Impacts on Crop Production from Stratospheric Aerosol Injection

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Brendan Clark, Lili Xia, and Alan Robock

Department of Environmental Sciences, Rutgers University, New Brunswick, NJ (bjc204@rutgers.edu)

Stratospheric aerosol injection (SAI) is a proposed method to counteract anthropogenic climate change. This could have impacts on crop production and food security due to changes in temperature, precipitation, total solar radiation, and diffuse radiation. To analyze impacts to maize, rice, soybean, and spring wheat production, we analyzed fully coupled Earth System Model simulations performed by National Center for Atmospheric Research scientists that implement SAI to limit global warming to 1.5°C above pre-industrial (1850-1900) levels. Results show that average global crop production benefits from global cooling compared to SSP2-4.5 from years 2060-2069. This benefit is not uniform. Some countries show increased production of up to 100% for certain crops, while other major producers show decreases of up to 12%. Offline runs of CLM5crop were conducted to test for crop sensitivities to changes in certain climate variables. Results show that offline CLM5crop runs have large differences in all crop yields compared to coupled runs for the same time period and climate. Further work is needed to understand why these runs show different results, and caution should be taken when conducting offline CLM5crop simulations for impact studies in the future.

Stratospheric Aerosol Injection and Climate Change Scenarios:

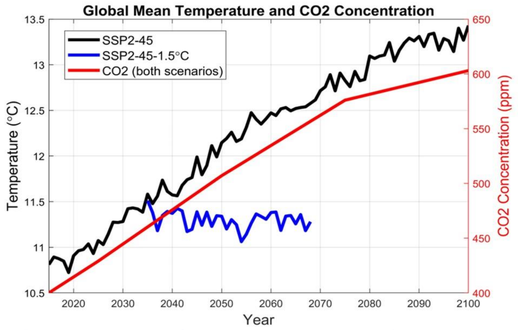

Figure 1. 2 m surface air temperature and CO_2 concentration (ppm) for SSP2-4.5 and SSP2-4.5-1.5°C.

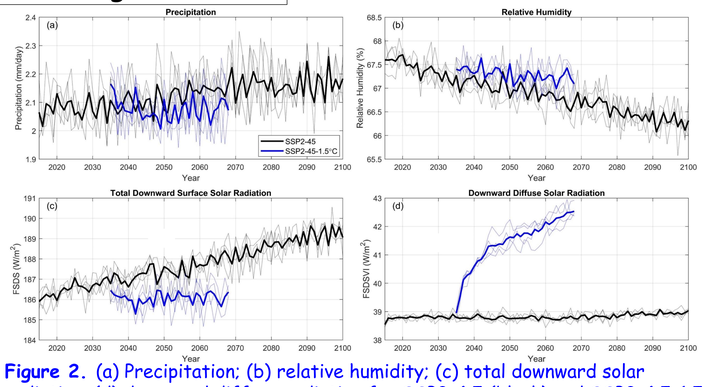

Figure 2. (a) Precipitation; (b) relative humidity; (c) total downward solar radiation; (d) downward diffuse radiation for SSP2-4.5 (black) and SSP2-4.5-1.5°C (blue) five ensemble members (thin lines) and ensemble average (thick lines).

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 discussed and researched methods for intentionally manipulating the climate system to counteract anthropogenic warming is the use of stratospheric aerosol injection (SAI; Crutzen, 2006). Continuous injections of SO_2 into the stratosphere would be designed to mimic volcanic eruptions (Robock et al., 2008).

This study used the fully coupled Earth system model CESM2 with CLM5crop (Lawrence et al., 2016) active to analyze SAI impacts on crop production under scenarios SSP2-4.5 and SSP2-4.5-1.5°C (with stratospheric SO_2 injections to limit global mean, pole-to-equator, and interhemispheric temperature changes). Decreases to precipitation, increases to relative humidity, decreased total solar radiation, and increased diffuse radiation, as well as increasing CO_2 (Figs. 1 and 2), would all impact global crop production (Figs. 3-4). Offline CLM5crop runs forced with atmospheric data from the coupled runs were used to understand how changes to specific climate variables impact crop production (Figs. 5), but there are some still unexplained differences between the online and offline results.

Impacts on Crop Production:

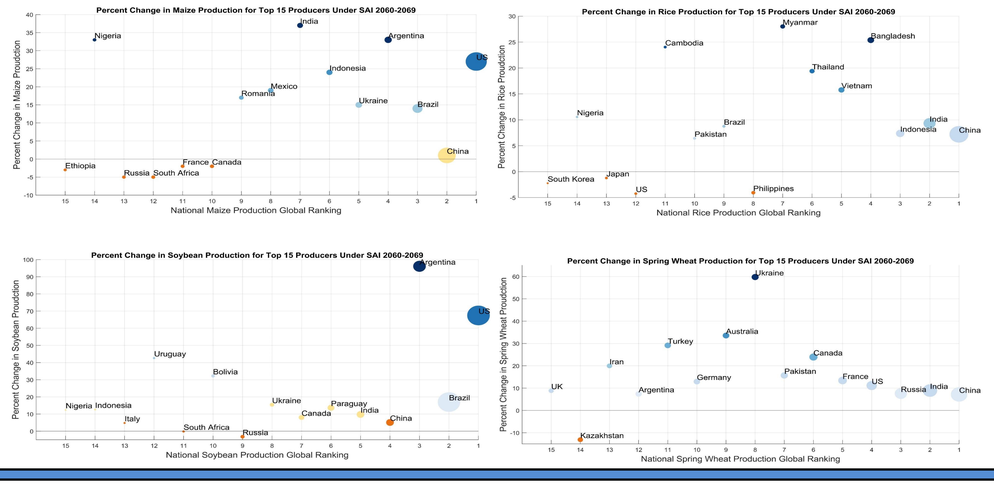

Figure 3. Percent change in crop production for top 15 producers for maize, rice, soybean, and spring wheat under SSP2-4.5-1.5°C from 2060-2069 compared to SSP2-4.5. Circle sizes represent magnitude of production and colors correspond to relative increase or decrease in production. Production information was obtained from the Food and Agriculture Organization of the United Nations (FAO, 2021).

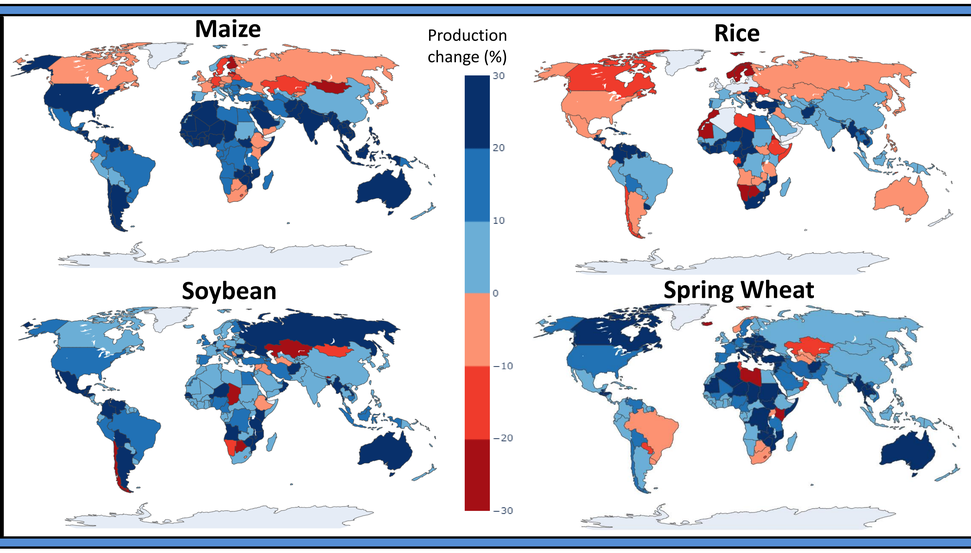

Figure 4. Maps of crop production percent change for individual countries under SSP2-4.5-1.5°C compared to SSP2-4.5 from 2060-2069 for maize, rice, soybean, and spring wheat. Grid cell changes were aggregated to country level using Food and Agriculture Organization of the United Nations data (FAO, 2021).

Offline CLM5crop preliminary results:

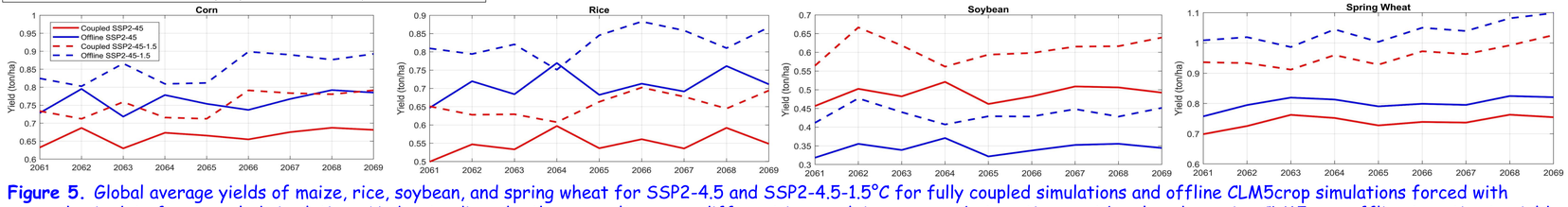

Figure 5. Global average yields of maize, rice, soybean, and spring wheat for SSP2-4.5 and SSP2-4.5-1.5°C for fully coupled simulations and offline CLM5crop simulations forced with atmospheric data from coupled simulations. Understanding why these results are so different is a work in progress, but caution must be placed on using CLM5crop offline to estimate yield changes for impact studies in the future.

Conclusions:

- SAI to limit warming to 1.5°C under SSP2-4.5 would benefit global crop production but would vary by country, with some countries increasing production by nearly 100% for some crops, and some countries showing reductions of up to 30%.
- Further work is needed to understand why offline and online CLM5crop simulations differ in representing crop yields.

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