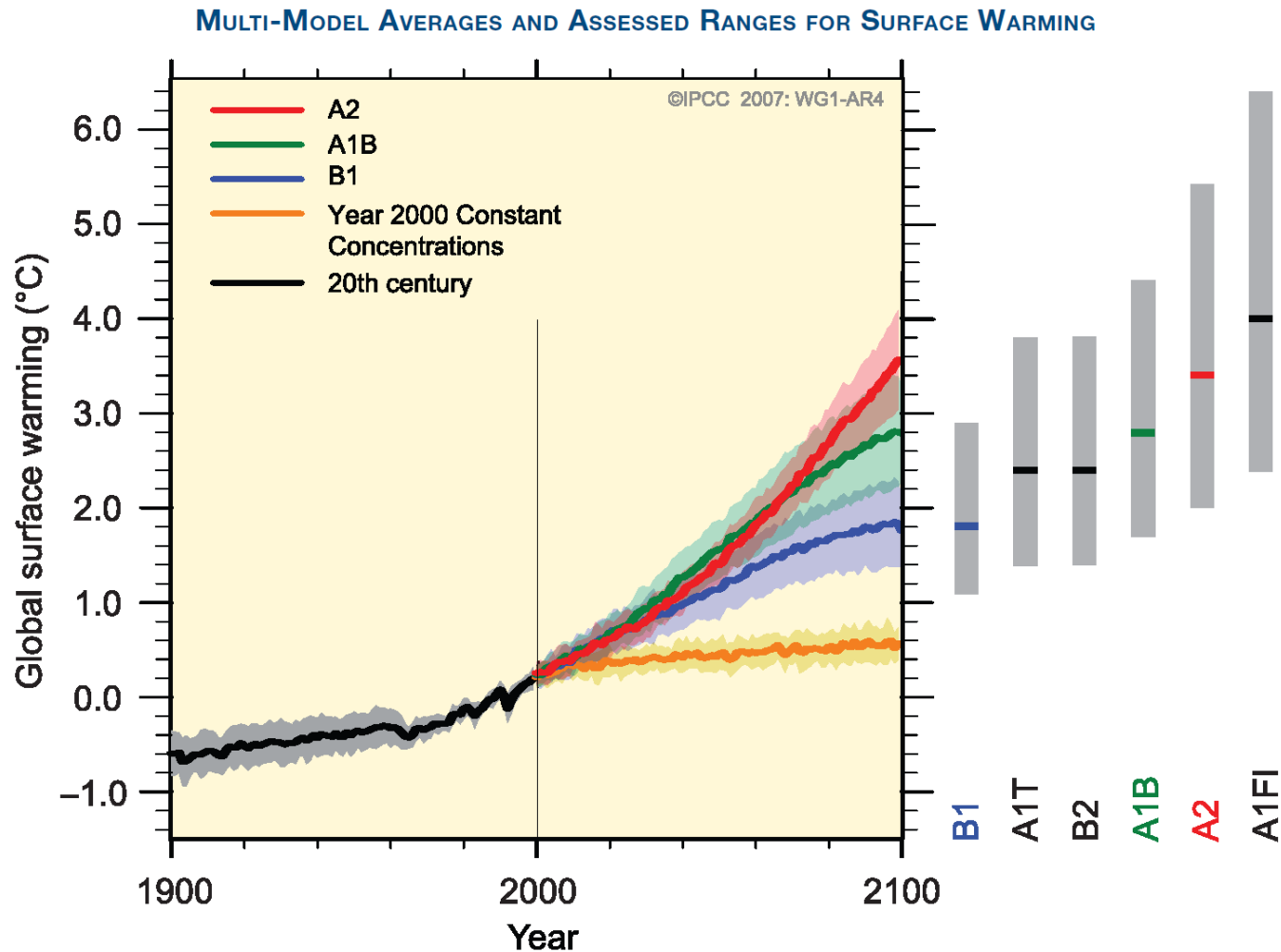


**Smoke and Mirrors:
Is Geoengineering
a Solution to Global Warming**

Adopted after Dr. Alan Robock <http://envsci.rutgers.edu/~robock>

“For the next two decades a warming of about 0.2°C per decade is projected for a range of SRES emission scenarios.

“Even if the concentrations of all greenhouse gases and aerosols had been kept constant at year 2000 levels, a further warming of about 0.1°C per decade would be expected.”



Despairing of prompt political response to global warming, renewed interests in geo-engineering
Paul Crutzen (Nobel Prize in Chemistry) and **Tom Wigley** (NCAR) in 2006

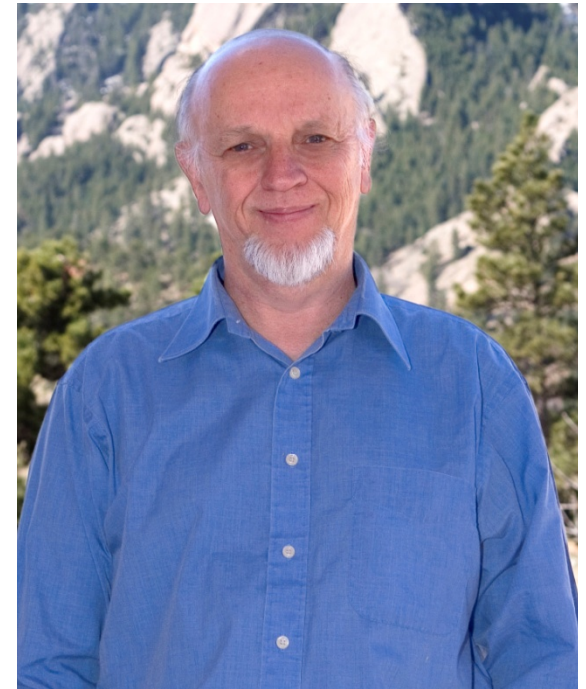
suggests that we consider temporary **geoengineering as an emergency response.**

Early Geo-engineering works:

Budyko 1977

National Academy of Sciences 1992

Dickinson 1996
(currently at UT Austin)



1992 National Academic Sciences on Policy Implications of Greenhouse Warming

Proposed GEOENGINEERING approaches:

- Reforestation Reforest 28.7 Mha of economically or environmentally marginal crop and pasture lands and nonfederal forest lands to sequester 10% of U.S. CO₂ emissions.
-
- Sunlight Screening
-
- *Space Mirrors* *Place 50,000 100-km² mirrors in the earth's orbit to reflect incoming sunlight.*
- *Stratospheric Dustc* *Use guns or balloons to maintain a dust cloud in the stratosphere to increase the sunlight reflection.*

- *Stratospheric Bubbles* *Place billions of aluminized, hydrogen-filled balloons in the stratosphere to provide a reflective screen.*
- *Low Stratospheric Dustc* *Use aircraft to maintain a cloud of dust in the low stratosphere to reflect sunlight.*
- *Low Stratospheric Sootc* *Decrease efficiency of burning in engines of aircraft flying in the low stratosphere to maintain a thin cloud of soot to intercept sunlight.*
- *Cloud Stimulationc* *Burn sulfur in ships or power plants to form sulfate aerosol in order to stimulate additional low marine clouds to reflect sunlight.*
- *Ocean Biomass Stimulation* *Place iron in the oceans to stimulate generation of CO₂-absorbing phytoplankton.*
- *Atmospheric CFC Removal* *Use lasers to break up CFCs in the atmosphere.*

Current Proposed [Geoengineering Schemes](#):

A. Space

Modifier of solar radiation

B. Stratospheric

Stratospheric aerosols (sulfate, soot, dust)

Stratospheric balloons or mirrors

C. Tropospheric

Modifying total reflection from marine stratus clouds

D. Surface

Making deserts more reflective

Modifying ocean albedo

Reforestation (CO₂ effect, but albedo effect causes warming)

Direct absorption of CO₂

Ocean fertilization

W

The WILSON QUARTERLY
SURVEYING THE WORLD OF IDEAS

Q

Africa's Village of Dreams

By SAM RICH

The Homeland Security Hash

By PAUL C. LIGHT

Portrait of a Math Genius

By JOHN DERRYSHIRE

Scatteration

By WITOLD RYBCZYNSKI



The Climate Engineers

Playing God to
Save the Planet

By JAMES R. FLEMING

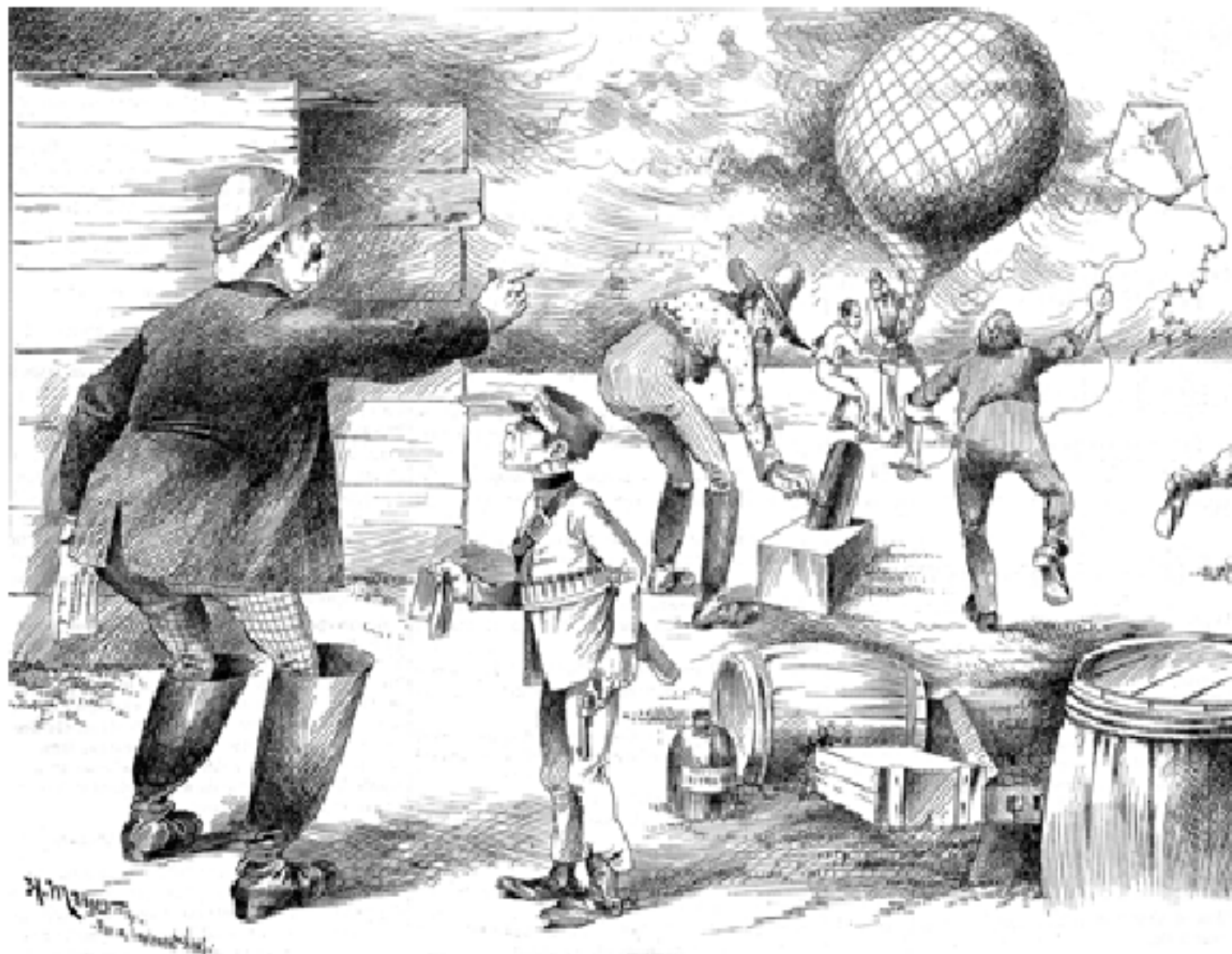
SPRING 2007

\$6.95 (USD/CAN)

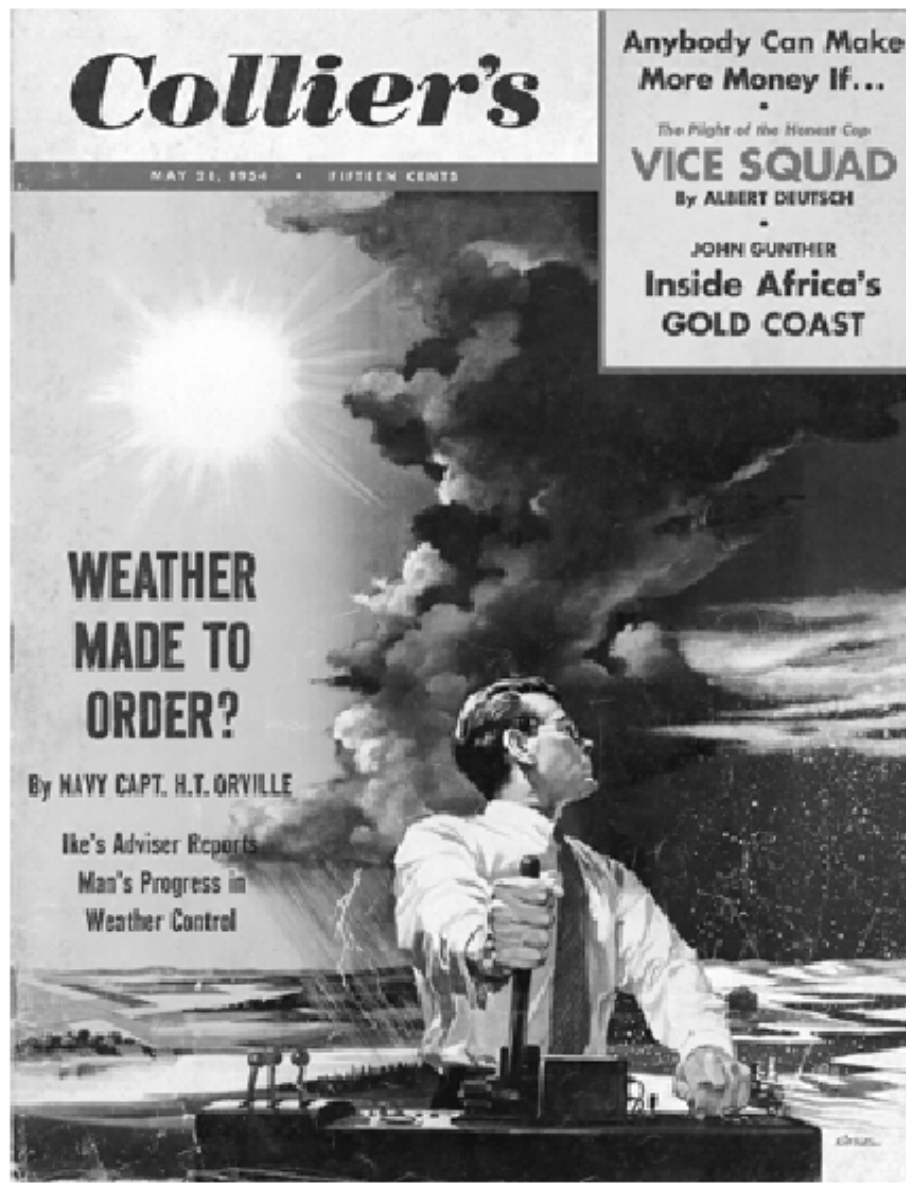


Woodrow Wilson
International
Center
for Scholars

The Climate Engineers



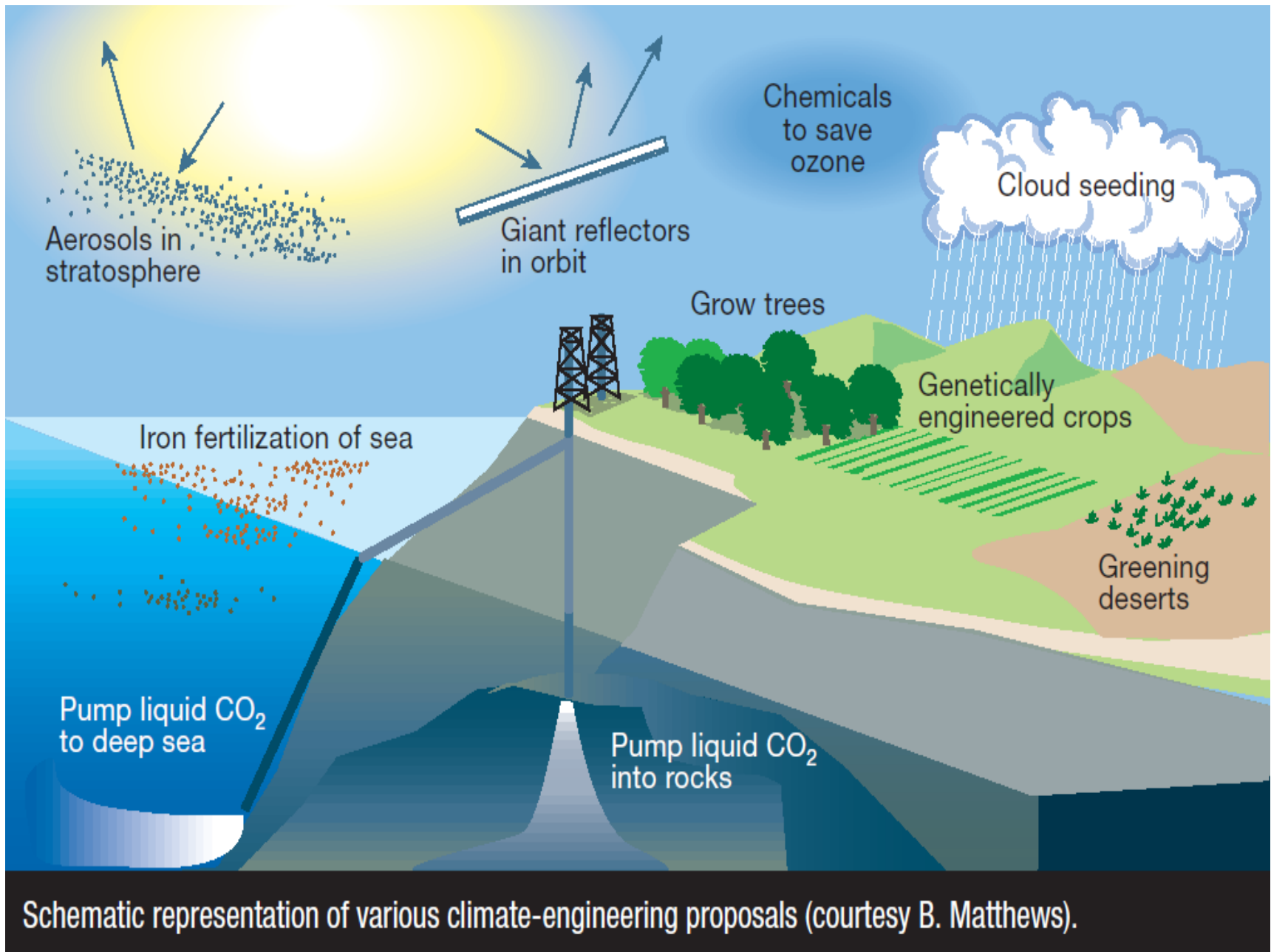
Robert St. George Dyrenforth claimed success after his federally funded rainmaking mission to Texas in 1891, but in this cartoon from a local magazine he is shown ordering his assistants to speed up: "Here's a telegram announcing a storm. If we don't hurry, it will be on before we raise our racket."



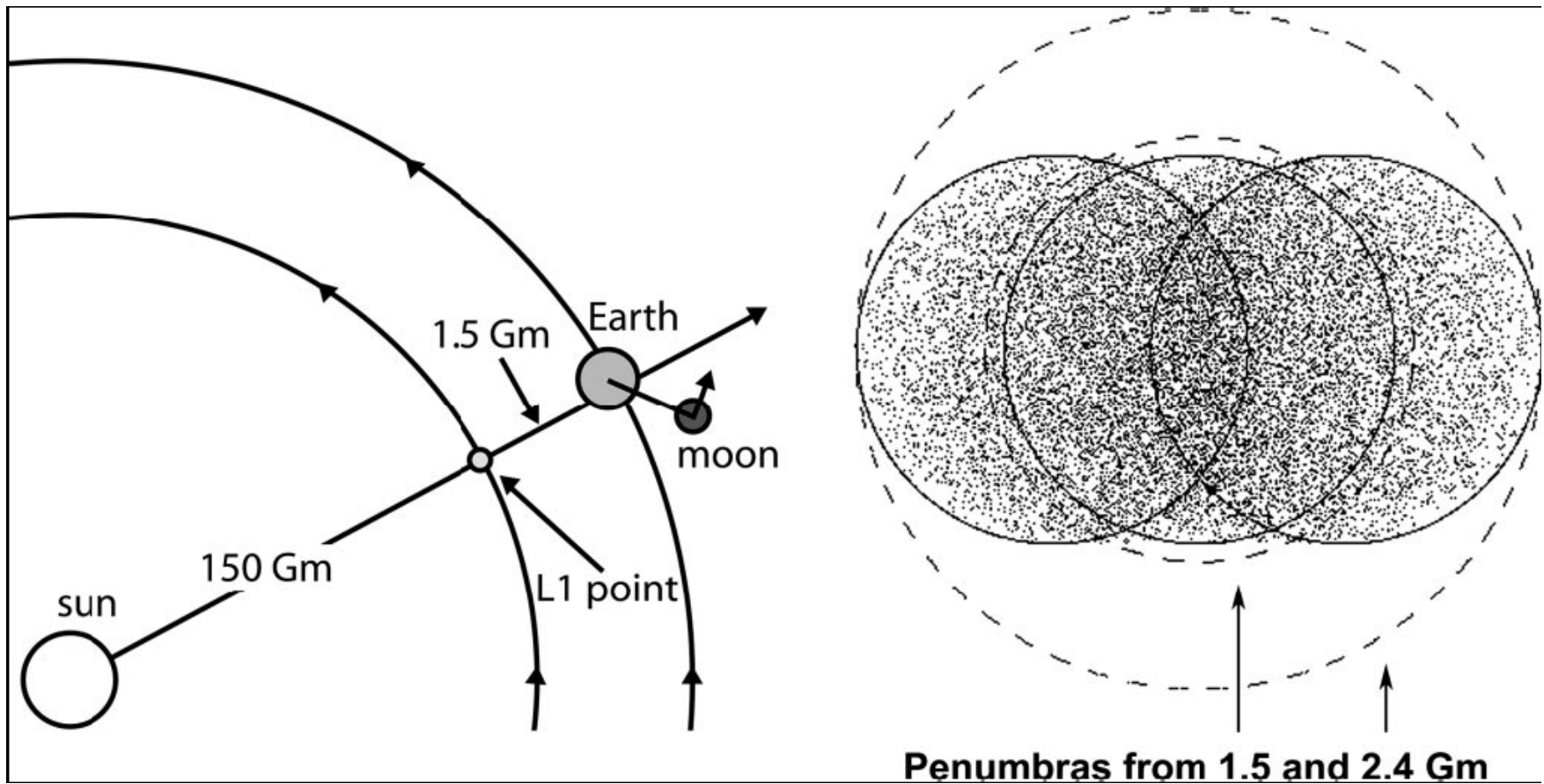
Experiments with cloud seeding during the Cold War inspired fantastic predictions about America's ability to control the weather, as in this 1954 article, and use it as a weapon against its communist adversaries.



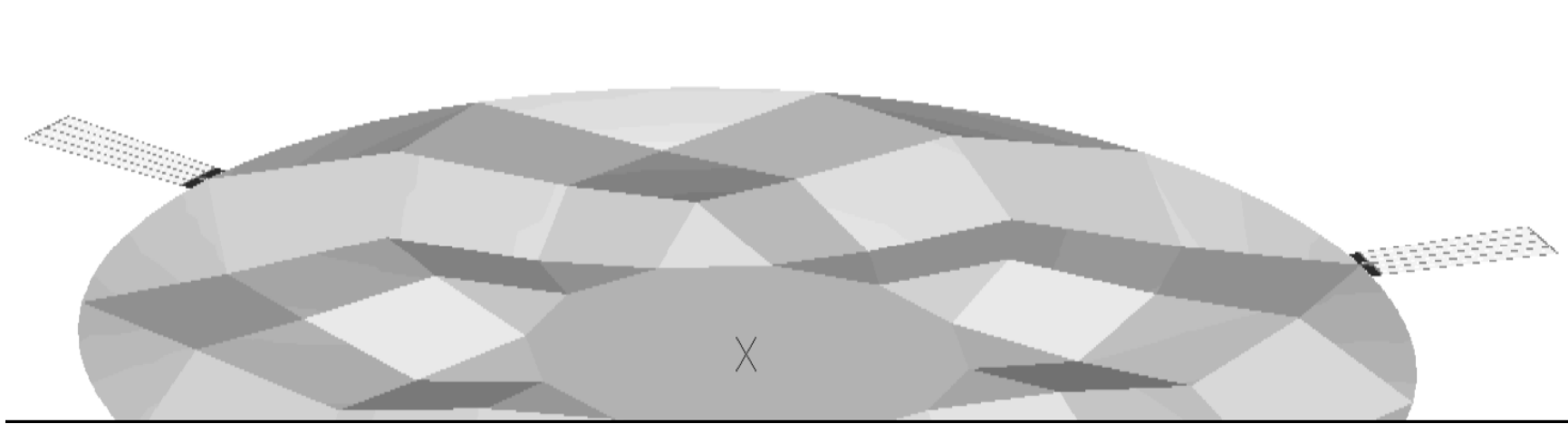
Ridicule greeted a 1992 proposal to combat global warming by shooting reflective particles into the atmosphere. The response could be different today.



Keith, David, 2001: Geoengineering, *Nature*, **409**, 420.



Angel, Roger, 2006: Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1). *Proc. Nat. Acad. Sci.*, **103**, 17,184-17,189.

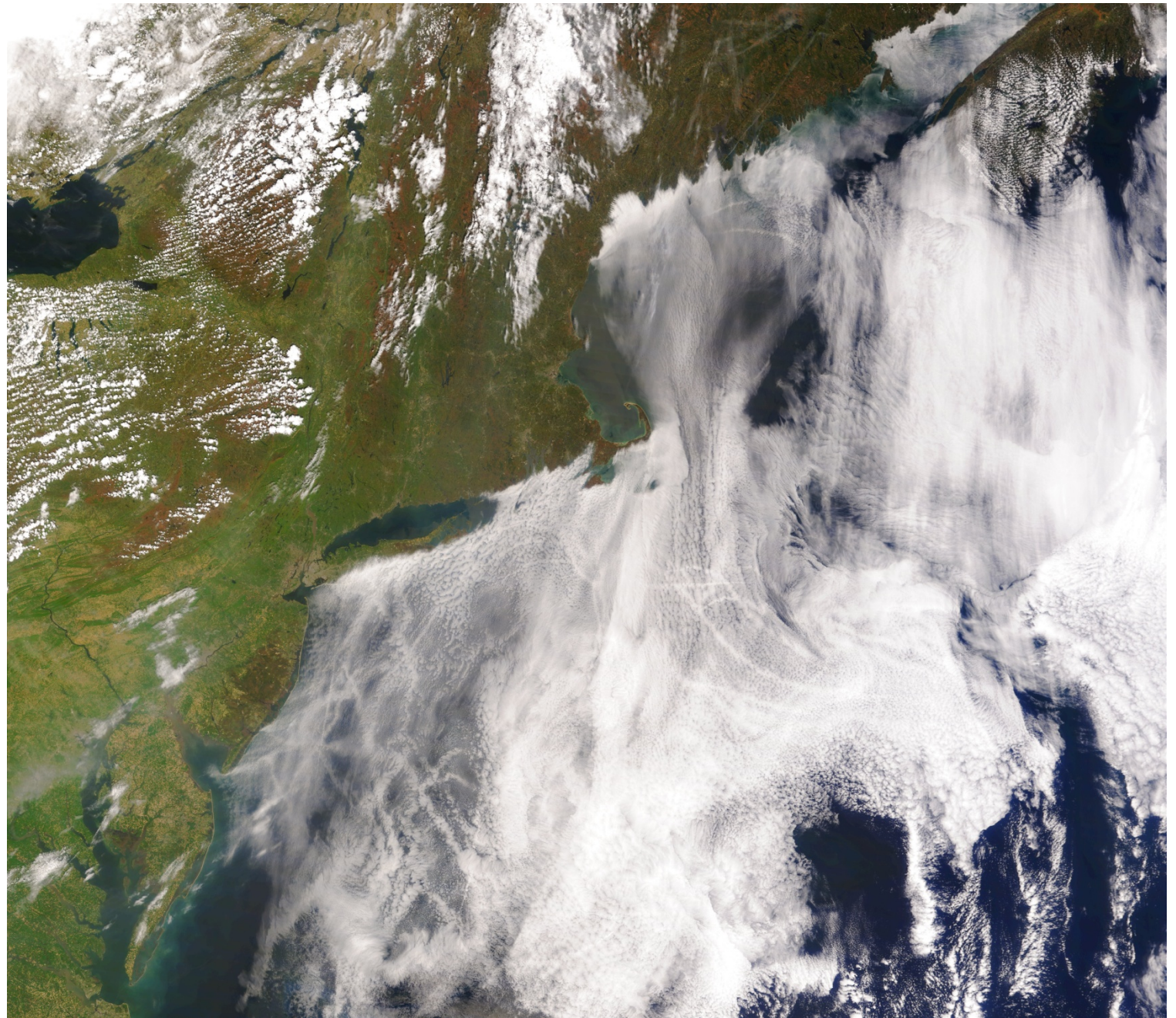


Flyer concept. The 0.6 m diameter, 5 μm thick refracting disc is faceted to improve stiffness. The three 100 μm thick tabs have 2% of the disc area, and contain the MEMS solar sails, tracker cameras, control electronics and solar cells.

He envisions over a 10-yr period, vertical 2-km magnetic launchers with 800,000 flyers each, every 5 min from 20 sites simultaneously to put 20 Mt of flyers into orbit.

Angel, Roger, 2006: Feasibility of cooling the Earth with a cloud of small spacecraft near the inner Lagrange point (L1). *Proc. Nat. Acad. Sci.*, **103**, 17,184-17,189.

This image of **ship tracks** was taken by the Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Terra satellite on May 11, 2005.



Scheme by John Latham (University of Manchester, NCAR) and Steve Salter (University of Edinburgh) to increase cloud albedo with by injecting more sea salt cloud condensation nuclei into **marine stratus clouds.**

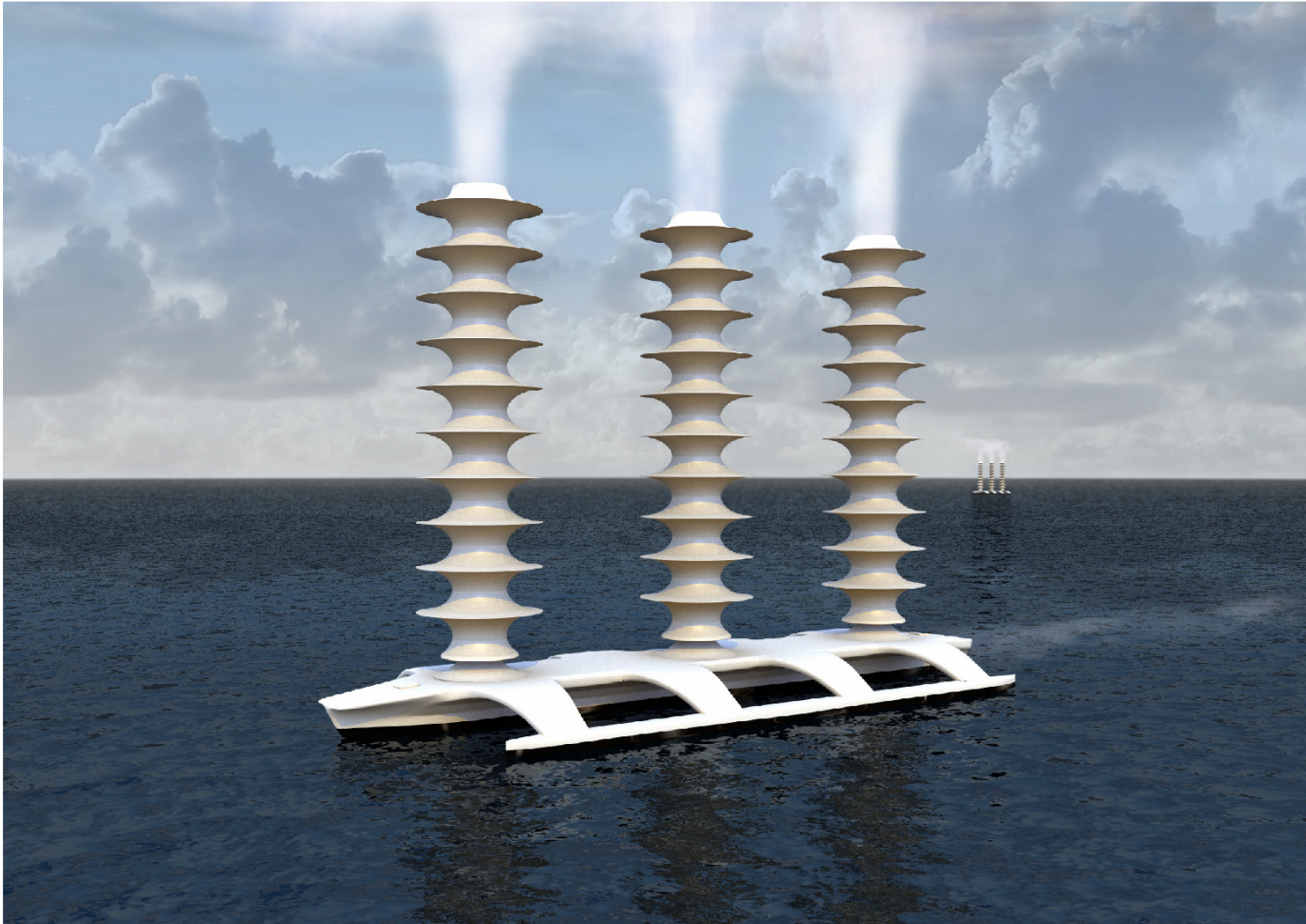


Figure 4. Albedo spray vessels. They would sail back and forth square to the local prevailing wind. Flettner rotors with Thom fences can give lift coefficients up to 20 and lift drag ratios of 35, much higher than cloth sails. Artwork by John MacNeill.

Proposals for “solar radiation management” using injection of stratospheric aerosols

1. Inject them into the tropical stratosphere, where winds will spread them around the world and produce global cooling, like tropical volcanic eruptions have.
2. Inject them at high latitudes in the Arctic, where they will keep sea ice from melting, while any negative effects would not affect many people.

How could we actually get the sulfate aerosols into the stratosphere?

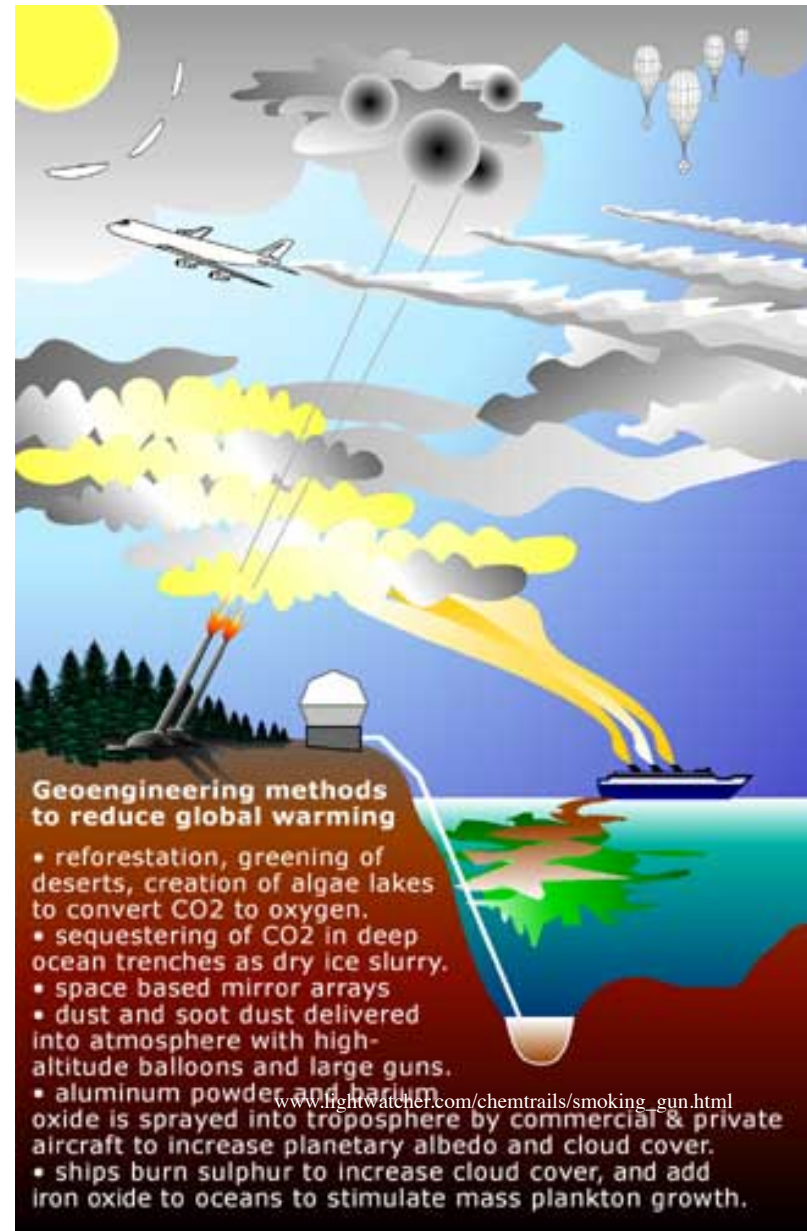
Artillery?

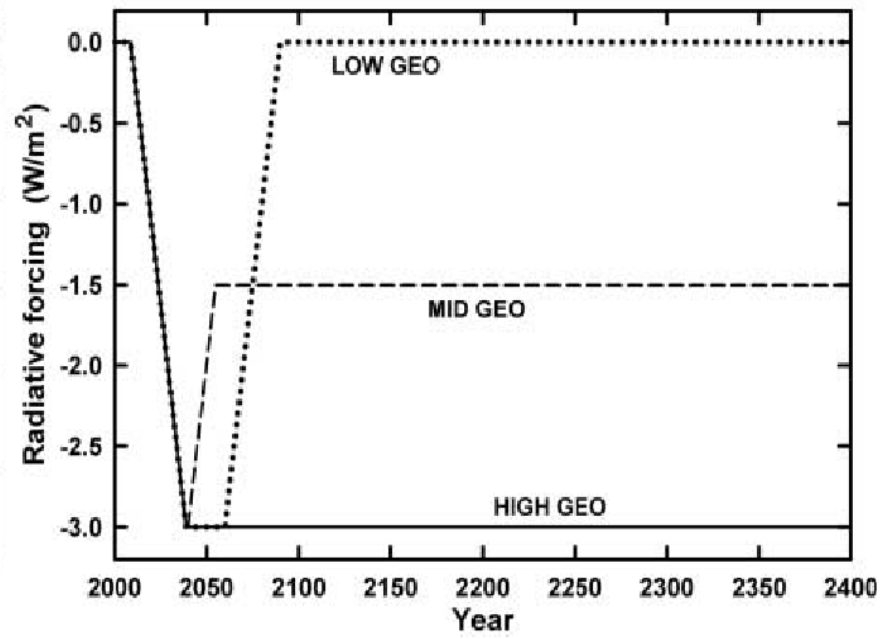
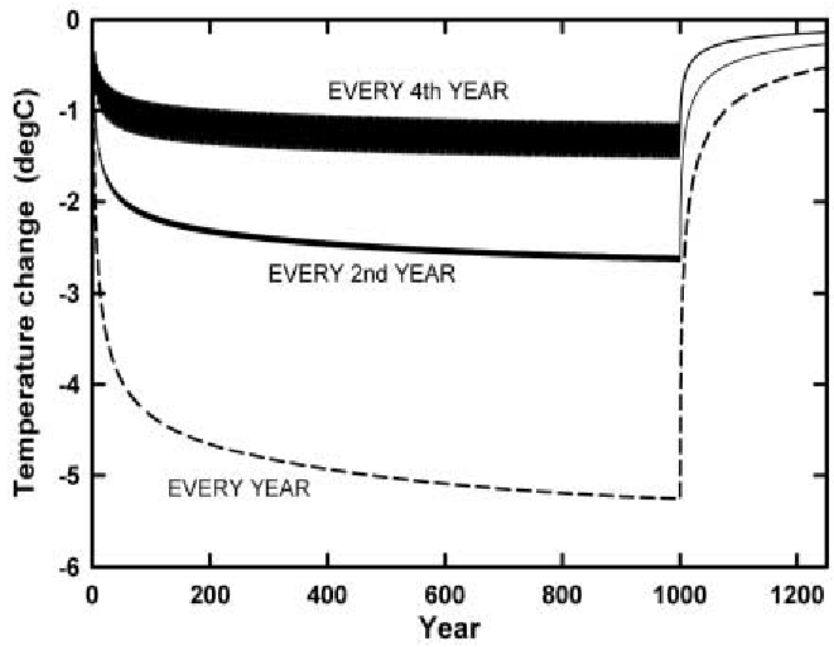
Aircraft?

Missiles?

Balloons?

Tethered balloons with a hose?

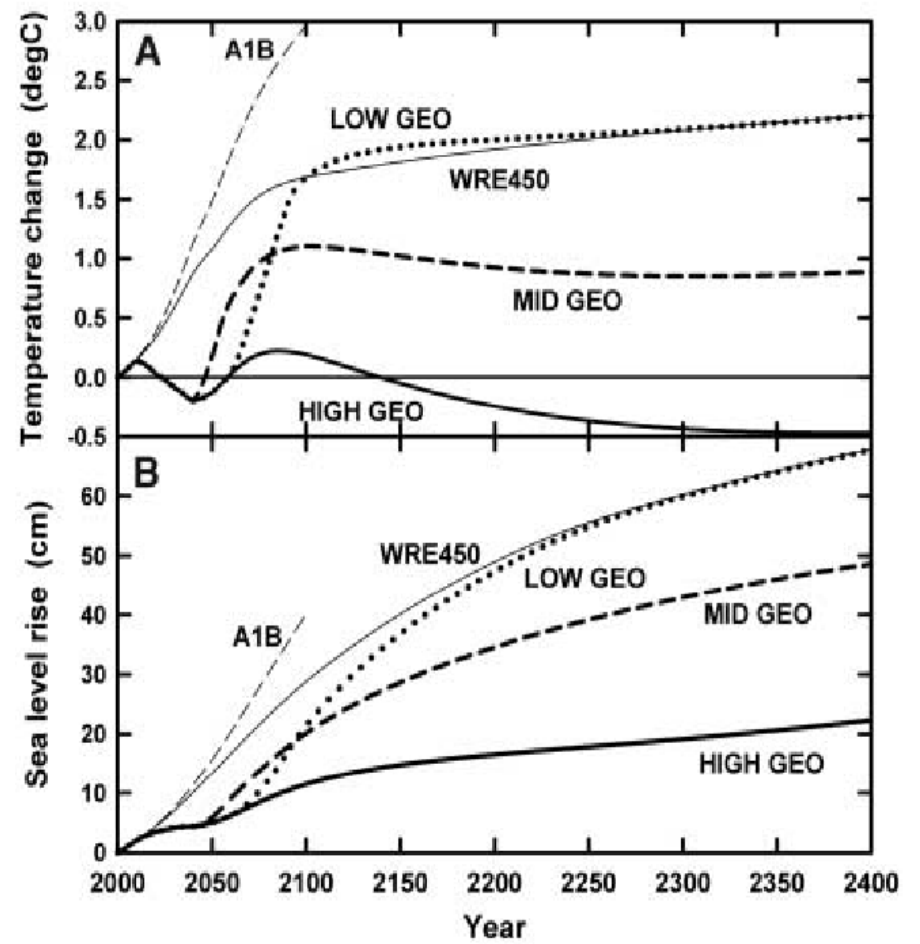
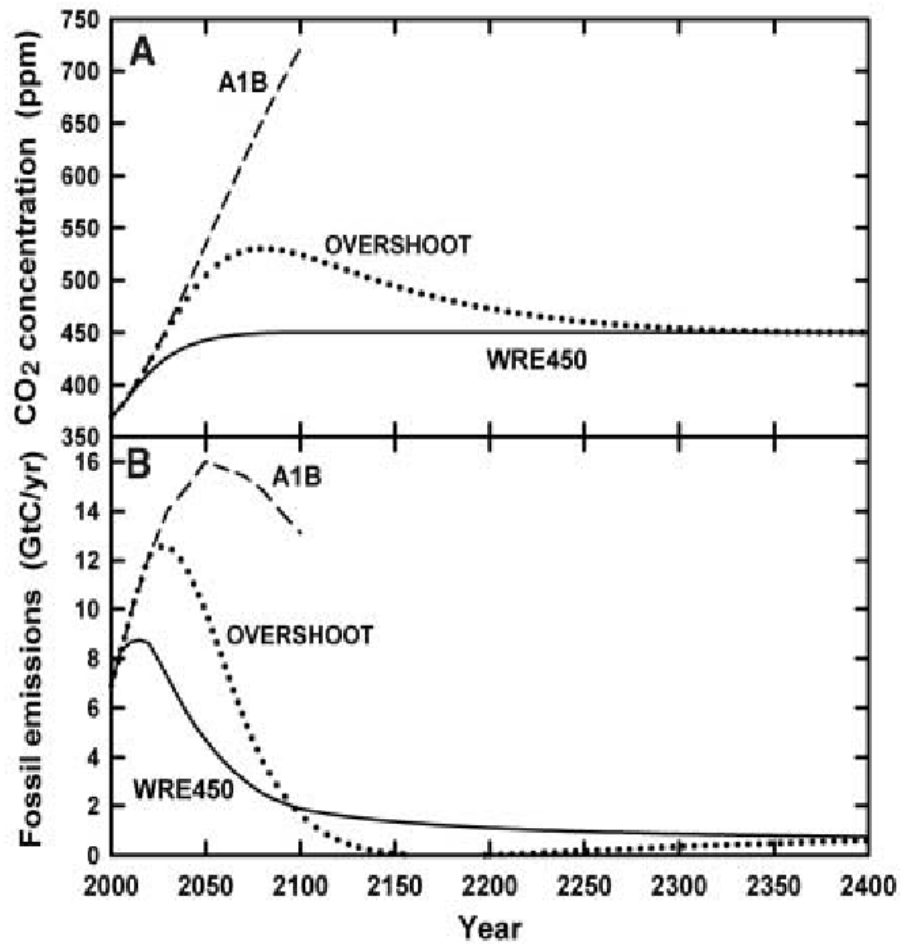




Global mean temperature response to multiple volcanic eruptions (Pinatubo-size)

Radiative forcing scenarios for three geoengineering options considered. HIGH GEO option corresponds approximately to the steady-state forcing that would result from eruptions of Mount Pinatubo every 2 years.

Wigley, T. M. L., 2006: A combined mitigation/geoengineering approach to climate stabilization. *Science*, **314**, 452-454.



Wigley, T. M. L., 2006: A combined mitigation/geoengineering approach to climate stabilization. *Science*, **314**, 452-454.

Two views on Arctic geoengineering: 1

A STEP TOWARD SAVING OUR ARCTIC

Gregory Benford

Department of Physics & Astronomy, Univ. of California, Irvine

Dec. 4, 2006, Google Geoengineering Groups

“One could use just enough of the tiny particles to create a readily measurable shielding effect. An initial experiment could occur north of 70 degrees latitude, over the Arctic Sea and outside national boundaries. The particles would reflect mostly UV rays back into space. They would reduce warming and stop the harm of UV rays to plants and animals, as a side effect. Robust photosynthesis would still occur in the tundra, fueled by the visible spectrum.

“This idea exploits our expanding understanding of the climate system. It also uses our historical knowledge of the marked cooling driven by volcanoes in the last several centuries, from sulfate aerosols at high altitude. But sulfates interact chemically with the high altitude air. We can avoid that by using less chemically reactive particles, such as diatomaceous earth. Our aim should be to edit the incoming sunlight, not to interfere with our atmosphere's chemistry.”

Two views on Arctic geoengineering: 2

(In response to New York Times Op-Ed “How to Cool the Globe” by Ken Caldeira, October 24, 2007)

Screwing (with) the Planet

James Fleming
Colby College, Waterville, ME

We would all like to see the polar bears flourish, but Ken Caldeira's suggestion to “seed” the Earth's stratosphere with acidic particles using military technology is not the way to do this.

Naval artillery, rockets, and aircraft exhaust are all “manly” ways to declare “war” on global warming. “A fire hose suspended from a series of balloons” alludes to the proposal by Edward Teller's protégé Lowell Wood to attach a 25-mile long phallus to a futuristic military High Altitude Airship. If the geoengineers can't keep it up, imagine a “snake” filled with more than a ton of acid ripping loose, writhing wildly, and falling out of the sky!

The pair of overheated polar bears in the cartoon alludes to such nonsense. And whose warships are those in the distance? Better check with Vladimir Putin before we screw (with) the Arctic.



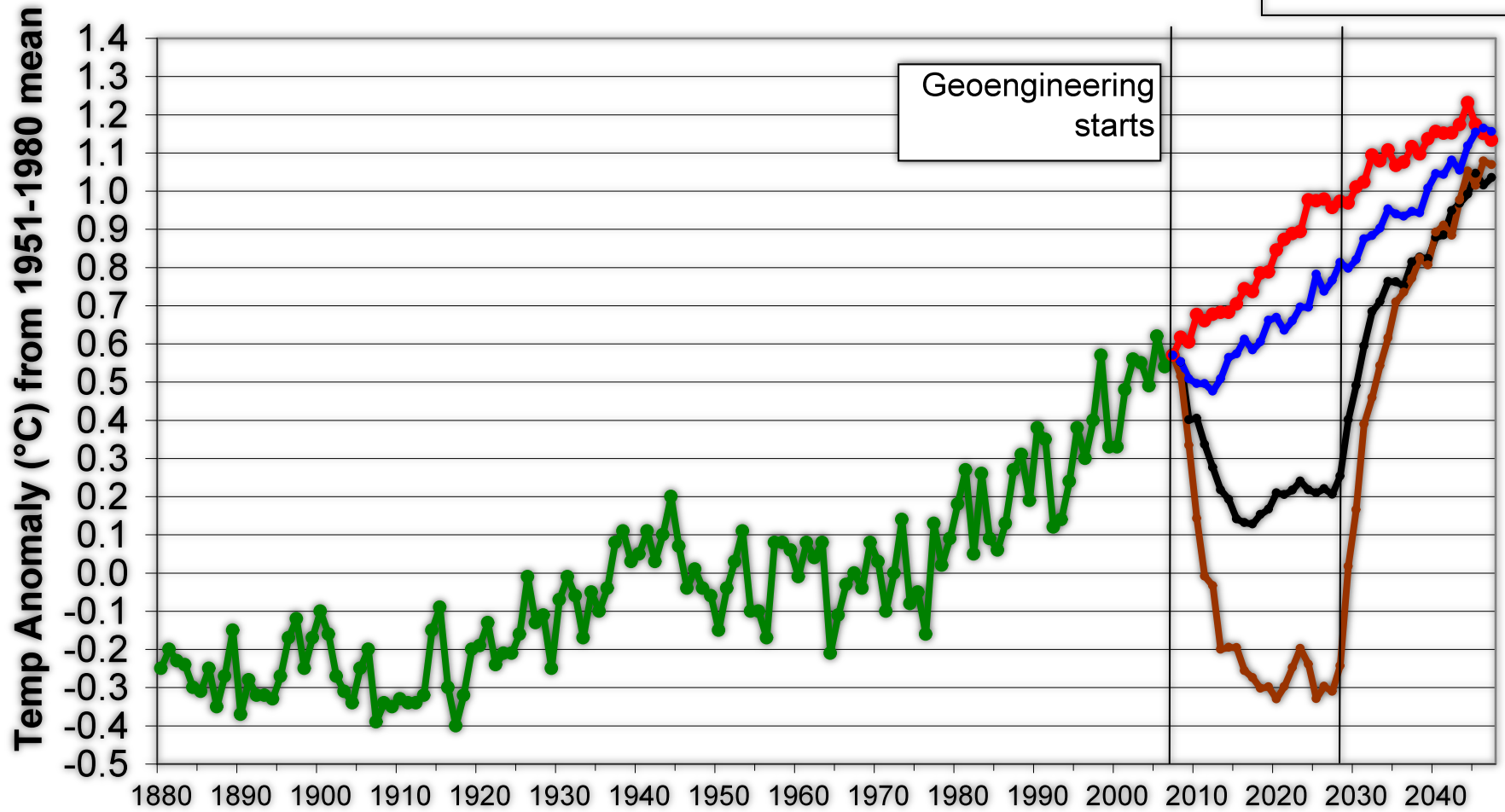
Robock et al. conducted the following geoengineering simulations with the NASA GISS ModelE atmosphere-ocean general circulation model run at 4°x 5° horizontal resolution with 23 vertical levels up to 80 km, coupled to a 4°x 5° dynamic ocean with 13 vertical levels and an online chemistry and transport module:

- 80-yr **control** run
- 40-yr **anthropogenic** forcing, IPCC A1B scenario: greenhouse gases (CO₂, CH₄, N₂O, O₃) and tropospheric aerosols (sulfate, biogenic, and soot), 3-member ensemble
- 40-yr **Arctic lower stratospheric injection** of 3 Mt SO₂/yr, 3-member ensemble
- 40-yr **tropical lower stratospheric injection** of 5 Mt SO₂/yr , 3-member ensemble

GISS Global Average Temperature Anomaly

+ Anthro Forcing, 3 Mt/yr Arctic,
5 Mt/yr Tropical, 10 Mt/yr Tropical

Geoengineering
ends



Conclusions

1. If there were a way to continuously inject SO₂ into the lower stratosphere, it would produce global cooling.
2. Tropical SO₂ injection would produce sustained cooling over most of the world, with more cooling over continents.
3. Arctic SO₂ injection would not just cool the Arctic.
4. Both tropical and Arctic SO₂ injection would disrupt the Asian and African summer monsoons, reducing precipitation to the food supply for billions of people.

Reasons geoengineering may be a bad idea

Climate system response

1. Regional climate change, including temperature and precipitation
2. Continued ocean acidification
3. Ozone depletion
4. Effects on plants of changing the amount of solar radiation and partitioning between direct and diffuse
5. Enhanced acid precipitation
6. Effects on cirrus clouds as aerosols fall into the troposphere
7. Whitening of the sky (but nice sunsets)
8. Less solar radiation for solar power, especially for those requiring direct radiation
9. Rapid warming when it stops
10. How rapidly could effects be stopped?
11. Environmental impacts of aerosol injection, including producing and delivering aerosols, or of launches every 5 minutes of Angel's flyers

Reasons geoengineering may be a bad idea

Unknowns

12. Human error
13. Unexpected consequences (How well can we predict the expected effects of geoengineering? What about unforeseen effects?)

Political, ethical and moral issues

14. Schemes perceived to work will lessen the incentive to mitigate greenhouse gas emissions
15. Use of the technology for military purposes. Are we developing weapons?
16. Commercial control of technology
17. Violates UN Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques
18. Would be tremendously expensive
19. Even if it works, whose hand will be on the thermostat? How could the world agree on the optimal climate?
20. Who has the moral right to advertently modify the global climate?

Reasons mitigation is a good idea

Proponents of geoengineering say that mitigation is not possible, as they see no evidence of it yet. But it is clearly a political and not a technical problem.

Mitigation will not only reduce global warming but it will also

- reduce ocean acidification,
- reduce our dependence on foreign sources of energy,
- stop subsidizing terrorism with our gas dollars,
- - provide economic opportunities for a green economy, to provide solar, wind, cellulosic ethanol, energy efficiency and other technologies we can sell around the world.

What do you think?

