Can Crop Production be used as a Metric to Design Climate Intervention?

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Abstract

Stratospheric aerosol climate intervention (SAI) is a proposed scheme to counteract anthropogenic climate change. This could have impacts on crop production and food security due to changes in temperature, precipitation, humidity, total solar radiation, and diffuse radiation. To analyze impacts to maize, rice, soybean, and wheat production, we looked at output from fully coupled Earth system model simulations of CESM2-WACCM6 with CLM5crop active that simulated climate change and SAI scenarios. While SAI benefits global crop production, different nations would produce the most calories from crops under different temperature targets. This motivates the question of whether SAI could be used to control for crop production. Temperature is typically the metric used to calculate injections of stratospheric SO_2, using impact metrics such as regional crop production could help reduce potential suffering from SAI.

Introduction

Climate change is diminishing food production (Fugile, 2021; Kummu et al., 2021). With decreasing food production and increasing global population, studying proposed schemes to limit warming is increasingly important. One of the most researched methods to counteract anthropogenic warming is the use of stratospheric aerosol climate intervention (Crutzen, 2006). Continuous injections of SO_2 into the stratosphere would be designed to mimic volcanic eruptions. A feedback algorithm is used to maintain global mean, equator to pole, and interhemispheric temperature by injecting SO_2 at 30°N, 15°N, 0°N, 15°S, and 30°S. (Kravitz et al., 2017). These injections would impact global and regional crop production. This algorithm could potentially be used to control crop production metrics rather than temperature. A new controller algorithm may be able to modify several climate targets important for crops in addition to temperature.

Methods

This study used the fully coupled Earth system model CESM2-WACCM6 with CLM5crop (Lawrence et al., 2016) active to analyze climate intervention impacts on national crop production. Single point injections at individual latitude bands can help inform how to utilize the controller algorithm to control for crop production rather than temperature. All scenarios follow SSP2-4.5, a medium emissions future climate change scenario. The controller algorithm is then used to inject SO_2 in order to maintain global average temperatures of 1.5°C, 1.0°C, and 0.5°C above pre-industrial (MacMartin et al., 2022) (Richter et al., 2022). Additional scenarios follow SSP2-4.5 but inject 12 Tg-SO_2 per year at either 30°N, 15°N, 0°N, 15°S, or 30°S (Visioni et al., 2022). Offline CLM5crop was run to determine the individual climate contributions to total changes to crop production under SAI.

Results

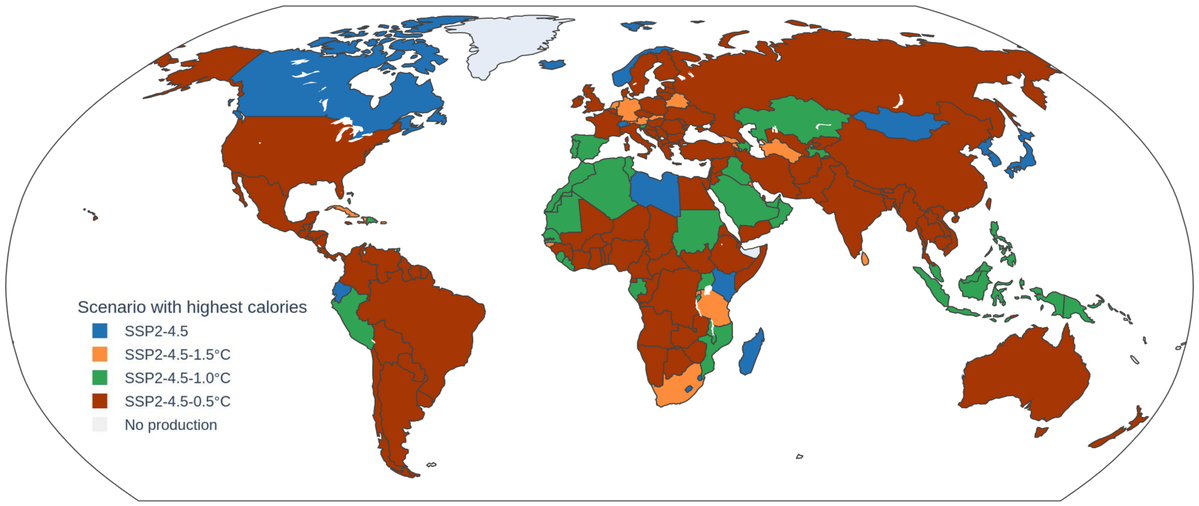

Figure 1. SSP2 scenario that produces the highest calories from total crop production (maize + rice + soybean + wheat) for each nation during the years 2060-2069 (Clark et al., 2022).

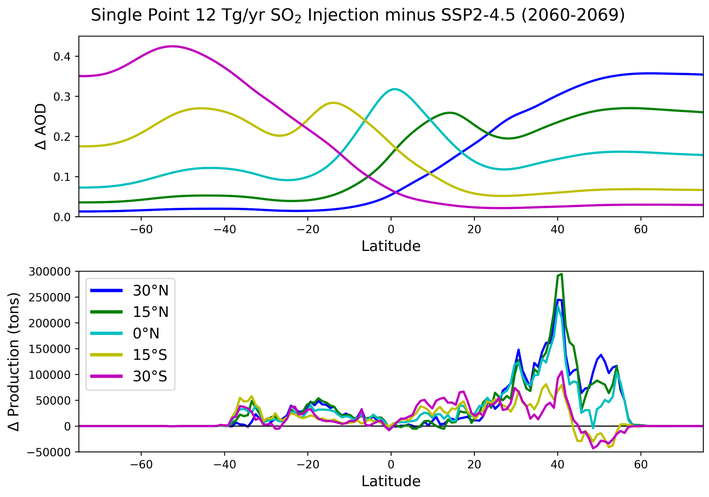

Figure 2. Change in AOD and total crop production with latitude under single point injections of SO_2 relative to SSP2-4.5.

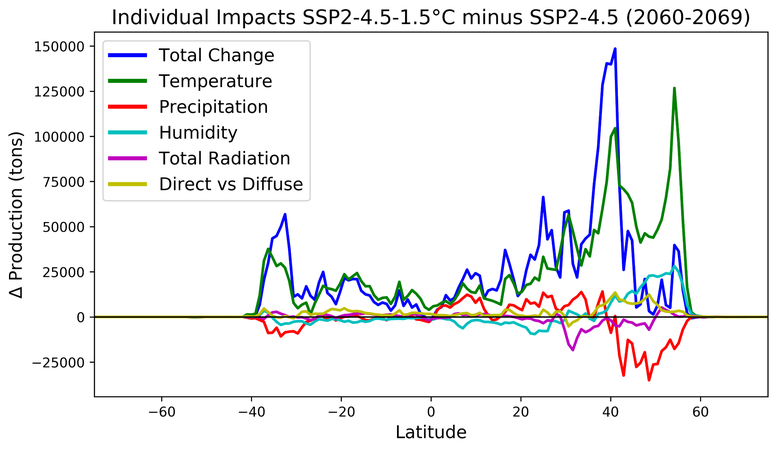

Figure 3. Changes to total crop production with latitude due to changing individual and total climate forcings from SAI relative to climate change.

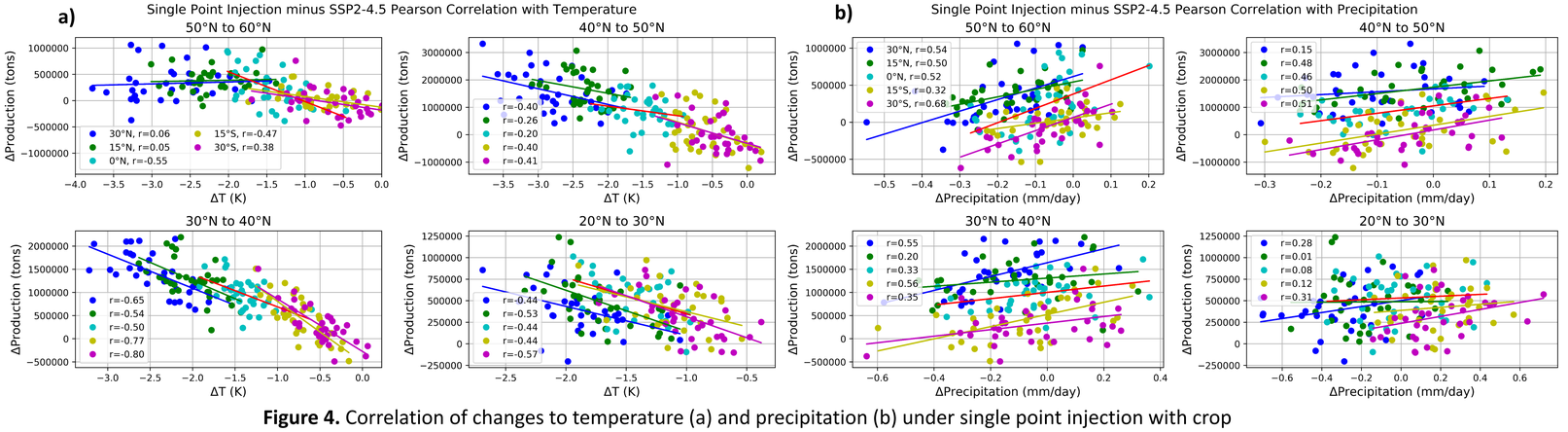

Figure 4. Correlation of changes to temperature (a) and precipitation (b) under single point injection with crop production for different latitude bands for years 2035 to 2069. Points represent changes to crop production and climate for individual years under single point injection relative to SSP2-4.5. Lines represent the linear regression of points.

Conclusion

Different nations would produce the most calories from crops under different SAI temperature targets. Total production is most correlated with temperature, but precipitation becomes important at certain latitude bands. SO_2 injection in the southern hemisphere causes decreases to midlatitude production due to precipitation changes.

Discussion

Current SAI injection algorithms use temperature metrics to inject SO_2 into the stratosphere every year. The ability to use other impact metrics instead of temperature to control injections could have more policy relevance and importance to individual nations. Crop production in CLM5crop is highly correlated with temperature. It is possible that current injection algorithms could be modified to control for crops instead of temperature. However, precipitation changes seem to cause decreases to production at midlatitudes, primarily from southern hemisphere SO_2 injection. Building a new controller to feed back on regional temperature and precipitation or removing injections in the southern hemisphere may be necessary. How crops respond to SAI will vary depending on the climate and crop model used.

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References

Clark, B., et al., 2022: The Optimal Climate Intervention Scenario for Crop Production Varies by Nation, *Nature Food*, under revision.

Crutzen, P., J., 2006: Albedo Enhancement by Stratospheric Sulfur Injections: A Contribution to Resolve a Policy Dilemma?, *Climate Change*, **77**, 211-219, doi.org/10.1007/s10584-006-9101-y

Fugile, P. 2021: Climate change upsets agriculture, *Nature Climate Change*, **11**, 293–299, doi.org/10.1038/s41558-021-01017-6

Kravitz, B., et al. First simulations of designing stratospheric sulfate aerosol geoengineering to meet multiple simultaneous climate objectives. Journal of Geophysical Research: Atmospheres, **122**, 12,616–12,634, doi:10.1002/2017JD026874, 2017.

Kummu, M., et al., 2021: Climate change risks pushing one-third of global food production outside the safe climatic space. *One Earth*, **4**, 720–729, doi.org/10.1016/j.oneear.2021.04.017

Lawrence, D. M., et al., 2019: The Community Land Model version 5: Description of new features, benchmarking, and impact of forcing uncertainty. *Journal of Advances in Modeling Earth Systems,* **11**, 4245– 4287, doi:10.1029/2018MS001583.

MacMartin, D., et al., 2022: Scenarios for modeling solar radiation Modification, *PNAS,* doi.org/10.1073/pnas-2022

Richter, J., et al., 2022: Assessing Responses and Impacts of Solar climate intervention on the Earth system with stratospheric aerosol injection (ARISE-SAI), *EGUsphere,* doi.org/10.5194/egusphere-2022-125

Visioni, D., et al., 2022: Climate response to off-equatorial stratospheric sulfur injections in three Earth System Models - Part 1: experimental protocols and surface changes. *EGUsphere* , doi.org/10.5194/egusphere-2022-401.