Influence of Climate Change on Inter-annual Variation of $PM_{2.5}$ and Ozone

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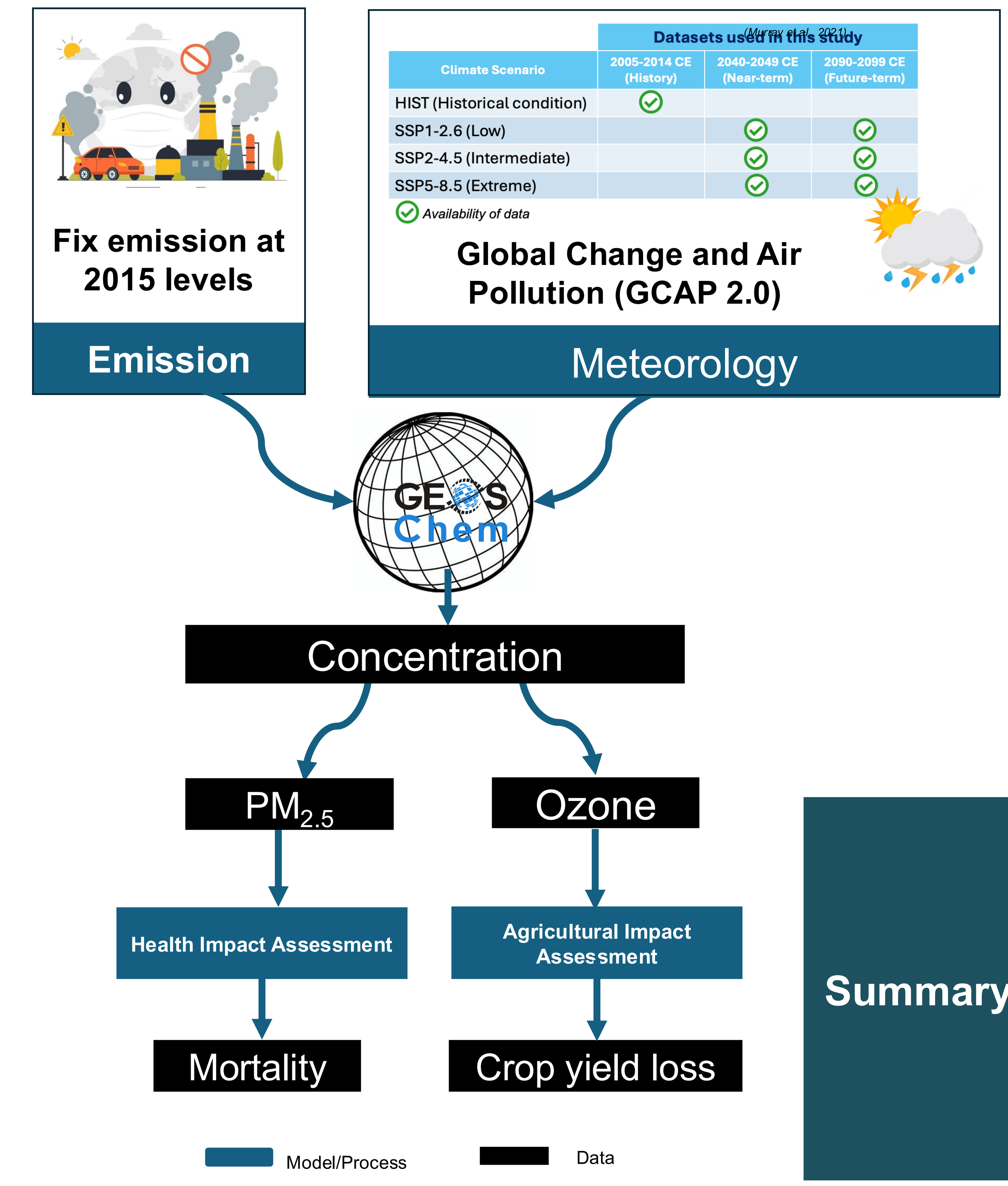
Introduction

- **Climate change** alters meteorological conditions (e.g., temperature, precipitation, & humidity) that influence **air pollution** levels.
- This study examines **how climate-driven changes alone affect future surface $PM_{2.5}$ and O_3** concentrations across different warming scenarios.
- We focus on **inter-annual variability** and regional differences, offering a global assessment.
- The results highlight the importance of considering climate impacts in air quality related **health risk and crop production** projections and implications.

Objective:

This study aims to quantify the impacts of climate-driven meteorological changes on surface $PM_{2.5}$ and O_3 concentrations and assess their implications for air quality–related mortality and crop yield loss.

Method



Datasets used in this study (Murray et al., 2021)

Climate Scenario	2005-2014 CE (History)	2040-2049 CE (Near-term)	2090-2099 CE (Future-term)
HIST (Historical condition)	✓		
SSP1-2.6 (Low)		✓	✓
SSP2-4.5 (Intermediate)		✓	✓
SSP5-8.5 (Extreme)		✓	✓

✓ *Availability of data*

Results & Discussion

Climate-driven changes on Global Air Quality

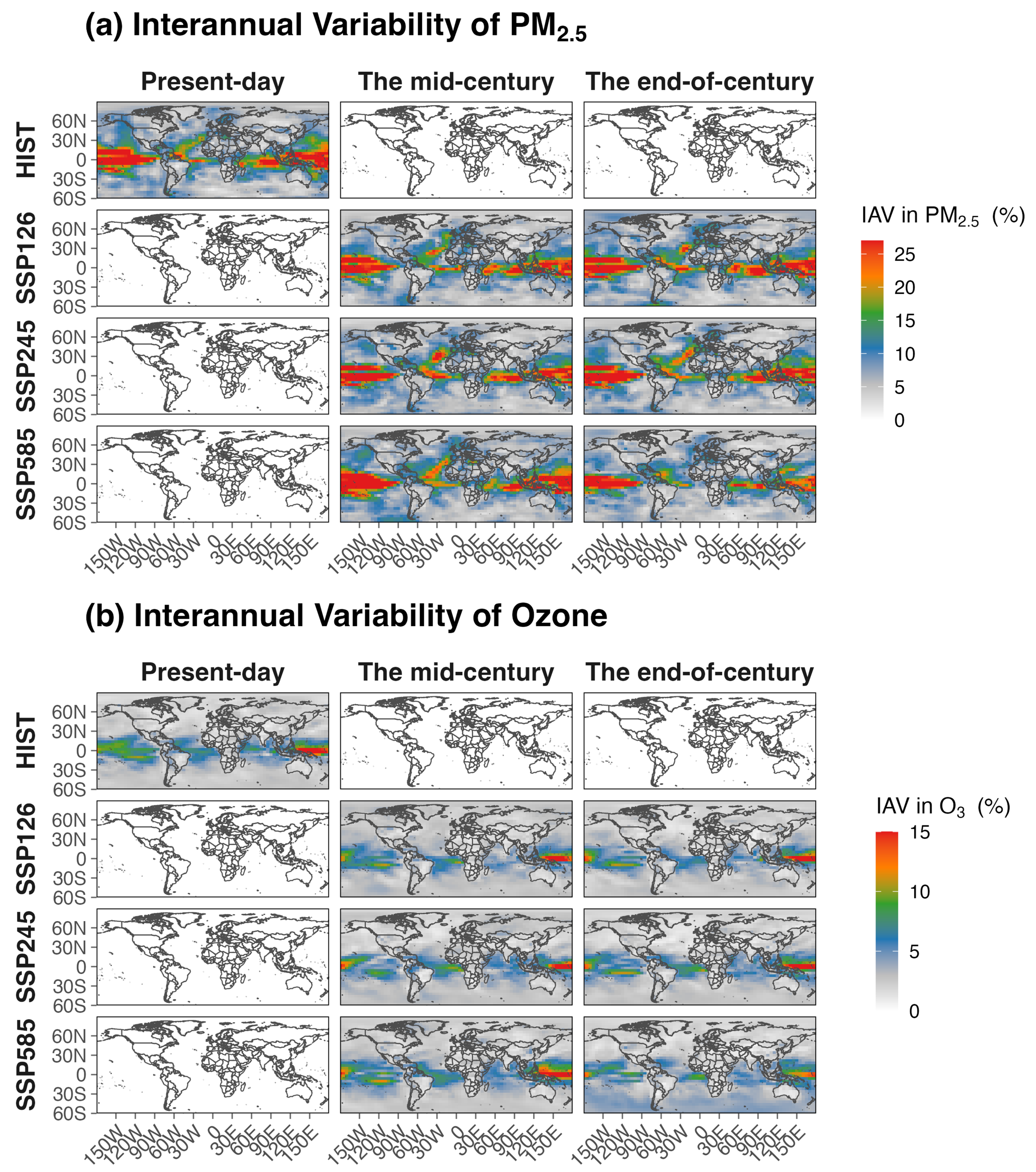


Fig.1 Spatial distribution of the inter-annual variability (%) of $PM_{2.5}$ (a) and Ozone (b).

- ❖ Regions with high IAV may experience more frequent extreme pollution years.
- ❖ These findings emphasize the importance of accounting for climate-induced variability in air quality planning, especially in vulnerable regions such as South Asia, Africa, and the tropics, where both pollutant levels and IAV are projected to increase.

To capture the climate change signal on surface $PM_{2.5}$ and Ozone over both oceanic and land-based regions, I applied a grid-point regression analysis to derive the spatial patterns of regression coefficients representing the sensitivity of changes in $PM_{2.5}$ ($\Delta PM_{2.5}$) and Ozone (ΔO_3) to climate driven changes

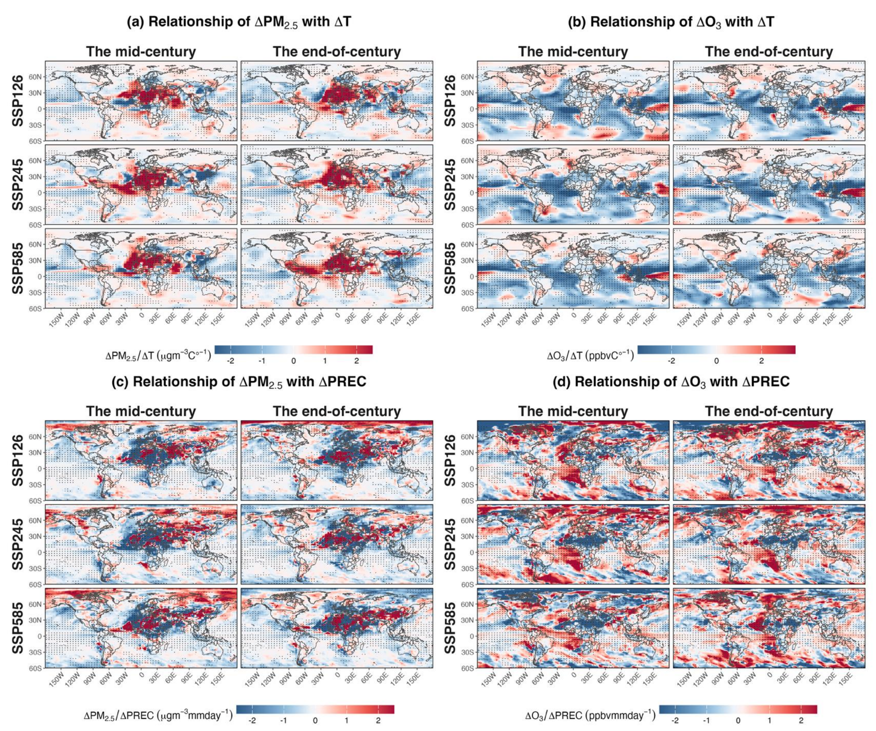


Fig.2 Spatial distribution of the regression coefficients representing the sensitivity of $PM_{2.5}$ ($\Delta PM_{2.5}$) and ozone (ΔO_3) concentrations to changes in surface temperature (ΔT) and precipitation ($\Delta PREC$). Dots indicate grid cells where the relationships are statistically significant (p-value < 0.05) with respect to interannual variability.

Global Perspectives on Impact Assessments

Mortality due to $PM_{2.5}$

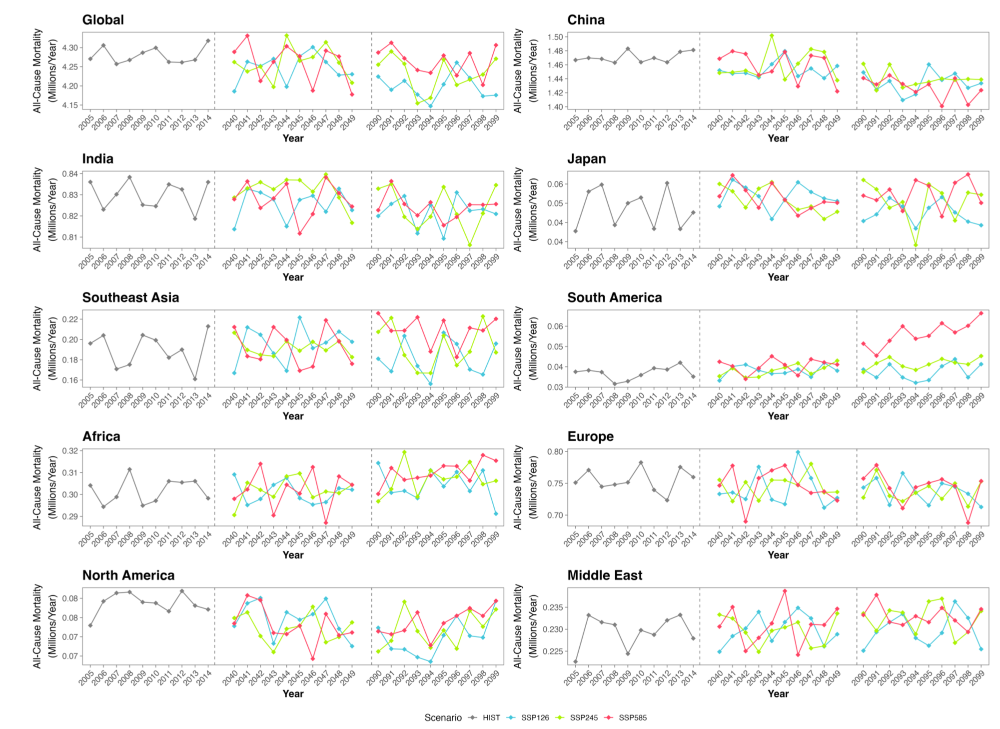


Fig.3 Annual mean of all-cause mortality in all age ranges under different climate scenarios during present-day (2005-2014), mid-century (2040-2049), and end of century (2090-2099)

Global perspective

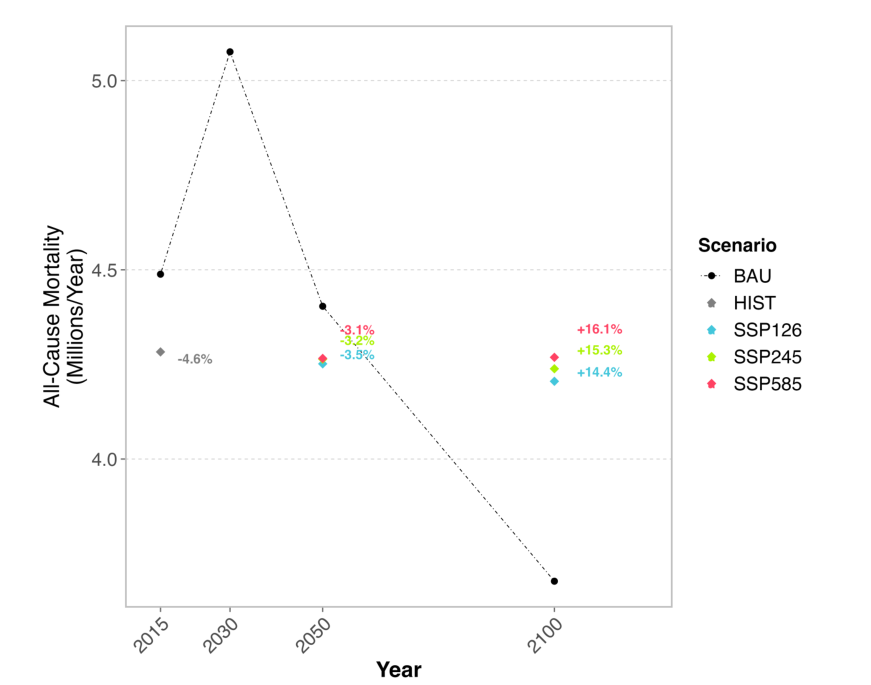


Fig.4 Comparison of mortality projections between climate-driven changes (this study) and emission-driven change (SSP2_BaU_NoCC). The percentage indicate relative changes to BAU.

Crop Yield Loss due to O_3

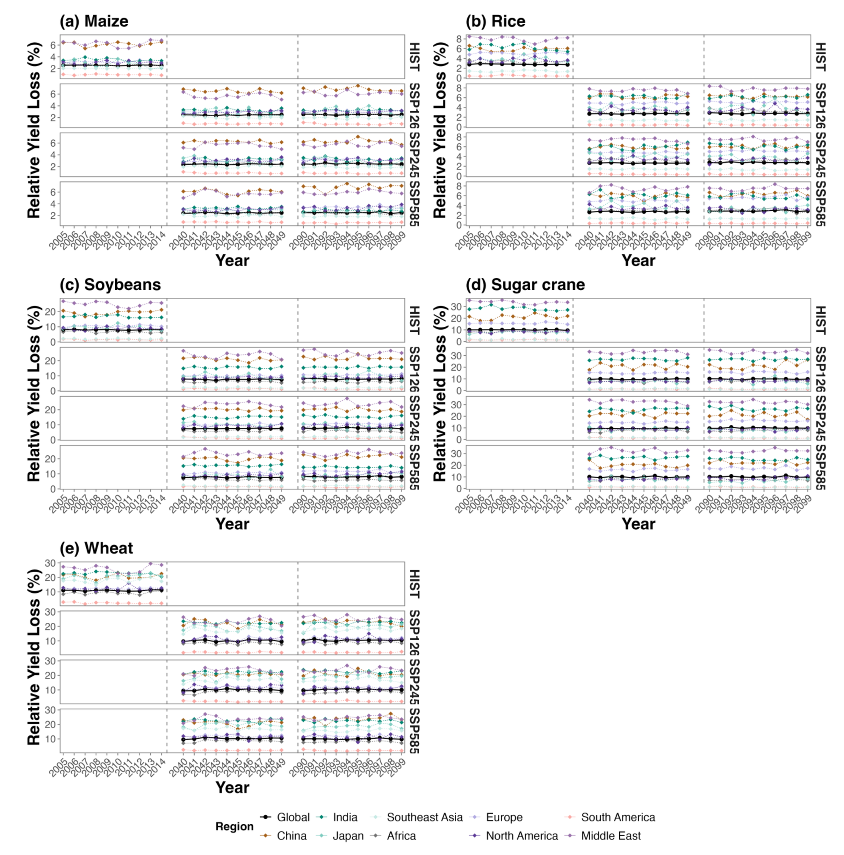


Fig.5 Annual mean of crop yield loss (%) ranges under different climate scenarios during present-day (2005-2014), mid-century (2040-2049), and end of century (2090-2099).

Global perspective

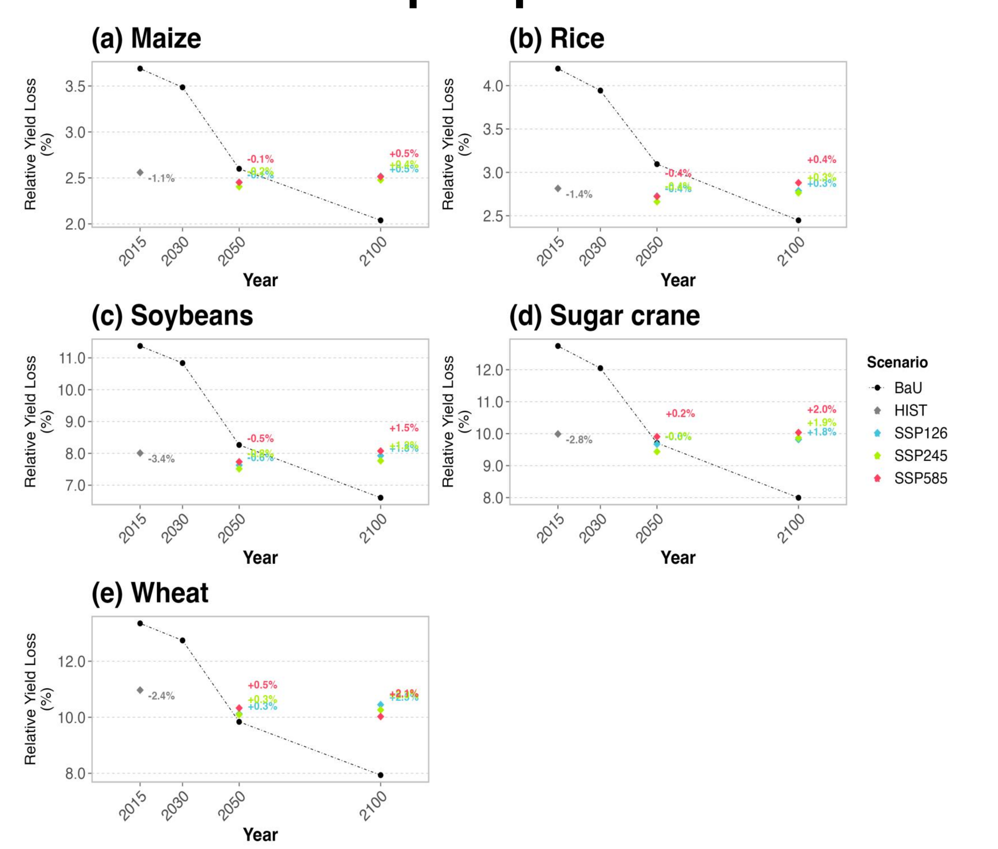


Fig.6 Comparison of crop yield loss projections between climate-driven changes (this study) and emission-driven change (SSP2_BaU_NoCC). The percentage indicate relative changes to BAU.

Health impacts:
Air pollution–related mortality increases by +16.1% under SSP5-8.5 by 2100, with high interannual variability in tropical and densely populated regions. Climate-driven meteorological changes amplify pollution-related health risks despite fixed emissions.

Agricultural impacts:
Major crops such as wheat, rice, and maize face rising yield losses, especially in tropical regions. Under SSP5-8.5, wheat loss reaches +11%, highlighting the need to integrate climate variability into food security strategies.

Summary

- ➢ We assess interannual variability (IAV) of $PM_{2.5}$ and Ozone under future climate-driven meteorology using GEOS-Chem with fixed emissions.
- ➢ High IAV emerges across tropical agricultural regions, particularly in South Asia, Africa, and South America.
- ➢ By 2100 under SSP5-8.5, enhanced variability may exacerbate crop exposure to air pollution extremes.
- ➢ These results highlight the need to integrate climate variability into crop yield and food security assessments.

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