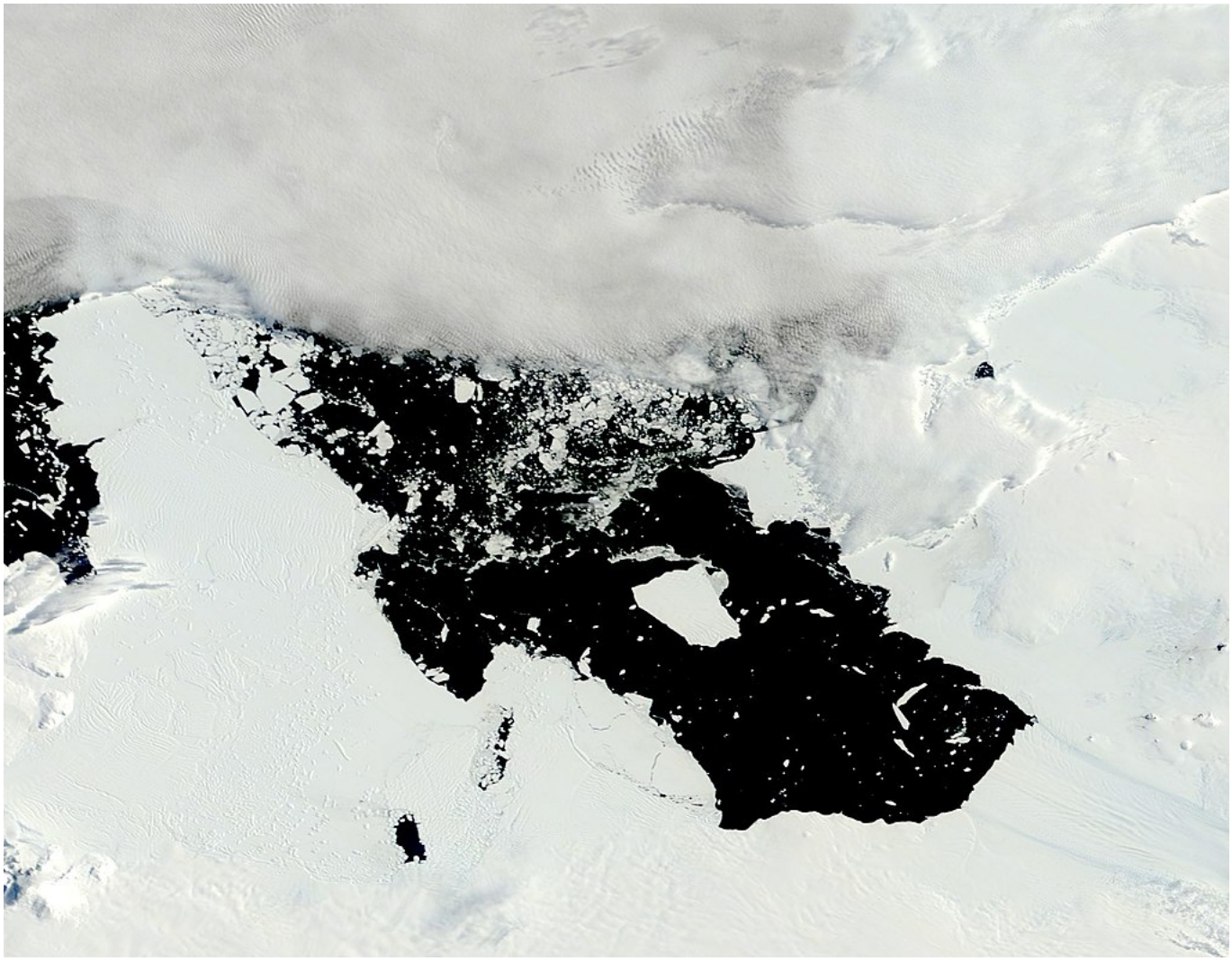


Newly calved iceberg in Pine Island Bay, Antarctica (NASA 2014)

As the planet warms over the coming centuries, glacial melt in Greenland and Antarctica will lead to significant sea level rise. This phenomenon threatens to flood coastal cities, submerge island nations, and displace hundreds of millions of people. Coastal adaptation projects underway give us a glimpse into how we will respond to this future. Some communities are building seawalls and restoring coastal ecosystems to limit flooding and erosion. Others face overwhelming sea level rise, and now must consider deliberate abandonment of their homes in a process called “managed retreat” (one of the more striking euphemisms in climate-policy speak).

These adaptation methods react to sea level rise as experienced on specific coastlines. But some scientists have begun to think bigger. What if there were a way to slow the melt and collapse of these ice sheets themselves? Say, a massive

underwater berm to block warm waters from melting glaciers from below? In theory, such an endeavor could slow the rate of sea level rise worldwide, perhaps for hundreds of years. This post takes an in-depth look at a few Antarctic glacial geoengineering proposals, the problems they present for long-term governance, and how the law of Antarctica would frame oversight of early scientific research.

What is glacial geoengineering?

Scientists Michael Wolovick and John Moore envision a glacial geoengineering project that would target the Thwaites Glacier of West Antarctica. The Thwaites Glacier is estimated to be "the largest individual source of future sea level rise" and may already be on the path to "runaway collapse." One idea would artificially pin the glacier in its current position by building a massive earthen berm on the seafloor. The giant mound, made from about 1.5 cubic miles of dredged material, would block the flow of warm water melting the glacier from underneath, while also providing a solid surface for new glacial ice to attach to. (An alternative proposal would build a miles-long system of pumps and tunnels to remove or freeze water at the glacier's base.) Slowing the collapse of the glacier could slow the global rise in sea levels.

The underwater-berm proposal can be thought of as "geoengineering" because it directly, and dramatically, counteracts a globally felt consequence of climate change. Like other geoengineering projects, Antarctic berm-building would be no substitute for cutting CO_2 emissions: a warming atmosphere would eventually melt the glacier if warming seas couldn't. There is, however, an important difference between this proposal and geoengineering ideas like solar radiation management ("SRM"). Unlike the extremely controversial idea of SRM, which would "dim" incoming sunlight by spraying reflective aerosols in the stratosphere, the Thwaites Glacier project would have a more limited footprint. Much like building a canal or an artificial island, the interference wouldn't be global. Because glacial geoengineering proposals strongly resemble past mega-projects (though there are exceptions), it's easier to imagine workable systems of governance for them than for SRM.

"Easier" being the operative word: cryoengineering the Thwaites Glacier would entail a tremendous amount of dredging and construction, in an extremely remote area, with the potential to greatly disturb some of the most pristine environments on the planet. The timescales are also daunting. Wolovick and Moore describe a process "decades or perhaps centuries" long for studying the glaciers, improving designs, and construction, all to offset sea level rise in the 22nd and 23rd centuries.

There is little precedent for projects unfolding over such a long time to deliver benefits so far in the future.

The Law of Antarctica

The Antarctic Treaty System ("ATS") is the international legal framework governing Antarctica. Initial field research into glacial geoengineering could be permitted under the ATS, especially if focused on questions of general glaciology. Development and construction of a cryoengineering project, however, would be prohibited.

Antarctica covers more than five million square miles, an area larger than the U.S. and Mexico combined, 95% of which is buried under a layer of ice averaging more than mile thick. It has been described as "a continent without a sovereign," though it may be better understood as a continent with many sovereigns deferred. The Antarctic Treaty, signed in 1959, and entering into force in 1961, preserved the territorial claims of seven countries—Argentina, Australia, Chile, France, New Zealand, Norway, and the United Kingdom—while also preserving a "basis of claim" of the United States and Russia. No new territorial claims can be made, and no existing claims can be enlarged.

The Antarctic Treaty declares the entire "area south of 60° South Latitude, including all ice shelves" as "in the interest of all mankind." The continent is to "be used for peaceful purposes only," namely, scientific research carried out through cooperative planning and with open sharing of results. Jurisdiction in Antarctica doesn't track countries' territorial claims. Instead, individuals are "subject only to the jurisdiction of the Contracting Party of which they are nationals." Dispute resolution is handled through consultation and negotiation of the parties, facilitated by annual meetings of the Consultative Parties. Major governance decisions are made at these annual Arctic Treaty Consultative Meetings, with 29 countries taking part in decisionmaking and an additional 25 non-consultative countries in attendance.

To protect Antarctica's landscapes, wildlife, and ecological systems, the ATS sets forth a strong legal regime for environmental protection. The chief environmental instrument is the 1991 Madrid Protocol to the Antarctic Treaty, which "designate[s] Antarctica as a natural reserve, devoted to peace and science." The Protocol bans mining and mineral exploration, other than activities classified as scientific research. It requires individuals subject to the jurisdiction of parties to adhere to

"fundamental" environmental principles to limit adverse effects on the environment, wildlife, and ecosystems (though the U.S. has stated that that section of the Protocol "does not impose substantive obligations"). The Protocol also imposes significant procedural requirements prior to commencing activities in Antarctica, such as conducting environmental impact assessments and planning for waste management.

Because nationals remain subject to the jurisdiction of their countries of origin while in Antarctica, ATS requirements are enforced by domestic law. For example, the U.S. enforces the permitting requirements of the Madrid Protocol against its nationals through the Antarctic Conservation Act, and bans mining exploration and development via the Antarctic Protection Act.

Glacial geoengineering and the Antarctic Treaty System

No cryoengineering or mega-adaptation building project could be authorized under the ATS. The present legal regime is designed for scientific research, environmental preservation, and a moderate amount of tourism. It isn't equipped to facilitate the permitting and oversight of projects built on a gargantuan scale that, by design, would cause enormous adverse direct impacts on the environment through dredging, sea and air traffic, pollution, noise, heat, and build infrastructure.

As a result, the harm-balancing argument advanced by some glacial geoengineering proponents—that allowing the glaciers' uncontrolled collapse would be far more disruptive than construction to save the glaciers—is legally inapt. It's possible that a *future* instrument within the ATS could countenance harms-balancing of this magnitude, but the present treaty system doesn't. Developing these projects beyond the initial stages of scientific investigation would therefore require significant revisions to the ATS.

Revising the ATS would have to be done with great care so not to disturb the compromises and agreements that have accumulated over the last sixty years. One sensitive area would be whether to continue the blanket prohibition on mining and, should it be lifted, how mineral rights would be assigned. (Allowing offshore dredging in a melting Antarctic would certainly bring hopes for mineral exploration to the fore.) The mining issue intersects with an even larger problem, which is the ambiguous status of the deferred territorial claims, some of which conflict. Additionally, many countries take issue with the fact that the "global common" of Antarctica is controlled by the exclusive group of Consultative Parties, rather than

through a more inclusive international body. A future geoengineering instrument would also need to determine project liability, jurisdiction at the project site, and apportionment of construction, remediation, and maintenance costs.

Permitting scientific field research

Fortunately for would-be cryoengineers, the hardest questions don't need to be answered yet. Development and construction of the Thwaites Glacier proposal, should it prove feasible, would be far off in the future. Much scientific research is needed first to assess feasibility. These feasibility questions are topics of general glaciology and ocean sciences, meaning they can be explored without triggering more fraught concerns related to design and construction.

Permitting field research in Antarctica follows a rigorous review process under international and domestic law. If a U.S. team wanted to study glacial calving on the Western Antarctic Ice Sheet, it would need to apply for a permit from the National Science Foundation. This process requires completing an application that describes the experiment, the proposed timing and location, the method of accessing the research area, and the need for the project. A summary of the proposal would then be published in the Federal Register, allowing for a 30-day public comment period, followed by internal and inter-agency review.

Prior to approving the permit, the agency would need to complete an initial environmental evaluation under NEPA to determine the environmental impacts of the activities. The results of this review could trigger even more extensive impacts analysis. Specifically, proposed experiments with more than "a minor or transitory impact" on the environment would also need to undergo a Comprehensive Environmental Evaluation, which involves international review and consultation, followed by consideration by the Consultative Parties at the next Antarctic Treaty Consultative Meeting.

It's unlikely that initial research on glacial geoengineering would automatically trigger that extensive process, which in the past has applied only to permanent infrastructure construction or experiments proposing to bore deep into the ice or offshore sediments. If a more thorough assessment is desired, though, a research team could voluntarily submit to the more involved Comprehensive Environmental Evaluation process. Other groups have voluntarily done so in the past where their experiments touched on sensitive issues.

Existing law provides sufficient mechanisms of governance for glacial geoengineering research, considering they provide opportunity for comment from a range of stakeholders. There's little basis in law for denying a permit because the results *might* be used to advance glacial geoengineering projects. Such experiments would answer general science questions, and they could just as easily prove glacial geoengineering infeasible as not. A line should therefore be drawn between the environmental impacts of field experiments themselves and the countless ways the results of those experiments might inform future actions.

Final thought

Geoengineering of any kind presents daunting questions of governance and environmental protection. It would be necessary to reimagine the ATS to accommodate construction of something like the Thwaites Glacier proposal. Sufficient legal mechanisms are in place, though, to supervise initial field research—especially if researchers voluntarily undergo heightened environmental review.