



Supplement of

The effect of atmospheric nudging on the stratospheric residual circulation in chemistry–climate models

Andreas Chrysanthou et al.

Correspondence to: Andreas Chrysanthou (eeac@leeds.ac.uk)

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Figure S1. Latitude vs. pressure climatology (1980-2009) of the annual mean \overline{w}^* for the extra REF-C1 simulations (GEOSCCM, NIWA-UKCA, ULAQ-CCM).



Figure S2: Vertical profiles of climatological turnaround latitudes in the stratosphere for the MMM of the REF-C1 runs (MMM-C1) analyzed in the manuscript along with the extra REF-C1 GEOSCCM, NIWA-UKCA, ULAQ-CCM model results for Southern Hemisphere (a) and Northern Hemisphere (b).



Figure S3. Mean strength of annual mean \overline{w}^* [mm s⁻¹] at 70 hPa for the MMM of the REF-C1 runs (MMM-C1) analyzed in the manuscript along with the extra REF-C1 GEOSCCM, NIWA-UKCA, ULAQ-CCM model simulations.



Figure S4. Vertical profiles of climatological (1980-2009) tropical upward mass flux $[x10^9 \text{ kg s}^{-1}]$ averaged between the turnaround latitudes for the MMM of the REF-C1 runs (MMM-C1) analyzed in the manuscript along with the extra REF-C1 GEOSCCM, NIWA-UKCA, ULAQ-CCM model results.



Figure S5. Climatological annual cycle in \overline{w}^* [mm s⁻¹] at 70 hPa for the extra REF-C1 GEOSCCM, NIWA-UKCA, ULAQ-CCM model simulations.



Figure S6. Regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for all available REF-C1 CCSRNIES-MIROC3.2 ensemble members.



Figure S7. Regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for all available REF-C1 CESM1-WACCM ensemble members.



Figure S8. Regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for all available REF-C1 CMAM ensemble members. Note that CMAM does not simulate a QBO hence the QBO terms were omitted.



Figure S9. Regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for all available REF-C1 SOCOL ensemble members.



Figure S10: Latitude vs pressure cross sections of the stratosphere showing absolute \overline{w}^* differences between the 7 REF-C1SD simulations and the respective reanalysis they were nudged towards to. Stippling denotes statistical significance at the 95% confidence level. The turnaround latitudes of the respective reanalysis are overlaid with green-yellow lines.



Figure S11. Tropical upward mass flux at 10 hPa (left bars) along with downward control calculations (right bars) showing contributions from EPFD (dark grey), OGW (mid-grey), and NOGW (light grey) for (a) REF-C1 and (b) REF-C1SD. For CMAM the NOGWD contributes negatively to TUMF and is indicated with two red horizontal lines inside the lighter grey bar.



Figure S12: Climatological annual cycle \overline{w}^* differences at 70 hPa between the 7 REF-C1SD simulations and the respective reanalysis they were nudged towards to. Stippling denotes statistical significance at the 95% confidence level. The turnaround latitudes of the respective reanalysis are overlaid with green-yellow lines.



Figure S13. Partial regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for REF-C1 simulations.



Figure S14. Partial regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for REF-C1SD simulations.



Figure S15. Timeseries for the reanalysis datasets of the components of the annual mean tropical upward mass flux attributed to (a) volcanic aerosol, (b) ENSO, (c) linear trend, (d, e) the QBO, and (f) the residuals from the mass flux timeseries and that reconstructed from the MLR.



Figure S16. Partial regression coefficients of each regressor ± 2 standard errors and R² values output from the MLR on the TUMF at 70 hPa for the reanalysis datasets.



Figure S17. Trend sensitivity plots of the mass flux at 70 hPa linear trend per decade (values with statistical significance are stippled) over period 1980-2009 for the reanalysis datasets.