Detailed reply to the referee remarks on "Radiative forcing and stratospheric ozone changes due to major forest fires and recent volcanic eruptions including Hunga Tonga" (third round)

In the following reviewer remarks are in bold and answers in normal font.

I would like to thank the authors for addressing my comments. I am happy for this paper to be accepted. I have a couple of technical corrections and a minor comment regarding an author response to review listed below.

Line 209: "aginst" to "against"
Corrected.

Figure 4 panel letters are not aligned and partly hidden.
Corrected as far as possible in the graphics software.

Please add y-axis labels to Appendix figures A8 and A9.
Done.

In the author's response letter they state: "A bias (offset) is also in Solomon et al. (2023). An exact agreement cannot expected because of resolution differences and necessary parameterizations with uncertainties.". I understand you can't simulate observation concentrations exactly. The point of the comment (and the original comment in the first review) was that your control run is in good agreement with MLS if you take into account your model bias. It seems this is also true for most years shown from 2017-2023, although I am eyeballing. This relates to the sentence on line 214: "almost complete loss at the edge of the ozone hole in winter 2020 in agreement with MLS (black and red curves), in contrast to the control run (green)". You are comparing MLS minimum values to the control run when the control run never captures the MLS seen minima even in years without fires or Hunga? Your statement might be true if you take into account the bias, but at the least, the wording here needs to be changed to acknowledge that your control run minimums don't agree with MLS in any year and therefore your fire simulations that do agree with the minimums are maybe overdoing the total amount of depletion (at least at 68 hPa, it might be different at other levels and in Figure 8).
We adjusted the respective paragraph as follows:

"Simulated and observed ozone is shown in Fig. 7. The high bias in EMAC lower stratospheric ozone is most likely caused by numerical diffusion and to a small fraction by the underestimated water vapour (Fig. A1) related to a cold bias at the tropical tropopause. In years with weak vortices, numerical diffusion can cause an underestimate of ozone depletion, which is not the case in years with strong vortices (e. g. 2018). Nevertheless, relative effects from fire and volcano emissions can be studied. Here the combined effect of perturbation of

dynamics and chemistry by smoke causes a zonal average decrease of almost 10% in the midlatitude lower stratosphere, almost complete loss at the edge of the ozone hole and complete loss south of 80^{o}S (not shown) in winter 2020 and 2021 in agreement with MLS (black and red curves). In contrast, the remaining ozone in the control run (green) and the run without heterogeneous chemistry on organics (blue) is 0.2 ppmv (80^{o}S) to 0.5 ppmv (72^{o}S) higher. In 2020 the calculated ClO increase near the edge of the Antarctic vortex occurs earlier than in the observations (Fig. 4d) leading to the earlier ozone decrease in Austral fall which reduces the bias between 60 and 80^o S. The effect of Hunga is mostly visible at the vortex edge in October 2022 (b, purple and blue or lightblue curves). Simulated ozone changes are consistent with Solomon et al. (2023), Stone et al. (2025) for the wildfires and Zhang et al. (2024) for Hunga."

The complete ozone loss in the vortex at 80^{o}S is depicted in Fig. 1, which is reproduced by the simulation including wildfires, compared to the control run (green) and the simulation without heterogeneous chemistry on organics (blue).

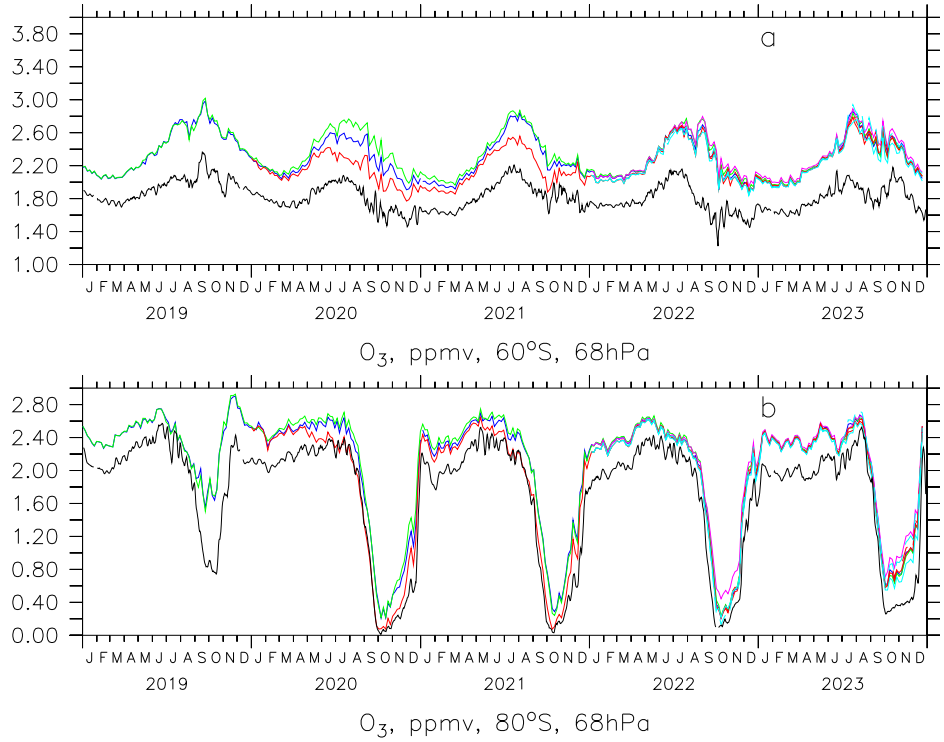

Figure 1: Simulated and observed O_3 at 68 hPa at 60^{o}S (a) and 80^{o}S (b). Legend as in Fig. 7 of the manuscript.

Additionally, we show in Fig. 2 that the model reproduces middle and upper stratospheric and lower mesospheric ozone distributions with latitude

and pressure as observed by MLS, including seasonal effects. Similar figures we have for the other MLS species HCl, ClO, HNO_3 and H_2O mentioned in the manuscript. MLS HCl appears to be high by at least 5% compared to the observed organic chlorine at ground (AGAGE, NOAA).

References

Solomon, S., Stone, K., Yu, P., Murphy, D. M., Kinnison, D., Ravishankara, A. R., and Wang, P.: Chlorine activation and enhanced ozone depletion induced by wildfire aerosol, Nature, 615, 259–264, https://doi.org/10.1038/s41586-022-05683-0, 2023.

Stone, K., Solomon, S., Yu, P., Murphy, D. M., Kinnison, D., and Guan, J.: Two-years of stratospheric chemistry perturbations from the 2019/2020 Australian wildfire smoke, Atmos. Chem. Phys., 25, 7683–7697, https://doi.org/10.5194/acp-25-7683-2025, 2025.

Zhang, J., Kinnison, D., Zhu, Y.and Wang, X., Tilmes, S., Dube, K., and Randel, W.: Chemistry Contribution to Stratospheric Ozone Depletion After the Unprecedented Water-Rich Hunga Tonga Eruption, Geophys. Res. Lett., 51, https://doi.org/10.1029/2023GL105762, 2024.

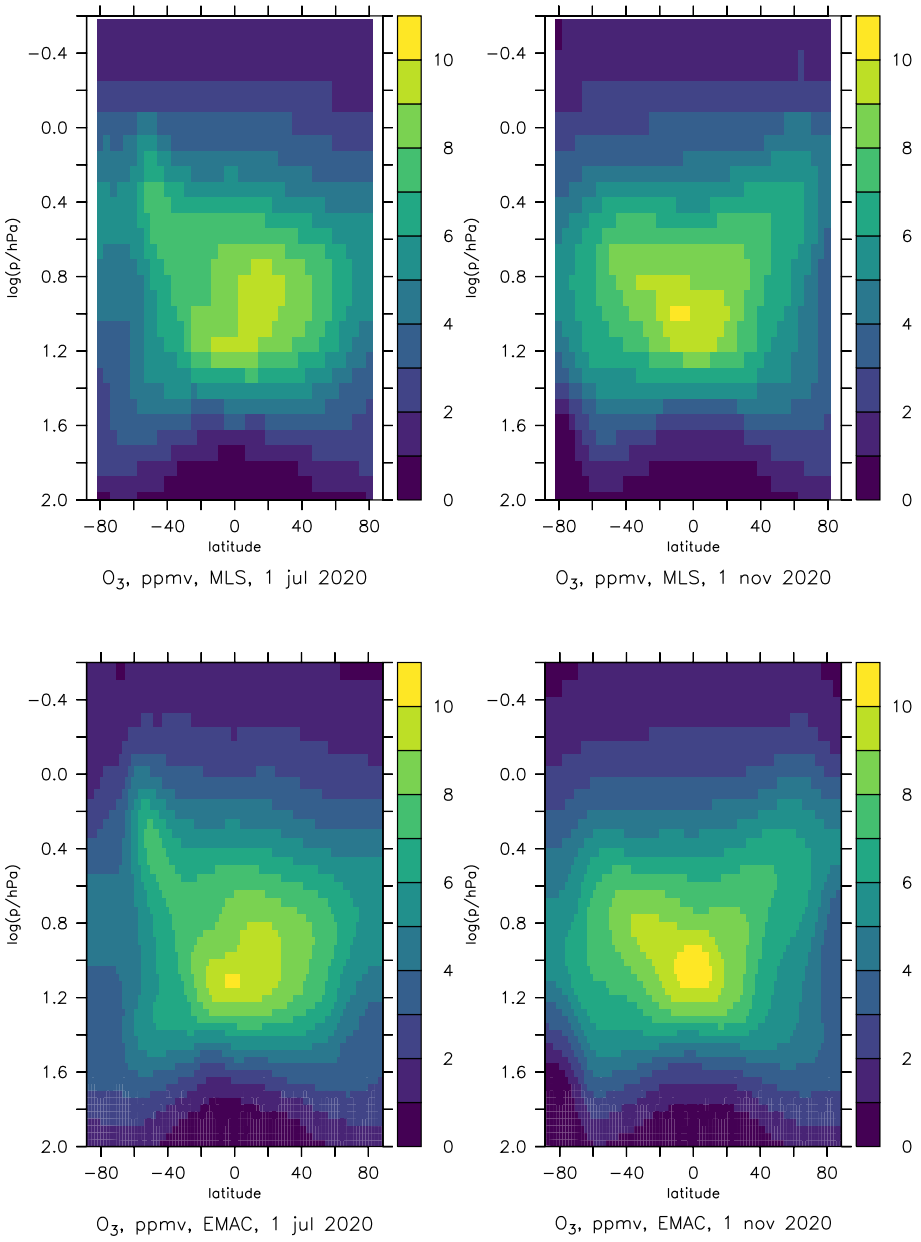

Figure 2: Observed and calculated ozone (5 day averages) at Jul. 1 and Nov. 1 2020.