ATM S 111, Global Warming Geoengineering

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Day 39: August 13, 2010

Assignments

- Should have read “Technological Solutions” pp. 286-332
- If you haven’t already, let me know what your project/paper topic will be today (email or verbal communication is fine).
- Rough draft of paper is due Monday, August 16.

Geoengineering

- 1. Removing CO_2 from the atmosphere
- 2. Manipulating earth's climate in some other way as to offset the effects of CO_2

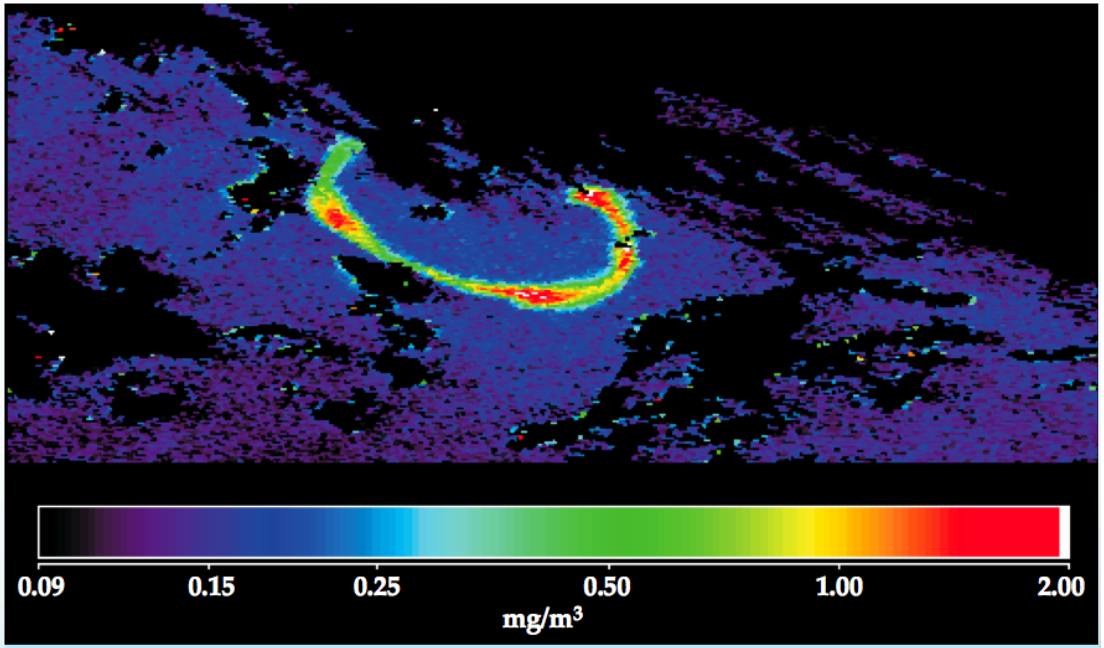
Removing CO_2 from the atmosphere

- One way is through reforestation.
- (This is usually not thought of as geoengineering!)
- Trees absorb CO_2 the fastest when they're first growing.
- In the long run, a lot of the carbon will be returned to the atmosphere when the trees die (or burn). Some will be buried and will stay out of the atmosphere as long as the soil isn't disturbed.

Promote Photosynthesis by Fertilizing the Ocean

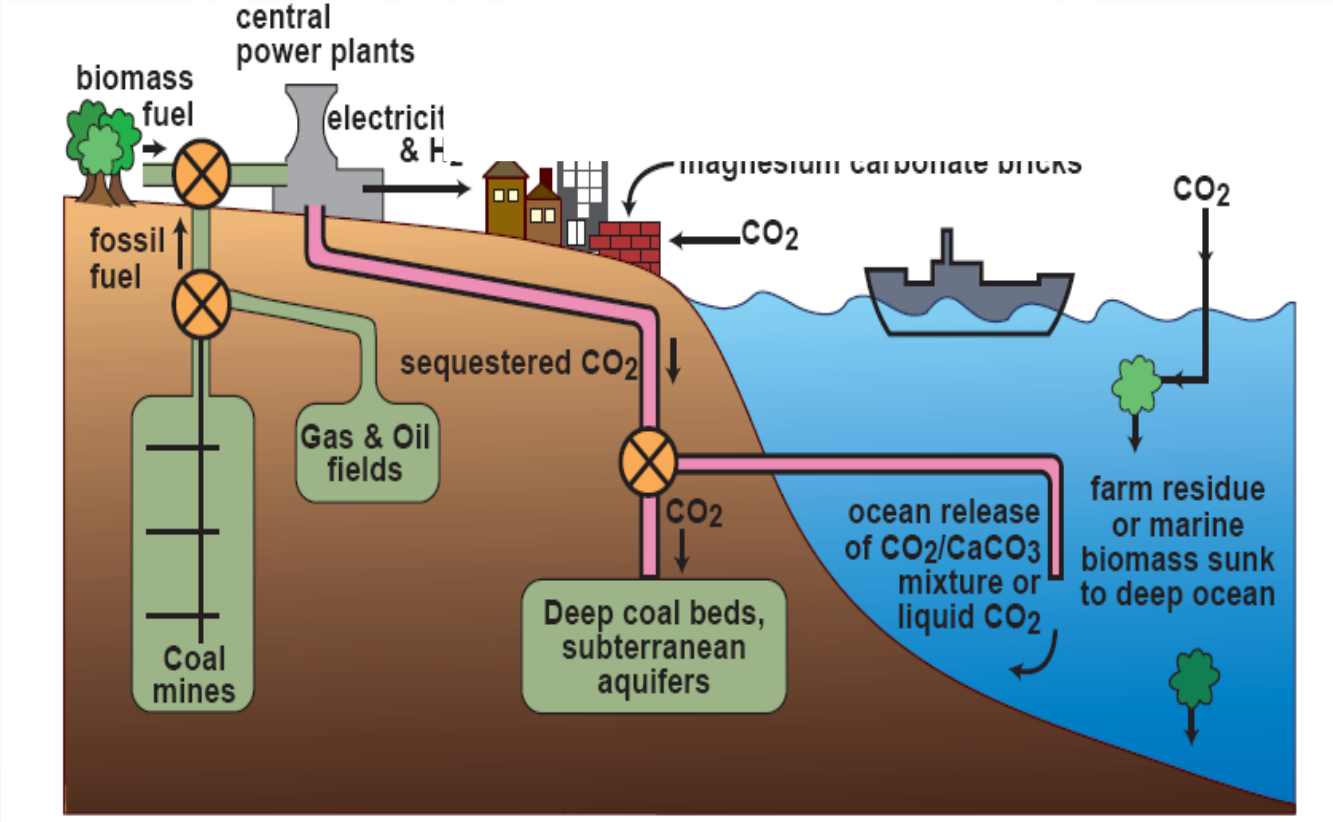
- Fertilize the ocean with iron (a limiting nutrient) to promote photosynthesis and thus remove CO_2 from the atmosphere

- Downsides:
  - Studies show after the phytoplankton bloom, most carbon goes right back into the atmosphere
  - Major disruption to the base of the marine food chain



Phytoplankton bloom following an iron-fertilization experiment in the Southern Ocean. The area covered spans about 1 degree of latitude and 2 degrees of longitude. Color scale indicates the mass of chlorophyll per cubic meter of seawater, mostly contained in phytoplankton. (Image provided by the NASA Goddard Earth Sciences Data and Information Services Center.)

Carbon Capture and Storage



- Works for CO_2 emitted from coal, but not applicable to non-point sources (e.g., CO_2 emitted from tailpipes)
- Makes energy from coal expensive compared to many other sources, including renewables.
- Risky if CO_2 escapes from storage (asphyxiation)

“Clean Coal” is not the same thing as Carbon Capture and Storage

May include among the following procedures

- Wash coal to remove harmful chemical
- Gasify coal by heating it to release and capture SO_2, some CO_2 is released and often pumped into depleted oil and gas fields to create pressure
- Produce Synfuels, which are burnt later (releasing CO_2 later)

This term is used by the coal industry but they offer no analysis to show it lowers CO_2 emissions

Climate engineering AKA geoengineering

"The intentional, large-scale manipulation of the environment." [David Keith]

"The deliberate modification of Earth's environment on a large scale 'to suit human needs and promote habitability.'" [wikipedia.org]

Climate Engineering: a brief history

- 1974: Mikhail Budyko proposed injecting sulfur dioxide in the stratosphere to create aerosols that would reflect sunlight (like volcanoes).
- 1992: The National Academy of Sciences issues a detailed study on geoengineering options for avoiding climate change, which includes evaluation of the science and a cost-benefit analysis for each option.
- 2006: Paul Crutzen (Nobel Prize winner for his work on the Ozone Hole) re-discovers Budyko's plan. He argues persuasively that the scope and speed of climate changes due to increasing CO_2 -- coupled with the lack of any progress on mitigation -- requires this geoengineering solution be seriously considered.

Climate Engineering: a brief history

- 2009: The Blackstock report - An influential group of US scientists write a prototype plan for Geoengineering research and development, testing and deployment and deliver it to the pentagon. The UK Royal Society writes an influential report outlining the state of the issue.

- 2009: The wildly popular Superfreakonomics book has a chapter about climate cooling that is (according to Joe Romm) “simultaneously skeptical of global warming science, critical of all mitigation measures, but certain that geo-engineering using sulfate aerosols is the answer”.

Why would we consider Climate Engineering?

- The projected climate changes are large and fast enough to cause large disruptions and distress in the global economy, society and in the environment.
- The potential for unanticipated climate catastrophes.
- Hard to rule out high sensitivity climates – possibility of very large warming.
- It might be cheaper than a lot of mitigation strategies (e.g., re-tooling our energy infrastructure).

The basic strategy: Block enough sunlight to cancel radiative forcing due to increasing CO_2

- Solar reflectors placed in outer space at a point where the gravitational field from the earth cancels that from the sun
- Mirrors orbiting the earth to reflect sunlight
- Make more clouds or more reflective clouds
- Place/shoot tiny particles in the stratosphere that reflect visible sunlight but don't absorb infrared radiation

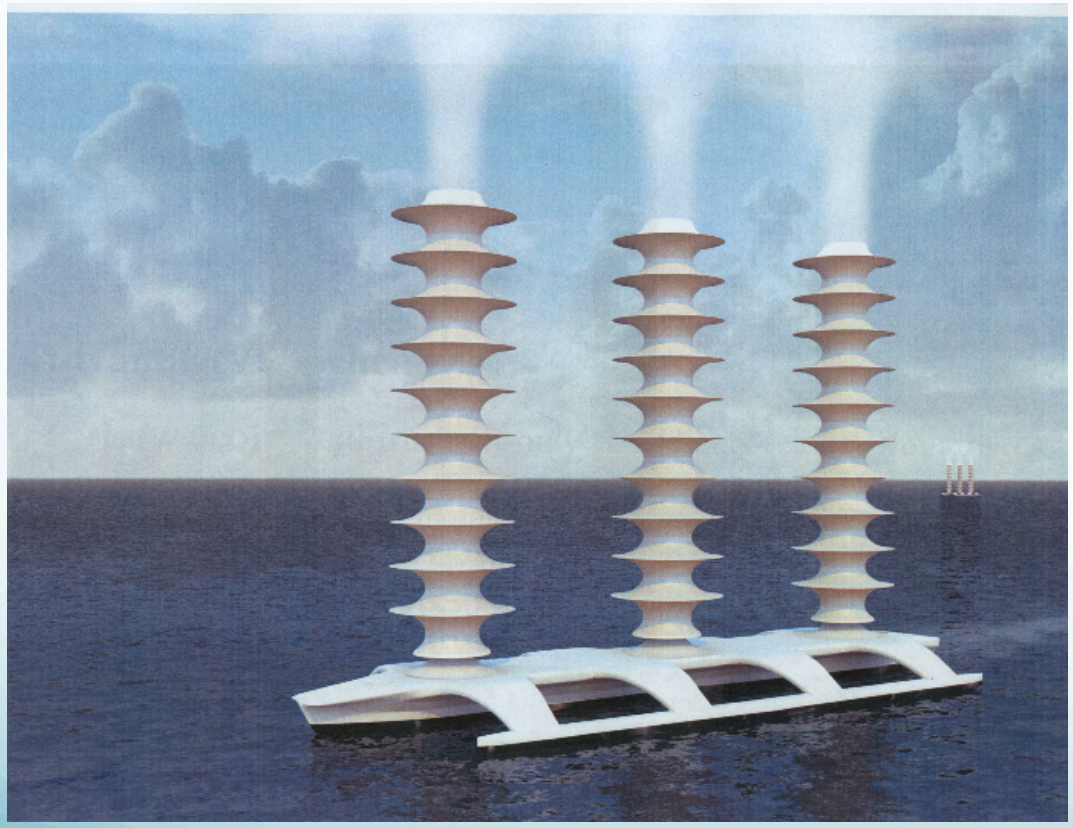
Stratospheric Sulfur Injections

© New York Times
Henning Wagenbreth
Oct. 24, 2007

- Inject a sulfate aerosol precursor (such as sulfur dioxide SO_2) into the stratosphere that then chemically forms sulfate particles.
- These aerosols increase earth's albedo by reflecting solar radiation back to space.
- Lifetime in the stratosphere (~1-5 years) is much longer than troposphere (days).
- Cheap compared to mitigation, 10-20 billion $US/year
- Natural analogue: volcanic eruptions.

Cloud modification

Latham and Salter propose controlled enhancement of the albedo and longevity of low-level maritime clouds



- Shoot a very fine spray of sea water up, making cloud droplets smaller and thus more reflective of sunlight
- Works best in pristine (ocean) areas. Need thousands of ships
- Natural analogue: ship tracks (sort of)

Cheap: 2-4 billion $US/year

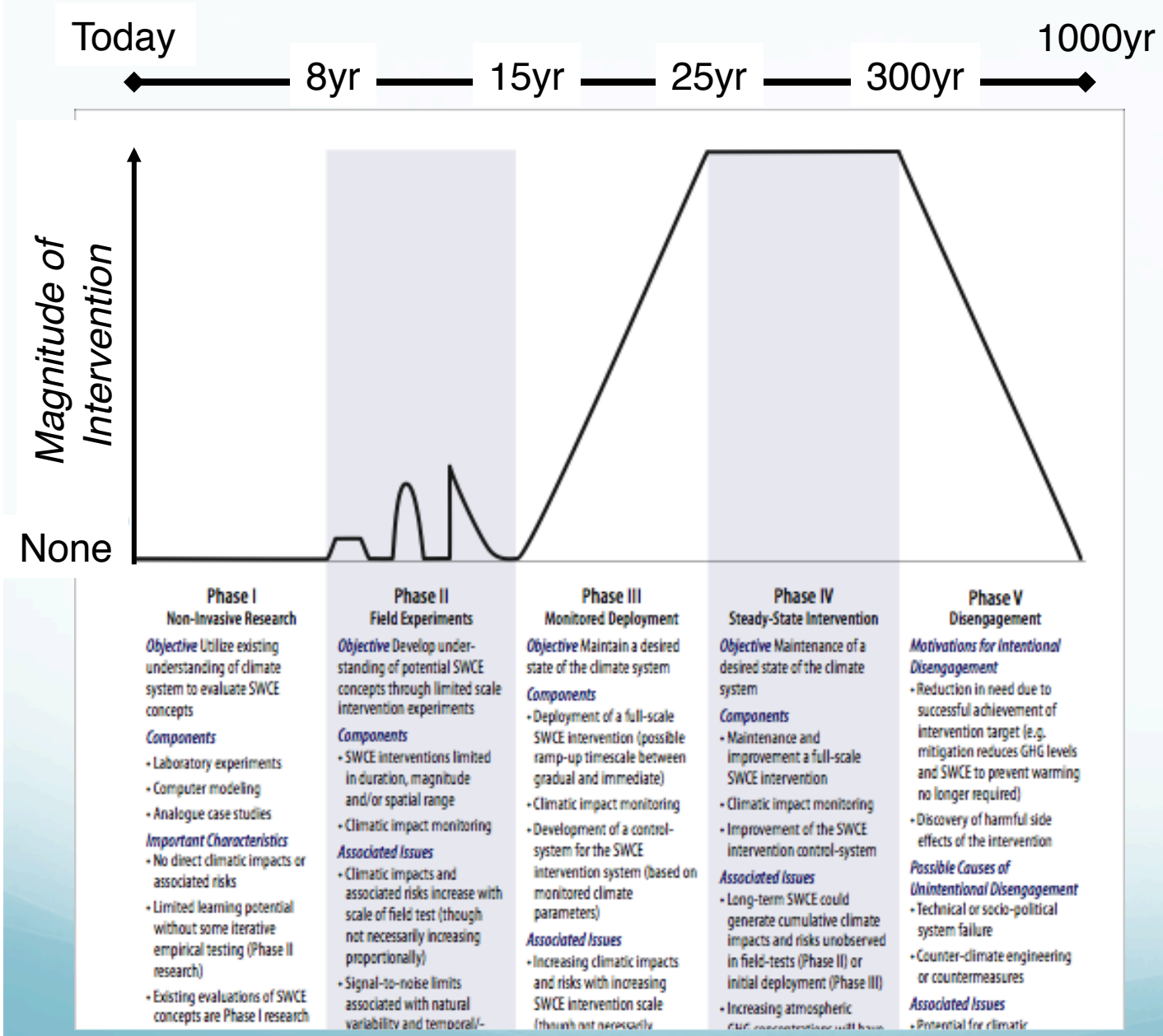

Note ship tracks are visible in thin cloud areas ONLY
No tracks here where there aren't clouds

May be able to offset global temperature rise **but** since it's not the same kind of forcing it's impossible to exactly cancel.

For example, these schemes alter precipitation too:

Reducing incoming solar radiation tends to dry the tropics

Sea spray-cloud brightening over ocean preferentially cools the ocean, causing land-sea temperature gradients that tend to strengthen summer monsoons



Timeline of research, development, testing and deployment (stratospheric aerosols)

Blackstock et al 2009

Possible (unproven) options for getting 10Mt of sulfur aerosols in stratosphere each year

- Artillery: shooting barrels of particles into stratosphere with 16” Iowa Class naval guns
  - Three guns firing twice per minute for 300 yrs
  - “...surprisingly practical” (NAS 1992)

Blackstock et al 2009

Possible (unproven) options for getting 10Mt of sulfur aerosols in stratosphere each year

Some downsides of the stratospheric aerosol sunshade solution

- Large uncertainty to how much/how often you have to inject sulfur into the stratosphere to cancel warming effect of increased CO_2
- Not clear injecting SO_2 works, recent study suggests injecting sulfuric acid instead
- CO_2 will continue to increase in the atmosphere and continue to acidify the upper ocean
- Sulfur chemicals in the stratosphere may destroy ozone in the protective ozone layer. So try nanoteched particles (may be difficult or impossible to remove).

General arguments *against* doing climate engineering
(including sun shading by stratospheric aerosols)

- The ocean will continue to acidify
- Technology is still in its infancy
  - We have a large community of scientist and ~50 years of experience on the global warming problem (with modest progress on reducing uncertainty)
  - A handful (10-20) of scientist have spent ~5-10 years thinking about what might happen if we deploy a particular climate engineering solution. The science is in its infancy, and all of the work being done in the US is funded by private sources.
- Even when emissions of CO_2 go to zero, we will have to continue to deploy the aerosols until the CO_2 returns to a safe level (~1000 years)
- Once you start, you can never stop. Stopping either deliberately (an adverse side-effect is discovered, or a terrorist act) or unintentionally (loss of capability, political will) will result in disaster.

General arguments *against* doing climate engineering

(including sun shading by stratospheric aerosols)

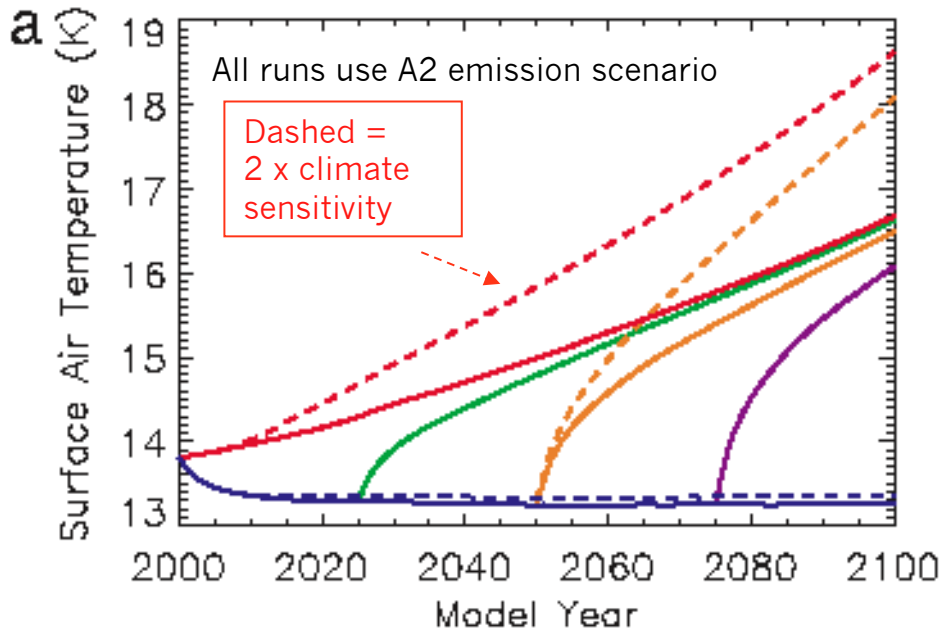


Fig. 3. Simulated surface air temperature (*a*) and annual rate of temperature change (*b*) for runs A2 (red), GEO (BLUE), OFF_2025 (green), OFF_2050 (orange), and OFF_2075 (purple). Runs with doubled climate sensitivity (A2+CS, GEO+CS, and OFF_2050+CS) are plotted as dashed lines.

- If sun shade technology is deployed to cancel warming due to large increases in CO_2, then a temporary failure in deployment (unintentional or not) would cause the planet to warm greatly and catastrophically

  e.g., 1-4C in 10 years

  (cf. 20th century at 0.09 C/10 yrs, or nature at 4C/10,000 yrs)

Calderia and Wood 2008

Arguments *against* doing climate engineering

- *Overwhelmingly, climate scientists are very skeptical of -- and do not support -- climate engineering. Why?*

  The climate system is inherently complex and the possibility of "[unanticipated] harmful side effects" is too large for any intentional human intervention to *ever* be considered safe.

Final Comments on Climate Engineering

- The possibility of "[unanticipated] harmful side effects" may be too large for any intentional human intervention to *ever* be considered safe.

- Shortwave climate engineering can be perceived as a substitute for greenhouse gas (GHG) emission reductions, and might therefore "undercut human resolve to deal with the cause of the original problem".

- If a wide spread political belief developed that climate control is (or will become) possible through climate engineering, significant international tensions might emerge surrounding who gets to define what the "optimum" climate should be.

Final Comments on Climate Engineering

- WILL CLIMATE ENGINEERING HAPPEN?
  - It is incredibly easy and (in the short term) inexpensive compared with reducing emissions and transitioning to a non-carbon emission economy
    - Cost is ~10B/yr compared to ~200B/yr to reduce carbon emissions
    - Cost is less than 0.1% GDP for US, less than 2%for about 30 countries
  - Players who are currently influential and have a lot to lose if greenhouse gas emissions are limited/reduced (oil and gas companies, libertarians) don't lose from climate engineering
  - Whoever holds the contracts for CE solution has huge influence and profits for a millennium
    - E.g., initial work is largely funded by defense contractors and venture capitalists, including some of the richest people in the world
  - Will we develop and deploy this technology?

20 Reasons Why Geoengineering May be a Bad Idea by Alan Robock

1) Effects on Regional Climate, weaker effect in Arctic and drying in the tropics
2) Continued Ocean Acidification
3) Ozone depletion via surface processes on particles
4) Effects on Plants
5) More Acid Deposition

20 Reasons Why Geoengineering May be a Bad Idea

6) Effects on cirrus clouds via seeding

7) Whitening of the sky

8) Less sun for solar power

9) Environmental Impacts of Implementation

10) Rapid Warming if Deployment Stops

20 Reasons Why Geoengineering May be a Bad Idea

11) No Going Back

12) Human Error

13) Undermining Emissions Mitigation

14) Cost - not known (Wood says 1 billion/yr and Crutzen says 25-60 billion/yr)

15) Commercial control of Technology - Who controls it and who is the intended beneficiary (Procedural Justice)

20 Reasons Why Geoengineering May be a Bad Idea

16) Military use of Technology

17) Conflict with Treaties - UN's ENMOD forbids "use of enviro. modification techniques having widespread, long-lasting or severe effects as the means of destruction , damage, or injury to any other State Party"

18) Who controls the thermostat (Procedural Justice)

19) Moral authority - to alter the climate knowingly

20) Unexpected consequences