

# Supporting Information for “A Zonally-Averaged Global Atmospheric Transport Model for Long-lived Trace Gases”

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## Text S1 Further description of advective scheme

Here we detail more explicitly the approach to the advective scheme used. Using a time step of 8 hours the Courant number does not exceed one, therefore the semi-Lagrangian extension in Lin and Rood (1996) is not needed, i.e., we only use the fraction flux component and not the integer flux component. The steps taken in order to advect the tracer are:

1. Calculate the Courant number for both the vertical and horizontal winds.

2. Define the input tracer fields to the advection scheme (i.e., the vertical and horizontal advection each receive a different tracer field) following equation 3.11 in Lin and Rood (1996).

3. Calculate the slope of the tracer fields using the fourth-order difference, using equation 4.1 from Lin and Rood (1996). The second-order difference is used at the boundaries.

4. The slopes of the tracer fields are monotonised using the constraint presented in equation 5 in Lin, Chao, Sud, and Walker (1994).

5. Fluxes are calculated using the piecewise parabolic method (PPM) (Colella & Woodward, 1984). In order to compute the PPM fluxes, parabolas at the edges of each grid cell must be calculated. These are controlled by the variables  $a_R$ ,  $a_L$  and  $a_6$  from Carpenter, Droegemeier, Woodward, and Hane (1990) (page 589, equations not numbered).

6. Any under- and over-shoots introduced by the calculation of  $a_R$ ,  $a_L$  and  $a_6$  can be eliminated, and we choose the first constraint proposed in Lin and Rood (1996).

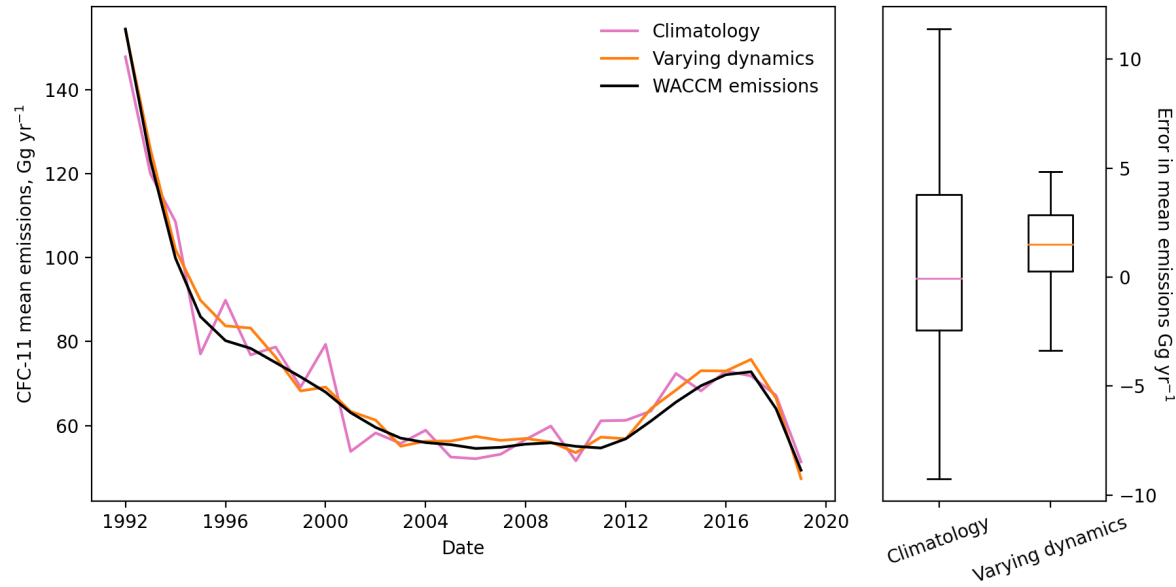
7. Finally, fluxes between grid cells are computed using equations 1.13 and 1.14 from Colella and Woodward (1984).

## References

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**Figure S1.** The mean CFC-11 emissions derived as in the main text using dynamics that vary each month (orange line) or using monthly climatological (1980-2020) transport (pink line). Box plots show the variability in the residual between the WACCM emissions and the mean 2D-model-derived emissions.