



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

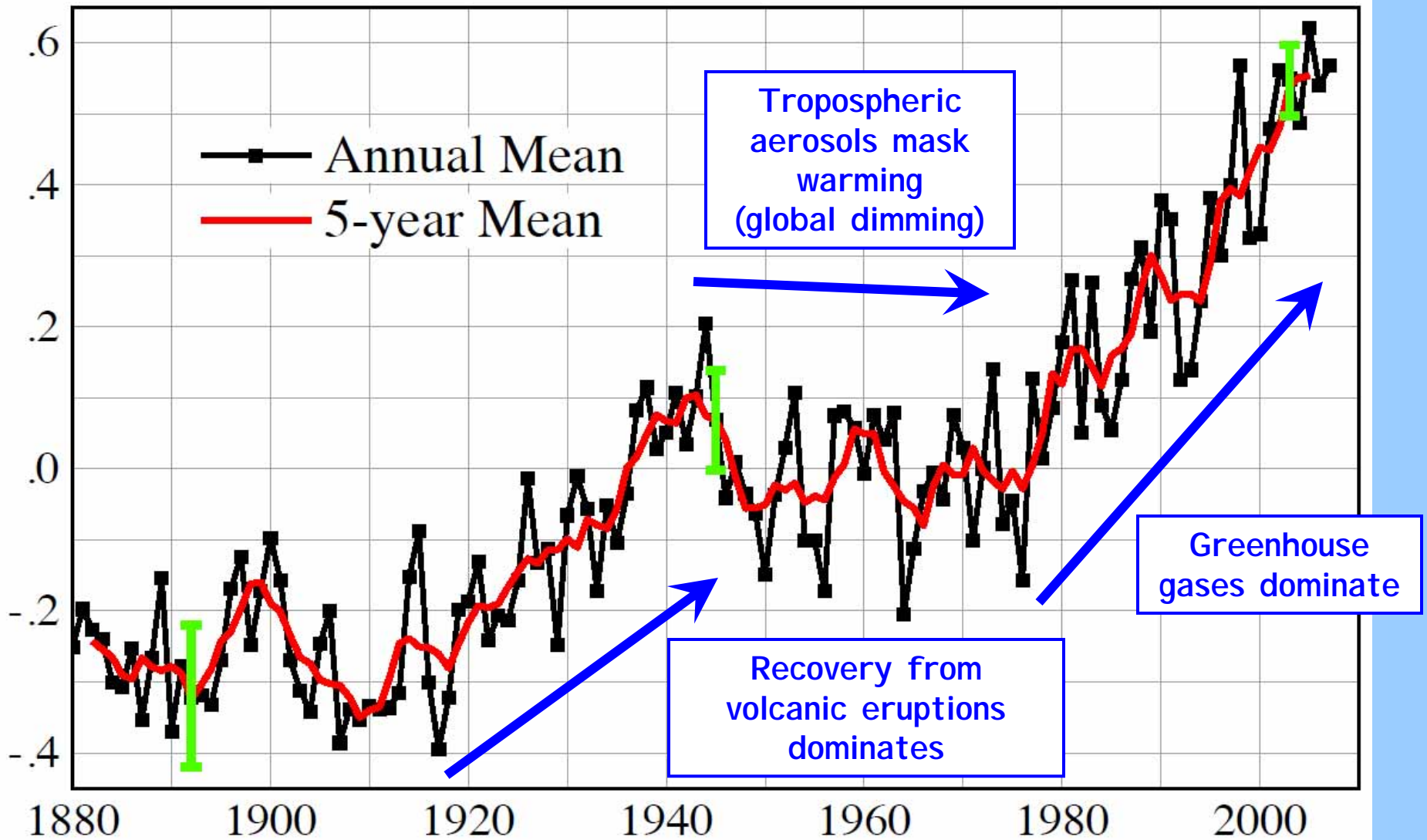
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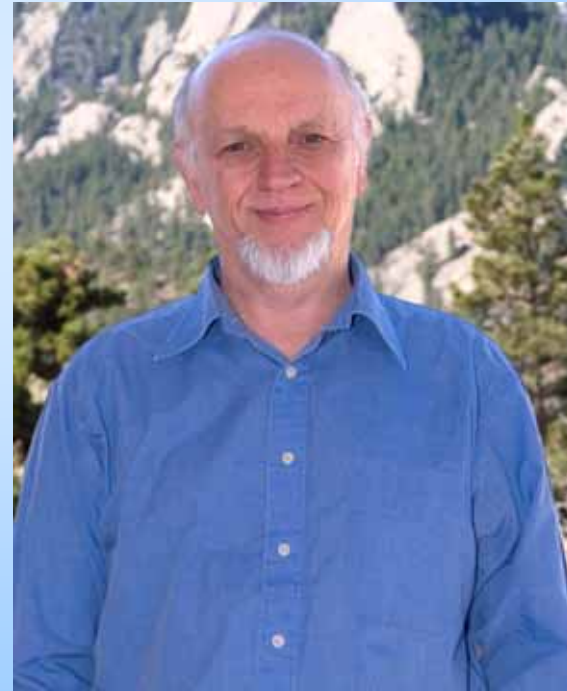
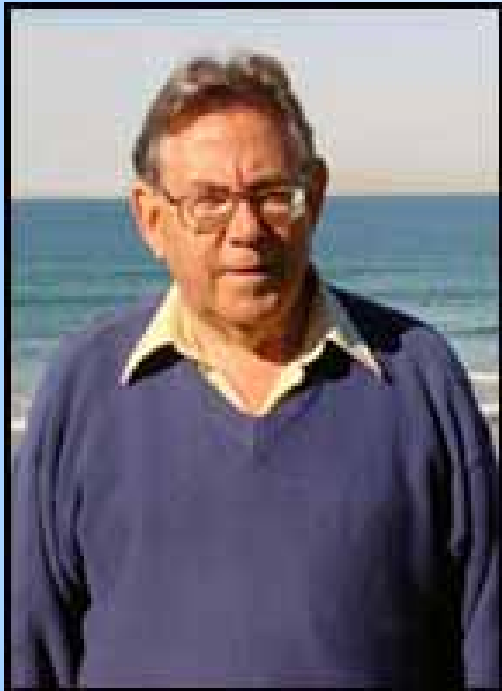
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(a) Global Temperature Change ($^{\circ}\text{C}$)



Despairing of prompt political response to global warming, in August and September 2006, Paul Crutzen (Nobel Prize in Chemistry) and Tom Wigley (NCAR) suggested that we consider temporary geoengineering as an emergency response.



DR. EVIL'S PLAN TO STOP GLOBAL WARMING

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HIP-HOP
REPORT

JAY-Z

NAS

DIDDY

YOUNG

JEEZY

TUPAC

Jon Stewart &
Stephen Colbert

AMERICA'S
ANCHORS

By Maureen Dowd

★★★★
THE WHO
RETURN!

BORAT
COMEDY OF
THE YEAR

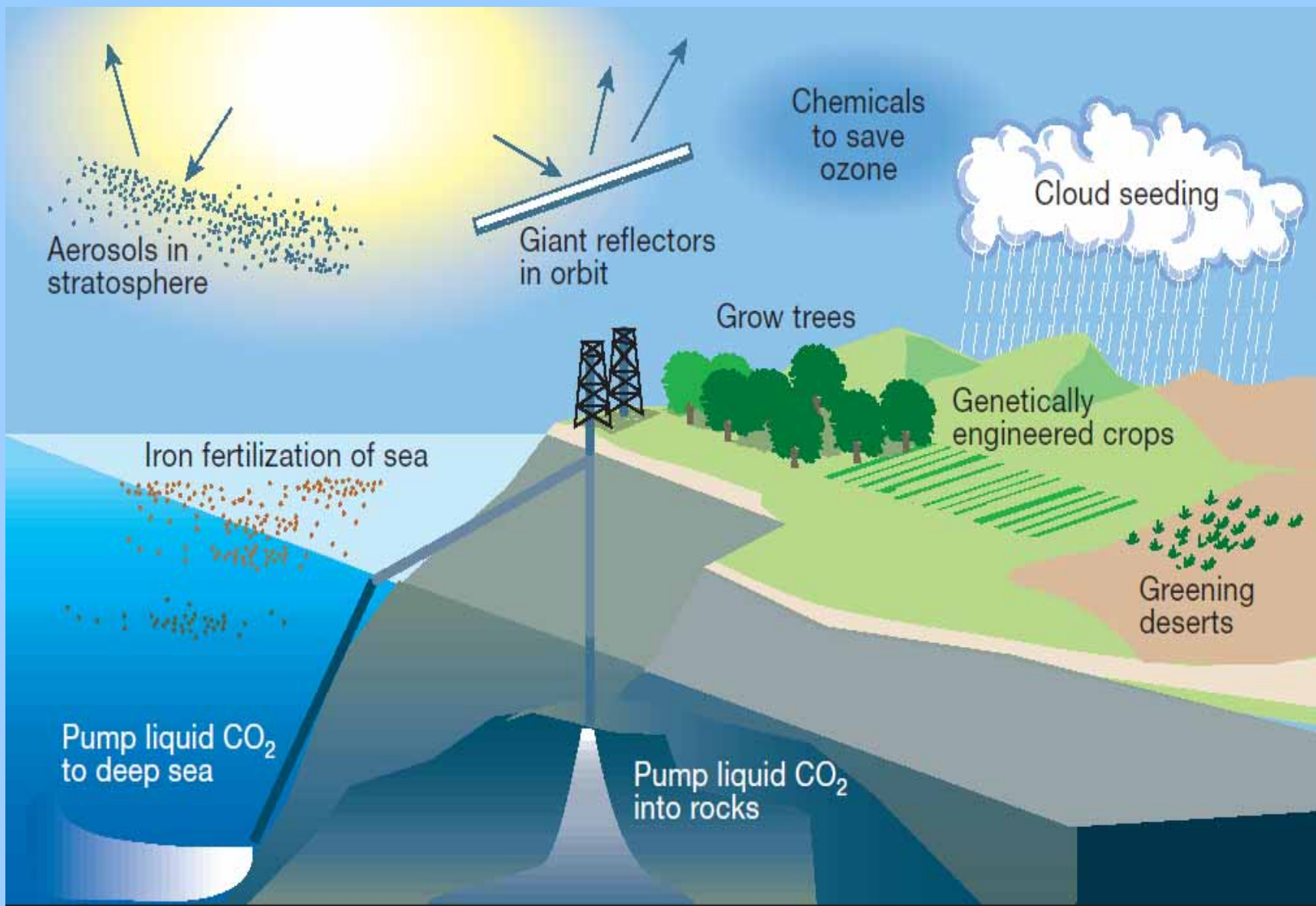
Can Dr. Evil Save The World?

Forget about a future filled with wind farms and hydrogen cars. The Pentagon's top weaponeer says he has a radical solution that would stop global warming now -- no matter how much oil we burn.

Jeff Goodell
Rolling Stone

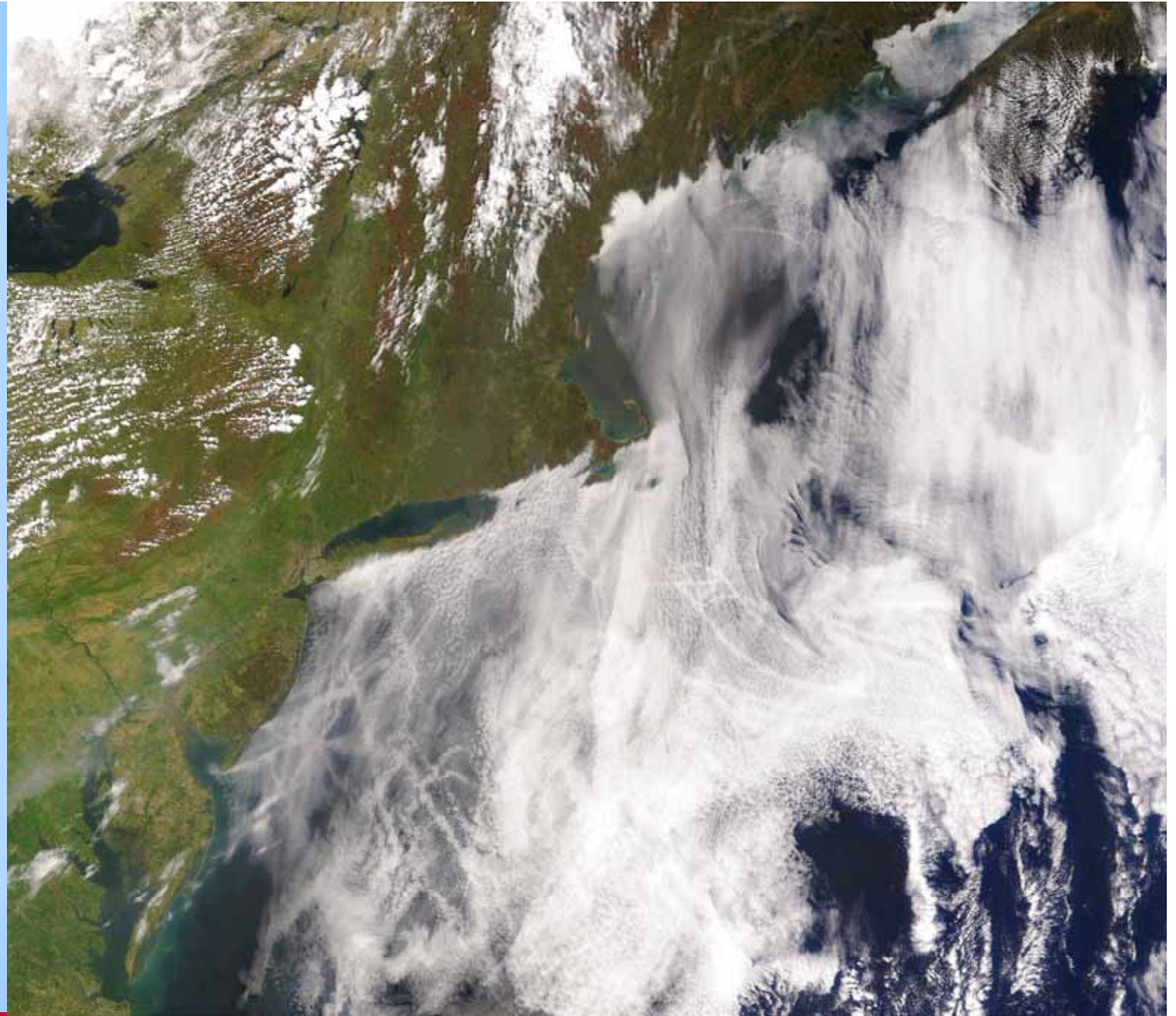
November 3, 2006





Schematic representation of various climate-engineering proposals (courtesy B. Matthews).

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.



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

Robock, Alan, 2008: 20 reasons why geoengineering may be a bad idea. *Bull. Atomic Scientists*, 64, No. 2, 14-18, 59, doi:10.2968/064002006.

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.



© New York Times, Henning
Wagenbreth, Oct. 24, 2007

We 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:

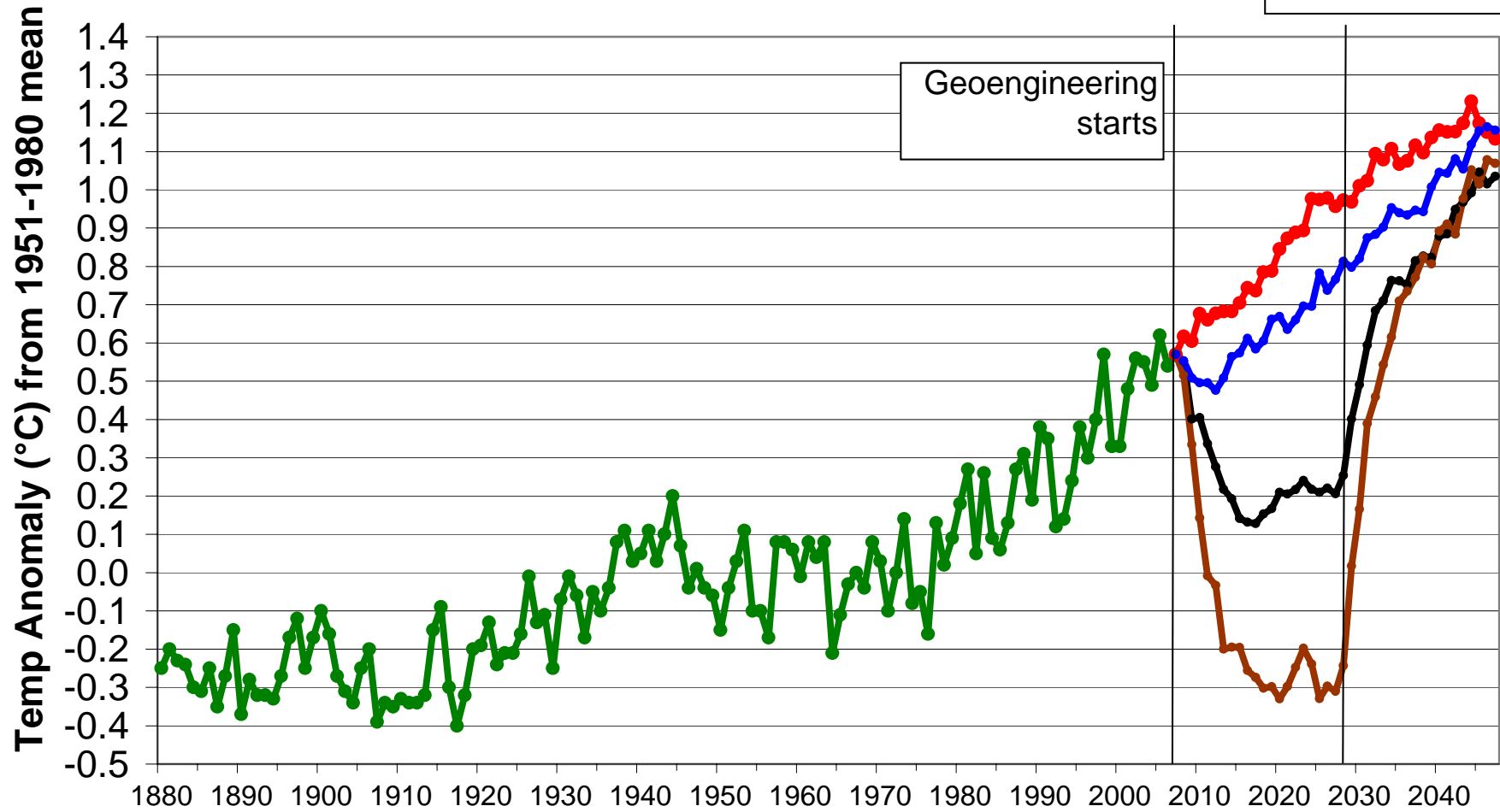
- 80-yr control run
- 40-yr anthropogenic forcing, IPCC A1B scenario: greenhouse gases (CO₂, CH₄, N₂O, O₃) and tropospheric aerosols (sulfate, biogenic, and soot), 3-member ensemble
- 40-yr IPCC A1B + Arctic lower stratospheric injection of 3 Mt SO₂/yr, 3-member ensemble
- 40-yr IPCC A1B + Tropical lower stratospheric injection of 5 Mt SO₂/yr, 3-member ensemble
- 40-yr IPCC A1B + Tropical lower stratospheric injection of 10 Mt SO₂/yr

Robock, Alan, Luke Oman, and Georgiy Stenchikov, 2008: Regional climate responses to geoengineering with tropical and Arctic SO₂ injections. *J. Geophys. Res.*, 113, D16101, doi:10.1029/2008JD010050

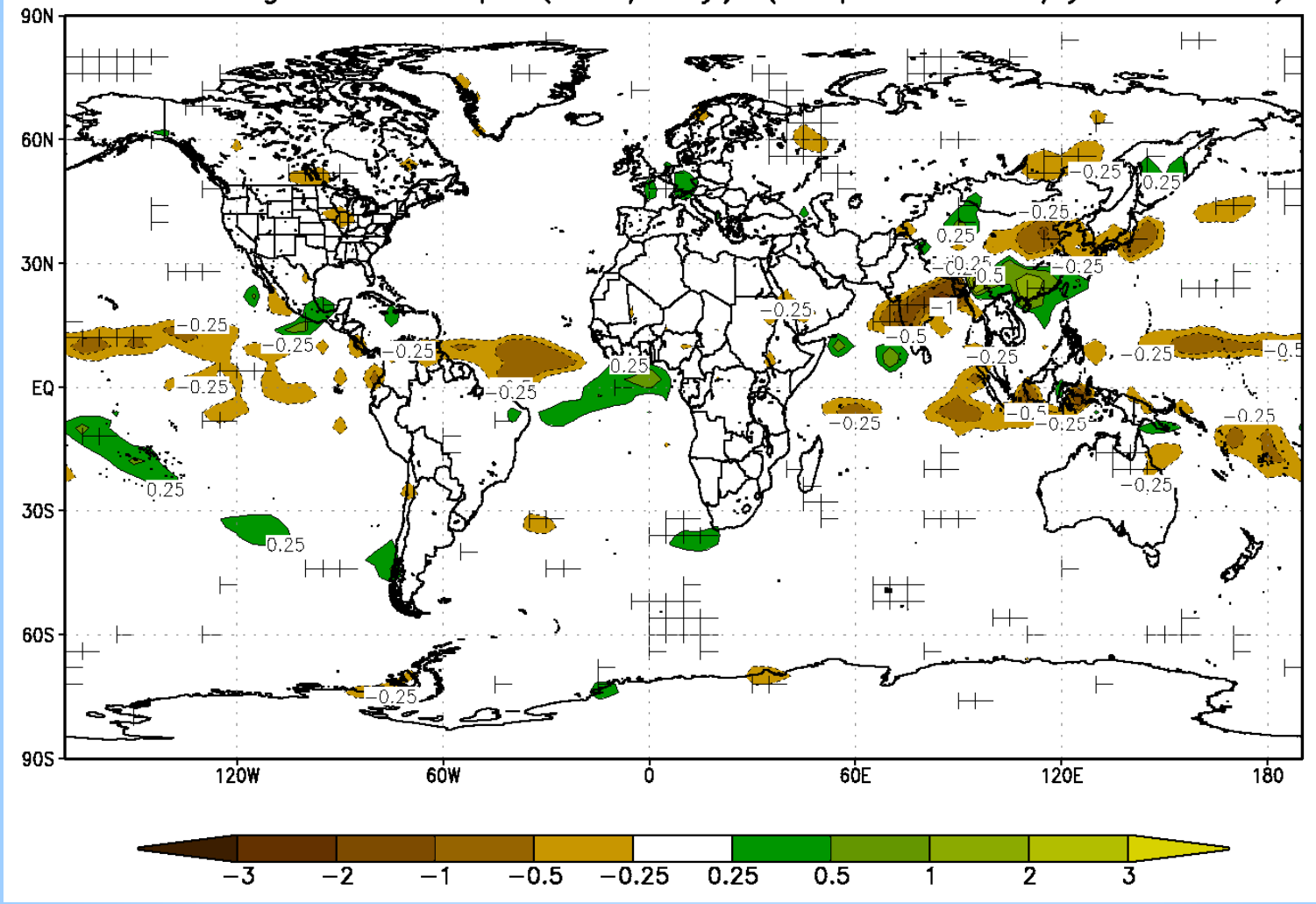
GISS Global Average Temperature Anomaly

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

Geoengineering ends

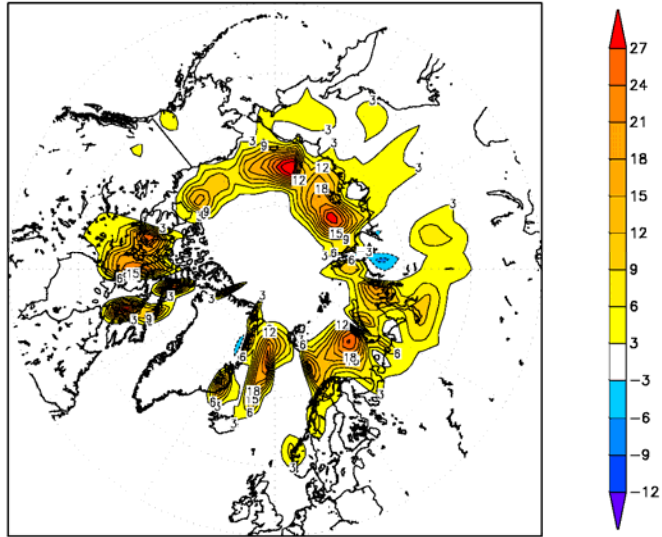


JJA Change in Precip. (mm/day) (Tropical 5 Mt/yr-Control)

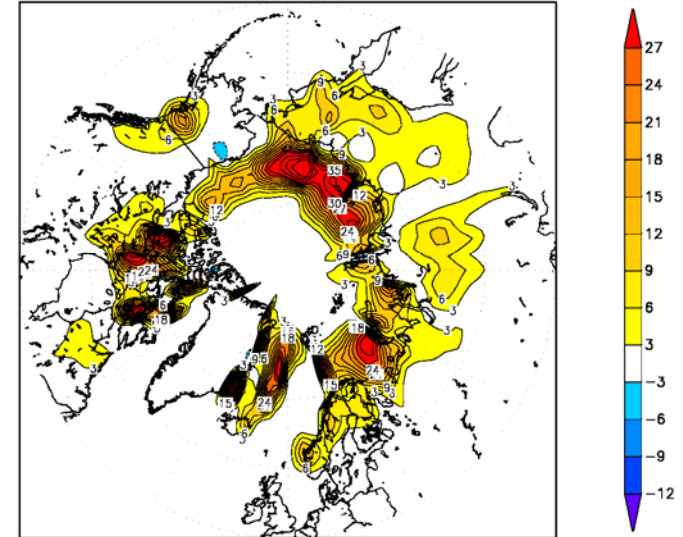


⊞ = significant at the 95% level

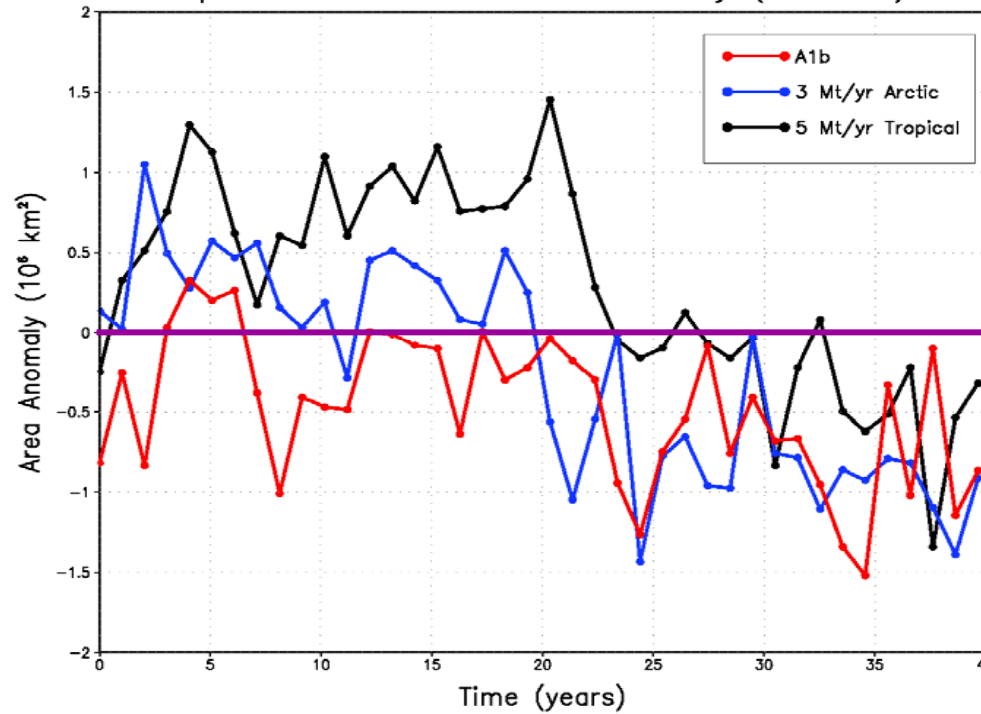
Sept. Change in Snow & Ice (%) Years 10–19 (Arctic 3 Mt/yr)



Sept. Change in Snow & Ice (%) Years 10–19 (Trop. 5 Mt/yr)



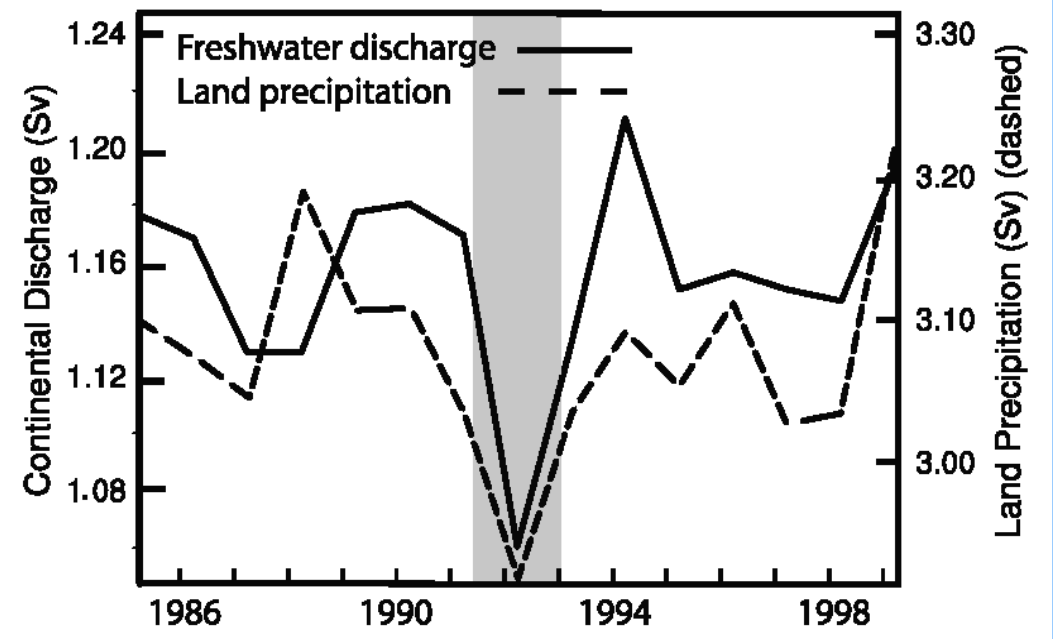
Sept. NH Ocean Ice Area Anomaly (10^6 km^2)



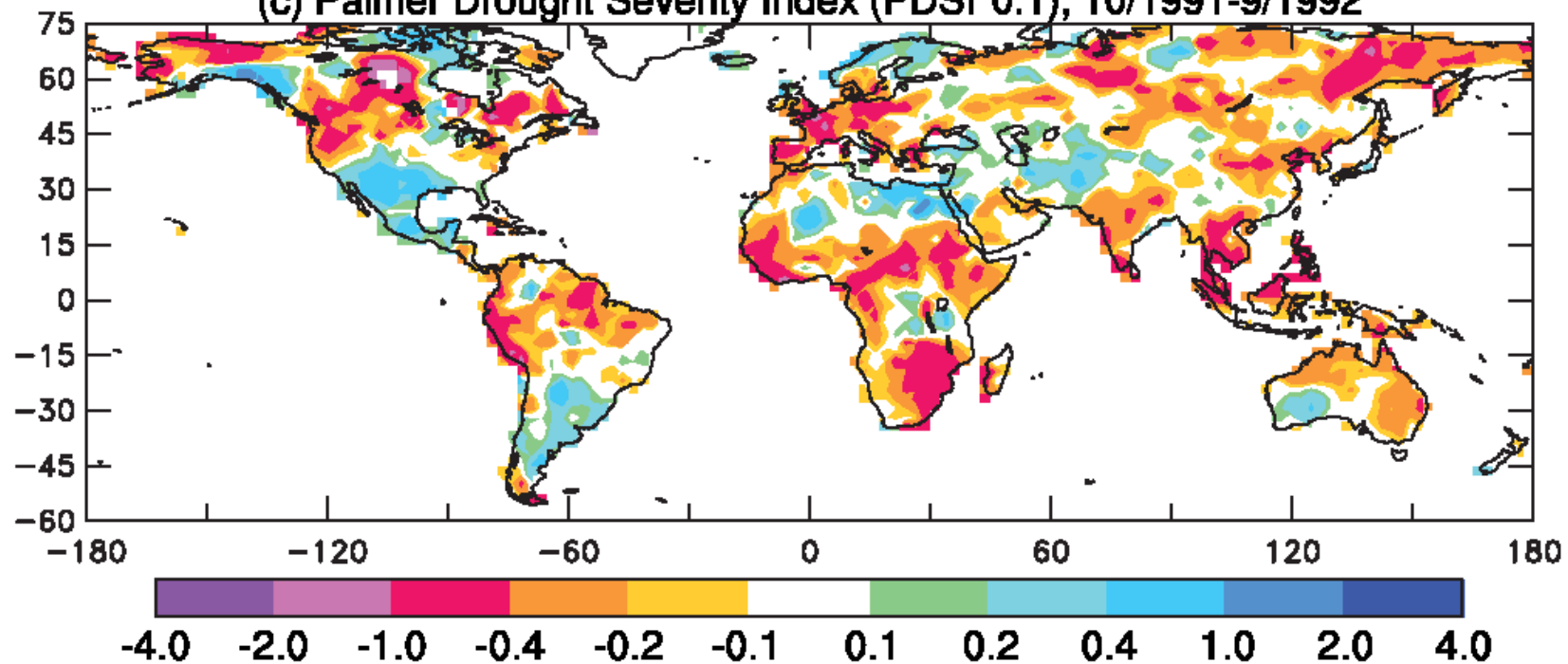
Summary of climate response

1. If there were a way to continuously inject SO_2 into the lower stratosphere, it would produce global cooling.
2. Tropical SO_2 injection would produce sustained cooling over most of the world, with more cooling over continents.
3. Arctic SO_2 injection would not just cool the Arctic.
4. Solar radiation reduction produces larger precipitation response than temperature, as compared to greenhouse gases.
5. Both tropical and Arctic SO_2 injection would disrupt the Asian and African summer monsoons, reducing precipitation to the food supply for billions of people.

Trenberth and Dai (2007)
Effects of Mount Pinatubo
volcanic eruption on the
hydrological cycle as an
analog of geoengineering
Geophys. Res. Lett.



(c) Palmer Drought Severity Index (PDSI*0.1), 10/1991-9/1992



Baseline Run

Geoengineering Run

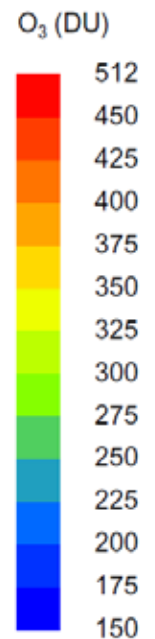
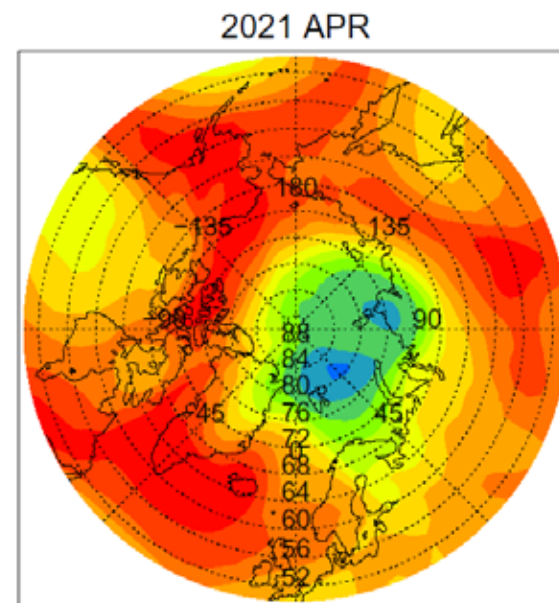
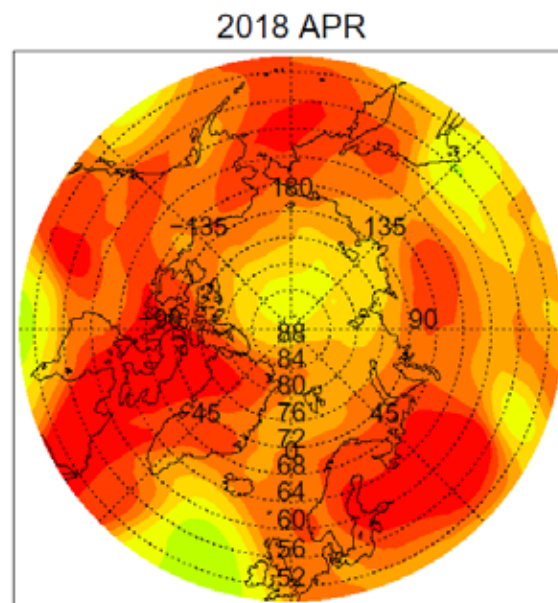
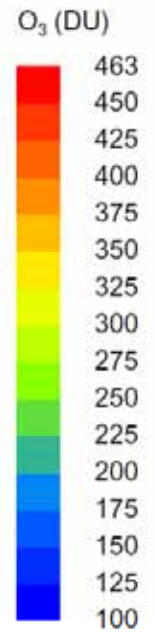
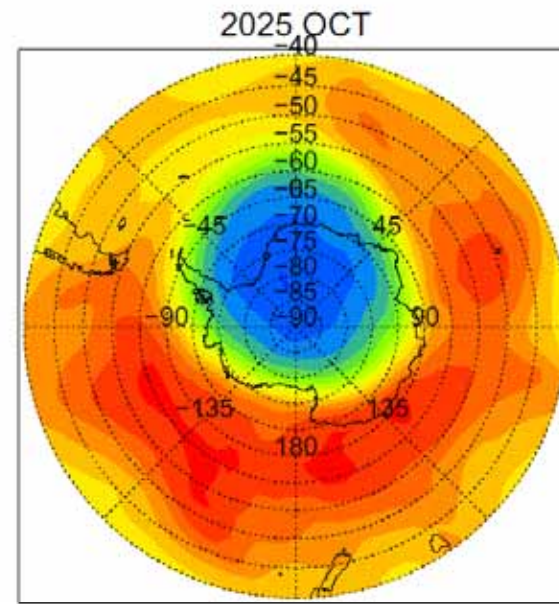
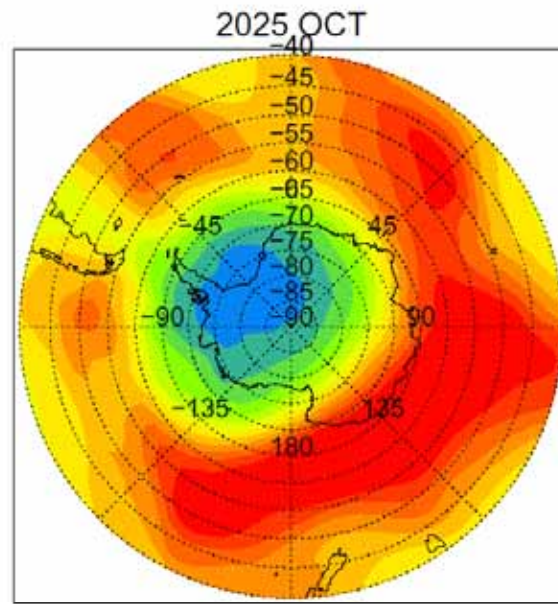
SH

Rasch et al.
(2008)

Ozone concentration
for coldest winters
with and without
geoengineering

WACCM3 model runs
by Tilmes et al.
(2008)
with 2 Tg S/yr

NH



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
- X5. 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

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
- X18. Could 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?

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

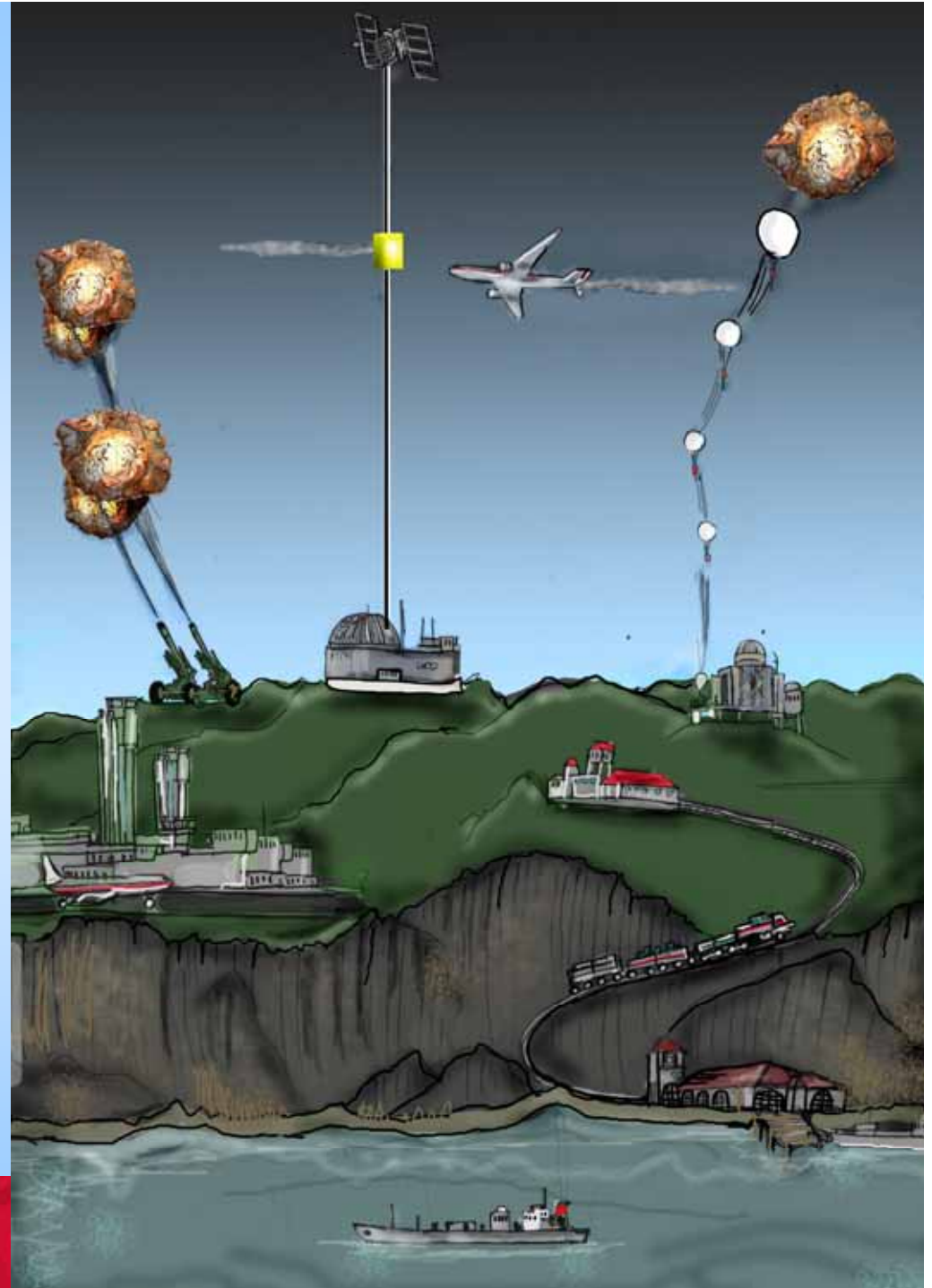
Artillery?

Aircraft?

Balloons?

Space elevator?

- There is currently no way to do geoengineering.
- No means exist to inject aerosol precursors (gases).
- Even if we could get the gases up there, we do not understand to produce particles of the appropriate size.



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,
- reduce our military budget, freeing resources for other uses,
- clean up the air, and
- provide economic opportunities for a green economy, to provide solar, wind, cellulosic ethanol, energy efficiency, and other technologies we can sell around the world.

Conclusions

As of now, there are at least 13 reasons why geoengineering is a bad idea. But there still may be pressures to attempt it to address planetary emergencies, as a stop-gap measure while we implement mitigation and carbon sequestration.

We need a well-funded research effort, through the national climate program, to examine the efficacy and dangers of different proposed geoengineering schemes, and to do engineering studies of the means of doing geoengineering.

Small-scale field tests of stratospheric geoengineering cannot be done; you would have to actually do geoengineering in the real world to test it.

The United Nations Framework Convention On Climate Change 1992

Signed by 194 countries and ratified by 188
(as of February 26, 2004)

Signed and ratified in 1992 by the United States

The ultimate objective of this Convention ... is to achieve ... stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The UN Framework Convention on Climate Change thought of “dangerous anthropogenic interference” as due to inadvertent effects on climate.

We now must include geoengineering in our pledge to “prevent dangerous anthropogenic interference with the climate system.”