Geoengineering and the Future Ozone Layer

Simone Tilmes

Jadwiga (Yaga) Richter, Mike Mills (NCAR)

Ben Kravitz (PNNL) and Doug MacMartin (Caltech)

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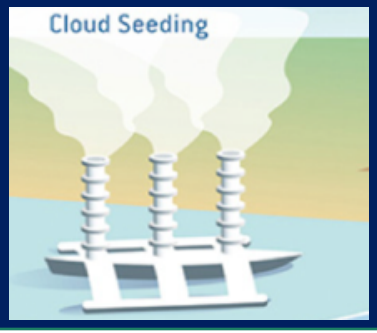
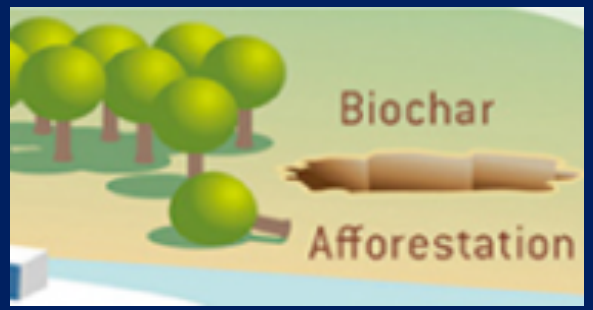
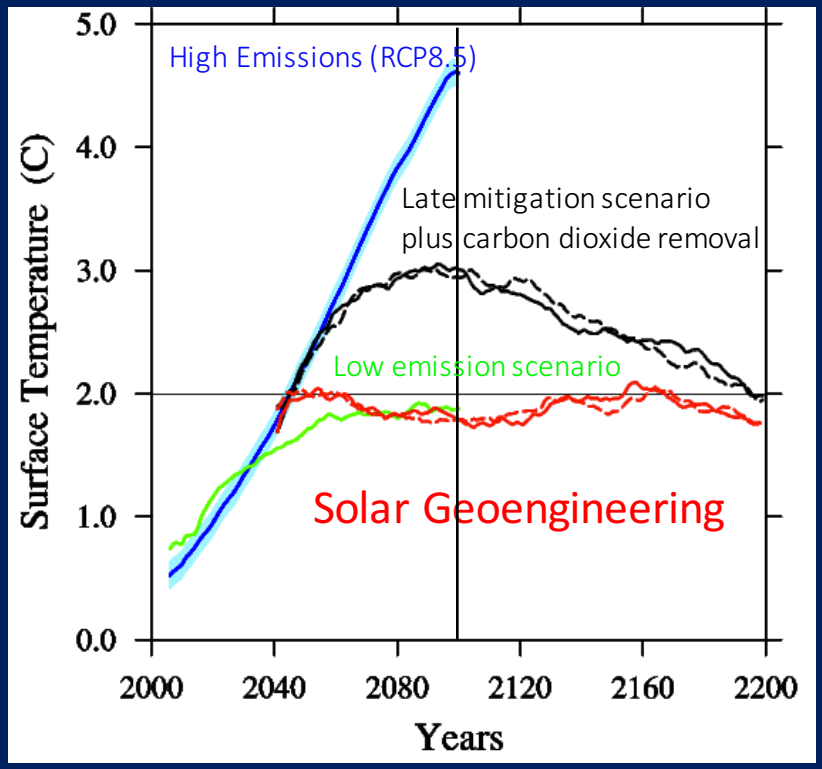
- Why research Geoengineering?
- New strategies to explore Geoengineering
- Impact on the ozone layer in a future climate





Decarbonization and Solar Geoengineering

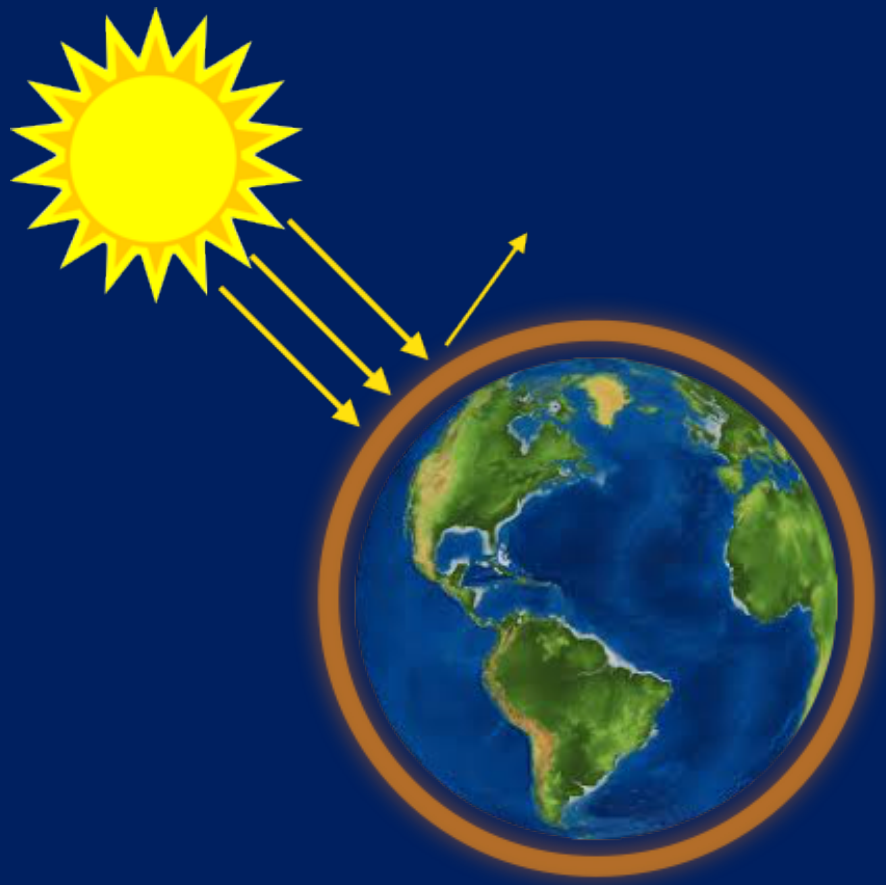


Tilmes et al., 2016 (Wigley 2006)

Example of temporary Solar Radiation Management

- Last resort if mitigation and decarbonization is not sufficient
- Could be used to reduce worst impacts of climate change
- 1 degree cooling would require 1.5 Mt Pinatubo injections per year

Solar Radiation Management (SRM)

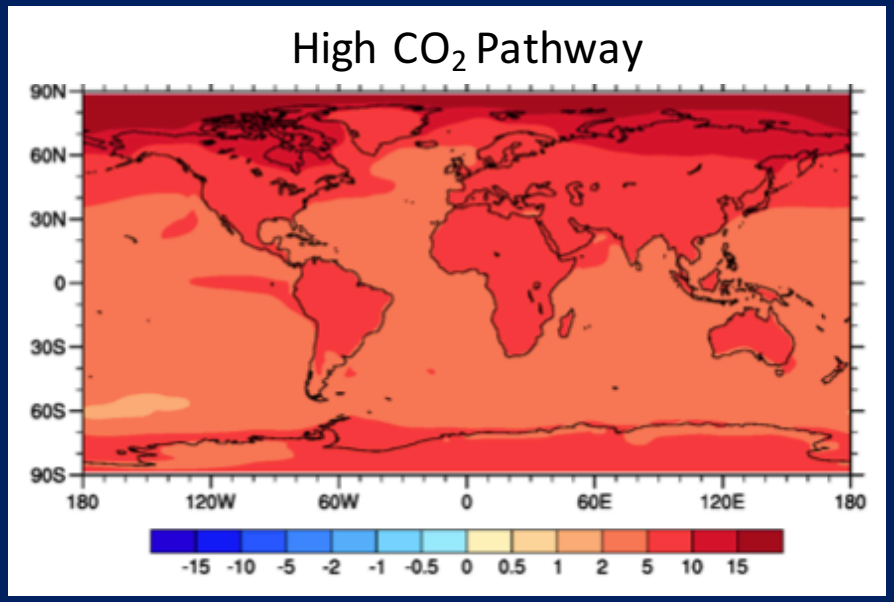


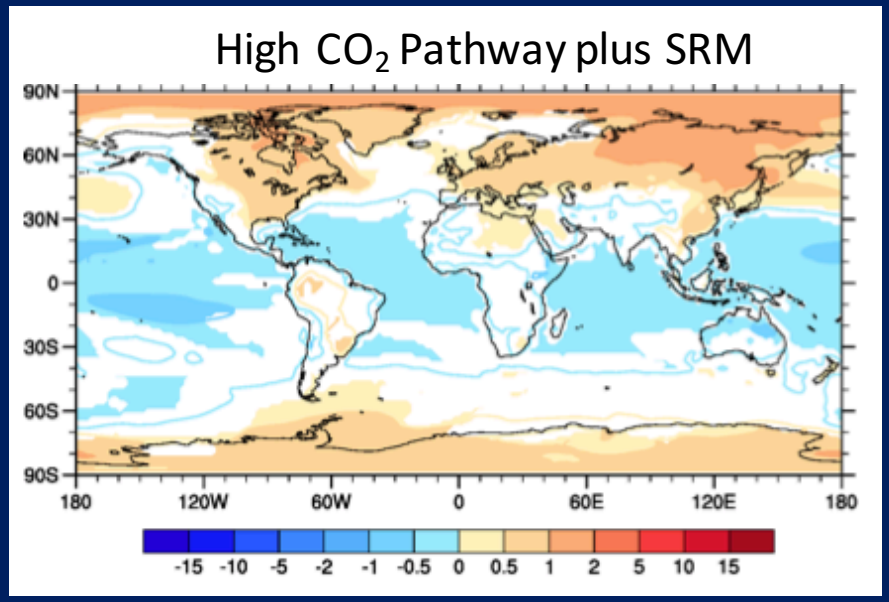
Stratospheric Aerosol Modification

Natural Analog: Volcanoes

Benefits, Side Effects, and Risks of SRM

Surface Air Temperature Change





Benefits

- Reduced heat waves and excessive flooding
- Reduced Arctic sea-ice melt
- Reduced sea-level rise
- Reduced climate impacts

Known side effects and uncertainties

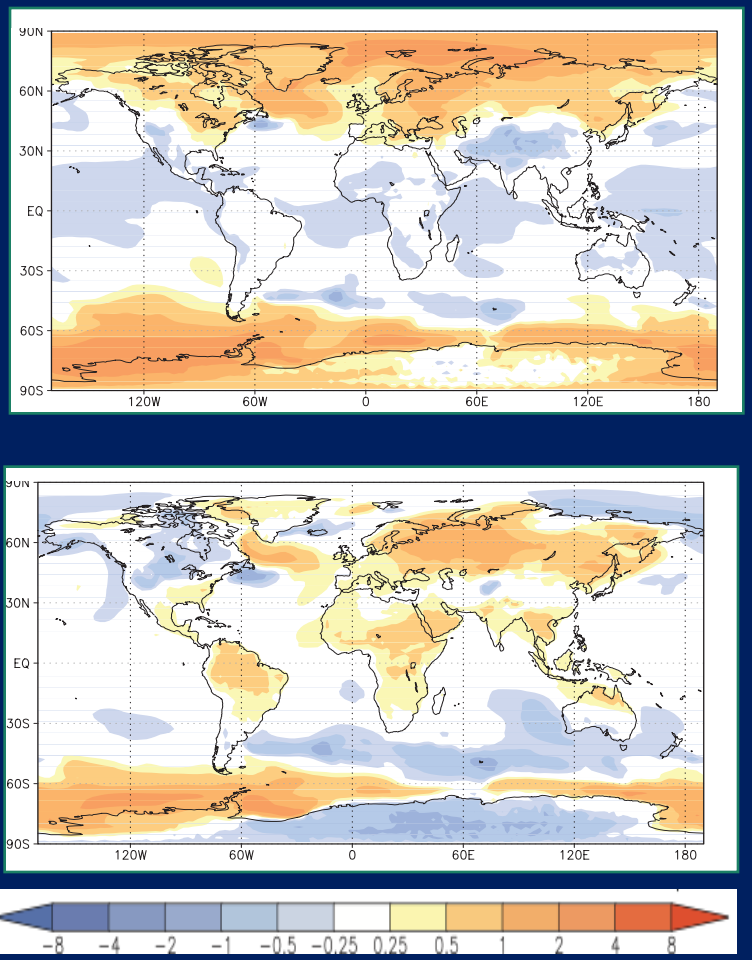
- Regional climate change, reduced rainfall
- Delay in the healing of the ozone layer
- Impact on agriculture, crop, biosphere

Risks /Challenges

- Sudden termination
- Climate forcing and variability
- Political, ethical challenges

New Strategies to Reduce Side Effects and Risks

Surface Air Temperature Change

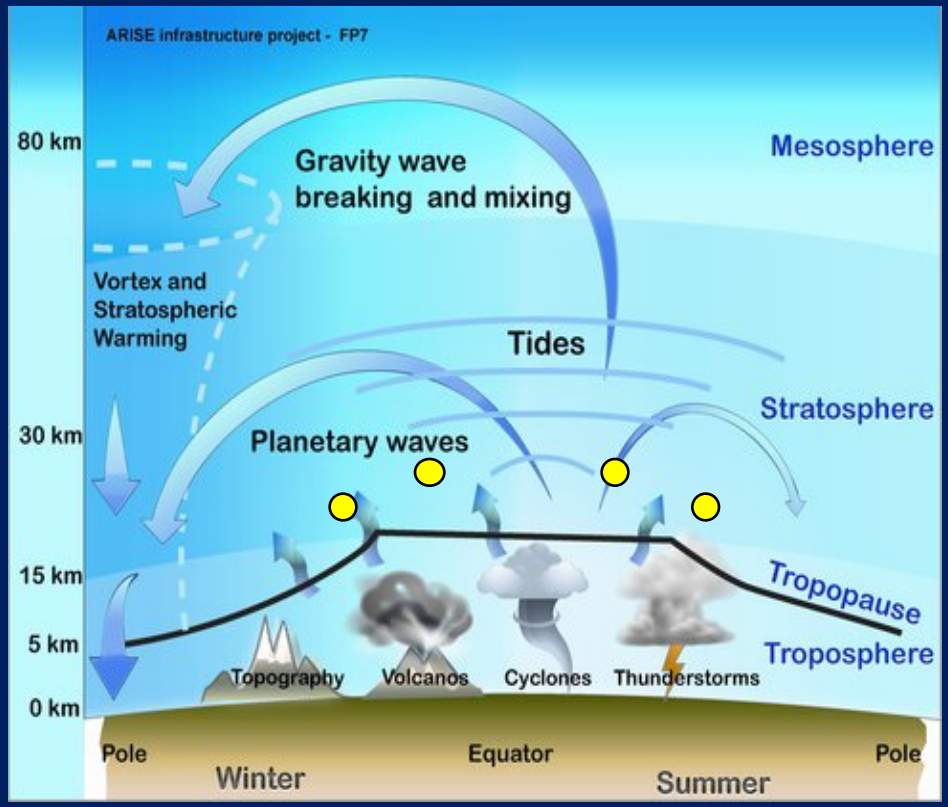


New Approach

1. Set climate goals to reduce side effects
2. Design experiment, e.g. choose multiple injection locations
3. Run feedback control to manage variability and uncertainty
4. Examine side effects, set new goals

Kravitz et al., 2016

NCAR Whole Atmosphere Community Climate Model



CESM(WACCM):

- 0.9x1.25^{o} horizontal resolution
- 140 km lid
- 70 vertical layers
- Interactive Quasi-Biannual Oscillation (QBO)
- Modal aerosol model
- Prognostic volcanoes and aerosol microphysics
- Full stratospheric chemistry
- Coupling to ocean, ice, land

System Identification:

Single Injection Matrix (42 experiments) for SO_2 injections:

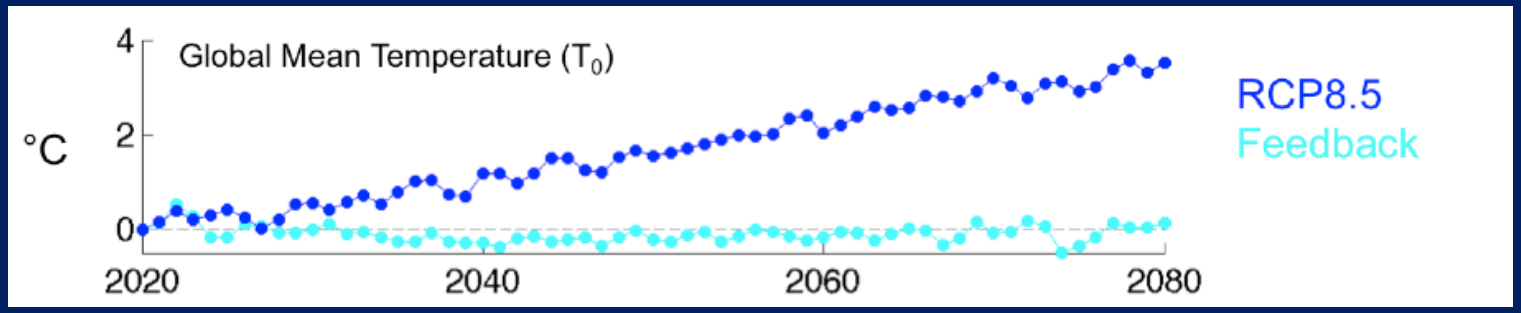
Identify correlation between injection locations and temperature response

Best combination: 30N/30S, 15N/15S; 5 km above the tropopause

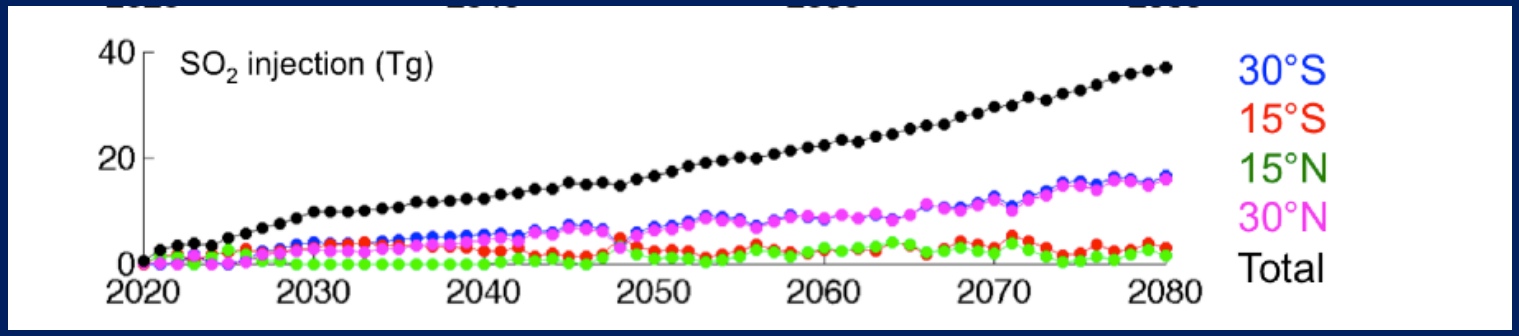
Mills et al., 2017, Tilmes et al., 2017, MacMartin et al, 2017, Richter et al, 2017

Feedback-Controlled Simulation with CESM(WACCM)

Goal: to keep climate at 2020 conditions using stratospheric SO_2 injections

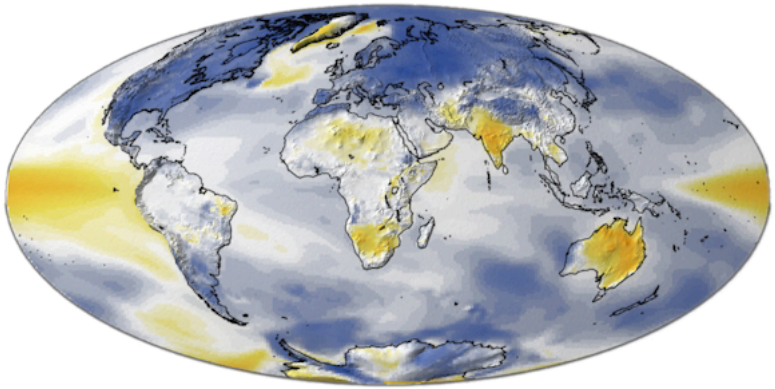


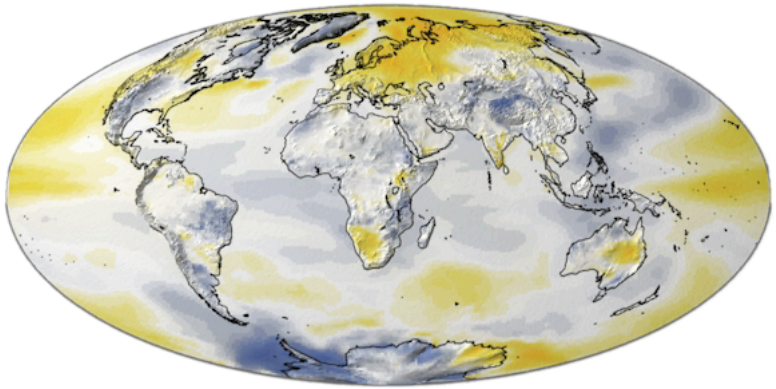
- Running a feedback algorithm to identify amount and location of annual injection of SO_2
- Prior knowledge of emissions scenario or climate sensitivity not required



Kravitz et al., 2017

Surface Temperature Anomaly

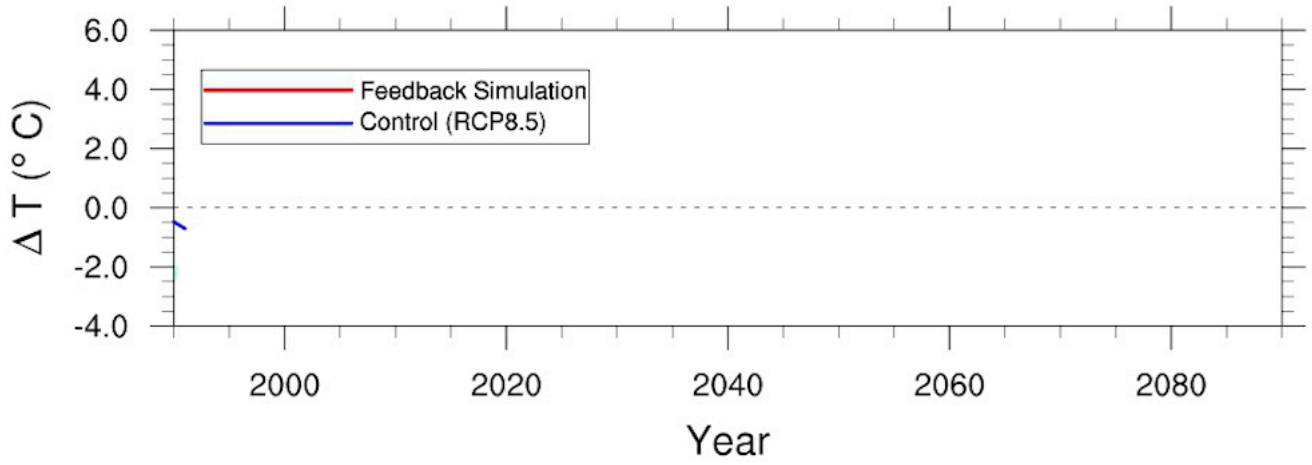




RCP8.5

Year: 1990

Feedback Simulation

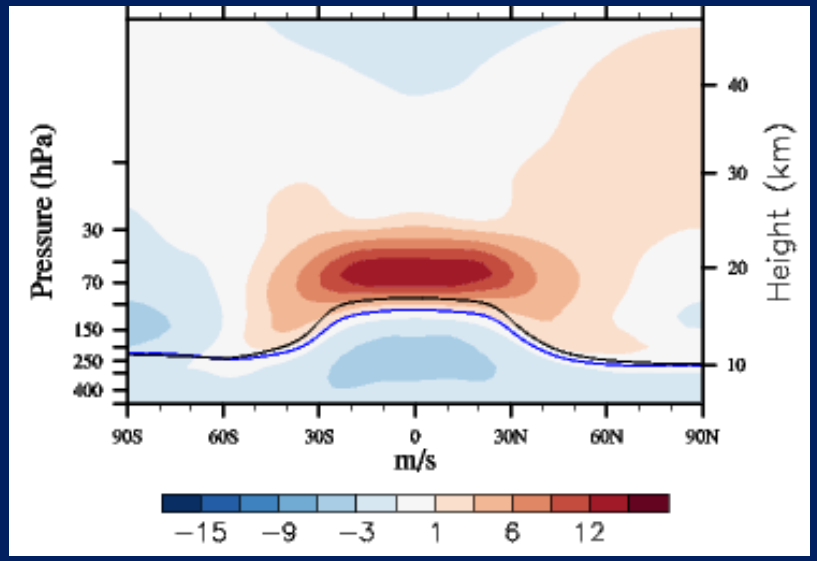


NCAR

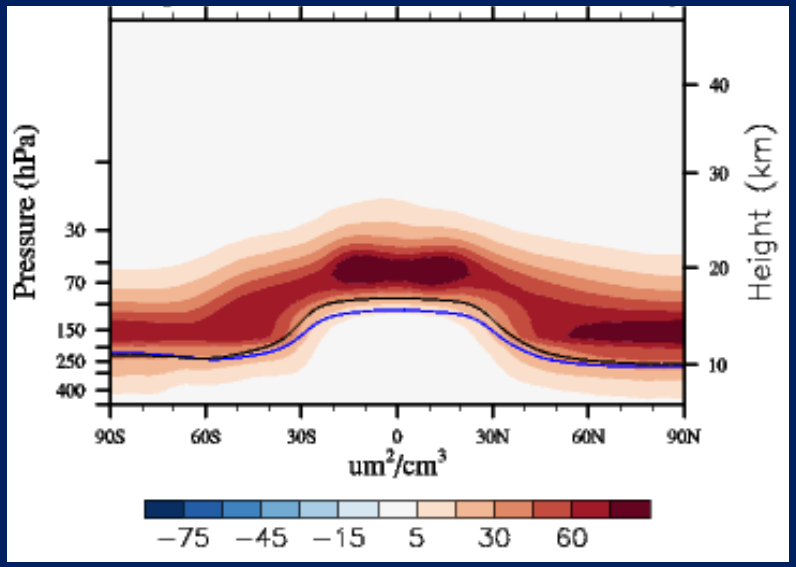
NSF

Impact on the Stratosphere

Temperature (Geoeng. – Control)



Stratospheric surface area density

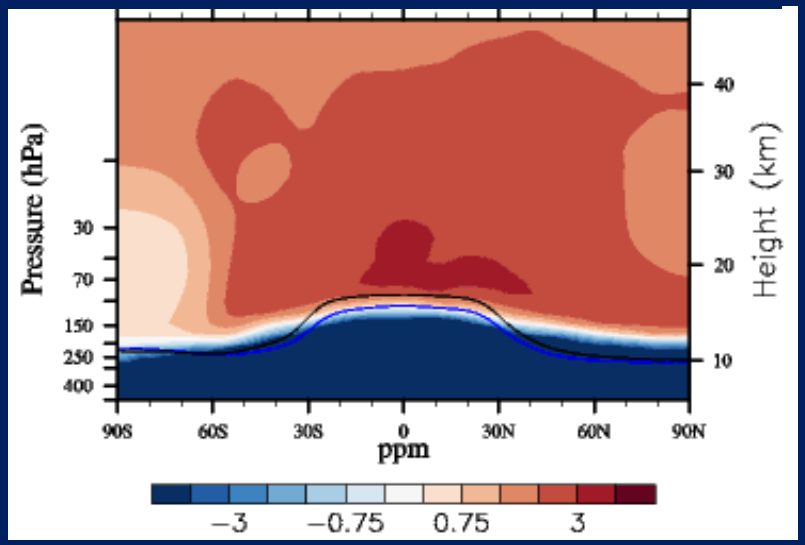


Changes in 2042-49, ~2 degrees surface cooling using SO_2 injections

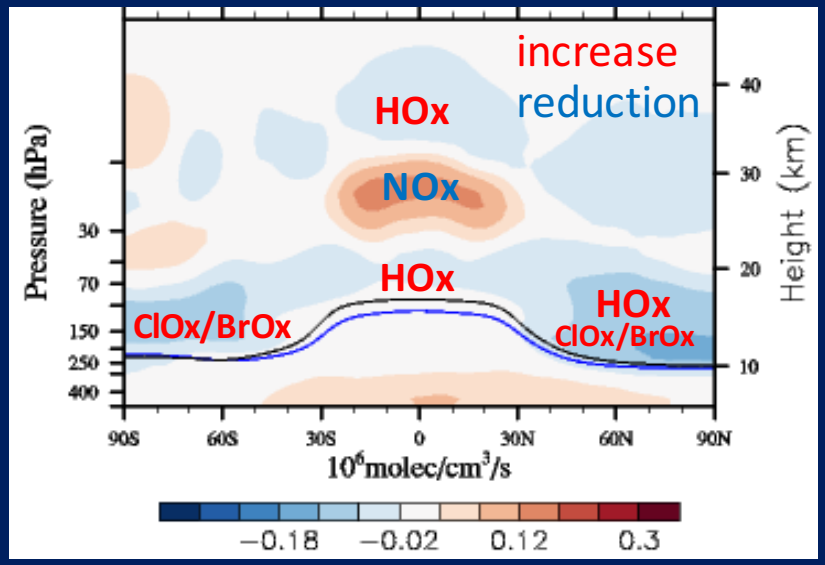
- Heating of the lower tropical stratosphere
- Drop in tropopause temperatures
- Changes in stratospheric circulation

Impact on Stratospheric Chemistry

Water Vapor (Geoeng. – Control)



Net chemical production of Ozone (Geoeng. – Control)

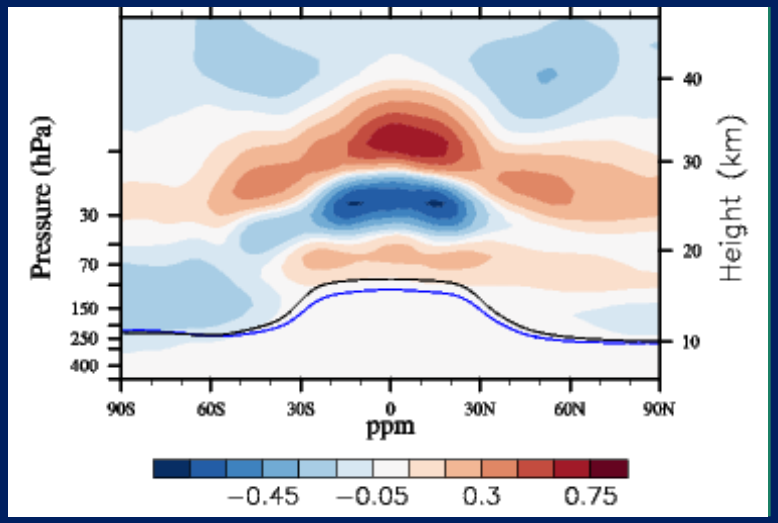


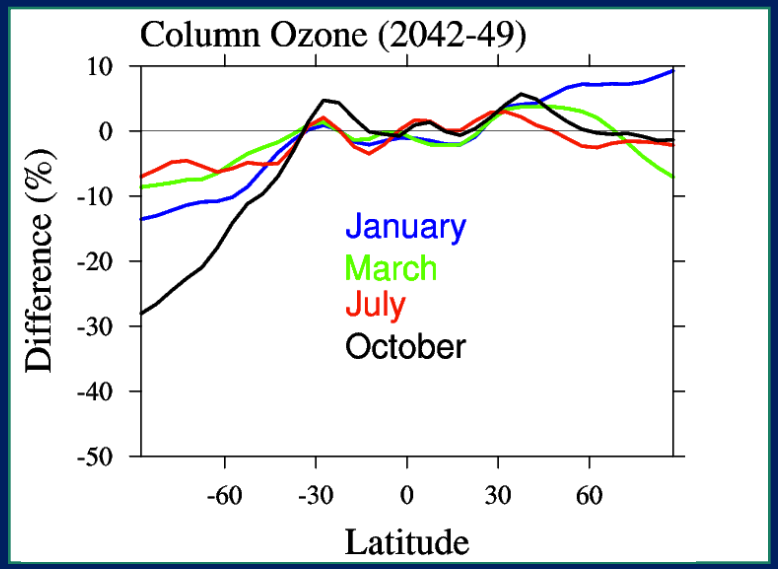
Changes in 2042-49, ~2 degrees surface cooling using SO_2 injections

- Increase in stratospheric water vaper
- Changes in ozone loss cycles
- Changes in net chemical production of ozone

Impact on Stratospheric Ozone

Delta Ozone (Geoeng. – Control)

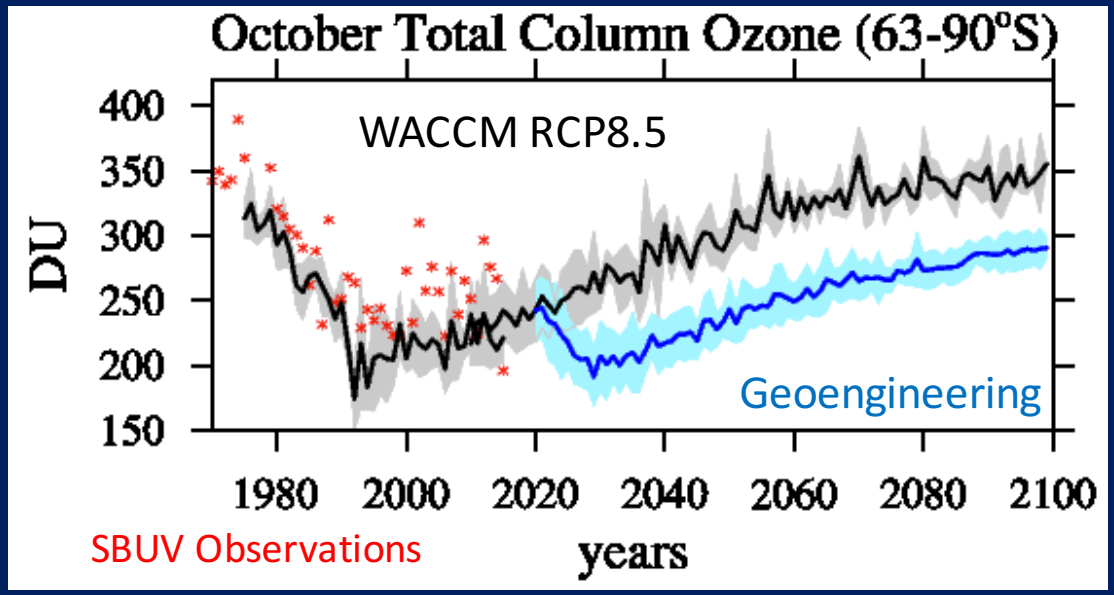


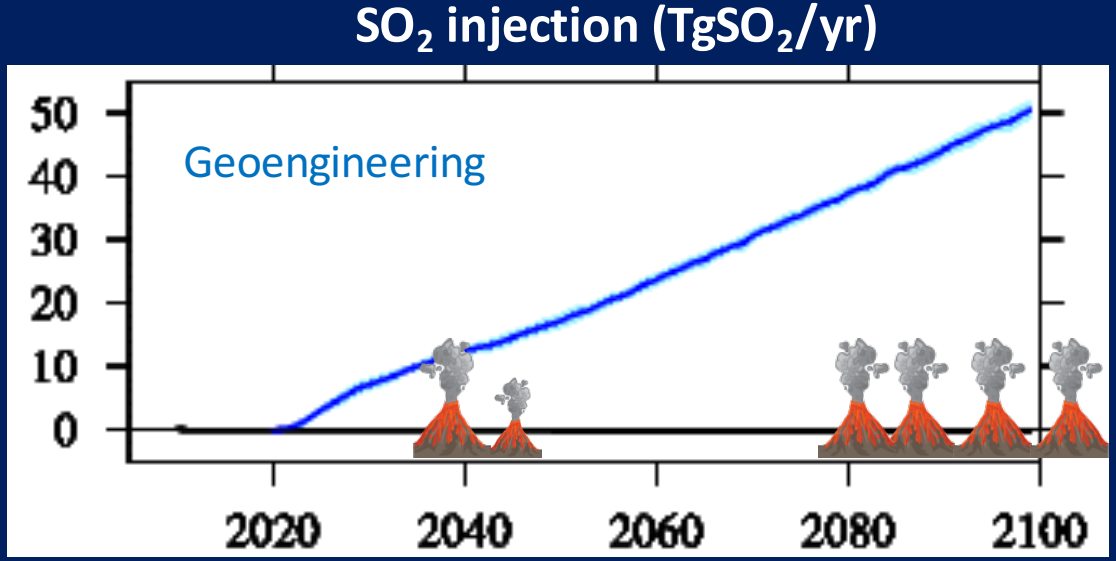


- Chemical and dynamical changes important depending on region and season
- Impact on surface UV and climate

Tilmes et al. (in preparation)

Geoengineering and Future Ozone





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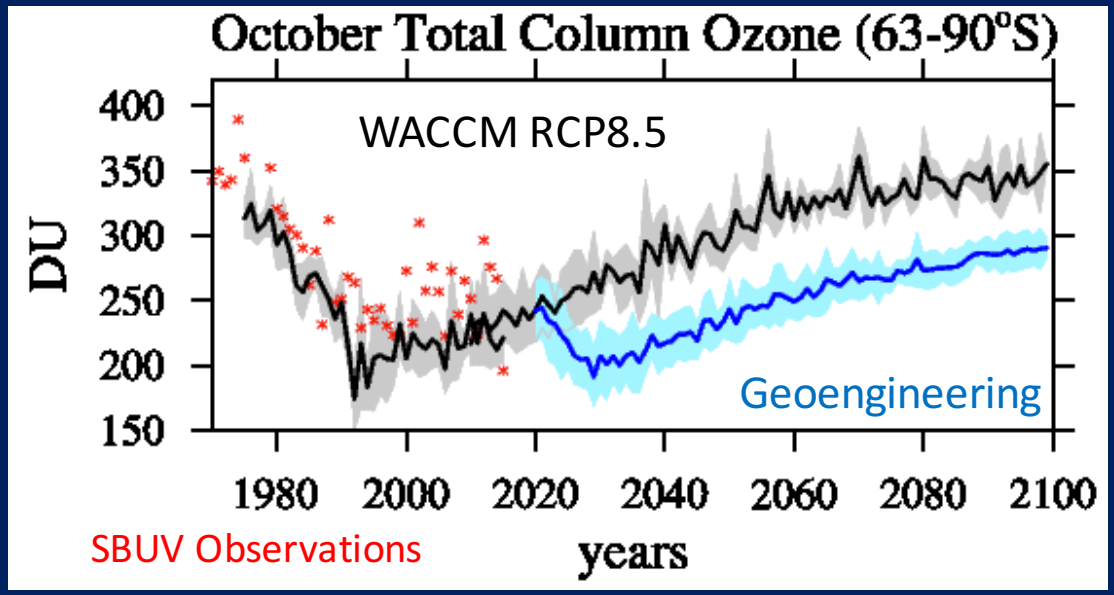

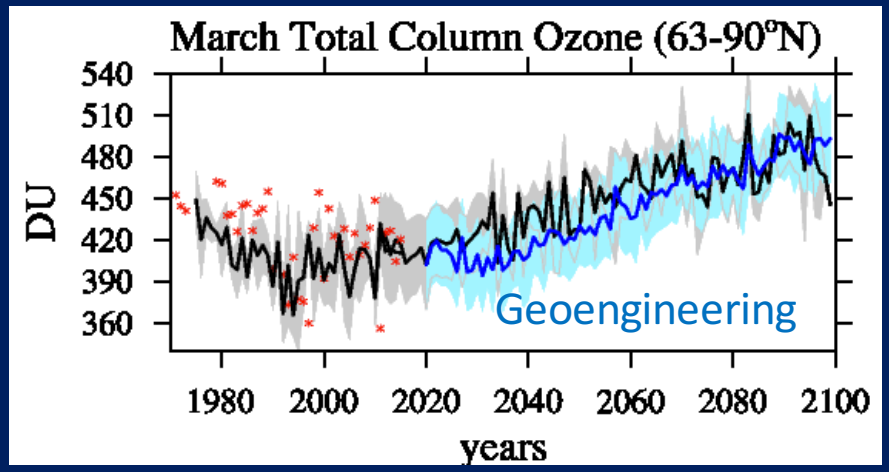

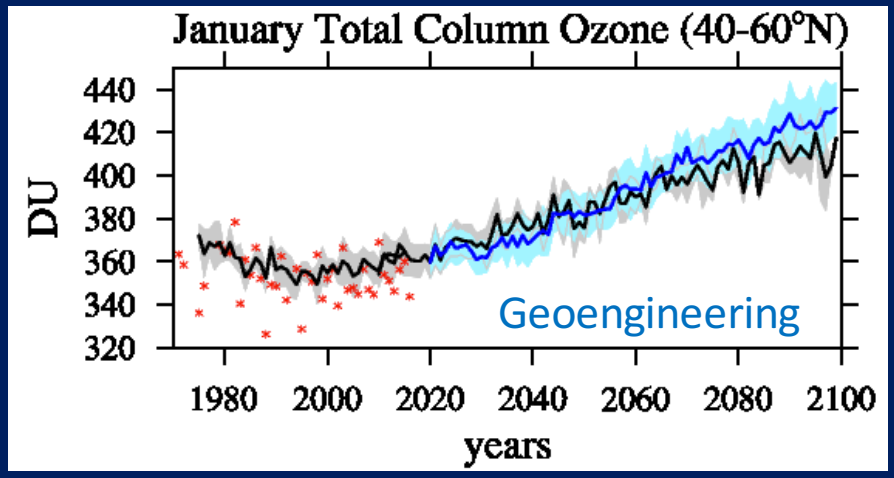

Summary

- Global climate can be restored with solar radiation management using new strategies in climate models
- Significant impact on stratospheric chemistry and dynamics, delay of the Antarctic ozone recovery, small impacts elsewhere
- Comprehensive research program is needed to explore safe solar radiation management options
- Combined with rapid decarbonization would reduce risk of abrupt termination