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Learning from Success: Lessons in Science and Diplomacy from the Montreal Protocol

Greg Whitesides

The Montreal Protocol (1987) is considered a landmark achievement in international scientific cooperation and American environmental leadership. *The New York Times* called it "The Little Treaty That Could" and even the industries regulated by the Protocol champion its preventative impact. Emissions of chlorofluorocarbons (CFCs) and other ozone-depleting substances could have destroyed two-thirds of the stratospheric ozone layer by 2065.[1] Today, however, scientists believe the near-total ban on the production of these chemicals could allow the ozone layer to recover to 1980 levels, although the date of recovery remains uncertain.

This paper revisits the history of U.S. advocacy for the Montreal Protocol. Although scientific data provided the impetus for the Protocol, data did not determine U.S. policy or compel ratification, in part because opponents of global CFC regulations disputed its interpretation. Instead, non-scientific actors – including diplomats, industry representatives, and the public – played key roles in U.S. diplomacy. After a brief history, the paper considers the influence of scientific evidence and commercial innovation on U.S. diplomacy while highlighting lessons for contemporary statecraft.

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Lead-up to the Montreal Protocol

Global scientists had studied stratospheric ozone long before it became a national and political concern.[2] European researchers discovered ozone absorbed ultraviolet light in the late nineteenth century and British physicist Henry Dobson invented the spectrometer to measure atmospheric ozone in 1924.[3] Collaboration during the International Geophysical Year (1957-1958) led to the Global Ozone Observing System. Supervised by the World Meteorological Organization (WMO), the system relied on Dobson meters at over 100 sites, including British and Japanese stations in the Antarctic, to produce consistent measurements stored in a Canadian data center.[4] Thus, atmospheric ozone was a focus of international scientific collaboration decades before garnering diplomatic or commercial attention, as scientists recognized the importance of the ozone layer in shielding the earth from harmful radiation.

Alarm first arose over the impact of emissions from high-altitude supersonic aircraft, but CFCs became a primary concern after University of California researchers Mario Molina and Sherwood Rowland proposed the chemicals could damage the atmosphere in 1974. Their suggestion was shocking: CFC's had been considered safe – even a "miracle compound" – and existed in nearly every household, whether in air conditioners, aerosol sprays, fire retardants, or other products.[5] In response, the newly established United Nations Environmental Program (UNEP) organized a committee to study the Molina-Rowland hypothesis while Du Pont, a major CFC manufacturer, organized American industrial producers to do the same.[6] Meanwhile, building upon a consumer awareness campaign, the Carter administration banned domestic use of aerosol spray products and NASA launched the Nimbus-7 satellite (1978) to measure atmospheric levels of ozone with the first Total Ozone Mapping Spectrometer. However, the United States had few partners and global interest in CFC reductions remained minimal through 1980.[7]

As the global use of CFCs continued to increase, the U.S. and UNEP launched another round of international negotiations in 1981. Numerous countries, including Canada, Finland, Norway, Sweden, and others (a coalition later known as the "Toronto Group"), supported limits on CFC production. Global engagement intensified after NASA's satellite revealed a loss of ozone, leading American researchers to forecast an increase in ultraviolet (UV) radiation reaching the Earth's surface and raising the risks for skin cancer and cataracts. In response, the UN and U.S. mounted a campaign to reduce ozone-depleting chemicals worldwide, achieving their first success in 1985, when twenty nations signed the Vienna Convention acknowledging ozone depletion as a problem. Reports of

decreased ozone from government research stations on Antarctica, a phenomenon later christened the "ozone hole," galvanized the public while a 1986 NASA/WMO assessment represented the first international consensus.[8] Finally, in 1987, dozens of nations signed the Montreal Protocol, establishing a global compliance regime which limited the production of ozone-depleting substances like CFCs and halons and provided a framework for future international agreements.[9] As such, this groundbreaking environmental accord provides lessons for science and diplomacy, beginning with the influence of scientific evidence on U.S. policy.

Atmospheric Science in U.S. Diplomacy

Scientific evidence was necessary but not sufficient to determine to determine U.S. policy. Early accounts of the Montreal Protocol process, such as those by U.S. Department of State negotiator Richard Benedick and political scientist Peter Haas, emphasized the centrality of the scientific community and evidence in determining American policy.[10] Others have written about the "forcing function" of science, arguing that new knowledge demands a policy response. This heroic narrative of scientists and scientific evidence overcoming political and industrial opposition remains evident in popular media today. However, in the case of the Montreal Protocol, this narrative overstates the influence of scientific evidence on U.S. diplomacy.

The U.S. signed the Montreal Protocol even though the science remained unsettled in 1987. Scientists, for example, disagreed over the level of reductions needed, while the ozone hole, understood by the public as confirmation of scientific claims, actually revealed a lack of scientific understanding because researchers had predicted uniform depletion of the ozone layer, not regional variations.[11] Scientists learned only years later of the uniquely cold conditions needed to catalyze ozone depletion, explaining the concentration of ozone losses over arctic regions.[12] Finally, the "smoking gun" research – NASA's ground and air-based Antarctic measurements – established scientific certainty only after the Protocol had been signed.[13] As such, scientific evidence was insufficient to determine U.S. policies; rather, as political scientist Karen T. Litfin has argued, "[s]cience did not offer a set of objective facts from which a policy consensus evolved."[14]

The history of the Montreal Protocol illuminates the interaction of science and public policy. As political scientist Brenda Seaver points out, "the science did not speak for itself; it required interpretation," allowing "policymakers and scientists to frame results in a manner consistent with their interests."[15] Policymakers, for example, had access to the same scientific evidence, yet disagreed about its significance and the need for regulations; both proponents and opponents of the

Protocol relied upon the same 1986 scientific assessment to support their positions. Litfin concluded, "The impact of scientific knowledge [was] determined far more by its incorporation into larger discursive practices than by either its validity or the degree to which it [was] accepted by scientists."[16] Public policy scholar Edward Parson adds that all sides used scientific claims selectively, but that "informed neutrals" were unlikely to be swayed and the claims had little impact on policy.[17]

Scientific data intersected with competing national interests within the Reagan administration. A variety of federal agencies and Congress weighed the impact of mitigating stratospheric ozone depletion, helping shape diplomacy and providing opportunities for politicization.[18] Once NASA, the Environmental Protection Agency (EPA), and the National Oceanic and Atmospheric Administration (NOAA) analyzed the data, multiple departments considered both the evidence and impact of regulations on their constituents: The Department of Commerce fielded complaints from industry representatives about disruptions to infrastructure, the Department of Energy worried about costs to the foam insulation industry, the Department of Defense worried about losing halons as flame retardants and in extinguishing fires, and the Department of Interior adopted an anti-regulatory posture more broadly.[19] Members of Congress also weighed in: Michigan Representative John Dingell (D-MI), for example, questioned the necessity of regulations given the potential economic impact on his state's auto industry.[20] As regulations moved closer to reality, the "scientization of politics" led to the "politicization of science."[21] The Department of Commerce and Office of Management and Budget raised questions about the research, while congressional opponents of CFC regulations argued that "the ozone around the world really has not changed."[22] Nor did the ozone hole convince skeptics; instead, Donald Hodel, Secretary of the Interior, proposed hats and sunglasses to protect people against increased UV radiation.[23] Indeed, when the U.S. delegation landed in Montreal for negotiations, only the Department of State and scientific agencies supported the original U.S. position.

The relationship between science and U.S. ozone diplomacy offers lessons for contemporary statecraft. First, overstating the influence of scientific evidence on policy could lead to the erroneous assumption that policy will follow naturally from science or that scientific evidence will outweigh other national interests in U.S. diplomacy. Instead, science must be interpreted for policymakers and the public, recognizing that scientific evidence is only one among many competing interests in the political arena. Additionally, scientific evidence is rarely complete or certain and history illustrates the importance of framing scientific uncertainty and risk.[24] In the case of the Protocol, uncertainty acted as a catalyst for action, leading stakeholders to endorse at least a minimum policy prescription while the public applied a precautionary principle in arguing for regulations to prevent worst-case scenarios.[25] Neither the policy or science need to be certain at the

start, as reduction targets, even when uncertain, created market opportunities for CFC alternatives and aided regime development and sophistication.[26] Successful diplomacy required flexibility and negotiators designed the Protocol with the expectation that the science and regulations would evolve together, an approach crucial to its success.[27] In sum, scientific evidence is not a sufficient explanation for U.S. ozone diplomacy, but rather was one of many factors shaping American statecraft. Another common misconception overstates the role of commercial science – specifically a breakthrough in CFC alternatives – to the success of the Montreal Protocol, requiring a more in-depth look at commercial innovation and influence on U.S. diplomacy.

Commercial Innovation and Influence on U.S. Diplomacy

U.S. administrations believed international support for environmental regulations was necessary to minimize domestic economic consequences. The U.S. ban on aerosol spray products, for example, led to a "trap of unilateral leadership" as the country lost leverage once it made concessions.[28] With international regulations stalled and the global market for CFCs intact, major American producers like Du Pont reduced research on CFC substitutes, instead organizing over 500 producers and users of CFCs into the Alliance for Responsible CFC Policy in 1980. In the words of Joe Steed, an environmental manager at Du Pont, "There wasn't scientific or economic justification to proceed. How do you trade a possible [environmental] risk for a [business] risk that is real?"[29] Commercial concerns carried equal weight across the Atlantic, splitting Europeans: large CFC exporters like Great Britain and France opposed strict controls and included industry representatives in international negotiations, while the Scandinavian nations supported regulation.

Momentum for regulations increased in 1986, when Du Pont announced the possibility of CFC substitutes, shifting the position of American industry. The Protocol promised to create a market for substitutes, leading Du Pont and the Alliance for Responsible CFC Policy to support limited reductions; Alliance executive Brian Fay argued that without global regulations, the "U.S. [would] go its own way and commit industrial suicide."[30] Steed agreed: "By mid-1986, I saw that future regulation was definite. I concluded that there should be a real push for alternatives and that an international agreement was the only way to go."[31] However, Du Pont and the Alliance became less supportive as the proposed reductions were increased; as late as April 1987, Du Pont and many European nations favored only 20% reductions, while EPA Administrator Lee Thomas proposed 95% (the Protocol required 50% when signed in September 1987).[32] As Parson notes, "industry preferences and positions shifted only modestly, in line with those of the most reluctant states; and the controls in the 1987 Protocol were adopted against the

strongly expressed preferences of major industry actors in both the United States and Europe."[33] Nonetheless, Du Pont's 1986 pronouncement allowed advocates and diplomats to argue that industry acknowledged the possibility of substitutes and controls. Indeed, a closer examination of Du Pont's strategy is necessary to reveal why commercial innovation is not a sufficient explanation for U.S. diplomacy.

From 1974 to 1995, Du Pont pursued a policy designed to maximize shareholder returns by manipulating the "facts" around CFC alternatives to its benefit.[34] Scholar Brigitte Smith determined Du Pont's strategy towards CFC regulations had three phases: in the first phase (1974-1986), Du Pont questioned the science and opposed regulations; in the second phase (1986-1988), the company lobbied to influence regulations, finally transitioning to alternatives in the third phase (1988-1995).[35] As such, Du Pont's 1986 statement on alternatives was only an opening to further negotiations. More importantly, there had been no breakthrough; instead, research on alternatives remained stalled after initial consideration between 1974-1980.[36] Nonetheless, the announcement worked, expanding the firm's influence over negotiations. As Smith concluded, "A technically sophisticated science-based company, Du Pont changed the facts with respect to its ability to produce substitutes in each phase."[37] In reality, Du Pont only increased funding on alternatives after the Protocol was signed and regulations were assured, even resisting congressional and environmental pleas to stop producing CFCs until 1995 (the final phase-out date).[38] In other words, there was no breakthrough in commercial research behind the Protocol, although addressing economic concerns was critical to the success of U.S. ozone diplomacy.

To garner global support, U.S. negotiators offered incentives, or "side-payments" to major CFC producers, including their European allies, the Soviet Union, Japan, and China.[39] Concerns about competition were paramount: worried about the economic consequences if the country acted alone again, the United States required ratification from two-thirds of the world's CFC producers and consumers before the regulations would go into effect.[40] The Europeans, for example, had increased production of CFCs in the 1980s and argued to delay the freeze on CFCs until 1989 and halons until 1992, overcoming the U.S. preference for freezes at 1986 levels.[41] Negotiators also allowed the Soviet Union to include the planned production of two CFC plants still under construction.[42] To win the support of Japan, whose semiconductor industry relied on CFC-113 as a solvent for cleaning computer chips, negotiators set a total ozone depleting limit for each nation, rather than limits on specific chemicals, allowing Japan to maintain their use of CFC-113 while reducing other CFCs.[43] Finally, U.S. diplomats worked with the People's Republic of China on future funding mechanisms and technical assistance, eventually resulting in China's participation and the Multilateral Fund established by the London Amendments (1991) to the Protocol.[44]

The Protocol history offers lessons on the role of economics in international relations, including negotiations with a scientific and technical framework. First, although atmospheric data informed U.S. diplomacy, commercial interests and research also shaped the U.S. approach to the Protocol, whether the ratification requirements, concerns about domestic consequences, incentives for foreign participation, or the possibility of CFC alternatives. Though the close relations between industry and diplomacy upset many environmentalists, the Protocol demonstrated that commercial, national, and environmental interests could align; international controls reduced the costs of unilateral U.S. action and incentivized innovation, increasing commercial research and development as the ozone layer recovered.[45] At the same time, overstating the influence of CFC alternatives on the Protocol – the "myth of technological breakthrough" – is problematic because it assumes that such technology may be required for regulatory success, possibly delaying other actions while waiting for a technical solution.[46] Additionally, the myth reinforces the idea that a complicated problem can be solved by a "magic bullet"; although CFCs were phased out at a lower cost than initially projected, many of the substitutes are now recognized as contributing to global warming.[47] A final lesson involves limited vs. universal participation in the Protocol: the U.S. initially focused on securing only the participation of CFC producers, but were eventually convinced of the utility of universal participation; later American climate change negotiators, for example, began with a requirement for universal participation.[48] U.S. diplomacy, like atmospheric science, evolved throughout the process, demonstrating American leadership and remarkable initiative.

U.S. Advocacy for Ozone Layer Protection

When considering U.S. diplomacy for ozone layer protection, a recent book on transnational science, *How Knowledge Moves* (2019), is instructive, because it treats "the movement of knowledge embodied in people (and things) as a social accomplishment."[49] Educating policymakers and the public about ozone depletion and its consequences, for example, required work, funding, and travel from a variety of people and organizations. This section considers how U.S. diplomacy "moved" scientific knowledge to secure global support for the Protocol while the public and environmental activists pressured U.S. policymakers at home.

U.S. leadership on ozone depletion depended on individual actions and activism within the Reagan administration. At the EPA, a small group of researchers and officials consistently pushed for regulations before the ozone hole was revealed, while the appointment of William Ruckelshaus, and later Lee Thomas, as EPA Administrator shifted the organization's leadership in favor of the Protocol. At the State Department, Secretary Schultz was a prominent supporter

of CFC reductions and promoted diplomatic initiatives.[50] With these leaders in the EPA and State Department, the U.S. advocated for worldwide reductions in ozone-depleting chemicals, organizing multiple workshops with the UNEP.[51] Richard Benedick, the primary State Department negotiator, traveled to Europe, Japan and the Soviet Union (all previous holdouts) to explain why the Protocol was necessary; over sixty embassies received scientific talking-points.[52] John D. Negroponte, the Assistant Secretary of State assigned to the Protocol, remembers scientists playing an integral role in U.S. diplomacy: "it was our scientists, scientists from NOAA and from NASA, who together with a small diplomatic team from the State Department went around to countries… to explain the science as we understood it."[53] Additionally, for more than a year, the State Department used the United States Information Agency's Worldnet satellite to provide live tele-conferencing on the research, educating participants in twenty capitals around the world.[54] And when administration members began to backtrack in early 1987, EPA and State Department officials contacted U.S. allies to send messages of support for the U.S. position, helping convince President Reagan.[55] Given the President's anti-environmental predisposition, scholars disagree over why he finally signed the Protocol, though his love of the outdoors and personal experience with skin cancer may have contributed – he had growths removed in the years before the Montreal Protocol.[56] Of course, other actors and forces also influence U.S. diplomacy, requiring a shift from state-centered explanations to society-centered explanations.[57]

A diverse coalition – including environmental organizations, scientists, and the public – lobbied for further research and the eventual Protocol. Non-governmental organizations (NGOs) were essential to the consumer awareness campaign to ban aerosol products in the 1970s and helped educate the public and pressure politicians on ozone depletion the following decade.[58] NGOs also turned to the courts when the administration refused to act: when officials first disputed the data in 1984, EPA staffers leaked an internal report to the Natural Resources Defense Council, which sued the government under the Clean Air Act.[59] The suit's eventual resolution, which included negotiation with CFC producers, included a "Stratospheric Ozone Protection Plan" requiring continued EPA research and cooperation with the UNEP. Scientists also became advocates for increased research: Susan Solomon, the atmospheric chemist who led the two "smoking gun" National Ozone Expeditions in 1986 and 1987, remembers policymakers as being "initially cool" to the discovery of the ozone hole "because they did not want to upset the apple cart of the delicate diplomacy embarked on with the Vienna Convention."[60] Finally, although some scholars downplay the importance of the ozone hole and skin cancer fears on diplomacy, others argue the ozone hole galvanized the public while NGOs maintained media coverage, causing citizens to demand action.[61]

The significance of the Montreal Protocol is clear in the broader history of science and U.S. foreign relations. Indeed, the Protocol reflected a decades-long tradition; the United States instituted scientific cooperation and non-cooperation as tools of statecraft during World War II and the country strove to maintain scientific pre-eminence throughout the Cold War.[62] By the 1970s, U.S. environmental leadership was important, and diplomats advocated for numerous international treaties, with the Convention on Long-Range Transboundary Pollution (1979) as the most prominent success until the Protocol.[63] In hindsight, the breadth of the U.S. effort on ozone depletion is remarkable: between 1974 and 1987, American scientists advanced the theory and the U.S. led on the policy, launched testing equipment, undertook global education initiatives, and funded the confirming scientific missions.[64] But why? U.S. national interests ranged, including the desire to maintain scientific and global leadership, the "appeal of appearing green," the need to shape global industrial regulations, the advancement of scientific knowledge, and the protection of human health and the environment.[65] This combination makes the Protocol unique: the U.S. has not ratified a major environmental treaty with effective controls since (the United Nations Framework Convention on Climate Change lacked controls). Instead, post-Montreal, environmental sciences have flourished, but become increasingly politicized in the United States, leaving diplomacy gridlocked as the nation has walked away from global environmental leadership. Finally, the Protocol history emphasizes the importance of being case-specific when considering international scientific relations – U.S. diplomacy for ozone protection was exceptional. Research with economic consequences, commercial possibilities, or implications for national security exists within a separate political sphere; sociologist Daniel Sarewitz, for example, has argued the complexity of environmental science makes environmental controversies worse and diplomacy harder.[66]

Final Thoughts

The Montreal Protocol history remains relevant to contemporary environmental diplomacy. But it is easy to forget the nuances and lessons of the past. In 2012, for example, former Assistant Secretary of State Negroponte credited the scientific community for the Protocol; a year later, former Secretary of State Shultz credited Du Pont.[67] Neither explanation is wrong, but both are incomplete. As history shows, scientific evidence is often insufficient to sway public or political opinion, and research must be properly framed to have an impact; consider the politics of acid rain, ozone depletion, climate change, or COVID-19. When opponents questioned the evidence, supporters of the Montreal Protocol responded with additional research and education, helping connect the ozone hole to the science. At the same time, given the political discord, advocates allied with sympathetic

officials within the U.S. government, while NGOs demanded administrative action through the courts. Finally, perhaps it is better to think of "scientific relations" than "science diplomacy," as successful diplomatic initiatives create new relations and obligations, whether scientific networks or geopolitical responsibilities. Protection of the ozone layer, for example, remains ongoing. In 2018, scientists in Hawaii measured an increase in CFC-11, a banned chemical; later reporting suggested two provinces in Eastern China might be responsible, illustrating the need for vigilant monitoring and the difficulty of ensuring compliance.[68]

In addition to controlling ozone-depleting chemicals, the Montreal Protocol is increasingly entangled in the global policy discussion over climate change mitigation. The Protocol demonstrated how to establish an effective international environmental compliance regime and the later global warming process followed its blueprint, with a framework convention (the UNFCCC) followed by a protocol establishing reduction targets and limitations (the Kyoto Protocol).[69] At the same time, the Protocol's impact went beyond merely providing a precedent; historian Joshua Howe has proposed that the Protocol "put powerful corporate and governmental bodies on notice," pitting environmental activists and the "forcing function" of science against the lobbying power of the oil and gas industry.[70] Geographer Mike Hulme has also cautioned that the Montreal Protocol offered a false optimism because global warming arises from a broader set of economic activities, a point stressed by opponents of climate change action like the *Wall Street Journal*, which opined in 2015, "The Montreal Protocol is not a model for climate-change policy."[71] Yet it is impossible to separate ozone protection from climate change, as many of the first-generation replacements for CFCs, especially hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs), are now recognized as contributing to global warming. This discovery led many nations to ratify the Kigali Amendment to the Montreal Protocol in 2016, though the Trump administration has hesitated to sign, ignoring bipartisan and industrial support.

The Montreal Protocol history reveals the complexity of science in U.S. foreign relations. The United States and international community managed to construct an "adaptive management" system for controlling ozone-depleting substances even though there were disagreements about the science and regulations required.[72] And the impact of the Protocol continues to this day, in the need to continue monitoring for emissions of ozone-depleting substances and the ongoing policy discourse around CFC alternatives and their role in exacerbating climate change. Sadly, the politicization of environmental science also continues, demonstrating the importance of evidence-based leadership and diplomacy in the international environmental sphere. **SD**

Endnotes

1. Justin Gillis, "The Little Treaty That Could," *New York Times*, December 10, 2013, D3. See also Stephen O. Andersen, Marcel L. Halberstadt, and Nathan Borgford-Parnell, "Stratospheric Ozone, Global Warming, and the Principle of Unintended Consequences – An Ongoing Science and Policy Success Story," *Journal of the Air & Waste Management Association* vol. 63 (2013): 607–647.
2. A wide literature addresses the history of ozone research and the Montreal Protocol. The primary texts used for this brief history were: Karen T. Litfin, *Ozone Discourses: Science and Politics in Global Environmental Cooperation* (New York: Columbia University Press, 1994); Richard Elliot Benedick, *Ozone Diplomacy: New Directions in Safeguarding the Planet*, enlarged edition (Cambridge: Harvard University Press, 1998); Stephen Anderson and K. Madhava Sarma, *Protecting the Ozone Layer: The United Nations History* (London: Earthscan Publishing, 2002); Edward A. Parson, *Protecting the Ozone Layer: Science and Strategy* (Oxford: Oxford University Press, 2003); Matthew J. Hoffman, *Ozone Depletion and Climate Change: Constructing A Global Response* (Albany, NY: State University of New York Press, 2005); James Gustave Speth and Peter M. Haas, Global Environmental Governance (Washington, D.C.: Island Press, 2006); and David W. Fahey and Michaela I. Heggelin, eds., *Twenty Questions and Answers About the Ozone Layer: 2010 Update and Scientific Assessment of Ozone Depletion* (Geneva: World Meteorological Organization, 2011).
3. Rolf Muller, "A Brief History of Stratospheric Ozone Research," *Meteorologische Zeitschrift* vol. 18 (February 2009): 1–24.
4. Anderson, Halberstadt, and Borgford-Parnell, "Stratospheric Ozone, Global Warming, and the Principle Of Unintended Consequences," 611.
5. Elizabeth L. Chalecki, "Knowledge in Sheep's Clothing: How Science Informs American Diplomacy," *Diplomacy and Statecraft* vol. 19 (2008): 1–19, quote on 9.
6. See "Constructing a Counternarrative: The Fight over the Ozone Hole," in Naomi Oreskes and Erik M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming* (Bloomsbury Press: New York, 2010), 107–135, esp. 111–118.
7. Parson, *Protecting the Ozone Layer*, 110.
8. Litfin, *Ozone Discourses*, 79.
9. Fahey and Heggelin, *Twenty Questions*, Q.3.
10. Political scientist Karen T. Litfin was among the first to analyze the early explanations for the Protocol; see Litfin, *Ozone Discourses*, 5–6. The works referenced above are Benedick, *Ozone Diplomacy (*1992 ed.) and Peter Haas, "Banning Chlorofluorocarbons: Epistemic Community Efforts to Protect Stratospheric Ozone," *International Organization* vol. 46 (Winter, 1992): 187–224.
11. Note public concern was also based on a misunderstanding: the ozone hole limited the danger of skin cancers to polar regions while most researchers considered damage to food supplies, aquatic ecosystems, and human immune systems to be more important; see Muller, "A Brief History of Stratospheric Ozone Research."
12. Additionally, differences in polar geography make ozone depletion more severe over the Antarctic than Arctic. See Susan Solomon, "The Discovery of the Antarctic Ozone Hole," *Nature* vol. 575 (November 7, 2019): 46–47.
13. See "The Science of Ozone Depletion: From Theory to Certainty," in Anderson and Sarma, *Protecting the Ozone Layer*, 1–41.
14. Litfin, *Ozone Discourses,* 10.
15. Brenda M. Seaver, "Stratospheric Ozone Protection: IR Theory and the Montreal Protocol on Substances that Deplete the Ozone Layer," *Environmental Politics* vol. 6 (1997): 31–67, quote on 48.
16. Litfin, *Ozone Discourses*, 98.
17. Parson, *Protecting the Ozone Layer*, 107.
18. See "Forging the U.S. Position," in Benedick, *Ozone Diplomacy*, 51–67.
19. Litfin, Ozone Discourses, 104–105. Litfin argues that the State Department lost control of the interagency process.
20. Parson, *Protecting the Ozone Layer,* 135.
21. This couplet was first used by Peter Weingart and adopted in Litfin, *Ozone Discourses*, 13.
22. Sen. Symms (R-IN) quoted in Benedick, *Ozone Diplomacy,* 62.
23. Stephen Hopgood, *American Foreign Environmental Policy and the Power of the State* (Oxford: Oxford University Press, 1998), 227.
24. See "Uncertainty," in Roger A. Pielke, Jr., *The Honest Broker: Making Sense of Science in Policy and Politics* (Cambridge: Cambridge University Press, 2007), 54–75.
25. J. Roger Jacobs, "The Precautionary Principle as a Provisional Instrument in Environmental Policy: The Montreal Protocol Case Study," *Environmental Science & Policy* vol. 37 (2014): 161–171.
26. Parson, *Protecting the Ozone Layer*, 217.

27. Roger A. Pielke Jr. and Michele M. Betsill, "Policy for Science for Policy: A Commentary on Lambright on Ozone Depletion and Acid Rain," *Research Policy* vol. 26 (1997): 157–168. The authors suggest a feedback loop between policy and research in which the research implications generate new policy, arguing that this fueled U.S. ozone policy beginning in the 1970s; a similar process unfolded internationally after the Montreal Protocol was ratified.
28. Ibid., 276. In negotiations, if X makes unilateral concessions, they lose leverage when later demanding others make concessions (because X has nothing left to concede), hence the "trap" – a dynamic visible in international negotiations over CFC bans, arms reductions, global warming mitigation, and more.
29. Steed quoted in Litfin, *Ozone Discourses*, 70.
30. Fay quoted in Ibid, 93.
31. Steed quoted in Ibid., 95.
32. See Elizabeth L. Chalecki, "Knowledge in Sheep's Clothing: How Science Informs American Diplomacy," *Diplomacy and Statecraft* vol. 19 (2008): 1–19, esp. 11 and Seaver, "Stratospheric Ozone Protection," 50.
33. Parson, *Protecting the Ozone Layer,* 249.
34. For a detailed look at Du Pont's strategy and emphasis on shareholders, see Brigitte Smith, "Ethics of Du Pont's CFC Strategy 1975-1995," *Journal of Business Ethics* vol. 17 (April 1998): 557–568. See also "Protocol Negotiations, 1986-1987" and "The Myth of a Technological Breakthrough," in Parson, *Protecting the Ozone Layer,* 129–139 and 248–249.
35. Smith, "Ethics of Du Pont's CFC Strategy 1975-1995." As late as 1985, the company held a strong, flexible position: 50% of the American CFC market and 27% of the global market, yet CFCs comprised only 2% of sales.
36. Parson, *Protecting the Ozone Layer*, 248.
37. Smith, "Ethics of Du Pont's CFC Strategy 1975-1995," 561.
38. Ibid., 562. See also Anderson and Sarma, *Protecting the Ozone Layer*, 200–201.
39. Seaver, "Stratospheric Ozone Protection," 39.
40. The United States secured the signatures of more than two-thirds of the producers (US, EEC, Japan, & USSR) via incentives; Article 16 of the Protocol requires two-thirds of the consumers to sign as well. See John Negroponte, "Montreal Protocol: Controlling Substances that Deplete the Ozone Layer," *Department of State Bulletin* vol. 87 (December 1987). Accessed online.
41. Benedick, *Ozone Diplomacy*, 79.
42. On the European increase in CFC production, see Maximilian Auffhamer et al., "Production of Chlorofluorocarbons in Anticipation of the Montreal Protocol," *Environmental & Resource Economics* vol. 30 (2005): 377–391. See also Benedick, *Ozone Diplomacy*, 82–83.
43. Seaver, "Stratospheric Ozone Protection," 39.
44. In addition to multilateral funding, the PRC wanted to show it could cooperate and access foreign science, technology, and markets, while the state environmental agency used the Protocol to expand internal administrative power; see Jimin Zhao and Leonard Ortolano, "The Chinese Government's Role in Implementing Multilateral Environmental Agreements: The Case of the Montreal Protocol," *Global Environmental Politics* vol. 5 (2005): 708–725.
45. See "Technology and Business Policy," in Anderson and Sarma, *Protecting the Ozone Layer,* 187–223; see also 361–362.
46. The "Myth" is used in Parson, *Protecting the Ozone Layer,* 248–249.
47. Andersen, Halberstadt, and Borgford-Parnell, "Stratospheric Ozone," 617.
48. See "Participation Matters: Governing Ozone Depletion and Climate Change," in Hoffmann, *Ozone Depletion and Climate Change*, 1–20. See also Tine Birmpili, "Montreal Protocol At 30: The Governance Structure, the Evolution, and the Kigali Amendment," *Comptes Rendus Geoscience* vol. 350 (2018): 425–431.
49. John Krige, "Introduction: Writing the Transnational History of Science and Technology" in John Krige, ed., *How Knowledge Moves: Writing the Transnational History of Science and Technology* (Chicago: University of Chicago Press, 2019), 1–31, quote on 5.
50. "George P. Shultz: A Cold Warrior on a Warming Planet," *Bulletin of the Atomic Scientists* vol. 69 (2013): 1–8.
51. "Montreal Protocol: Controlling Substances that Deplete the Ozone Layer."
52. Benedick, *Ozone Diplomacy*, 58.
53. Negroponte quoted in John D. Negroponte and Vaughan Turekian, "Science and the U.S. Department of State" *Science & Diplomacy* online interview (April 24, 2012), https://www.sciencediplomacy.org/podcast/2012/science-and-us-department-state. Negroponte was the Assistant Secretary of State for Oceans and International Environmental and Scientific Affairs from 1985 to 1987.
54. Benedick, *Ozone Diplomacy*, 56.
55. Parson, *Protecting the Ozone Layer,* 135.
56. See "The Reagan Antienvironmental Revolution," in Samuel P. Hayes, *Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985* (Cambridge: Cambridge University Press, 1989), 491–526; see also the "Reagan Reaction, 1980-88," in Kirkpatrick Sale, *The Green Revolution: The American Environmental Movement 1962-1992* (New York: Hill & Wang, 1993), esp. 51.
57. Seaver, "Stratospheric Ozone Protection," 54.

58. Friends of the Earth – an international environmental group founded in the United States – was especially important in globally linking environmental movements, while the West German Green Party influenced European policies. See Seaver, "Stratospheric Ozone Protection," 56–58.
59. Neil E. Harrison and Gary C. Bryner, eds., *Science and Politics in the International Environment* (Lanham, MD: Rowman & Littlefield, 2004), 111. David Doniger was one of the NRDC lawyers; see David Doniger and Michelle Quibell, "How the NRDC Helped Save the Ozone Layer," available at www.nrdc.org. The NRDC briefly delayed the suit after the EPA argued it might undermine international negotiations; see Litfin, *Ozone Discourses*, 72.
60. Solomon, "The Discovery of the Antarctic Ozone Hole," 46.
61. Speth, Global Environmental Governance, 95.
62. See Greg Whitesides, *Science and American Foreign Relations since World War II* (Cambridge: Cambridge University Press, 2019).
63. Stephen Brain, "The Appeal of Appearing Green: Soviet-American Ideological Competition and Cold War Environmental Diplomacy," *Cold War History* vol. 16 (2016): 443–462.
64. Seaver, "Stratospheric Ozone Protection," 38–39.
65. Phrase borrowed from Brain, "The Appeal of Appearing Green."
66. Daniel Sarewitz, "How Science Makes Environmental Controversies Worse," *Environmental Science & Policy* vol. 7, no. 5 (2004): 385–403.
67. Negroponte and Turekian, "Science and the U.S. Department of State." See also "George P. Shultz: A Cold Warrior on a warming planet."
68. Brady Dennis, "Mysterious Spike of Ozone-Destroying Chemical is Traced to East China," *Washington Post* (May 22, 2018), https://www.washingtonpost.com/national/health-science/mysterious-spike-of-ozone-destroying-chemical-is-traced-to-northeast-china/2019/05/22/a434150a-789f-11e9-b3f5-5673edf2d127_story.html
69. This is known in the literature as the "framework convention plus protocol" model. The Montreal Protocol served as precedent for the climate regime, including on non-compliance procedures, financial mechanisms, technology transfer programs, and the concept of a "basket" of gases for regulation (among other elements). See Sebastian Oberthür, "Linkages between the Montreal and Kyoto Protocols: Enhancing Synergies between Protecting the Ozone Layer and the Global Climate," *International Environmental Agreements: Politics, Law and Economics* vol. 1 (2001): 357–377, esp. 360. See also Hoffman, Ozone Depletion and Climate Change, 194–195; Mike Hulme, *Why We Disagree About Climate Change* (Cambridge: Cambridge University Press, 2009), 290–291.
70. Joshua P. Howe, *Behind the Curve: Science and the Politics of Global Warming* (Seattle: University of Washington Press, 2016), 153–54 and 186–187.
71. Mike Hulme, *Why We Disagree About Global Warming*, 292. See also Guus J.M. Velders et al., "The Importance of the Montreal Protocol in Protecting Climate," *Proceedings of the National Academy of Sciences* vol. 104 (March 20, 2017): 4814–4819; "The Hole in Tapper's Ozone Tale: The Montreal Protocol is not a model for climate-change policy," *Wall Street Journal* (October 2, 2015), https://www.wsj.com/articles/the-hole-in-tappers-ozone-tale-1443828001
72. Parson, *Protecting the Ozone Layer,* 277–280.