Dear referee#1,
we thank you very much for your in-depth review of our manuscript egusphere-2024-324. Please find our replies to your comments below. Your original comments are repeated in italics, our replies in normal font, and text passages which we included in the text are in bold.

The study quantifies the contributions of emissions from the transport sector to tropospheric ozone and the hydroxyl radical (OH) using a global chemistry-climate model equipped with a source tagging method. The contributions are estimated for present-day level and several future scenarios.The novelty largely lies in the tagging techniques used to account for the non-linear source contribution to ozone and OH, as well as the analysis of different scenarios, which can provide new insights into controlling emissions from the transport sector. Overall, the study is well-designed and falls within the scope of ACP. I have a few suggestions.

Reply: Thanks a lot for your positive comments and your suggestions. Please find below more detailed responses to your comments and changes in the manuscript.

1.Introduction: The rationale for emphasizing emissions from the transport sector in this study needs to be clarified. Is it due to the large scale of emissions from the transport sector, or is it because these emissions are expected to undergo significant changes in the future and across different scenarios, offering a potential means to mitigate air pollution?

Reply: Thanks for this point. Indeed, the rationale is a combination of both. We added the following explanation in the introduction:

The emissions of the transport sector are an important source of ozone precursors and other species affecting climate and air quality. Due to various efforts in reducing the effect of the transport sector on climate and air quality, for example shifts towards electric vehicles, the emissions of the transport sector will likely undergo large changes in the future. When designing such mitigation measures for the transport sector these non-linear processes in atmospheric chemistry need to be considered.

2. While the EMAC model has been widely used, there is a need for an evaluation of the model results, particularly regarding ozone in the free troposphere, where it has a stronger radiative impact. Additionally, it is important to assess how well the EMAC model captures present-day OH levels and methane lifetime.

Reply: Our model configuration has only minor updates (e.g. more recent model version, changed emissions) compared to the configuration in Jöckel et al. (2016) including a detailed evaluation. We compared some key species with the results of the *RC1SD-base-10a* model simulation as described by Jöckel et al. (2016).

Overall, our analysis shows that the magnitude of the differences between the results of the two simulations is as expected given the different emission inventories. Therefore, we conclude that the detailed evaluation presented by Jöckel et al. (2016) holds also for the simulations analysed in the present manuscript. In addition, we compared upper tropospheric/lower stratospheric ozone simulation results with the SWOOSH data-set. This comparison confirms the known positive bias of ozone in the troposphere. Moreover, we want to stress that our goal was not to use the 'best' available emissions inventory for present day, but to use the CMIP6 emissions inventory in their original form, since model results based on these emissions inventories have been used in many studies.

In the revised manuscript we added a new, rather short, subsection 'Evaluation' and included additional resources in the Supplement.

The added section reads:

The EMAC model has been extensively evaluated in the past. Jöckel et al. (2016) present a detailed evaluation of various atmospheric variables, including tropospheric and stratospheric ozone. From these evaluations we know that EMAC has a positive bias of tropospheric ozone and a negative bias of carbon monoxide. Estimates of the methane lifetime simulated by EMAC are typically at the lower end of the range of values estimated by other models. However, multi-model inter-comparisons show that the biases compared to observational data of EMAC are within the range of those of comparable models (Naik et al., 2013; Stevenson et al., 2013; Voulgarakis et al., 2013; Young et al., 2013).
Given these extensive previous evaluation efforts, we reduce the evaluation of our model results to a minimum. In a first step we compare the ozone mixing ratios of the results from our PD simulation with the results of the *RC1SD-base-10a* simulation discussed by Jöckel et al. (2016). The set-up of both simulations are very similar, despite changes of the emission inventories, small updates and bug-fixes in the model infrastructure, and the fact that we simulate more recent years. Ozone is larger by 2−4 nmol mol^{-1} **in PD compared to *RC1SD-base-10a* in the extra-tropical lower and middle troposphere. In the extra-tropical free troposphere the difference between the two simulation is slightly larger, reaching up to 8** nmol mol^{-1}**. In the tropical troposphere the difference range between -2−2** nmol mol^{-1}**. Overall, the change is lower than 8 % with the largest increase in the Southern Hemisphere, dominated by the variability of the polar vortex. Figures of the comparison of ozone and of further trace gases are provided in the Supplement (see Supplement Sect. S10). From this analysis we conclude that the extensive evaluation presented by Jöckel et al. (2016) remains valid.**
In addition, we compared the simulated ozone mixing ratios in the

upper troposphere and lower stratosphere (UTLS) with Satellite measurements published as the Stratospheric Water and OzOne Satellite Homogenized dataset (SWOOSH) by Davis et al. (2016). The SWOOSH data are a homogenized, gridded, monthly-mean data set for ozone and water vapour based on several satellite data. For the considered period the data set is based on Aura MLS. We used the SWOOSH data in version 2.6 with a horizontal resolution of 2.5° and 31 vertical levels. Horizontally, the SWOOSH data are interpolated onto the slightly coarser EMAC grid, vertically the data are interpolated onto the much coarser SWOOSH grid similar as by Pletzer and Grewe (2024). The monthly-mean SWOOSH data are compared with monthly-mean data from the model, meaning that satellite data and model data are not co-located in space and time. Averaging Kernels of the Satellite are not considered, accordingly the satellite data can only be used for a qualitative evaluation. The evaluation is performed for the years 2013−2017.

Figure A1 shows the difference between the ozone mixing ratios of the PD simulation and the SWOOSH data. Overall, the inter-comparison confirms the known bias of simulated ozone, as discussed above, also in the upper troposphere. We would like to stress that the results can only be used for qualitative evaluation (i.e. confirming the ozone bias), as neither averaging kernels are used, nor are the data spatially and temporally co-located. Moreover, the number of considered years are very limited and we found that the magnitude and location of the peak of the upper tropospheric ozone bias strongly depends on the approach used for vertical remapping due to the limited vertical resolution of SWOOSH. For a detailed quantitative evaluation of UTLS ozone we refer to previous inter-comparisons for example with the IAGOS (in-situ measurements on board passenger aircraft) measurements presented by Jöckel et al. (2016); Pletzer et al. (2022); Cohen et al. (2024).

3. Figure 10 is an excellent illustration of the non-linear nature of ozone chemistry and the higher ozone production efficiency from aviation emissions. Would it be feasible to perform a comparable calculation for the radiative efficiency from land transport and aviation? Can we expect that aviation-emitted NOx has a significantly higher radiative efficiency, as indicated by Wang et al. (2022)? Wang, H., et al. Global tropospheric ozone trends, attributions, and radiative impacts in 1995–2017: an integrated analysis using aircraft (IAGOS) observations, ozonesonde, and multi-decadal chemical model simulations, Atmos. Chem. Phys., 22, 13753–13782,

Reply: We are not sure if we understand your comment correctly. We do analyse the radiative efficiency in Sect. 5.1 for both, the land transport and the aviation sectors. However, Wang et al. (2022) investigated ozone changes, whereas we are analysing contributions for a specific year. Hence a direct intercomparison is

difficult. Figure 11 shows that aviation radiative forcing (RF) is around 25-50% of the RF from land transport, whereas Figure 12 clearly indicates that the RF efficiency, e.g. for PD, is roughly 2.5 to 5 times larger than for land transport, which seems to be consistent with Wang et al. (2022) and also Dahlmann et al. (2011).

4. Section 4: While the impacts of NOx and ozone on OH are discussed (Line 535), changes in CO and VOCs emissions also influence OH and methane lifetime, yet they are not addressed in this section. This discussion should be included.

Reply: Of course, changes of emissions of CO, VOCs, etc. also affect the methane lifetime. We clarified our statement. The changed paragraph reads:

Accordingly, increases of the NO_x emissions from land transport lead to an increase of OH^{TRA} and vice versa. **Besides the changes of** NO_x**, also changes of the** VOC **or** CO **emissions will affect OH. Contributions of land transport emissions to** CO **and** VOC **are, however, not analysed in detail in the present study, because it is beyond the scope of the present study.**

5. Figure caption in Figure 1: "Please not" should be "please note"?

Reply: Indeed, thanks!

References

Cohen, Y., Hauglustaine, D., Bellouin, N., Lund, M. T., Matthes, S., Skowron, A., Thor, R., Bundke, U., Petzold, A., Rohs, S., Thouret, V., Zahn, A., and Ziereis, H.: Multi-model assessment of climatologies in the upper troposphere–lower stratosphere using the IAGOS data, EGUsphere, 2024, 1–64, https://doi.org/10.5194/egusphere-2024-2208, 2024.

Dahlmann, K., Grewe, V., Ponater, M., and Matthes, S.: Quantifying the contributions of individual NOx sources to the trend in ozone radiative forcing, Atmos. Environ., 45, 2860–2868, https://doi.org/http://dx.doi.org/10.1016/j.atmosenv.2011.02.071, 2011.

Davis, S. M., Rosenlof, K. H., Hassler, B., Hurst, D. F., Read, W. G., Vömel, H., Selkirk, H., Fujiwara, M., and Damadeo, R.: The Stratospheric Water and Ozone Satellite Homogenized (SWOOSH) database: a long-term database for climate studies, Earth System Science Data, 8, 461–490, https://doi.org/10.5194/essd-8-461-2016, 2016.

Jöckel, P., Tost, H., Pozzer, A., Kunze, M., Kirner, O., Brenninkmeijer, C. A. M., Brinkop, S., Cai, D. S., Dyroff, C., Eckstein, J., Frank, F., Garny, H.,

Gottschaldt, K.-D., Graf, P., Grewe, V., Kerkweg, A., Kern, B., Matthes, S., Mertens, M., Meul, S., Neumaier, M., Nützel, M., Oberländer-Hayn, S., Ruhnke, R., Runde, T., Sander, R., Scharffe, D., and Zahn, A.: Earth System Chemistry integrated Modelling (ESCiMo) with the Modular Earth Submodel System (MESSy) version 2.51, Geosci. Model Dev., 9, 1153–1200, https://doi.org/10.5194/gmd-9-1153-2016, 2016.

Naik, V., Voulgarakis, A., Fiore, A. M., Horowitz, L. W., Lamarque, J.-F., Lin, M., Prather, M. J., Young, P. J., Bergmann, D., Cameron-Smith, P. J., Cionni, I., Collins, W. J., Dalsøren, S. B., Doherty, R., Eyring, V., Faluvegi, G., Folberth, G. A., Josse, B., Lee, Y. H., MacKenzie, I. A., Nagashima, T., van Noije, T. P. C., Plummer, D. A., Righi, M., Rumbold, S. T., Skeie, R., Shindell, D. T., Stevenson, D. S., Strode, S., Sudo, K., Szopa, S., and Zeng, G.: Preindustrial to present-day changes in tropospheric hydroxyl radical and methane lifetime from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP), Atmospheric Chemistry and Physics, 13, 5277–5298, https://doi.org/10.5194/acp-13-5277-2013, 2013.

Pletzer, J. and Grewe, V.: Sensitivities of atmospheric composition and climate to altitude and latitude of hypersonic aircraft emissions, Atmospheric Chemistry and Physics, 24, 1743–1775, https://doi.org/10.5194/acp-24-1743-2024, 2024.

Pletzer, J., Hauglustaine, D., Cohen, Y., Jöckel, P., and Grewe, V.: The climate impact of hydrogen-powered hypersonic transport, Atmospheric Chemistry and Physics, 22, 14 323–14 354, https://doi.org/10.5194/acp-22-14323-2022, 2022.

Stevenson, D. S., Young, P. J., Naik, V., Lamarque, J.-F., Shindell, D. T., Voulgarakis, A., Skeie, R. B., Dalsoren, S. B., Myhre, G., Berntsen, T. K., Folberth, G. A., Rumbold, S. T., Collins, W. J., MacKenzie, I. A., Doherty, R. M., Zeng, G., van Noije, T. P. C., Strunk, A., Bergmann, D., Cameron-Smith, P., Plummer, D. A., Strode, S. A., Horowitz, L., Lee, Y. H., Szopa, S., Sudo, K., Nagashima, T., Josse, B., Cionni, I., Righi, M., Eyring, V., Conley, A., Bowman, K. W., Wild, O., and Archibald, A.: Tropospheric ozone changes, radiative forcing and attribution to emissions in the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP), Atmospheric Chemistry and Physics, 13, 3063–3085, https://doi.org/10.5194/acp-13-3063-2013, 2013.

Voulgarakis, A., Naik, V., Lamarque, J.-F., Shindell, D. T., Young, P. J., Prather, M. J., Wild, O., Field, R. D., Bergmann, D., Cameron-Smith, P., Cionni, I., Collins, W. J., Dalsøren, S. B., Doherty, R. M., Eyring, V., Faluvegi, G., Folberth, G. A., Horowitz, L. W., Josse, B., MacKenzie, I. A., Nagashima, T., Plummer, D. A., Righi, M., Rumbold, S. T., Stevenson, D. S., Strode, S. A., Sudo, K., Szopa, S., and Zeng, G.: Analysis of present day and future OH and methane lifetime in the ACCMIP simulations, Atmospheric

Chemistry and Physics, 13, 2563–2587, https://doi.org/10.5194/acp-13-2563-2013, 2013.

Wang, H., Lu, X., Jacob, D. J., Cooper, O. R., Chang, K.-L., Li, K., Gao, M., Liu, Y., Sheng, B., Wu, K., Wu, T., Zhang, J., Sauvage, B., Nédélec, P., Blot, R., and Fan, S.: Global tropospheric ozone trends, attributions, and radiative impacts in 1995–2017: an integrated analysis using aircraft (IAGOS) observations, ozonesonde, and multi-decadal chemical model simulations, Atmospheric Chemistry and Physics, 22, 13 753–13 782, https://doi.org/10.5194/acp-22-13753-2022, 2022.

Young, P. J., Archibald, A. T., Bowman, K. W., Lamarque, J.-F., Naik, V., Stevenson, D. S., Tilmes, S., Voulgarakis, A., Wild, O., Bergmann, D., Cameron-Smith, P., Cionni, I., Collins, W. J., Dalsøren, S. B., Doherty, R. M., Eyring, V., Faluvegi, G., Horowitz, L. W., Josse, B., Lee, Y. H., MacKenzie, I. A., Nagashima, T., Plummer, D. A., Righi, M., Rumbold, S. T., Skeie, R. B., Shindell, D. T., Strode, S. A., Sudo, K., Szopa, S., and Zeng, G.: Pre-industrial to end 21st century projections of tropospheric ozone from the Atmospheric Chemistry and Climate Model Intercomparison Project (ACCMIP), Atmos. Chem. Phys., 13, 2063–2090, https://doi.org/10.5194/acp-13-2063-2013, 2013.