Investigating the Short-Term Climate Responses to Stratospheric Aerosol Injection

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Introduction

- Climate change is a critical challenge affecting all individuals
- Stratospheric Aerosol Injection (SAI) is a proposed climate intervention strategy
- This strategy involves:
  - Injecting aerosols above the tropopause
  - Increasing atmospheric albedo
  - Cooling the Earth
- Research has been done mainly on timescales of 10 years or longer[1]
- We target poorly-understood short-term responses

Materials and Methods

- Data generated with the Community Earth System Model 2 (CESM2) with Whole Atmosphere Community Climate Model version 6 in middle-atmosphere configuration (WACCM6ma)[2]
- Data consists of:
  - 8 ensemble members
  - Data ocean
  - Perpetual 2000s
- Each ensemble has:
  - 232 years
  - 116 different injection scenarios
    - 8 different latitudes
    - 4 different longitudes
    - 4 different injection rates
  - Some ensembles are missing data
- A different, randomly selected injection scenario occurs every 2 years
  - Proceeding injection is random and different

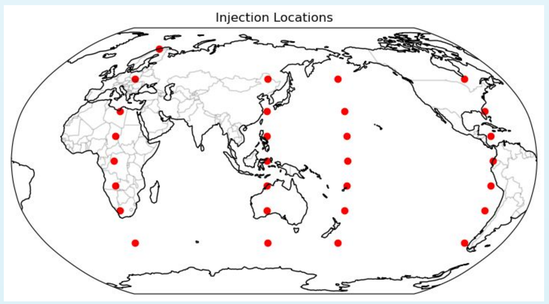


Figure 1. This shows every location where aerosols are injected

Latitude and Temperature

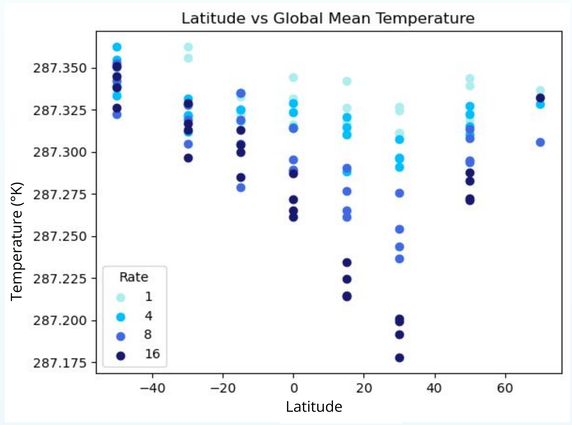


Figure 2. Plot showing the relationship between the injection latitude and global mean temperature. Rates are shown in different colors. There is a clear relationship between higher injection rates and lower temperatures.

Rates & Linear vs Nonlinear Relationships

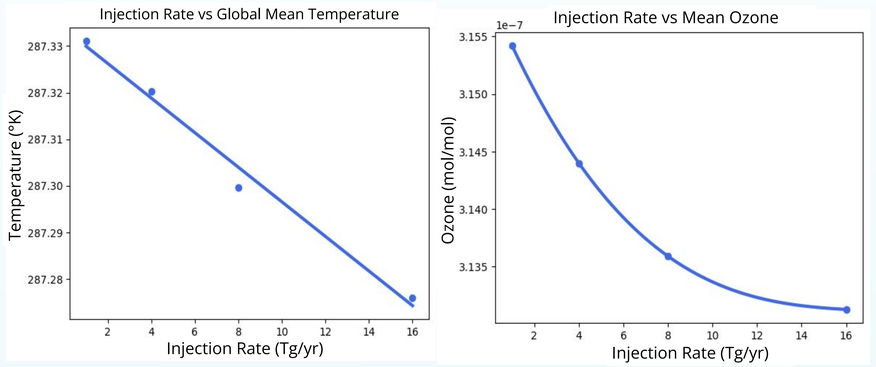


Figure 4. Left: The global mean temperature as a function of rate. This shows that global mean temperature changes linearly with injection rate.
Right: Total column ozone as a function of injection rate. This shows that total column ozone changes nonlinearly with injection rate.

Temperature Response to SAI

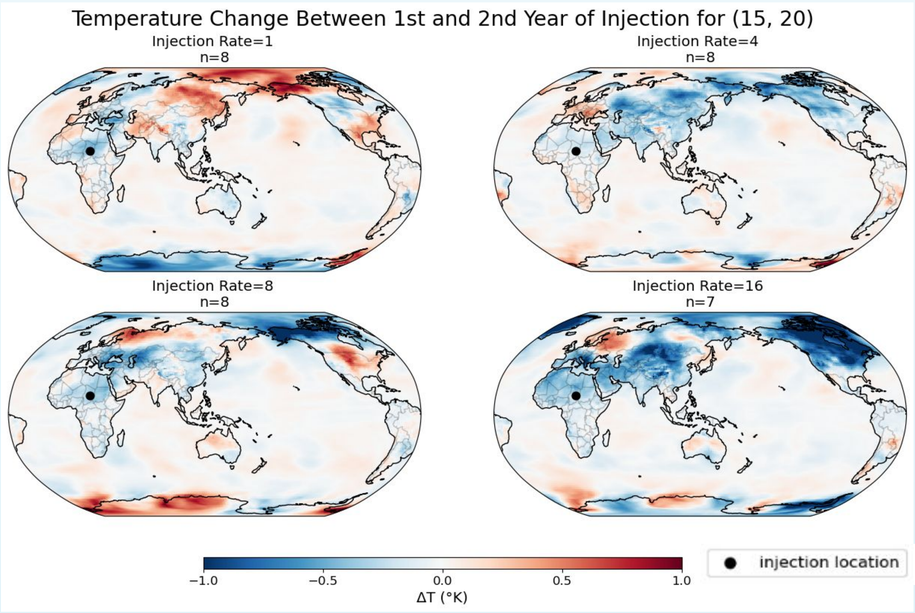


Figure 3. Each subplot shows the difference in temperature between the first and second years of injection for the location 15°, 20°, each at a different injection rate. 'n' shows the number of ensembles included in the ensemble mean.
Upper left: injection rate is 1 Tg of SO_2 /year.
Upper right: injection rate is 4 Tg of SO_2 /year.
Lower left: injection rate is 8 Tg of SO_2 /year.
Lower right: injection rate is 1 Tg of SO_2 /year

Conclusion

- Climate responses are apparent on the 2-year horizon
- Global mean temperature is dependent on latitude
  - 15N and 30N have the largest temperature response
- Less of a response in the Southern Hemisphere
  - Could be due to the prescribed data ocean
  - The ARISE simulations suggest that 15S is best latitude to inject[3,4]
- As the injection rate increases, the change in temperature becomes larger
- Injection rate and global mean temperature are linearly related
- Injection rate and total column ozone are nonlinearly related

Future Research

- Examine other variables such as precipitation, temperatures of other layers in atmosphere, etc. to search for nonlinearities in the short-term response
- Further characterize nonlinear ozone responses
- Complete a control simulation with the same model configuration and no SAI to calculate anomalies
- Complete additional experiments with a dynamic ocean to better quantify Southern Hemisphere responses to SAI

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References: 1. Hueholt et al. (2023) doi.org/10.1029/2023EF003488 **2.** Data from Climate Response After Stratospheric SULfAte injection (CRASSULA) simulations conducted by Charlotte Connolly, with final archive and publication in preparation. Direct inquiries to cconn@rams.colostate.edu. **3.** Fasullo & Richter (2023) doi.org/10.5194/acp-23-163-2023 **4.** Visioni et al. (2023) doi.org/10.5194/acp-23-663-2023