Impacts to Crop Production from Stratospheric Aerosol Climate Intervention: A Multi-Scenario Overview

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Abstract

Stratospheric aerosol climate intervention 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 spring wheat production, we looked at output from fully coupled Earth system model simulations of CESM2-WACCM6 with CLM5crop active that simulated climate change and solar radiation modification scenarios. Our results show that climate intervention to limit anthropogenic warming while maintaining elevated CO_2 increases global production by 11-25% for maize, 7-13% for rice, 20-41% for soybean, and 10-24% for spring wheat by the decade 2060-2069, depending on scenario. This response is dominated by temperature reduction and is not uniform. Although global crop production increases, there is a decrease to production for several top producing countries of each crop under each climate intervention scenario. Further work is needed to update the model with impacts from ultraviolet radiation and ozone damage on crops, and analysis using multiple global climate models and crop models could reduce uncertainties.

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 for intentionally manipulating the climate system 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. This technique can also be represented by simply reducing incoming solar radiation, also called solar dimming.

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 crop production under scenarios:

- **SSP2-4.5**
- SSP2-4.5-1.5°C
- SSP2-4.5-1.0°C
- SSP2-4.5-0.5°C
- **SSP5-3.4-OS**
- SSP5-3.4-1.5°C
- SSP5-3.4-2.0°C
- **SSP5-8.5**
- SSP5-8.5-1.5°C
- G6Sulfur
- G6Solar

SSP2-4.5, SSP5-3.4-OS, and SPP5-8.5 are future climate change scenarios with accompanying scenarios limiting anthropogenic warming to 0.5, 1.0, 1.5, or 2.0 °C above preindustrial levels using stratospheric aerosol climate intervention. Scenarios following SSP5-3.4-OS and SSP5-8.5 limit global mean warming to both targets set by the IPCC of 1.5 and 2.0 °C above preindustrial levels (Tilmes et al., 2020). The scenario SSP2-4.5-1.5°C is named "Assessing Responses and Impacts of Solar climate intervention on the Earth system (ARISE)" and was conducted by the National Center for Atmospheric Research and funded by SilverLining (Richter et al., 2022). SSP2-4.5-1.0°C and SSP2-4.5-0.5°C reduce global mean temperature increase to 0.5 and 1.0 °C above preindustrial levels, below the warming targets set by the IPCC (MacMartin et al., 2022). G6Sulfur uses SO_2 injections to bring global mean temperatures from the high emissions climate change scenario SSP5-8.5 down to medium emissions scenario SSP2-4.5, and G6Solar uses solar dimming to achieve the same temperature reduction (Visioni et al., 2021). The G6 scenarios were run as part of the Geoengineering Model Intercomparison Project Phase 6 (Kravitz et al., 2015). CO_2 concentrations are consistent across reference climate change scenarios. Production calculations for all scenarios use constant cropping area from the year 2000.

Results

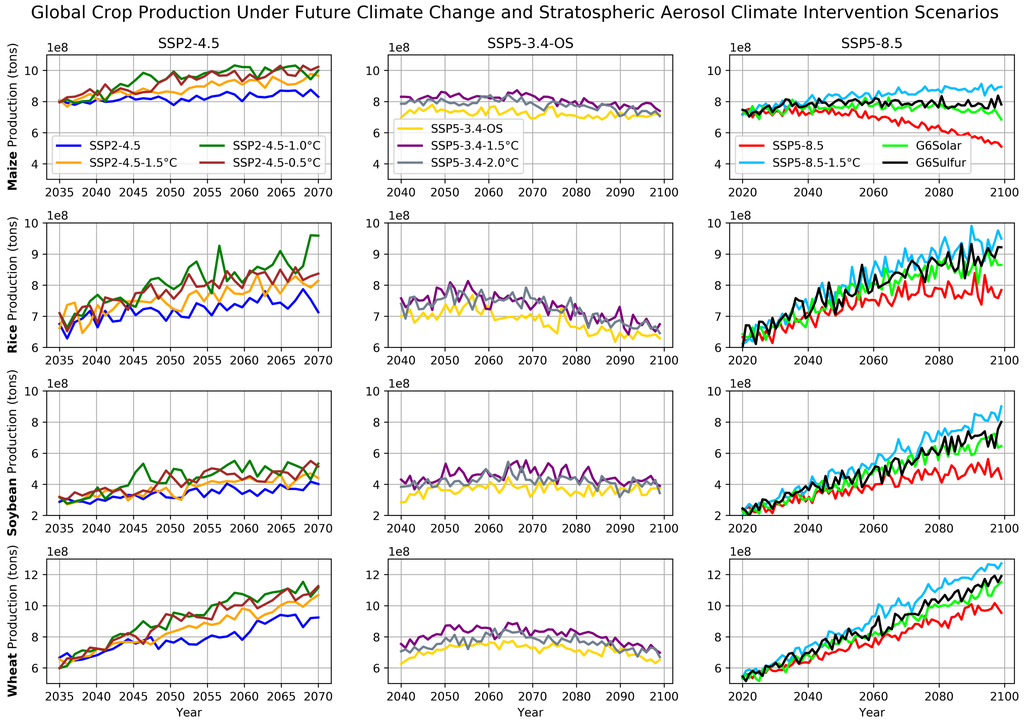

Figure 1. Time series of global maize, rice, soybean, and spring wheat production (in units of 100 million tons) under climate change and climate intervention scenarios.

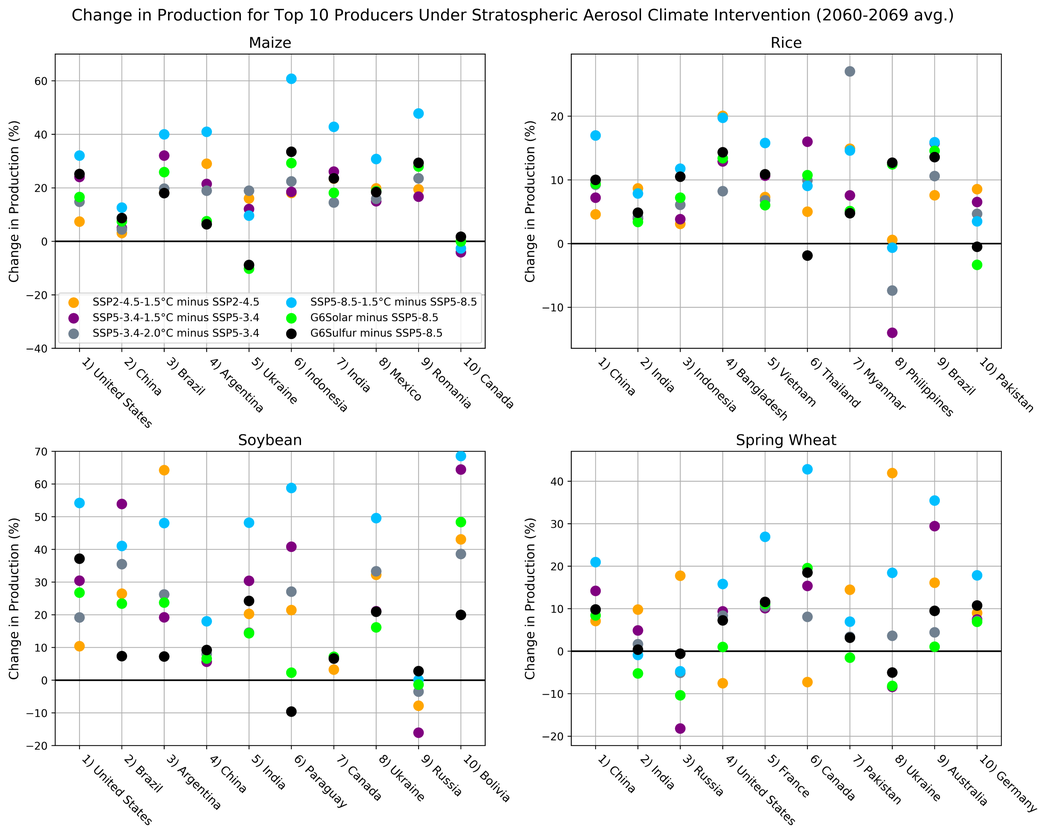

Figure 2. Percent change to maize, rice, soybean, and spring wheat production for the top 10 producers of each respective crop (2060-2069 average) under different climate intervention scenarios.

Results Continued

Offline CLM5crop runs forced with atmospheric data from the coupled SSP2-4.5 and SSP2-4.5-1.5°C runs were used to understand how changes to specific climate variables under stratospheric aerosol climate intervention impact crop production (Fig. 3).

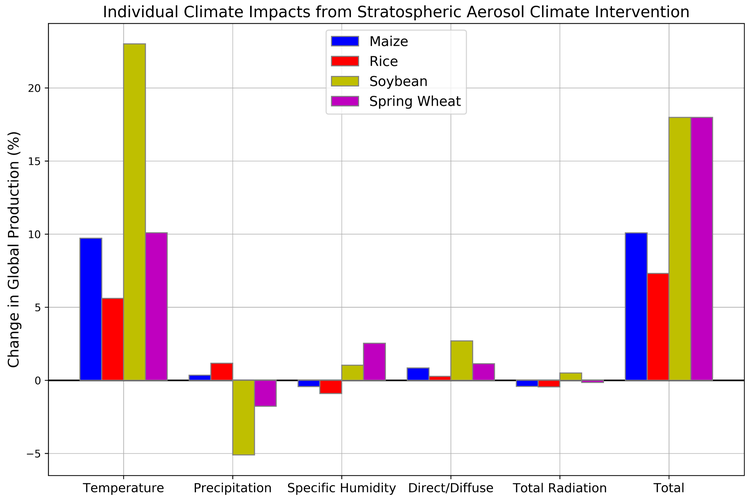

Figure 3. Individual contributions to global crop production changes under stratospheric aerosol climate intervention (SSP2-4.5-1.5°C minus SSP2-4.5, 2060-2069 average) for maize, rice, soybean, and spring wheat.

Discussion and Conclusions

Climate intervention to limit anthropogenic warming while maintaining elevated CO_2 increases global production of maize, rice, soybean, and spring wheat. Although total crop production increases, there is a decrease to production for several top producing countries of each crop under each climate intervention scenario. Temperature reduction dominates this impact to crop production. Further work is needed to update the model with impacts from ultraviolet radiation and ozone damage on crops, and analysis using multiple climate and crop models could reduce uncertainties.

Acknowledgments: This work was supported by NSF grant AGS-2017113 and SilverLining. Calculations were done on the National Center for Atmospheric Research computer system, which is supported by NSF. We thank Simone Tilmes, Jadwiga Richter, and Daniele Visioni for supplying climate model output.

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