

cenia

Slabé signály v oblasti změny klimatu: *Geoinženýring*

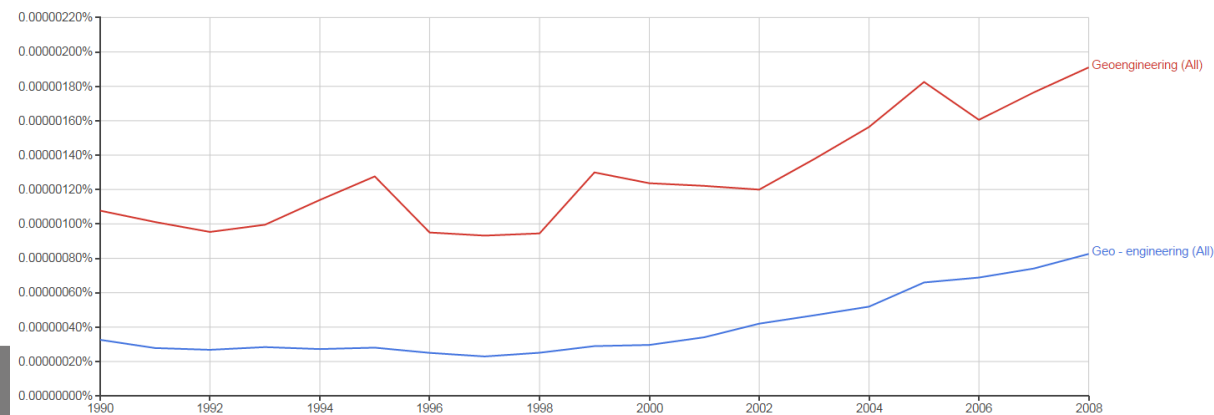
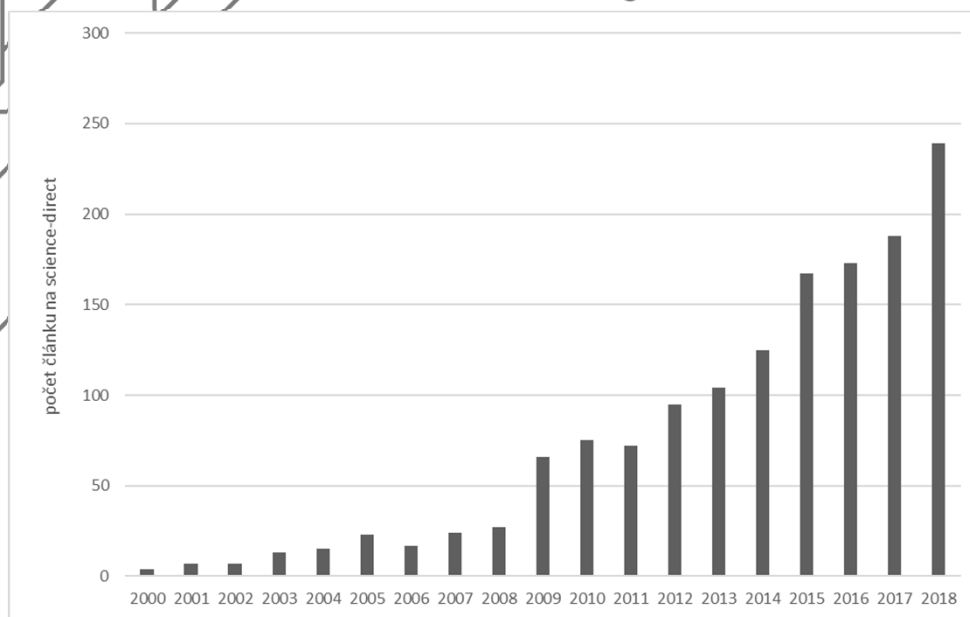
Miroslav Havránek

CENIA, česká informační agentura životního prostředí

15.11.2019, Změna klímy, Bratislava

- Otevření a zarámování tématu které je:
 - Trendy
 - Téma na které bychom měli mít pozici, která je výsledkem politické diskuse
 - Zajímavá oblast výzkumu z různých hledisek (akceptace, mechanismy, náklady, bezpečnost...), kde lze použít dříve vyvinuté metodologické přístupy
 - Jedna z největších divokých karet lidstva vůči přírodě (WEF, 2010)

Jak identifikovat signál?





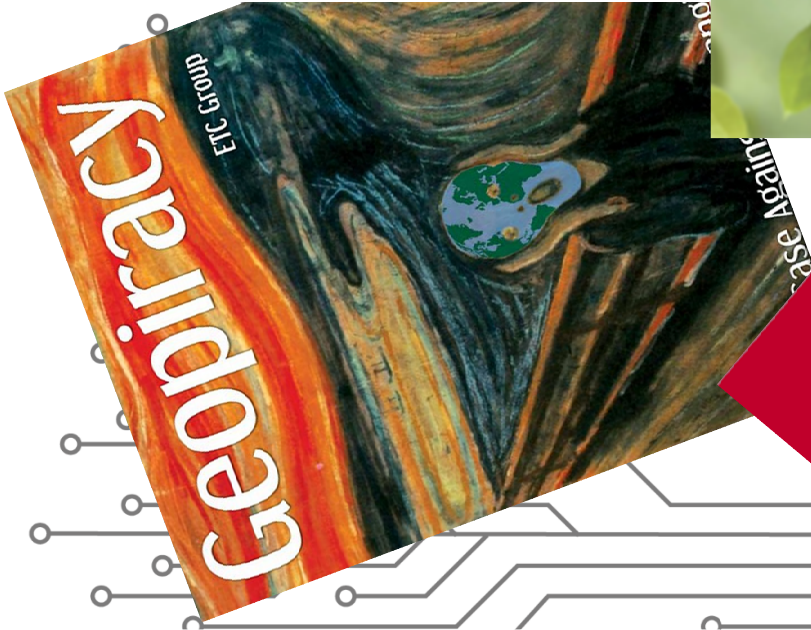
Co je to geoengineering?

Záměrná manipulace planetárního klimatu velkého rozsahu (*Deliberate large-scale manipulation of the planetary environment*, Keith, 2000))

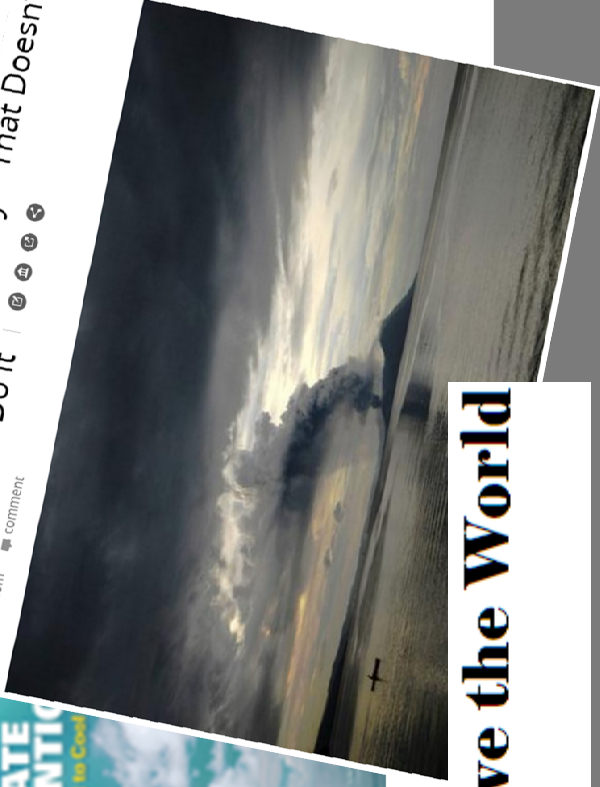
Co je to klimatická intervence?

Záměrná manipulace planetárního klimatu velkého rozsahu za účelem potlačení změny klimatu (*Deliberate large-scale manipulation of the planetary environment to counteract anthropogenic climate change*)

The Climate Fixers



'Climate Hacking' Would Be Easy - That Doesn't Mean We Should Do It | [ifscience.com](#) comment



Can Geoenineering Save the World from Global Warming?



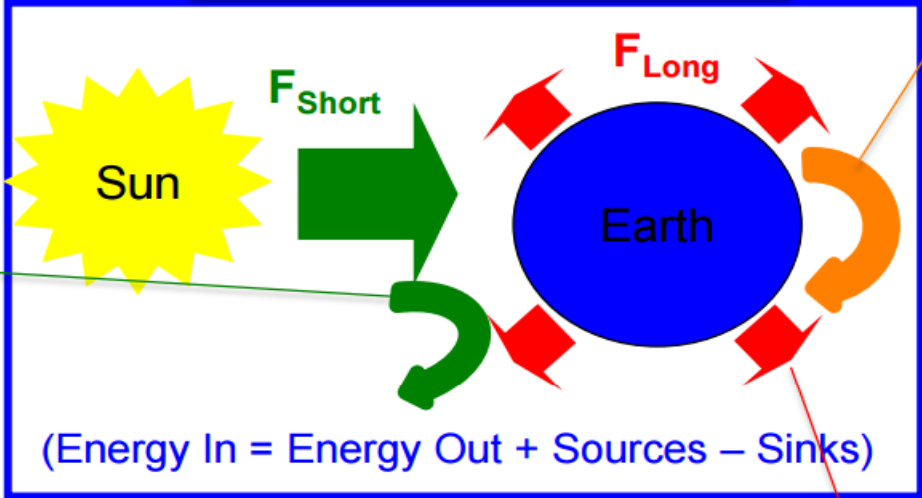


Why play with/research it

- Geoengineering: A Bad Idea Whose Time Has Come
- We are already doing it (although unintentionally)
- Energy system transformation is proceeding too slowly to avoid the risk of dangerous climate change
- Even if we ceased carbon emissions tomorrow, it would take centuries for the planet to cool
- Impacts of climate change might be unbearable for some parties and they might do it anyway

Earth's "Energy Balance"

$$S_0(1 - \alpha_p) + F_{ghg} = \sigma T_{surf}^4$$



Aerosol-enhanced albedo effect
 $F_{Short} = S_0(1 - \alpha_p)$

- Hilding Köhler 1936
- Sean Twomey 1974

CO₂-enhanced greenhouse effect

- Joseph Fourier 1824
- John Tyndall 1858
- Svante Arrhenius 1896



1st Law of Thermodynamics
 $F_{Short} = F_{Long}$



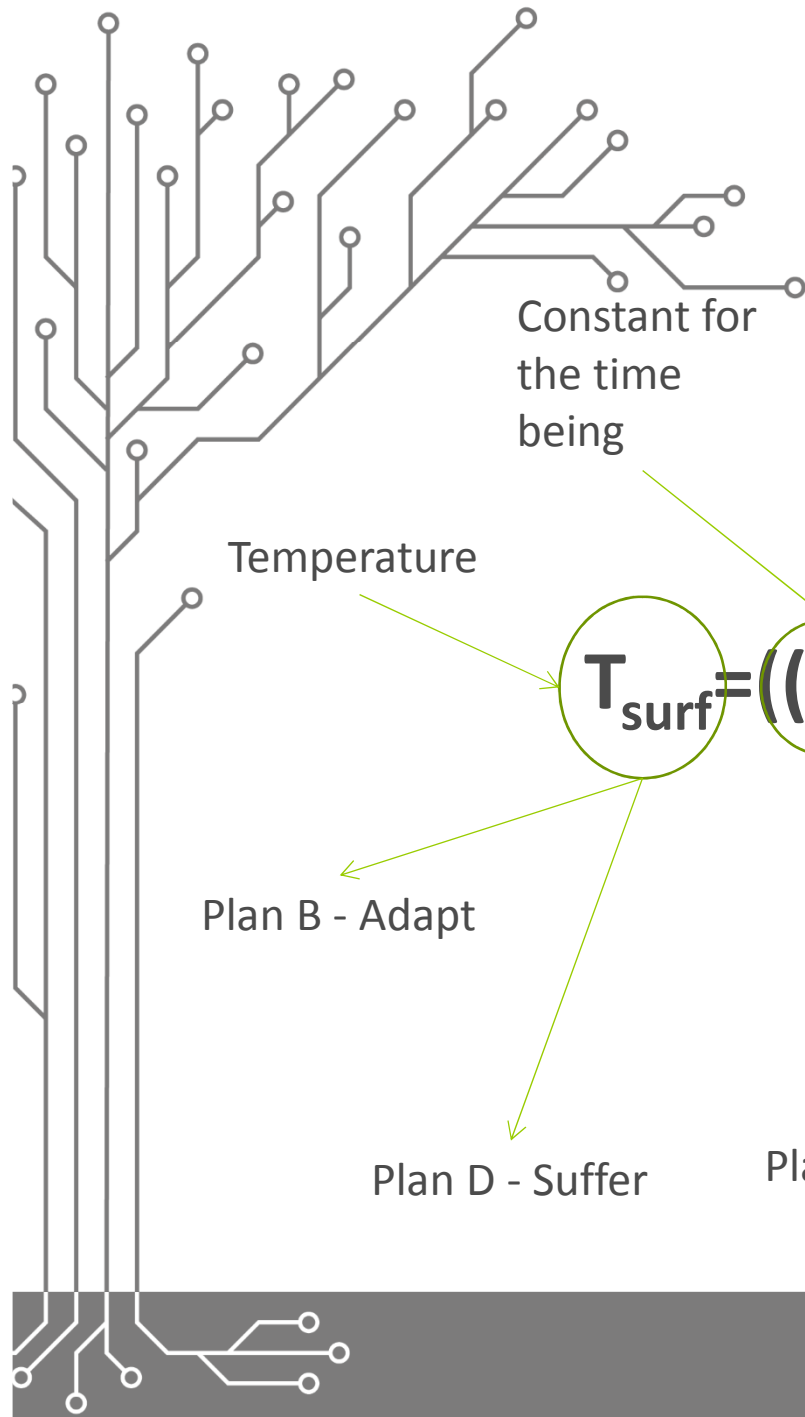
- Rudolf Clausius 1850
- William Thompson (Lord Kelvin) 1848

Stefan-Boltzmann Law
 $F_{Long} = \sigma T_{surf}^4$



- Josef Stefan 1874
- Ludwig Boltzmann 1884
- Max Planck 1901

Climate policy equation



Constant for the time being

Albedo

GHG forcing

S-B constant

Temperature

$$T_{\text{surf}} = \left(\frac{S_o(1-\alpha) + F_{\text{ghg}}}{\sigma} \right)^{1/4}$$

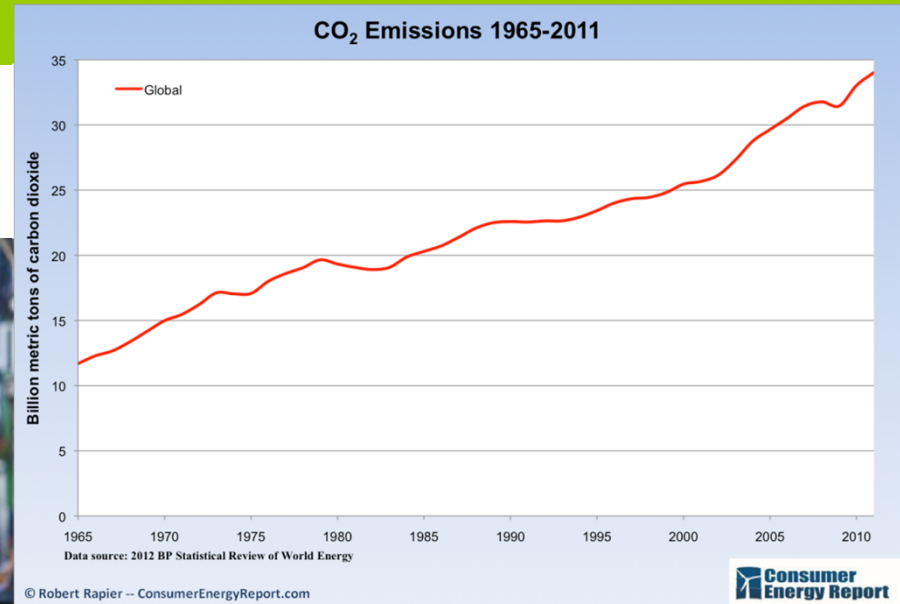
Plan B - Adapt

Plan D - Suffer

Plan C - Intervene

Plan A - Mitigate

What options do we have?

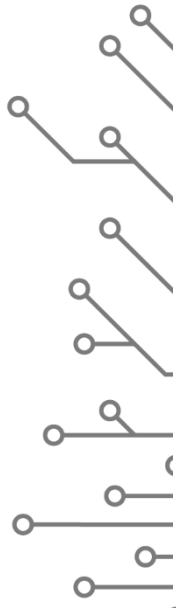


Reduction of anthropogenic GHG emissions

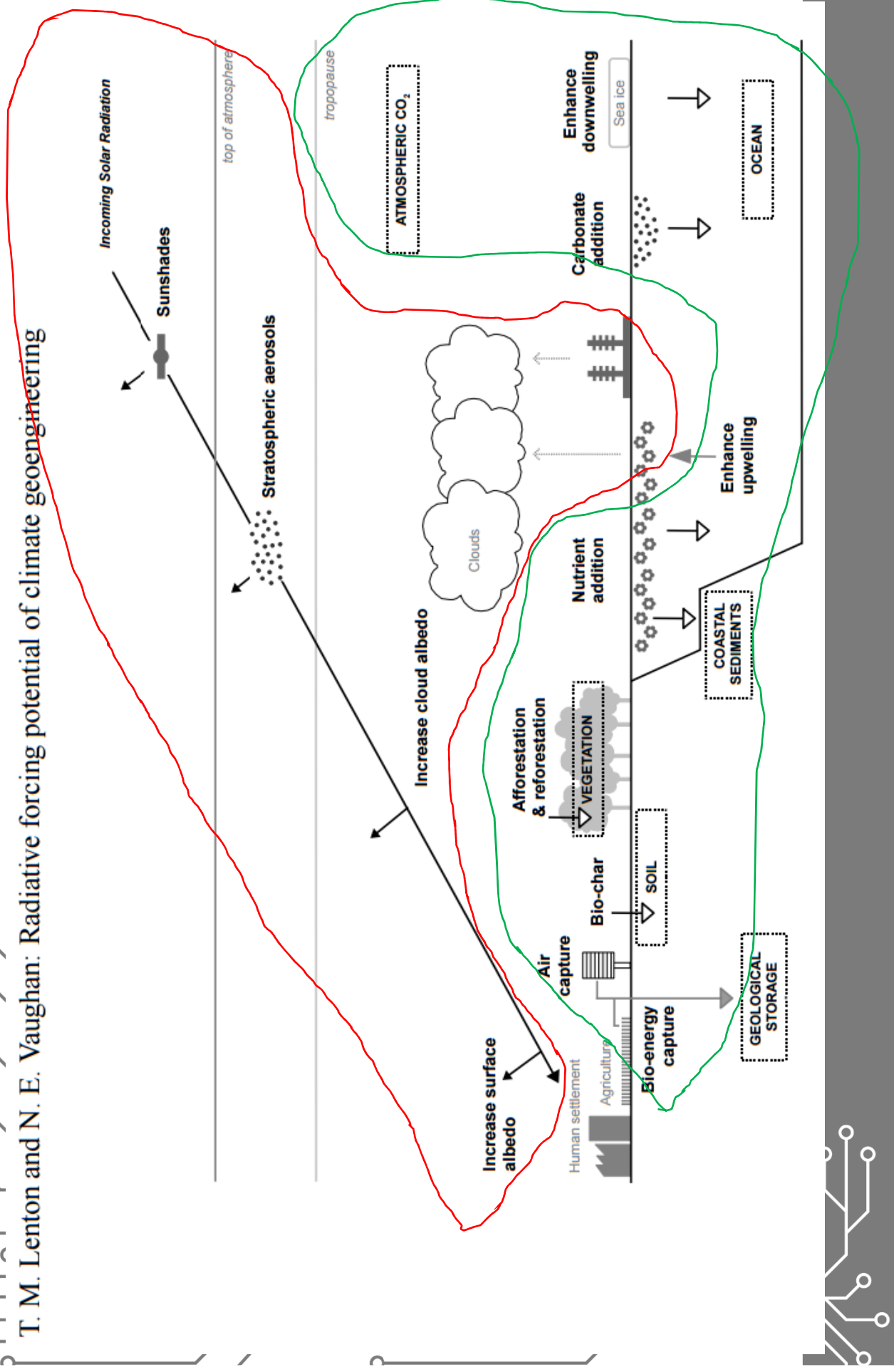
Adaptation on climate change impacts

Geoengineering /climate intervention





T. M. Lenton and N. E. Vaughan: Radiative forcing potential of climate geoengineering





Three options

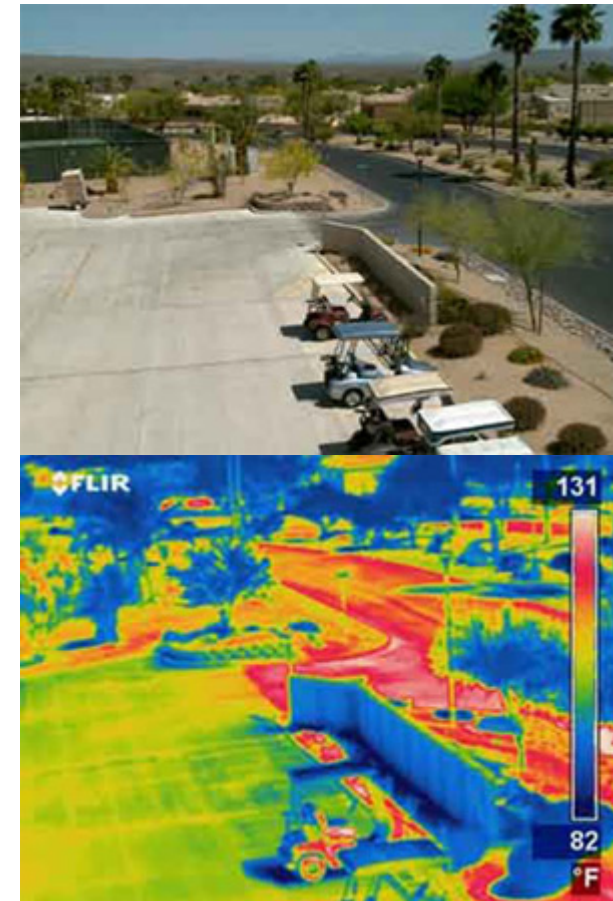
- Albedo modification
 - Changing reflectivity of earth surface, atmosphere (or our of atmosphere)
- CO₂ sequestration
 - Actively removing carbon dioxide from atmosphere
- *Large scale change of Earth circulation (fringe)*
 - *E.g. Barents sea, Bering strait*

Increase albedo of manmade structures

White Roof Project

Take Action ▾ Donate ▾ Programs ▾ About ▾ Blog Events

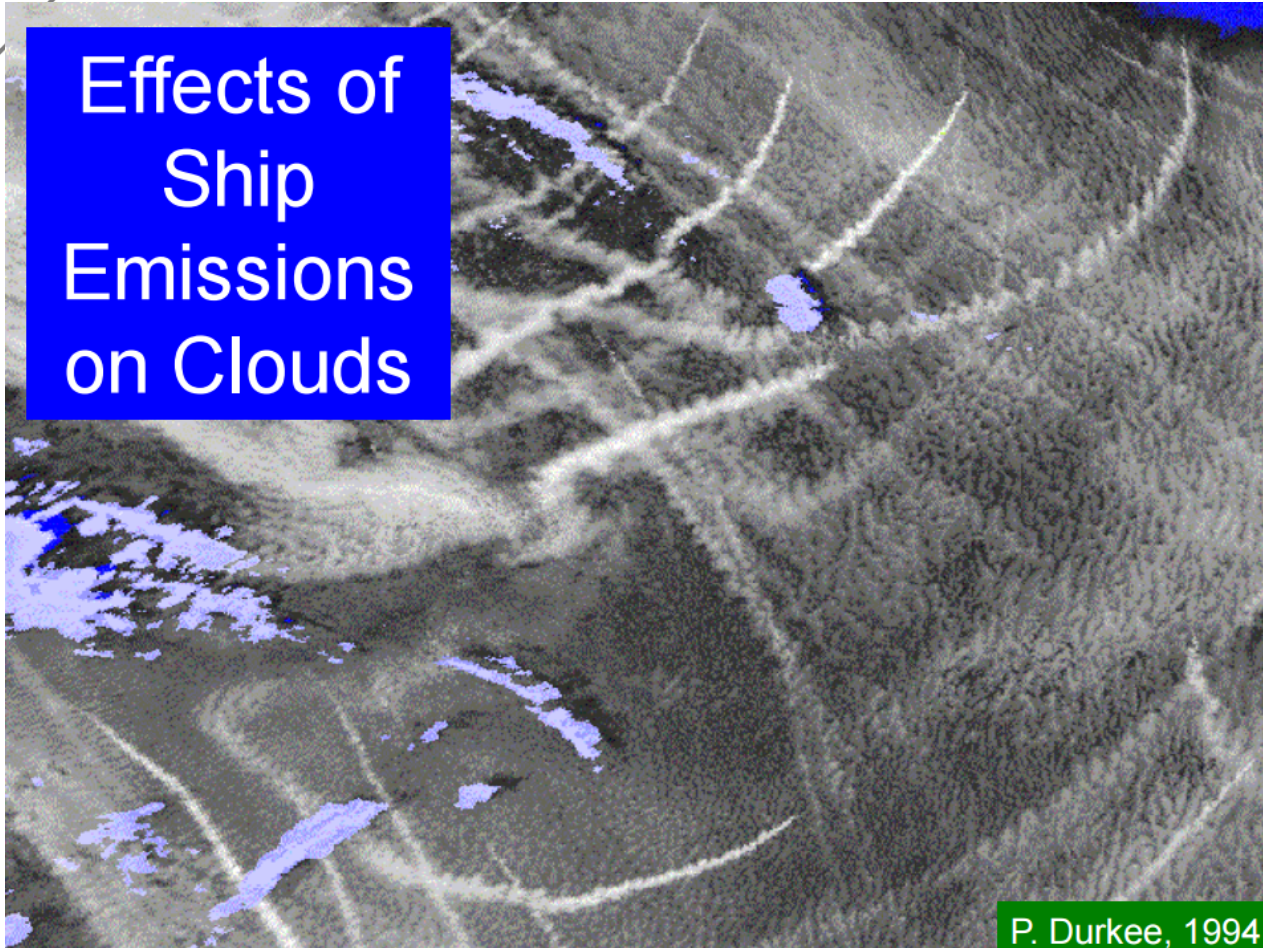
Do-It-Yourself and save up to 40% on your electricity bill.



<http://www.ecocem.ie/>

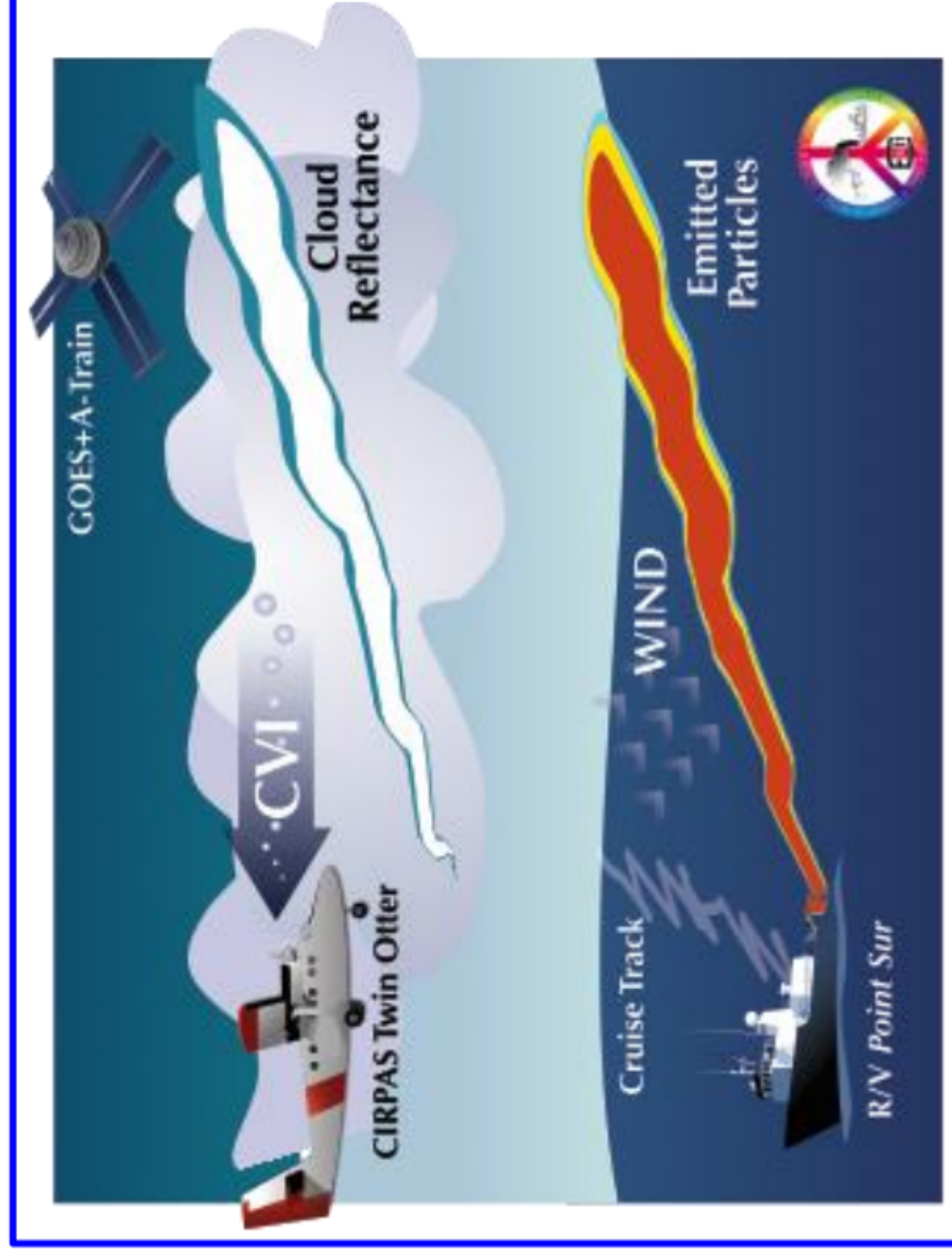
**Low clouds brightening
(marine stratocumulus
seeding)**

**Effects of
Ship
Emissions
on Clouds**



P. Durkee, 1994

Eastern Pacific Emitted Aerosol Cloud Experiment (E-PEACE) 2011



Lynn M. Russell¹,

Armin Sorooshian³,

John Seinfeld²,

Bruce Albrecht⁵,

Athanasios Nenes⁴,

Lars Ahlm¹, Yi-Chun

Chen², Jill S Craven²,

Matthew Coggon²,

Amanda Frossard¹, Haf

Jonsson⁶, Eunsil Jung⁵,

Jack J Lin⁴, Andrew R

Metcalfe², Robin Modini¹,

J. Muelmenstaedt¹,

Greg Roberts¹, Taylor

Shingler³, Siwon Song⁵,

Zhen Wang³, Anna

Wonaschuetz³

1.Scripps/UCSD,

2.Caltech,

3.Univ.Arizona,

4.GeorgiaTech,

5.Univ.Miami,

6.CIRPAS.

R/V *Point Sur* Smoke Operations

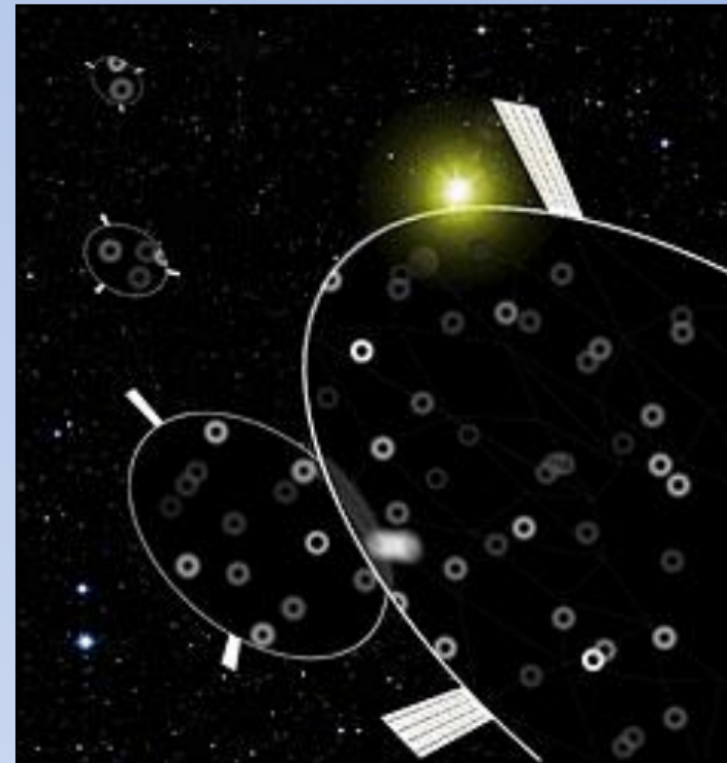
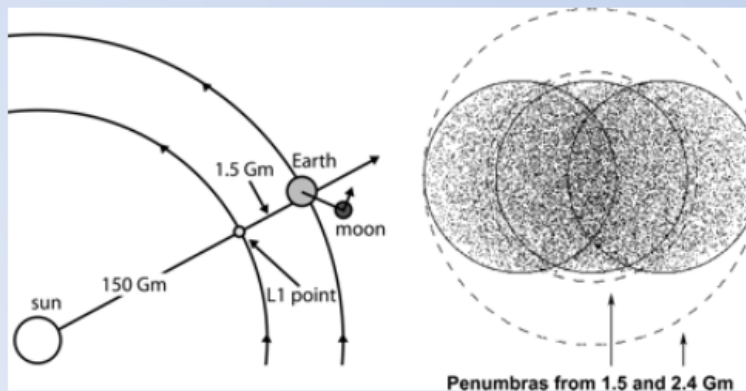


Lynn M. Russel, FOE 2012

Global shade

Blocking Sunlight:

- A 100,000 km cloud
 - comprised of 16 trillion manhole-cover sized discs,
 - ~3 million miles from earth,
 - blocking 2% of the sun's rays.
- \$1 -\$5 trillion depending on launch technology.



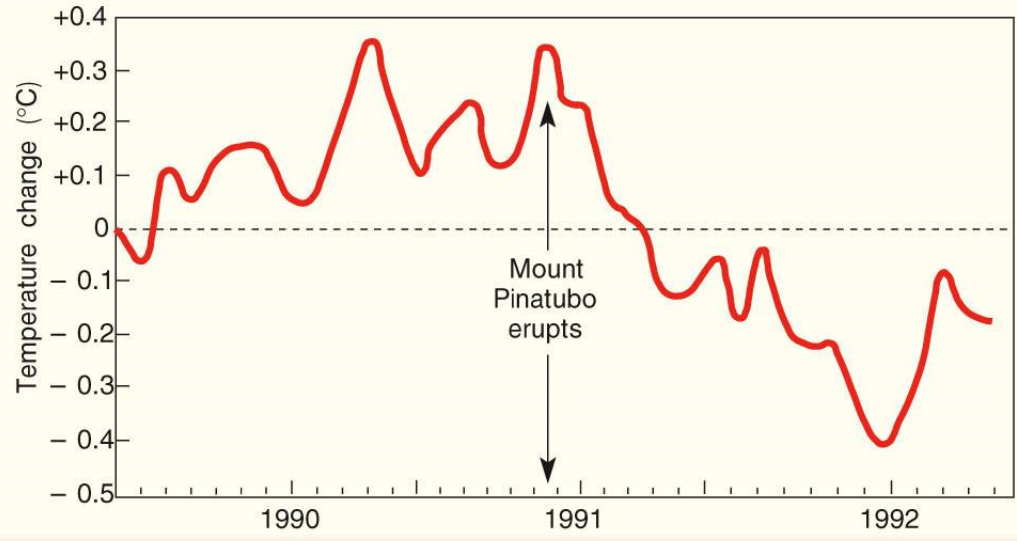
Stratosphere aerosol injection (Mt. Pinatubo Effect)



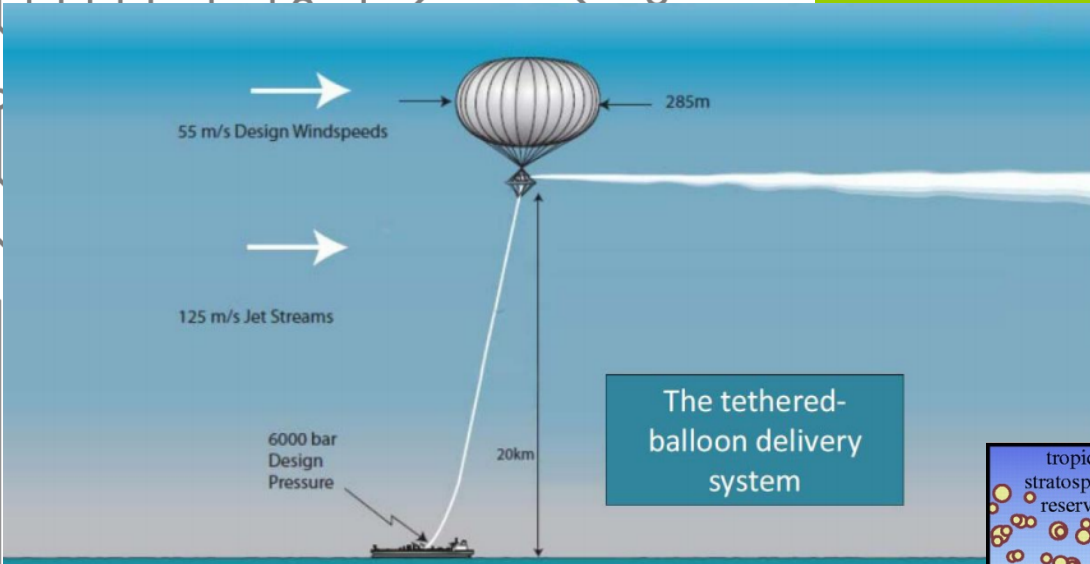
U.S. Geological Survey Photograph taken by Richard P. Hoblitt



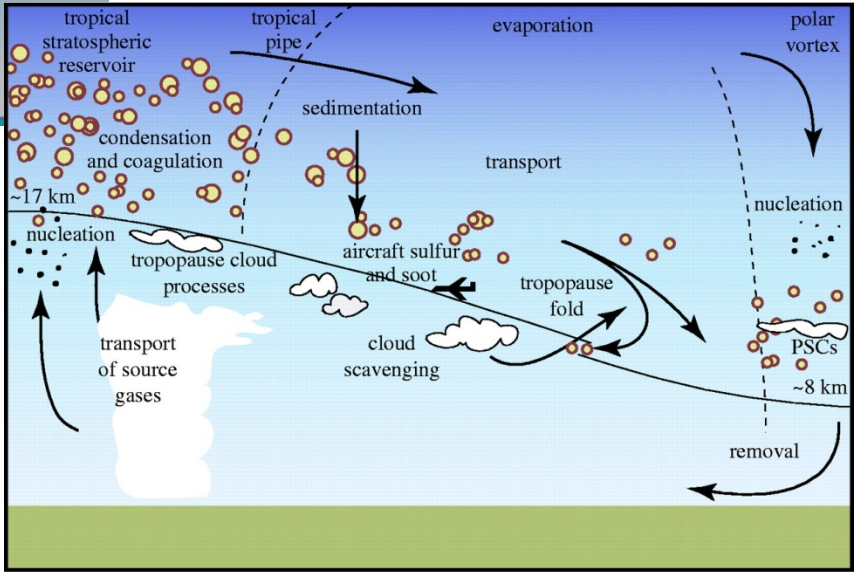
NASA



Aerosol injection

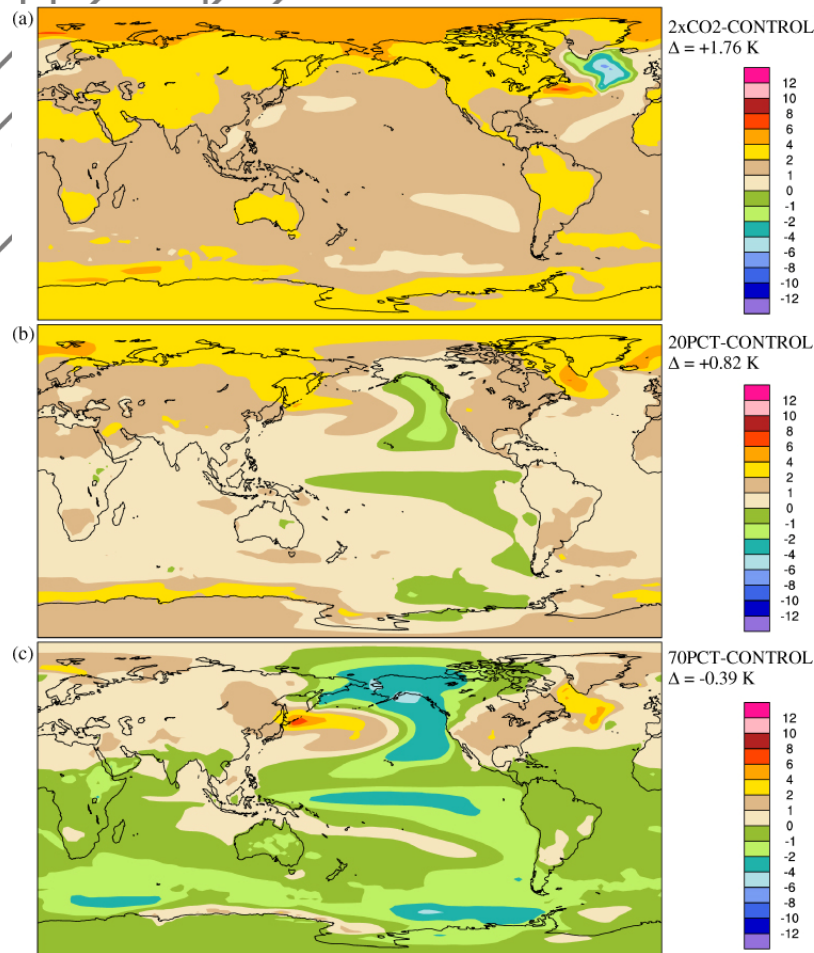


Eli Kirtisch, FOE, 2012



An overview of geoengineering of climate using stratospheric sulphate aerosols
 Philip J Rasch, Simone Tilmes, Richard P Turco, Alan Robock, Luke Oman, Chih-Chieh (Jack) Chen, Georgiy L Stenchikov, Rolando R Garcia
 Phil. Trans. R. Soc. A 2008 366 4007-4037; DOI: 10.1098/rsta.2008.0131. Published 13 November 2008

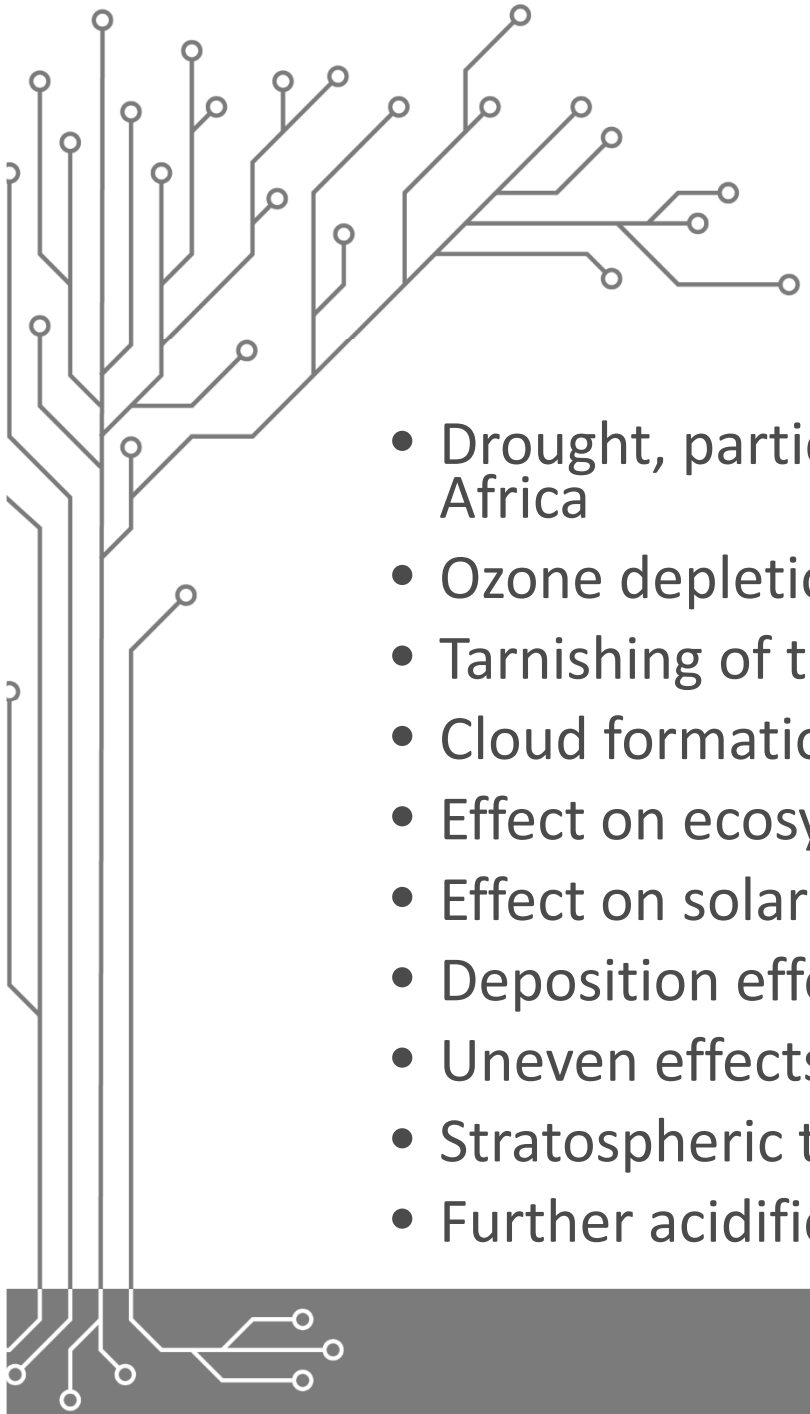
Would it work ?



Geoengineering by cloud seeding: influence on sea ice and climate system

Philip J Rasch¹, John Latham^{2,3} and Chih-Chieh (Jack) Chen² Environ. Res. Lett. 4 (October-December 2009) 045112
doi:10.1088/1748-9326/4/4/045112

- Crutzen, P. J. (2006), Albedo enhancement by stratospheric sulfur injections: A contribution to resolve a policy dilemma? *Clim. Change*, **77**, 211–220, doi:[10.1007/s10584-006-9101-y](https://doi.org/10.1007/s10584-006-9101-y).
- Rasch, P. J., P. J. Crutzen, and D. B. Coleman (2008), Exploring the geoengineering of climate using stratospheric sulfate aerosols: The role of particle size, *Geophys. Res. Lett.*, 35, L02809, doi:[10.1029/2007GL032179](https://doi.org/10.1029/2007GL032179)



Aerosols in stratosphere might not be good idea because ...

- Drought, particularly monsoon failure in Asia and Africa
- Ozone depletion
- Tarnishing of the sky
- Cloud formation may be affected
- Effect on ecosystems
- Effect on solar energy
- Deposition effects
- Uneven effects
- Stratospheric temperature change
- Further acidification of planet

Reforestation and afforestation (biosequestration of atmospheric carbon dioxide)



NASA photo of deforestation in Tierras Bajas project, Bolivia, from ISS on April 16, 2001.

Aerial Reforestation?



photo: Discovery Channel

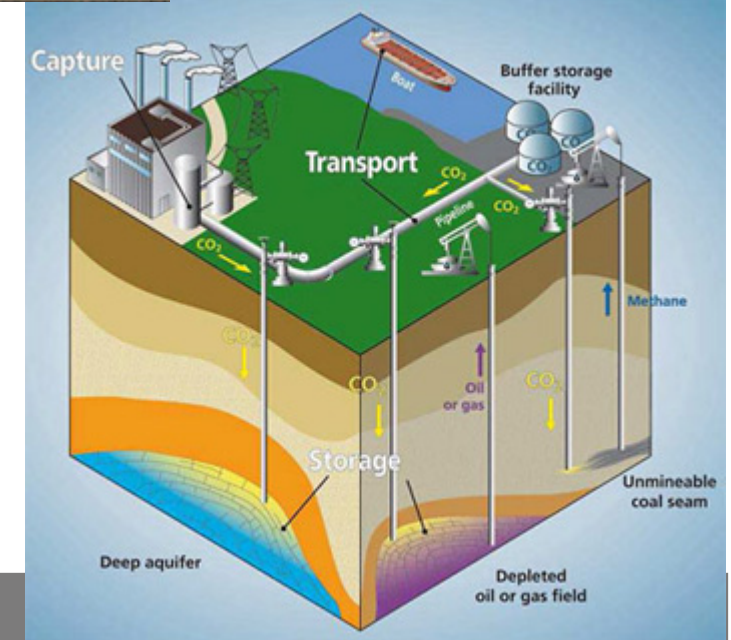
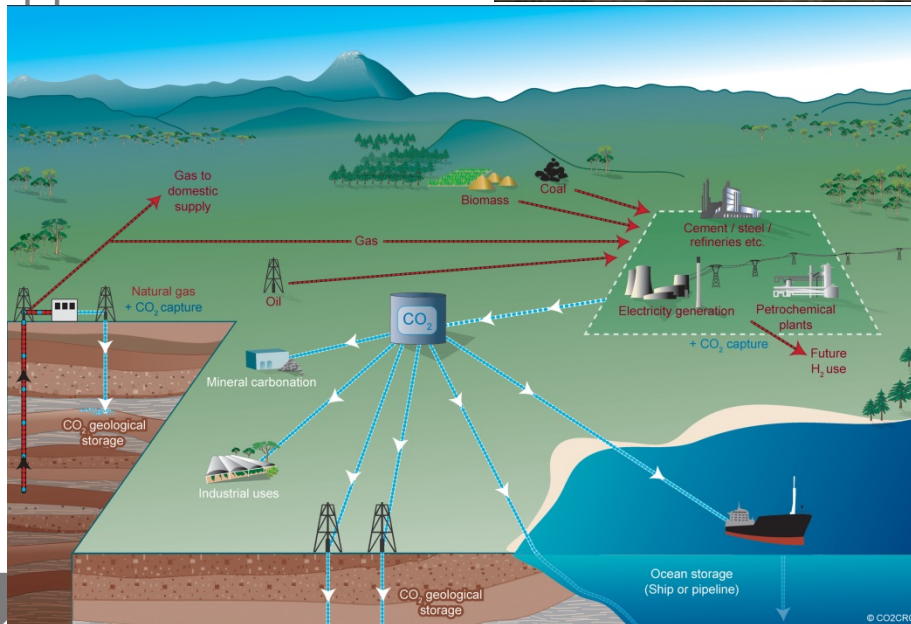
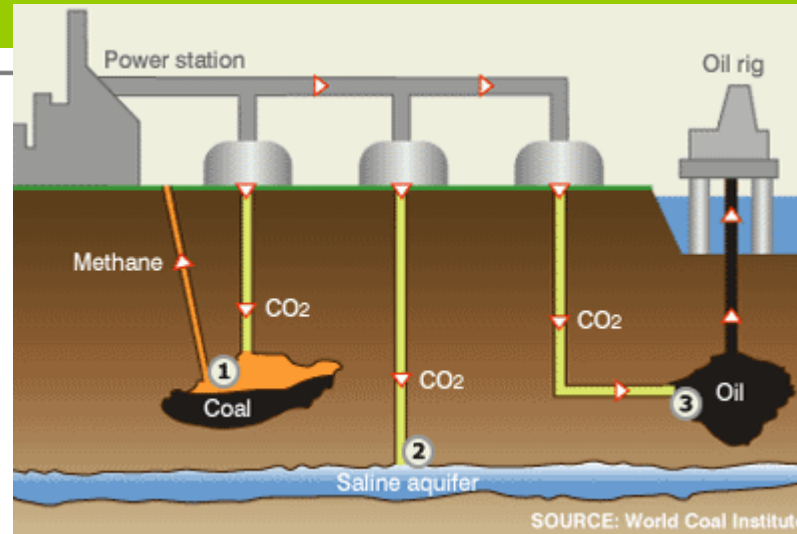
Biochar

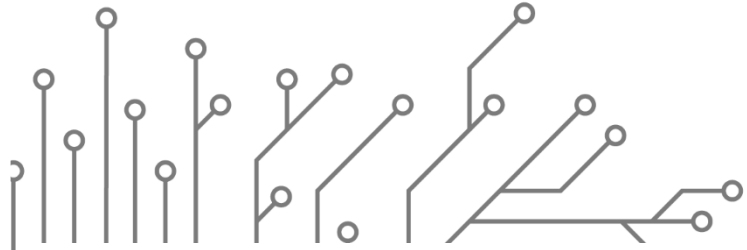
- Biomass pyrolysis
- Charcoal
- Shallow deposit to soil
- Possibly enriching the Soil
- Storing Away CO₂



Wikimedia commons

„Classical“ CCS and carbon offsets might not be enough





CO2 Atmospheric scrubbing

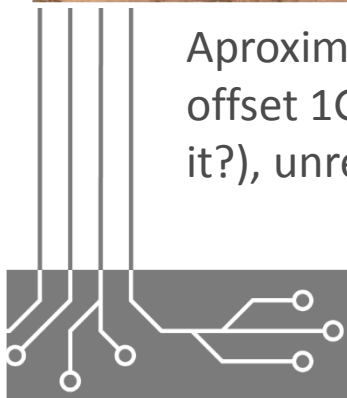
Geoffrey Holmes et al. / Energy Procedia 37 (2013) 6079–6095



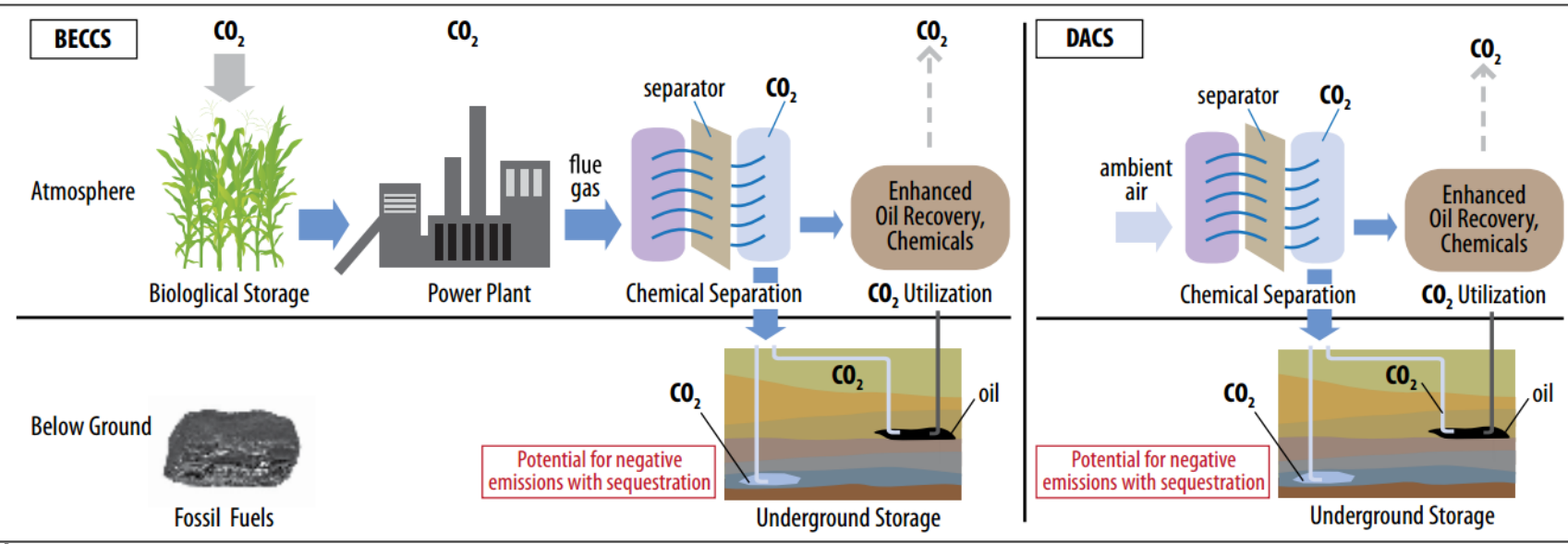
Geoffrey Holmes et al. / Energy Procedia 37 (2013) 6079–6095



Aproximately 1Mt CO₂/year, 3 units to offset 1GW block (+how much to power it?), unrealistic at zero price of carbon



CO₂ sequestration (BECCS a DACS)

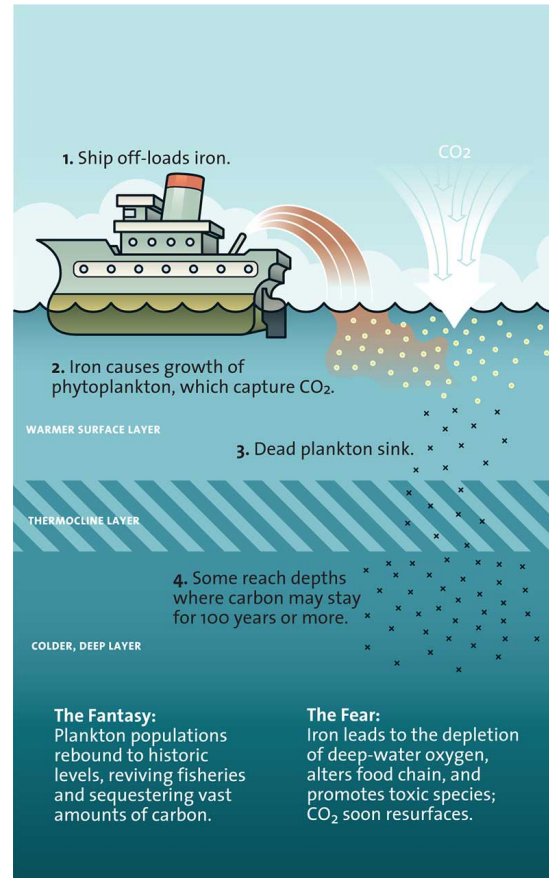


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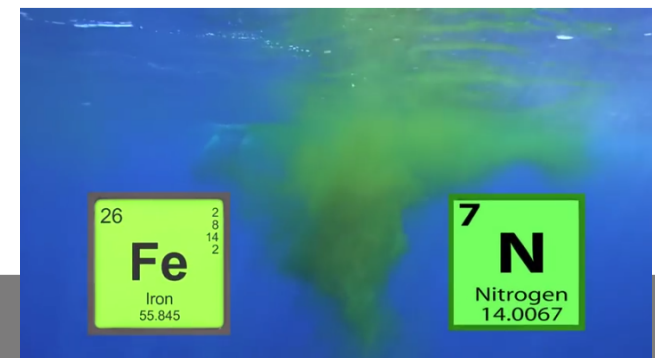
Iron fertilisation of ocean

A massive phytoplankton bloom induced by an ecosystem-scale iron fertilization experiment in the equatorial Pacific Ocean, KENNETH H. COALE et al, Nature, 1996

Achieving optimum carbon sedimentation from plankton growth may require the right "recipe" of iron and other trace nutrients to grow the right kind of phytoplankton



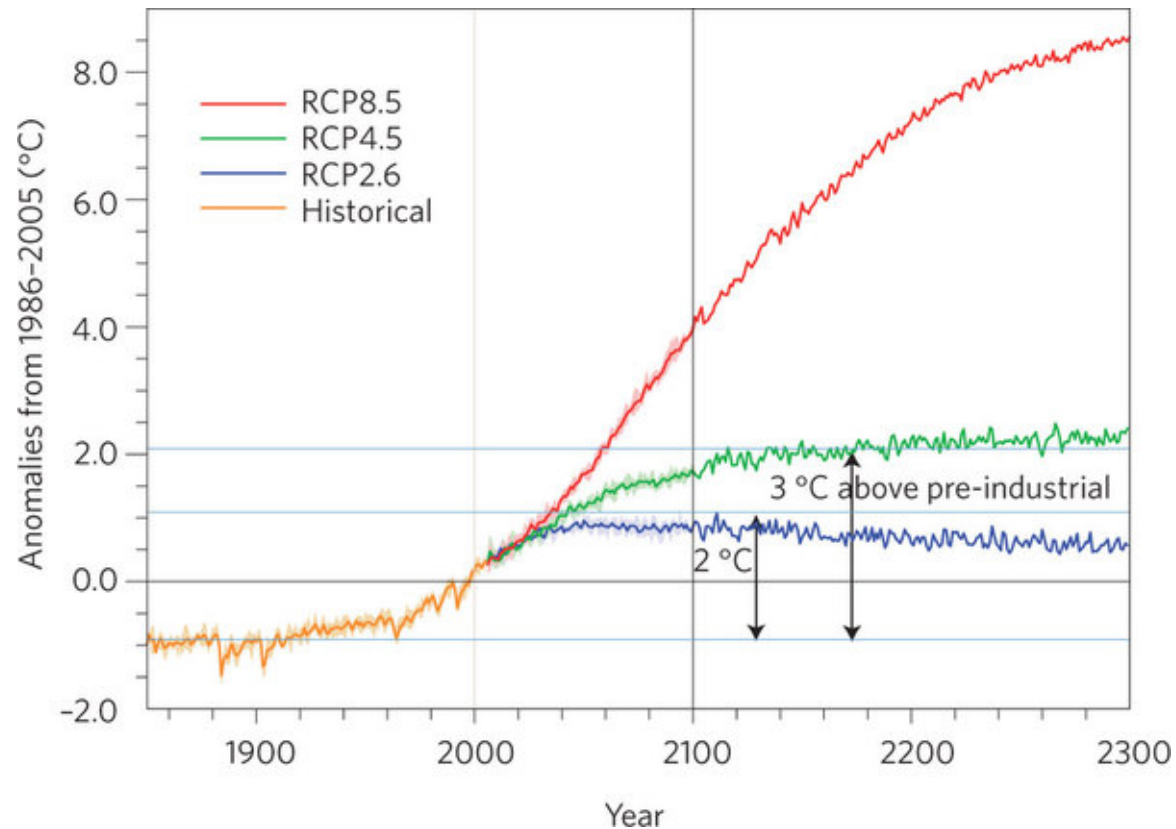
Nicol, S., Bowie, A., Jarman, S., Lannuzel, D., Meiners, K. M. and Van Der Merwe, P. (2010), Southern Ocean iron fertilization by baleen whales and Antarctic krill. Fish and Fisheries, 11: 203–209. doi: 10.1111/j.1467-2979.2010.00356.x



Pros and cons

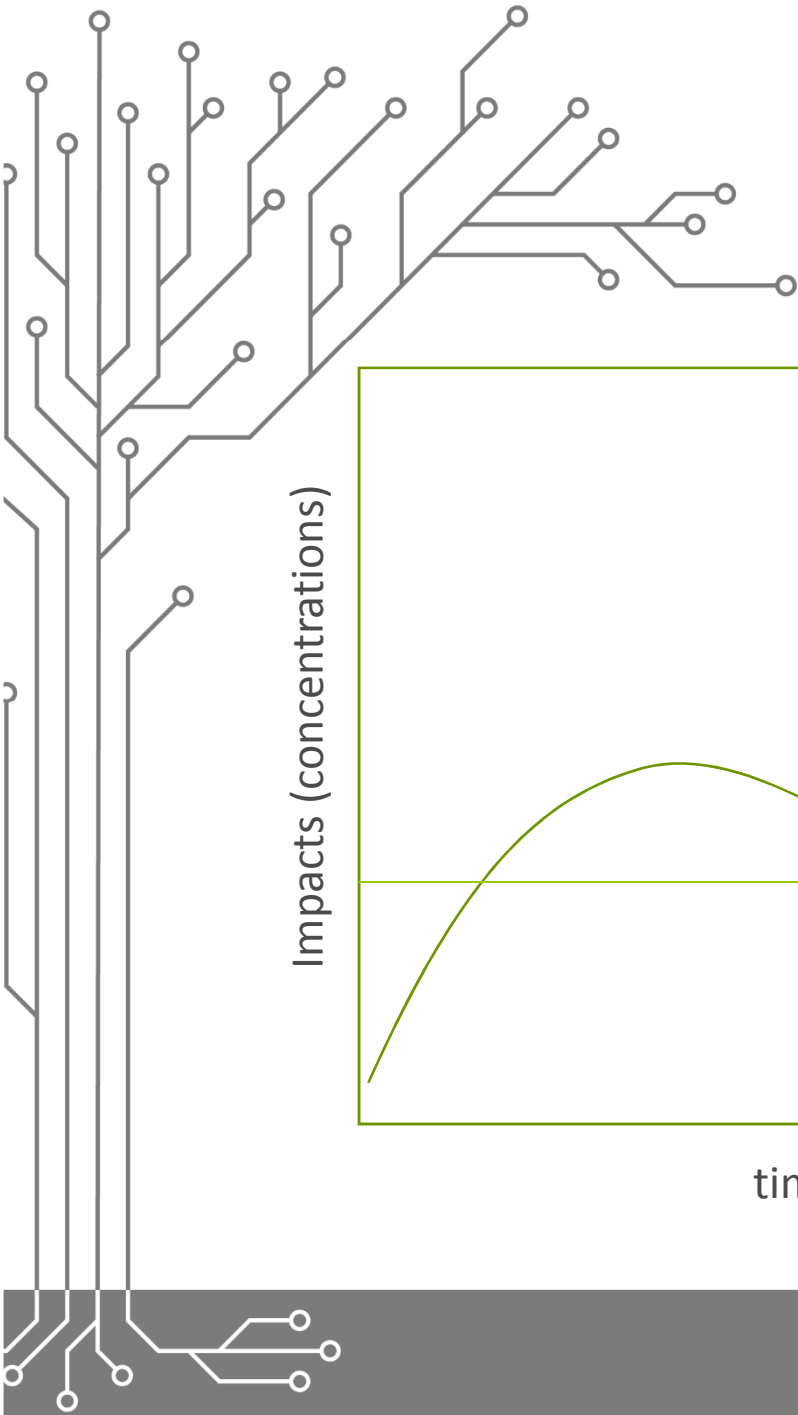
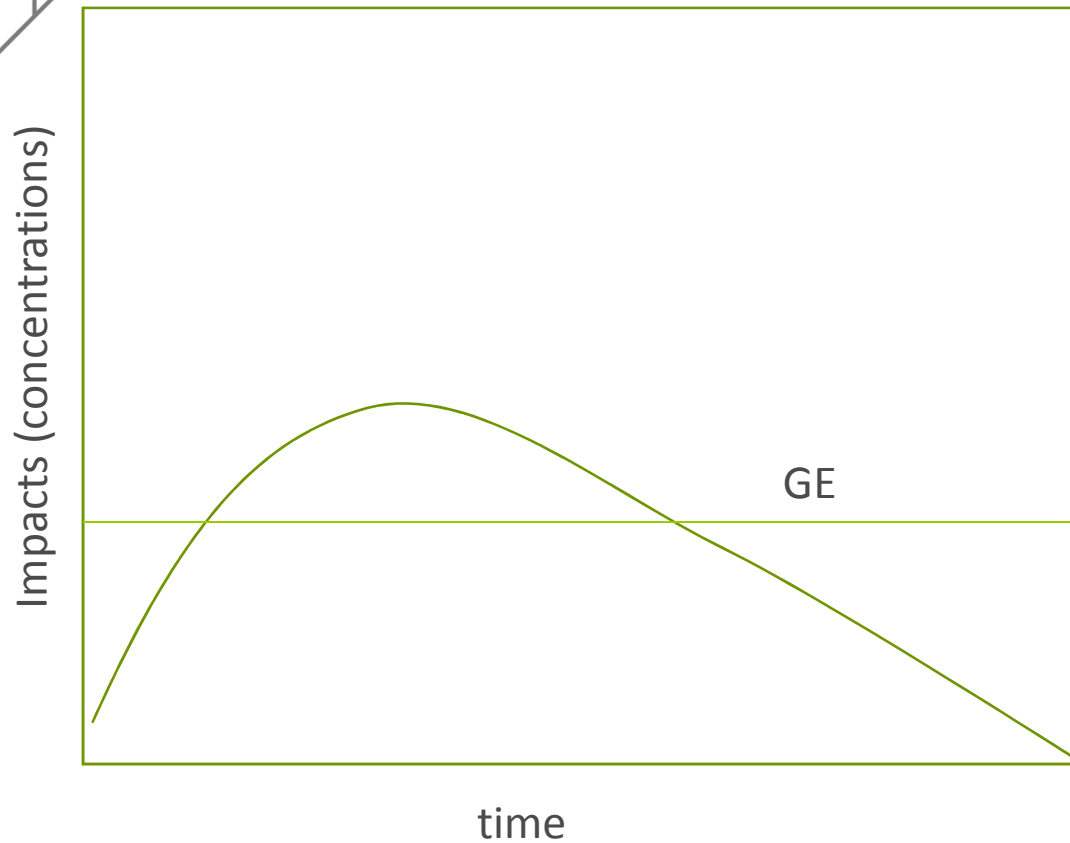
Carbon Dioxide Removal proposals...	Albedo Modification proposals...
... address the cause of human-induced climate change (high atmospheric GHG concentrations).	...do not address cause of human-induced climate change (high atmospheric GHG concentrations).
...do not introduce novel global risks.	... introduce novel global risks.
...are currently expensive (or comparable to the cost of emission reduction).	...are inexpensive to deploy (relative to cost of emissions reduction).
...may produce only modest climate effects within decades.	...can produce substantial climate effects within years.
...raise fewer and less difficult issues with respect to global governance.	...raise difficult issues with respect to global governance.
...will be judged largely on questions related to cost.	...will be judged largely on questions related to risk.
...may be implemented incrementally with limited effects as society becomes more serious about reducing GHG concentrations or slowing their growth.	...could be implemented suddenly, with large-scale impacts before enough research is available to understand their risks relative to inaction.
...require cooperation by major carbon emitters to have a significant effect.	...could be done unilaterally.
...for likely future emissions scenarios, abrupt termination would have limited consequences.	...for likely future emissions scenarios, abrupt termination would produce significant consequences.

Why do we might consider GE?



Source: Relative outcomes of climate change mitigation related to global temperature versus sea-level rise, Gerald A. Meehl, Aixue Hu, Claudia Tebaldi, Julie M. Arblaster, Warren M. Washington, Haiyan Teng, Benjamin M. Sanderson, Toby Ault, Warren G. Strand & James B. White III, Nature Climate Change 2, 576-580 (2012) doi:10.1038/nclimate1529

Why do we might consider GE?





Who should controls global thermostat?

- Do we have platform to negotiate that?
 - UN/OECD/WTO?
- Do we have tool ?
 - UNFCCC
 - ENMOD
- Do we have body to enforce?
 - UNSC



Who should controls global termostat? ENMOD note

- Operation Popeye - Project Popeye
Motorpool Intermediary-Compatriot
- Cloud seeding by silver and lead iodine
- Vietnam war
- Result is ENMOD convention (1977)
- Czech/Slovak Republic is party of the
convention



Who should control Earth thermostat?

ENMOD
(Convention on the Prohibition of Military or
Any Other Hostile Use of Environmental
Modification Techniques)

.... party to this Convention undertakes not to engage in military or any other **hostile** use of environmental modification techniques having widespread, long-lasting or severe effects ...



GE problems

- As with CC there will be winners and losers
- Some GE is relatively cheap compared to mitigation/adaptation
- Climate inertia (i.e. climate has no breaks and some GE options do have neither)

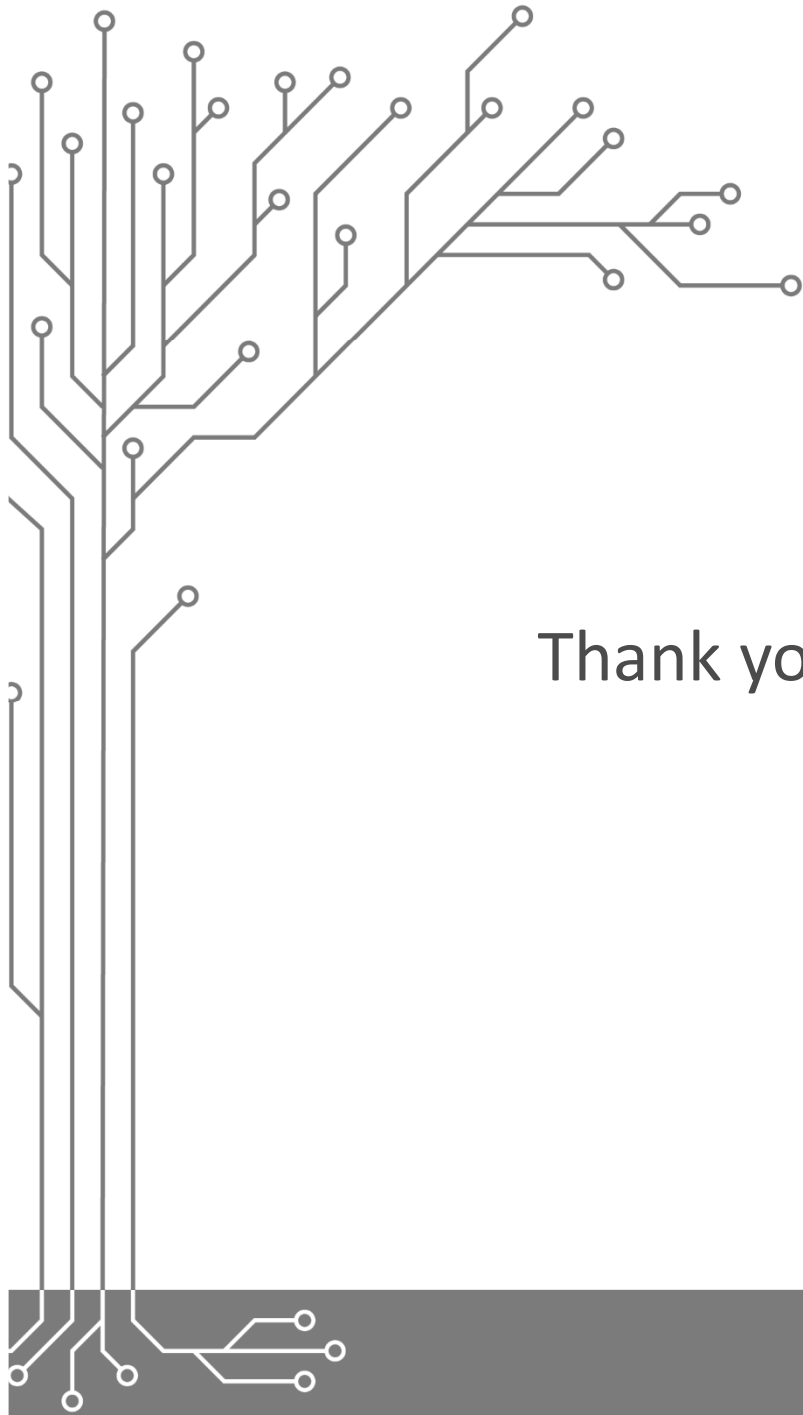


Food for thought

Geoengineering is good insurance

vs.

Geoengineering is moral hazard



Thank you for your attention