Simulated fire aerosol-climate interactions drive hemispherically asymmetric climate responses and reduce global climate variability

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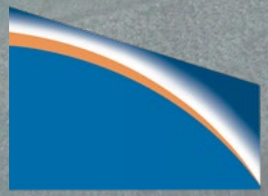
CESM Workshop 2025, Boulder, Colorado

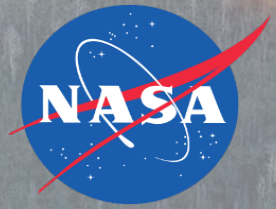
June 10, 2025

CU Boulder Department of Atmospheric and Oceanic Sciences (ATOC)[1]

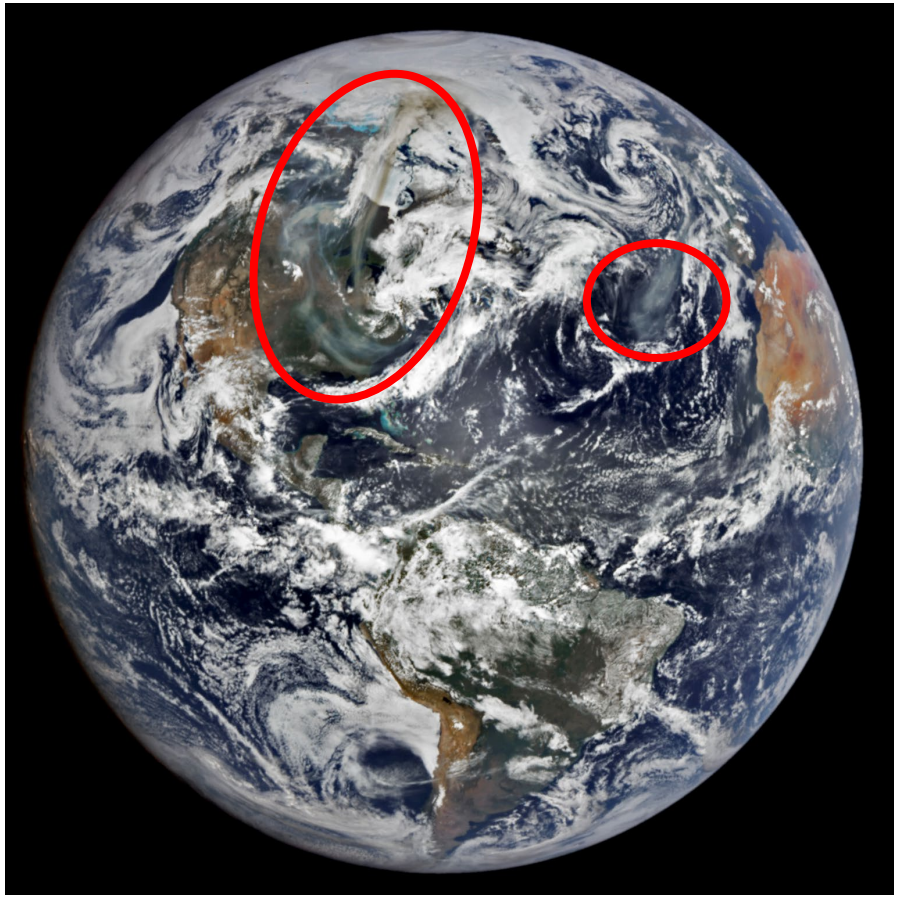
National Center for Atmospheric Research (NCAR)[2]



NCAR



2025 Canadian fire smoke extends across the globe



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Earth

Canadian wildfire smoke blankets huge swath of North America

Posted by Rachel Duensing | June 4, 2025

Hazy sky to persist as Canadian wildfire smoke and Saharan dust invade US

More smoke and dust are ahead for the northern, eastern and southern states into mid-June, as AccuWeather meteorologists continue to track Canadian wildfires and dust sweeping in from Africa.

By Bill Deger, AccuWeather senior meteorologist

Published Jun 5, 2025 9:10 AM MDT | Updated Jun 8, 2025 1:12 PM MDT

Canadian wildfire smoke blows over to Europe

First plumes reached Mediterranean on May 18, with more arriving this week

Emily Chung · CBC News · Posted: Jun 03, 2025 11:10 AM MDT | Last Updated: June 4

NOAA DISCOVR (May 31, 2025)

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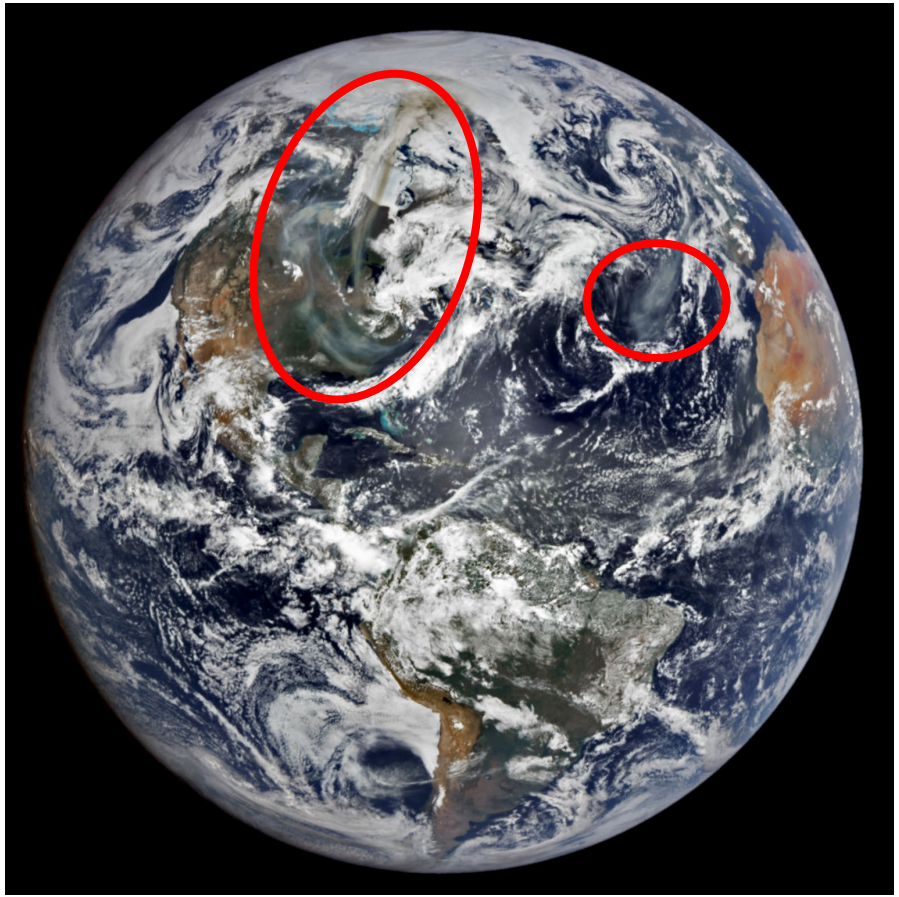
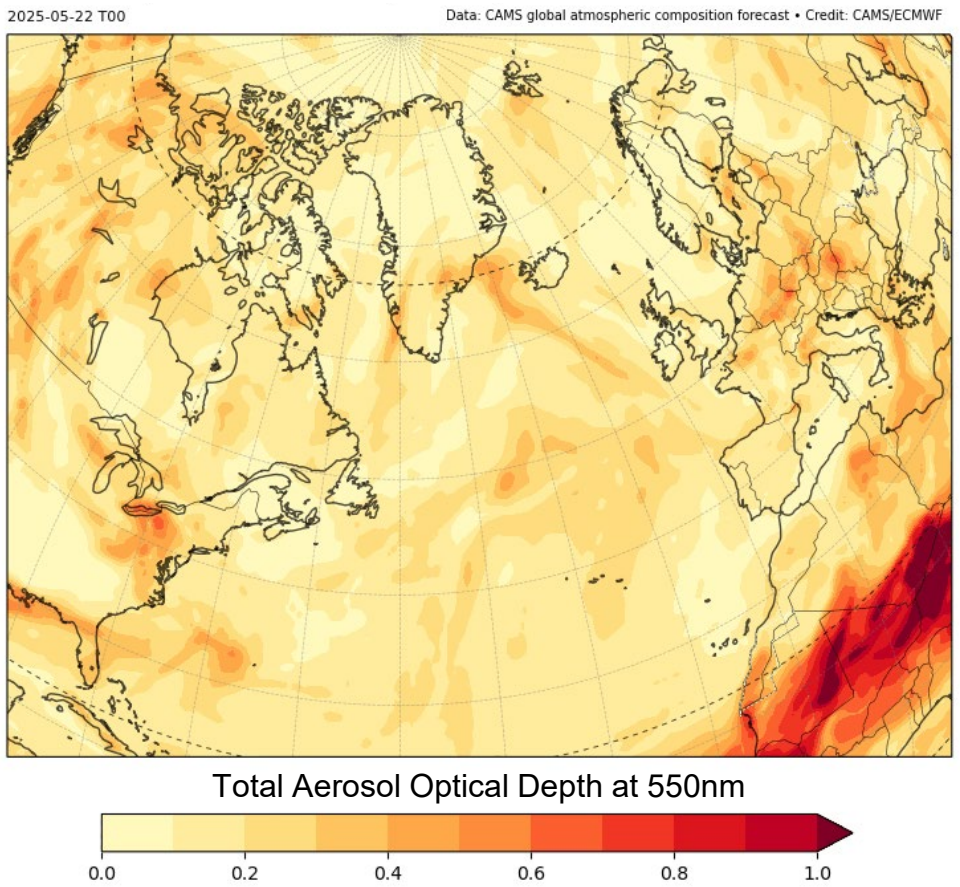
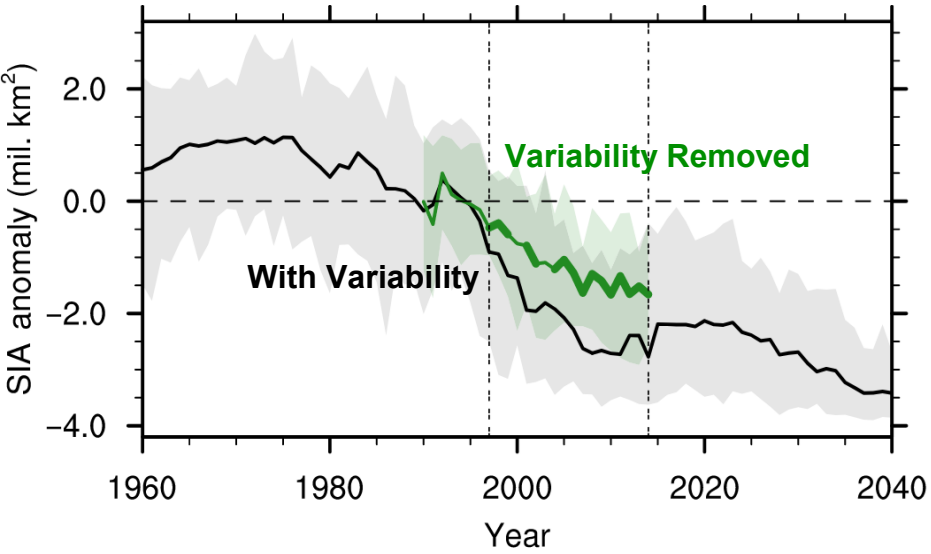




NOAA DISCOVR (May 31, 2025)

Fire emissions can be important drivers of present-day climate change



DeRepentigny et al. 2022 (Modified)

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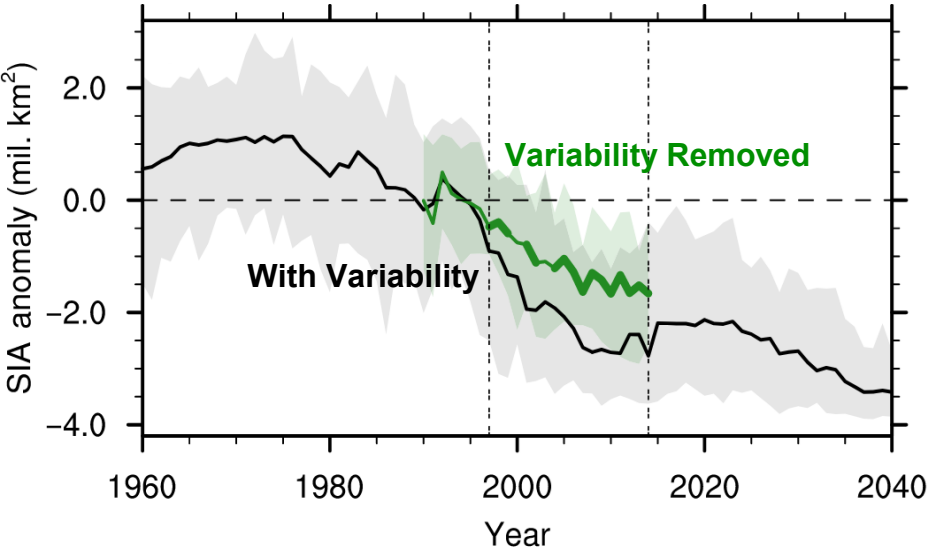
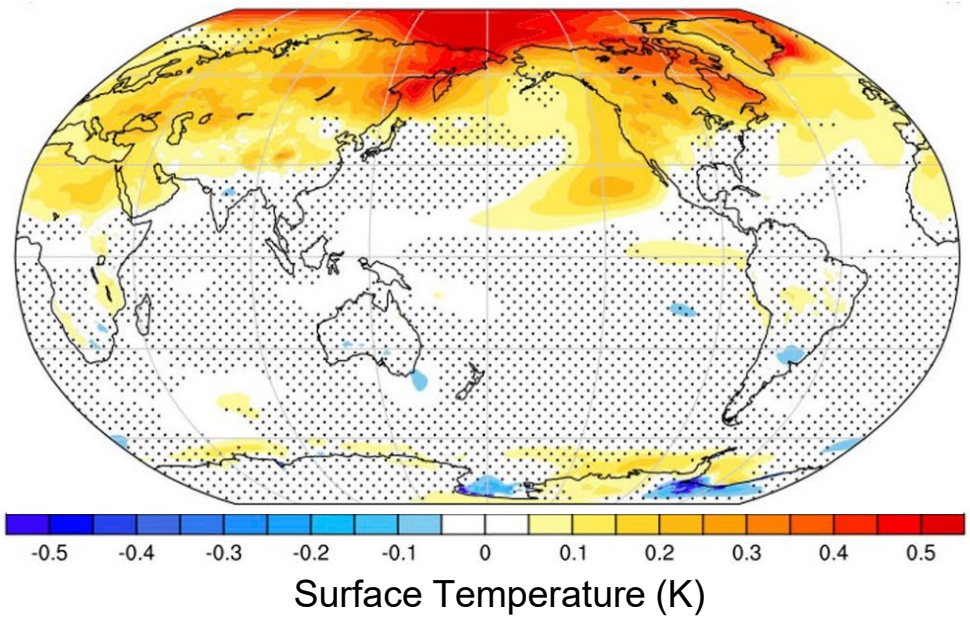


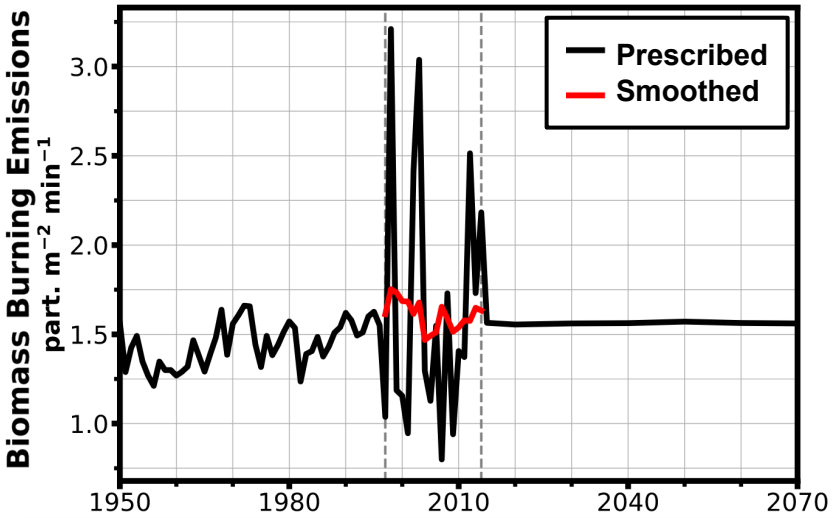


DeRepentigny et al. 2022 (Modified)

Fasullo et al. 2022

Yet the climate impacts due to fire emissions remain uncertain

Newest generation of climate models have discontinuities in prescribed fire emissions



Heyblom et al. 2023 (Modified)

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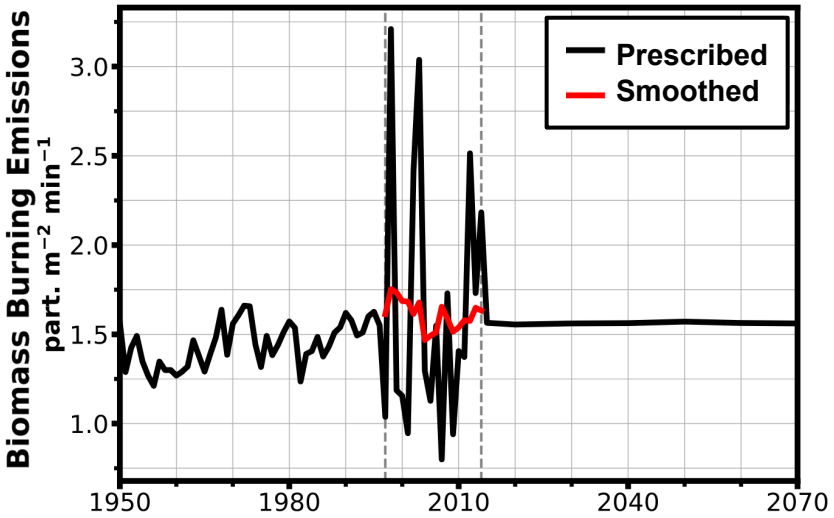

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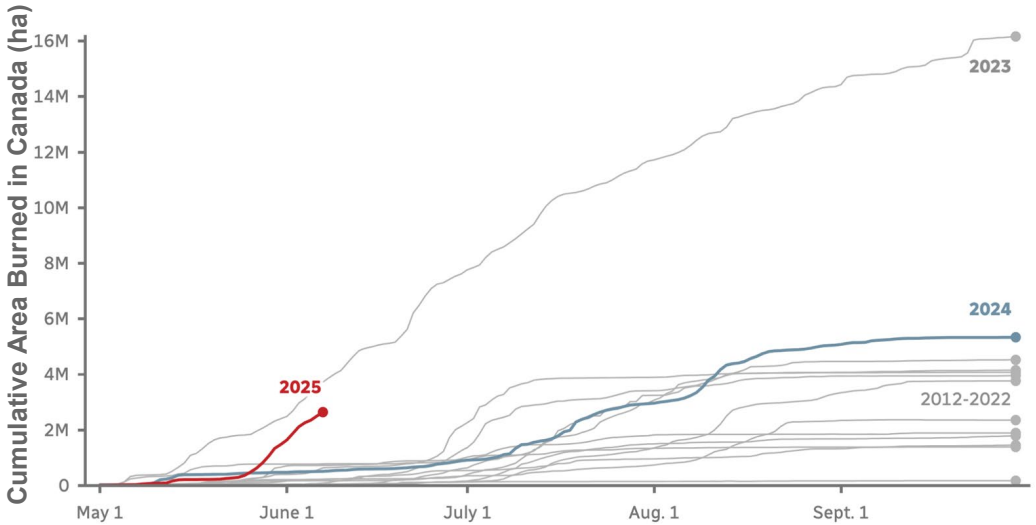
Prescribed fire emissions do not match the climate state they occur in



Canadian Wildland Fire Information System (Modified)

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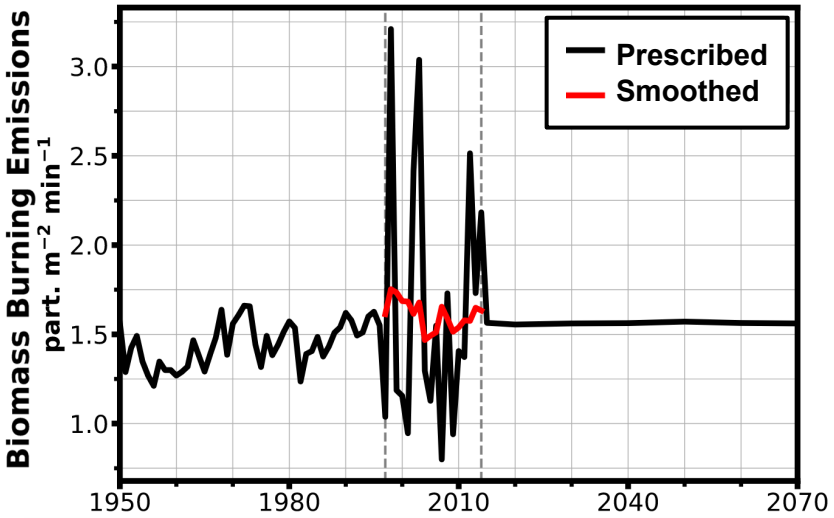

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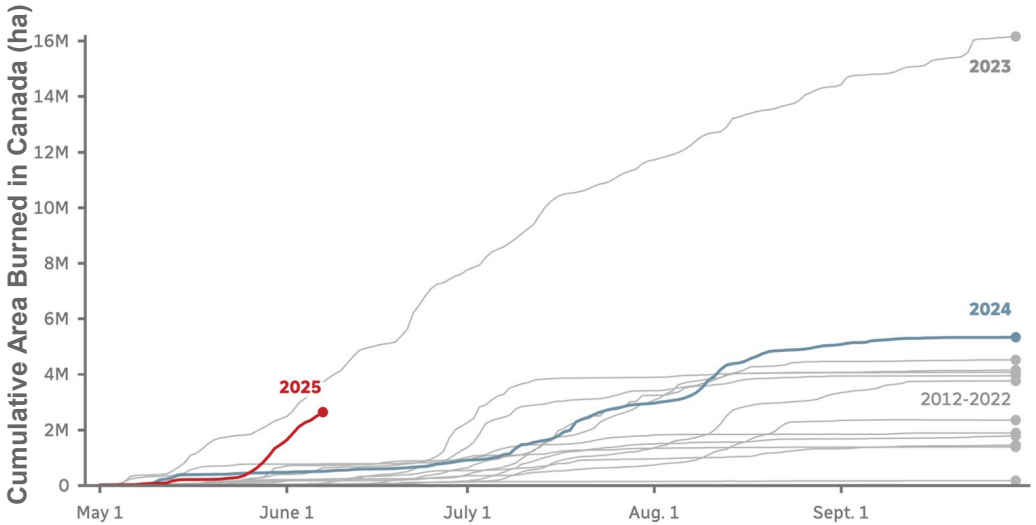


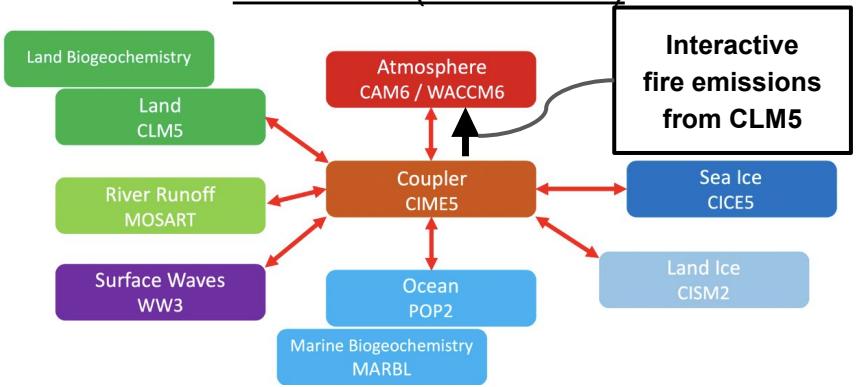
How would a more realistic evolution of fire emissions affect the climate?
What is the long-term climate response to fires?
Do fire-climate feedbacks significantly change over time?
How important are fire emissions to regional and global climate change?

Heyblom et al. 2023 (Modified)

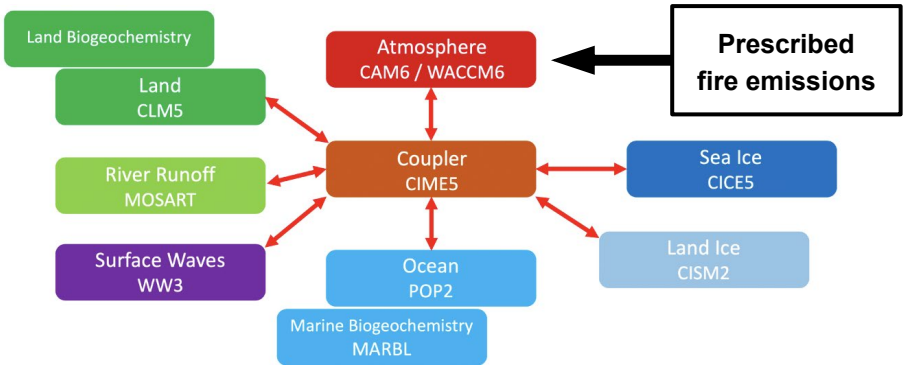
Canadian Wildland Fire Information System (Modified)

The Community Earth System Model version 2 (CESM2)

New CESM2 Simulations with Interactive Fire Emissions (5 members)



CESM2 Large Ensemble (50 members)



Danabasoglu et al. 2020 (Modified)

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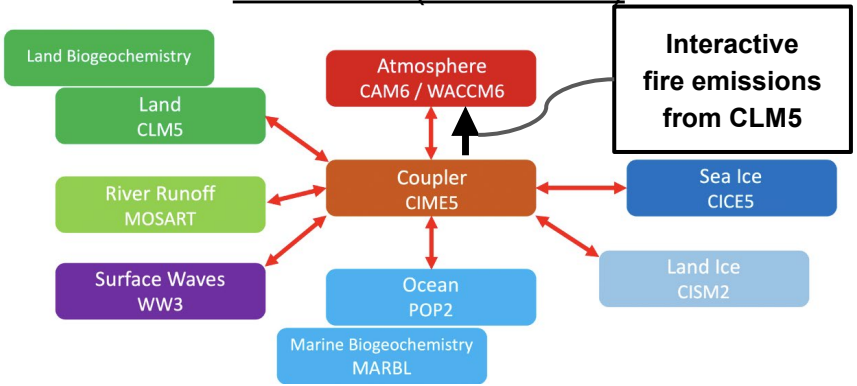

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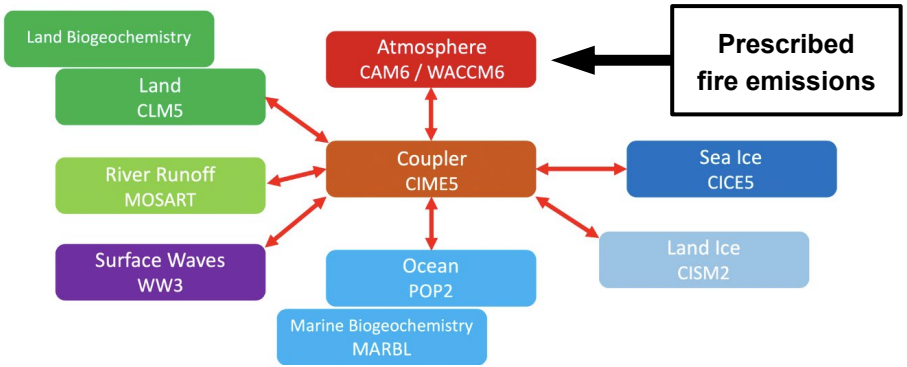


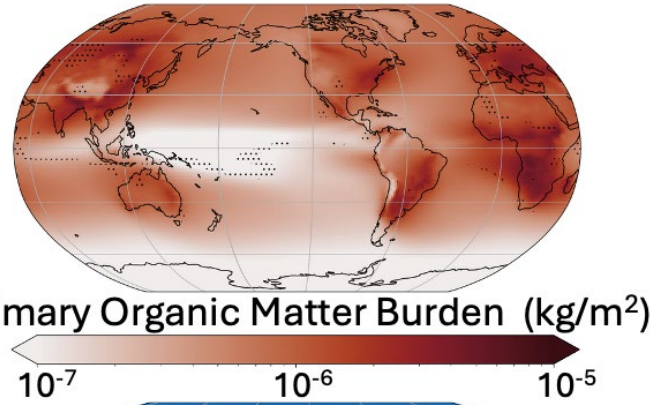
Main Research Questions

What are the impacts of interactive fire on the mean state, variability, and trends under climate change?

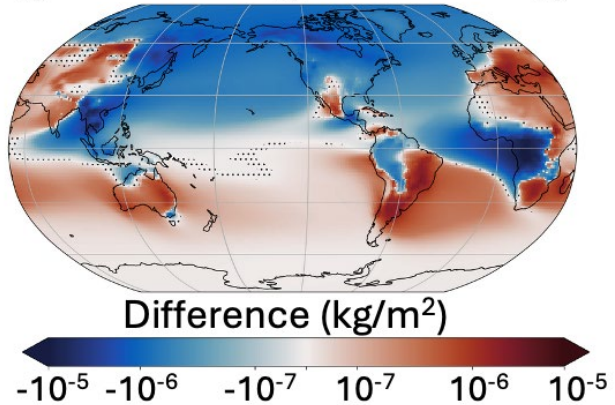
Danabasoglu et al. 2020 (Modified)

The change in fire aerosol burden distribution is hemispherically asymmetric with interactive emissions

Interactive



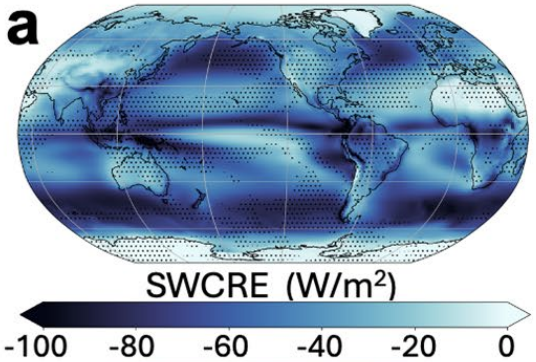
Interactive minus Prescribed



- Mean responses over PiControl periods

Interactive emissions drive hemispherically asymmetric mean state climate responses due to aerosol radiative effects

Interactive



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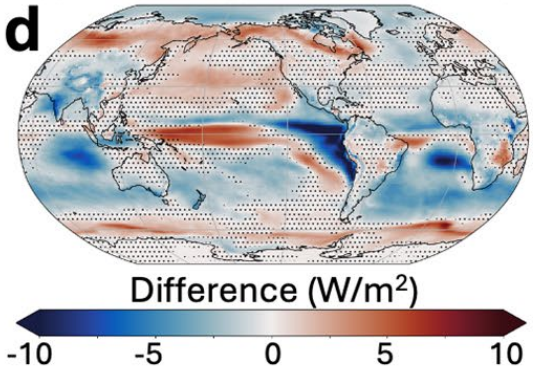

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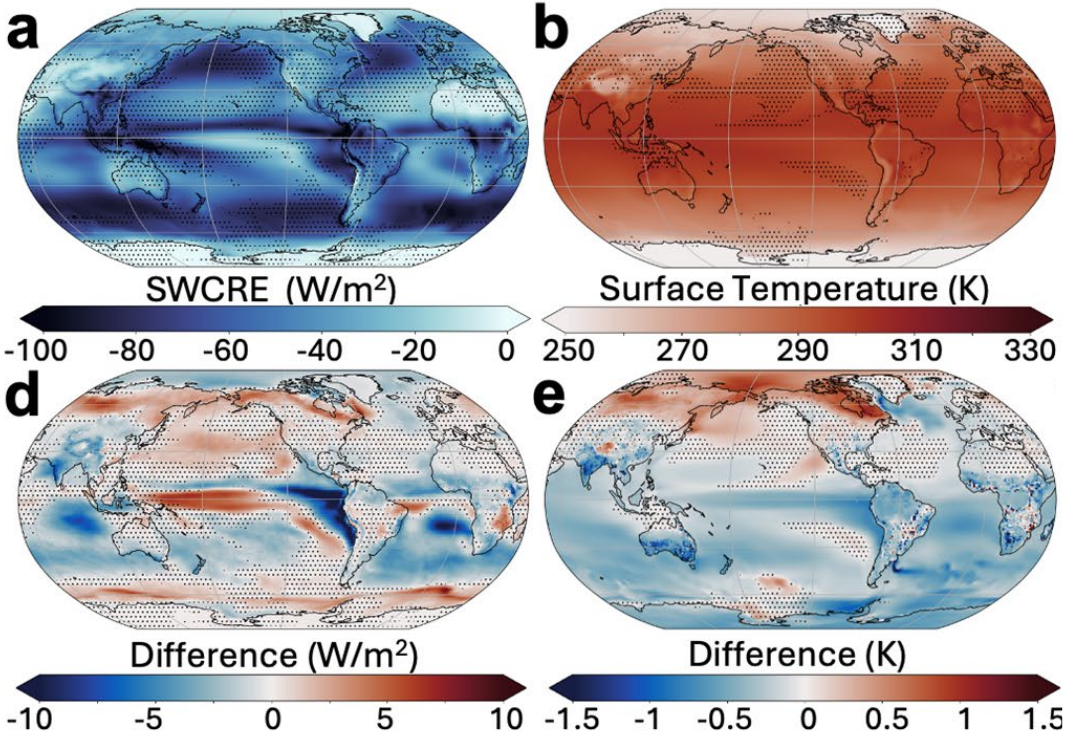

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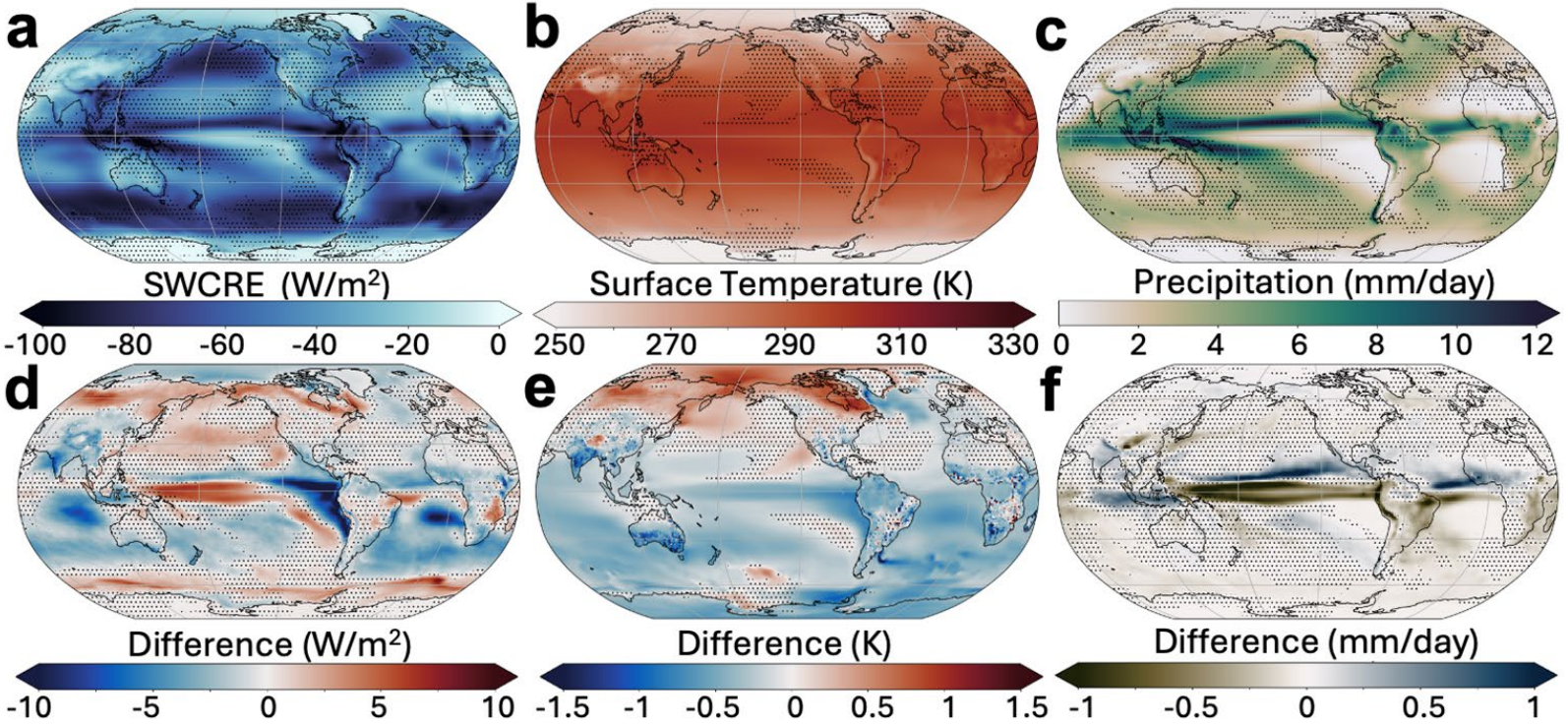
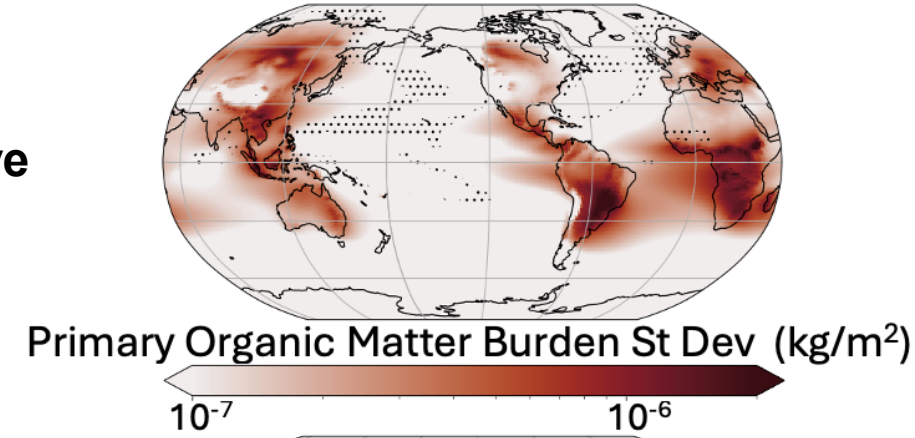


- Mean responses over PiControl periods

There is more fire aerosol burden variability with interactive emissions

Interactive



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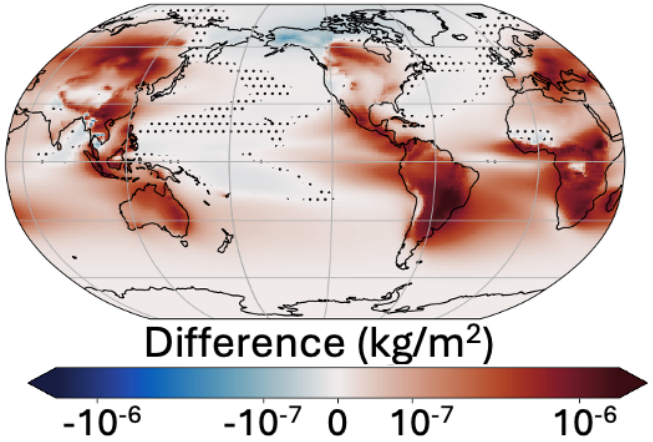
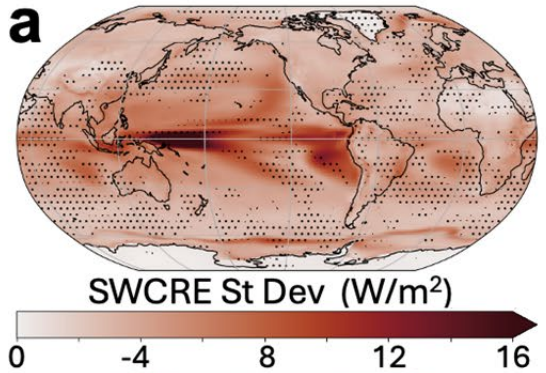


- Analyzed over 1850-1990

Interactive emissions drive global reductions in interannual climate variability

Interactive



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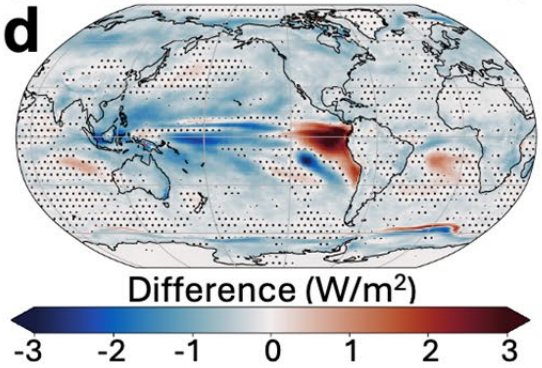

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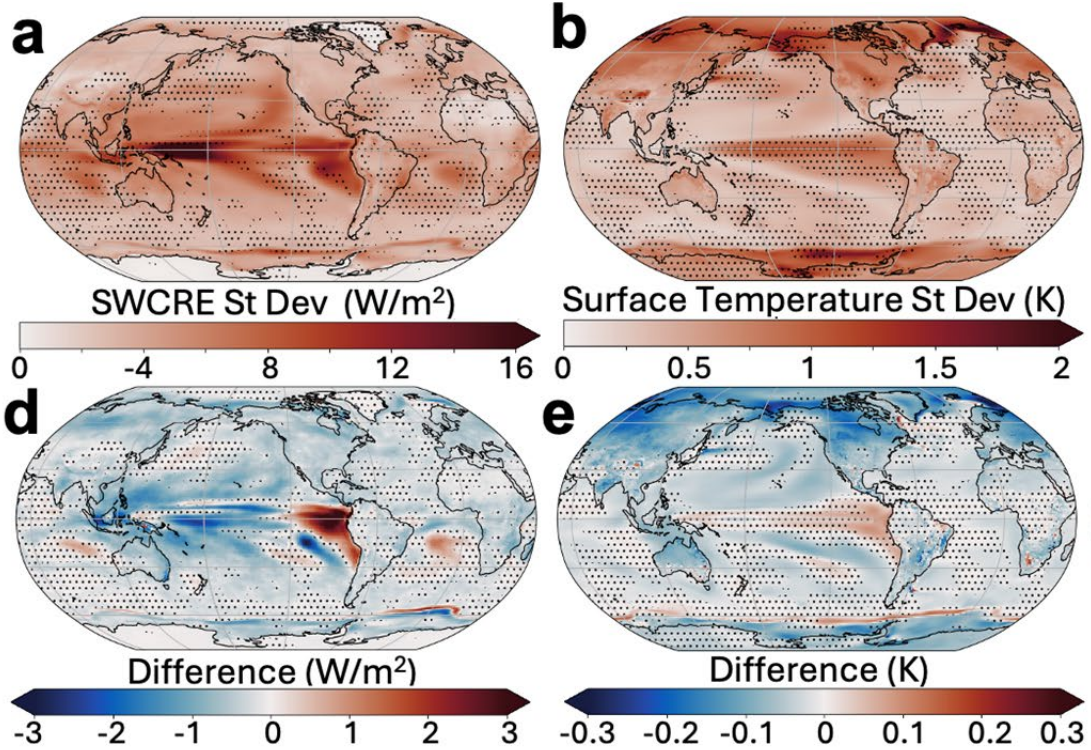

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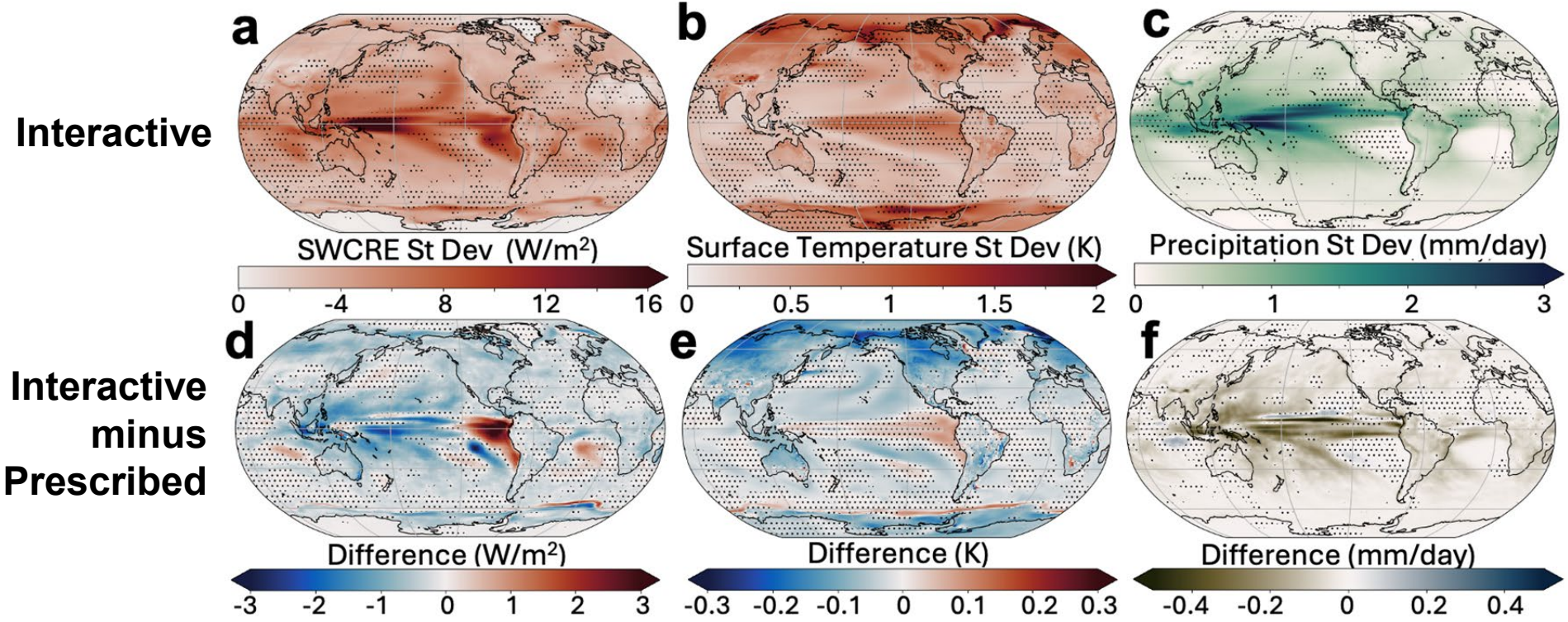

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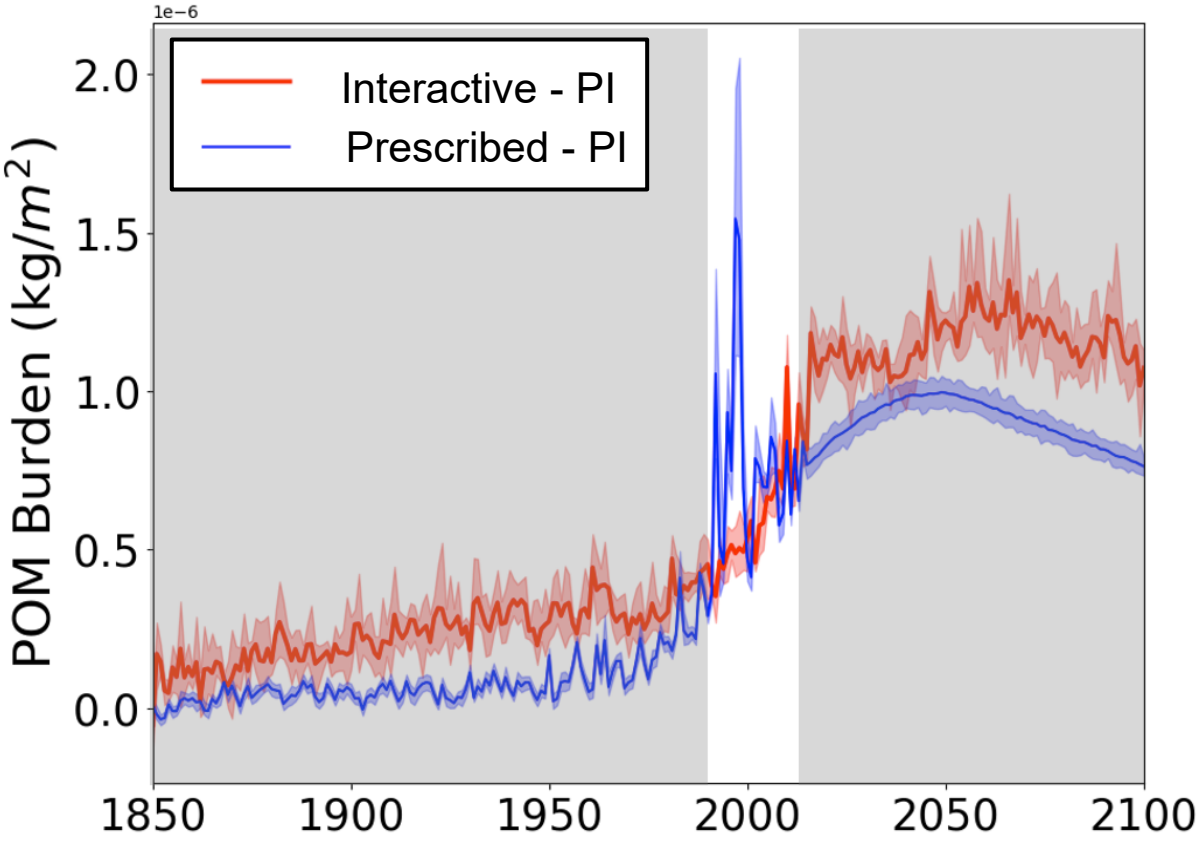
Interactive emissions impact climate trends and feedbacks differently during historical and future periods

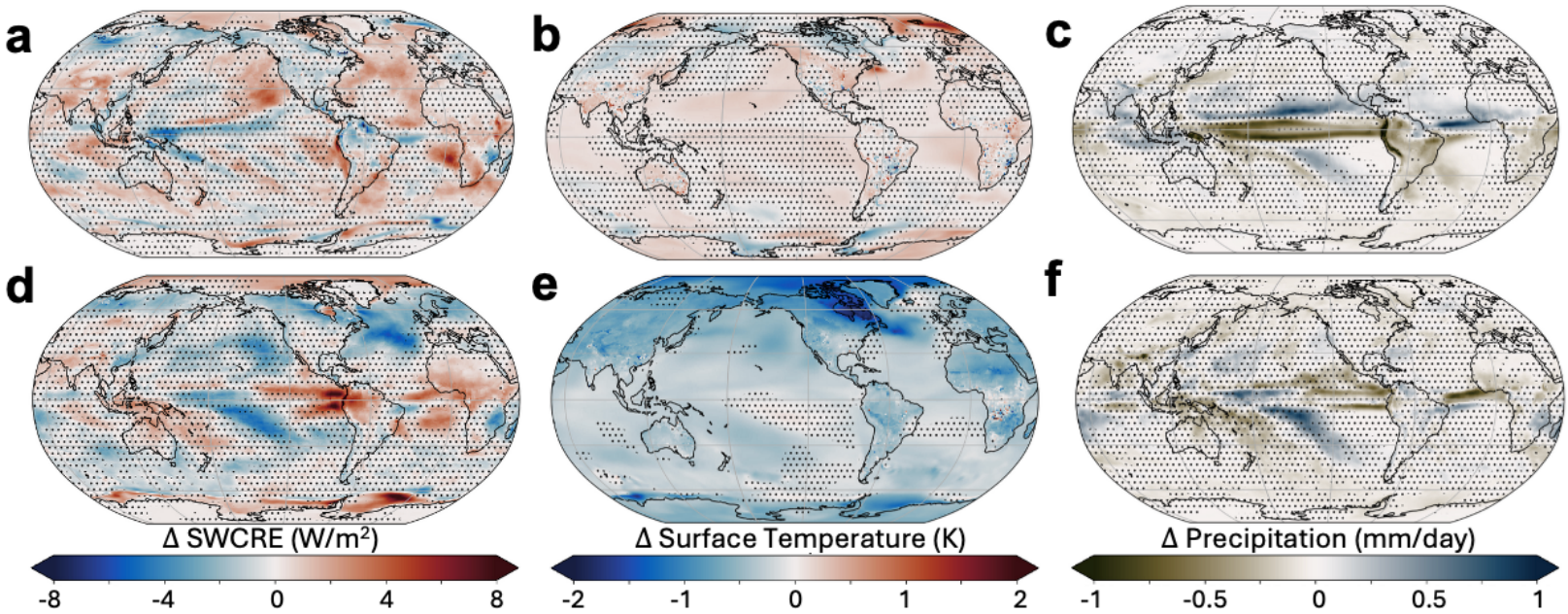


- Global mean POM burden similarities in Interactive and Prescribed are partly due to prescribed land use/land cover

Interactive emissions impact climate trends and feedbacks differently during historical and future periods

PI-1990:

2021-2100:



Conclusions

- Interactive fire emissions induce a substantial and hemispherically asymmetric climate response driven by fire aerosol-climate interactions

- Interactive fire emissions cause persistent global reductions in interannual climate variability

- Fire aerosol-climate interactions reduce the trend in global mean surface temperature by ~0.8K through the 21st century as fires become more frequent across both hemispheres.
    - Regional reductions in surface temperature trends can exceed 2K