Leveraging Integrated Assessment Models to Assess Socioeconomic Impacts of Potential Stratospheric Aerosol Injection (SAI)

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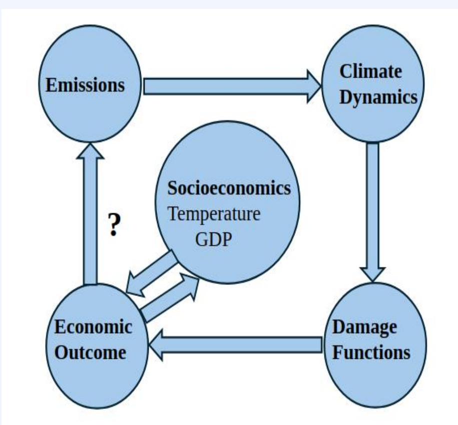
ABSTRACT

Stratospheric aerosol injection (SAI) is a proposed climate intervention that involves injecting aerosols (or aerosol precursors) into the stratosphere to reduce global warming and associated devastating impacts. This study estimates the socioeconomic effects of potential SAI using model results from the Stratospheric Aerosol Geoengineering Large Ensemble (GLENS-SAI) and the Assessing Responses and Impacts of Solar Climate Intervention on the Earth System (ARISE-SAI) as inputs to the Climate Framework for Uncertainty, Negotiation, and Distribution Integrated Assessment model (FUND). GLENS-SAI and ARISE-SAI are an ensemble of SAI simulations between 2020 and 2100 (GLENS) and 2035-2064 (ARISE-SAI-1.5) using the Community Earth System Model, wherein SAI is simulated to offset the warming produced by a high-emission scenario (RCP 8.5) and a middle of the road (SSP2-4.5). FUND quantifies climate damages across sectors including agriculture, forestry, heating, cooling, water resources, tropical and extratropical storms, biodiversity, cardiovascular and respiratory mortality, vector-borne diseases, diarrhea, migration, morbidity, and rising sea levels. Aggregate impacts culminate in net damages, reported as a percentage of gross domestic product (GDP). Without SAI, global damages take a more linear trajectory, with up to 1% (SSP2-4.5) and 6% (RCP8.5) losses in global GDP. Under SAI, the reversed warming trajectory yields GDP savings of up to 0.6% (GLENS-SAI) and 1% (ARISE-SAI). Key contributors to net damages include cooling and heating demand, agriculture productivity, and water resources. Whereas cooling costs increase under both warming scenarios, savings accrue from avoided heating costs. However, while the suppressed warming under SAI yields the opposite effect, reduced cooling costs and returns from agriculture culminate in net benefits. A cost analysis was also conducted for ARISE and GLENS using operational and deployment cost estimates from Wagner and Smith (2018). The current analysis depicts a linear cost function near the onset of injection, transitioning to a nonlinear pattern over time. Nevertheless, benefits (savings) significantly outweigh the costs of operation and deployment. In the extreme case (GLENS-SAI), peak costs only reach about 0.03% of global GDP. The current analysis is pivotal in advising policymakers on the socioeconomic outcomes and feasibility of SAI.

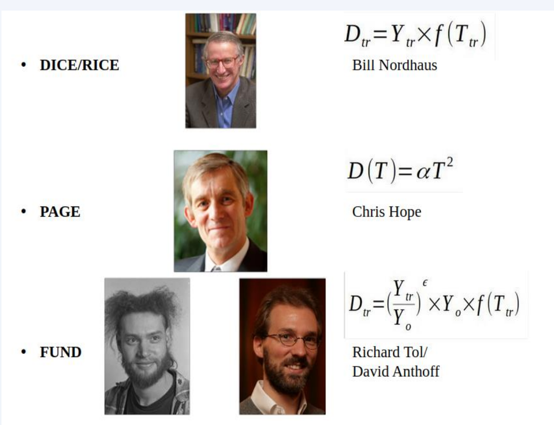
Key Definitions

- Integrated Assessment Models (IAMs)?
  "computational models of global climate change that include representation of the global economy and greenhouse gas emissions, the response of the climate system to human intervention, and impacts of climate change on the human system" - National Academies of Sciences, Engineering, and Medicine (2017)

Typical IAM Structure



Existing IAMs



Proposed Climate Mitigation Strategies

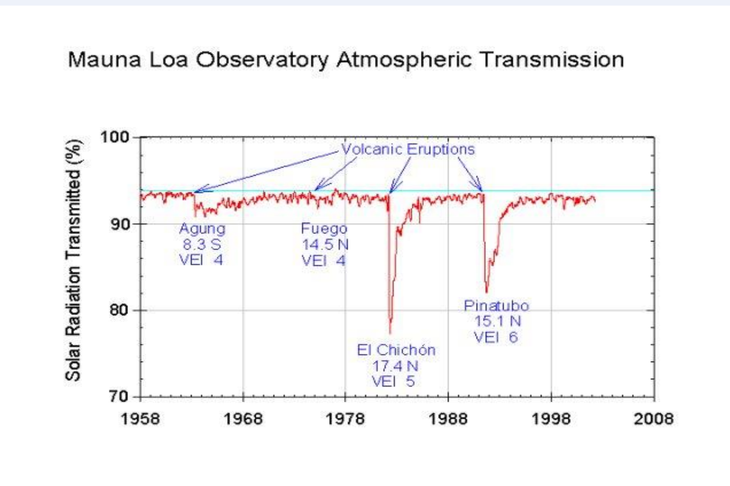
- Emissions abatement
- Stratospheric Aerosol Injection (SAI)

Why abatement is expensive

- Technological limitations
- Political resistance
- Economic disruption

Motivation for SAI

- Relatively cheap to execute
- Volcanic signatures validate SAI feasibility

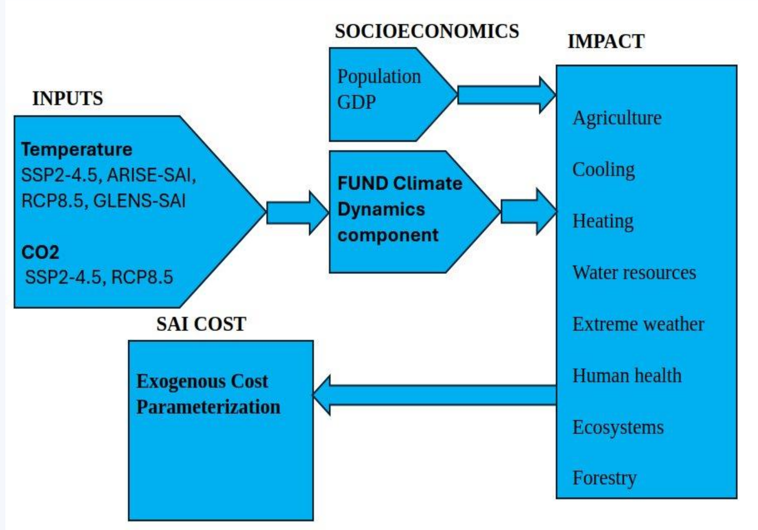


RESEARCH QUESTIONS

- How could Stratospheric Aerosol Injection (SAI) mitigate the socioeconomic impacts of climate change at a global scale?
- How do the effects of SAI vary across regions, and what region-specific climate damages are expected under SAI deployment?
- In a cost-benefit framework, how do the potential socioeconomic costs of implementing SAI compare to its projected benefits in terms of avoided climate damages?

WORKFLOW

Model results from the GLENS-SAI () and ARISE-SAI scenarios () are used as inputs to the Framework for Uncertainty, Negotiation, and Distribution (FUND) model, which is deployed here under the terms of the MIT License, which permits the use, modification, and distribution of the software.



ARISE-SAI	GLENS-SAI
• SSP2-4.5 (2015-2100)	• RCP8.5 (2010-2100)
• ARISE-SAI (2035-2070)	• GLENS-SAI (2020-2100)
• Temperature target 1.5 degrees above preindustry	• Temperature target (maintain 2010-2030 average)

Global Temperatures

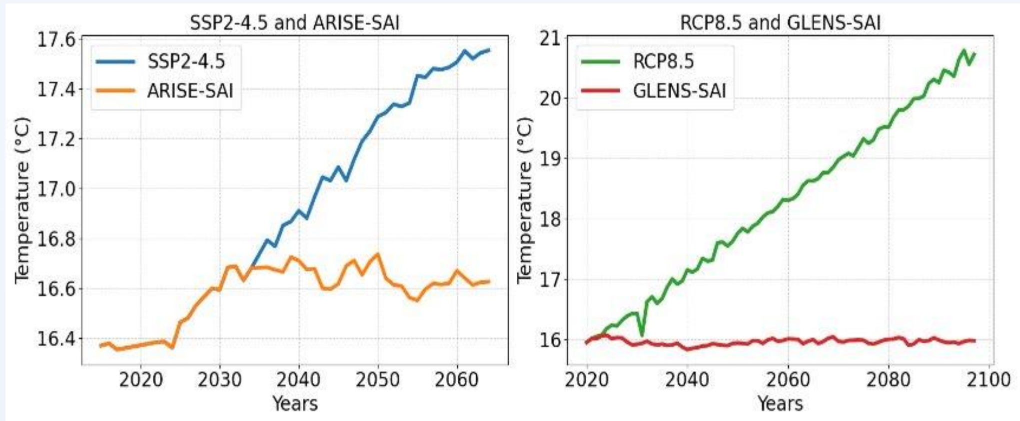


Figure 1: Global temperatures: Left - SSP2-4.5 (blue), ARISE-SAI (orange); Right: RCP8.5 (green), GLENS-SAI (red)

RESULTS

Global Damages With Normalization

- Global wealth substantially offsets losses.
- Global GDP accounts for the steepness of trajectories.

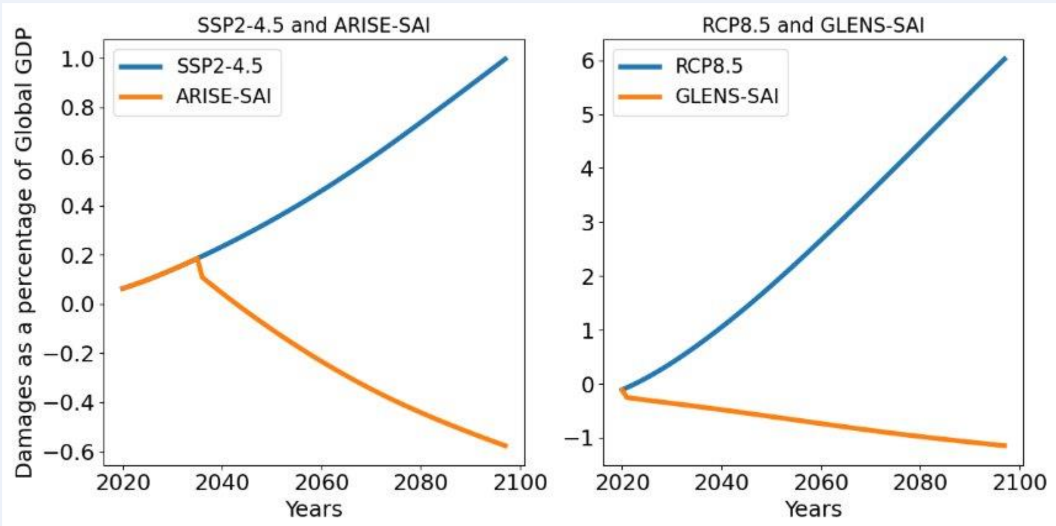


Figure 2: Global Damages normalized by global GDP: Left - SSP2-4.5 (blue), ARISE-SAI (orange); Right: RCP8.5 (green), GLENS-SAI (orange)

Global Damages Without Normalization

- Raw damages (without normalization) highlight the role of a wealthy global economy in normalizing damage impacts

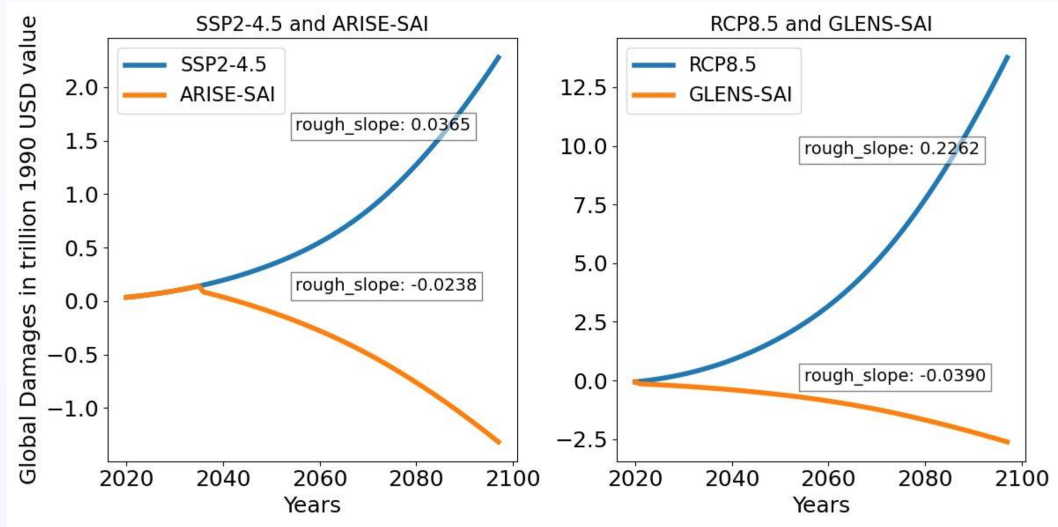


Figure 3: Global Damages in 1990 USD: Left - SSP2-4.5 (blue), ARISE-SAI (orange); Right: RCP8.5 (blue), GLENS-SAI (orange)

Aggregates

- Under SSP2-4.5 and RCP8.5, while cooling costs rise with warming, savings accrue from avoided heating costs.
- Net agricultural savings

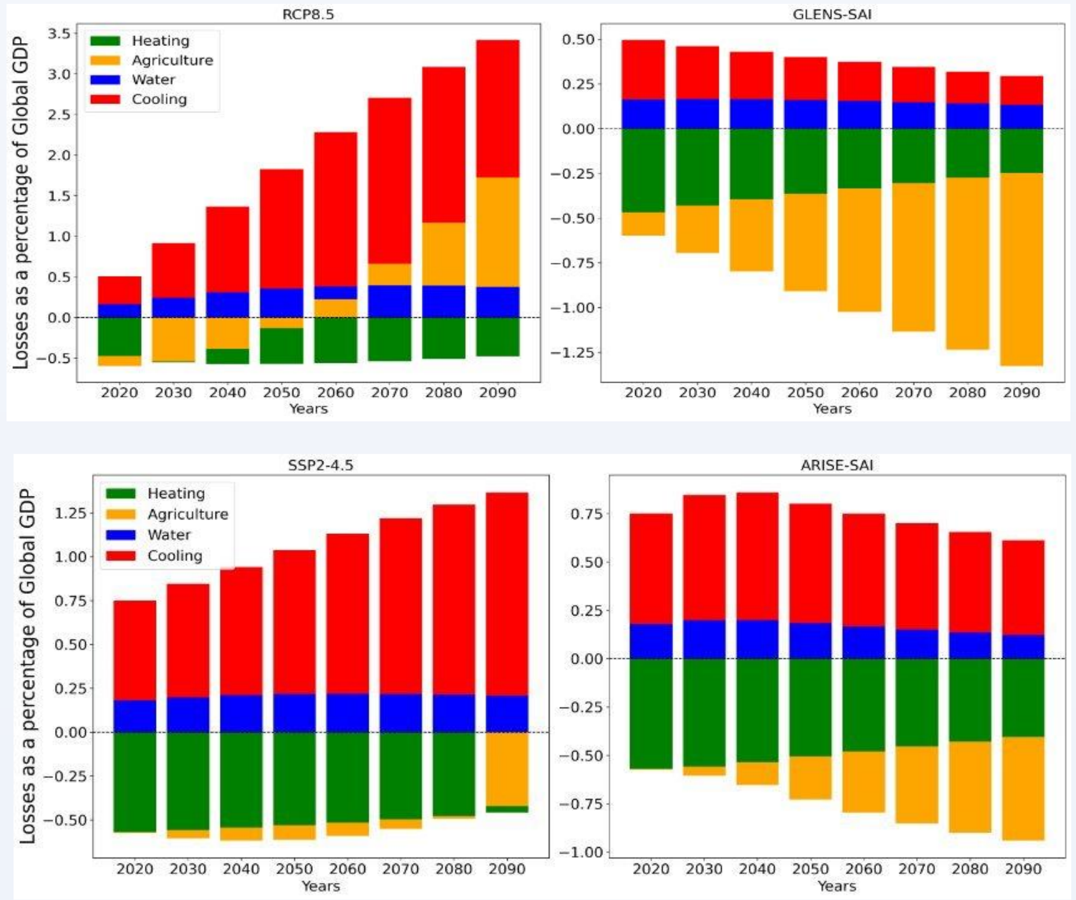


Figure 4: Aggregate damages for heating, cooling, water resources, and agriculture as a percentage of global GDP under RCP8.5 and GLENS-SAI (top left and right) and SSP2-4.5 and ARISE-SAI (bottom left and right)

Cost-Benefit Analysis

- Benefits (savings) substantially outweigh costs.

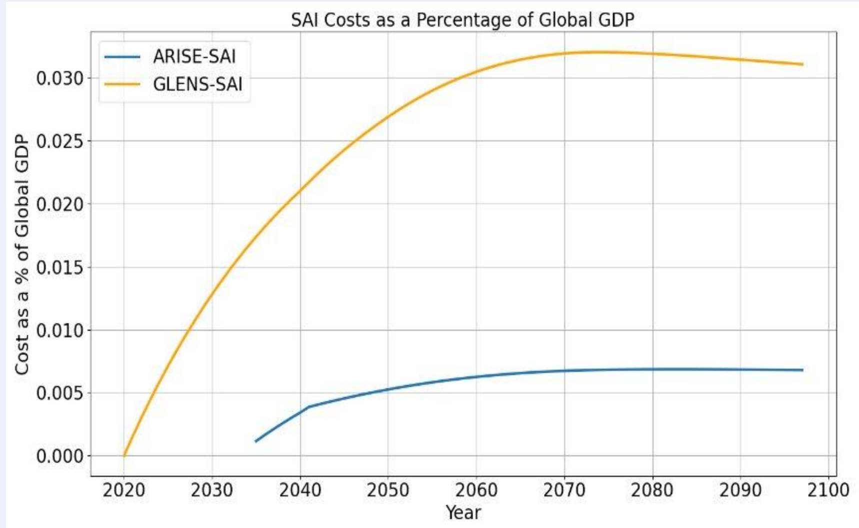


Figure 5: SAI cost estimates for ARISE-SAI (blue) and GLENS-SAI (yellow)

Regional Disparities

- Whereas global savings are appreciable, regional disparities could be a strong socioeconomic motivation to pursue SAI

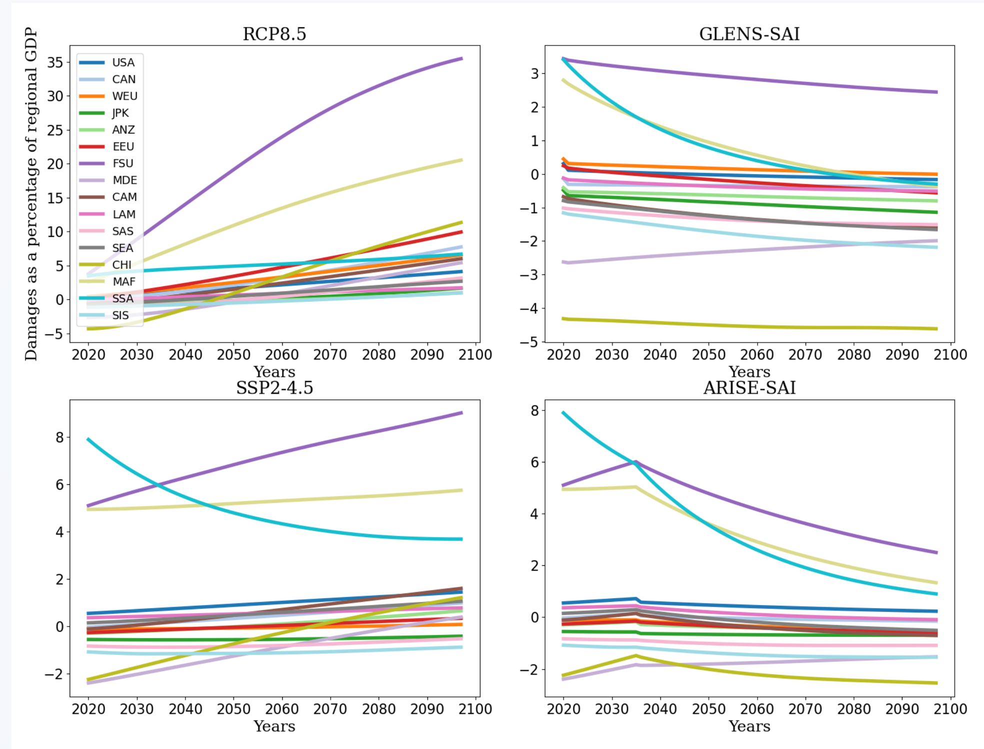


Figure 6: Regional Damages normalized by regional GDP: top- RCP8.5 and GLENS-SAI; bottom- SSP2-4.5 and ARISE-SAI-

Regional nomenclature: USA- United States CAN – Canada WEU – Western Europe JPK – Japan ANZ- Australia and New Zealand EEU – Eastern Europe FSU – Former Soviet Union MDE- Middle East CAM – Central America LAM- South America SAS- South Asia SEA- South East Asia CHI- China MAF- North Africa SSA – Sub-Saharan Africa SIS- Small Island States

How the current estimates compare with others

Greenhouse Gas Impacts Value Estimator (GIVE)

Data-driven Spatial Climate Impacts Model (DSCIM)

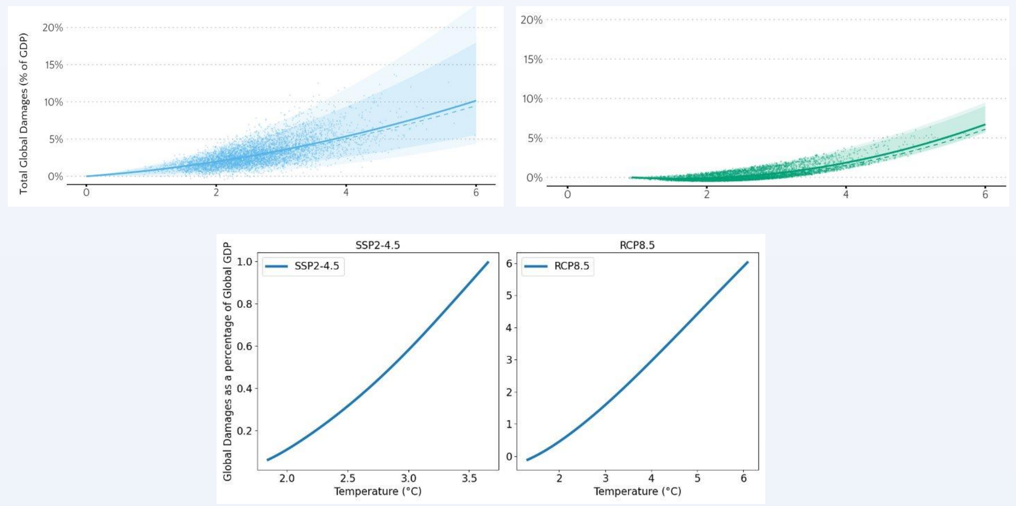


Figure 7: Comparing the estimates (bottom) with EPA's estimates (Environmental Protection Agency. 2022) using the GIVE (top left) and DSCIM (top right).

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