Global Impacts of SRM on the Carbon Cycle, Agriculture and Ocean Biodiversity

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frontiers of science

Effects of SRM on Ecosystems and Human Health

- SAI may suppress precipitation (Ferraro and Griffiths, *Environ. Res. Lett.*, 2016) and increase tropospheric ozone (Xia et al., *Atmos. Chem. Phys.*, 2017)
- SAI can increase the global land carbon sink (Yang, *Environ. Res. Lett.*, 2020), decrease wildfire (Tang, *Atmos. Chem. Phys.*, 2023), mitigate climate extremes (Muthyala et al., *Curr. Sci.*, 2018)
- SAI may exacerbate deep ocean acidification and impact the food chain (Tjiputra et al., *J. Geophys. Res. Biogeosci.*, 2016)
- Effects of SRM on agricultural crop production and yield
  - CO_2 fertilization vs. cooling, precipitation suppression, and solar radiation reduction on rice and maize in China (Xia et al., *J. Geophys. Res. Atmos.*, 2014)
  - Shifts in direct:diffuse radiation vs. cooling, using volcanic eruptions (Proctor et al., *Nature*, 2018)
  - Yields for six major crops increase by ~10% under SAI and decrease by 5% under emissions reduction (due to reduced CO_2 fertilization); humidity has larger effect than precipitation and no effect from reduced solar insolation (Fan et al., *Nature Food*, 2021)
- Ecosystem and biodiversity risk from rapid termination (Trisos et al., *Nat. Ecol. Evol.*, 2018)
- Human health impacts of SRM (Trisos et al., *Nat. Clim. Change*, 2018)

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Geoengineering Increases the Global Land Carbon Sink

Objective: To examine stratospheric aerosol intervention (SAI) impacts on plant productivity and terrestrial biogeochemistry.

Approach: Analyze and compare simulation results from the Stratospheric Aerosol Geoengineering Large Ensemble (GLENS) project from 2010 to 2097 under RCP8.5 with and without SAI.

Results/Impacts: In this scenario, SAI causes terrestrial ecosystems to store an additional 79 Pg C globally as a result of lower ecosystem respiration and diminished disturbance effects by the end of the 21st century, yielding as much as a 4% reduction in atmospheric CO_2 mole fraction that progressively reduces the SAI effort required to stabilize surface temperature.

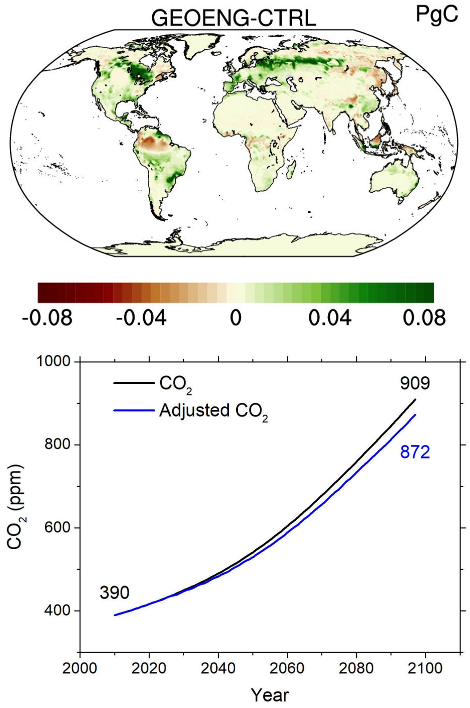

Figure: The larger sink under SAI increased land C storage by 79 Pg C by 2097, which would reduce the projected atmospheric CO_2 level.

Yang, C.-E., **F. M. Hoffman**, D. M. Ricciuto, S. Tilmes, L. Xia, D. G. MacMartin, B. Kravitz, J. H. Richter, M. Mills, and J. S. Fu (2020), Assessing Terrestrial Biogeochemical Feedbacks in a Strategically Geoengineered Climate, *Environ. Res. Lett.*, doi:10.1088/1748-9326/abacf7.

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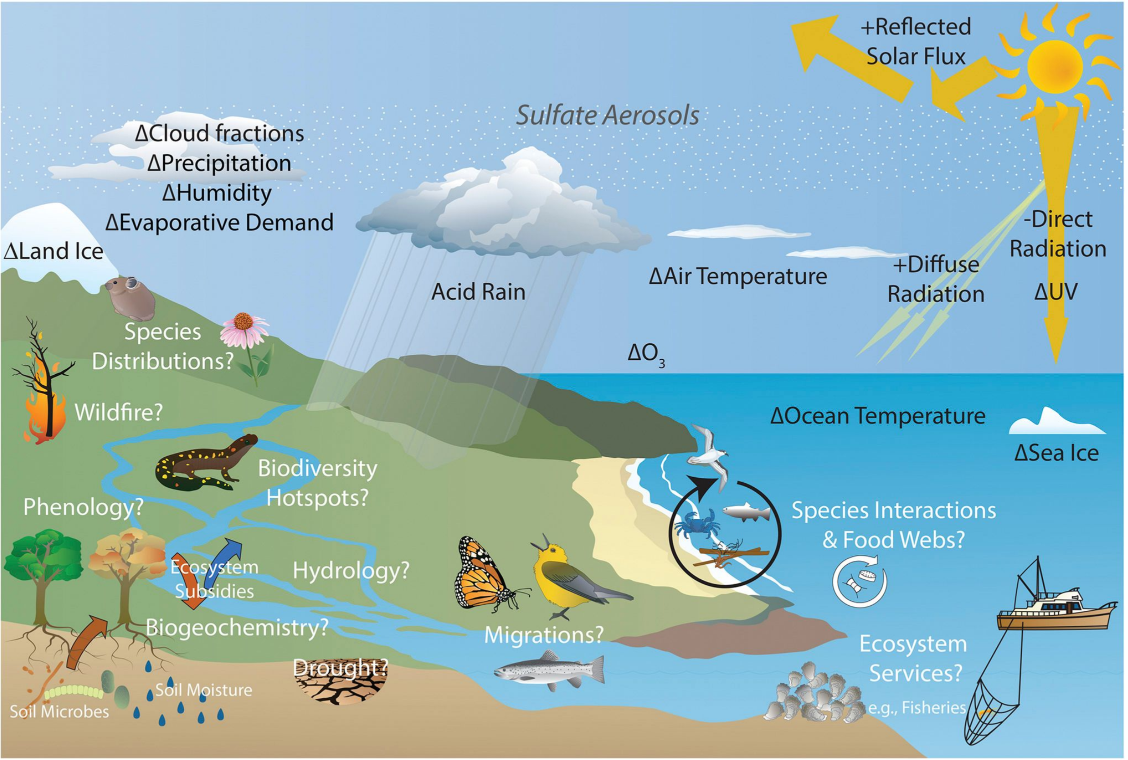
Potential Ecological Impacts of Climate Intervention

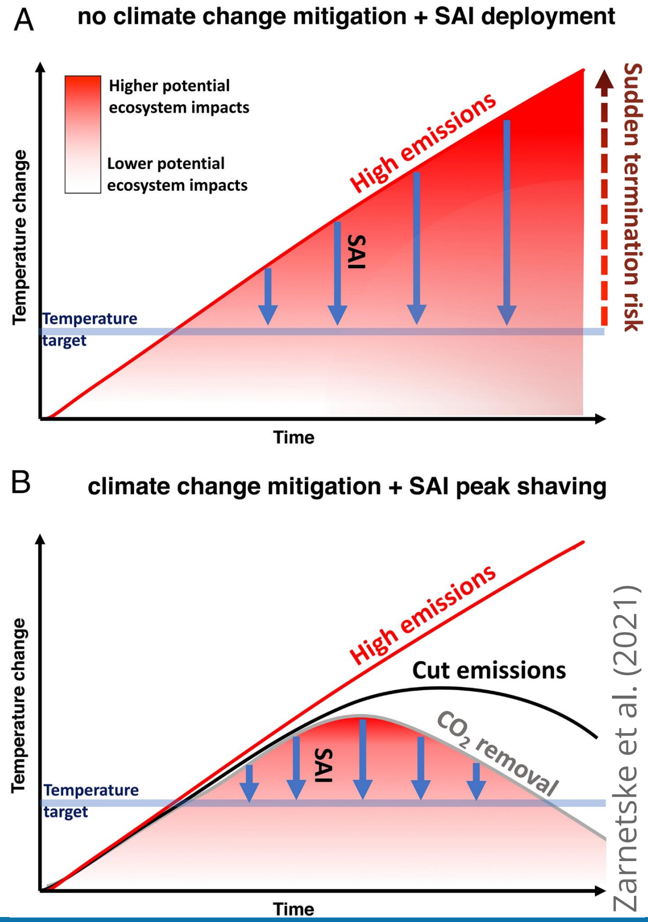


Although some effects of SRM with SAI on climate are known from certain SAI scenarios, the effects of SAI on ecological systems are largely unknown. Adopted from Zarnetske et al. (2021).

- While climate research has focused on predicted climate effects of SRM, few studies have investigated impacts that SRM would have on ecological systems
- Impacts and risks posed by SRM would vary by implementation scenario, anthropogenic climate effects, geographic region, and by ecosystem, community, population, and organism
- A transdisciplinary approach is essential, and **new modeling paradigms are required**, to represent complex interactions across Earth system components, scales, and ecological systems

Exploring Feedbacks of SAI and CDR

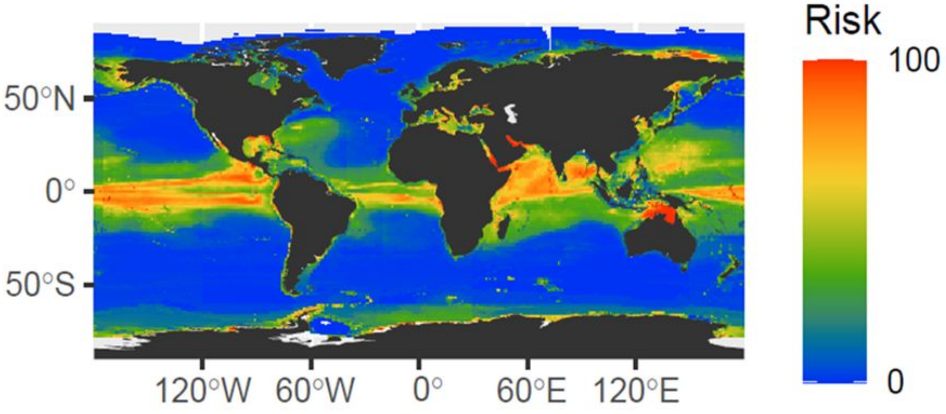
- To explore Earth system feedbacks of SAI on ecosystems, we are planning a series of geoengineering simulations with the **Energy Exascale Earth System Model (E3SM)** and compare with similar Community Earth System Model (CESM) simulations
- **Simulations will mimic effects of CDR, SAI, and CDR plus SAI**
- Start with SSP5-3.4-OS mid-range overshoot CO_2 trajectory from CMIP6, which prescribes a drawdown of CO_2
- Global surface temperatures will rise by >2.5°C around 2040, **above the 2°C threshold that may induce irreversible impacts**
- Next, introduce SAI to simultaneously cool the surface until drawdown is sufficient to assure <2°C warming, called **temperature "peak shaving"**
- Quantify feedbacks from reducing, not increasing, atmospheric CO_2, **but this may not capture all the as-yet-unobserved processes**

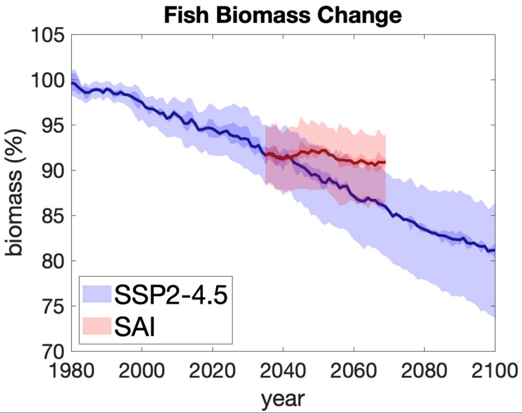


Zarnetske et al. (2021)

Impacts of SRM on Marine Ecosystems

Kelsey Roberts (Louisiana State University)





No studies to date have quantified the implications of SRM on marine ecosystems

- research on the ecosystem drivers is minimal
- research on combined interventions is completely lacking

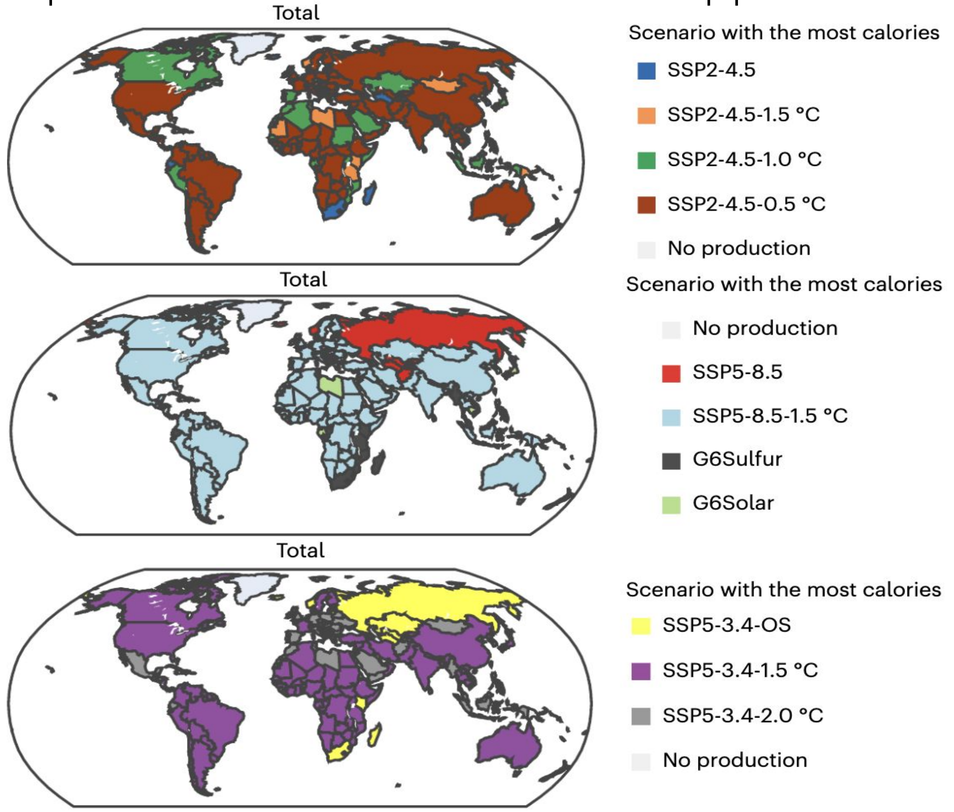
High level of uncertainty in how marine ecosystems will respond to climate intervention scenarios, building on the uncertainty of how marine ecosystems will respond to climate change

Is the overall net effect of climate interventions more or less beneficial for marine ecosystems than non-intervention scenarios? *We don't know…but we now have a place to start*

Agricultural Impacts of Solar Radiation Modification

Jyoti Singh (Rutgers University)

Optimal climate intervention scenarios for crop production SAI



- Research on SAI's agricultural effects has focused mainly on temperature and precipitation changes
- SAI would also alter ozone levels, UV radiation, and light distribution
- Crop model development is required to simulate SAI's specific climate impacts
- Crop yield as a metric in designing SAI scenarios