development with respect to all geoengineering technologies is arguably the most apposite regulatory solution. However, although a stand-alone designated treaty is *prima facie* an attractive option, the segregation of geoengineering from climate change mitigation and adaptation more generally is undesirable.

This article advocates the adoption of a geoengineering protocol to the 1992 UNFCCC.³¹⁰ Although the UNFCCC has, to date, focused on the mitigation-adaptation paradigm,³¹¹ the climate change framework undoubtedly provides the most appropriate forum from which to debate geoengineering within the context of other responses to climate change such as emissions reductions and adaptation. The 1992 UNFCCC itself has near-universal support and benefits from a policy-making forum (the conference of the parties) as well as associated scientific, technical, and financial bodies.³¹² This

307. Precedents for such a research program include the European Organization for Nuclear Research, the Human Genome Project, and InterRidge, a nonprofit organization established to promote the study, use, and protection of midocean ridges. This (non)regulatory framework is advocated by Victor, *supra* note 52, at 325; cf. Barrett, *supra* note 80, at 53. It should be noted that the Solar Radiation Management Governance Initiative (SRMGI) was launched by the Royal Society, the Academy of Sciences for the Developing World, and the Environmental Defense Fund following the issue of the Royal Society report on geoengineering in 2009. The goal of SRMGI is to produce a clear set of recommendations for the governance of SRM research. See SRMGI, SOLAR RADIATION MANAGEMENT: THE GOVERNANCE OF RESEARCH 11–13 (2011), available at http://www.srmgi.org/files/2012/01/DES2391_SRMGI-report_web_11112.pdf; see also Richard Elliot Benedick, *Considerations on Governance for Climate Remediation Technologies: Lessons from the "Ozone Hole,"* 4 STAN. J.L. SCI. & POL'Y 6, 8 (2011) (advocating the creation of a Climate Remediation Policy Council consisting of scientists, policy makers, and representatives of civil society from twenty-five countries).

308. The Asilomar International Conference on Climate Intervention Technologies was convened in California in 2009 with the purpose of developing principles relevant to geoengineering governance. See Margaret Leinen, *The Asilomar International Conference on Climate Intervention Technologies: Background and Overview*, 4 STAN. J.L. SCI. & POL'Y 1, 3 (2011).

309. I have explored the option of informal and formal institutional and regime collaboration with respect to geoengineering elsewhere. See Karen N. Scott, *Transboundary Environmental Governance and Emerging Transboundary Threats: Geoengineering in the Marine Environment*, in TRANSBOUNDARY ENVIRONMENTAL GOVERNANCE OF INLAND COASTAL AND MARINE AREAS (Simon Marsden & Robin Warner eds., 2012).

310. Albert C. Lin also favors the adoption of a protocol to the UNFCCC, although one that is rather differently constructed than the proposal in this Article. See Albert C. Lin, *Geoengineering Governance*, 8 ISSUES LEGAL SCHOLARSHIP 1, 3 (2009).

311. Virgoe, *supra* note 162, at 113.

312. See 1992 UNFCCC, *supra* note 32, arts. 9, 11, 24.

Article recommends that the geoengineering protocol be structured as a framework instrument, designed to set out general principles and policies applicable to all geoengineering technologies and techniques. Principles might include the following: a statement on when (if at all) geoengineering can be considered appropriate for deployment as a climate change mitigation measure; an articulation of acceptable and unacceptable environmental risks; the precautionary approach; principles relating to cooperation, information exchange, scientific research, and environmental impact assessment; principles setting out the relationship between geoengineering and climate change mitigation and adaptation more generally; and principles relating to state responsibility and individual liability for damage to the environment and the global commons as a result of geoengineering activities. Where geoengineering activities are authorized in principle, it is highly likely that other bodies such as the International Maritime Organization or the U.N. Committee on the Peaceful Uses of Outer Space are better placed than the geoengineering protocol conference of parties to develop detailed regulations designed to protect the environment and the rights of all states. This Article recommends that the task of developing detailed regulations be devolved to the appropriate body, taking into consideration the principles, definitions, and other constraints provided for in the geoengineering protocol. This proposal³¹³ therefore acknowledges and draws on the expertise developed within a number of international and regional bodies with respect to environmental protection but also provides an overall policy and ethical framework within which that expertise should be exercised.

CONCLUDING REMARKS

Geoengineering constitutes a critical threat to the environment—directly through intended and unintended impacts resulting from the manipulation of the atmosphere, biosphere, and oceans, and indirectly as a consequence of diverting attention and resources from emissions reductions and other measures designed to mitigate and adapt to climate change. As such, geoengineering also poses a regulatory challenge for international environmental law. More significantly, however, geoengineering is symbolic of a much greater challenge to the international community: the Anthropocene. The traditional distinction between humankind and nature and the characterization of the latter as something outside of, or other than, the human sphere no longer accurately reflects the relationship between humankind and the environment in

313. This proposal was developed in a paper presented at the 2011 International Scientific Conference on Problems of Adaptation to Climate Change, sponsored by the Russian Academy of Sciences together with the World Meteorological Organization, U.N. Environment Program, and U.N. Educational, Scientific and Cultural Organization. See KAREN N. SCOTT, *THE LEGAL AND POLICY IMPLICATIONS OF GEOENGINEERING: AN EVALUATION* (paper presented at the 2011 International Scientific Conference on Problems of Adaptation to Climate Change, Moscow, Rus., Nov. 7–9, 2011) (on file with author). This proposal was noted in the final report of the conference. See Frolov, *supra* note 150.

the Anthropocene. For lawyers and policy makers, the vital question is whether international environmental law is capable of responding to the integrated composites of “human” and “natural” in the Anthropocene.³¹⁴

Geoengineering provides an ideal case study to evaluate the scope, extent, and indeed the limits of international environmental law in the Anthropocene. No longer merely the descriptor of a substantive area of international regulation, international environmental law can be said to consist of the norms and principles generally applicable to activities that pose a risk of significant harm to the transboundary or commons environment. The core of these principles comprise prevention of harm; prevention of pollution; protection of vulnerable ecosystems and species; precaution; cooperation, information exchange, and environmental impact assessment; due regard for other states and users; and state responsibility for environmental harm. Other principles such as sustainable development may be added as the discipline matures. This normative core is supplemented and enhanced by detailed obligations that are applicable to particular activities or types of impacts and that are generally found within treaty regimes developed by states. The integration of human and nature that characterizes the Anthropocene has implicitly been recognized by the application of the core principles of international environmental law to *all* activities likely to have a significant impact on the environment, rather than just those activities subject to particular negotiated rules or individual treaty regimes.

Nevertheless, as the case study on geoengineering demonstrates, international environmental law as a discipline has inherent limits. Many of those limits result from significant differences among states in their cultural attitudes toward the environment, risk assessment, and climate change in particular, and, consequently, divergent interpretations of key definitions and thresholds of harm. In the particular case of geoengineering, this Article advocates a regulatory solution that establishes a forum under the 1992 UNFCCC within which fundamental ethical, legal, and policy questions can be debated and the relationship between geoengineering and other responses to climate change can be explored. However, a crucial component of this proposal seeks to develop close connections between the 1992 UNFCCC and other bodies and regimes of relevance to geoengineering—and climate change more generally—in order to develop a coherent, consistent, and, importantly, a preemptive response to geoengineering. Recognizing and exploiting the connections and intersection between environmental and other regimes is arguably central to the development of international environmental law in the Anthropocene.

In recognizing the Anthropocene as a new geological era, we have implicitly accepted the overwhelming impact that humankind has had, and continues to exert, on planet Earth. Responding to this impact constitutes one of the greatest challenges for international law. However, within a relatively short period of time, international environmental law has emerged as a coherent

314. See Allenby, *supra* note 46, at 110.

discipline comprising core principles and norms developed to protect the transboundary and commons environment. By no means entirely successful—as demonstrated by the climate change regime itself—international environmental law nevertheless is growing in potency as a mechanism to constrain the actions of states. Geoengineering—the ultimate poster child of the Anthropocene—undoubtedly represents the next great challenge for international environmental law.