Supplementary Information

Investigating the role of stratospheric ozone as a driver of inter-model spread in CO_2 effective radiative forcing.

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Text S1 – NorESM2-MM model configuration

The Norwegian Earth System Model version 2 (NorESM2) is the latest generation of Earth system models developed by the Norwegian Climate Center (Seland et al., 2020). Here, we use the "medium-resolution" version of NorESM2 (hence named NorESM2-MM) which has a horizontal resolution of 0.9° latitude by 1.25° longitude in the atmosphere-land components and a tripolar irregular ocean grid, with a 1° latitude by 0.25° longitude resolution at the equator that progresses towards more isotropic grid boxes at higher latitudes (with sea-ice discretised on the same horizontal grid). NorESM2 is based on the Community Earth System Model version 2 (CESM2; Danabasoglu et al., 2020) and shares many Earth system features along with the same computer code infrastructure. However, the ocean and ocean biogeochemistry components are completely different and the atmospheric component of the model (CAM6-Nor) employs a different module for aerosol physics and chemistry, including cloud and radiation interactions. Radiative fluxes and heating rates are computed by the Rapid Radiative Transfer Model for General circulation models code (RRTMG; Iacono et al., 2008). RRTMG utilizes the correlated k-distribution method to calculate radiative transfer across longwave and shortwave spectral intervals from 3.1 to 1000 μm and 0.2 to 12.2 μm, respectively. CAM6-Nor has 32 vertical levels with a model top at about 2.26 hPa (40 km). Note that NorESM2-MM output used in this study uses the model top layer midpoint as it's uppermost level at 3.64 hPa and the stratospheric vertical resolution of CAM6-Nor is relatively coarse. CAM6-Nor has no prognostic chemistry module for ozone and other stratospheric species, therefore ozone fields are prescribed using output from previous CESM-Whole Atmosphere Community Climate Model version 6 (WACCM6) simulations as zonally-averaged 5 day fields (see Supplementary Figure 1). WACCM6 is configured identically to CAM6-Nor albeit with 70 vertical levels and a model top at 4.5×10^{-6} hPa. Hence, WACCM offers a much higher stratospheric vertical resolution and includes comprehensive interactive chemistry. For use in NorESM2-MM, these ozone fields are interpolated from the 70 WACCM6 vertical levels onto the 32 CAM6-Nor vertical levels by an internal model subroutine. Note that CAM6-Nor and WACCM6 share the same vertical level structure from the surface up to 87 hPa. Further NorESM2 model description is given by Seland et al., 2020.

NorESM2-MM					
Horizontal resolution	**Vertical resolution**	**Radiative transfer code**	**Atmospheric component**	**O_3 dataset**	**Reference**
0.9°x1.25°	32 levels (uppermost level at 3.64 hPa)	RRTMG Iacono et al., 2008	CAM6-Nor	Zonal-mean 5-day fields from CESM2-WACCM6	Seland et al., 2020

NorESM2-MM model configuration details

Figure S1: CESM2-WACCM6 zonal 5-day mean O_3 field

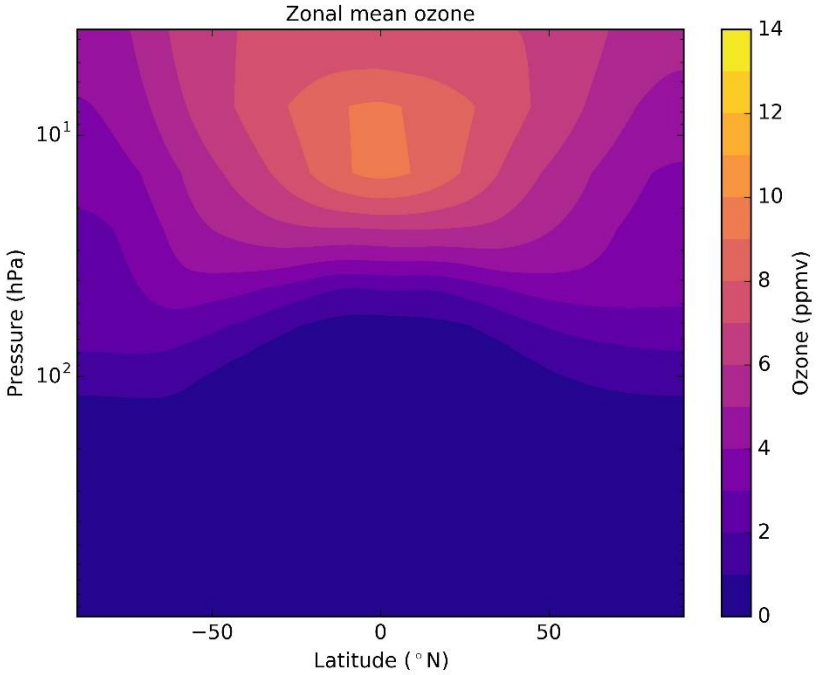


Table S1: Model experiments

Experiment name	Baseline integration	Perturbed integration	Integration length
'Standard' 4xCO_2	Pre-industrial	4xCO_2	30 years
Strat O_3x1.5	Pre-industrial with stratospheric O_3 increased by 50%	4xCO_2 with stratospheric O_3 increased by 50%	15 years
Strat O_3x0.5	Pre-industrial with stratospheric O_3 decreased by 50%	4xCO_2 with stratospheric O_3 decreased by 50%	15 years

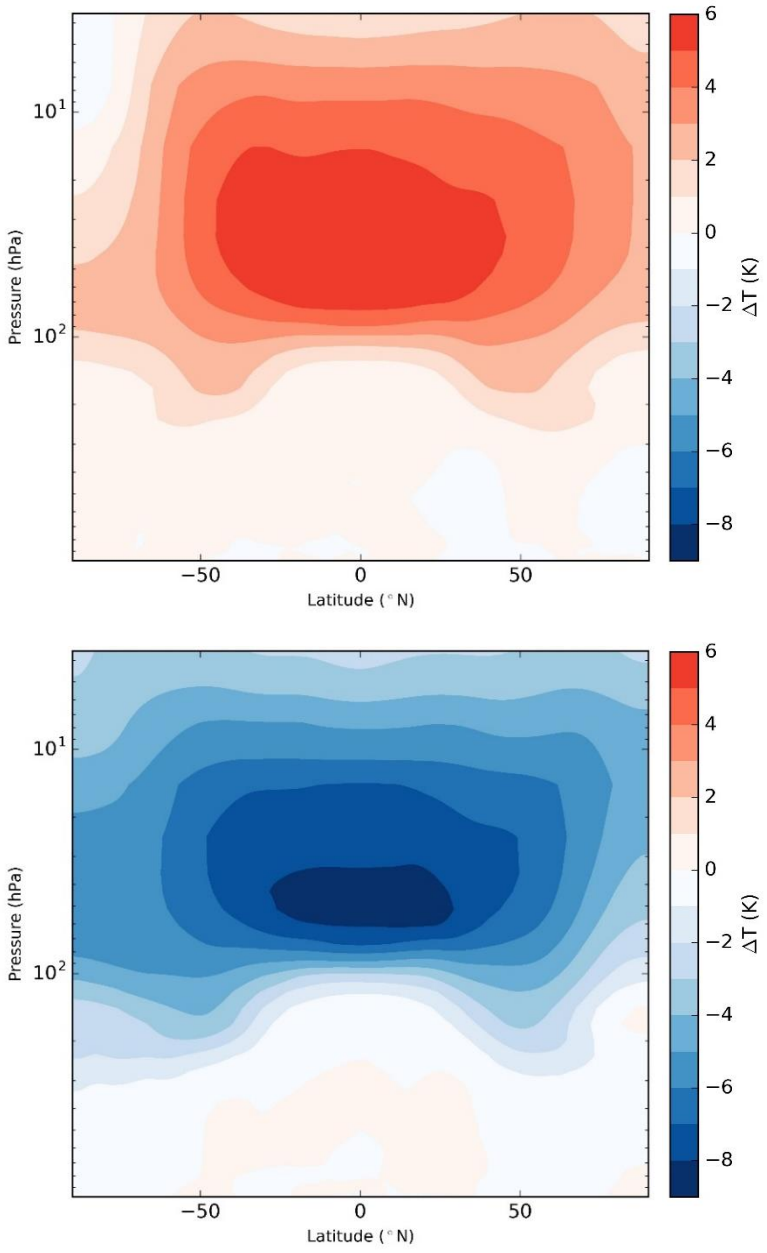
Text S2: CESM2 supporting simulations

CESM2 is the most recent generation of Earth system models developed by the National Center for Atmospheric Research (NCAR) and several universities and research institutes (Danabasoglu et al., 2020). CESM2 employs the Community Atmosphere Model version 6 (CAM6) as its atmospheric component with radiative transfer calculated by RRTMG. The horizontal resolution of CAM6 is 0.9° latitude by 1.25° longitude with a vertical resolution of 32 levels (with a model top at 2.26 hPa). Both the ocean and sea-ice components employ a nominal 1° horizontal resolution. CAM6 has no prognostic chemistry module for ozone therefore ozone fields are prescribed using the same output as in the NorESM2-MM simulations i.e., from previous CESM-WACCM6 simulations as zonally-averaged 5 day fields (see Supplementary Figure 1). We run the exact same simulations in CESM2 as are detailed for NorESM2-MM (Supplementary Table 1).

CESM2.1.3					
Horizontal resolution	**Vertical resolution**	**Radiative transfer code**	**Atmospheric component**	**O_3 dataset**	**Reference**
0.9°x1.25°	32 levels (uppermost level at 3.64 hPa)	RRTMG (Iacono et al., 2008)	CAM6	Zonal-mean 5-day fields from CESM2-WACCM6	Danabasoglu et al., 2020

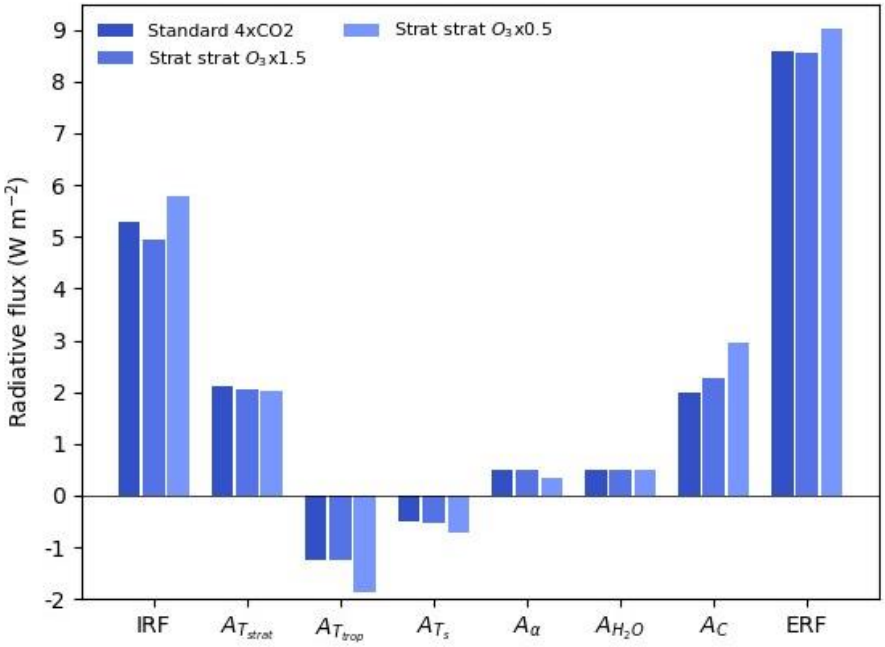
CESM2 model configuration details

Figure S2: Impact of ozone perturbations on baserun atmospheric temperature in CESM2



Zonal-mean difference in atmospheric temperature between the control integration of 'Strat O_3x1.5' and the control integration of the 'standard' 4xCO_2 ERF simulation (upper) and between the control integration of 'Strat O_3x0.5' and the control integration of the 'standard' 4xCO_2 ERF simulation (lower) in CESM2.

Figure S3: Impact of stratospheric ozone perturbations on 4xCO2 ERF and components in CESM2



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