Global Governance of Planetary-scale Albedo Modification

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Informal Remarks to the World Academy

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A word about definitions

I have recently stopped using the term "geoengineering" because it turns out this word means very different things to different people.

Indeed some people even include activities such as capturing carbon dioxide from power plants and sequestering it deep underground (CCS).

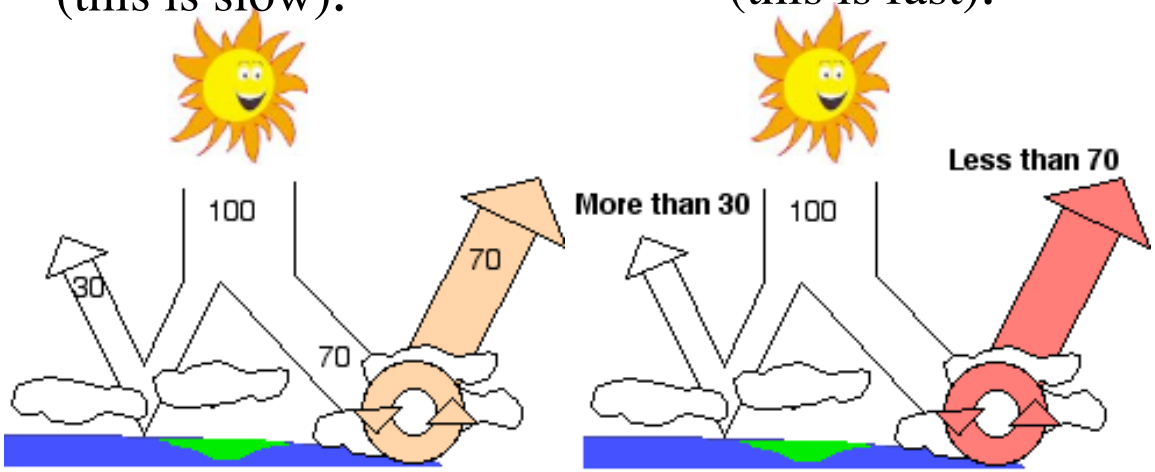
Definitions…(Cont.)

To cool the earth either:

Remove CO_2 and other GHGs (this is slow).

OR

Increase albedo just a little bit (this is fast).



- Grow trees
- Ocean fertilization
- Direct air scrubbing

- Change the surface or clouds
- Add reflectors in space
- Add fine particles to the stratosphere

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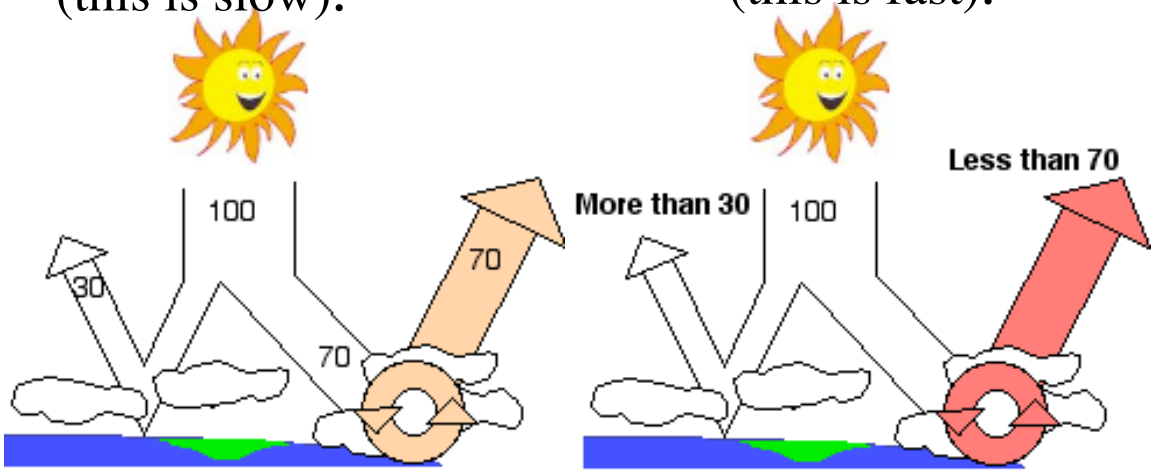

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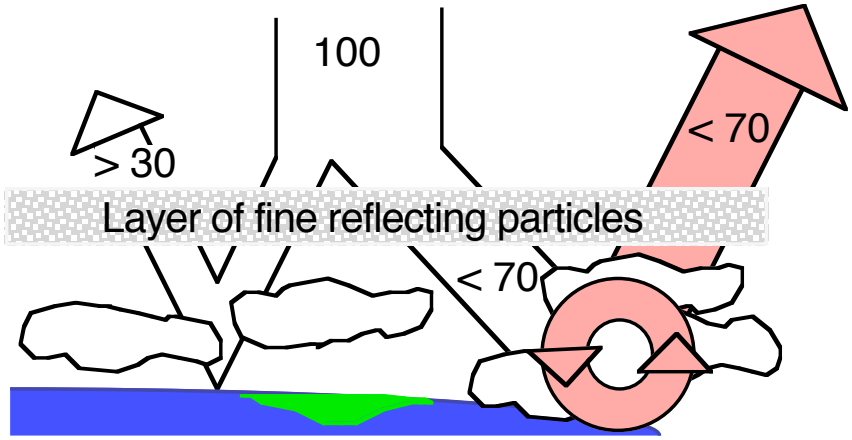
In the face of the abysmally slow progress…

…that the world's leading nations were making in reducing their emissions, about three years ago I began to get concerned that one day a major state would wake up to a very serious climate impact and decide they needed to take matters into their own hands and start increasing the planet's albedo to reverse warming.

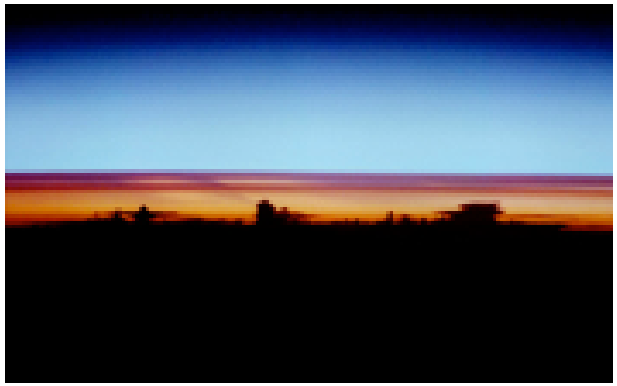
My concern was that if this was a major (nuclear) state it was not clear that the rest of the world could do much about it. I enlisted the help of my colleague Jay Apt, recruited Ph.D. student Kate Ricke, and political scientists David Victor and John Steinbruner to work with us.

Stratospheric aerosols

Adding more of the right kind of fine particles to the stratosphere can increase the amount of sunlight that is reflected back into space.



There is clear evidence from many large past volcanic eruptions that this mechanism can cool the planet (Mount Pinatubo produced global scale cooling of about 0.5°C).



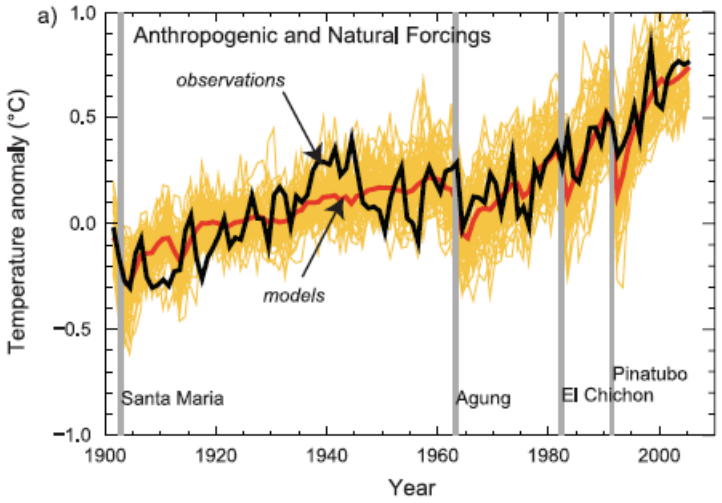
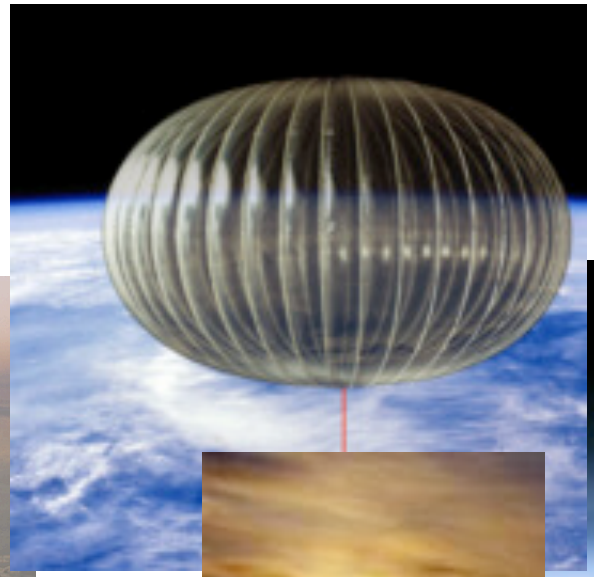


Figure sources: NASA and IPCC.

This is not hard to do



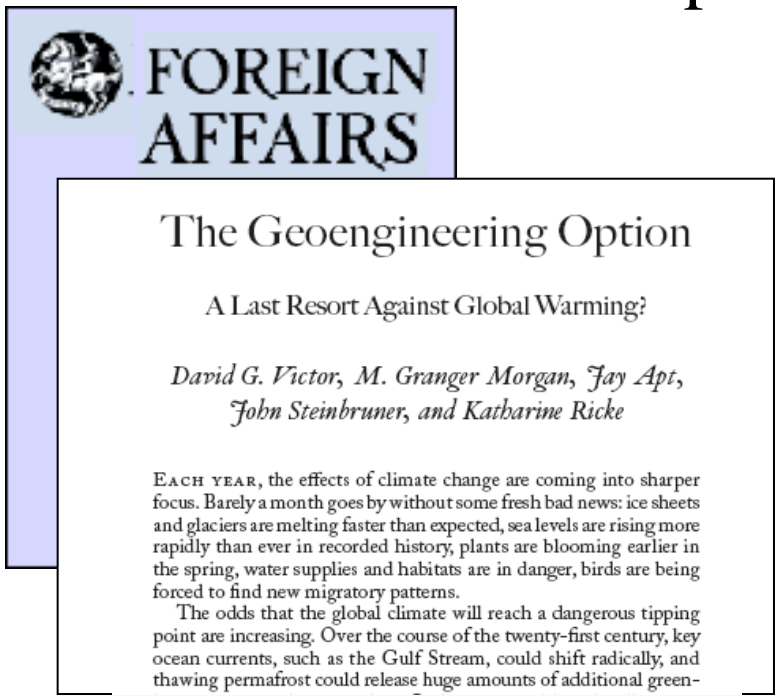
David Keith has suggested that it should be possible to create microscopic reflecting composite particles that would be self-orienting and self-levitating, and thus might not have to be replaced very frequently.

Figure sources: EADS; NASA; www.carlstumpf.com

A single nation could do these within its national boundaries

Because the…

diplomatic community was almost completely unaware of this issue, a year ago the five of us organized a workshop at the Council on Foreign Relations in Washington. That led in turn to a paper that appeared in the 2009 March/April issue of *Foreign Affairs*.


FOREIGN AFFAIRS

The Geoengineering Option

A Last Resort Against Global Warming?

David G. Victor, M. Granger Morgan, Jay Apt, John Steinbruner, and Katharine Ricke

EACH YEAR, the effects of climate change are coming into sharper focus. Barely a month goes by without some fresh bad news: ice sheets and glaciers are melting faster than expected, sea levels are rising more rapidly than ever in recorded history, plants are blooming earlier in the spring, water supplies and habitats are in danger, birds are being forced to find new migratory patterns.

The odds that the global climate will reach a dangerous tipping point are increasing. Over the course of the twenty-first century, key ocean currents, such as the Gulf Stream, could shift radically, and thawing permafrost could release huge amounts of additional green-

Participants in that workshop were all from North America.

To extend the conversation to a more international group, we ran a second workshop this past April in Lisbon, Portugal.

Source: Council on Foreign Relations

The Lisbon Workshop…

…was hosted by the Ministry of Science, Technology and Higher Education of the Government of Portugal.

The two-day workshop was held at the facilities of the Gulbenkian Foundation.

Co-sponsors included: IRGC, CMU-CDMC, U Calgary.

Participants from N. America, EU, China, Russia, and India.

Sources:
Gulbenkian & Qian Yi

Issues that the diplomatic community should begin to address:

1. The likelihood that the direct costs of geoengineering would be much cheaper than abatement
2. Once started we're on a slippery slope
3. Few have "standing" to argue for a serious research program
4. Anything done in this area should be transparent
5. Issues of reversibility
6. Issues of equity
7. Issues of liability

1. Potentially *much* cheaper

When we do a back-of-the-envelope estimate of the cost of achieving ~80% reduction in the emissions of CO_2 and other GHGs compared with the cost of geoengineering, it looks like the ***direct*** costs of offsetting warming via geoengineering may be *much* cheaper than the cost of doing emissions abatement.

The cost of GHG abatement

Today, the world is emitting about 50×10^9 tonnes per year CO_2-eq
(of which about 30×10^9 is CO_2)

The IPCC 4th assessment says:

> "Modelling studies show that global carbon prices rising to US$20-80/ tCO_2-eq by 2030 are consistent with stabilisation at around 550ppm CO_2-eq by 2100. For the same stabilisation level, induced technological change may lower these price ranges to US$5-65/$tCO_2$-eq in 2030."

$$(50 \times 10^9 \text{ tCO}_2\text{-eq})(5 \text{ to } 65\$/\text{tCO}_2\text{-eq}) = 250 \text{ to } 3300 \times 10^9 \$/\text{year}$$

The size of the global economy is of the order of $\$60 \times 10^{12}$

$$\frac{0.25 \text{ to } 3.3 \times 10^{12} \$/\text{year}}{60 \times 10^{12} \$/\text{year}} \longrightarrow$$

0.4% to 5.5% of world GDP/year

The cost of geoengineering

As noted in the briefing paper:

A National Research Council 1992 report estimated the undiscounted annual costs for a 40-year project to be $100-billion.

Teller, Wood and Hyde have suggested that well designed systems might reduce this cost to as little as a few hundred million dollars per year.

If we take cost to be between $100-million and $100-billion per year

$$\frac{0.1\text{-}100 \times 10^{9}\ \$/\text{year}}{50 \times 10^{12}\ \$/\text{year}} \longrightarrow$$

0.0002% to 0.2% of world GDP/year

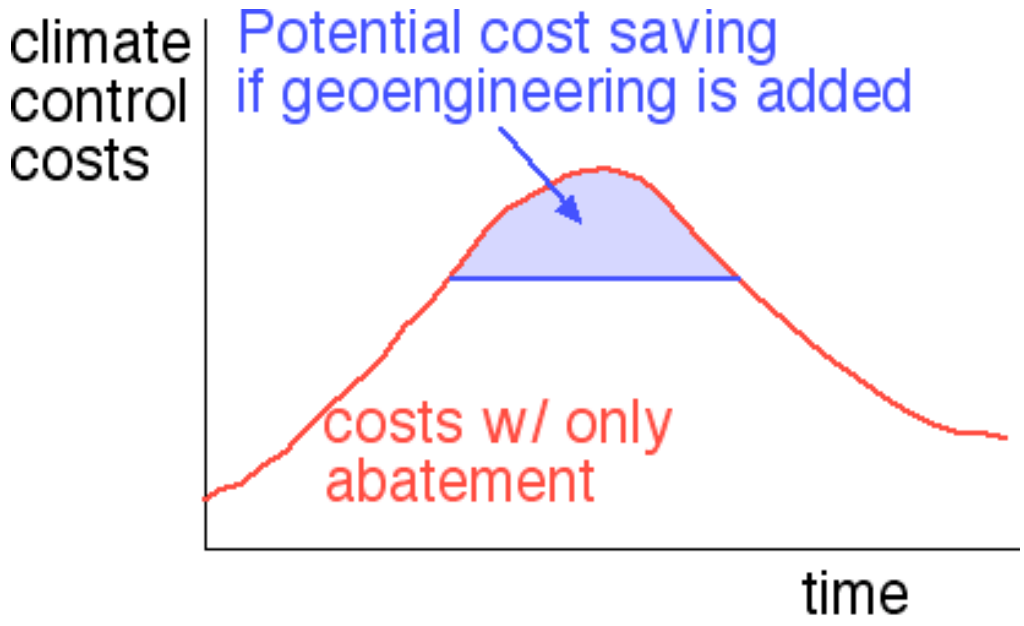
Bottom line

It is probably safe to assume that the direct monetary cost of geoenginering would be *at least* 100 times less than the cost of a full program of GHG abatement…

…and perhaps even cheaper than that.

As this becomes widely understood…

… pressure to engage in at least some geoengineering will likely grow, if not as a sole strategy at least as a strategy to "take the top off" the costs of abatement.



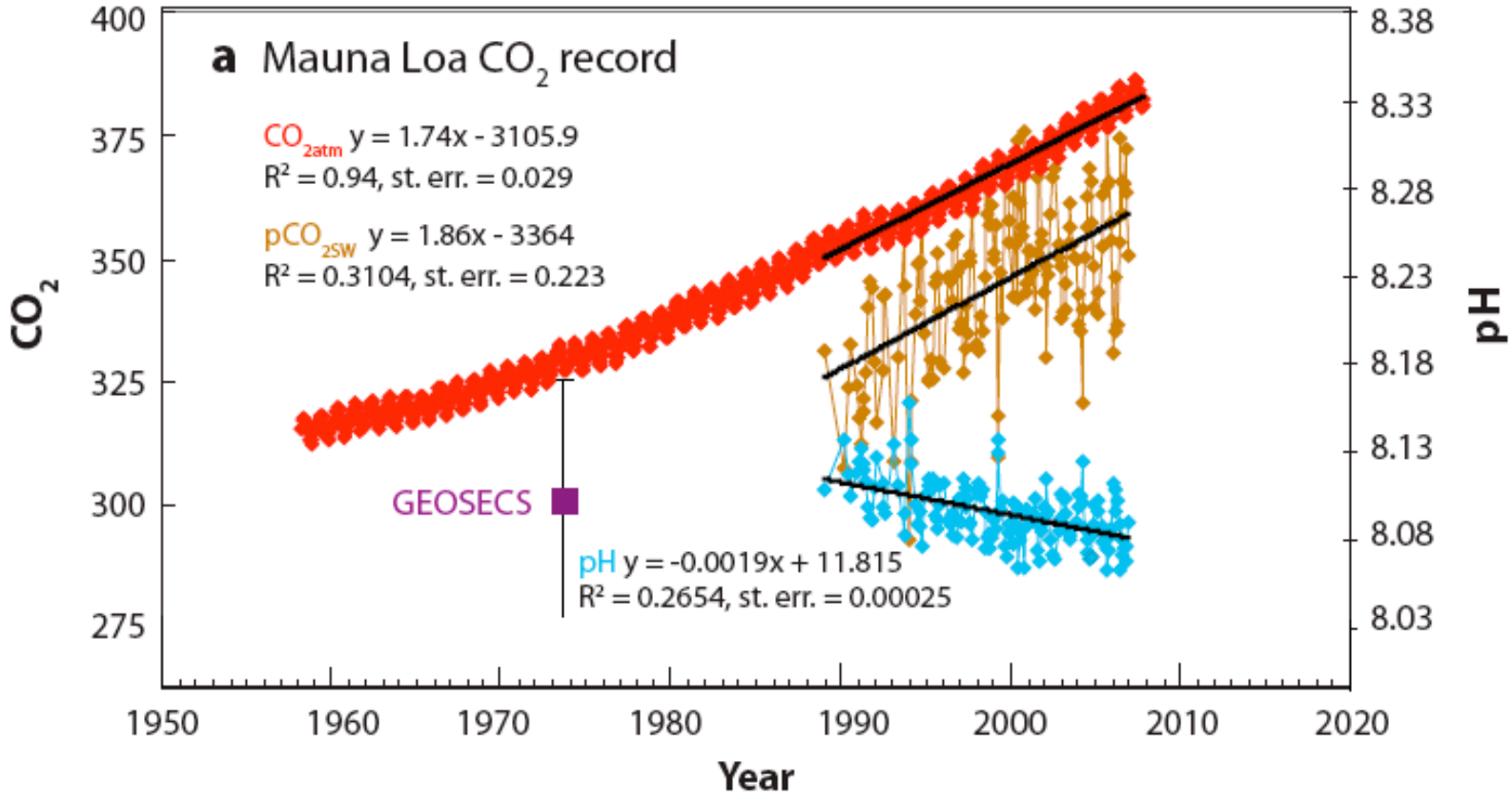
2. Slippery slope

The diplomatic community and scientific communities need to find ways to persuade the world to stay focused on emissions abatement and to avoid or strictly limit geoengineering.

Research and public communication about factors such as ocean acidification may be able to help that process. Today, few people understand the potential consequences of acidification. For example, the editor handling our *Foreign Affairs* paper asked us "why does it matter if the world loses its coral reefs."

Source: wikimedia.org

As CO_2 rises, oceans become more acidic



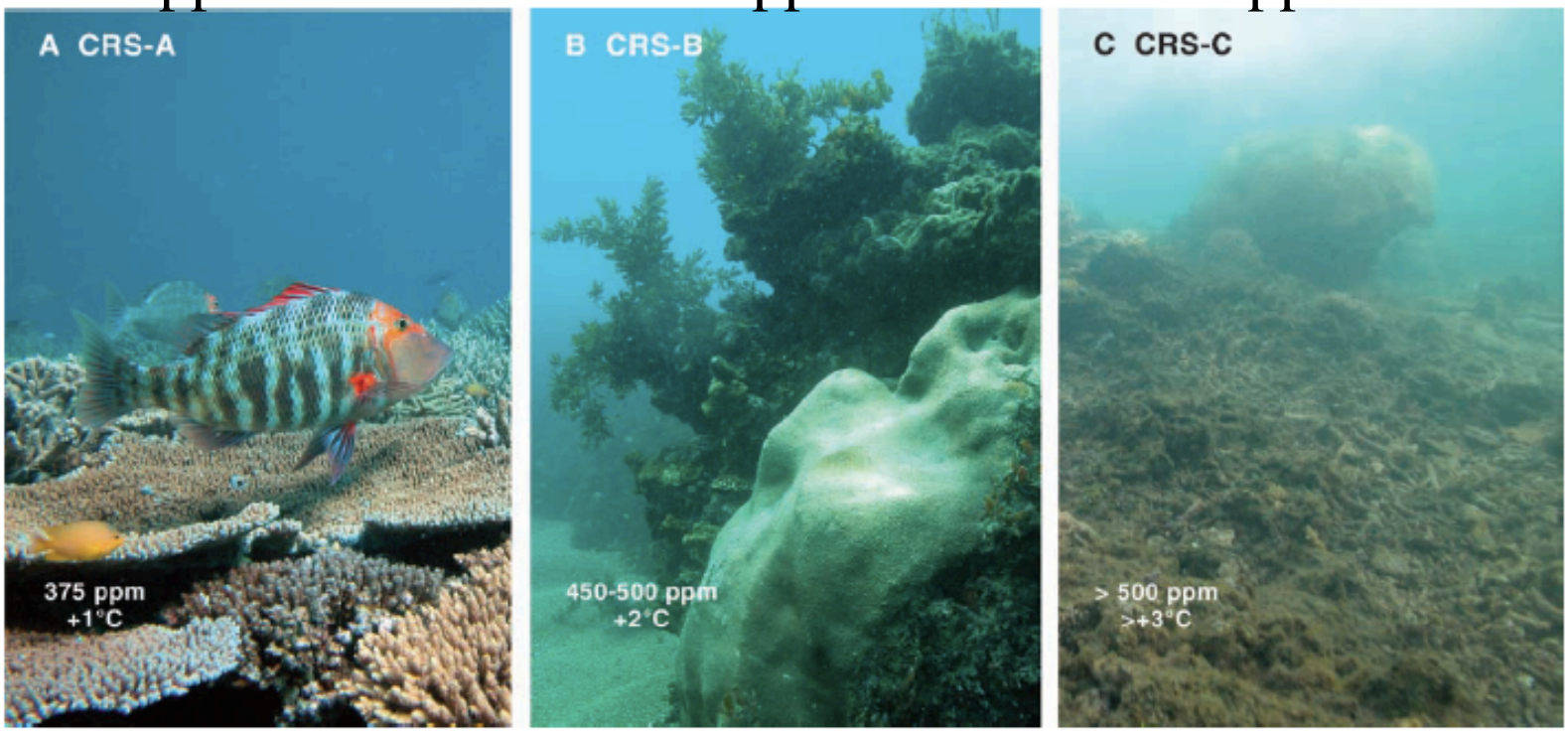
Today the surface ocean is 30% more acidic than before the industrial revolution.

Source: Doney et al., *Annual Reviews of Marine Science*, 2009

A more acidic ocean…

…*may* mean the demise of coral reefs *and all the ecosystems they support*.

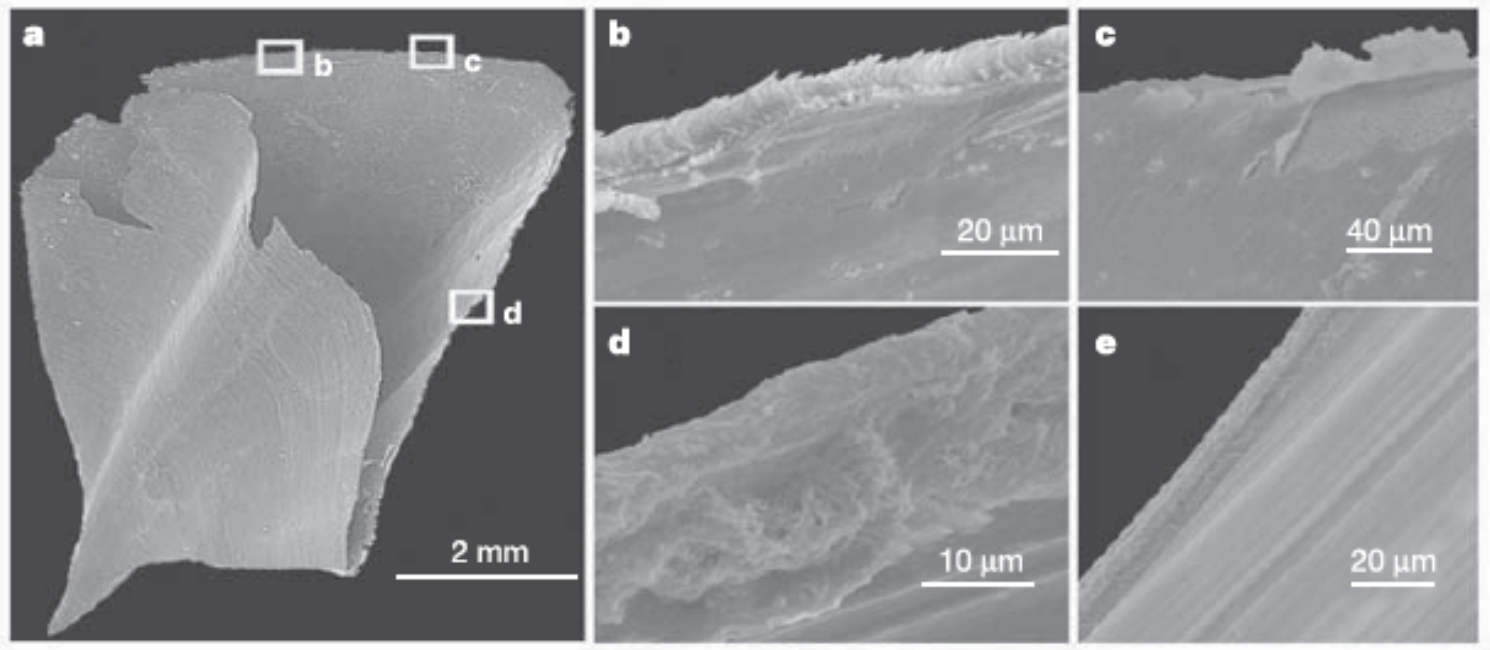
375ppm +1°C | 450-500ppm +2°C | >500ppm >3°C



Source: O. Hoegh-Guldberg et al., "Coral reefs under rapid climate change and ocean acidification," *Science*, *318*, pp. 1737-1742, December 14, 2007.

Fig. 5. Extant examples of reefs from the Great Barrier Reef that are used as analogs for the ecological structures we anticipate for Coral Reef Scenarios CRS-A, CRS-B, and CRS-C (see text). The $[CO_2]_{atm}$ and temperature increases shown are those for the scenarios and do not refer to the locations photographed. (**A**) Reef slope communities at Heron Island. (**B**) Mixed algal and coral communities associated with inshore reefs around St. Bees Island near Mackay. (**C**) Inshore reef slope around the Low Isles near Port Douglas. [Photos by O. Hoegh-Guldberg]

Shell dissolution (e.g. pteropod or "sea butterfly")



A key food source for juvenile pink salmon and other small fish.

Sources: Orr et al., *Nature*, 2005; Wikipedia; www.ims.uaf.edu.

Serious studies of acidification have hardly begun

Physiological response	Major group	Species studied	Response to increasing CO_2 a	b	c	d
Calcification						
	Coccolithophores[1]	4	2	1	1	1
	Planktonic Foraminifera	2	2	–	–	–
	Molluscs	4	4	–	–	–
	Echinoderms[1]	3	2	1	–	–
	Tropical corals	11	11	–	–	–
	Coralline red algae	1	1	–	–	–
Photosynthesis[2]						
	Coccolithophores[3]	2	–	2	2	–
	Prokaryotes	2	–	–	1	–
	Seagrasses	5	–	–	–	–
Nitrogen Fixation						
	Cyanobacteria	1	–	1	–	–
Reproduction						
	Molluscs	4	4	–	–	–
	Echinoderms	1	1	–	–	–

1) Increased calcification had substantial physiological cost; 2) Strong interactive effects with nutrient and trace metal availability, light, and temperature; 3) Under nutrient replete conditions.

Source: Doney et al., *Annual Reviews of Marine Science*, 2009.

…and impact assessments are even scarcer

Anticipating ocean acidification's economic consequences for commercial fisheries

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Abstract

Ocean acidification, a consequence of rising anthropogenic CO_2 emissions, is poised to change marine ecosystems profoundly by increasing dissolved CO_2 and decreasing ocean pH, carbonate ion concentration, and calcium carbonate mineral saturation state worldwide. These conditions hinder growth of calcium carbonate shells and skeletons by many marine plants and animals. The first direct impact on humans may be through declining harvests and fishery revenues from shellfish, their predators, and coral reef habitats. In a case study of US commercial fishery revenues, we begin to constrain the economic effects of ocean acidification over the next 50 years using atmospheric CO_2 trajectories and laboratory studies of its effects, focusing especially on mollusks. In 2007, the $3.8 billion US annual domestic ex-vessel commercial harvest ultimately contributed $34 billion to the US gross national product. Mollusks contributed 19%, or $748 million, of the ex-vessel revenues that year. Substantial revenue declines, job losses, and indirect economic costs may occur if ocean acidification broadly damages marine habitats, alters marine resource availability, and disrupts other ecosystem services. We review the implications for marine resource management and propose possible adaptation strategies designed to support fisheries and marine-resource-dependent communities, many of which already possess little economic resilience.

Source: Environ. Res. Lett. **4** (2009) 024007 (8pp).

3. Few have "standing"

While I believe that there is an urgent need for a serious research program on geoengineering, having done so little to promote abatement over the past decade, the U.S. is not in a very strong position to make this argument.

In April, when we asked our European colleagues if they thought the EU might be prepared to take the lead in calling for such a program they were pretty dubious.

4. Anything done should be transparent

Participants in both the Washington and Lisbon workshops stressed that any research program in this area should be undertaken in a transparent and international manner as possible. BUT…I continue to hear rumblings that folks in the national security community are beginning to think about this, and it will take a serious effort to persuade them to do any research they undertake in an open and transparent way.

Perhaps one of the very first international agreements the diplomatic community works to achieve should be a guarantee that all work will be open and transparent.

5. Issues of reversibility

This is a two-edged sword. If we were ever to start doing planetary-scale albedo modification it would be wise to be able to back off quickly if there were serious unanticipated negative consequences.

That may be an argument against putting things at the L1 Lagrange point unless there is a means to easily reorient them or push them off the saddle point.

Most stratospheric aerosols decay fairly quickly so are inherently reversible. However, extended replenishment followed by sudden failure to replenish could result in a large abrupt ΔT and devastating ecosystem impacts.

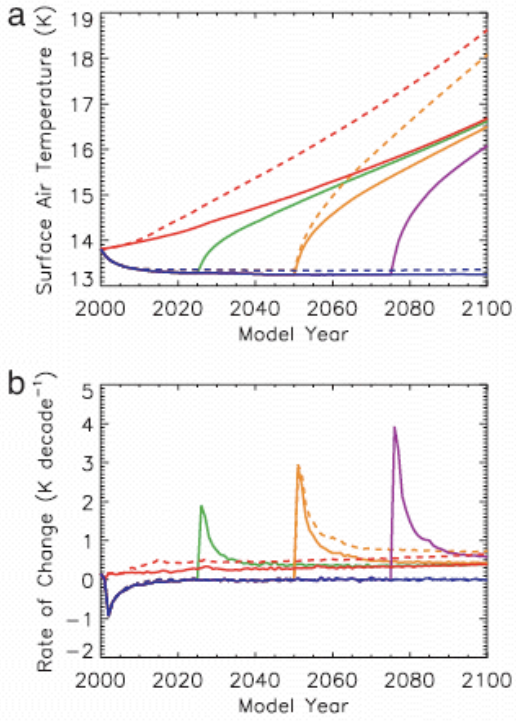
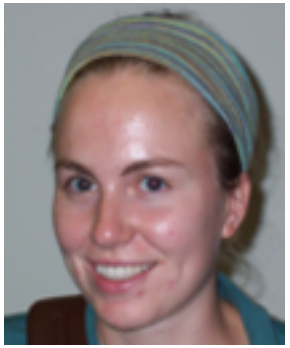


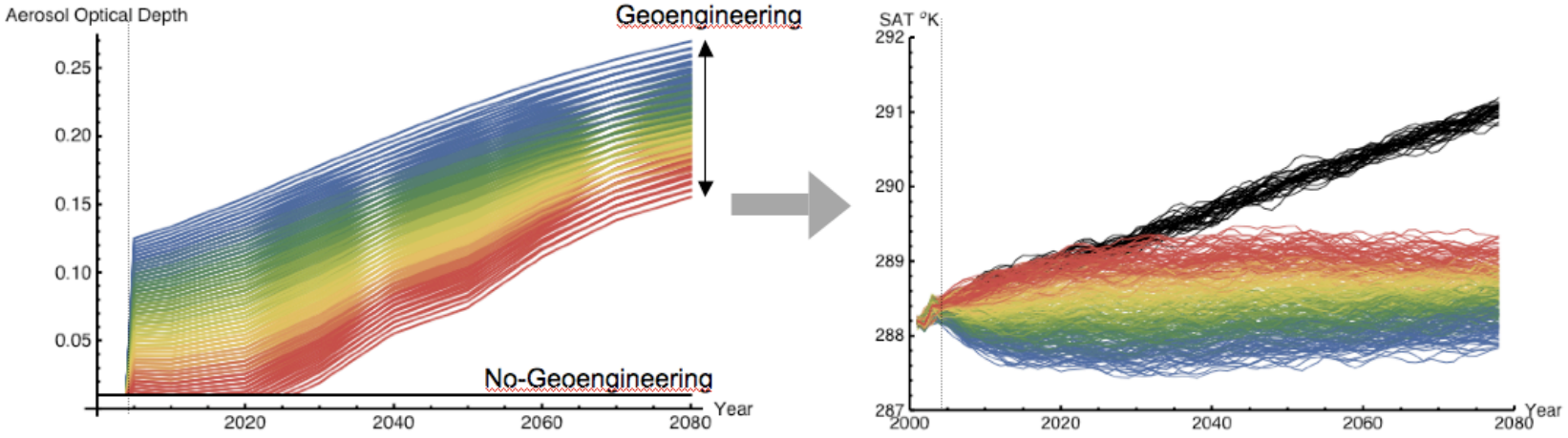
Fig. 3. Simulated surface air temperature (*a*) and annual rate of temperature change (*b*) for runs A2 (red), GEO (BLUE), OFF_2025 (green), OFF_2050 (orange), and OFF_2075 (purple). Runs with doubled climate sensitivity (A2+CS, GEO+CS, and OFF_2050+CS) are plotted as dashed lines.

Source: Matthews and Caldeira, *PNAS*, July 12, 2007.

6. Equity

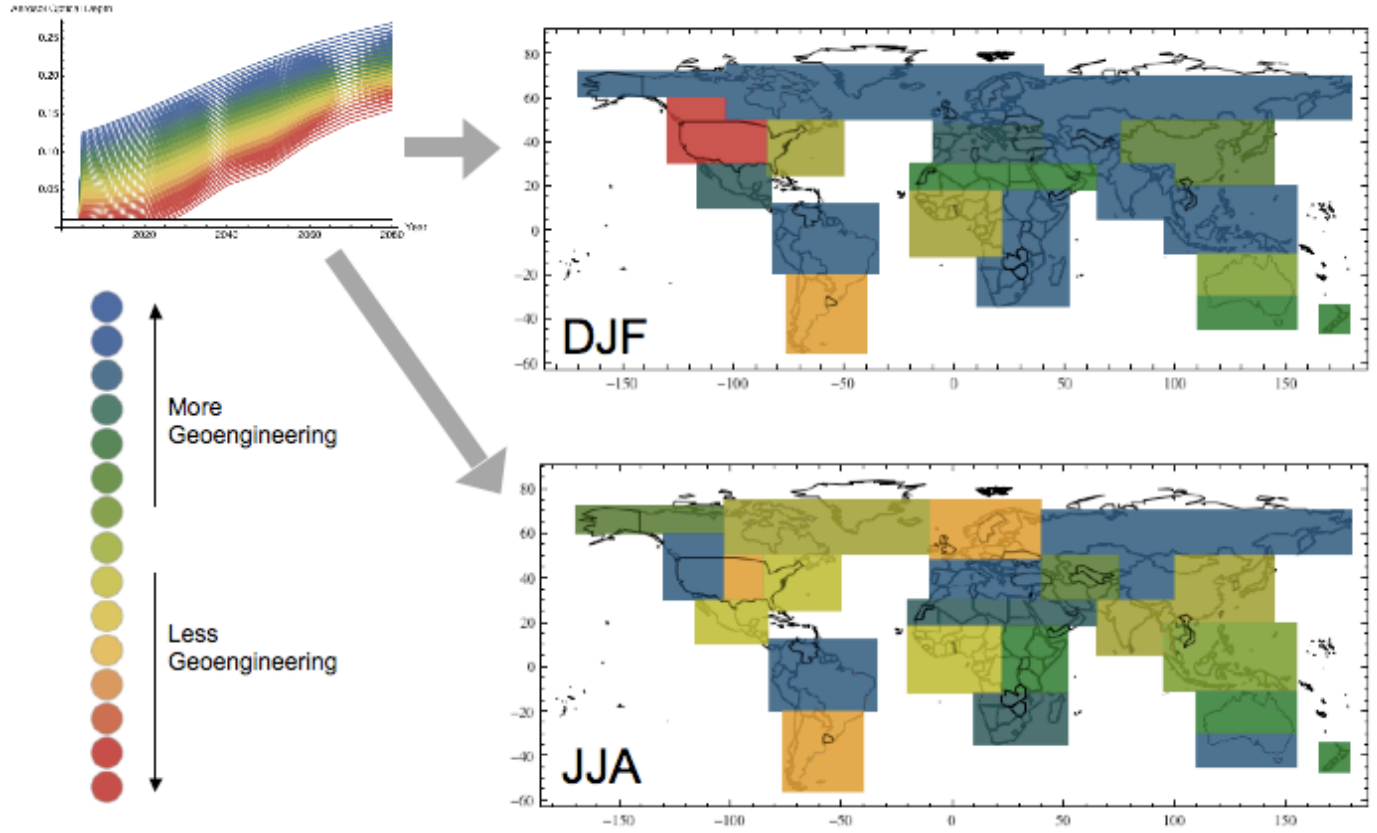


My EPP Ph.D. student Kate Ricke has been using the climateprediction.net HadCM3 model to do geoengineering experiments. One of the things she has done is use multiple forcing trajectories to look at resulting changes in T and precipitation.



Kate finds that…

…the forcing scenario that returns precipitation to its previous level is different for different parts of the world.



Clearly, there will be issues of equity and winners and losers, which brings me to my last topic…

7. Liability

As soon as there are winners and losers, issues of liability will surely arise. While governments generally enjoy sovereign immunity, inventive lawyers may find grounds for suits, either in international…

…or U.S. domestic courts.

Sources: www.denhaag.com; www.supremecourtus.gov

In short…

…given all the complexities, it is likely to take the foreign policy community at least as long to sort out its thinking on issues related to geoenginering as it will take the scientific community to mount a significant program of research on the effectiveness, and direct and indirect impacts, of geoengineering.

The time to start working on this problem is now.

Q&A and Discussion