Consensus, Certainty, and Catastrophe: Discourse, Governance, and Ocean Iron Fertilization

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Abstract

States, transnational networks of scientists, corporate actors, and institutions in the climate change regime have known for decades that iron ore, when dumped in the ocean, can stimulate the growth of plankton. Over the past twenty years, normative disagreements about appropriate behavior have shaped international governance of the phenomenon. Prior to 2007, firms lobbied governments to treat the oceans as a carbon sink and to allow corporations that dumped iron to sell carbon credits on the international market. However, after 2007 a transnational coalition of oceanographers and advocates opposed this agenda by linking it to an emergent antigeoengineering discourse. Crucial to their efforts was their interpretation of uncertainty: for opponents, scientific uncertainty implied possibly devastating consequences of iron dumping, which was thus best addressed with extreme caution. This normative approach ultimately shaped governance, since advocates successfully used it to lobby institutions in ocean governance to prevent carbon credits from being issued for ocean fertilization. Since these subjective understandings of certainty influenced global ocean governance, this article explains international behavior as a consequence of changing norms.

> Geoengineering is an entirely derogatory spin term. If they can pin that to you, you've lost already.
>
> — Russ George, interview with *Scientific American*, October 24, 2012

The oceans, through biological and chemical processes, can absorb millions of tons of CO_2 from the atmosphere. After the adoption of the UN Framework Convention on Climate Change (UNFCCC), firms in the United States began

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lobbying to permit the sale of carbon credits from ocean iron fertilization (OIF). OIF is a procedure through which iron is added to the oceans to stimulate plankton growth. In theory, the plankton blooms would then capture CO_2 and sink to the bottom of the ocean. Firms believed that OIF would be a cost-effective way to reduce atmospheric greenhouse gases when compared to contemporary carbon storage methods, and argued that international society should let them sell offset credits generated from this process to states with emissions requirements. But rather than promoting it, international society, through the London Convention and the Convention on Biological Diversity (CBD), adopted a de facto moratorium preventing the generation and sale of carbon credits from OIF. Given the mounting concerns about climate change and the economic profitability of creating a new carbon market, why did this occur?

I argue that international institutions responded to an advocacy campaign from a transnational network of environmental advocates. These advocates opposed OIF because they were highly sensitive to the risks of tampering with the ocean. Furthermore, this opposition and risk perception was rooted in the fact that OIF fell into a category of actions called "geoengineering," comprising large-scale interventions in the world's environment. Among other things, this meant that the potential harms created by OIF could travel far beyond the initial point of impact, with severe global consequences.

How does this help us explain the behavior of international institutions? One school of thought about how to understand governance is the rationalist approach. In short, international society comprises actors with fixed, hierarchically arranged preferences that are determined and ordered by material reality. We can understand governance if we understand the incentives of the key actors, by measuring things like the payoffs, costs of action, and vulnerabilities they face in a given area. Authors including Victor (2006), Helm and Sprinz (2000), Sprinz and Vaahtoranta (1994), and Keohane and Victor (2011) have used rationalism to explain governance in a variety of areas, including climate change, ozone, and acid rain. For OIF, the potential payoff to firms that could sell carbon credits and the projected lower cost of credits from OIF than from current mechanisms in the climate change regime suggest that both firms and governments had material incentives to support it. In addition, there were no clear material reasons for states to oppose OIF, since it could provide them a cheaper compliance mechanism for their obligations under the Kyoto Protocol.

Because international society rejected OIF, I attribute governance in this issue area to nonmaterial explanations. Here, institutional behavior was shaped by normative interpretations of risk and uncertainty by networks of researchers and environmental NGOs. Whereas OIF proponents interpreted uncertainty as a justification for moving forward, critics interpreted uncertainty as a cause for alarm and used their political influence in key institutions to successfully lobby for a moratorium on OIF.

Geoengineering and Discourse

I draw here from metastudies of geoengineering by authors such as Anshelm and Hansson (2014), Buck, Gammon, and Preston (2014), and Sikka (2012), which have shown that geoengineering differs conceptually from other kinds of environmental interventions. "Geoengineering" has several broad but overlapping definitions, but all include a reference to the fact that it comprises "large-scale" interventions. According to the IPCC, this refers to interventions that "use or affect the climate system (e.g., atmosphere, land or ocean) globally or regionally and/or … cross national boundaries" (IPCC 2012, 2). For example, geoengineering methods, such as placing mirrors in space, take place transnationally or in the global commons. In contrast, climate interventions that take place entirely within states, such as planting trees, do not count as geoengineering, even though they also address a global problem (IPCC 2012; Shepherd et al. 2009; UmweltBundesAmt 2011).

Since it takes place on the high seas, OIF is a global intervention, and thus vulnerable to the critiques and risk assessments associated with geoengineering. As Anshelm and Hansson have shown, some of the common storylines in the emerging geoengineering discourse are that it poses unacceptable risks to global ecosystems, does not address the underlying dysfunction causing ecological degradation, and undermines democratic governance (Anshelm and Hansson 2014, 138–140; Buck et al. 2014). As I will show later, OIF critics used these precise arguments to undermine its support in the international arena.

To be clear, I am not arguing that OIF critics purposively adopted a geoengineering discourse to shape their arguments. However, a discourse does not need to be purposively adopted to influence behavior, as long as the policy claims and arguments that advocates use in a given issue area follow the same outlines (Anshelm and Hansson 2014; Epstein 2008; Fairclough 2013; Jørgensen and Phillips 2002; Litfin 1994; Sikka 2012).

Discourses matter in policy-making because, when science is used to make policy claims, it will always have some element of uncertainty. First, uncertainty is inherent in the epistemological and ontological tensions between science and policy claims. Preston (2011) and others (Buck et al. 2014; Jasanoff 2009; Litfin 1995; Shepherd et al. 2009) have recognized that policy questions are characterized not just by cause-and-effect relationships, but also by ethical and normative questions: Who is responsible for taking action? How do we situate marginalized people in governance mechanisms? What is the relationship between mankind and nature? Is it one of control, or codependence?

Second, uncertainty is inherent in the fact that humans are not omniscient and will never have perfect information to predict the behavior of complex ecosystems. As feminist scholars like Haraway have argued, claiming that we can have such knowledge amounts to a "God trick," wherein we insist that we operate from a position of perfect information while ignoring the limitations of human knowledge (Haraway 1988; Haraway 2013; Harding 1991).

Discourses matter because they can give guidelines in terms of how to manage this uncertainty and assess risk, and therefore how to adjudicate among different claims. To be clear, I am not arguing that science is incapable of truth claims, only that, as the critical literature has shown, there is unavoidable subjectivity when science turns to policy (Anshelm and Hansson 2014; Forsyth 2004; Haraway 1988; Harding 1991; Jasanoff 2009; Litfin 1994; Litfin 1995; McCormick 2009; Merton 1973).

Research Methods

First, I identified the key knowledge producers, by identifying the authors of the most widely cited literature on OIF in journals such as *Nature*, presentations to governments, and studies by research institutions. Then I conducted interviews with the authors, to identify other key researchers, as well as NGO members. This is known as "snowball sampling" (Biernacki and Waldorf 1981; Noy 2008), which helps triangulate upon the identities of core actors.

Once I had defined these populations, I conducted critical-discourse analysis to learn how scientists and advocates constructed and shared knowledge about the relationship between the ocean and atmospheric CO_2, and how they used this to try to influence governance. This analysis consisted of qualitative interviews in which I asked respondents how they had learned about the issue, including such questions as whether they were aware of a scientific consensus about the problem, how and when the terms used to describe the problem had become adopted into general use, and what were appropriate policies to respond to the emerging problem. I triangulated upon their answers using archival documents, including opinion statements in trade journals as well as policy arguments in the media, submitted to policy-maker agencies, or shared as internal memoranda. I supplemented this research with interviews in the media and other secondary sources, and cross-referenced with materials produced by such institutions as the UNFCCC, the London Convention, and the CBD.

Sinks, Science, and the Policy Interface in an Age of High CO_2

After it was adopted, the UNFCCC stimulated interest in creating carbon sinks through Article 4, which called on its parties to "formulate, implement, publish, and regularly update … sinks of all greenhouse gases," including those in "coastal and marine ecosystems."[1] At almost the same time, John Martin proposed the "iron hypothesis" (Martin 1990). Martin noted that modern oceans were absorbing less CO_2 than they had during glacial periods, which he believed was due to a decline in plankton productivity. Notably, this low productivity was discernible in areas that had most of the other nutrients that should have

1. UNFCCC 1992, Text of the Convention, Article 4 §1(d)

spurred growth—so-called "high-nutrient, low-chlorophyll" (HNLC) areas (Chisholm and Morel 1991). Martin hypothesized that plankton growth could be stimulated by adding iron ore, because iron was thought to be a key missing nutrient. With more plankton, the oceans could then absorb more CO_2 and, as the plankton sank to the bottom of the ocean, sequester it for decades.

Although later interviews suggest that Martin did not intend for this to happen,[2] his work became tied to policy discussions on climate change. When Martin presented his hypothesis at a 1988 conference at the Woods Hole Institute, he said in his "best Dr. Strangelove accent" that with "a half a tanker of iron … I will give you the next ice age" (Chisholm et al. 2001, 309–310). This statement was then cited over the next two decades in research articles (Buesseler et al. 2008; Chisholm and Morel 1991; Chisholm et al. 2001; Joos et al. 1991), reports to the US Congress (NOAA 2010), and media reports[3] as the primary way to frame and understand Martin's work.

For example, the *Washington Post* cited Martin's comment about a "next ice age" to claim that the purpose of OIF was "[soaking] up much of the excess carbon dioxide believed to be responsible for global warming."[4] In 1991, Joos and Siegenthaler of the University of Bern, with Jorge L. Sarmiento, indicated that if OIF were carried out in the Indian Ocean over the next 100 years, it would reduce the atmospheric concentration of CO_2 by 90–107 parts per million (ppm) (Joos et al. 1991). After Martin died in 1993, his obituary in *The New York Times* said that his research on OIF showed that "fertilizing the oceans with iron could slow the increase of carbon dioxide in the atmosphere."[5]

To be sure, interviews with some of Martin's former colleagues suggest that some of the oceanographers promoting OIF as a climate mechanism were "playing up" this connection to "get financing for experiments."[6] But whether researchers advocating OIF were doing so strategically, to generate support for research, or out of a sincere belief in OIF is immaterial: by the 1990s, the public understanding of OIF was that it could be used to address climate change.

Consensus and the Political Economy of the Ocean in a High-CO_2 World

Firms were soon able to use consensus on one aspect of OIF to justify proposals to make it a legitimate carbon storage mechanism. For scholars of science in

2. Author's personal communication with a prominent oceanographer, September 2016.
3. See, among other reports, *Scientific American*, Controversial Spewed Iron Experiment Succeeds as Carbon Sink, July 18, 2012 (accessed November 7, 2016, from www.scientificamerican.com/article/fertilizing-ocean-with-iron-sequesters-co2/); *Washington Post*, Ironing Out "Greenhouse Effect," May 20, 1990 (accessed November 2, 2016, from http://wapo.st/2m6Tk3J); and *Wired*, Dumping Iron, November 1, 2000 (accessed November 2, 2016, from www.wired.com/2000/11/ecohacking/)
4. *Washington Post*, Ironing Out "Greenhouse Effect," May 20, 1990.
5. *New York Times*, John Martin, 58, Dies; Theorized on Warming, June 22, 1993. Accessed November 2, 2016, from www.nytimes.com/1993/06/22/obituaries/john-martin-58-dies-theorized-on-warming.html
6. Author's personal communication with prominent oceanographer, September 2016.

politics, scientific consensus is a key variable explaining when and why advocates are more likely to prevail in policy debates. As the epistemic community literature shows, a consensus delegitimizes competing claims, clarifies cause-and-effect relationships, and provides a rationale for action under complexity (Cross 2013; Dimitrov 2003; Haas 1990; Haas 1992; Haas 2004; Keck and Sikkink 1998; Litfin 1994; Litfin 1995; McCormick 2009; Peterson 1992). At the same time, scholars including Dimitrov (2003) and Bray (2010) have argued that consensus is unlikely to be absolute across all dimensions of knowledge. For any issue area, experts may have a consensus on some claims, such as the extent, causes, and consequences of a problem, but are unlikely to have complete agreement on all of them at the same time.

When advocates are able to link a consensus on relevant dimensions to issues that seem salient to their target audiences, they are more likely to strengthen their policy positions (Bray 2010; Dimitrov 2003; Fuentes-George 2016; McCormick 2009; Moser 2005; Moser 2006). Conversely, if consensus is not strong enough on salient dimensions, target audiences will be able to justify ignoring policy implications (Dimitrov 2003; Fuentes-George 2016). Anyone who is aware of the slow response of the US political system to the science on climate change is cognizant of how minor scientific uncertainty can be exploited by vested interests as a rationale for (in)action. In this case, however, supporters of OIF extrapolated from a consensus on one dimension of the iron hypothesis to push for OIF credits.

Responding to Martin's hypothesis, oceanographers conducted research of increasing sophistication to clarify causal relationships, because different models had come to differing conclusions about how much planktonic growth could be stimulated by iron (Joos et al. 1991, 1–2). Between 1990 and 1995, one dimension of the iron hypothesis was confirmed: adding iron ore to HNLC areas could indeed stimulate plankton growth. In 1995, Ken Coale and Ken Johnson of Moss Landing carried out an OIF experiment called IronEx II, which prompted a plankton bloom equivalent to 100 redwoods at the end of two weeks, and which Johnson described favorably as "a phytoplankton explosion of almost biblical proportions."[7]

In 1996, Coale and other researchers from England and Mexico published an article in *Nature* arguing that the growth of plankton from IronEx II had contributed to a "drawdown of carbon dioxide in the surface waters of the fertilized patch," creating a "sink [for] carbon dioxide" (Coale et al. 1996, 500). The researchers were so confident that they concluded that "it [was] now time to regard the 'iron hypothesis' as the 'iron theory'" (Coale et al. 1996, 500).

For those in favor of using OIF to create carbon sinks, this finding strengthened their position. In 1999, Undersecretary of Commerce and administrator of NOAA James Baker opened the Revelle lecture at MBARI, investigating how to store CO_2 in the ocean (Pomponi 2001). Peter Brewer, who conducted

7. *Wired*, Dumping Iron, 2000.

the lecture, reiterated Coale's statement that the hypothesis was an "iron theory" (Pomponi 2001, 91), and noted that this "ingenious idea" showed that "carbon removal on a scale of Gt/year might be possible" (Pomponi 2001, 90).

However, when the Kyoto Protocol was negotiated in 1997, it recognized only those sinks generated by terrestrial processes: land use, land use changes, and forestry activities. For OIF proponents, this was a missed opportunity, particularly since (they claimed) it would be cheaper to sequester CO_2 in the ocean than on land. For example, in a 2000 interview with *Wired*, Michael Markels, founder of GreenSea Ventures, claimed that he could sequester CO_2 in the ocean for $2 a ton, in comparison to the $20 per ton offered by forestry services.[8] For supporters of OIF, "if credit can be garnered for the carbon sucked up by photosynthesis … then why not cultivate phytoplankton, the most abundant plants on Earth?"[9]

For firms, access to the carbon market had tremendous economic potential. In 2007, the value of credits from destroying HFC-23 was estimated at €4.7 billion (Wara 2007). OIF supporters were vocal that international society should take all possible action to address climate change. In 2007, Dan Whaley, who founded Climos, argued that "if atmospheric CO_2 that we have already put into the atmosphere is ever to decline, it will be photosynthesis that eventually does the work."[10] Similarly, Ken Buesseler stated in an interview with *The New York Times* that year that he was "willing to consider [OIF], when I consider the consequences of doing nothing."[11]

Scholars of geoengineering describe this as the idea of "exceptionalism" (Anshelm and Hansson 2014; Buck et al. 2014; Preston 2011; Sikka 2012). In short, and as both Whaley and Buesseler indicated above, the accumulation of greenhouse gases is seen as such an exceptional problem that it "justifies new means to counteract global warming" (Anshelm and Hansson 2014, 135). According to this view, even if OIF is problematic or risky, the risks are projected to be less severe than those posed by climate change, giving OIF some moral cover (Preston 2011; Victor et al. 2009).

Shortly after negotiation of the Kyoto Protocol, firms that believed they could profitably create and sell carbon credits through OIF began appealing to member states of the UNFCCC to allow them to do so under a new legal regime. In 1998, the company GreenSea Ventures planned to dump iron in the Gulf of Mexico, claiming that seeding an area of 5,000 square miles would trap CO_2 equivalent to a 1,000-acre forest (ETC Group 2007, 8). In 1999, New Zealand's National Institute of Water and Research joined academic institutions

8. *Wired*, Dumping Iron, 2000.
9. *Wired*, Dumping Iron, 2000.
10. C/NET, 2008, Interview with CEO and Founder Dan Whaley of Climos. Accessed online November 7, 2016, from www.cnet.com/news/bringing-seapower-to-the-fight-against-global-warming/.
11. *New York Times*, Recruiting Plankton to Fight Global Warming, May 1, 2007. Accessed online November 2, 2016, from www.nytimes.com/2007/05/01/business/01plankton.html.

from the US, the UK, and Canada to conduct research on OIF in the Southern Ocean under the Southern Ocean Iron Release Experiment (SOIREE). *Nature* and NASA described SOIREE as intending to "iron out [the] atmospheric puzzle" and clarify how OIF could be used to capture CO_2 (Newton 1999). In 2001, Markels and Barber of Duke University gave a presentation at the US Department of Energy in which they claimed that OIF could "bring the net increase in CO_2 emissions to zero" (Markels and Barber 2001, 2). That year, "numerous patents were filed on ocean fertilization processes, anticipating a global market in which credits for carbon sequestered through fertilization might be traded" (Chisholm et al. 2001, 309).

In 2002, Russ George borrowed a boat from Neil Young to dump iron off the coast of Hawai'i. In 2006, Dan Whaley and Margaret Leinen, former assistant director of geosciences at the NSF, started Climos to "bring a next generation Ocean Iron Fertilization project to realization."[12] In 2007, under the direction of Russ George, Planktos planned to dump iron off the Galapagos Islands to assess "whether large-scale iron additions result in carbon sequestration that can be quantified, verified, and sold in the global carbon credit market" (International Maritime Organization 2007).

From a rationalist perspective, the potential economic incentive that the OIF market offered to firms was clear. Early-mover firms like Planktos and GreenSea Ventures that had access to boats and a willingness to dump tons of iron ore in the oceans could potentially sell millions of credits to governments to cover the cost of carrying out OIF in the high seas and still make a profit. There were also potential material incentives for states to support OIF. As proponents indicated, OIF credits were projected to be substantially cheaper to purchase than existing carbon credits at the time—if advocates could reformulate the carbon market under the Kyoto Protocol. Both then and now, states can only buy or sell carbon credits through the Protocol's flexibility mechanisms from actions that take place within their territorial jurisdiction. As OIF would take place on the high seas, it would not qualify under the current legal regime.

To be fair, one lingering question about assessing OIF's incentive to states is that there was no scientific consensus, even at the start, that OIF would capture CO_2 and sequester it at the scale and in the time that proponents suggested. However, the fact that governance mechanisms may not perform as expected does not necessarily mean that states have no interest in implementing them. As the rationalist school illustrates, states often create environmental institutions with binding requirements under the law of the "least ambitious program" (Hovi and Sprinz 2006; Keohane and Victor 2011; Miles et al. 2001; Raustiala and Victor 2004; Underdal 1980; Victor 2006). In other words, when states structure agreements to entice laggards to join, they often water down obligations such that the least ambitious parties can comply, sometimes by taking minimal action or continuing with business-as-usual politics. As a result, environmental

12. Climos, *About Us,* Accessed online November 7, 2016, from www.climos.com/aboutus.php.

governance is rife with examples of mechanisms that have been adopted as legitimate methods of compliance, but which do little or nothing to address environmental problems (Helm and Sprinz 2000; Keohane and Victor 2011; Miles et al. 2001; Mitchell 2001; Victor 2006; Young 1999). Ineffectiveness is clearly not a barrier to creating institutions under a rationalist framework.

The Moral Weight of Uncertainty in an Age of Geoengineering

To explain why OIF has not been added as a governance mechanism, I attribute this behavior not to materially determined interest but to the normative claims of a network of critics about how to interpret appropriate action and risk in times of uncertainty. In doing so, it should be clear that resistance to OIF cannot be simply attributed to the adoption of the precautionary principle, primarily because there is not a consistent understanding of what precaution means. Lempert and Collins (2007) argue that in areas of deep uncertainty about complex environmental problems, such as the threshold responses of ecosystems to change, a blanket application of "precaution" could lead to incoherent policy responses. In the case of climate change, for example, they suggest that precaution could just as easily justify *any* action taken to limit global temperature increases to 2° C as justify caution in the application of geoengineering methods (Lempert and Collins 2007). This argument is also supported by the literature on geoengineering ethics, and shown by Ken Buessler's quote above (Anshelm and Hansson 2014; Buck et al. 2014; Preston 2011; Sikka 2012).

In order to understand action under uncertainty then, we need to look more closely at the discourses actors use to explain their world. As Lempert and Collins point out, under situations of deep uncertainty, individuals may "choose to believe different probability distributions, in particular, the ones most compatible with their own values, policy priorities, and decision contexts" (2007, 1010–1011). By using the storylines illustrated by Anshelm and Hansson (2014), we can see how the values and priorities used to assess the risk of OIF fit with the antigeoengineering discourse.

Opposition to OIF can be traced back as early as 1999, but the key points of advocacy took place in response to the 2007 plan by Planktos to dump iron. Critics developed research emphasizing the risk of OIF, and then a transnational coalition of advocates, including Greenpeace, the ETC Group, and the World Conservation Union (IUCN) presented this research to the London Convention on Dumping and the CBD. Notably, these institutions had as their mandate the protection of the marine environment and global biodiversity, respectively, making them sensitive to assessments of risk to these areas.

Advocates supplemented this with domestic lobbying of environmental ministries and participating with policy-makers and nonstate actors at a conference at the Woods Hole Institute in 2007. This was a multistakeholder conference with people from oceanographic institutions, NGOs, international

institutions like the World Bank, firms, and US government agencies including the State Department. Throughout, critics maintained a consistent set of themes.

First, the antigeoengineering discourse argues that geoengineering is a "gamble" with the Earth's ecosystems. Critics often invoke the myth of Prometheus to argue that our lack of knowledge about downstream effects will lead to our ruin in ways that we cannot predict. As critical scholars (Buck et al. 2014; Haraway 1988; Haraway 2013) and research institutions alike have shown (Shepherd et al. 2009), our knowledge of ecosystems is, at best, fragmented and incomplete. Since we cannot be sure what the effects of interference will be, other than that they are likely to have global consequences, uncertainty under these conditions becomes a cause for alarm.

For example, in 1999, Greenpeace issued a report to the Scientific Group of the London Convention. This report synthesized the research community's studies on iron fertilization (Greenpeace International 1999; Joos et al. 1991; Sarmiento and Orr 1991) to argue that OIF could, among other things, transform planktonic communities and disrupt marine food webs (Greenpeace International 1999). In 2001, Sallie Chisholm, Paul Falkowski, and John Cullen from the Department of Oceanography in Canada published what became one of the most widely cited articles on OIF, raising "great concern" about the "potential long-term consequences" of OIF, including its "purposeful eutrophication" of ocean ecosystems (Chisholm et al. 2001, 309). In it, Chisholm and her co-authors argued that the oceans were beyond the bounds of human control: "It is not easily controlled. A fertilized patch in turbulent ocean currents is not like a plot of land. The oceans are a fluid medium, beyond our control" (Chisholm et al. 2001, 309).

To be sure, not all scientists interpreted uncertainty as a justification for halting commercial OIF. Like Buesseler, Kenneth Johnson of MBARI and David Karl of the University of Hawaii argued that critics "greatly overstated the current knowledge of ocean processes in reaching their opinion that iron fertilization is not a viable option for CO_2 management" (Johnson and Karl 2002). These actors' perceptions of risk and the probability of harm from OIF were informed by a different set of values and assessments from those of the critics, and emphasized the need to take action to stop climate change.

After Planktos's aborted 2007 experiment, the IUCN called on the London Convention not to grant credits for OIF (IUCN 2007). Citing Chisholm et al.'s 2001 paper, they called OIF a "geoengineering project" and noted that the actions by groups like Planktos raised a host of questions that would need to be addressed before selling carbon credits, including whether OIF would alter "the nature and function of the ocean marine food chains," increase the production of greenhouse gases like N_2O and CH_4, or actually sequester CO_2 in the ocean (IUCN 2007). Greenpeace and the ETC Group also submitted a recommendation to the London Convention's Scientific Group arguing that OIF and other geoengineering plans created the "potential for unpredictable and irreversible

adverse impacts on marine ecosystems," including increased net emissions of greenhouse gases and the creation of toxic algal blooms (Greenpeace International 2007a).

At the Woods Hole conference, critics continued emphasizing the unknown dangers of OIF. For example, a lecture by John Cullen, Chisholm's co-author on the 2001 study, reiterated the risk of ocean manipulation. Drawing from his experience studying past cases of fish kills from rapid drops in oceanic oxygen (known as hypoxic events) caused by massive algal blooms, Cullen said,

> Decreased oxygen concentrations in the deep ocean…*has* to happen. Nutrients are stripped from the surface area, and they go down there. This has to happen. What is predictable from decreasing the oxygen in the deep ocean? Well, here is what's predictable. You're going to have a greater probability of hypoxic events. I don't know how much greater. But it's greater.…I don't really have a high degree of confidence that we can predict what will happen when some of these manipulations are implemented. (Cullen 2007)

Invoking other cases of human interference via the introduction of species like kudzu and cane toads, Cullen continued: "How many ecological manipulations that were done with the greatest of intentions had unintended consequences? … Can we know when it's going wrong? I would argue that we can't" (Cullen 2007). Greenpeace also circulated a report noting the unknown dangers of OIF, stating "commercial iron fertilization could have unpredictable impacts on atmospheric chemistry and global climate through the formation of climate-active gases [and has] the potential for adverse and irreversible consequences" (Greenpeace International 2007b, 14).

Again, while Cullen and Greenpeace agreed with Buesseler, Johnson, and Karl that the science was characterized by uncertainty, their sensitivity to the risk of environmental harm from OIF was substantially higher. Moreover, continued research showed that the initial claims of OIF's CO_2 storage capability were exaggerated, and, as was indicated in the 2007 IUCN report, could possibly increase the production of greenhouse gases. Given the lower probability that OIF would actually work to capture carbon, risk-averse oceanographers and environmentalists became increasingly concerned about the probability of food web disruption and hypoxic events from stimulating plankton growth.

A second theme is that the problem with geoengineering is its structural dysfunction. In short, we have an environmental crisis because the global political economy and the distribution of power encourages some actors to overconsume, while externalizing costs to the less privileged and to future generations (Buck et al. 2014; Hiskes 2009; Klein 2015; Ridgeway and Jacques 2015). Geoengineering, which is supposed to ameliorate the environmental crisis without requiring a change in behavior, fails to address this underlying inequity.

Similarly, OIF critics criticized it for failing to address the root causes of climate change. In their submission to the London Convention, Greenpeace and the ETC Group asserted "climate change should to be tackled by reducing emissions, not by altering ocean ecosystems" (Greenpeace International 2007a). Jorge Sarmiento, who also participated in the Woods Hole symposium, reiterated this point:

> I think, too, that the notion that we screwed things up by putting a lot of carbon dioxide in the atmosphere, and that now we can screw something else up to remove it and keep pouring carbon dioxide in the atmosphere, was a big issue for many people.[13]

A third and final theme is that geoengineering raises serious questions about democratic governance (Buck et al. 2014, 651). Geoengineering is by design supposed to have global effects. If the technology becomes available to states or private actors, there is a real possibility that a few people could interfere with the climate unilaterally (Anshelm and Hansson 2014; Buck et al. 2014; Sikka 2012; Victor et al. 2009), particularly if they believe that doing so would make their own existence more secure (Bodansky 2013; Urpelainen 2012).

This concern was underlined by real tensions over the conduct of OIF firms. When Planktos planned their 2007 experiment, they quickly became embroiled in conflict with NGOs, state governments, and research groups. George claimed to have the support of Greenpeace, but Greenpeace publicly repudiated that and, citing potential ecosystem threats, threatened to blockade Planktos's boat (Kintisch 2010). After the EPA advised Planktos that they might run afoul of US law by dumping iron under a US-flagged ship, Planktos stated that they would reflag the ship under a different country. The US administration and the EPA then submitted its own request that the London Convention address OIF, recognizing the ineffectiveness of domestic law in regulating the high seas (United States 2007). Greenpeace and Acción Ecológica lobbied the Ecuadorean government, arguing that OIF was being carried out by "profit-driven individuals [who threaten] our climate, our marine environment and the sovereignty of our fisherfolk" (Greenpeace International 2007a). In December of 2007, the Spanish government barred George's ship from docking in the Canary Islands, under pressure from environmental NGOs (Kintisch 2010; Warner and Schofield 2012).

Although this opposition from political actors and advocacy groups stopped Planktos then, it did not do so permanently. In 2012 George successfully dumped 100 tons of iron off the coast of Canada, precipitating a plankton bloom approaching 10,000 square kilometers.[14] While George again insisted that he had the support of researchers and indigenous groups in Canada,[15]

13. Research assistant's interview with Jorge Sarmiento, via Skype, August 12, 2015.
14. *The Guardian*, World's Biggest Geoengineering Experiment "Violates" UN Rules, October 15, 2012.
15. Author's interview with Russ George, via Skype, August 16, 2016.

in public, the media, environmental groups, and oceanographers condemned his actions. In 2007, the ETC Group and Greenpeace described George as a "maverick" and a "geoengineering fanatic" (Greenpeace International 2007a). In 2012, *The New Yorker* described George unfavorably as a "geo vigilante" and concluded by stating that even if a local village approved, "no village on earth should have the power to approve a project the consequences of which, *for the entire planet, cannot possibly be foreseen*."[16] The fallout from George's actions led to such a backlash that Climos "joked about whether Planktos was actually a nefarious plot to make sure that ocean fertilization never happened" (Kintisch 2010, 146).

Thus, by 2007, critics had mobilized around a sustained critique of OIF, using language echoing the antigeoengineering discourse, portraying uncertainty as a cause for alarm. This is not to suggest that OIF criticism did not confront serious resistance. As Sarmiento described,

> It's amazing how long it took to kill the idea.… The verification problem [of carbon credits] is impossible … and the negative impacts we calculated in our last paper in 2008—there are just so many reasons why it's a bad idea. And I felt like all these people at [the Woods Hole] meeting were like slot machines, I could just see the dollar signs rolling in their eyes, and they just weren't really thinking of or aware of all this work and science that had been done to basically show that iron fertilization was not a good idea.[17]

Ultimately, however, anti-OIF advocacy was successful. After receiving the NGO reports in 2007, the Scientific Group of the London Convention issued a Statement of Concern, calling on the Convention to evaluate OIF and ensure that it did not contravene the goals of the antidumping regime (International Maritime Organization 2007b). In May of 2008, the Canadian government submitted a review of the science of OIF to the London Convention. This review, which cited the 2001 paper by Chisholm, work by Aumont and Bopp (2006), and others, also concluded that there was too much uncertainty about the probability of the harmful effects of OIF on marine ecosystems and concluded that "we should not pursue practices that do more harm than they remedy in the name of addressing climate change" (Canada 2008).

In 2008, the parties of the CBD at the 9th Conference of the Parties (COP-9) issued Decision IX/16, which argued that iron fertilization should "not take place until there is an adequate scientific basis on which to justify such activities, including assessing associated risks" (CBD 2008). While the CBD accepted the validity of research on OIF, the Convention called on parties to limit research to small-scale activities, stating that OIF should "not be used for generating and selling carbon offsets or any other commercial purposes" (CBD 2008). That year, with support

16. *The New Yorker*, The First Geo-Vigilante, October 18, 2012. Accessed November 7, 2016, from www.newyorker.com/news/news-desk/the-first-geo-vigilante.
17. Research assistant's interview with Jorge Sarmiento, via Skype, August 12, 2015.

from the US government, the London Convention issued Resolution LC-LP.1, which cited Decision IX/16 of the CBD and stated that "ocean fertilization activities other than legitimate scientific research should not be allowed" (London Convention 2008). In 2010, the Convention passed Resolution LC-LP.2, calling on parties to establish a permanent regulatory mechanism for ocean fertilization. That year, the body received a study from UNESCO and the Intergovernmental Oceanographic Commission, which similarly noted the dangers of the uncertainty of OIF in its potential "geoengineering applications":

> [It] is arguable that we have insufficient knowledge, let alone technique, to purposefully manipulate an ecosystem to reverse any large scale, long term changes to ecosystems that might be have been initiated by deliberate ocean fertilization. (Wallace et al. 2010, 15)

In 2013, the London Convention passed Resolution LP.4(8), reinforcing the findings of Decision IX/16 of the CBD, specifying that OIF counted as marine geoengineering, and reiterating that all ocean fertilization activities except for scientific research "shall not be permitted" (London Convention 2013). At the time of writing, international society has continued to reject the commercialization of OIF, despite sustained economic interest in doing so.

To clarify the importance of the geoengineering discourse, it is worth comparing how international society responded to criticisms of alternative sources of carbon sinks, particularly in forestry. Notably, critics have voiced objections to forest carbon storage similar to those invoked against OIF, particularly in terms of shifting responsibility and unforeseen harm. As Doherty and Schroeder (2011), Leggett and Lovell (2012), and Beymer-Farris and Bassett (2012) have indicated, indigenous groups and environmental advocates have criticized forest carbon credits in developing countries for shifting climate responsibility from rich to poor nations, allowing rich countries "indulgences" so they do not have to change their domestic behavior, and potentially harming local ecosystems. Furthermore, as with OIF, verifying credits claimed by creating sinks through forestry activities presents substantial challenges—there is no guarantee that forestry sinks will remain intact in the long term, nor is it always clear that the activities for which states claim credit would not have occurred anyway.

However, whereas critics used the link between OIF and geoengineering to invest criticisms of OIF with additional authority, forestry activities do not count as geoengineering, since they take place primarily within states, rather than at the regional or global scale required for geoengineering. In fact, all of the major reports on geoengineering by the CBD, the London Convention, the Royal Society, the IPCC, and the German Federal Environmental Ministry have specified that OIF is part of the geoengineering spectrum, while the IPCC and the German Federal Ministry have explicitly stated that forestry is not (IPCC 2012; UmweltBundesAmt 2011). For critics of OIF, the "fluid environment" of the oceans make them qualitatively different from terrestrial ecosystems when it comes to risk management, since any potential hazards of OIF have a greater

chance of spreading beyond their point of origin.[18] Consequently, the normative weight and perception of risk assigned to OIF's uncertainty was not available to critics of afforestation.

Conclusions

As this article has shown, discourses involve assumptions about appropriate behavior that can shape how international society responds to emerging environmental problems. Prior to 2007, firms such as Climos, Planktos, and GreenSea Ventures used the iron hypothesis to argue that international society should legitimate the sale of credits from OIF. In response, environmental NGOs and oceanographers stated that uncertainty in the science should disqualify OIF from carbon credits, since OIF was an unknown, and possibly serious, threat to global ocean ecosystems. This assertion that uncertainty indicated danger fits with the antigeoengineering discourse observed by Anshelm and Hansson (2014), among others, particularly since the scale of the effects of OIF exacerbated the perception of its risk to the world's environment. As was discussed above, other carbon credit mechanisms with lingering scientific and political questions, including afforestation, are still legitimate governance mechanisms because their consequences are not seen as globally threatening. I therefore conclude that discourses matter: narratives help actors make sense of their world, and give meaning to actions in ways that help navigate uncertainty.

This is not to argue that geoengineering is objectively good or bad. It is entirely possible that geoengineering could have negative effects on global ecosystems. It is also possible that the environmental effects of geoengineering might be better than the projected effects of global climate change on human society. However, governance must of necessity be shaped by value judgments in times of complexity and uncertainty, so as to avoid paralysis. All the same, if the normative framework around geoengineering discourses were to change, we might see the moral calculus concerning OIF and other geoengineering strategies also change.

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