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Key drivers of ozone change and its radiative forcing over the 21st century

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Introduction

This text presents additional information to evaluate the updated ozone radiative kernel (O_3 RK) and illustrate in more detail present-day tropospheric ozone (Cnt; year 2000), changes in column ozone and temperature due to the different drivers investigated in this study, and additional sensitivity simulations to further assess the robustness of the results presented in the main manuscript. Tables S1 and S2 present global and annual column ozone changes for the above drivers and period, and additional model simulations used in the main text to explore non-linearities respectively. Figure S1 compares an ozone RF calculated using the O_3 RK technique with the corresponding RF calculated directly with the SOCRATES radiative transfer model, which is based on Edwards and Slingo (1996). Figures S2 and S3 show annual mean tropospheric burden distribution for ozone and stratospheric ozone tracer (O3S) respectively. Finally, Figure S4 shows changes in annual and zonal mean temperature due to climate, lightning, ozone depleting substances (ODSs), and methane over 2000–2100.

Table S1. Global and annual mean ozone columns (DU)[a].

Simulation	Total column	Tropospheric column	Stratospheric column
Cnt	280.6 ± 8.7	28.9 ± 1.5	251.7 ± 8.1
Clm	281.5 ± 9.9	27.7 ± 1.6	253.8 ± 9.3
Ltn	284.2 ± 9.7	29.8 ± 1.7	254.4 ± 9.1
O3r	299.0 ± 9.5	31.2 ± 1.7	267.8 ± 8.8
Mth	308.9 ± 9.5	35.9 ± 1.9	273.0 ± 8.8
Cnt+fLNOx	280.3 ± 8.6	28.4 ± 1.5	251.9 ± 8.1

[a] The annual global mean is given along with the (±) standard error.

Table S2. Additional model simulations

Simulation	Climate[1]	ODSs[2]	CH_4[3]
Clm_Mth	2100 (fLNOx)[4]	2000	2100
Ltn_Mth	2100	2000	2100
O3r_Ods	2000	2100	2000

[1]Climate (sea surface temperatures, sea ice, CO_2 and N_2O, if not otherwise specified) follows the RCP8.5 emissions scenario.

[2]Relative to Cnt, ODS boundary conditions of −63.2 % (2.156 ppb) total chlorine, −35.7 % (8.1 ppt) total bromine and −67.6 % (1.376 ppb) total fluorine follow the halogen scenario A1.

[3]Relative to Cnt, CH_4 boundary conditions of 214.2 % (3744 ppb) follow the RCP8.5 emissions scenario.

[4]Offline lightning-induced NO_x emissions (fLNOx) are imposed by applying a monthly mean climatology of the Cnt simulation.

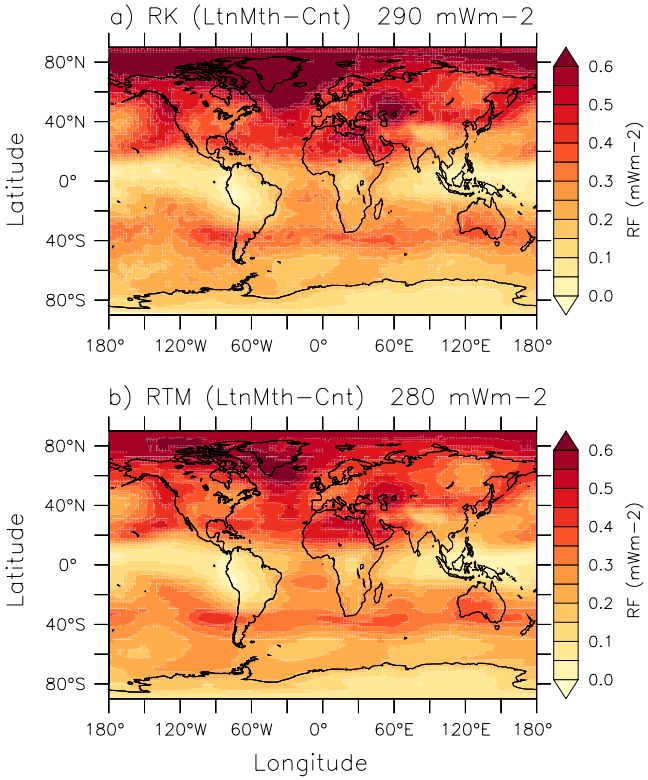

Figure S1. Annual mean maps of net ozone radiative forcing (Ltn_Mth−Cnt) calculated using a) the radiative kernel (RK) technique and b) the SOCRATES radiative transfer model (RTM). The annual and global mean is shown on the top (mWm^{-2}).

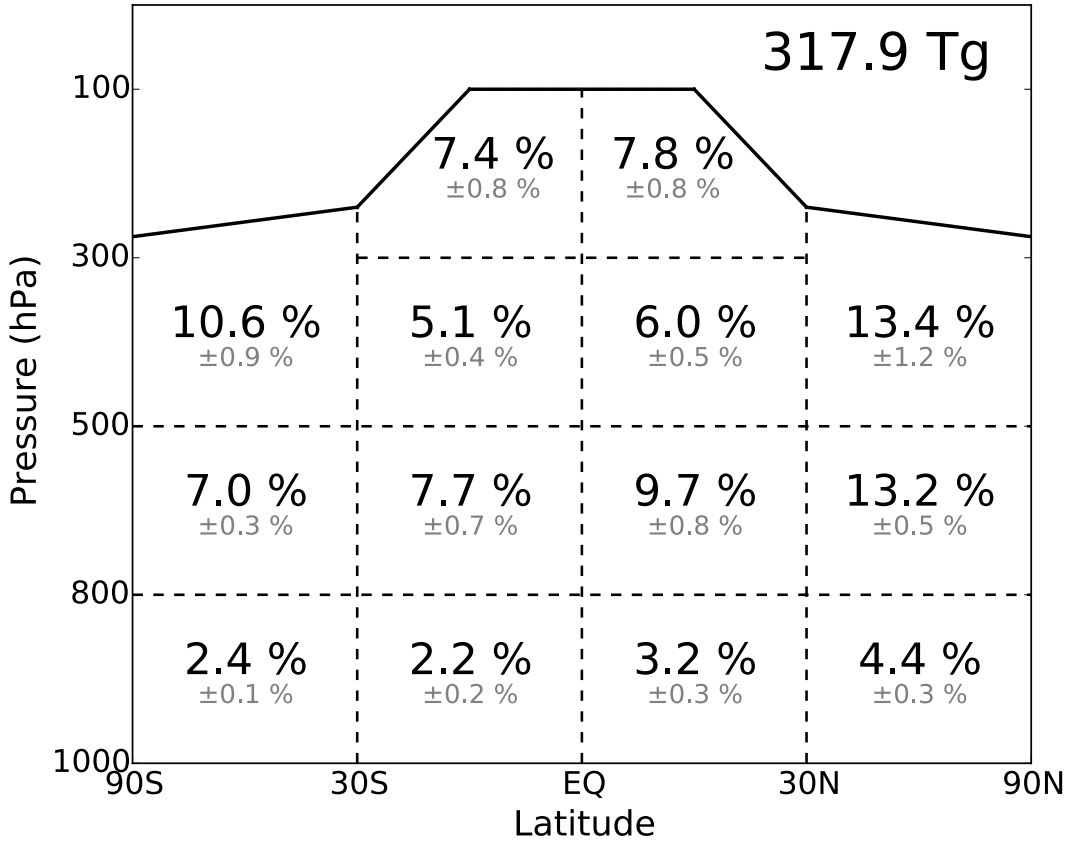

Figure S2. Present-day (Cnt) annual mean tropospheric ozone burden distribution (black) and the ±1 standard deviation (grey), represented by "boxes" (dashed black lines) of approximately equal air masses, as per Young et al. (2013). The tropopause is represented by the black thick line (i.e. regions below 150 ppb ozone levels). The annual and global tropospheric ozone burden mean is shown in the top right corner.

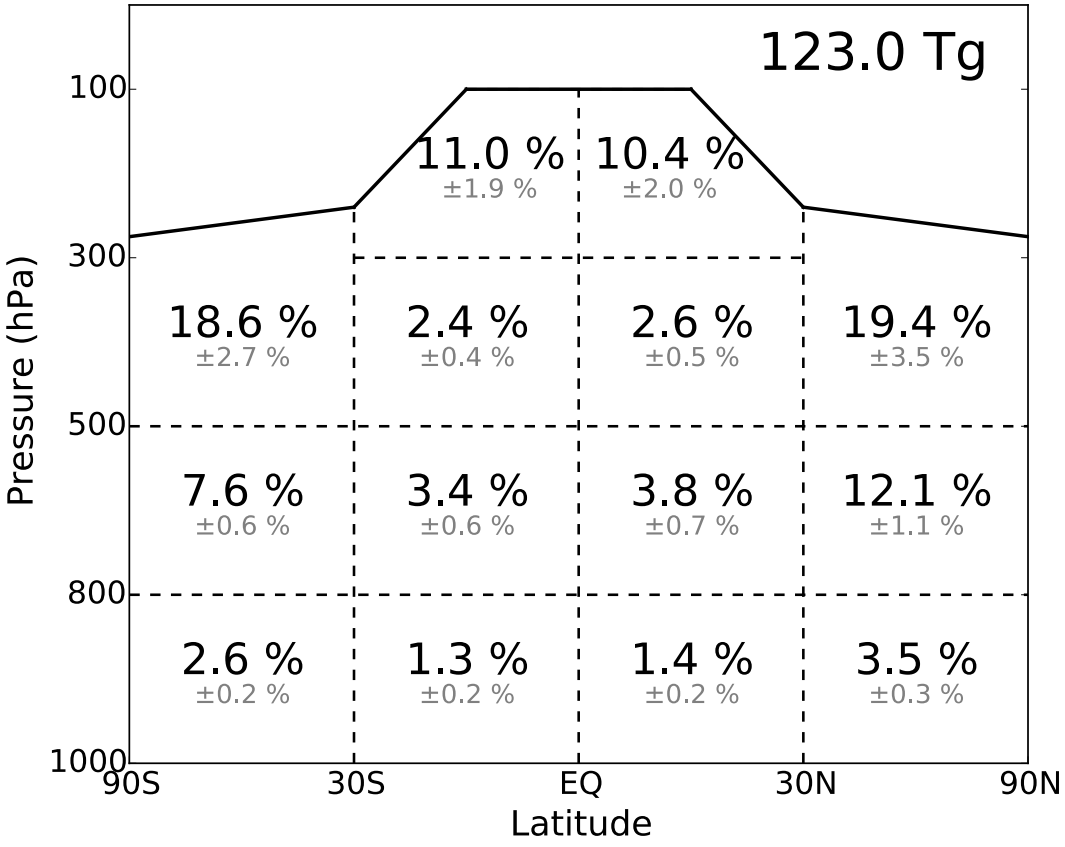

Figure S3. Same as Fig. S2 but for stratospheric ozone tracer (O3S).

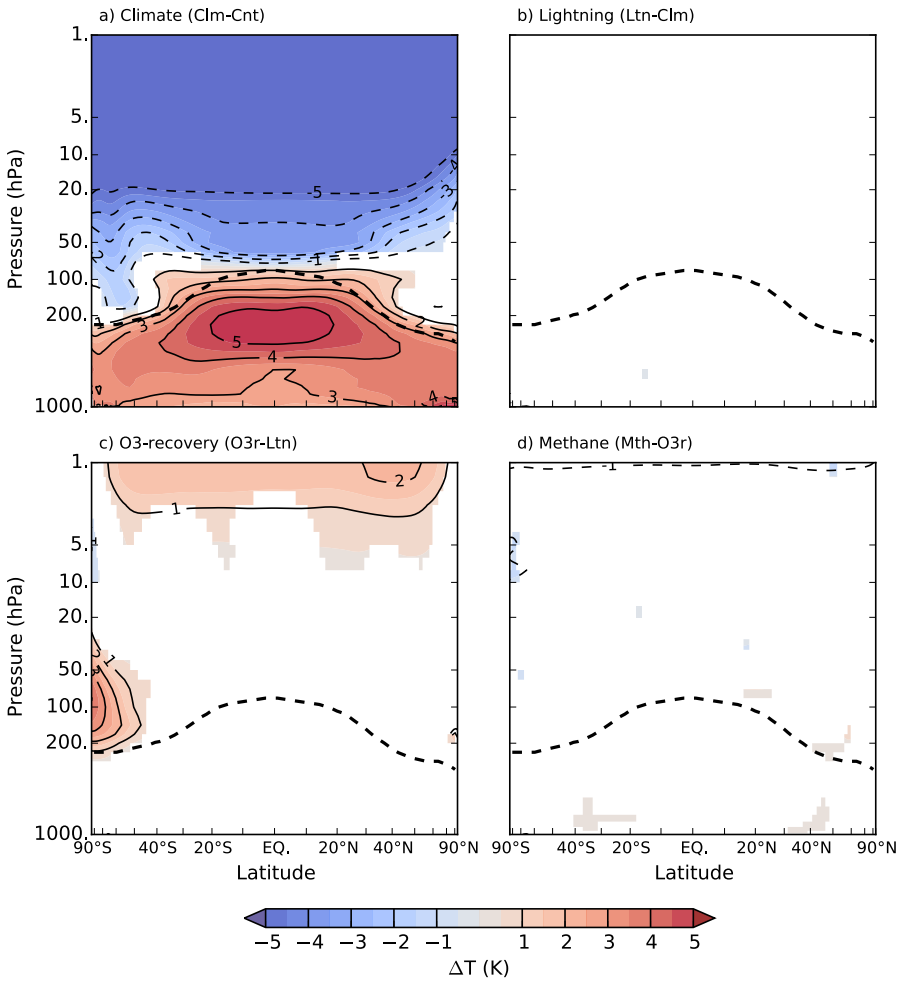

Figure S4. Same as Fig. 3 in the main text, but for temperature (K).

References

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