2023 CESM Land Model Working Group Meeting
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Impacts of Stratospheric Aerosol Intervention on Surface Air Pollutants

Lili Xia[1], Alan Robock[1], Jadwiga Richter[2], and Matthew Henry[3]

[1]Department of Environmental Sciences, Rutgers University, New Brunswick, NJ, US

[2]Climate and Global Dynamics laboratory, NCAR, Boulder, CO, US

[3]Mathematics and Statistics, University of Exeter, Exeter, UK

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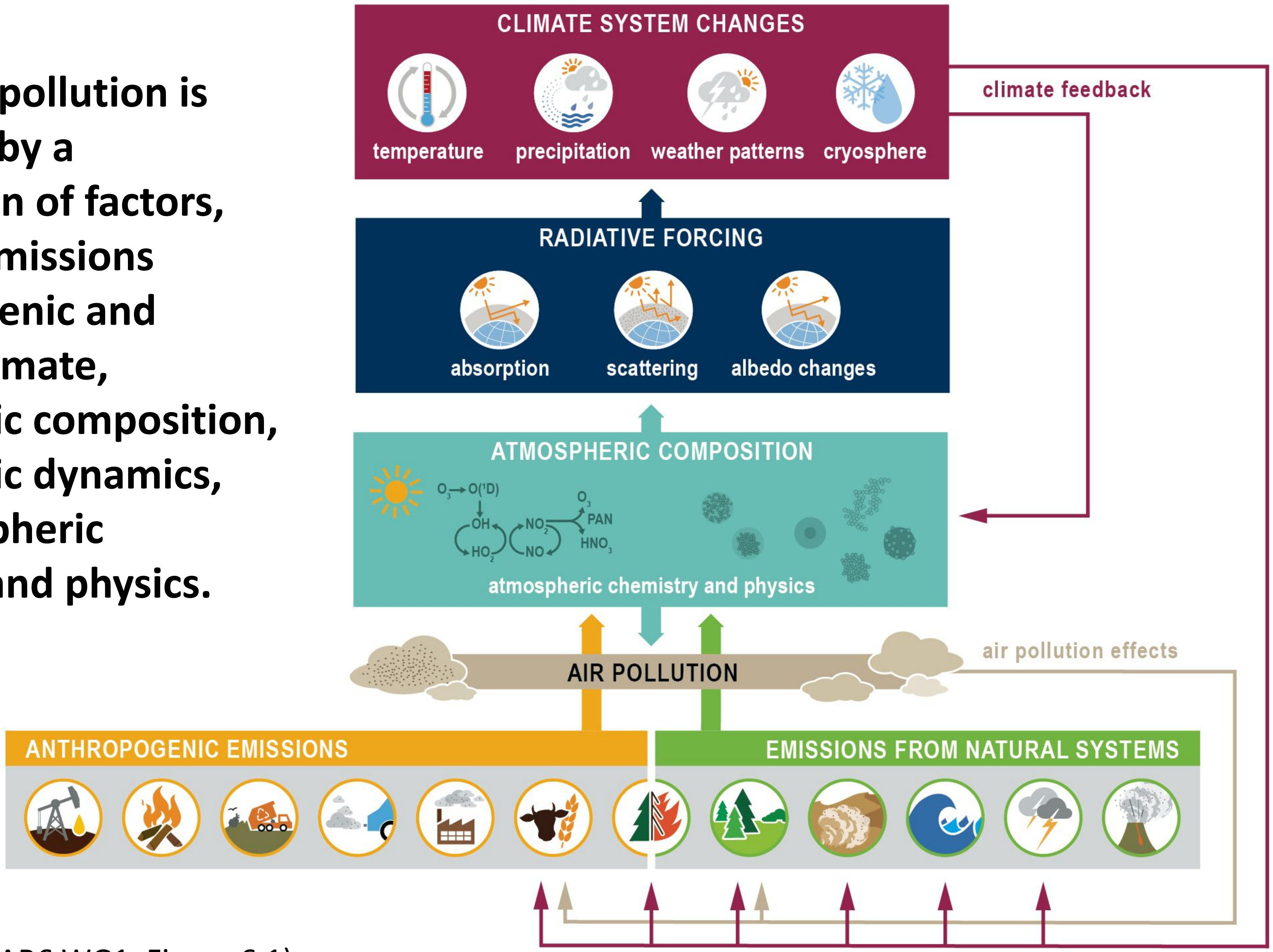
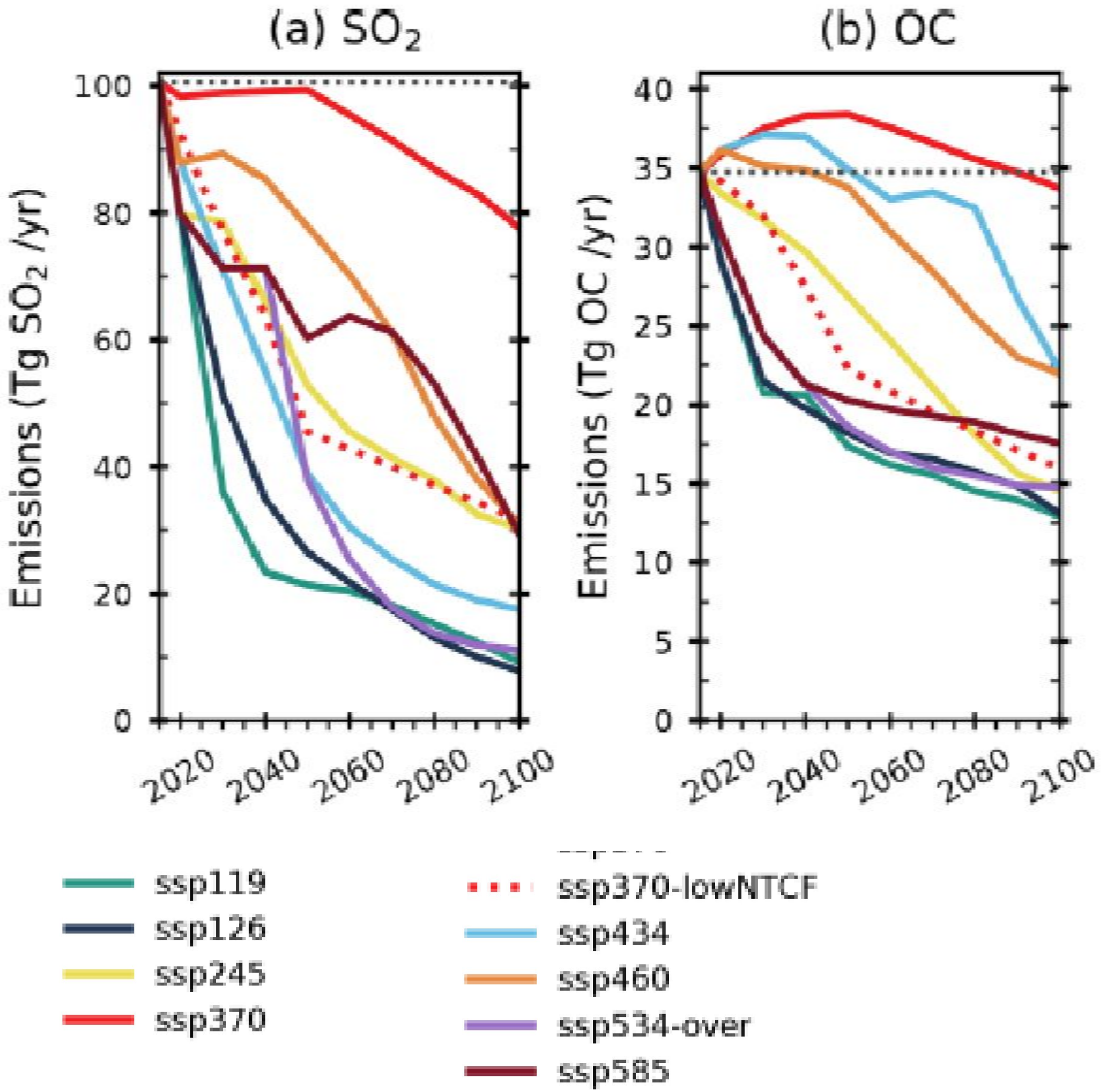
Surface air pollution is influenced by a combination of factors, including emissions (anthropogenic and natural), climate, atmospheric composition, atmospheric dynamics, and atmospheric chemistry and physics.



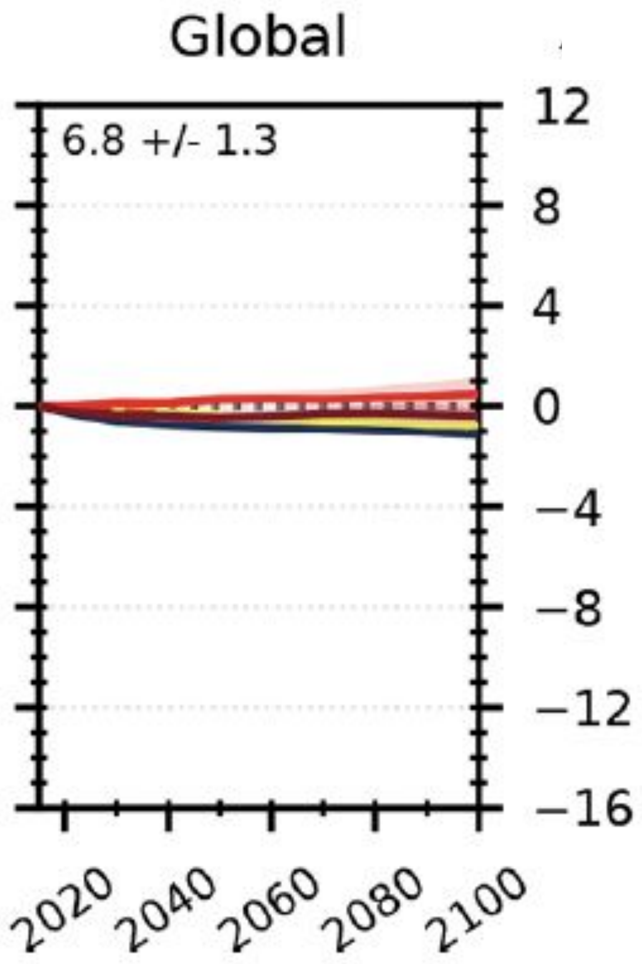
(AR6 WG1, Figure 6.1)

Air pollutions in CMIP6 simulations under different SSPs

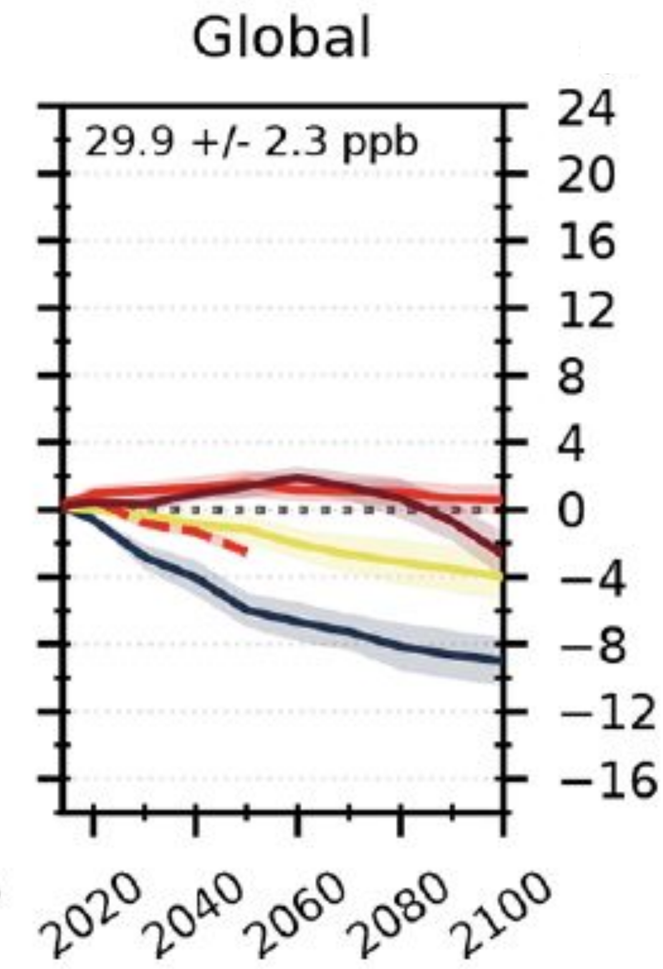
Emissions in SSPs



PM2.5 change ($\mu g/m^3$)



Surface O_3 change (ppb)



(Parts of Figures 1, 11, and 14 in Turnock et al., 2020)

Previous studies on Stratospheric Aerosol Intervention impacts on surface aerosols and ozone

Sulfuric acid deposition from stratospheric geoengineering with sulfate aerosols
Kravitz B. et al., *Journal of Geophysical Research*, 2009

"For annual injection of 5 Tg of SO_2 into the tropical stratosphere or 3 Tg of SO_2 into the Arctic stratosphere, **neither** the maximum point value of sulfate deposition... **nor** the largest additional deposition… **is enough to negatively impact most ecosystems**."

Impacts of Stratospheric sulfate geoengineering on tropospheric ozone
Xia L. et al., *Atmos. Chem. Phys.*, 2017

"In conclusion, surface ozone and tropospheric chemistry would likely be affected by SRM, but the overall effect is strongly **dependent on the SRM scheme**. "

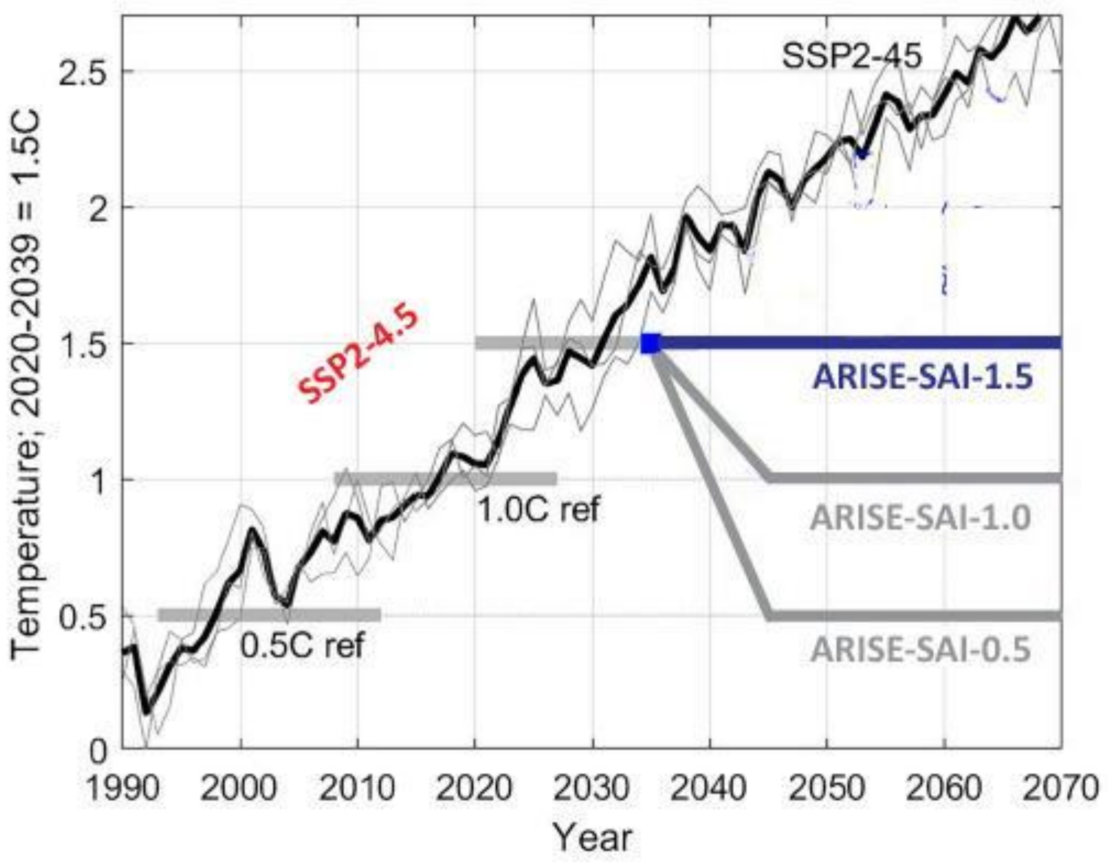
Quantifying the impact of sulfate geoengineering on mortality from air quality and UV-B exposure
Eastham S. D. et al., *Atmospheric Environment*, 2018

"As such we estimate that sulfate geoengineering in 2040 would cause **26,000 early deaths annually** relative to the same year without geoengineering. "

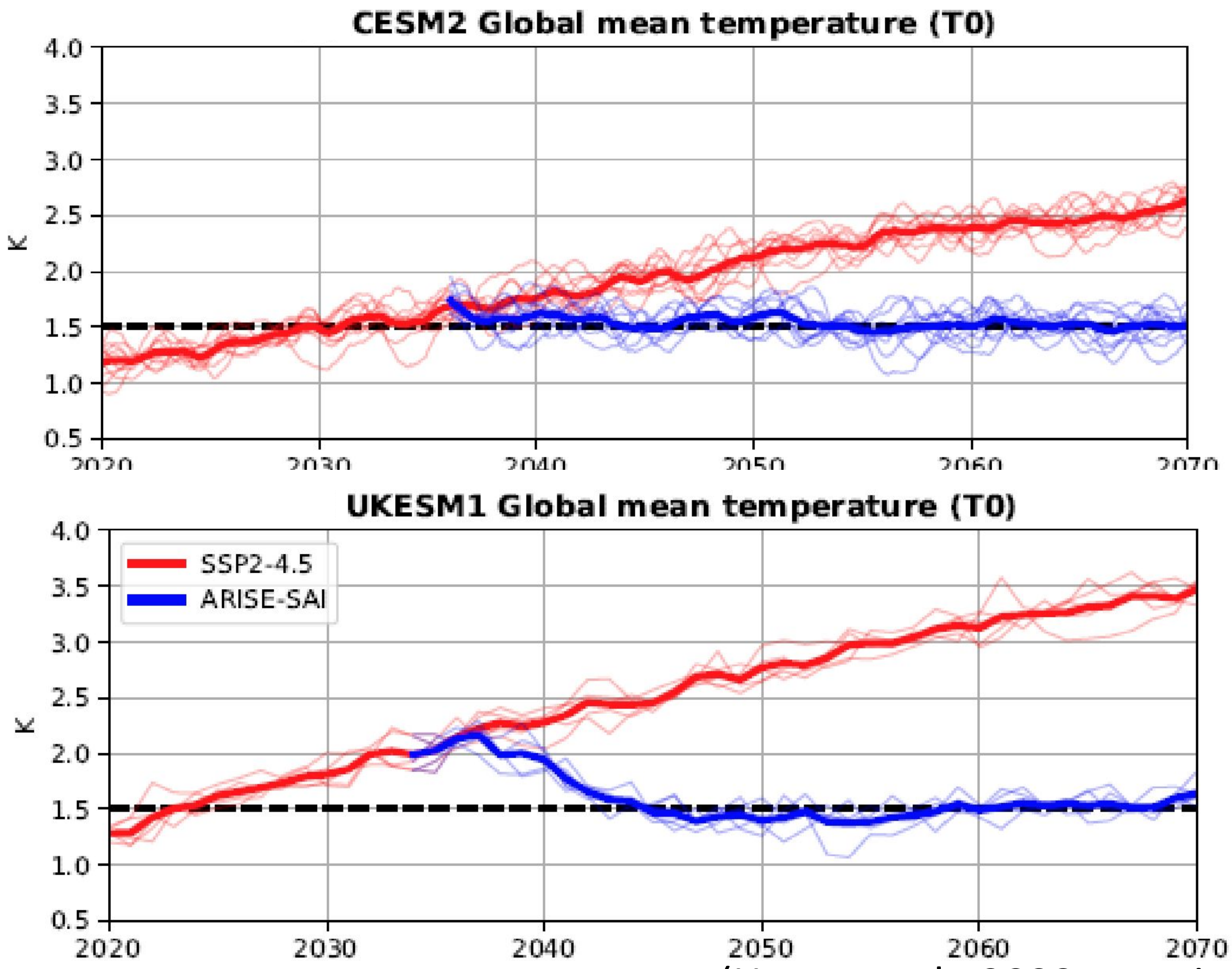
What goes up must come down: impacts of deposition in a sulfate geoengineering scenario
Visioni D. et al., *Environmental Research Letter*, 2020

Under RCP8.5, with SO_2 injection to keep the temperature at 2020 level, "we show that the amount of stratospheric sulfate needed could be **globally balanced** by the predicted decrease in tropospheric anthropogenic SO_2 emissions, **but the special distribution would move** from industrialized regions to pristine areas. "

Assessing Responses and Impacts of Solar climate intervention on Earth System with stratospheric aerosol injection (**ARISE-SAI**)

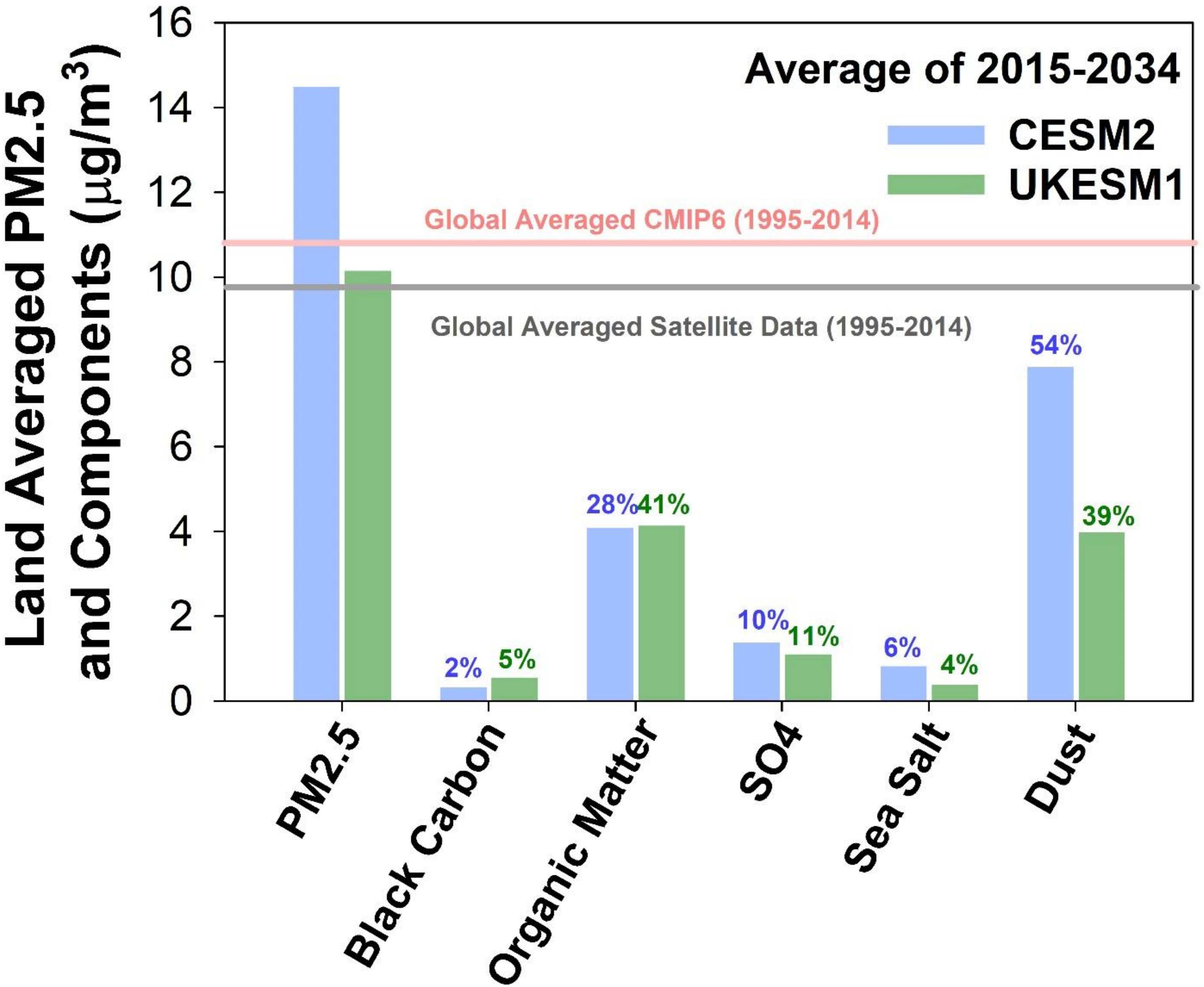


(Modified from Figure 2 in MacMartin et al., 2022)



(Henry et al., 2023 preprint)

PM2.5 in CESM2(WACCM6) and UKESM1-0-LL

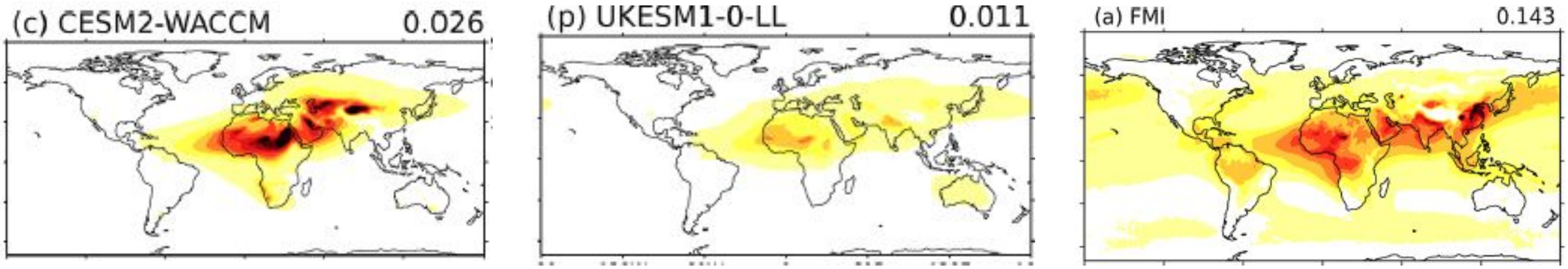


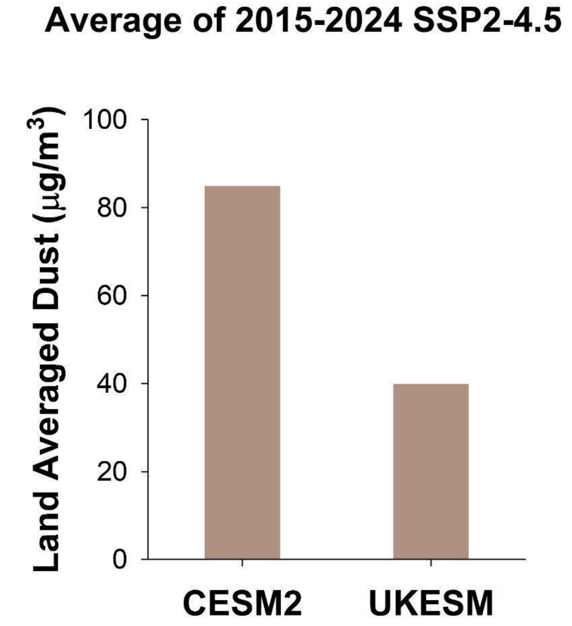
PM2.5 =
Black Carbon +
Primary Organic Matter +
Secondary Organic Matter +
SO4 +
(0.25 x Sea Salt) +
(0.1 x Dust)

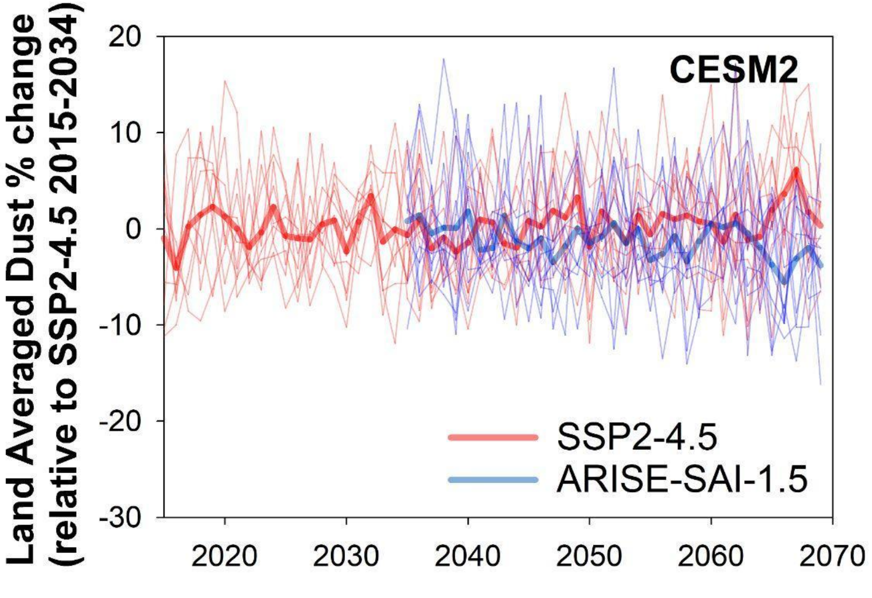
(Turnock et al., 2022)

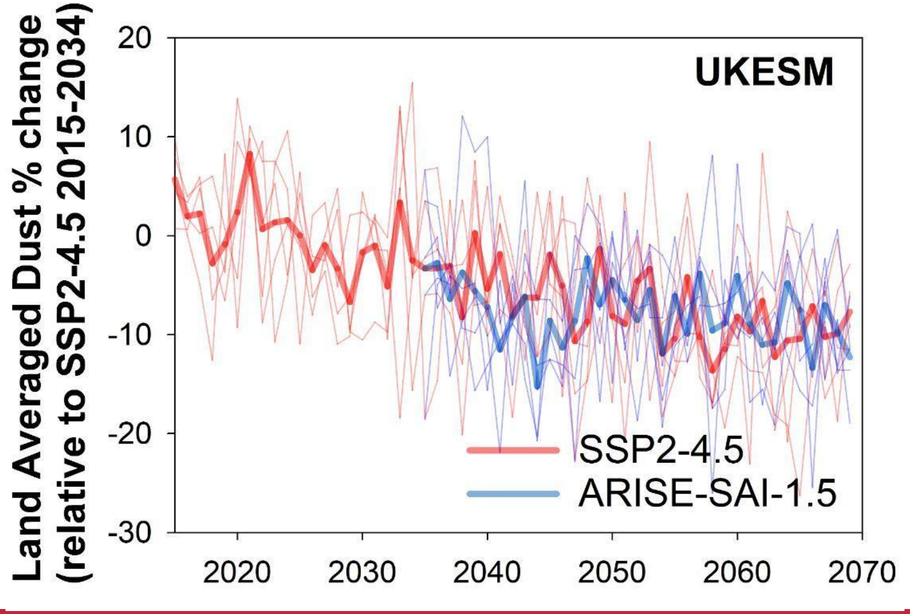
(Red and gray lines on the plot are from Shim et al., 2021)

Dust Optical Depth (2005-2014) (Zhao et al., 2022)

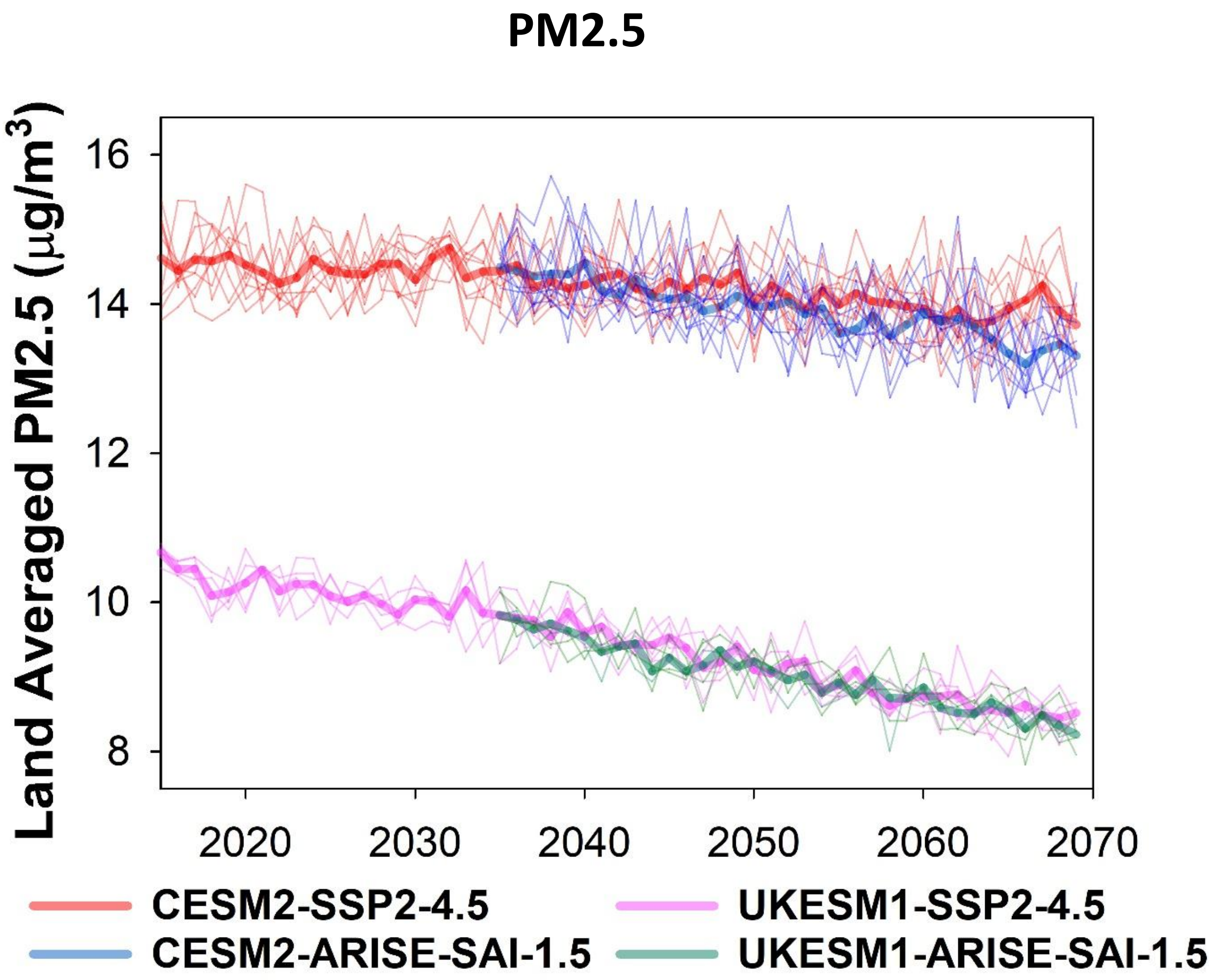


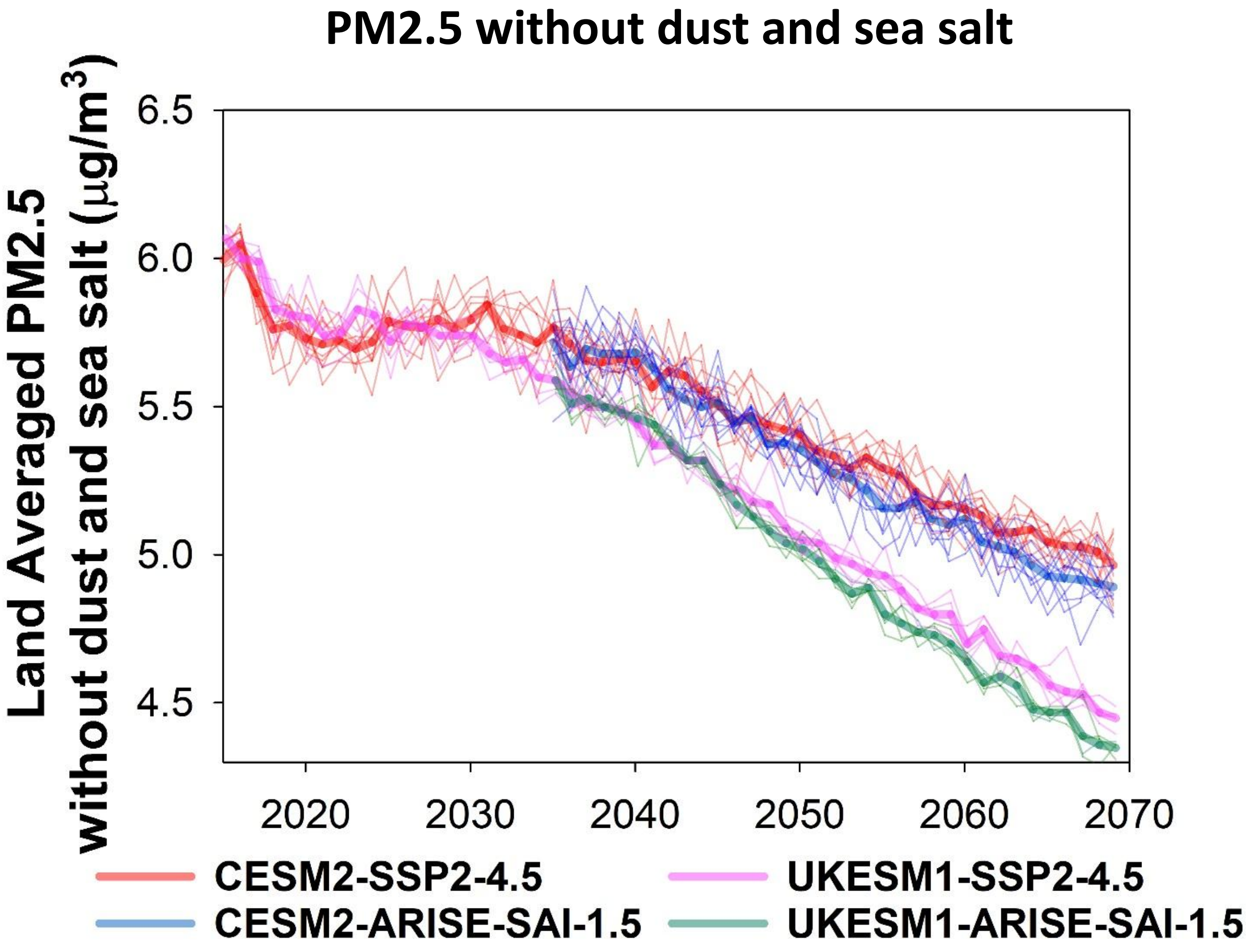






PM2.5 in CESM2(WACCM6) and UKESM1-0-LL



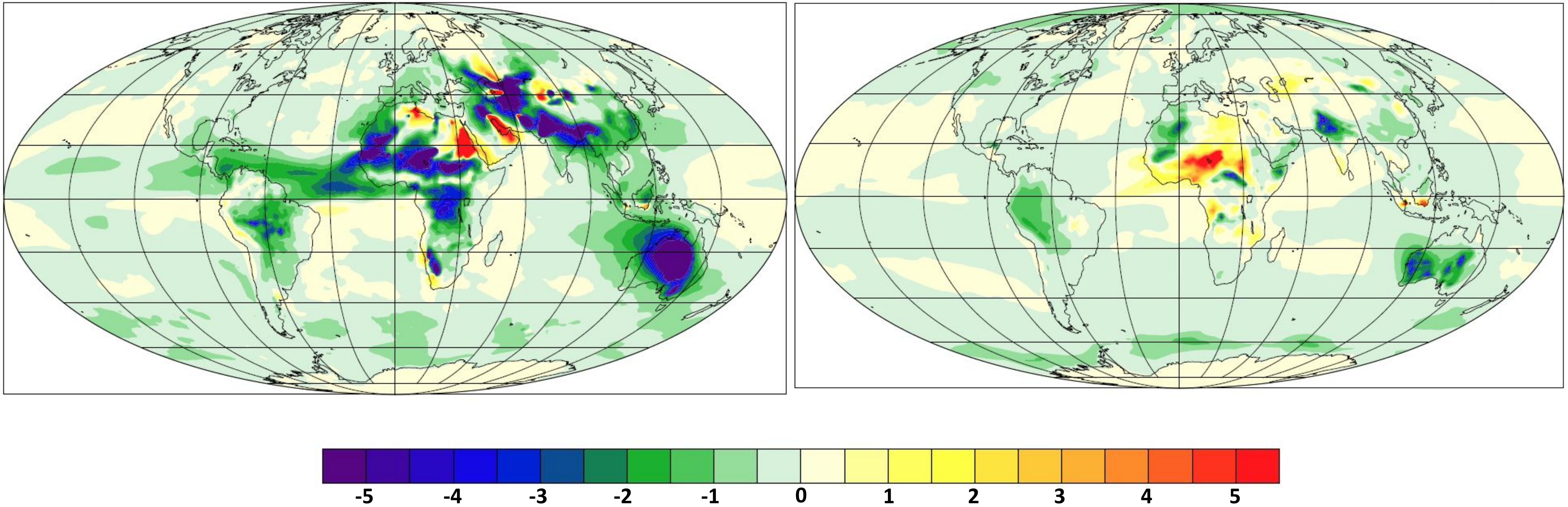


PM2.5 concentration difference (μg/m³)

(ARISE-SAI-1.5 minus SSP2-4.5) (2060-2069)

CESM2 (average of 10 ensembles)

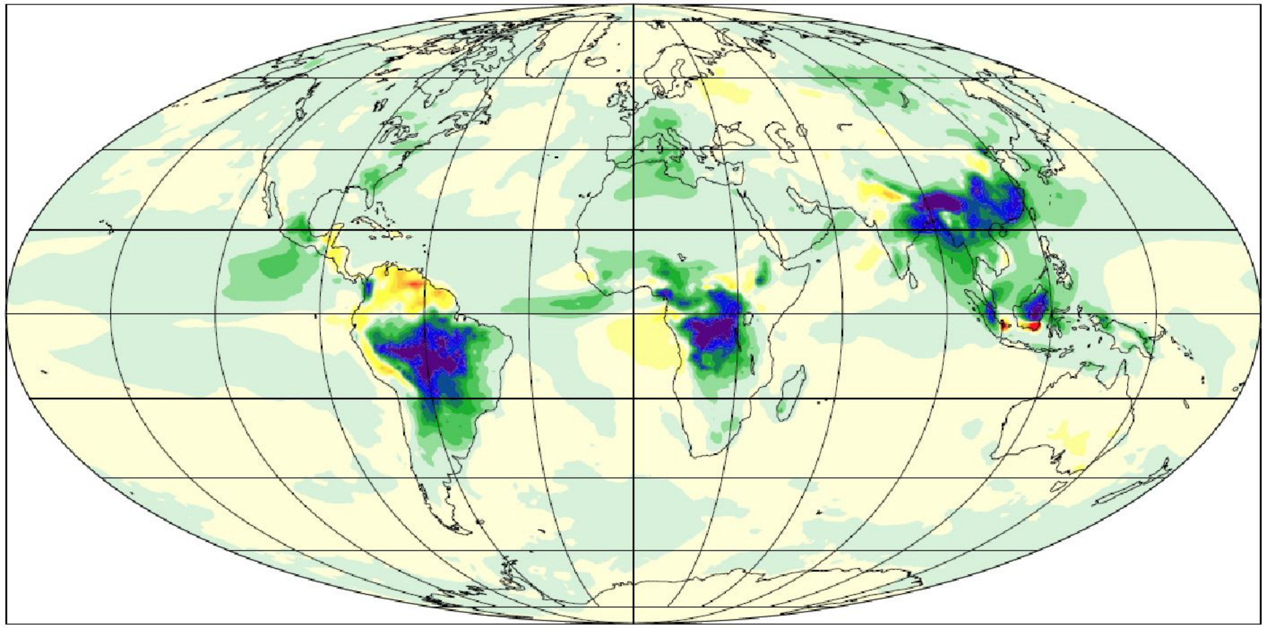
UKESM1 (average of 5 ensembles)



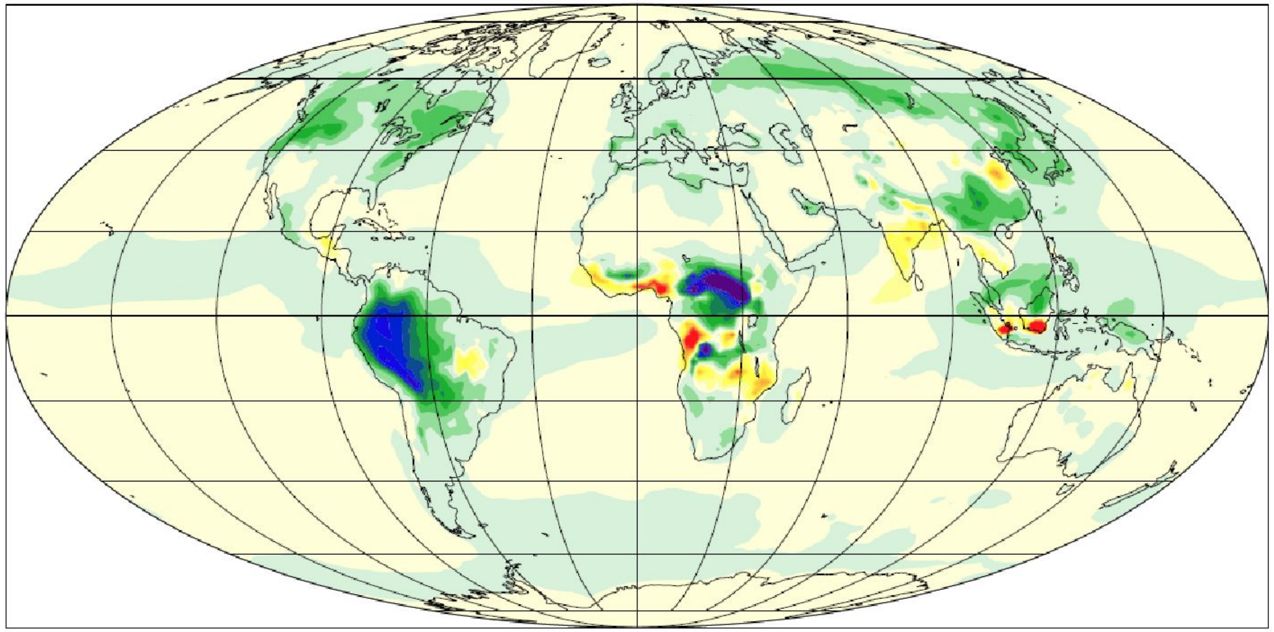
PM2.5 concentration difference (μg/m³) (without dust and sea salt)

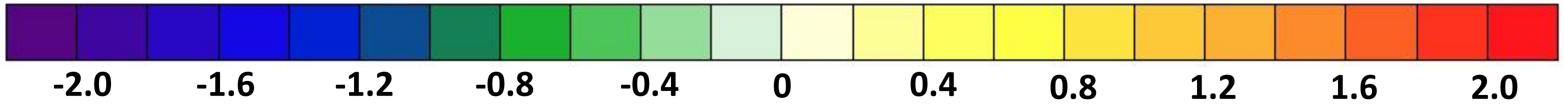
(ARISE-SAI-1.5 minus SSP2-4.5) (2060-2069)

CESM2 (average of 10 ensembles)

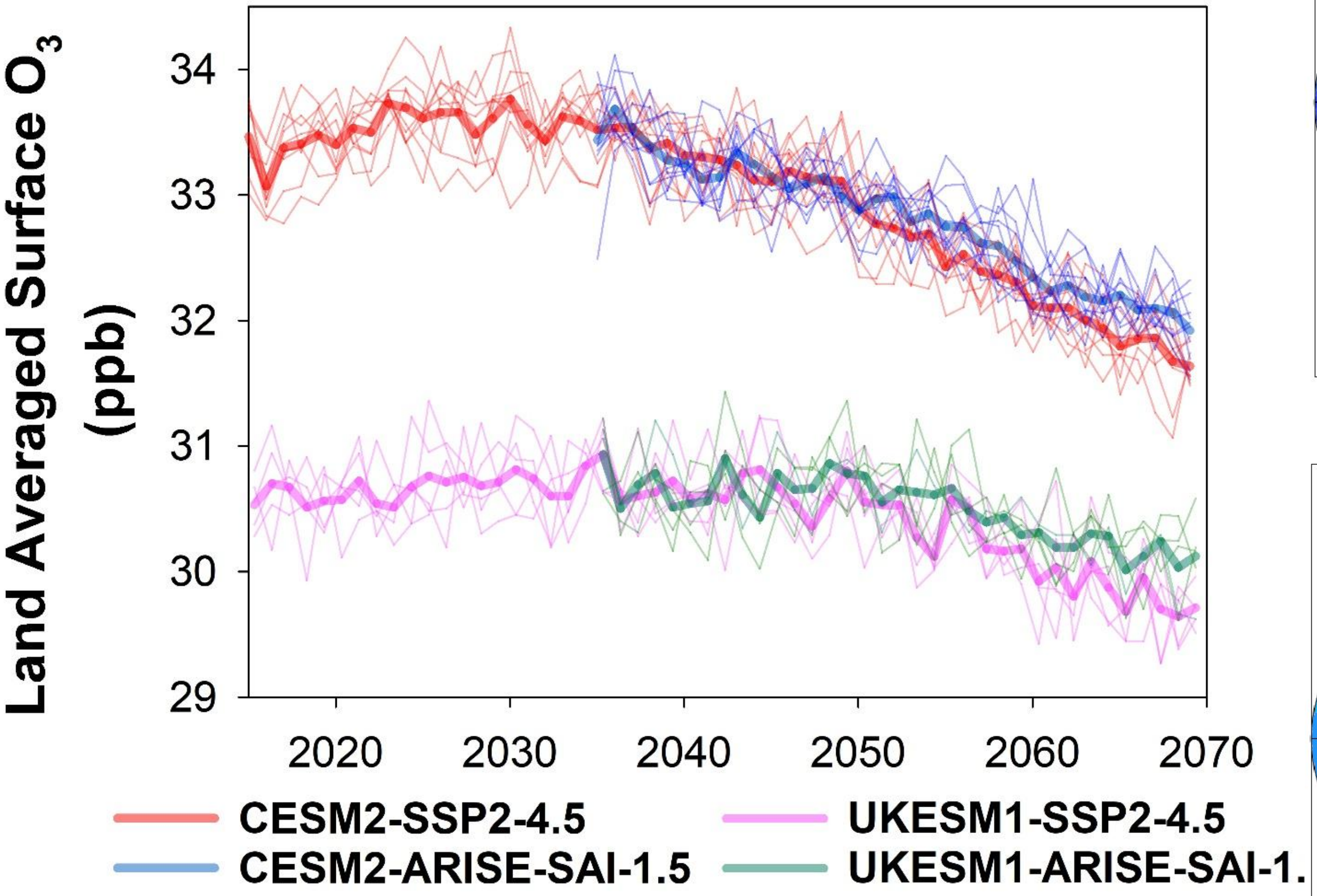


UKESM1 (average of 5 ensembles)

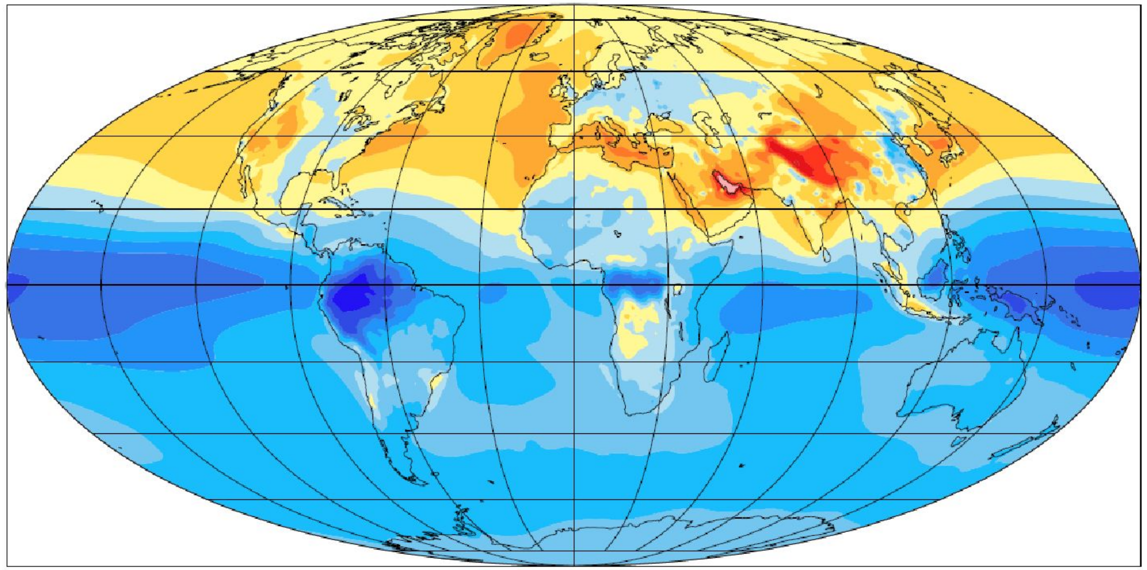




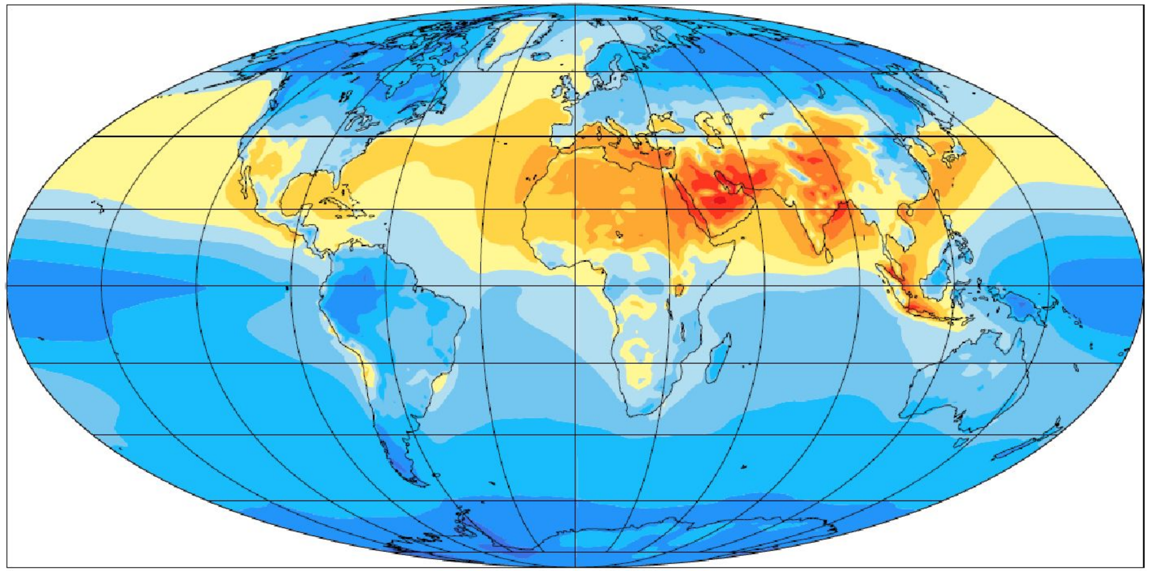
Surface ozone concentration (ppb)



CESM2 (2015-2024)



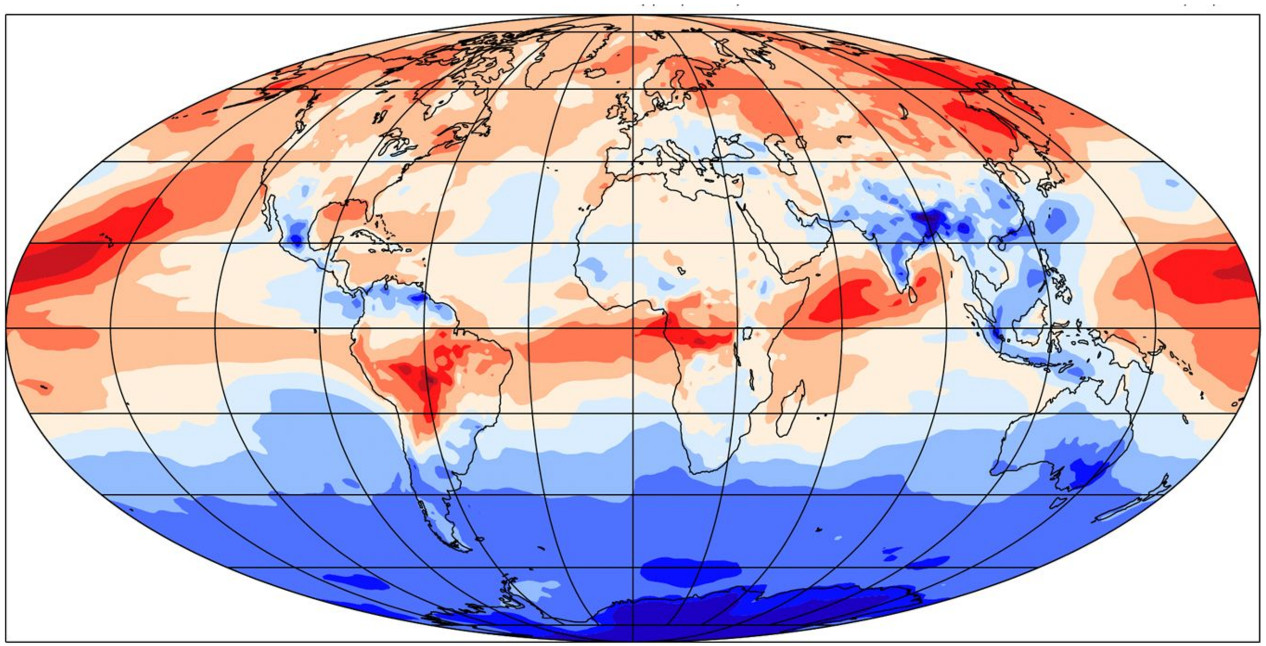
UKESM1 (2015-2024)



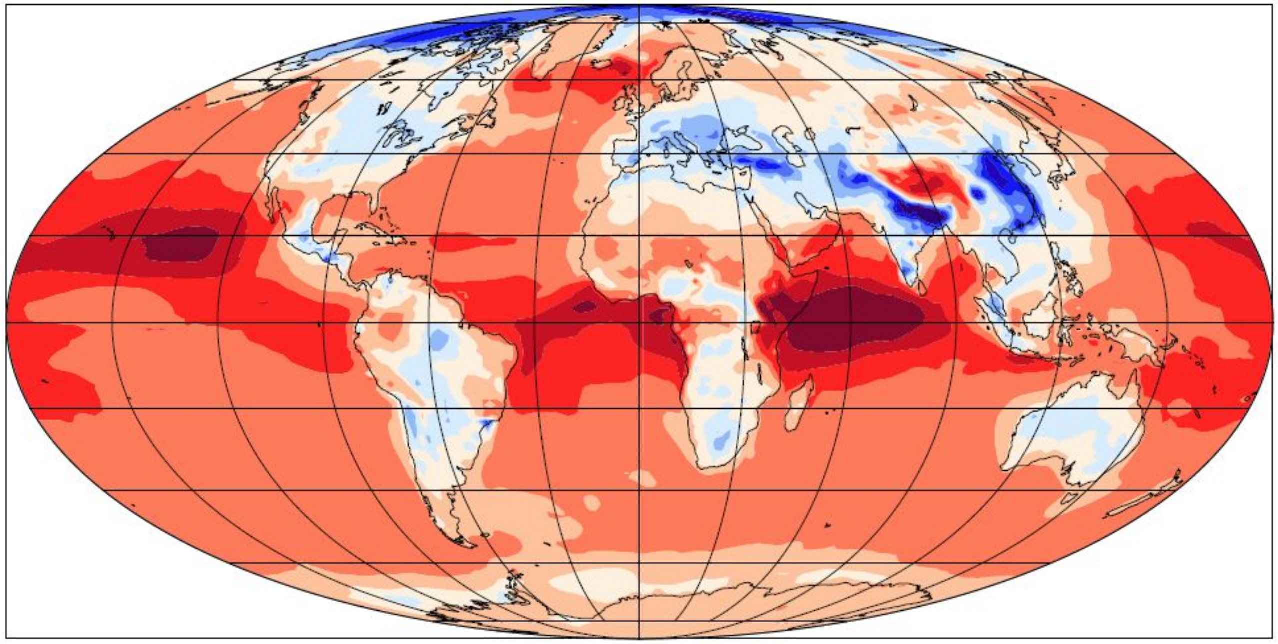
Surface ozone concentration difference (ppb)

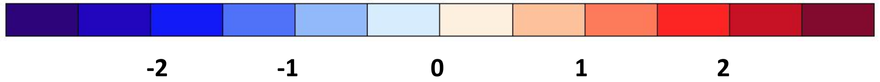
(ARISE-SAI-1.5 minus SSP2-4.5) (2060-2069)

CESM2 (average of 10 ensembles)

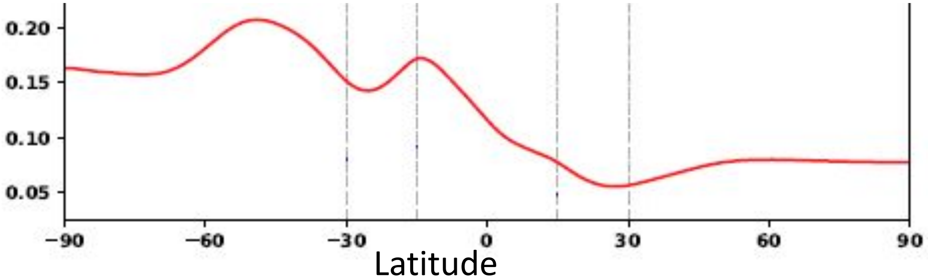


UKESM1 (average of 5 ensembles)

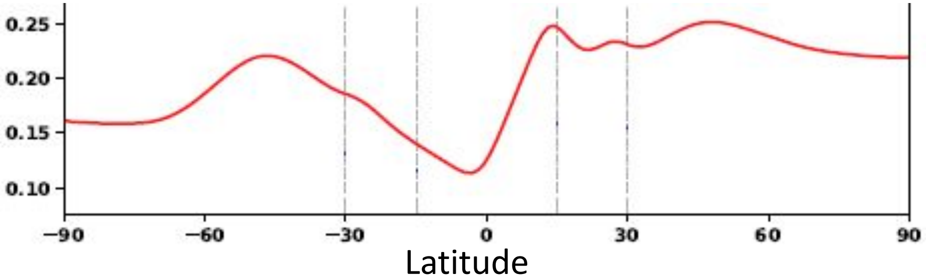




Aerosol Optical Depth



Aerosol Optical Depth



(Henry et al., 2023 preprint)

Conclusions and Next Steps

- In both CESM2 and UKESM1, anthropogenic emissions and O_3 precursors primarily drive the reduction of surface PM2.5 (excluding dust and sea salt) and surface O3 under the SSP2-4.5 and ARISE-SAI-1.5 scenarios;
- The concentration of dust in CESM2 is double that in UKESM1, which contributes the higher concentration of PM2.5 in CESM2;
- Although land averaged PM2.5 and O_3 show small differences between SSP2-4.5 and ARISE-SAI-1.5, there are large regional differences over urban areas.

- Analyze ozone budget;
- Use high frequency output to calculate the number of days where PM2.5 and surface O_3 exceed the EPA and WHO guidelines in various regions under SSP2-4.5 and ARISE-SAI;
- Explore the mechanisms driving changes in PM2.5 and surface O_3 change under the ARISE-SAI scenario in comparison to the SSP2-4.5.