Prospicience and Geoengineering: What If We Can Dial Our Future?

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Prospicience

Prospicience: “The art [and science] of looking ahead.” We need a new word to describe a new intellectual domain.

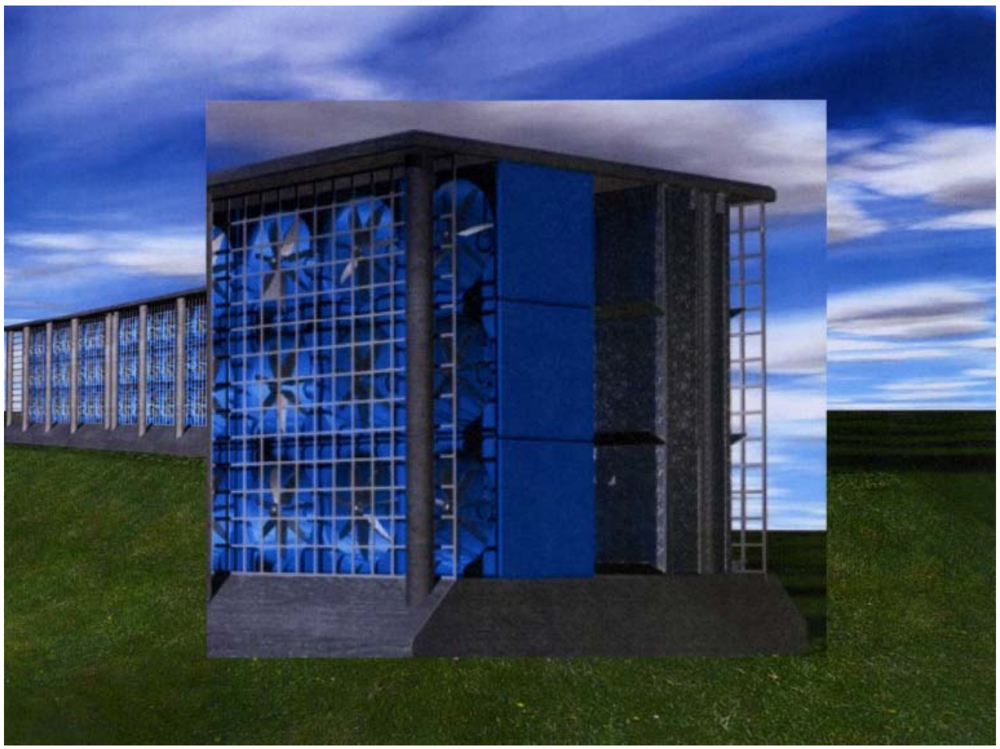
In the past 50 years we have become aware of our deep history: the history of our Universe, our Earth, and life.

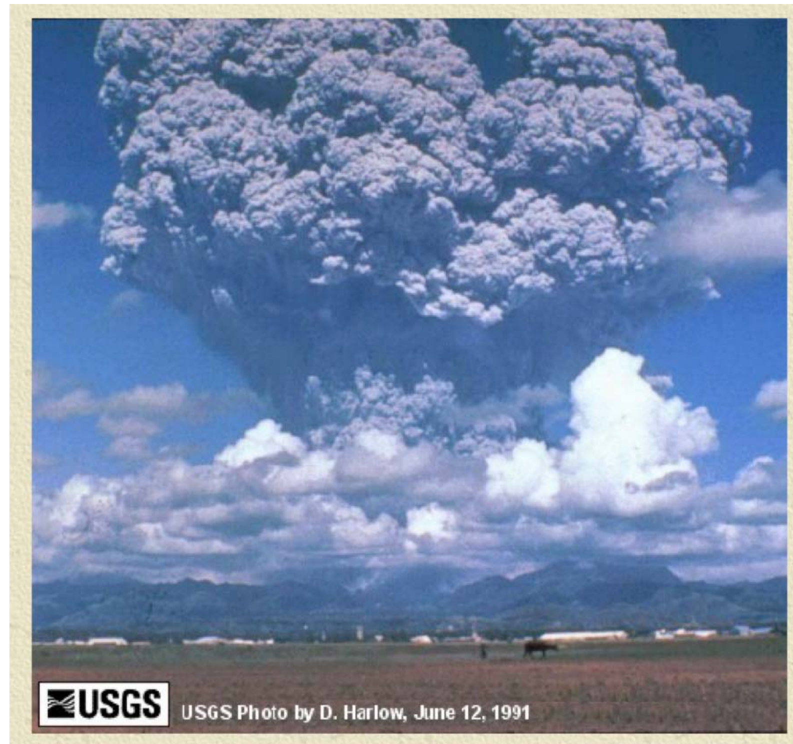
Can we achieve a comparable understanding of human civilization at various future times: 50 years ahead *vs.* 500 *vs.* 5000 *vs.* longer?

Prospicience is needed to guide decisions about infrastructure design, natural resources, wilderness preservation, reinsurance, endowment management ...and our understanding of what we are on Earth to do!

Compensatory interventions in the climate system

Direct capture of CO_2 from air





Injection of reflecting particles into the stratosphere

Source: David Keith, MIT talk, Sept. 16, 2008

Why Now?

1. The “hard slog” problem. To respond to climate change requires huge changes in current technological systems (power, transport, buildings), creates winners and losers, and presents deep challenges to equity.

   It would be wonderful to have a few more options.

2. The “fat tail” problem. Climate science cannot rule out extremely nasty outcomes of even modest increases in atmospheric CO_2.

   Might we be safer if we had tools for dealing quickly with acute emergencies?

The Hard Slog

1. Some carbon arithmetic for the planet and individuals
2. Implications for equity
3. Available alternatives, all problematic

“Stabilization at 2^{o}C”

The widely cited goal of “stabilization at 2^{o}C” requires that annual global per capita global CO_2 emissions average:

2 tCO_2 by mid-century

1 tCO_2 by 2100.

Today’s average American: 20 tCO_2.

It is *not* sufficient to limit emissions in the prosperous parts of the world and allow the less fortunate to catch up. Such an outcome would overwhelm the planet.

The emissions of the future rich must equal the emissions of today’s poor, not the other way around.

Four ways to emit 4 tonCO_2/yr (today's global per capita average)

Activity	**Amount producing 4 ton CO_2/yr emissions**
a) Drive	10,000 miles/yr, 30 miles per gallon
b) Fly	10,000 miles/yr
c) Heat home	Natural gas, average house, average climate
d) Lights	300 kWh/month when all coal-power (600 kWh/month, natural-gas-power)

Princeton University CO_2 in 2007

University emissions*	112,000 tCO2
12,500 participants**	
Per-capita emissions	9 tCO2

*On-site cogeneration plant, purchased electricity, fuel for University fleet.

**7,100 students and 5,400 employees

“Never in history has the work of so few led to so much being asked of so many!”

Nonetheless, grounds for optimism:

- The world today has a terribly inefficient energy system.
- Carbon emissions have just begun to be priced.
- Most of the 2058 physical plant is not yet built.

Global equity

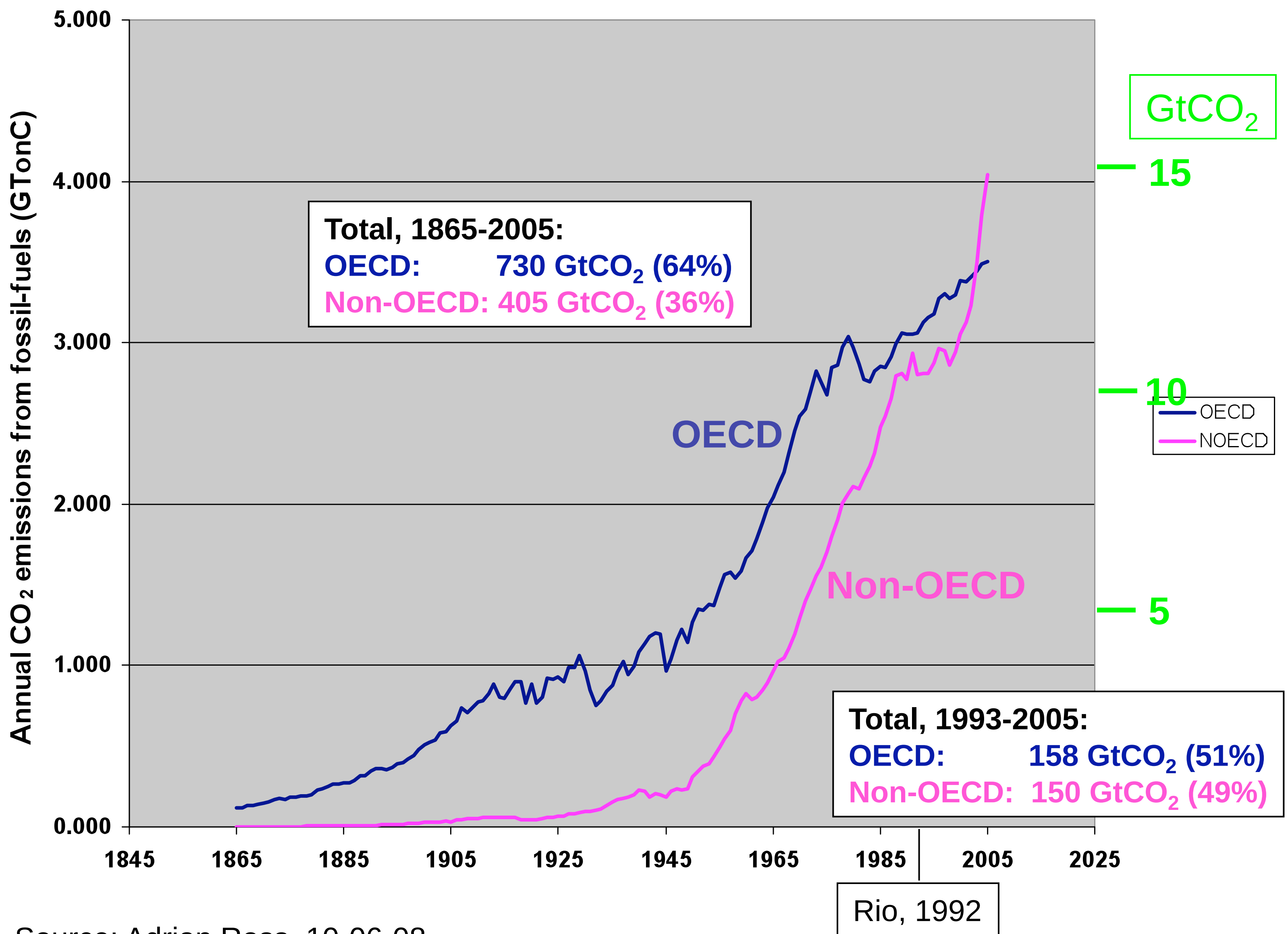
Two points:

1. Climate change cannot be managed without the participation of the developing countries.

2. The CO_2 emissions of the *global poor* (40% of the world's population) are negligible, from the perspective of global warming.

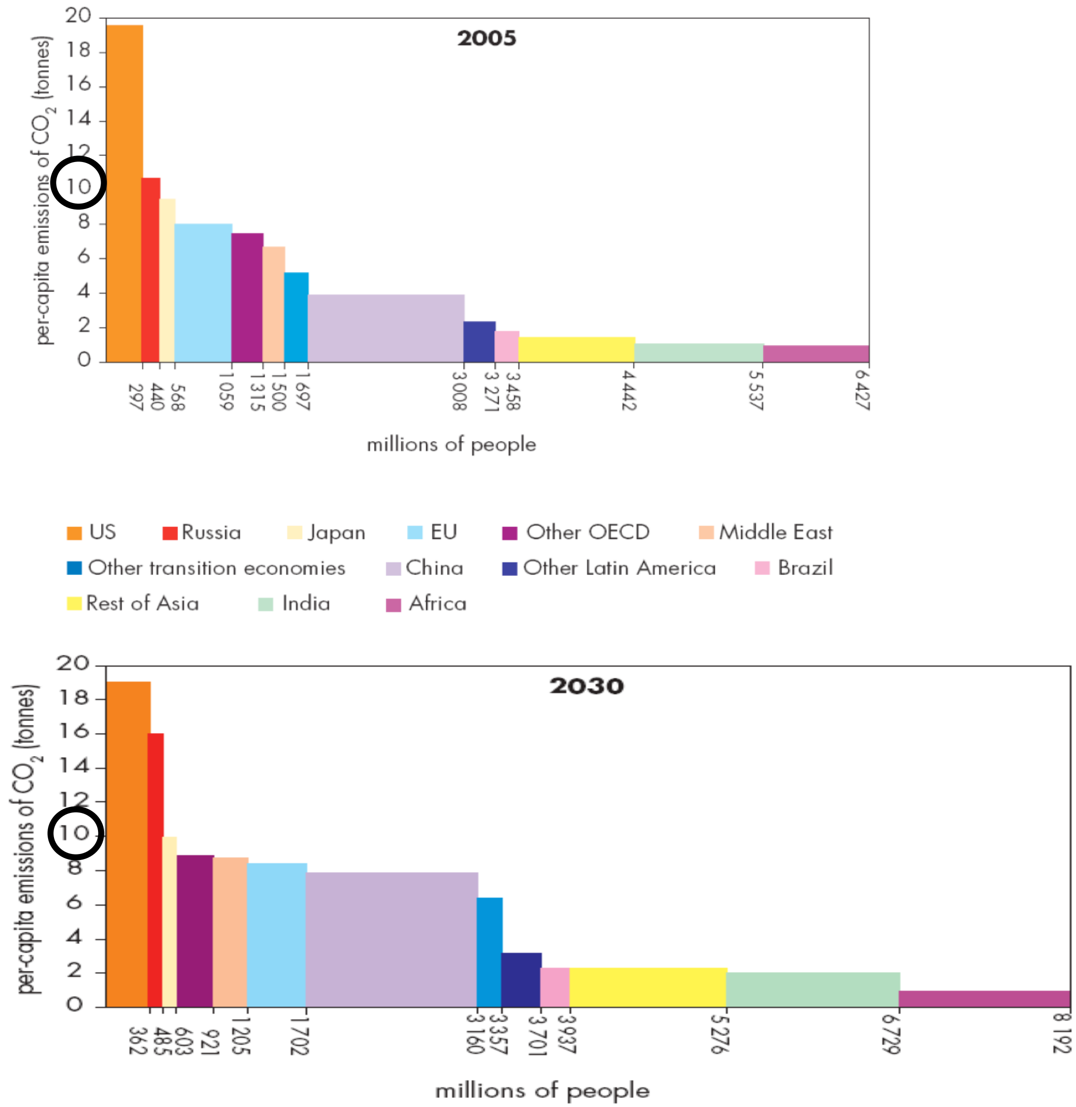
Collaborators: Shoibal Chakravarty (PEI), Ananth Chikkatur (Harvard), Heleen DeConinck (Free University, Amsterdam), Steve Pacala (PEI), Massimo Tavoni (FEEM, Milan)

CO_2 emissions, OECD and non-OECD, 1865-2005



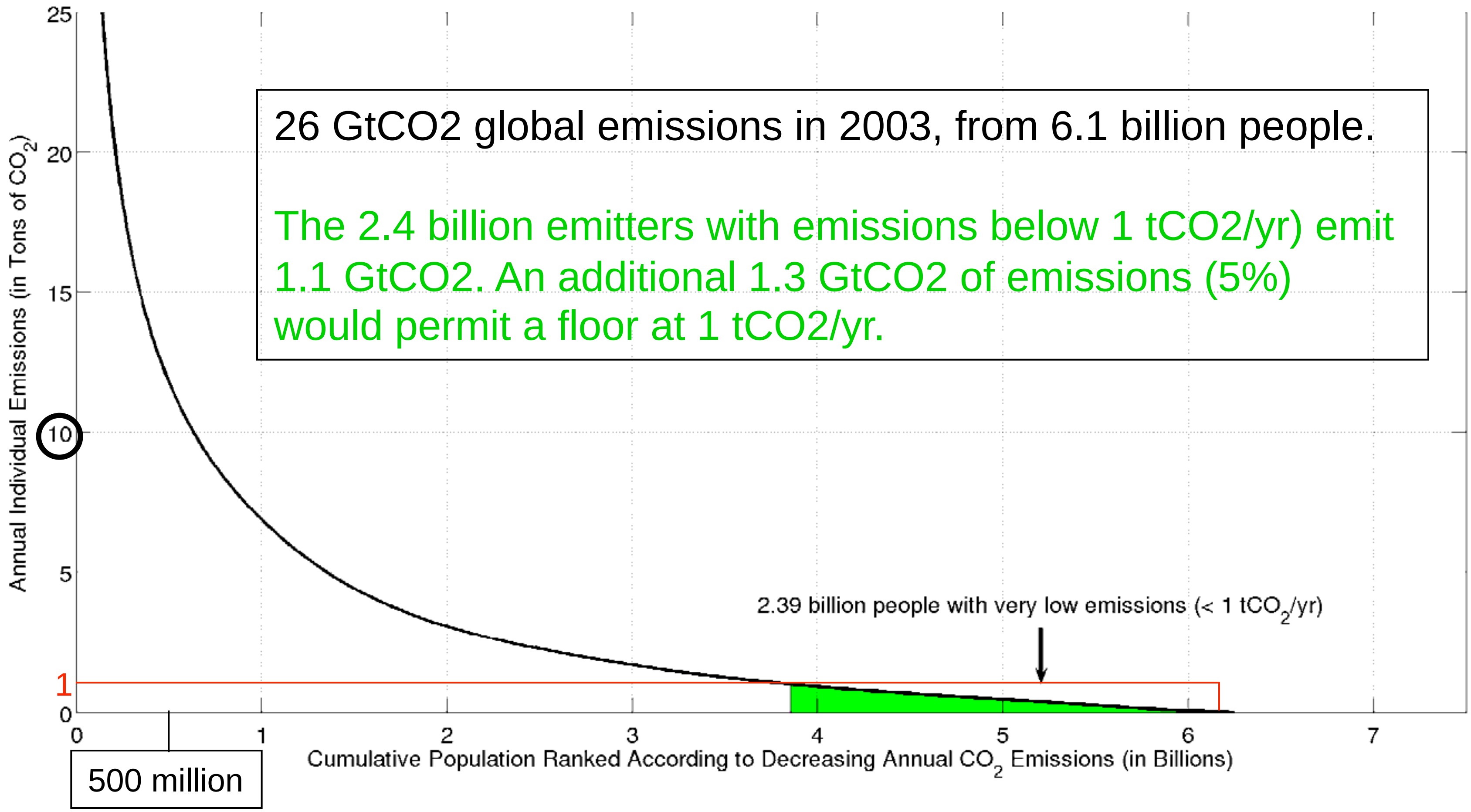
Source: Adrian Ross, 10-06-08

The developing countries cannot sit on the sidelines.



Source: IEA, *WEO 2007*

The aggregate emissions of the world's poorest people are negligible



The world's poor do not need to be denied fossil fuels

What does 1 tCO_2/person-yr allow today?

Direct Energy Use	*Household rate of use (4.5 people)*	*Individual emissions ($kgCO_2$/yr)*
Cooking	1 LPG canister per month	120
Transport	70 km by bus, car, motorbike per day	220
Electricity	800 kWh per year	160
Total		*500*

1 tCO2/yr: Double the "direct" emissions to account for "indirect" emissions.

Mitigation strategies available today

- Efficiency
- Renewable power
- Nuclear power
- Coal and biomass for power and fuels, with capture and storage of CO_2

Steve Pacala's and my 2004 paper in *Science* showed that what seemed to be an insoluble problem was soluble, though very difficult. Many activists and politicians then decided it must be soluble and *easy.*

Mitigation as surrogacy

Many of the advocates for policies that restrict mitigation to efficiency and renewables see such policies as a means to achieve other goals:

Bringing the fossil fuel era to a close.

Curtailing consumerism and human centeredness.

Promoting self-sufficiency.

Diminishing the power of technological elites.

For these advocates, climate change mitigation is a surrogate goal. Debate is hobbled by a failure to acknowledge this surrogacy.

Alas, renewables and efficiency do not suffice, if there is also urgency.

Prospicience and nuclear waste policy

We have been distracted by a set of irrelevant but mesmerizing time scales, the long half-lives of particular isotopes. Notably, plutonium-239, with a half life of 24,000 years.

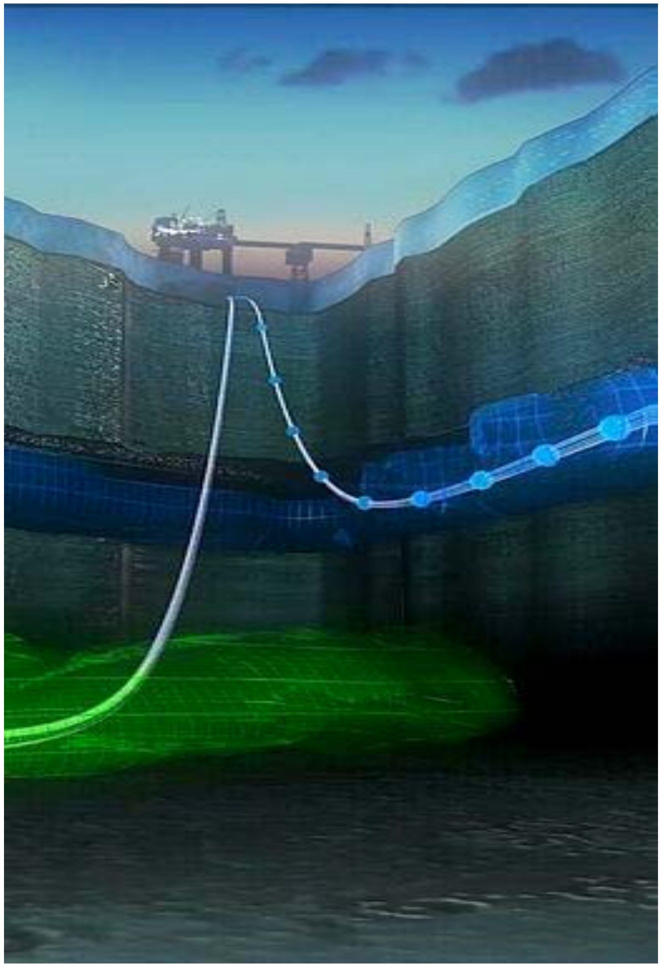
The result is chaos regarding the temporal objectives of nuclear waste management. Should the social contract be revised to accept the less demanding goal of “retrievable storage.”

Dry casks, adequate for 100 years.

Prospicience and geological storage of CO_2

How long should CO2 stay down?

Political processes at all levels will be grappling with this question over the next decade.



Graphics courtesy of DOE Office of Fossil Energy and *Statoil ASA*

Every strategy can be implemented well or poorly

Every “solution” has a dark side, generating opposition that thwarts implementation.

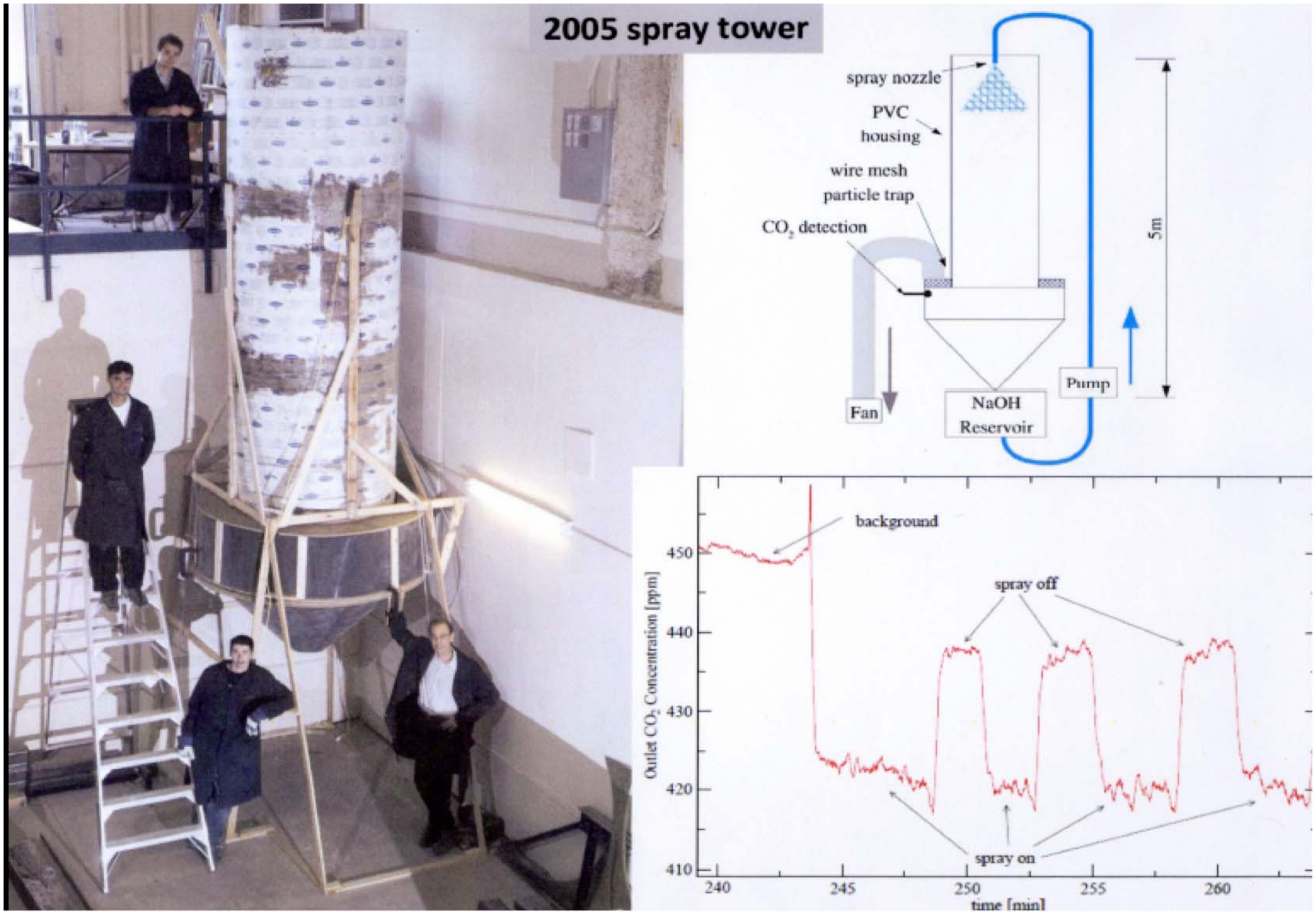
Conservation	Regimentation
Renewables	Competing uses of land
Nuclear power	Nuclear war
“Clean coal”	Mining: worker and land impacts

Wouldn’t it be nice to have a few more options?

For example, direct capture from air.

Informants: Peter Eisenberger, David Keith, Klaus Lackner.

A device to remove CO_2 from air



Source: David Keith, MIT talk, Sept. 16, 2008

Four approaches already

Four capture strategies are being investigated:

1. Absorption/desorption at high temperature (liquid amine)
   Keith (U Calgary)
2. Absorption/desorption at near ambient temperature (solid amines)
   Eisenberger (Columbia)
3. Absorb dry/desorb wet
   Lackner (Columbia)
4. Enhance CO_2 dissolution with carbonic anhydrase or a variant
   Aines (Lawrence Livermore)

There may be pressure on geological pore space for storage. But direct air capture and storage can be done anywhere.

A global thermostat

“Global Thermostat” (Eisenberger): Tune the CO_2 concentration (and, thereby, the surface temperature) by air capture.

> Drive the concentration as low as desired, e.g., below pre-industrial.
>
> Drive the concentration as high as desired, by storing CO_2 retrievably (parking it) – e.g., to prevent an ice age.

Can the world conceivably negotiate a most desired temperature?

Moral hazard

Direct air capture and traditional mitigation compete, if costs of direct air capture are low enough.

Even knowing that direct air capture *could* work will reduce, and *should* reduce, the level of effort on all other alternatives.

Exaggerating the commercial viability of direct air capture will lead to a flagging of mitigation strategies already known to be workable.

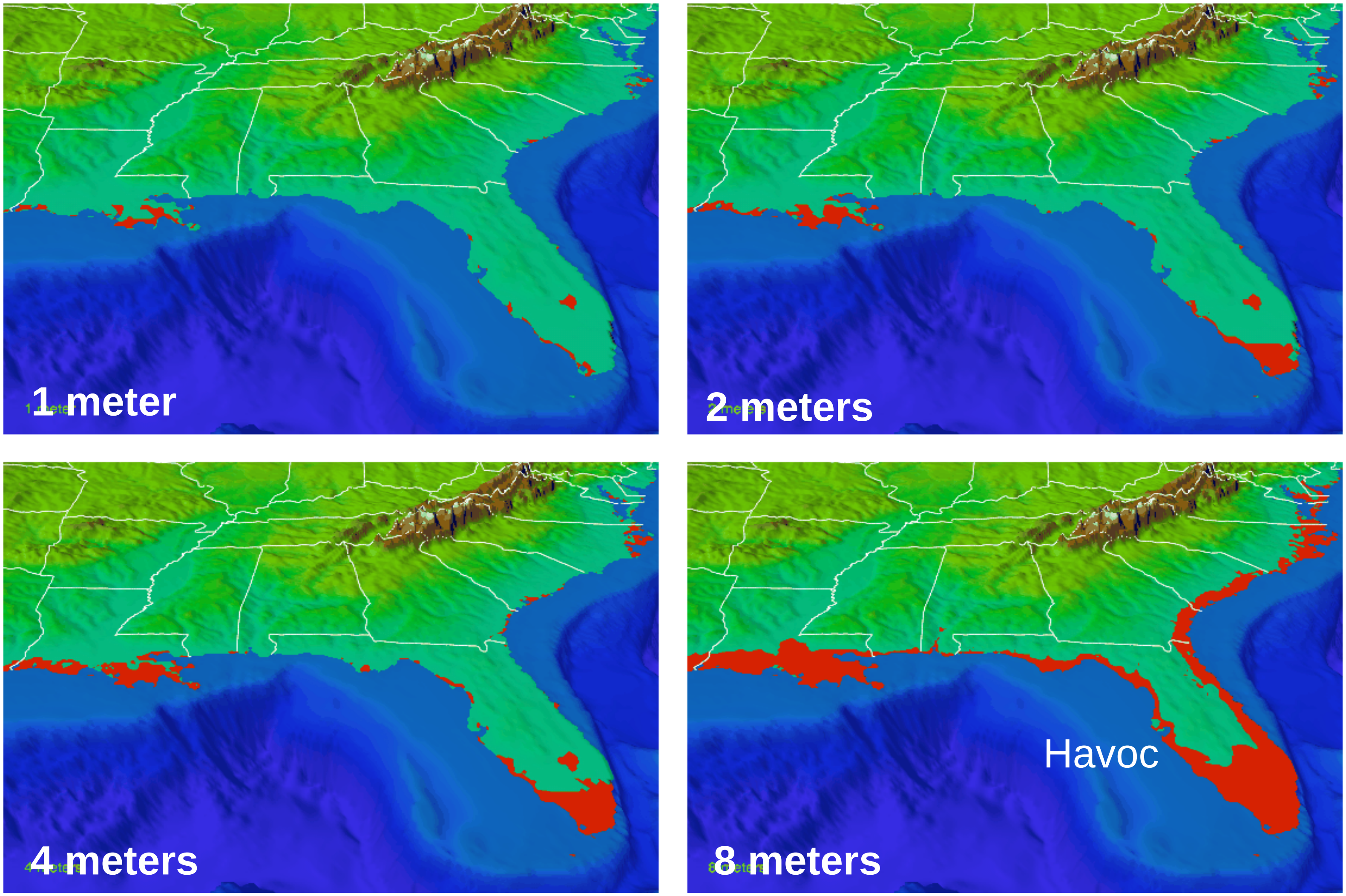
The Fat Tail

What concentration is dangerous?

Scientists cannot rule out the possibility that the planet is so “twitchy” (Pacala’s word) that small increases in CO_2 concentration produce havoc, via myriad feedbacks. Moreover, the probability distribution of adverse impacts has a “fat tail.”

“Climate change, at the fat tail, threatens to drive all of planetary welfare to disastrously low levels in the most extreme scenarios.” (Weitzman)

Sea Level Rise

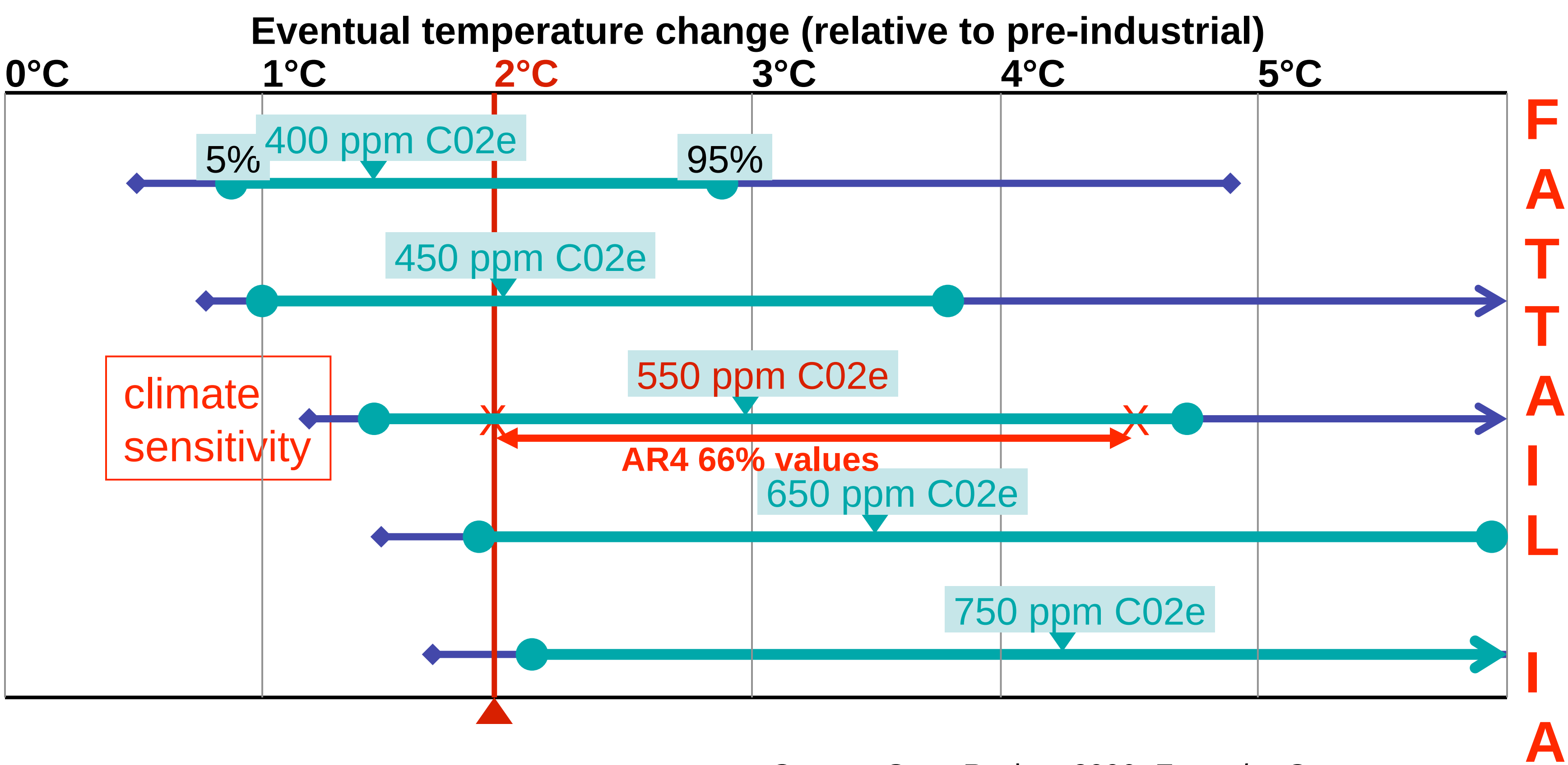


Greenland ice sheet:	7 meters (23 feet)
West Antarctic Ice Sheet:	5 meters (17 feet)

Source: T. Knutson, Geophysical Fluid Dynamics Laboratory, NOAA. See:
http://www.gfdl.noaa.gov/~tk/climate_dynamics/climate_impact_webpage.html#section4

When we choose a target, we are buying insurance, managing risk.

The worst and the best outcomes compatible with today's science are entirely different. There is no line in the sand, with safety on one side and disaster on the other.



Source:: Stern Review, 2006, *Executive Summary*, p. v.

How can we not know whether we live in Fattailia?

Havoc studies are a priority. They are a challenge to GFDL and the rest of the climate research community.

> Do we know for sure that the climate sensitivity is less that 20^{o}C? Is so, because of what evidence? Why can't the same reasoning rule out 10^{o}C? 5^{o}C?

We must assume that we *do* live in Fattailia, and that we could find out via sudden change. This motivates the search for "fast geoengineering," matched to the sudden onset of a crisis.

Mt. Pinatubo, 1991, cooled the planet.

The idea is to imitate the cooling effect of large volcanoes.

On June 15, 1991 (three days after this photo) , Mt. Pinatubo. injected 10 MtS (as SO_2) into the stratosphere.

The Earth's average surface temperature was 0.5°C cooler six months later.

S-injection: Emergencies

Wanted: Fast geoengineering. S injection may have large effects on climate in months to years. Most other responses (reduced emissions, direct capture) will be slow.

The analogy here is to the use of epinephrine to treat an acute allergic reaction. It is considered irresponsible for a doctor not to have epinephrine in his or her medicine cabinet.

Note, however, the comment of James Lovelock (Gaia): Geoengineering today is “comparable with 19th century medicine.”

Two thrusts for research: Deployment engineering (e.g., avoid coagulation) and Climate science (e.g., avoid depleting stratospheric ozone).*

**Study group (10 of us)*: Steve Koonin (head), David Battisti, Jason Blackstock, Ken Caldeira, Doug Eardley, Jonathan Katz, David Keith, Ari Patrino, Dan Schrag, and I.

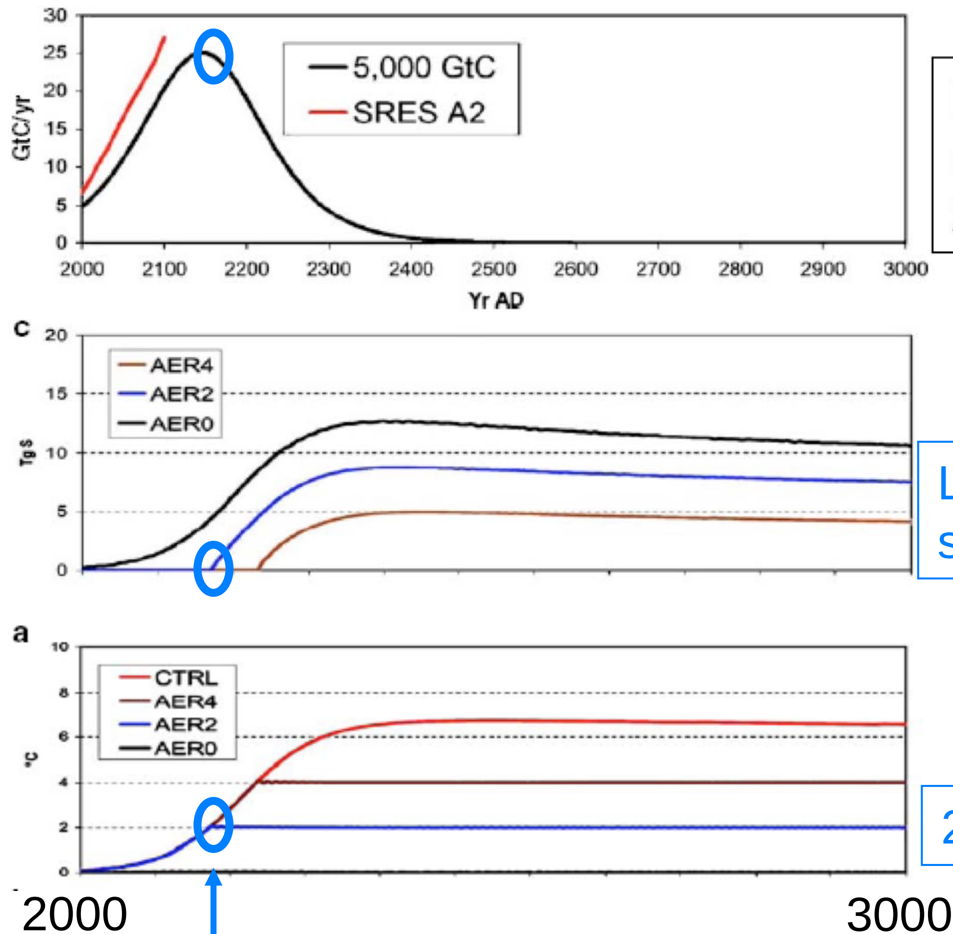
Rapid disengagement

Rapid disengagement from S-injection might be

a. deliberate: An adverse side-effect is discovered.

b. unintentional: Loss of capability, political will.

Compensatory sulfur injection



Fossil fuel burn rate (GtC/yr): 3x today at 2150 peak

Pinatubo injection

Sulfur load (MtS)

Load required to sustain 2°C

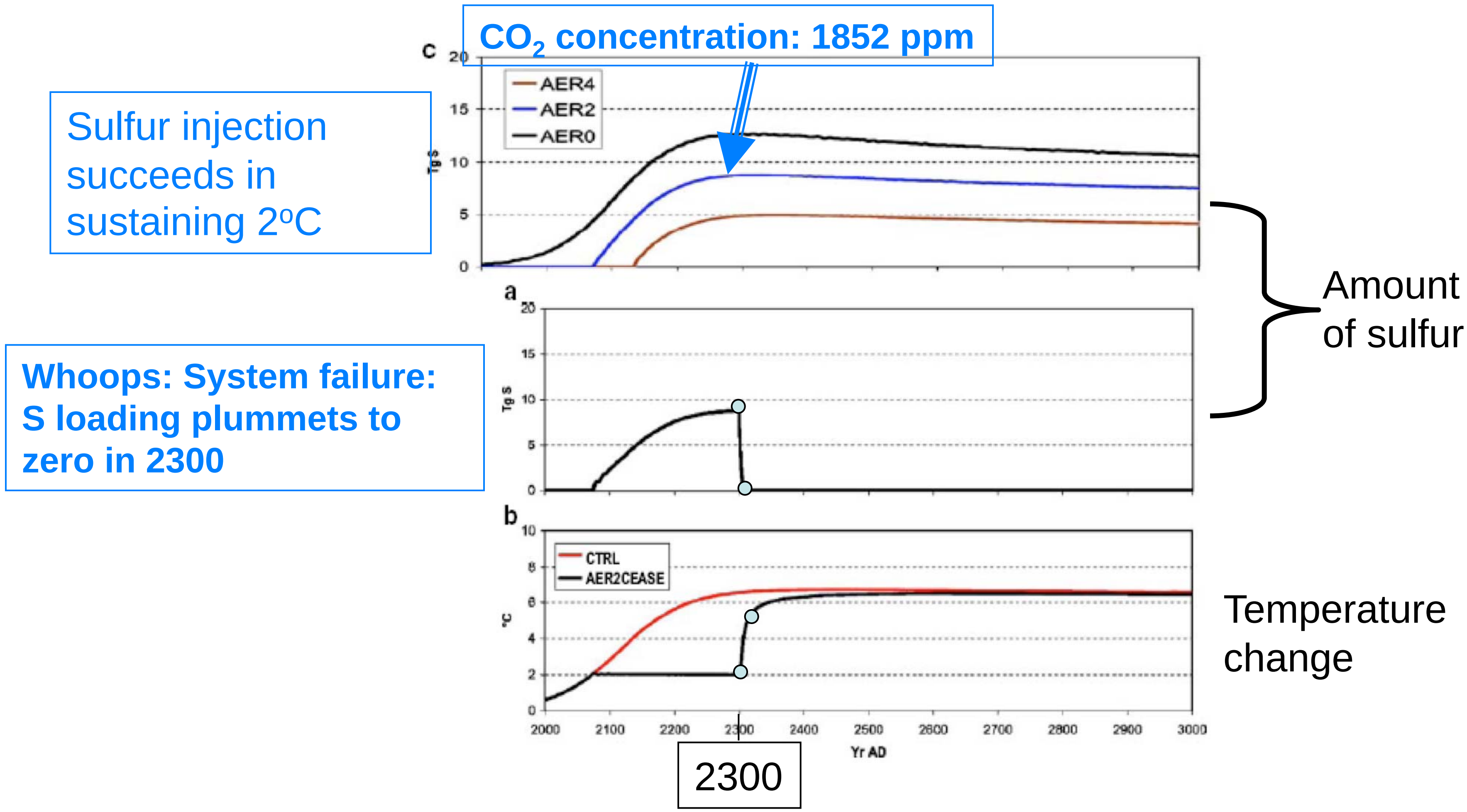
Temperature rise (°C)

2°C

Injection to prevent exceeding 2°C begins ≈ 2170

Victor Brovkin, et al., *Climate Change*, 2008

The Sword of Damocles (1)



Victor Brovkin, et al., *Climate Change*, 2008

The Sword of Damocles (2)

As a consequence of this interruption of injection, “within a few decades, winter warming in the polar regions exceeds 10^{o}C and summer warming in the northern temperate latitudes will be about 6^{o}C.”

“Coming generations will have to live with the danger of this ‘Sword of Damocles’ scenario, the abruptness of which has no precedent in the geologic history of climate.”

Victor Brovkin, et al., *Climate Change*, 2008

Getting to Yes

The more we fear climate change, the less we can allow ourselves to be squeamish about imperfect “solutions.”

We must remember that we want solutions to work. It can’t be enough to identify what’s wrong with a strategy as it is first proposed. We must ask: With what changes, would this strategy become acceptable? How might we get from here to there?

Sustain a much smaller sulfur loading (e.g., 2 MtS, offsetting ≈50 ppm)?
Sheath the sword by combining air capture with sulfate injection?

Getting to No

However, we may decide, in some situations, to forego an option.

This may be the result of a moral judgment. We will prefer enduring some amount of climate change to the compromises required to avoid it.

Geoengineering: toward what ends?

Some forms of geoengineering may work. We may judge the risks to be tolerable.

Geoengineering governance may be achievable.

Granting both conditions, how will geoengineering be used?

The goal of Earth enhancement

Genetic disease was the motivator of genetic engineering. The resultant tools now allow enhancement of the human species (prettier, taller, smarter,…)

Geoengineering is being motivated by the prospect of horrible climate change. We can anticipate that its tools will allow enhancement of the planet – notably, the moderation of extreme events:

warmer winters where people want them
cooler summers where people want them
less severe storms and droughts

sweet spots

A geoengineered world bears almost no resemblance to the world desired by environmentalists, who seek to *reduce* the influence of humans on other species and ecosystems.

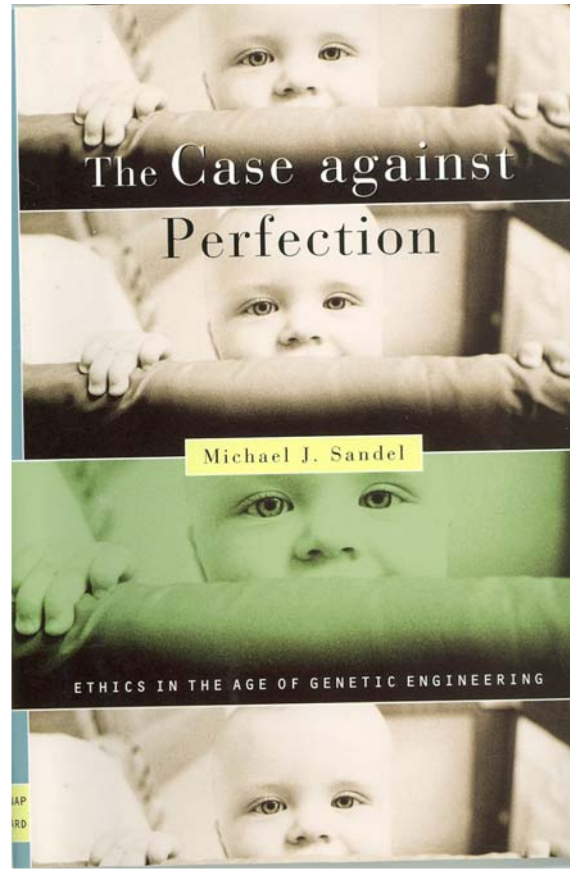
When geoengineering becomes enhancement

The analogies to medicine continue…

Michael Sandel sets up a dichotomy to explore modern medicine:

Cure or restore vs. enhance or perfect.

- Sex selection
- Eugenics
- Steroids and sports
- Cosmetic surgery
- Hyper-parenting



He argues that enhancement can be pursued to excess. He sees a loss of the ability to savor the life we have been "gifted." He sees value in randomness, the "unbidden."

"When science moves faster than moral understanding, as it does today, men and women struggle to articulate their unease."

Planetary identity

In the process of taking climate change seriously, we develop a planetary identity. We augment our previous loyalties to family, to tribe, and to a nested set of political entities from the village to the nation. Every man’s death diminishes us.

We also develop loyalties to future generations.

How do the world’s norms change when large numbers feel an allegiance to the planet? Might one consequence be strengthened efforts to address global poverty and world peace – negating the claim that climate change is a distraction from assignments of greater urgency.

Prospicience

Prospicience: “The art [and science] of looking ahead.”

We have scarcely begun to ask: What are we on this planet to do? What are our goals? What are our responsibilities?

Imagine spending as much effort on our collective destiny on Earth as we spend on our personal destiny in the afterlife!

CMI Collaborators

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Policy Group: Michael Oppenheimer (WWS and Geosciences), David Bradford (WWS and Economics, deceased), Harvey Lam (MAE), Klaus Keller (Penn State), Richard Tol (Hamburg), Shoibal Chakravarty (PEI), Jeff Greenblatt (Google.org), Brian Mignone (Brookings), Li Jie (WWS), Nicolas Lefevre (WWS), Xu Yuan (WWS)

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