Tuesday 12/7/10 Announcements

- Final exam Tuesday, Dec 14, 8am-10am, FCS 114
- Early exam (e.g. for AGU attendees): Thursday, Dec 9, 2-4pm, FCS 114 classroom.
- Study guides posted.

What to do about Global Change?: Mitigation, Geoengineering, and Adaptation
What to do about Global Change?:
Mitigation, Geoengineering, and Adaptation

I. Definitions and Background
II. Focus on Geoengineering:
   A. Carbon Dioxide Removal techniques
   B. Solar radiation management techniques
III. Conclusions

I. What to do about Global Change?:

Mitigation  Geoengineering  Adaptation
Avoid the problem  Fix the problem  Live with the problem
MITIGATION: avoiding the problem

Atmospheric Stabilization Emissions Paths
What would it take to get there?

Stabilizing at 2xCO₂ (green curve) is by no means “safe”, but achieving this much will be very difficult and more might not be possible.

We talked about mitigation in energy lecture:
Pacala & Socolow “wedges”
e.g. Windmills: Incredible Growth in Size, & Dramatic Cost Decreases

50 - 200 kW

100 - 400 kW

1500 kW - 4600 kW (1.5-4.6 MW)

Eff\text{max} = 16\%

Eff\text{max} = 30\%

Eff\text{max} = 45\%
Mitigation (‘‘avoid the problem’’) is eminently do-able. The cost: a few percent of global GDP (comparable to military defense expenditures; probably less than the future cost of health care).
At other end of spectrum: Adaptation (“live with the problem”)

Adaptation = policies designed to foresee, plan for, and eventually enable societies to adapt their economies and patterns of organization to a globally warmed world

Idea is that foresight and planning can reduce the burdens of dealing with global climate change

Adaptation, at some level, is inevitable (we have no choice, because some degree of climate change is inevitable)
Focus today: Geoengineering ("fixing the problem")

Geoengineering = intentional, large-scale manipulation of global environment

Idea is to do engage, by design, in globally significant activities which compensate for the globally significant activities that we are doing "by inadvertence"

What to do about Global Change?:

Mitigation       Geoengineering       Adaptation
Avoid the problem Fix the problem Live with the problem
What to do about Global Change?:

- **Mitigation**
  - Avoid the problem

- **Geoengineering**
  - Fix the problem

- **Adaptation**
  - Live with the problem

For much the past few decades, not much discussion of these.

WHY? The problem of what economists call “Moral Hazard”
What to do about Global Change?:

Mitigation       Geoengineering       Adaptation

Avoid the problem       Fix the problem       Live with the problem

Moral hazard = the problem caused when an agent is insulated from risks associated with its actions; it will act more recklessly than it would if fully exposed to the risk

For much the past few decades, not much discussion of these.

WHY? The problem of what economists call “Moral Hazard”

This is now changing rapidly
Geoengineering in the scientific literature

September 2009

December 2009
Geoengineering in the scientific literature

Published Items in Each Year

Papers published on “geoengineering climate”

A watershed publication in the scientific community:

Two main solutions

- Remove CO₂ from the atmosphere (sequestration in ocean and/or land)
- Reduce solar radiation (increase Earth’s albedo or reduce incoming solar radiation)

Royal Society Report, 2009
Geoengineering options for enhanced sequestration and solar energy management

Some proposed ideas for solar radiation management

- Reduce solar constant:
  - "Sunshade" world: screens at the Lagrange point (L1) between Earth and Sun
  - Sunshades in Earth's orbit
- Albedo modification schemes:
  - Albedo enhancement of marine stratocumulus clouds
  - Stratospheric aerosol injections
  - Increasing albedo of land surfaces (white plastic coverings over deserts, bioengineered plants, highly reflective roofs+roads in urban areas)
“Sunshade” world

- Space-based sunshade scattering sunlight away from Earth
- Near inner Lagrange point (P1): 1.5 million km from Earth. Same 1-year orbit as Earth
- Many small autonomous spacecraft: very thin refractive screen. 100,000s meter sized flyers forming a 100,000 km long cloud
- ~ a few trillion $$

Angel (2005) PMAS, 103, 17184-17189

Stratospheric Sulphate aerosols for radiation management:
Stratospheric Sulphate aerosols for radiation management:

1. We know for sure that it works
Stratospheric Sulphate aerosols for radiation management:

1. We know for sure that it works
2. It is cheap (maybe 0.0001% of GDP – at least 1000 X less than full scale mitigation)
Models are being used to investigate geoengineering

Temperature mitigation looks pretty good....


Precipitation mitigation less so....

What if Geoengineering by Aerosol abruptly failed?

A2 scenario
A2 scenario + GEO failure at 2025, 2050, 2075
A2 scenario + GEOEng.

Global Surface Temp

Rate of Temp change

Very large rates of warming!
(1-4 deg C per decade – 20X greater than current rate)

Impact on stratospheric ozone

Suiphate aerosols provide surfaces on which chemical reactions leading to ozone loss take place. They also lead to the increased formation of PSCs.

Worsening of stratospheric ozone depletion:
- substantial increase in Arctic ozone depletion especially during cold winters
- delay of 30-70 years in recovery of Antarctic ozone layer


III. Conclusions
The Royal Society Report (2009) Preliminary Assessment of various options:

The Royal Society Report (2009) Conclusions:

The safest and most predictable method of moderating climate change is to take early and effective action to reduce emissions of greenhouse gases. No geoengineering method can provide an easy or readily acceptable alternative solution to the problem of climate change.

Geoengineering methods could however potentially be useful in future to augment continuing efforts to mitigate climate change by reducing emissions, and so should be subject to more detailed research and analysis.

Geoengineering of the Earth’s climate is very likely to be technically possible. However, the technology to do so is barely formed, and there are major uncertainties regarding its effectiveness, costs, and environmental impacts.
The Royal Society Report (2009)
Conclusions:

The acceptability of geoengineering will be determined as much by social, legal and political issues as by scientific and technical factors. There are serious and complex governance issues which need to be resolved if geoengineering is ever to become an acceptable method for moderating climate change.

The Royal Society Report (2009)
2 main Recommendations:

1. Increase efforts to mitigate and adapt to climate change, and in particular, seek agreements to at least 50% reductions (relative to 1990) by 2050. “Nothing now known about geoengineering options gives any reason to diminish these efforts.”

2. Further research and development of geoengineering options should be undertaken to investigate whether low risk methods can be made available if it becomes necessary to reduce the rate of warming this century.

This should include observations, the development and use of climate models, and carefully planned experiments.