



Contribution of Southern Hemisphere ozone recovery to uncertainty in surface climate change

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Motivation

Antarctic stratospheric ozone depletion has driven substantial changes in Southern Hemisphere surface circulation over the late 20th century. Following the phase-out of ozone-depleting substances, stratospheric ozone has started recovering since the early 2000s and is projected to continue this trend in the coming decades, with associated surface climate responses partially reversing those associated with ozone depletion. However, the projected ozone recovery trends varies considerably across global chemistry-climate models. To date, it remains unclear whether this spread in ozone changes across models contributes to uncertainties in SH climate change projections. Here, we isolate the impact of ozone on the circulation using targeted model experiments and CMIP6 data.

Methods

- We relate changes in lower stratospheric ozone column (50-100 hPa) to circulation changes in **CMIP6 models with interactive chemistry** in two emission scenarios (SSP2 and SSP5).
- We perform targeted model simulations with two chemistry-climate models (WACCM and SOCOL) and contrast two runs: **one with fully coupled ozone** under a high emission pathway (RCP8.5), and **one with ozone fixed** to present day values.
- We **normalise** all changes by **global mean surface temperature (GMT)** changes to account for confounding effects.

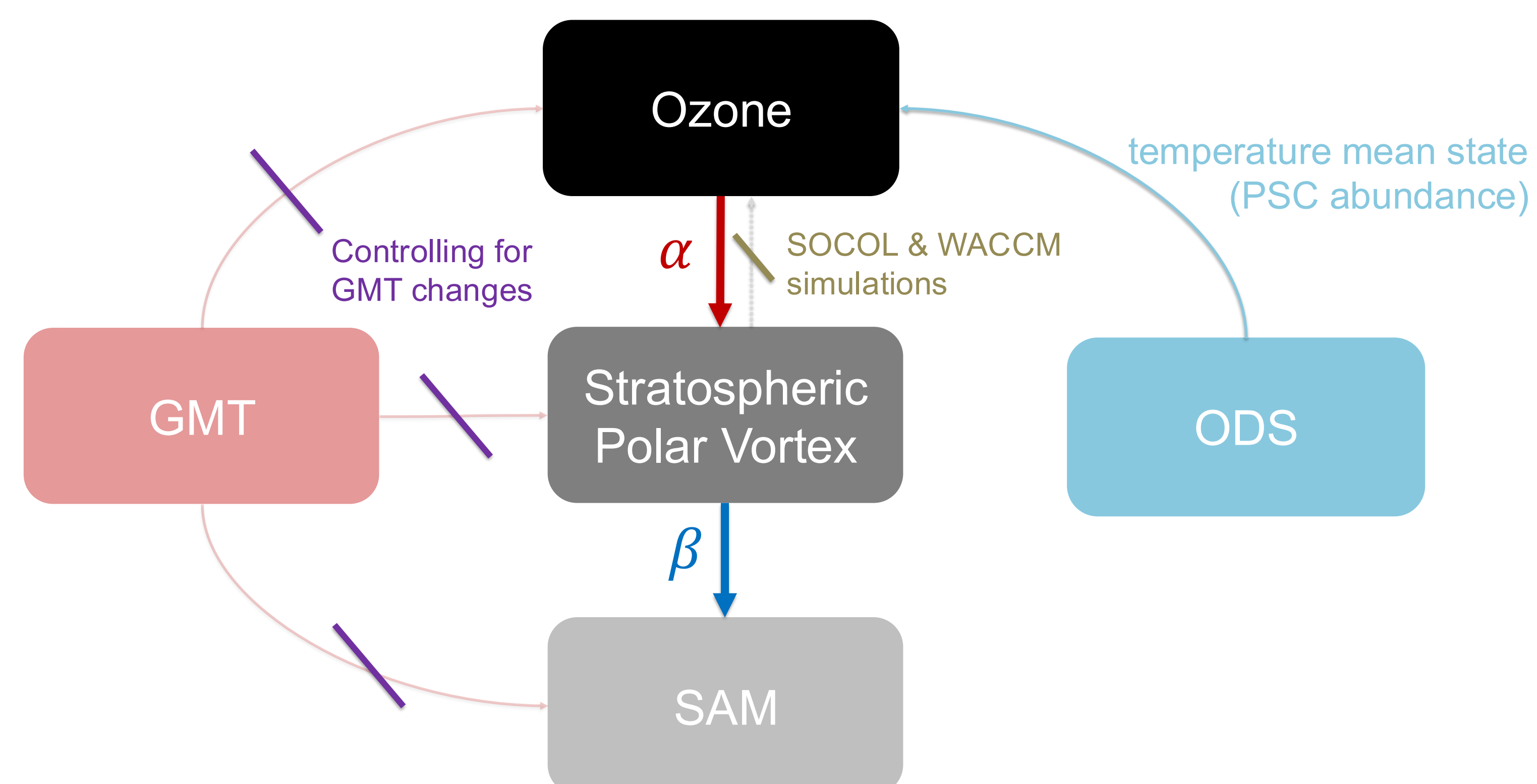
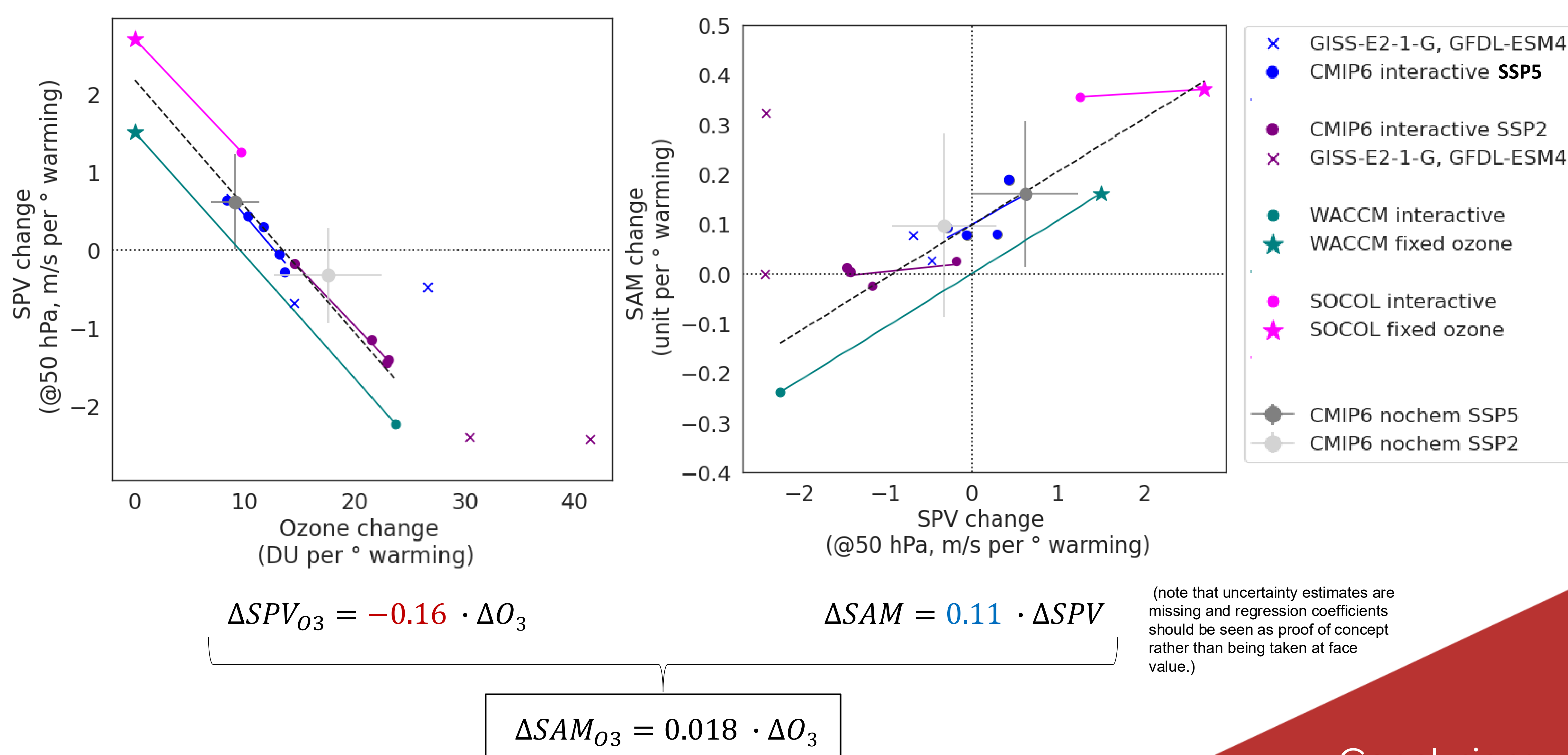


Fig. 1: Causal diagram linking external forcings (global mean temperature (GMT) and ozone depleting substances (ODS)), ozone and the circulation. ODSs impact the rate of ozone recovery. Changes in ozone can affect the strength of the polar vortex. In turn, changes in the Stratospheric Polar Vortex (SPV) also impact ozone. Any changes in the stratospheric circulation can propagate down and impact the circulation in the troposphere, such as the Southern Annular Mode (SAM). GMT impacts both ozone and the circulation via thermodynamic and dynamic processes. To account for these confounding effect, we control for GMT in our analysis. α is the link between ozone and the polar vortex, and β is link between the polar vortex and SAM quantified by linear regression coefficients.



This implies that: Under SSP5, projected O₃ changes of 10-22 DU per 1°C GMT change might induce SAM changes of -0.18 to -0.40, thereby largely contributing to uncertainties in circulation projections.

Conclusions

Here, we demonstrate that the spread in future Antarctic ozone changes translates directly into uncertainty in projected circulation changes. These results imply that projections in CMIP6 models using prescribed ozone may underestimate uncertainty in future Southern Hemisphere climate change, since they do not account for any uncertainties in future ozone changes. Moreover, the comparably small changes in the CMIP6 ozone forcing dataset compared to ozone projections by chemistry-climate models imply that CMIP6 models without interactive chemistry might systematically underestimate the ozone effect, thereby overestimating circulation trends.