Class 20: Geoengineering

- What are the ideas?
- Are they feasible?
- What are the downsides?

Learning Objectives

- List 4 geoengineering strategies that have so-far been proposed
- Explain the process by which these geoengineering strategies would address the effects of climate change
- Predict how a geoengineering strategy could go wrong relying on your understanding of the process by which it works and is likely to be implemented
- Argue for or against climate adaption, mitigation and geoengineering strategies for addressing climate change

GEOLOGY 095, 195. Climate: past, present, future
The Vermont Youth Climate Congress

It will take place at the State House in Montpelier this Sunday, November 17th from 12:30 - 4:30 pm

If you are interested in volunteering as a scribe for the committee sessions or to check in people at the event please email Kate@vpirg.org

Please visit out website at: https://vermontyouthcongress.com
Registration week – Geology classes next semester

- **GEOL 007** SU: Earth Hazards - Same teaching team - 11:40 12:55 T R
- **GEOL 096** Extraterrestrial Life – 4 faculty - 12:00 12:50 M W F
- **GEOL 055** Environmental Geology - 10:50 11:40 M W F

- **GEOL 195** Human Health and Geology - 10:05 11:20 T R

- **GEOL 235** Geochemistry of Natural Waters
- **GEOL 234** Global Biogeochemical Cycles

- **GEOG 143** Climatology - 02:50 04:05 T R
“Zebras” by Victor Vasarely

Tidied up by Ursus Wehrli,
https://www.kunstaufraeumen.ch/de
Schedule:

1. **Intro:** Critical Zone, water cycle, properties
2. Composition of rain, acid rain
3. Catchment processes, soils as aquatic systems
4. Catchment processes, organic and mineral soils
5. Streams and rivers, dissolved and particulates
6. Processes in lakes, and groundwater
7. Take a Break
Geochemistry of Natural Waters – GEOL235

Spring Semester 2020
Instructor: Julia Perdrial,
Office: 213C; Tel: (802) 656 0665;
Email: Julia.Perdrial@uvm.edu
Office hours: M&W 10:30-11:30 and by appointment;
Meeting Time: MWF 9:40-10:30; Credits: 3
Pre-requisites: Chemistry 31, 32.
What are the necessary ingredients for life to happen?

What do our fantasies about extraterrestrial life say about us?

How do we search for signs of life in other planets?

What is the Universe?

The future of life: What to expect?

What is it like to not be on your planet?

Inadvertently, Roy dooms the entire earth to annihilation when, in an attempt to be friendly, he seizes their leader by the head and shakes vigorously.
Human Health & Geology

GEOL 195

Tu/Th
10:05-11:30

3 credits
Jr. & Sr. standing
Review of last class (which was a bit snowy)

Doing nothing about the effects of CO₂ and climate change is not a “free ride”.

Dealing or not dealing with climate change will cost society – lives and money are on the line.

Ambitious GHG mitigation = Smaller increase in global temperatures = Less sea-level RISE = Less investment in adaptation and damage to coastal infrastructure.
Adaptation Strategies

Sea level
Water supply
Winter sports

Figure 5: Central adaptation approaches for sea level rise. After IPCC (2014).

Water Stress by Country: 2040

NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP4.5.
Climate Change Mitigation – some proposed ideas

Goal = Get CO₂ out of the atmosphere

1. Carbon capture and storage
2. Enhanced chemical weathering– almost geoengineering
3. Ecosystem protection and enhancement
4. Decarbonizing our energy system
The biggest challenge and why we are teaching this class

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Description</th>
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<tbody>
<tr>
<td>24%</td>
<td>believe that half of climate scientists, or fewer, think human-caused global warming is happening.</td>
</tr>
<tr>
<td>36%</td>
<td>believe that between 51 and 90 percent of scientists think global warming is happening.</td>
</tr>
<tr>
<td>17%</td>
<td>correctly understand that almost all climate scientists think global warming is happening.</td>
</tr>
<tr>
<td>21%</td>
<td>don’t know</td>
</tr>
</tbody>
</table>

Source: Yale Program on Climate Change Communication survey conducted in April; figures do not add up to 100 percent because of rounding
Trajectories of the Earth System in the Anthropocene

We explore the risk that self-reinforcing feedbacks could push the Earth System toward a planetary threshold that, if crossed, could prevent stabilization of the climate at intermediate temperature rises and cause continued warming on a “Hothouse Earth” pathway even as human emissions are reduced.
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Geoengineering

Solar radiation management → Cryospheric manipulation → Greenhouse gas removal
Geoengineering – what is it?

“The deliberate large-scale manipulation of an environmental process that affects the earth's climate, in an attempt to counteract the effects of global warming.”
Geoengineering in three parts

1 Solar radiation management

2 Manage the Cryosphere

3 Greenhouse Gas Removal
1 Solar radiation management

2 Manage the Cryosphere

3 Greenhouse Gas Removal

Given what you have learned this semester, propose a geoengineering approach for each of these three categories.
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- Solar radiation management
- Cryospheric manipulation
- Greenhouse gas removal
Solar Radiation Management (SRM) or Solar Geoengineering
**Solar Radiation Management (SRM) or Solar Geoengineering**

**Increase Albedo.** Increase the reflectiveness of clouds or the land surface so that more of the Sun’s energy is reflected.

**Space reflectors.** Block some sunlight before it reaches the Earth.

**Stratospheric aerosols.** Release small, reflective particles into the upper atmosphere to block some from reaching the surface of the Earth.
SRM - Increasing Earth’s Albedo – cut forests in snowy areas

Clear the planet’s remaining areas of boreal forest (Russia and Canada) to increase reflectivity. Would destroy ecosystems, decimate caribou, as well as the plants and people that depend on them. Carbon in forest would be released.

“I’m alarmed by Jason’s headlong rush into albedo management.”
In Peru, paint rocks with lime, industrial egg white and water.

This is to replace now-vanished glaciers in the hope they will return.

They have whitewashed two hectares in two weeks.

They plan is to paint about 70 hectares.

At best, the effects will be local.

Similar to the “white roof” approach.
SRM - Marine Cloud Brightening

Spray salt water into clouds so that they reflect more sunlight. Increase the amount and whiteness of clouds to reflect more sunlight. Mists of salt water would create more cloud condensation nuclei (the particles that provide a surface for vapor to condense). Viola, more clouds.
SRM - Reduce incoming solar energy – mirrors in space

Lawrence Livermore National Laboratory proposed a giant space mirror 2000. The mirror would be slightly smaller area than Greenland or billions of smaller mirrors would also do the trick. But...uneven temperature effects, including drought.
SRM - Reduce incoming solar energy – adding aerosols to the stratosphere

Aerosols reflect solar radiation thus lowering Earth’s temperature.

They are "seeds" for water to form clouds, increasing albedo.

They would be injected into stratosphere, a stable region of the atmosphere that begins about 8 km above the surface.
“We are working to build Harvard's Solar Geoengineering Research Program (SGRP) that will bring together an interdisciplinary group of faculty from across the university to accelerate the understanding of the effectiveness and risks of solar geoengineering. The program will combine three key elements: research on solar geoengineering technologies, analysis of environmental risks, and a broad program of assessment and governance research.”

David Keith explores the interface between climate science, energy technology, and public policy, with a particular interest in the science and public policy of solar geoengineering. He is a Professor of Applied Physics in Harvard’s School of Engineering and Applied Sciences Professor of Public Policy, Harvard Kennedy School.
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- Solar radiation management
- Cryospheric manipulation
- Greenhouse gas removal
“Geoengineering of glaciers will not mitigate global warming from greenhouse gases. The fate of the ice sheets will depend on how quickly we can reduce emissions. If emissions peak soon, it should be possible to preserve the ice sheets until they are again viable. If they keep rising, the aim will be to manage the collapse of the ice sheets to smooth the rate of sea-level rise and ease adaptation.” NATURE
Cryosphere management - Block warm ocean water from melting ice
Cryosphere management – artificial grounding lines

“Geoengineering interventions can be targeted at specific negative consequences of climate change, rather than at the entire planet,”

Michael Wolovick
Cryosphere management - remove subglacial water, slow down glacier sliding
Scientists have a crazy plan to fight rising oceans: Freeze the water over Antarctica

Earth scientists are exploring an outlandish strategy to deal with our rapidly rising oceans: Freeze an ungodly amount of sea water over Antarctica.

Dousing the world’s coldest continent would be a huge task, but it’s not impossible.

Uses nearly 10% of global energy
Would salinate the ice sheet
Would accelerate ice flow

Delivering future sea-level rise by storing water in Antarctica

K. Frieler¹, M. Mengel¹, and A. Levermann¹,²,³
¹Potsdam Institute for Climate Impact Research, Potsdam, Germany
²Institute of Physics, Potsdam University, Potsdam, Germany
³Lamont-Doherty Earth Observatory, Columbia University, New York, USA
This endeavor would make Western Antarctica an industrialized compound. But if we’ve destabilized (the ice shelf), everything will change dramatically anyway. So we either build our coastal protections as high as 5 meters worldwide, or do something crazy like this.”
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Greenhouse Gas Removal

Ocean Fertilization
Enhanced Weathering
Afforestation and other ecosystem services (Natural Carbon Storage)
And others we talked about Tuesday (carbon capture and storage, biochar)
Greenhouse Gas Removal - Ocean Fertilization

Dump iron pellets into the ocean to stimulate phytoplankton growth in areas of ocean with low productivity.

Stimulate phytoplankton growth.

Phytoplankton photosynthesize, capture CO2 and die.

They settle to the ocean bed and sequester carbon.
A 21% reduction of current net annual emissions of the United States is possible. At current carbon market prices (USD 10 per Mg CO2), offset of 5% of US emissions could be achieved. Natural climate solutions would also provide air and water filtration, flood control, soil health, wildlife habitat, and climate resilience benefits."
BUT....and this is a big BUT....decarbonization must also occur.

Natural climate solutions are not enough
Decarbonizing the economy must remain a critical priority
There must be downsides to geoengineering...indeed, there are.
Downsides. Even if we cool the Earth, what about the extra CO2 in the ocean?
Downsides. What happens when we stop?

“Rapid geoengineering termination would significantly increase the threats to biodiversity from climate change.”

The effects would be two to four times worse than with global warming alone, the study said.
Downsides – Unintended consequences?

Beyond that, critics say, regular aerosol injections would change the sky's color, ruin astronomy for optical telescopes on Earth, and remove the incentive for nations to clean up their own acts. And in a final act of irony, with less sunlight reaching the Earth's surface, solar panels would produce less power.
Downsides – what if we get clouds “wrong”? 

Clouds are whiter if the water droplets in them are smaller. Which happens when there are more condensation particles or aerosols in the cloud. 

This led John Latham to the idea of ‘cloud whitening’, by trying to increase the number of aerosols inside clouds over parts of the ocean, by using sea water spray.

But if the spray of droplets (containing salt aerosols) is too fine, these may compete with aerosols in existing clouds and clear the skies! 

And if the droplets are too heavy, they won't reach the clouds. Just one to two percent of aerosols may have effect. Cloud seeding is delicate...

© www.bitsofscience.org
Downsides. From where do the $$ and energy come?
Arguments against geoengineering

**IT DOESN’T WORK:** None of the technologies have a track record, all of them come with major risks and unknowns.

**WEAPONIZATION:** Geoengineering interventions can have regional winners and losers; to the extent that geoengineering successfully changes climate patterns in a predictable way, it will inevitably be weaponized.

**DETRACTS FROM REAL SOLUTIONS:** Geoengineering threatens to delay the implementation of a transition away from fossil fuels, and could redirect funding and investments away from real climate solutions. Some geoengineering proposals require vast amounts of energy.

**HUMAN RIGHTS AND BIODIVERSITY:** Many geoengineering proposals require the intensive exploitation of vast amounts of land. Those projects would inevitably displace millions of people and potentially wipe out entire ecosystems.

http://www.geoengineeringmonitor.org/reasons-to-oppose/
Climate change could kill an estimated half-million people annually by the middle of this century, through famine, flooding, heat stress, and human conflict. Preventing temperatures from rising 2 °C above preindustrial levels, long considered the danger zone that should be avoided at all cost, now looks nearly impossible.

Notably, even if every nation sticks to the commitments it’s made under the politically ambitious Paris climate accords, global temperatures could still soar more than 5 °C by 2100.

280 million more people without access to adequate water; 120 million more people exposed to major river floods; 12 million more people subjected to coastal flooding; 24% decline in global maize productivity.

https://www.technologyreview.com/s/604081/the-growing-case-for-geoengineering/
Will we do it?

Cloud seeding, chemtrails, geoengineering, H.A.A.R.P...

"TH' DANG GUM'MINT'S BEHIND ALL THIS CRAZY WEATHER!"

Prolly obama...

So human activity can affect climate?

That's crazy talk!

Geo-engineering tool kit for emergency use only

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“Most of these ideas are just theories, although some are much technologically simpler to implement than others. All these proposals are clear examples of the narrow-minded, reductionist mentality that characterizes geoengineering, which ignores the profound value of biodiversity and overlooks the multifunctionality and interconnectedness of ecosystems.”

http://www.geoengineeringmonitor.org/2018/05/surface-albedo-modification-technology-factsheet/