Supporting Information for "The Impact of Ozone Production on Future Cold Point Tropopause Warming and Expansion"

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Text S1. Radiative transfer code set-up

The dynamic heating profile above the level of zero radiative heating (LZRH) was taken from the radiative disequilibrium of the ERA5 zonal mean temperatures and was tapered back to observations at 30 hPa to keep the dynamic cooling of deep branch of the BDC fixed, and the water vapor profile in the upper troposphere was set to a fixed relative humidity of 0.4. The stratospheric water vapor concentration was set to the profile's minimum. All other constituents were taken from the base RRTMG profile as described

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in Kluft, Dacie, Buehler, Schmidt, and Stevens (2019). A zenith angle of 57.6 was used (Cronin, 2014), and the calculation was done with no diurnal cycle for 200 d with a timestep of 0.05 d. After reaching equilibrium, the temperature profile near the LZRH was smoothed to reduce jumps in the temperature profile.

References

Abalos, M., Randel, W., Kinnison, D., & Serrano, E. (2013). Quantifying tracer transport in the tropical lower stratosphere using waccm. *Atmospheric Chemistry and Physics*, *13*(21), 10591–10607. doi: 10.5194/acp-13-10591-2013

Cronin, T. W. (2014). On the choice of average solar zenith angle. *Journal of the Atmospheric Sciences*, *71*(8), 2994–3003.

Kluft, L., Dacie, S., Buehler, S. A., Schmidt, H., & Stevens, B. (2019). Re-examining the first climate models: Climate sensitivity of a modern radiative–convective equilibrium model. *Journal of Climate*, *32*(23), 8111–8125. doi: 10.1175/JCLI-D-18-0774.1

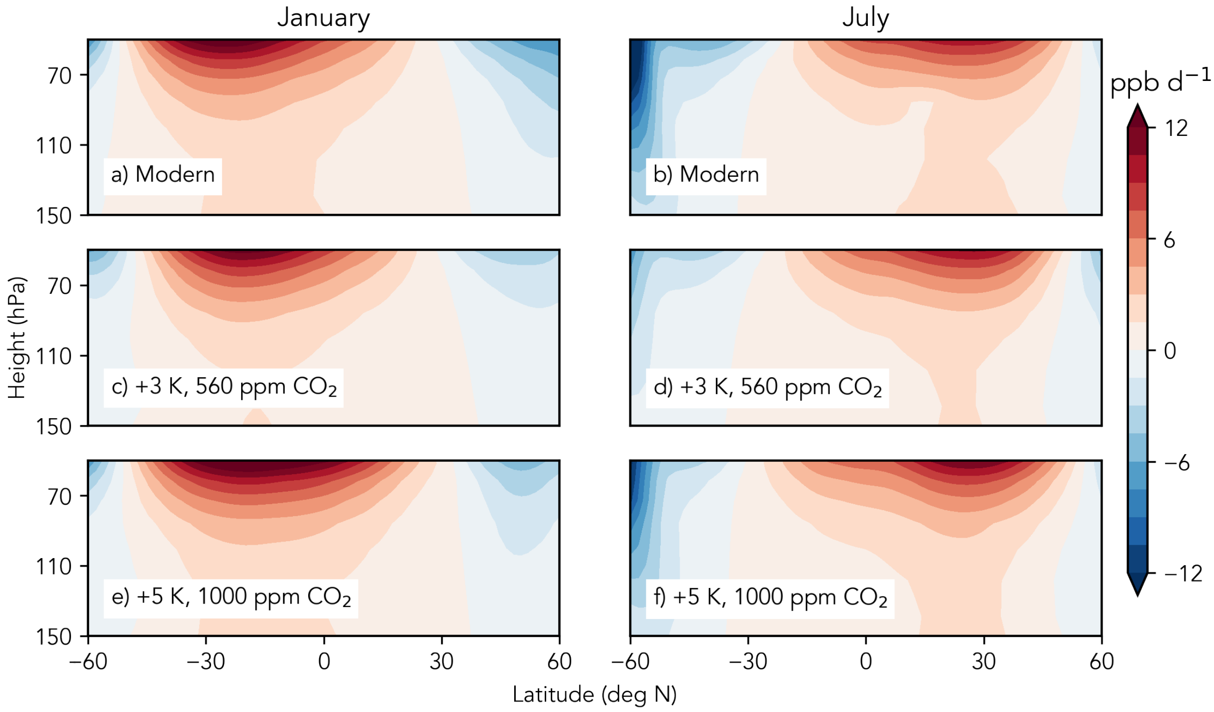

Figure S1. Zonal mean ozone production rates from WACCM January (left column) and July (right column). Modern rates were supplied by Marta Abalos (personal communication) and are described in Abalos et al. (2013). Simulations with increased CO_2 and surface temperatures were run with uniform surface warming.

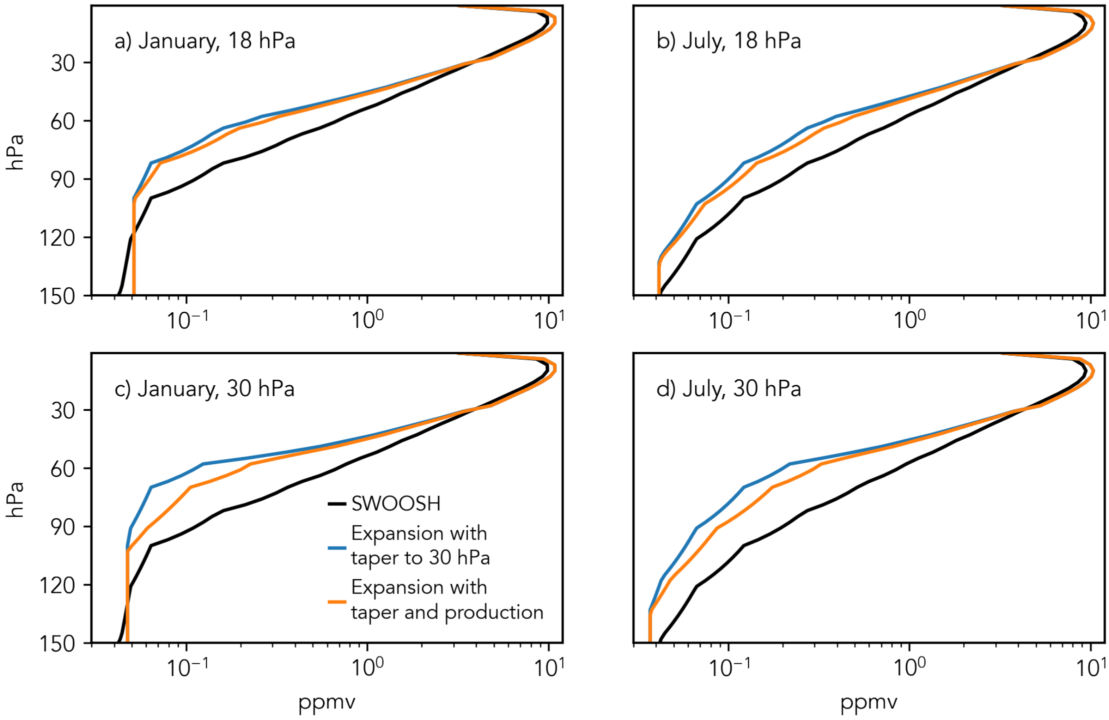

Figure S2. The 2002–2016 mean January and July ozone profile taken from SWOOSH (black line), and ozone profiles following 18 and 30 hPa of tropospheric expansion with and without increased ozone production (orange and blue, respectively). Panel c is the same as Figure 2 in the main text.

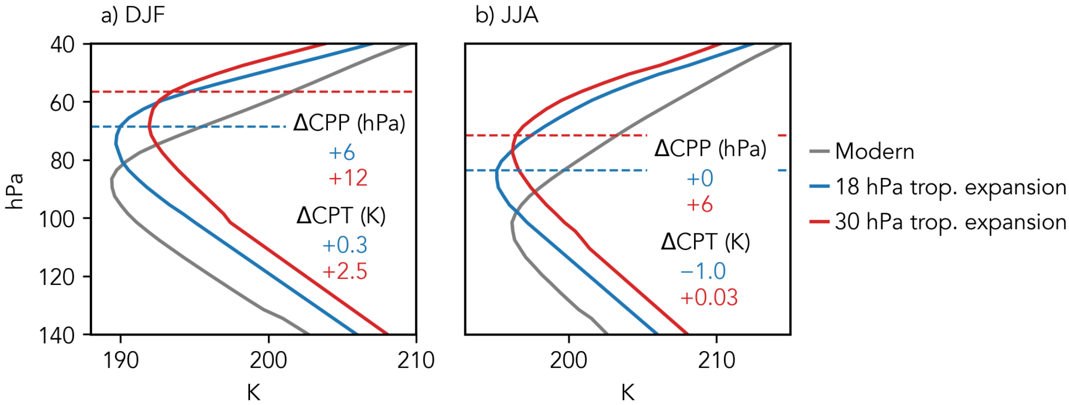

Figure S3. Temperature profiles for 18 hPa (blue) and 30 hPa (red) of tropospheric expansion in (a) DJF and (b) JJA, with the change in cold point temperature and pressure relative to a pure vertical shift listed. 30 hPa profiles are the same as in Figure 3 in the main text. The capping of the cold point tropopause becomes more pronounced as expansion progresses.

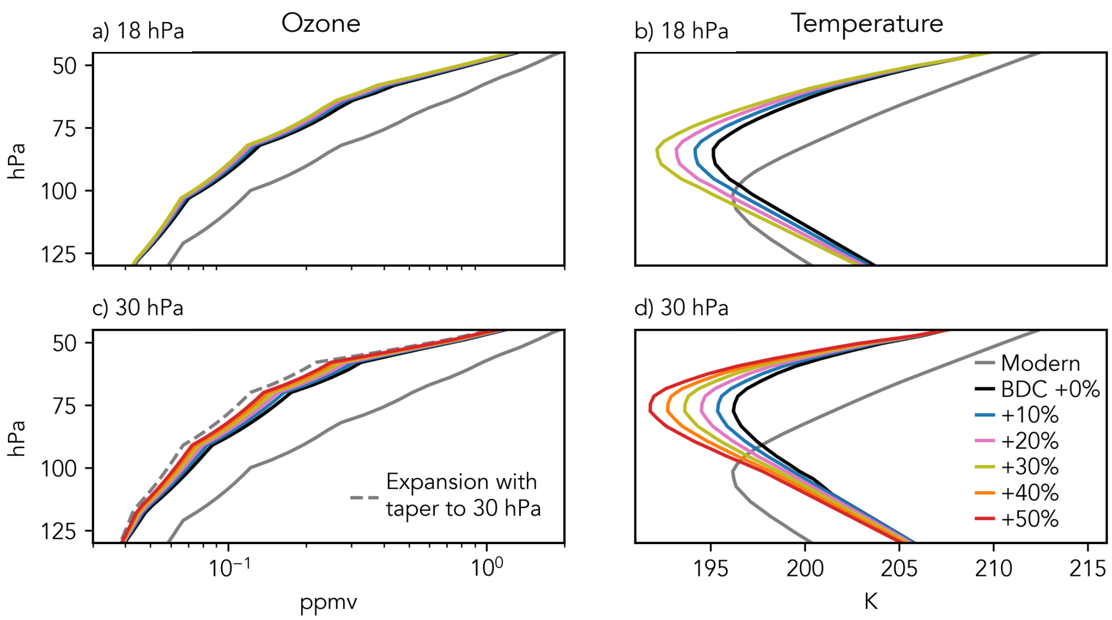

Figure S4. The effects of the BDC strength on lower stratospheric ozone (left column) and temperature (right column) profiles in JJA following 18 hPa (top row) and 30 hPa (bottom row) of tropospheric expansion. Details of the modified ozone profiles and radiative transfer calculations are described in the text, and corresponding profiles for DJF are shown in Figure 4.