

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

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 our website at:

<https://vermontyouthcongress.com>

Amelia Poch



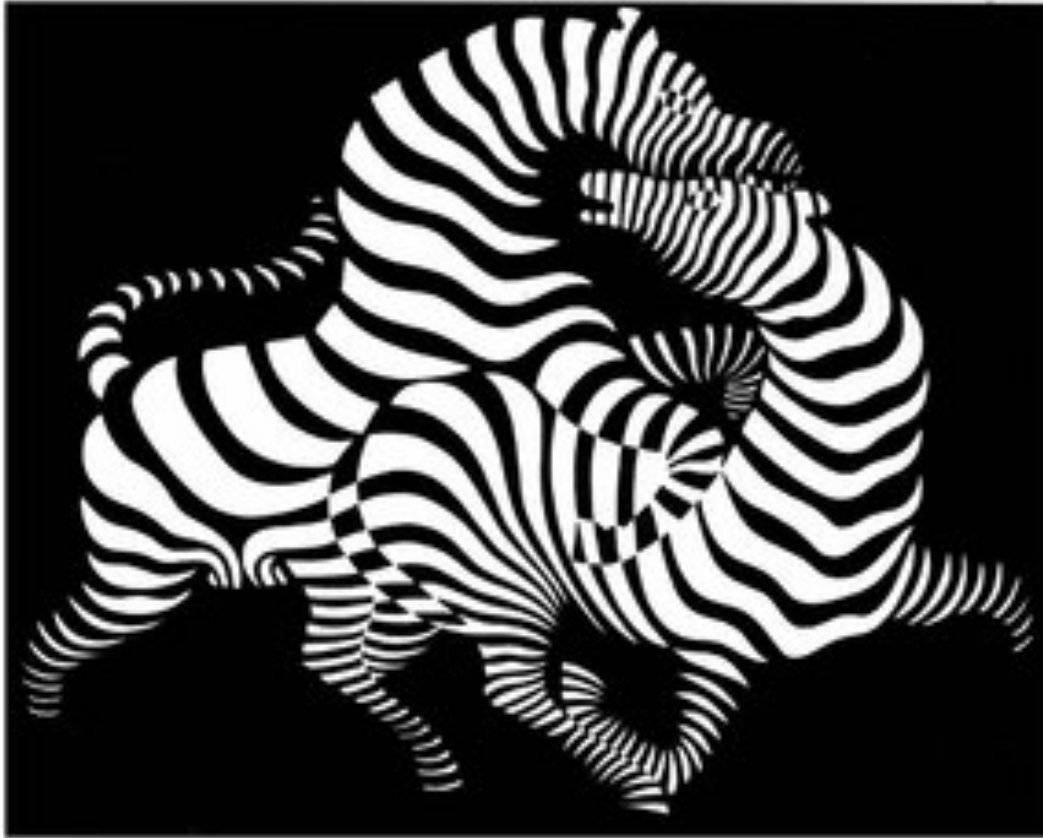
Registration week – Geology classes next semester

- [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

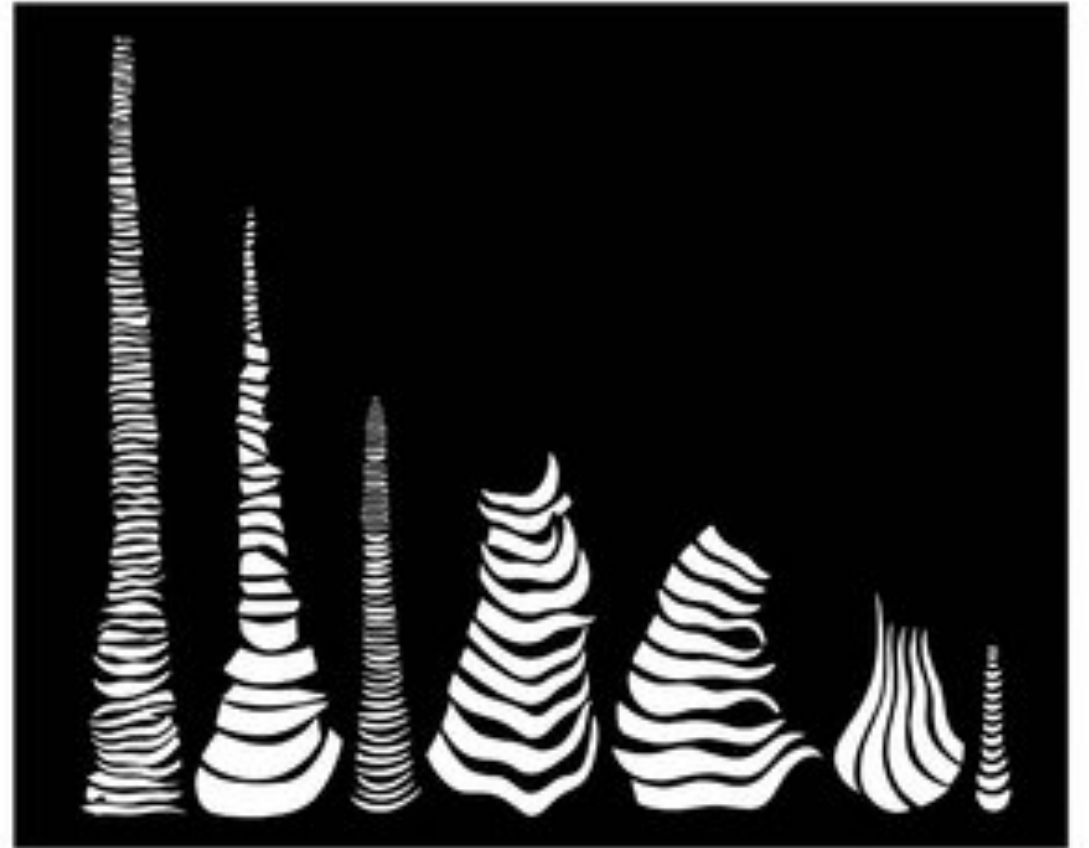
- [GEOL 195](#) Human Health and Geology - 10:05 11:20 T R

- [GEOL 235](#) Geochemistry of Natural Waters
- [GEOL 234](#) Global Biogeochemical Cycles

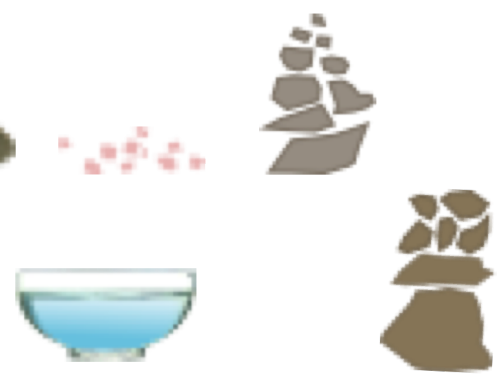
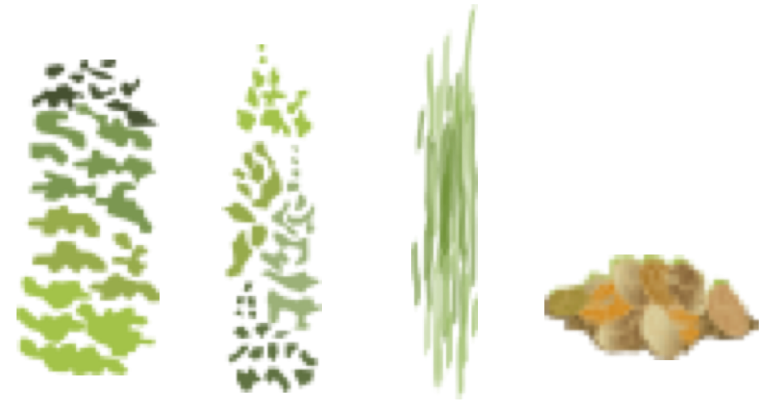
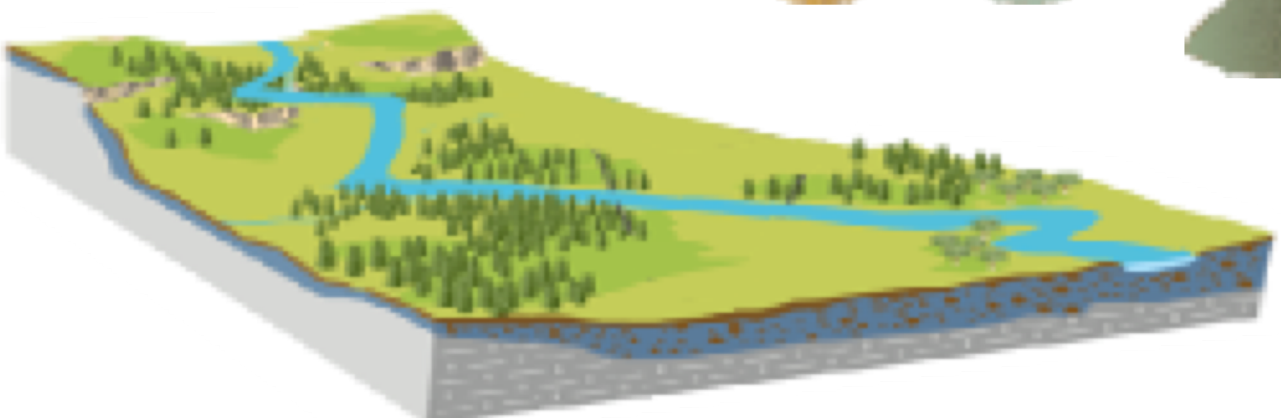
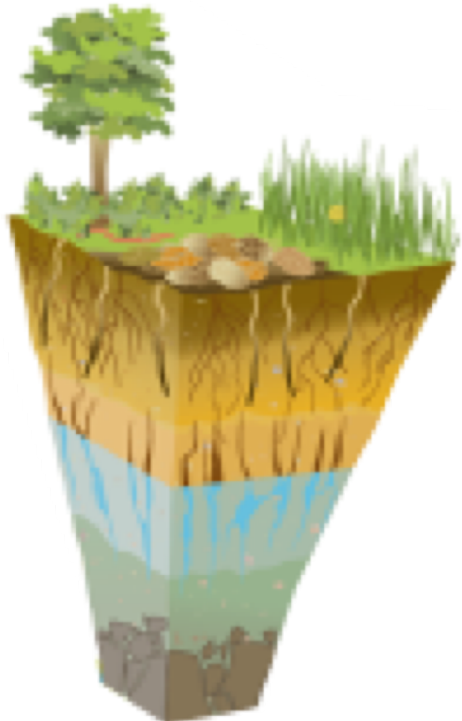
- [GEOG 143](#) Climatology - 02:50 04:05 T R



“Zebras” by Victor Vasarely



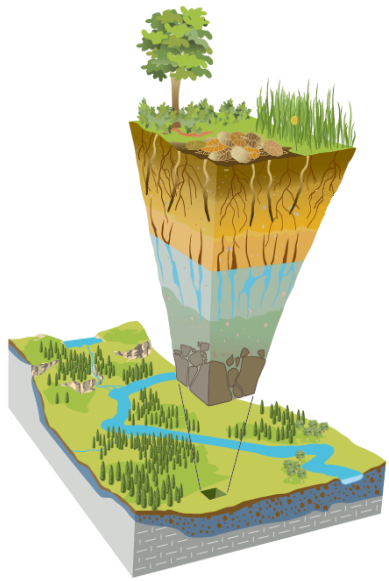
Tidied up by Ursus Wehrli,
<https://www.kunstaufraeumen.ch/de>



Plant stuff

Soil stuff

Rock stuff



Schedule:



1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

Intro:
Critical Zone,
water cycle,
properties

Composition
of rain, acid
rain

Catchment
processes, soils
as aquatic
systems

Catchment
processes,
organic and
mineral soils

Streams and
rivers, dissolved
and particulates

Processes in
lakes, and
groundwater



Geochemistry of Natural Waters – GEOL235

Spring Semester 2020

Instructor: Julia Perdrial,

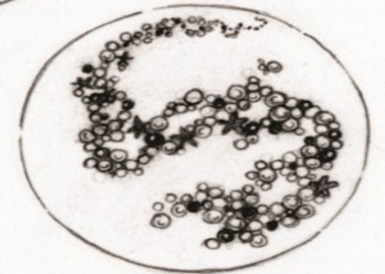
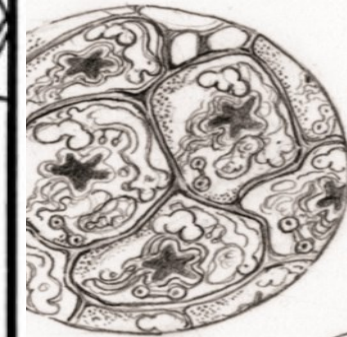
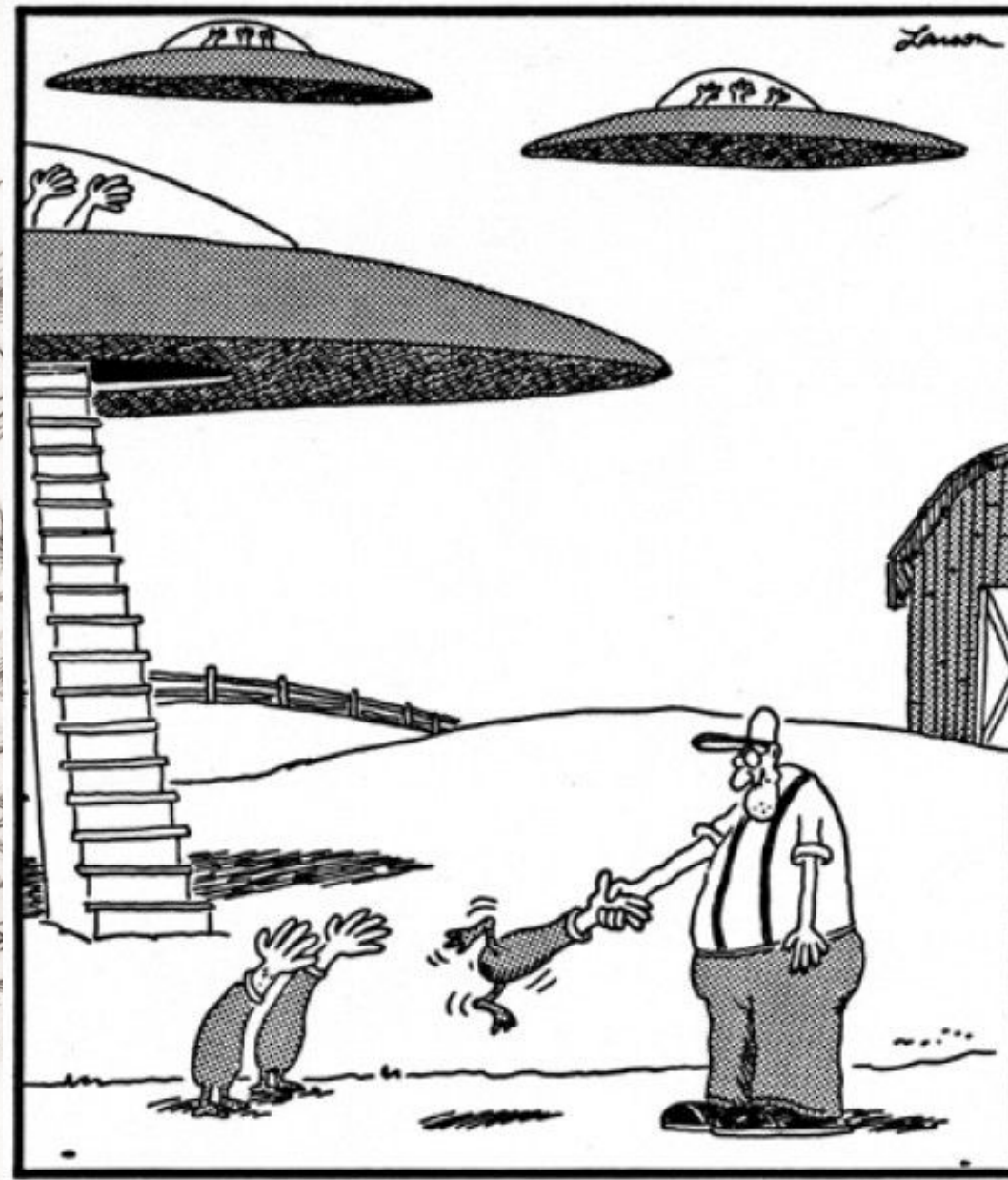
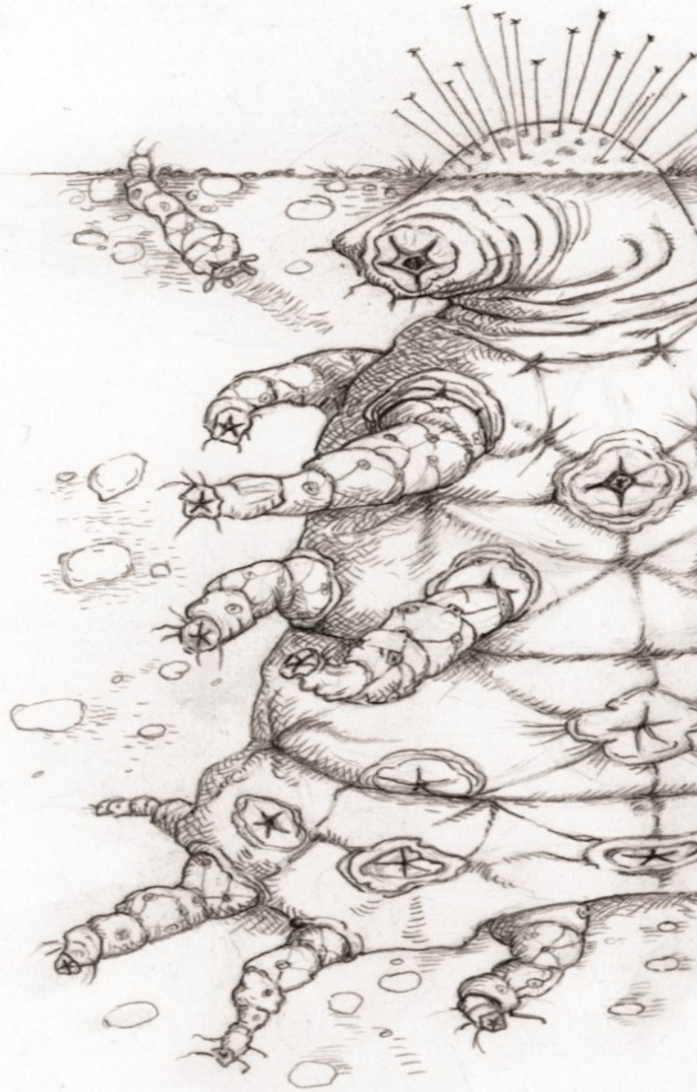
Office: 213C; Tel: (802) 656 0665;

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.



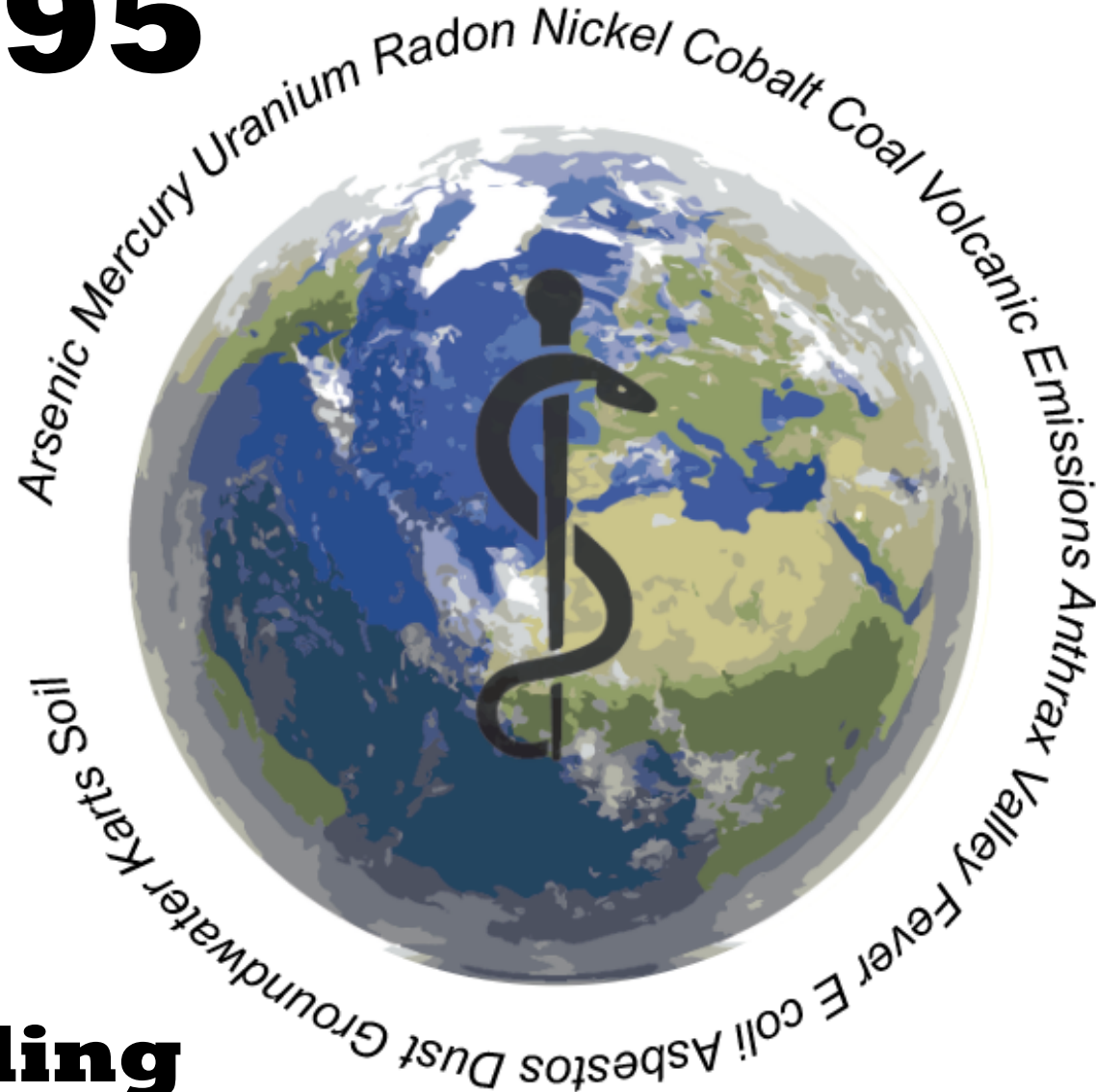
Inadvertently, Roy dooms the entire earth to annihilation when, in an attempt to be friendly, he seizes their leader by the head and shakes vigorously.

Human Health & Geology

GEOL 195

Tu/Th
10:05-
11:30

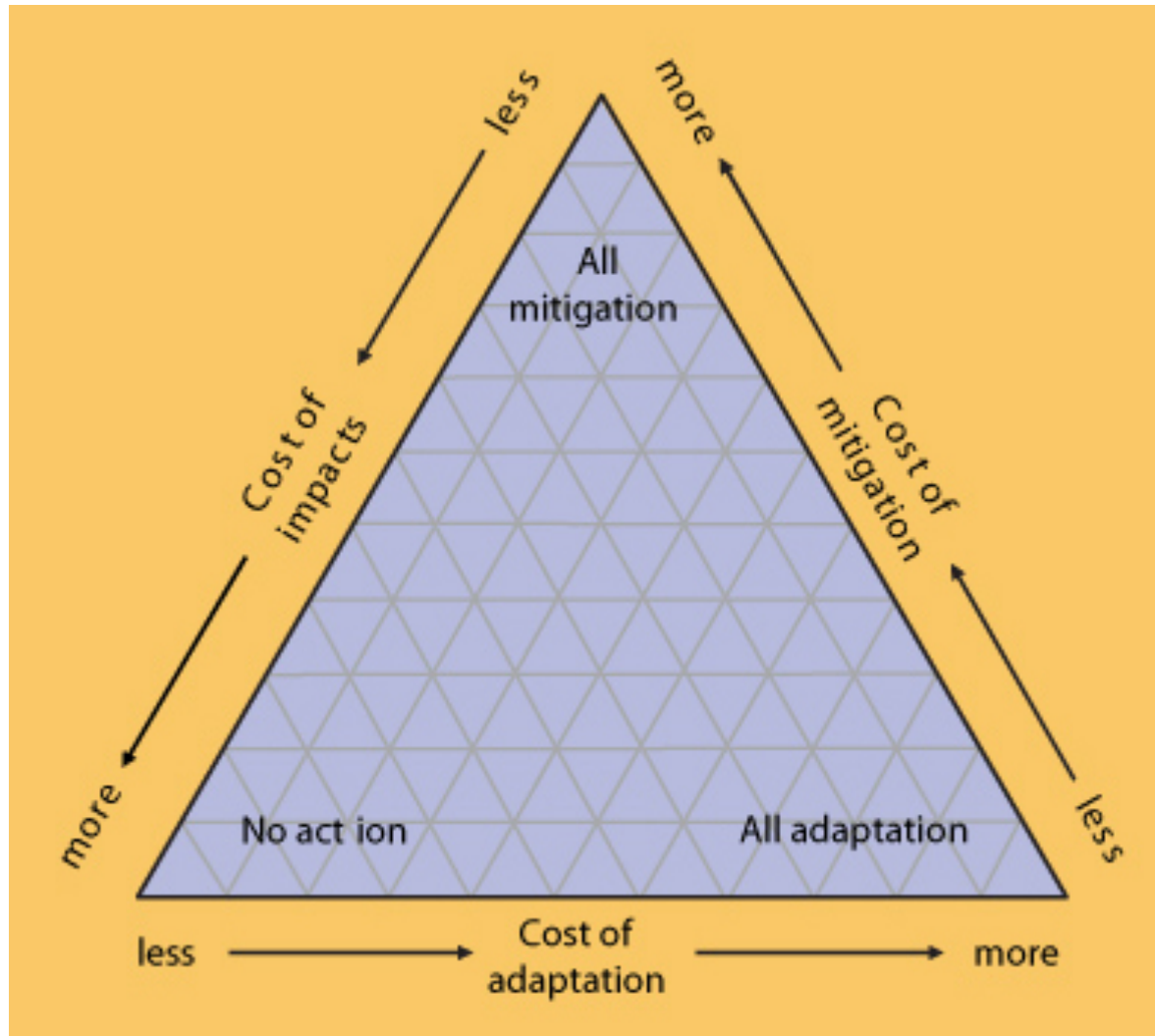
3 credits
Jr. & Sr. standing



Review of last class (which was a bit snowy)

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

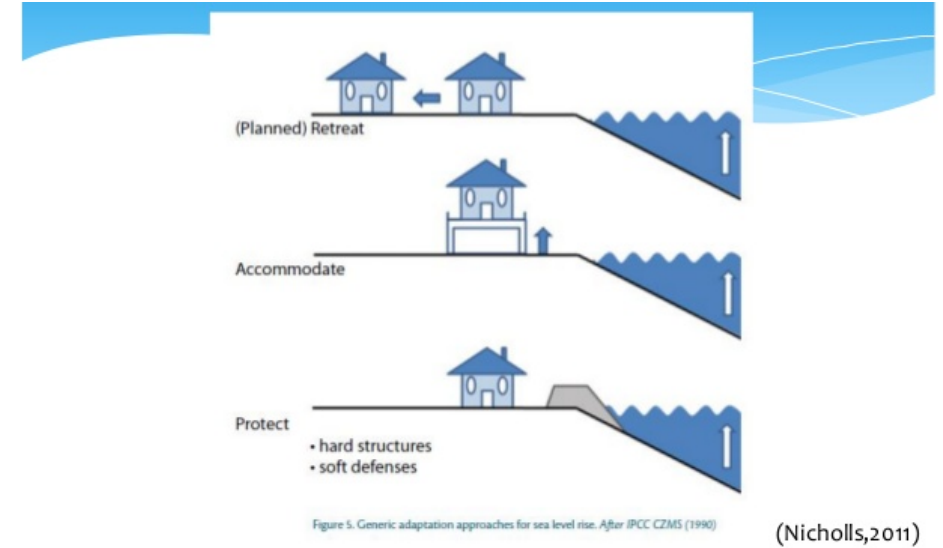
Dealing or not dealing with climate change will cost society – lives and money are on the line



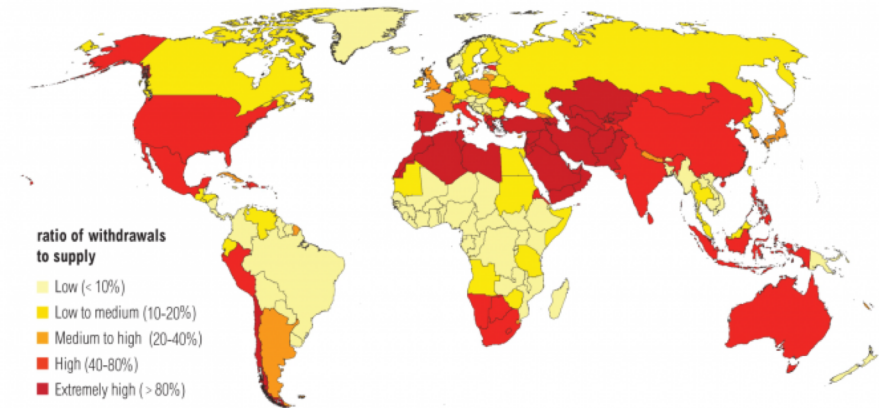
Ambitious
GHG mitigation = *Smaller*
INCREASE in global temperatures = *Less*
sea-level RISE
= *Less* investment in adaptation and damage to coastal infrastructure

Adaptation Strategies

Sea level
Water supply
Winter sports



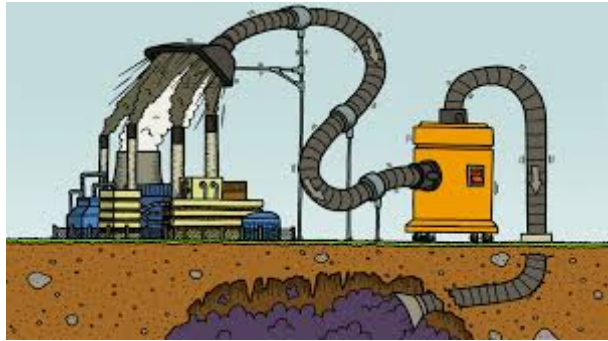
Water Stress by Country: 2040



NOTE: Projections are based on a business-as-usual scenario using SSP2 and RCP8.5.

For more: ow.ly/RWop

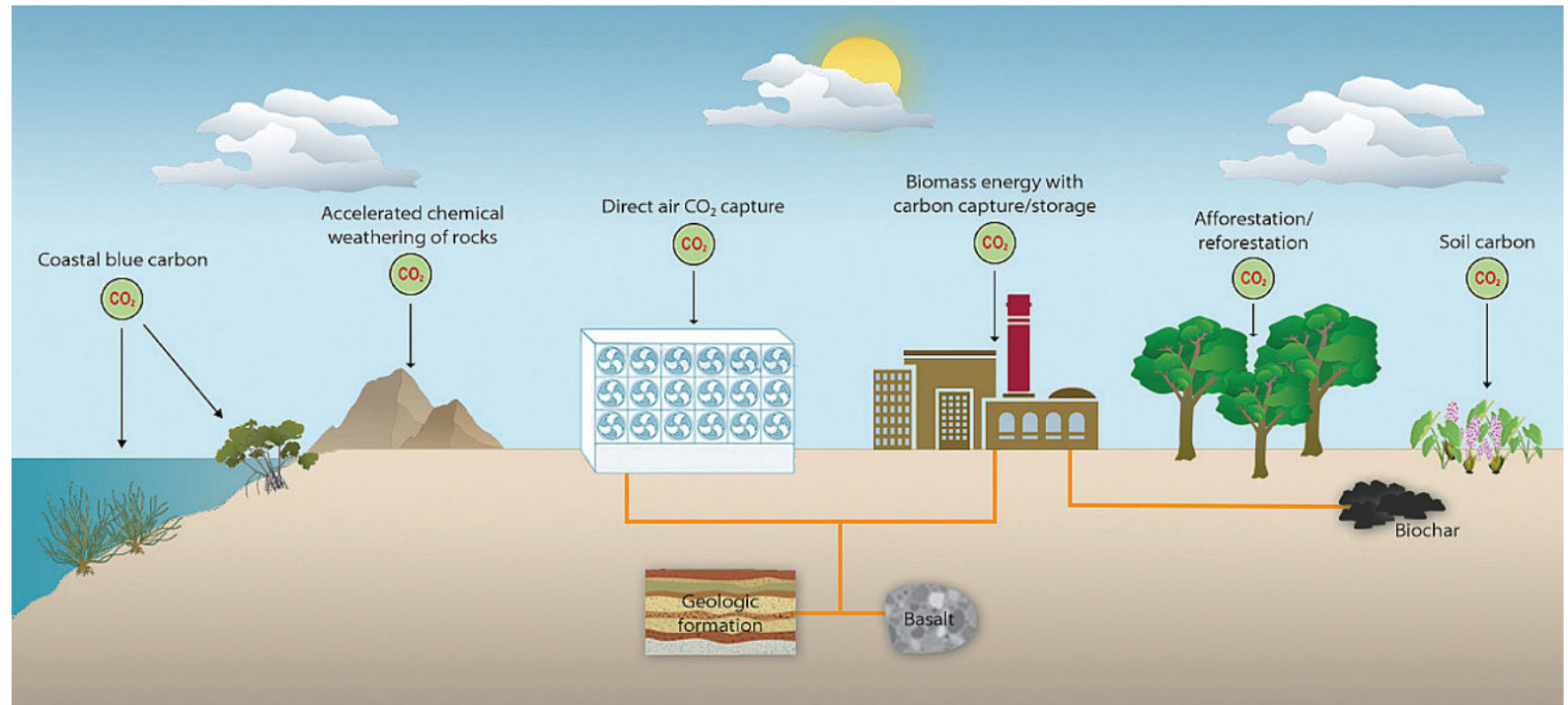
Climate Change Mitigation – some proposed ideas



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

24%

of Americans ...

... believe that **half of climate scientists, or fewer,** think human-caused global warming is happening.

36%

... believe that between **51 and 90 percent of scientists** think global warming is happening.

17%

... **correctly understand that almost all climate scientists think global warming is happening.**

21%

Don't know

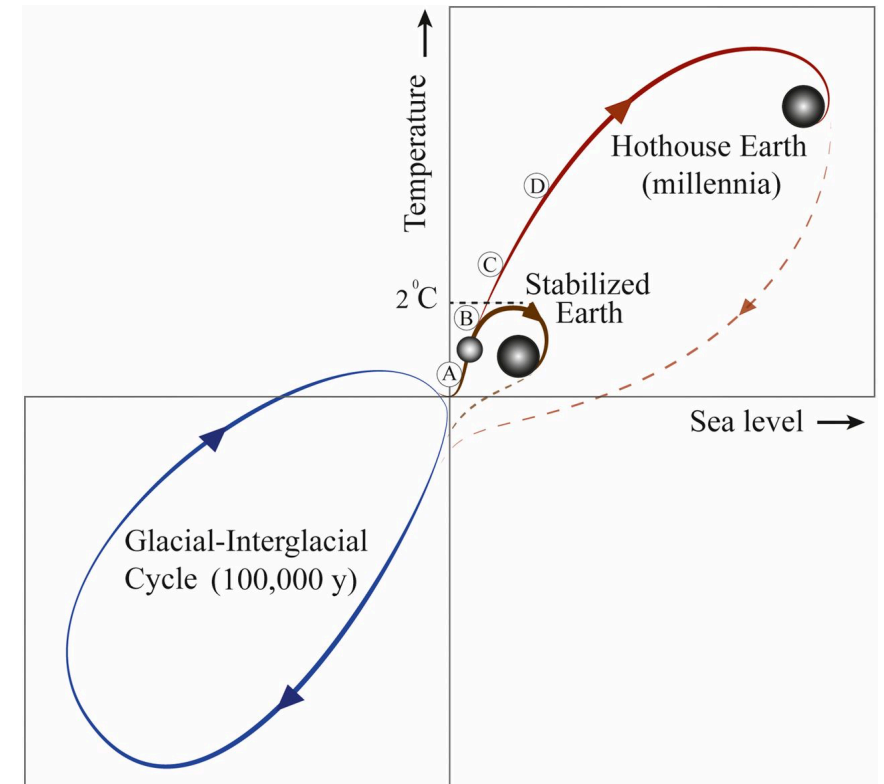
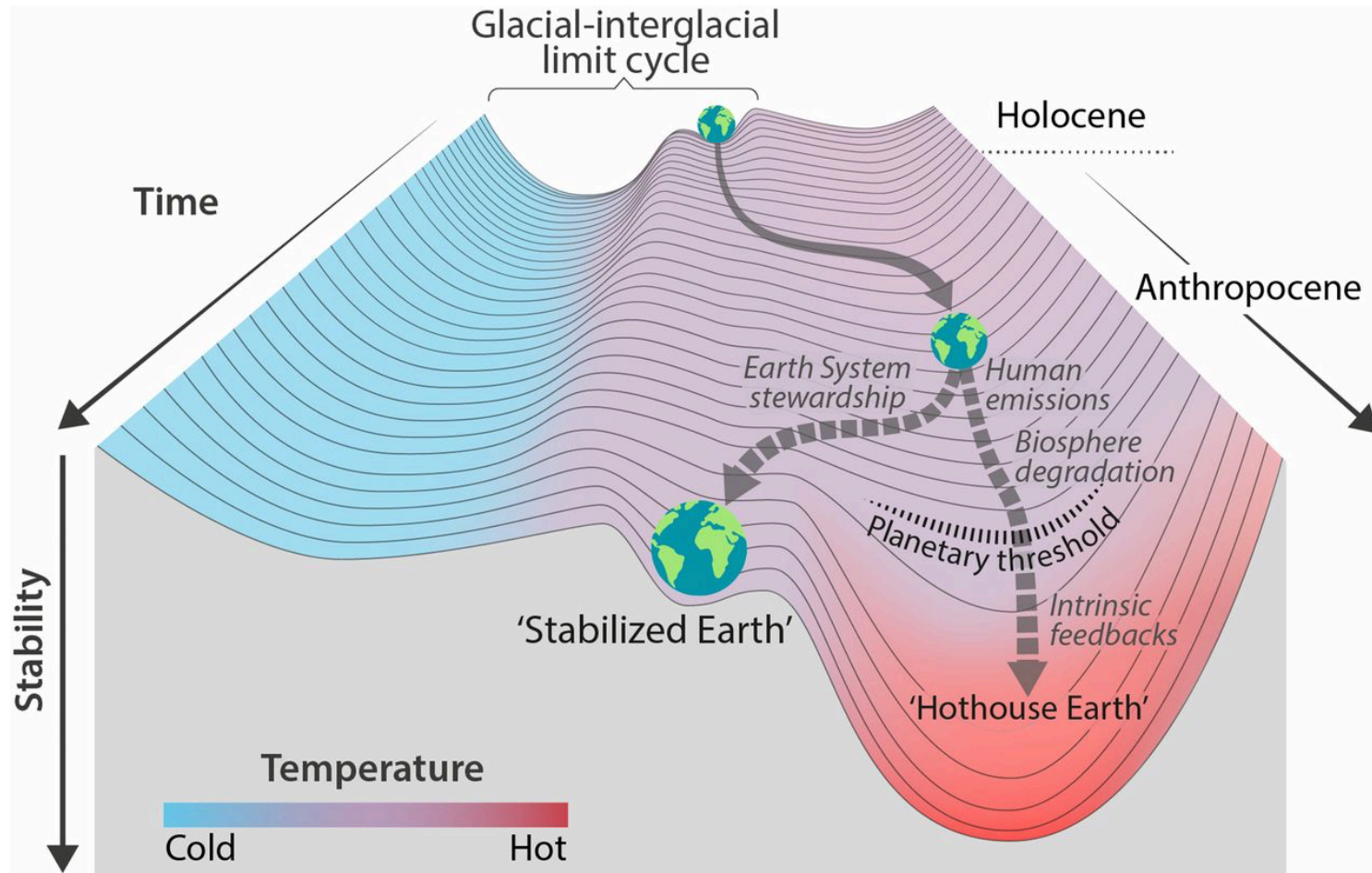
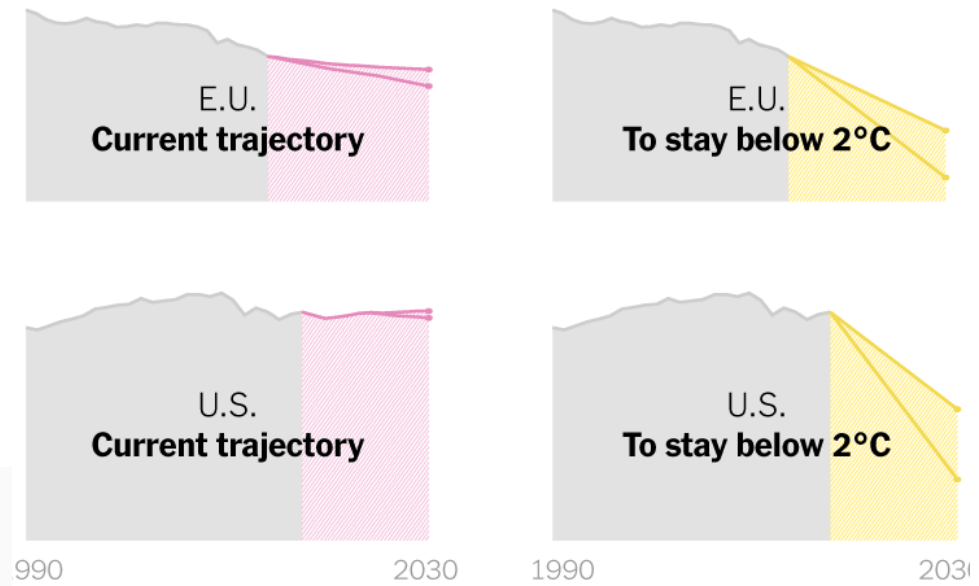


KING DONALD COMMANDS THE OCEAN to BACK OFF

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.



Geoengineering

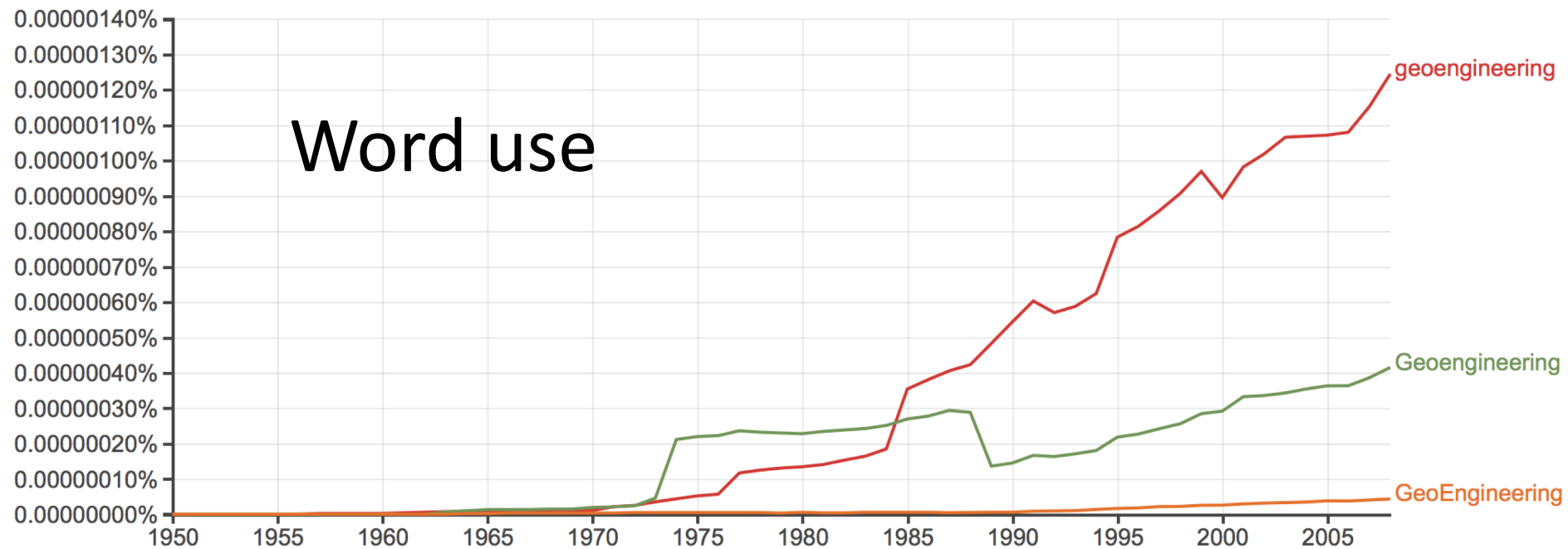
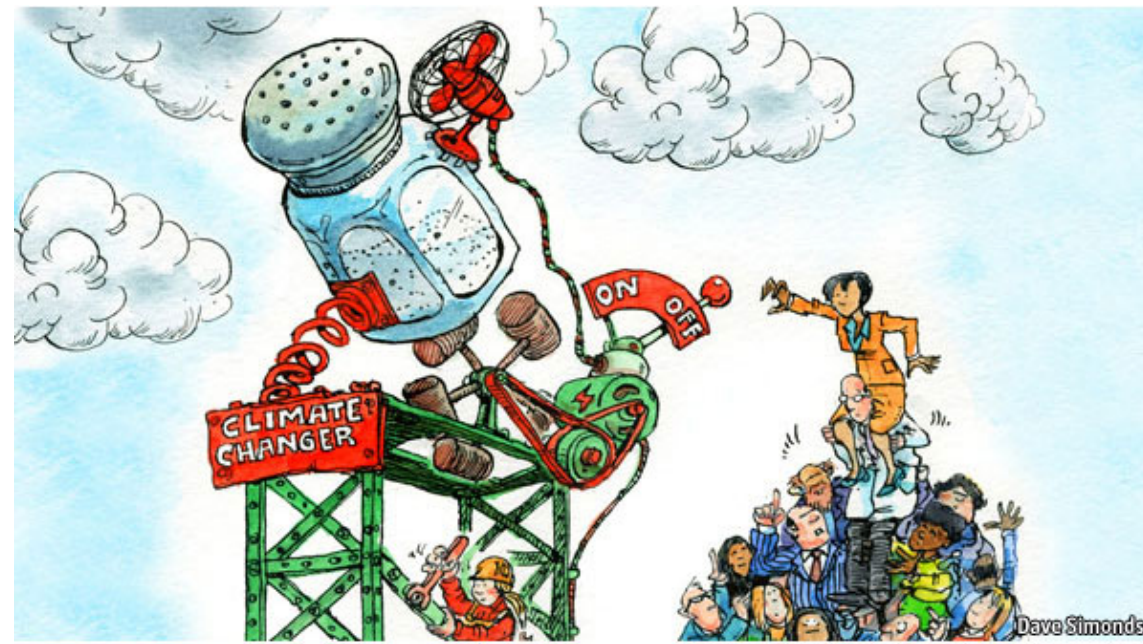
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Geoengineering – what is it?

“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.”

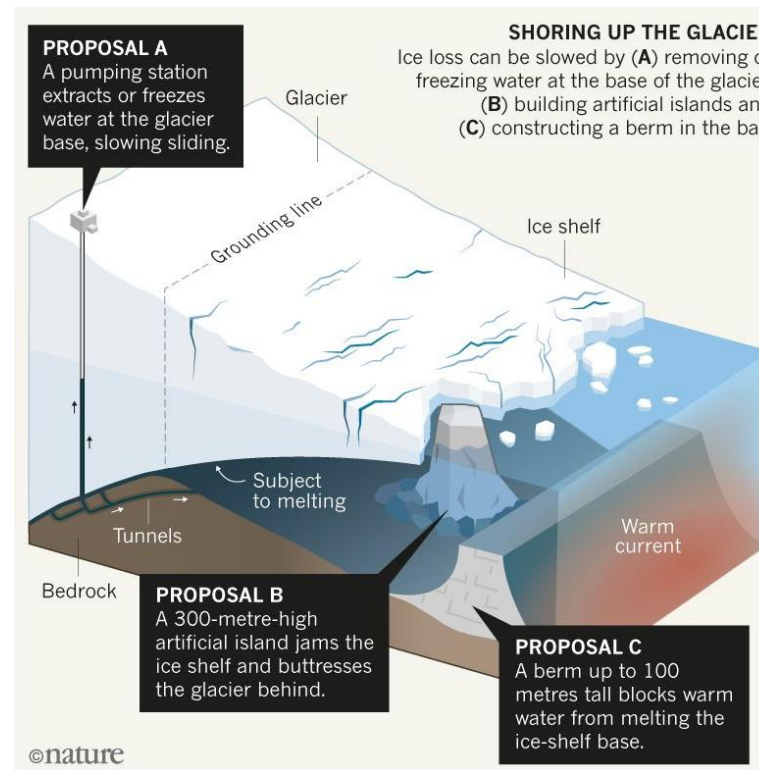


Geoengineering in three parts

1 Solar radiation management



2 Manage the Cryosphere



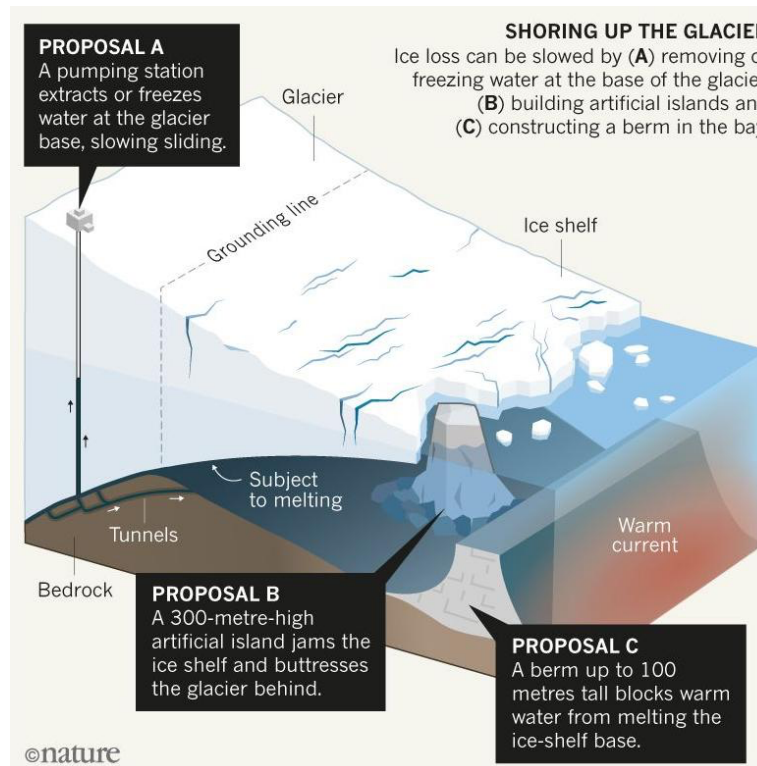
3 Greenhouse Gas Removal



Think – Pair - Share

Given what you have learned this semester, propose a geoengineering approach for each of these three categories

2 Manage the Cryosphere



1 Solar radiation management



3 Greenhouse Gas Removal



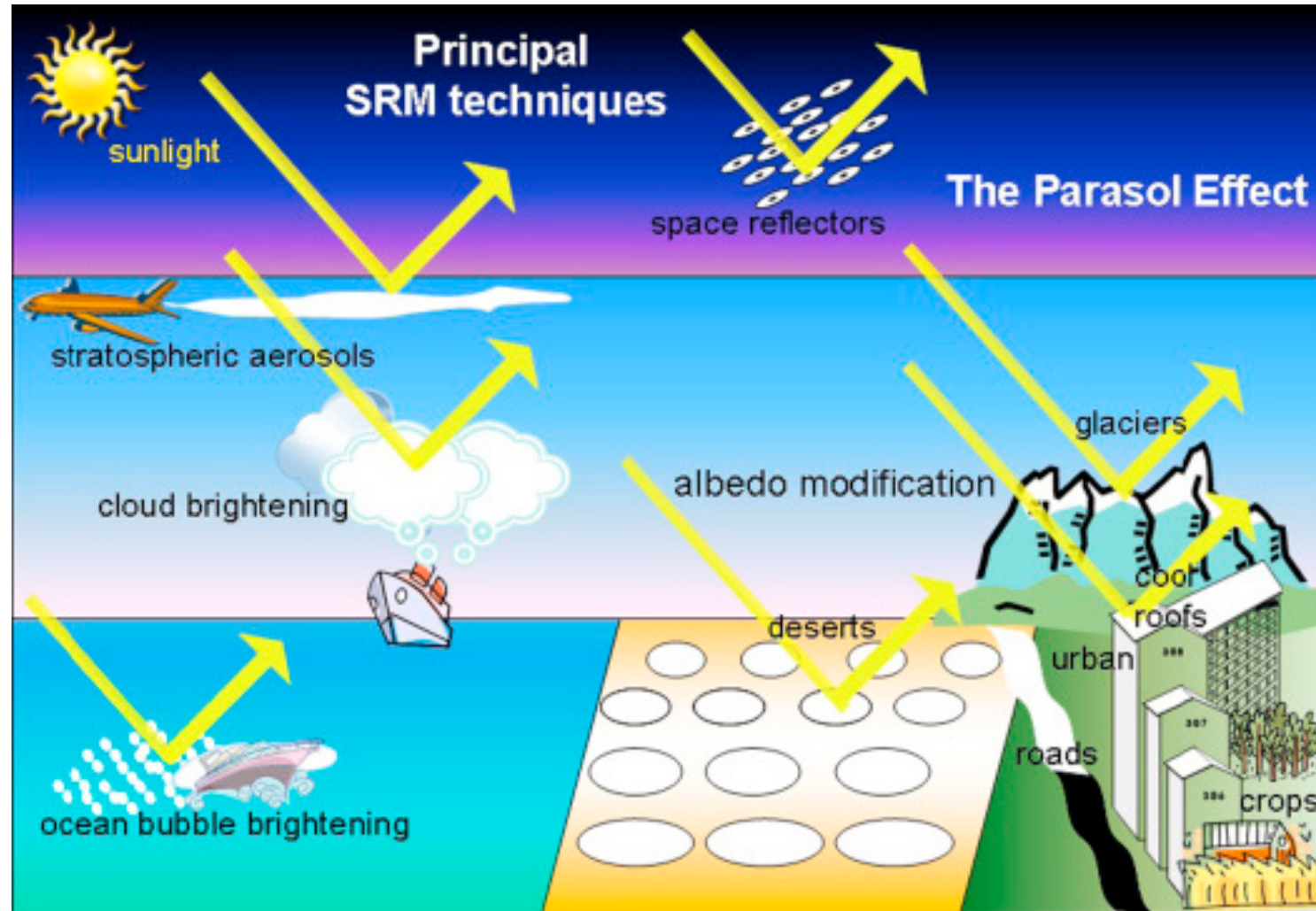
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Solar Radiation Management (SRM) or *Solar Geoengineering*



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



"I'm alarmed by Jason's headlong rush into albedo management."

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.

SRM - Replace glaciers with white rocks

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

Can painting a mountain restore a glacier?

By Dan Collyns
BBC News, Ayacucho

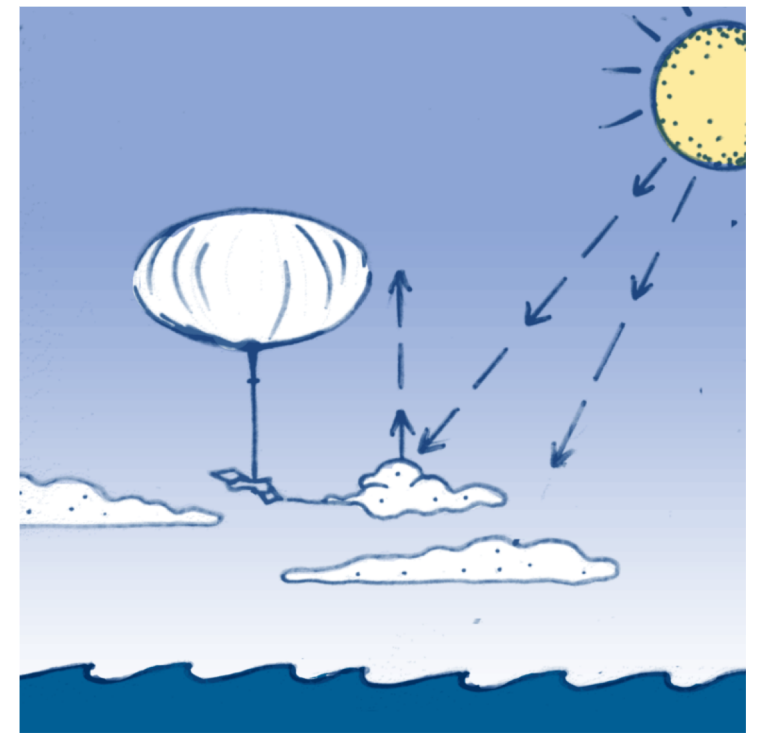
🕒 17 June 2010



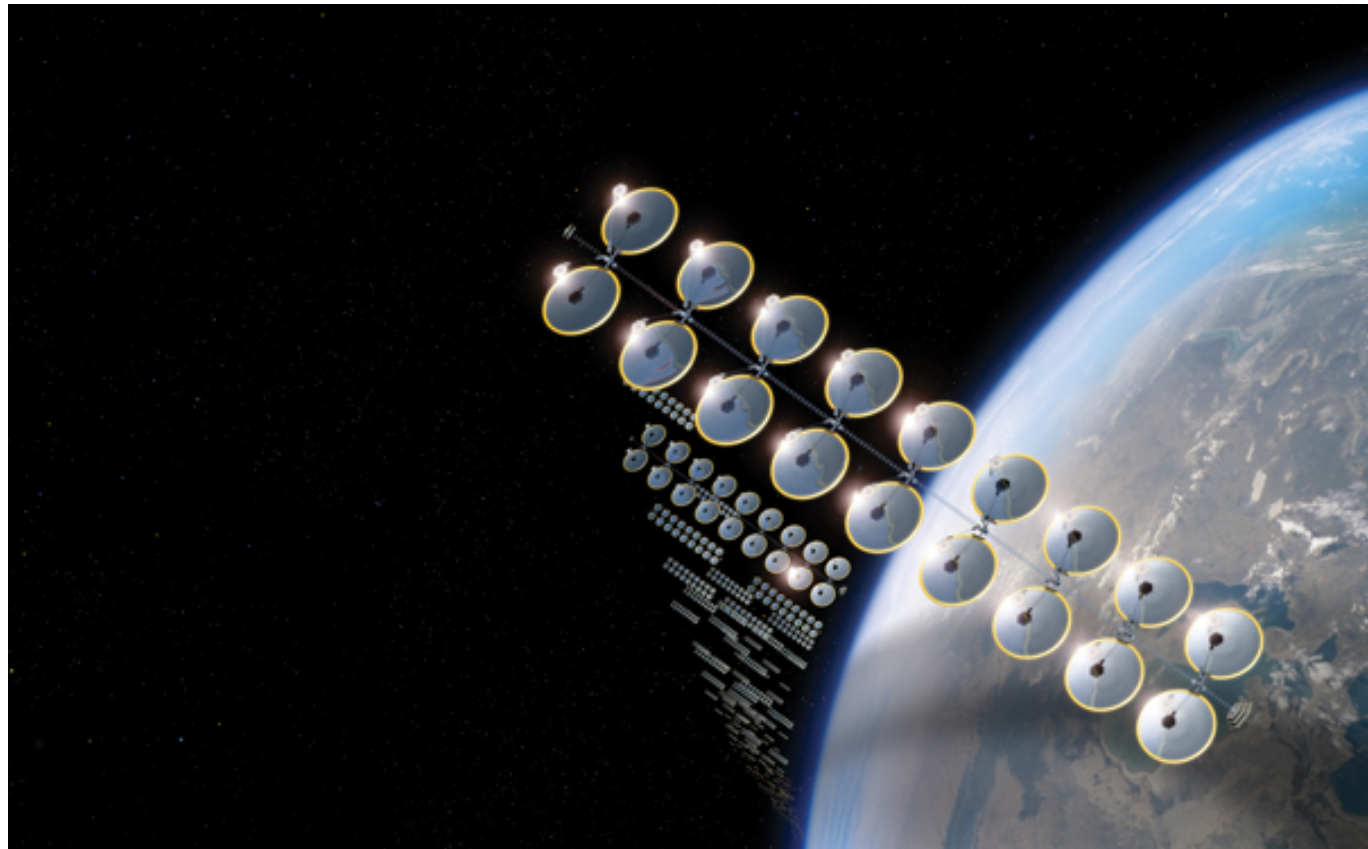
The team has nearly reached the peak of Chalon Sombrero

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

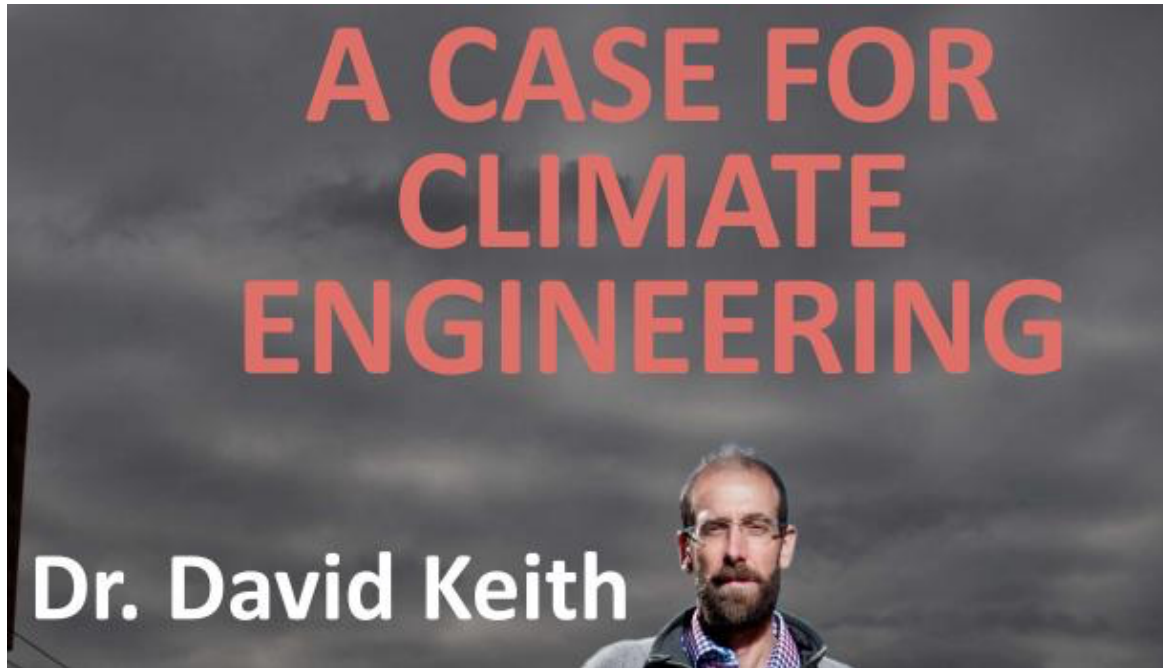


Aerosols reflect solar radiation thus lowering Earth's temperature.

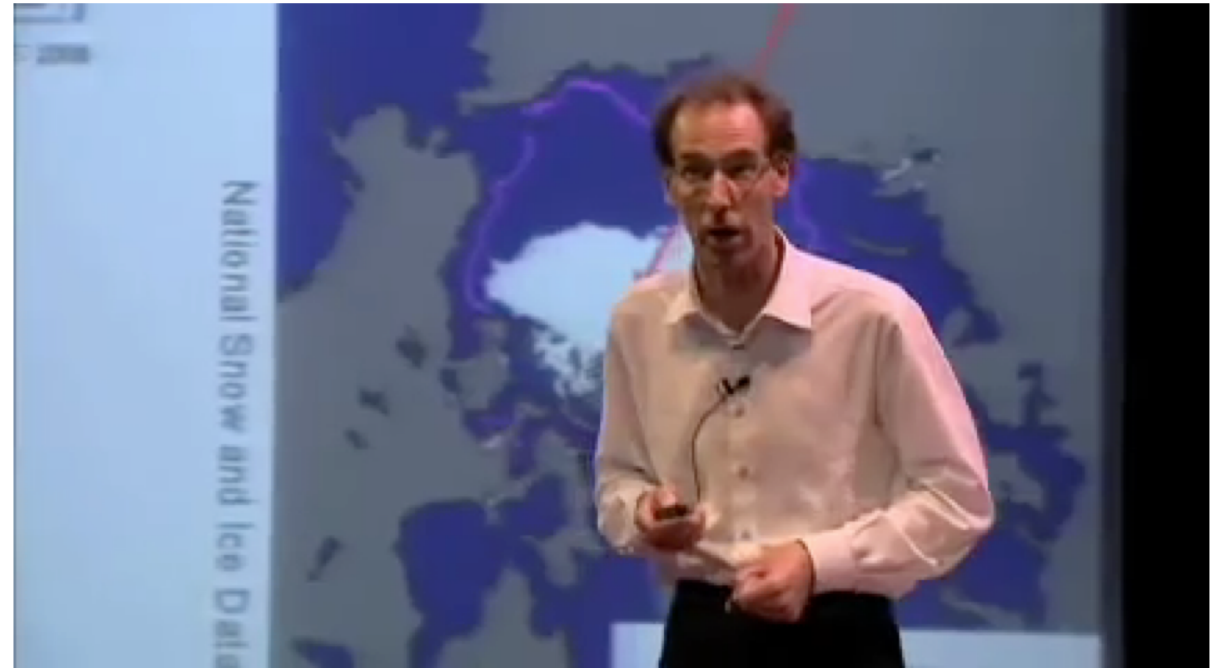
They are "seeds" for water to form clouds, increasing albedo

They would be injected into stratosphere, a stable region of the atmosphere that begins about 8 km above the surface.

Scientist Profile: Dr. David Keith, Harvard



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.



"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."

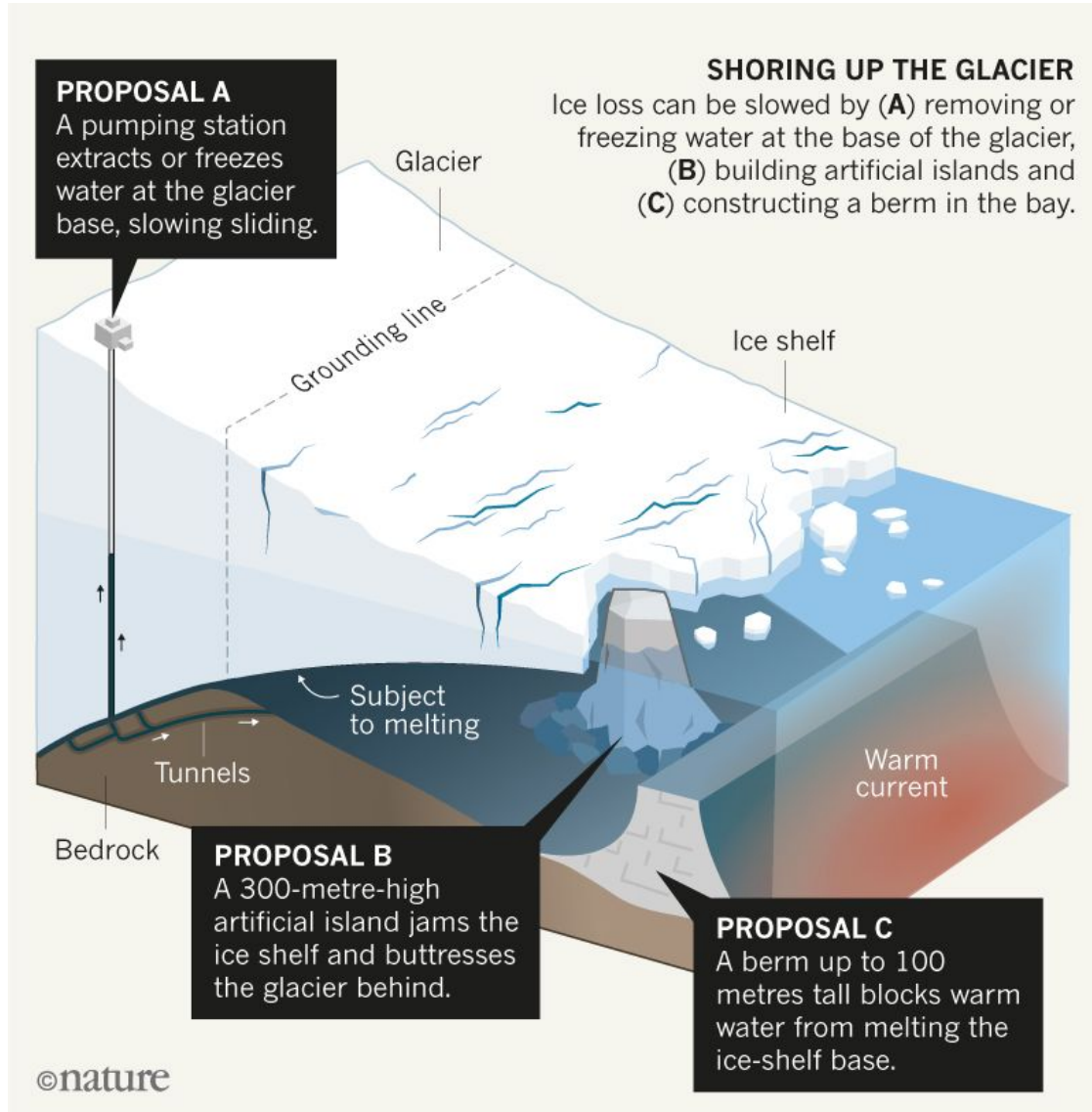
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Cryosphere management



1. Block warm water
2. Support ice shelves
3. Dry subglacial streams
4. Pump water back onto the ice

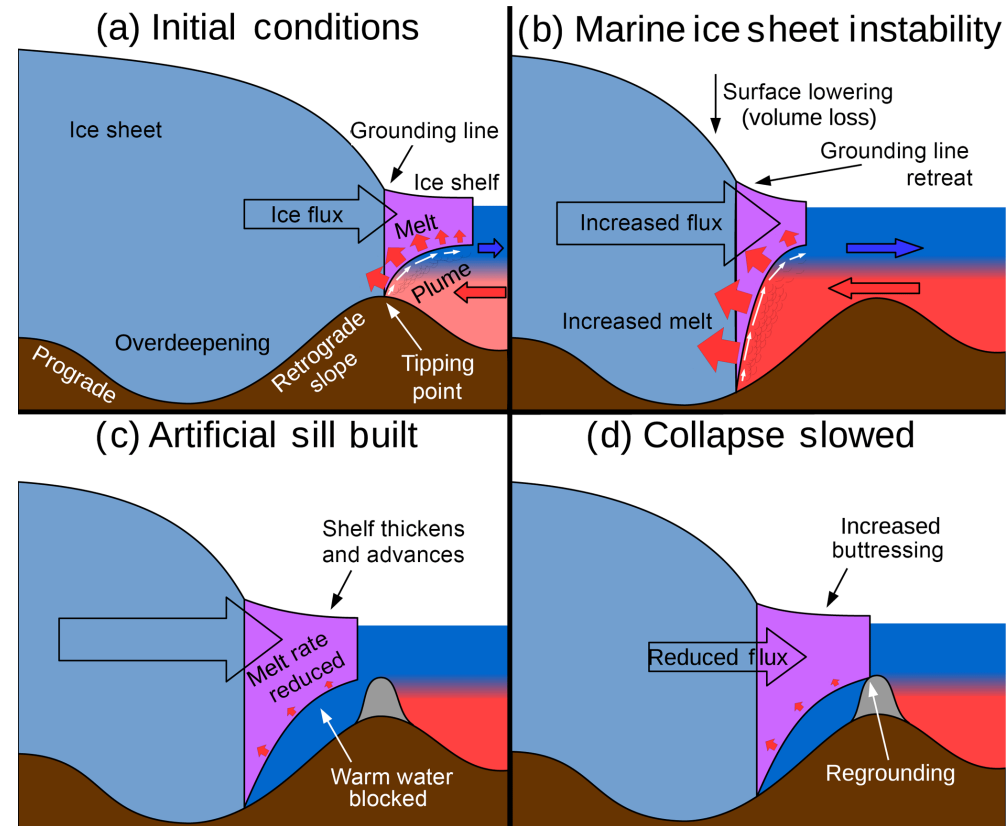
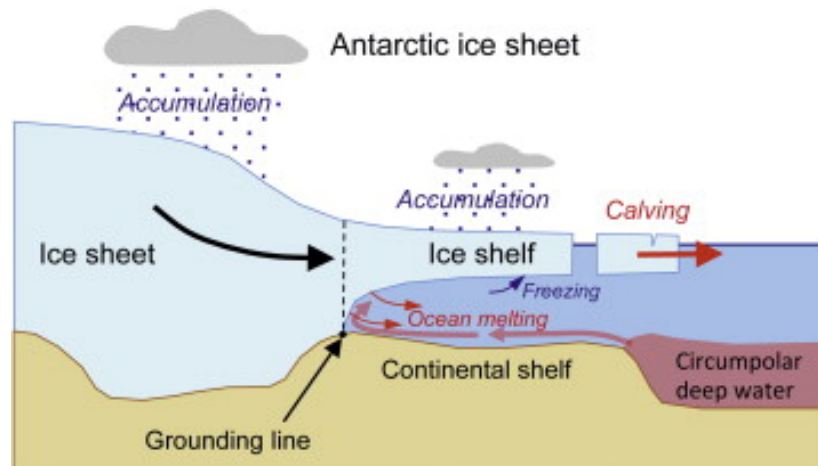
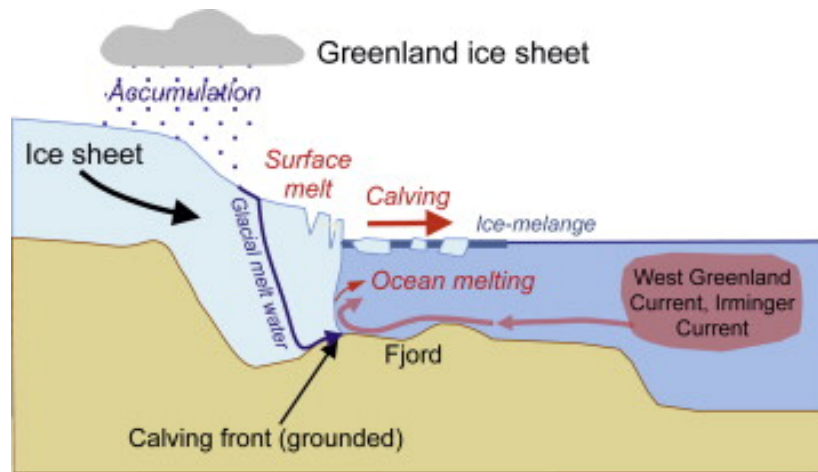
“Geoengineering of glaciers will not mitigate global warming from greenhouse gases. The fate of the ice sheets will depend on how quickly we can reduce emissions. If emissions peak soon, it should be possible to preserve the ice sheets until they are again viable. If they keep rising, the aim will be 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



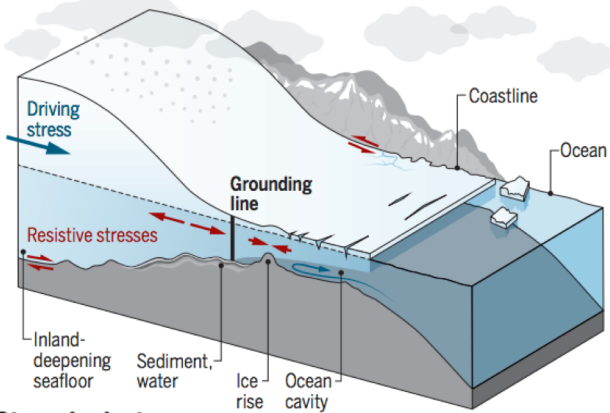
Build a Wall? A Wild Geoengineering Idea to Save the Glaciers



Cryosphere management – artificial grounding lines

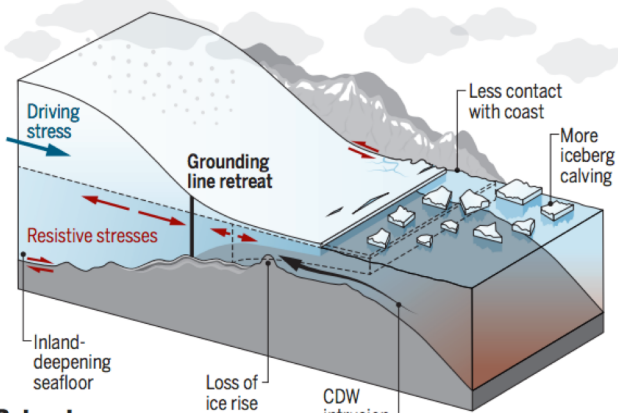
Precarious position

WAIS grounding lines are vulnerable because of the inland-deepening bed and connection to the ocean.



Stress budget

Ice flows in the direction of its surface slope due to gravity. Properties of the ice and materials at the boundaries determine other terms in the stress budget.

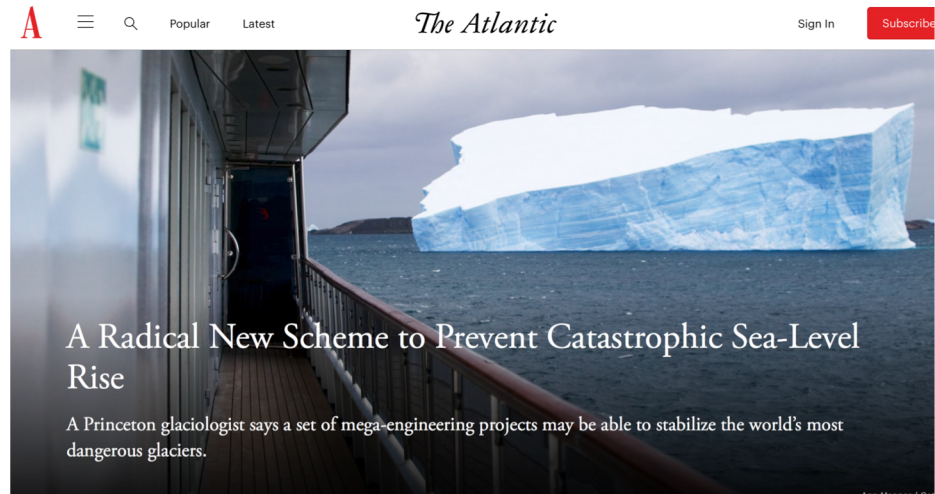


Retreat

An external forcing can cause runaway grounding line retreat if the perturbation to the stress budget is self-sustaining.



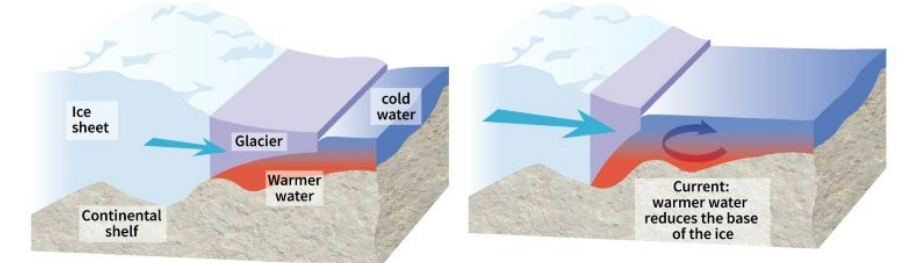
“Geoengineering interventions can be targeted at specific negative consequences of climate change, rather than at the entire planet,”
Michael Wolovick



Glacial engineering to slow collapse of Antarctic ice sheets

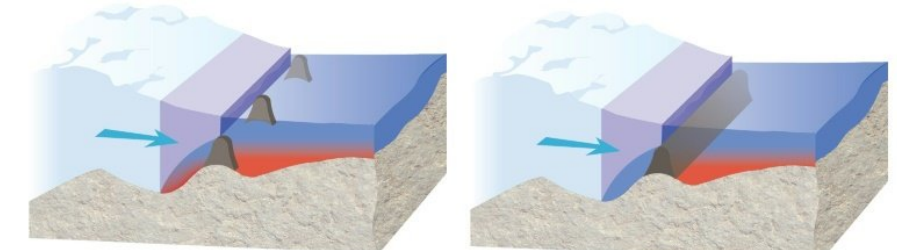
Study aims to provoke debate about possible projects to slow sea level rise due to climate change

- ▶ In a normal situation, the melting of the ice sheet is compensated by the advancing ice so there is no retreat of the ice
- ▶ Instability due to climate change: Less thick, the ice sheet retreats. Warmer water currents accelerate the retreat.



Possible Solutions

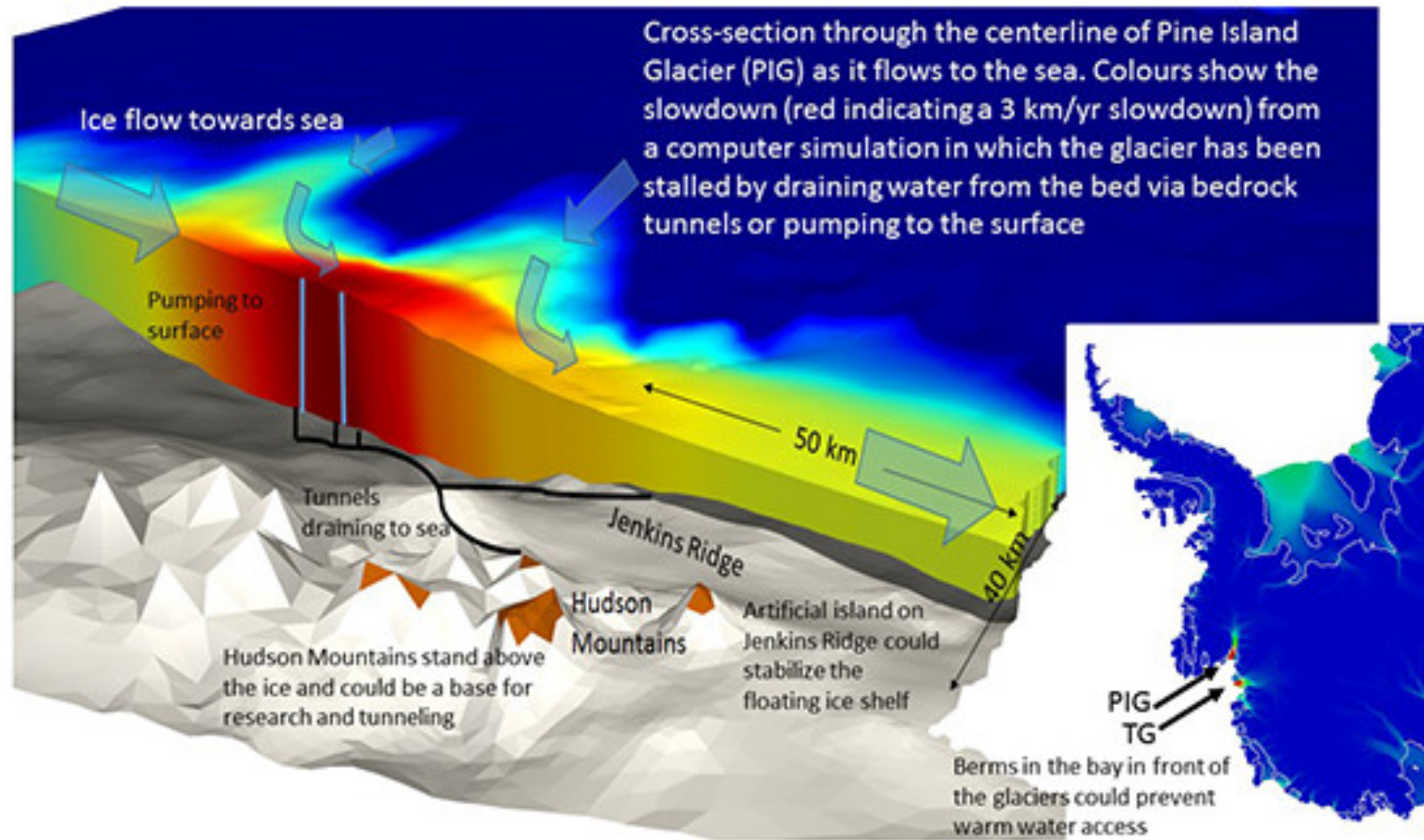
- 1 Construction of columns
30% chance of stabilising the glacier
- 2 A wall 80-120 km long
70% chance of success



Source: European Union for Geosciences

© AFP

Cryosphere management - remove subglacial water, slow down glacier sliding



Cryosphere management - Pump water back onto the ice to lower sea level

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

Scientists have a crazy plan to fight rising oceans: Freeze the water over Antarctica

Sarah Kramer Mar 11, 2016, 3:14 PM

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.



Not exactly how it'd look, but you get the idea. NASA/Michael Studinger (illustration by Tech Insider)



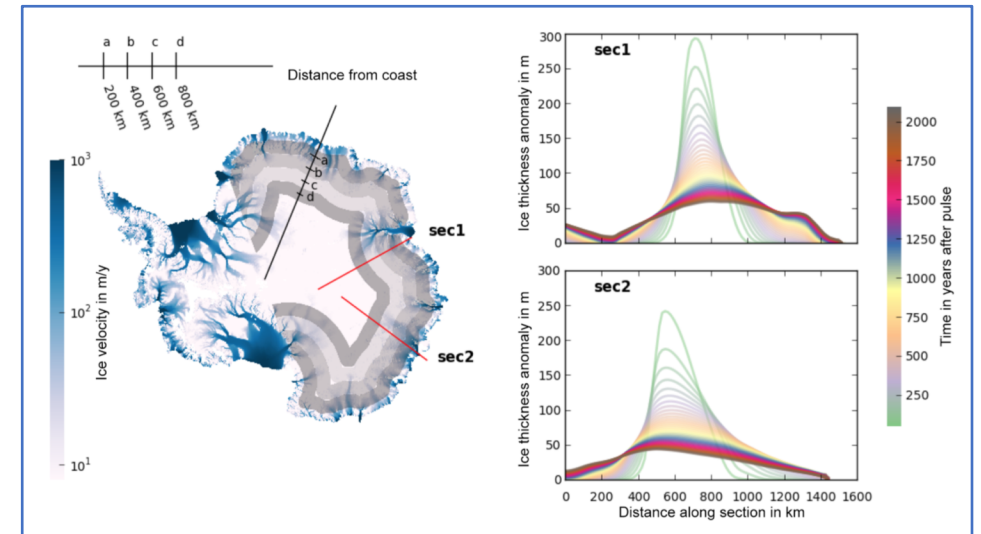
Delaying future sea-level rise by storing water in Antarctica

K. Frieler¹, M. Mengel¹, and A. Levermann^{1,2,3}

¹Potsdam Institute for Climate Impact Research, Potsdam, Germany

²Institute of Physics, Potsdam University, Potsdam, Germany

³Lamont-Doherty Earth Observatory, Columbia University, New York, USA



Cryosphere management – Make snow to stabilize WAIS

This Plan to Stop Sea Level Rise by Blasting Antarctica With Snow Is Extremely Wild

Scientists studied what would happen if we turned gigatons of ocean water into snow and shot it at Antarctica.

By **Madeline Gregory**
Jul 17 2019, 2:00pm [Share](#) [Tweet](#) [Snap](#)



“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.”

Manmade Antarctic snowstorm 'could save coastal cities from rising seas'

Blowing trillions of tonnes of snow on to ice sheet could halt its collapse, researchers say



▲ The huge geoengineering project would need energy from at least 12,000 wind turbines to power water pumps and snow cannons. Photograph: Christian Vorhofer/Alamy

Spraying trillions of tons of snow over west **Antarctica** could halt the ice sheet’s collapse and save coastal cities across the world from sea level rise, according to a new study.

SCIENTIST'S DRASTIC PLAN TO COVER THE WEST ANTARCTIC ICE SHEET BY SPRAYING BILLIONS OF TONS OF SNOW ONTO IT

Earlier studies have concluded that the loss of ice is accelerating, meaning the oceans will rise by three metres in the coming centuries.

A snow cannon, or cannons, would blow the artificial snow onto the sheet

The drastic plan would need energy from at least 12,000 wind turbines to power giant sea pumps and snow cannons



Water level rises 3 m

The giant pump would suck water from the ocean

Giant water pump

Ice shelf

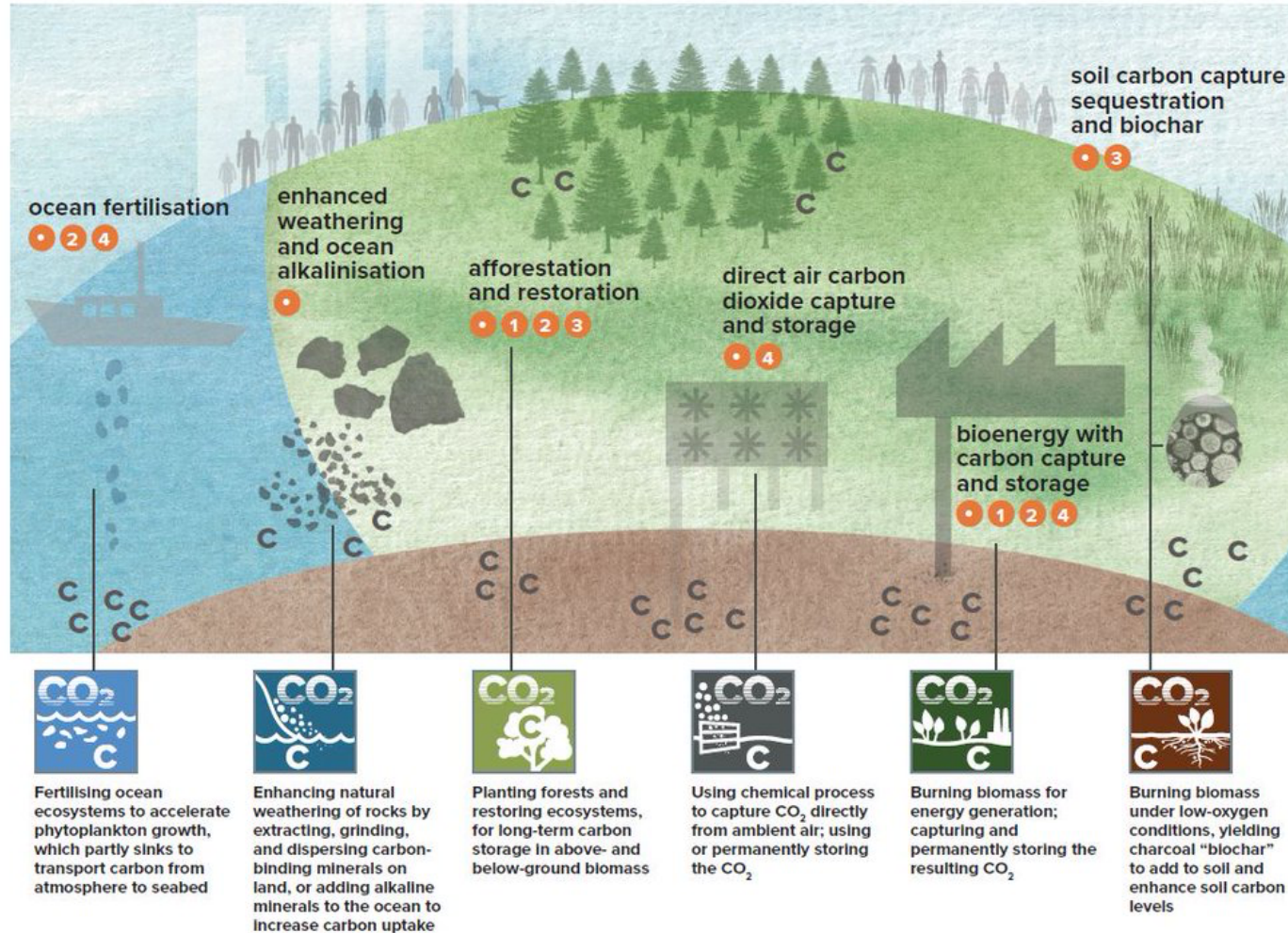
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Greenhouse Gas Removal



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

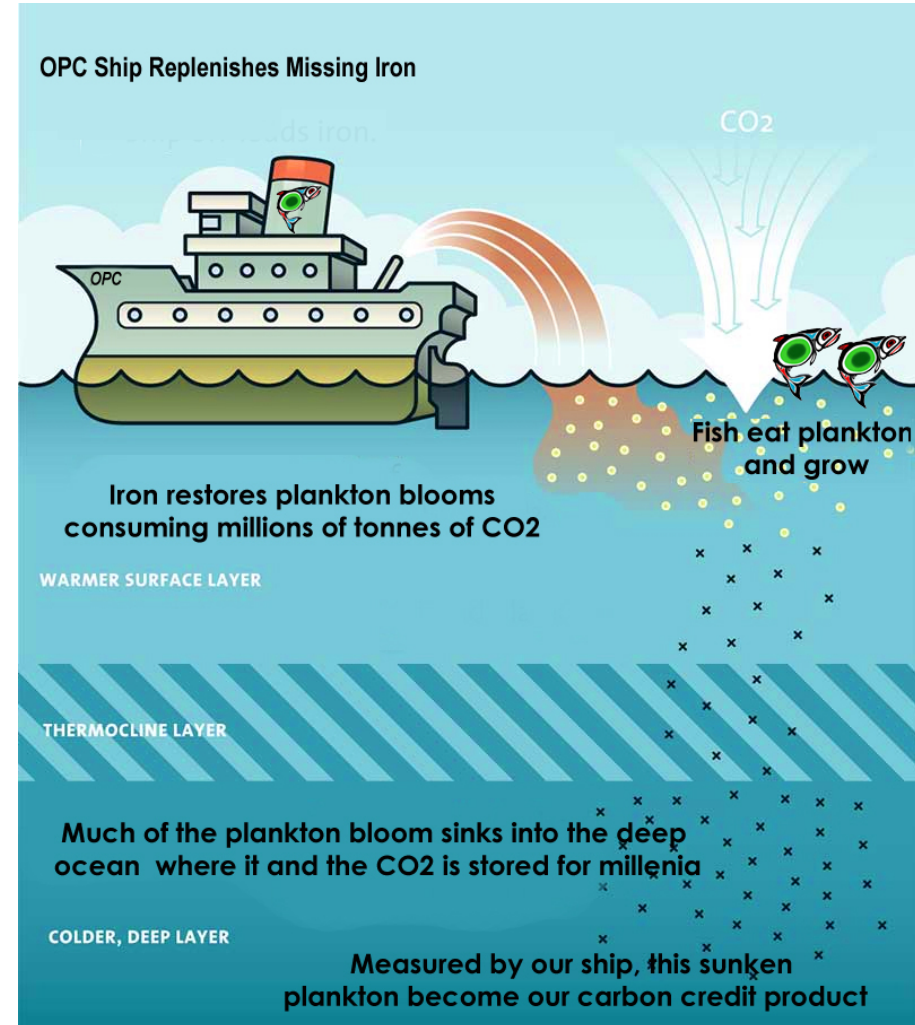
Greenhouse Gas Removal - Ocean Fertilization

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.



Greenhouse Gas Removal

RESEARCH ARTICLE | ENVIRONMENTAL STUDIES

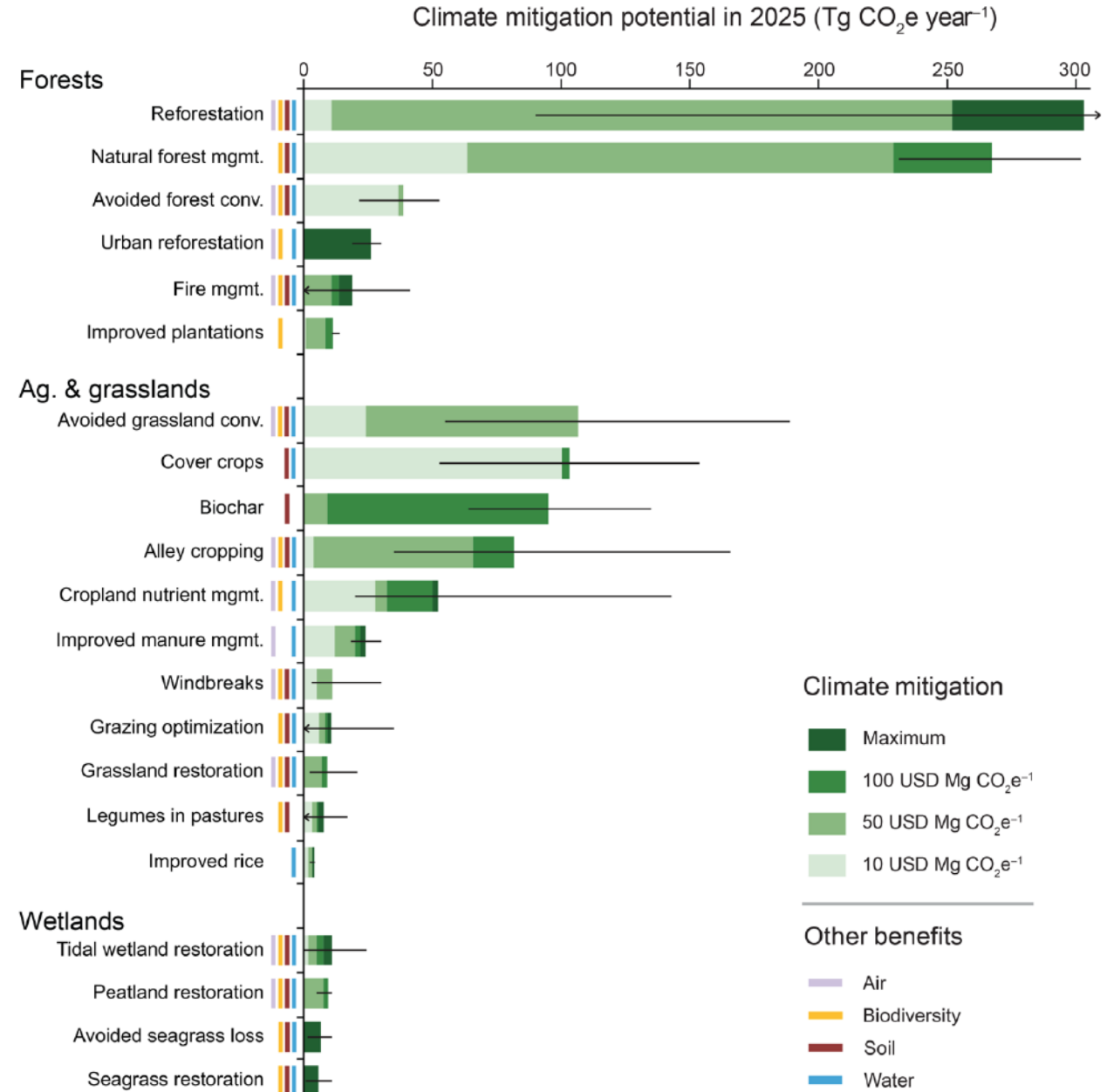
Natural climate solutions for the United States

Joseph E. Fargione^{1,*}, Steven Bassett², Timothy Boucher³, Scott D. Bridgman⁴, Richard T. Conant⁵, Susan C. Cook-Pa...

+ See all authors and affiliations

Science Advances 14 Nov 2018:
Vol. 4, no. 11, eaat1869
DOI: 10.1126/sciadv.aat1869

“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.



CLIMATE CHANGE

Natural climate solutions are not enough

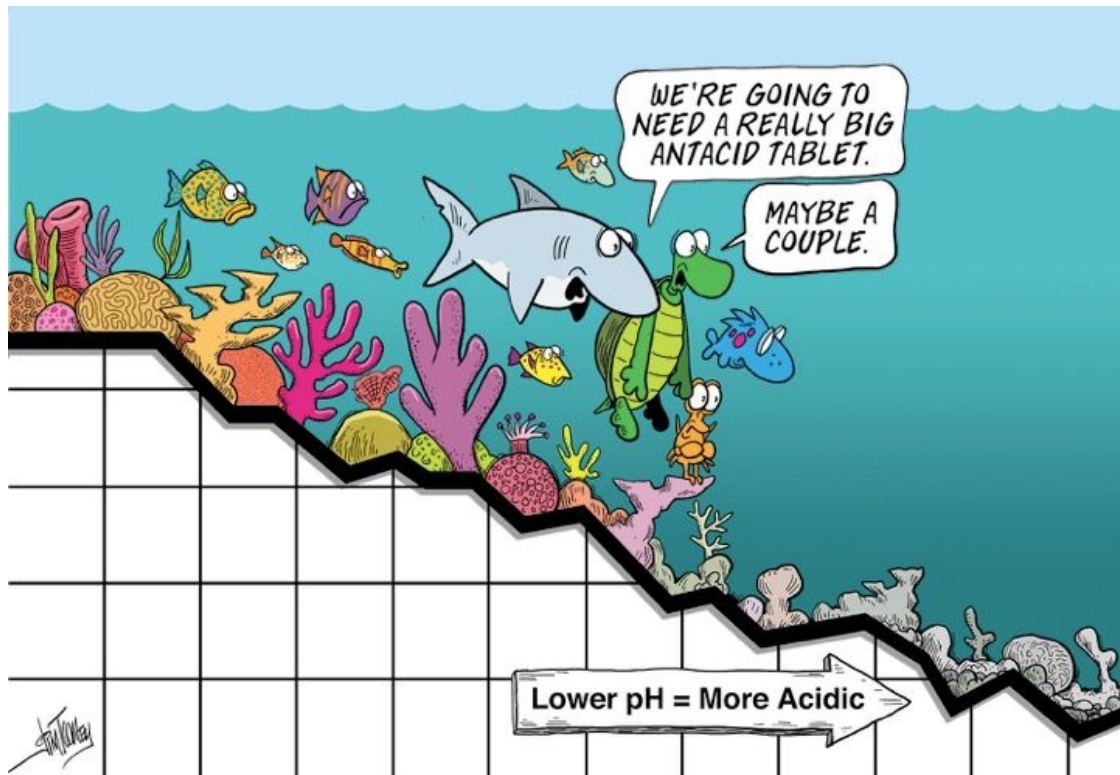
Decarbonizing the economy must remain a critical priority



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?



▼ nature
ecology & evolution

Article | Published: 22 January 2018

Potentially dangerous consequences for biodiversity of solar geoengineering implementation and termination

“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.

Geoengineering would turn blue skies whiter

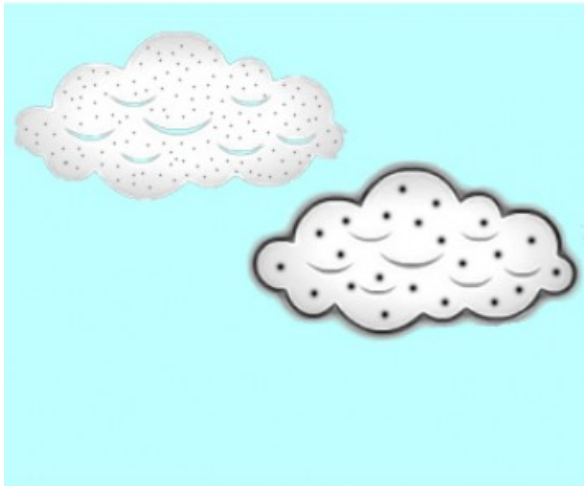


EARTH 1 June 2012

By **Jeff Hecht**



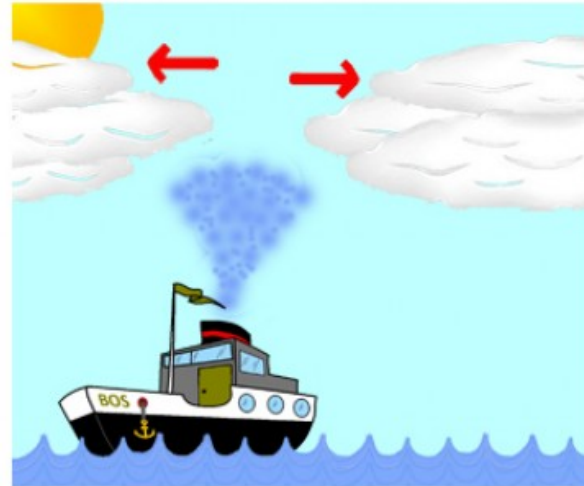
Downsides – what if we get clouds “wrong”?



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...

Downsides. From where do the \$\$ and energy come ?



Science news

@UpdateonScience



ift.tt/2M2k6tj A new plan to prevent the West Antarctic Ice Sheet from melting proposes using "snow cannons" to spray artificially created snow made of water from the nearby sea. Pumping 7,400 gigatons of snow could stabilize the melt if it's applied for 10 years. #sci...



11:18 AM - Jul 18, 2019



See Science news's other Tweets



State of the Planet

EARTH INSTITUTE | COLUMBIA UNIVERSITY

AGRICULTURE

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Pump Meltwater Back on Antarctica? Do You Have 850,000 Wind Turbines?

BY STACY MORFORD | MARCH 10, 2016



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Comments



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.

Arguments for geoengineering

Climate change could kill an estimated half-million people annually by the middle of this century, through famine, flooding, heat stress, and human conflict.

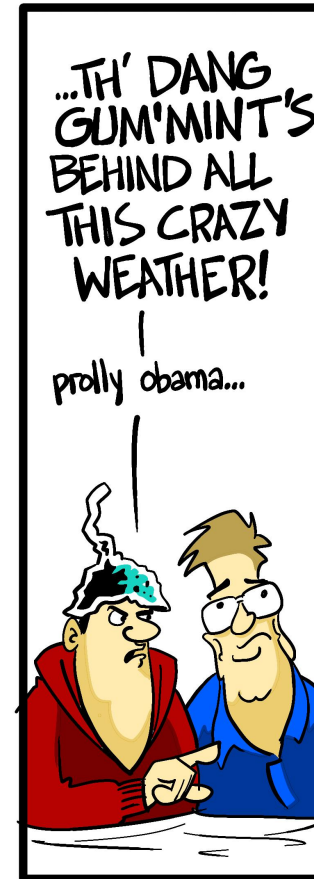
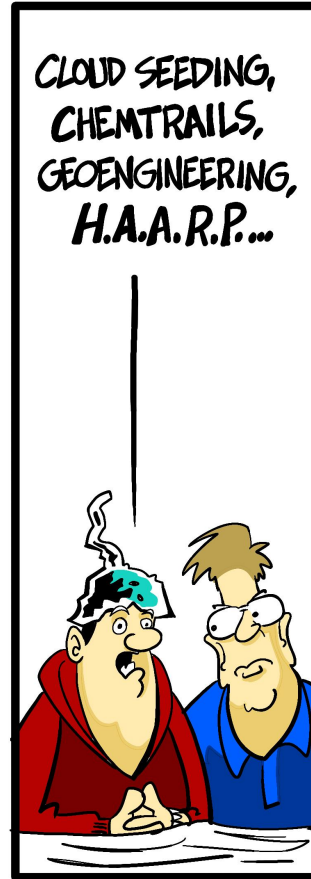
Preventing temperatures from rising 2 °C above preindustrial levels, long considered the danger zone that should be avoided at all cost, **now looks nearly impossible.**

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.**

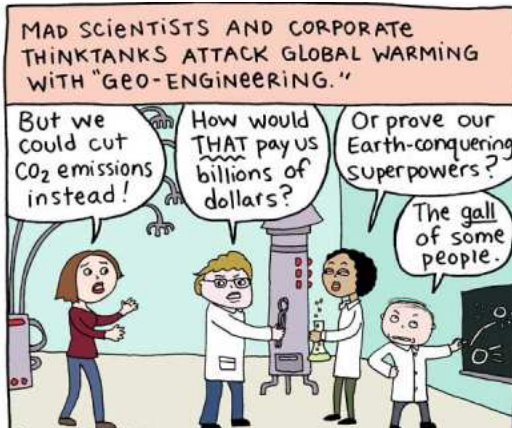
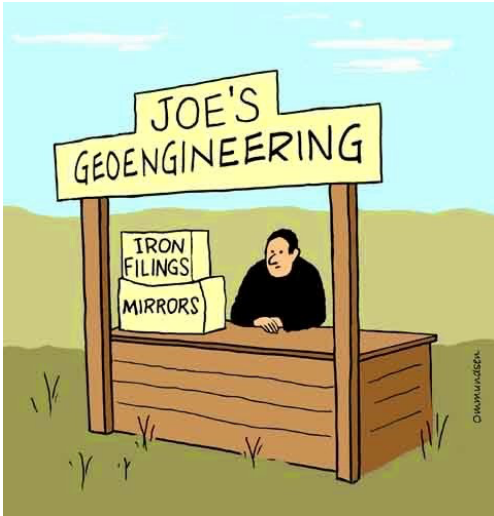
280 million more people without access to adequate water; 120 million more people exposed to major river floods; 12 million more people subjected to coastal flooding; 24% decline in global maize productivity



Will we do it?



I couldn't say it better...so here's a quote



“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/>