

Authors' response

To acp-2021-527-RC1 (29 Jul 2021): We thank anonymous referee #1 for their constructive comments and very positive review. We will address the specific comments in detail in our final revision of the manuscript. Here, we shall give a brief response to questions where it seems appropriate. We have already tended to the minor, technical comments.

Specific comments

- The title suggests a specific focus on biome modeling and ozone risk mapping which is also properly introduced in the Introduction section. However, throughout the rest of the manuscript this focus is lost and is shifted towards a quantitative assessment of the reanalysis products and the gap-filling method with minor discussion points on the further implication on biome modeling and ozone risk mapping. I suggest the authors to revise the title or to, preferably, put additional effort in quantifying the effects of the use of these different reanalysis products (and also gap-filling techniques) on biome modeling. For example: This manuscript shows that the representation of CAMSRA is poor in winter, but good in summer which coincides with the growing season and maximum in ozone uptake (e.g. Hayes et al. (2019)). The resulting effect on integrated flux quantities such as POD_y might therefore be limited. Thank you for your suggestion, we will address the implications on integrated ozone flux quantities more thoroughly in our discussions and conclusions in the final revision of the manuscript. We consider consulting Fig. 4 to consolidate implications on the biome (spatial) level.
- It is unclear why specifically these 3 ozone reanalysis products have been chosen to include in this study and other tropospheric ozone reanalysis products such as TCR-2 or JRA-55 have been excluded. See for example Huijnen et al. (2020) and Park et al. (2020) for global and regional application of these reanalysis products including comparisons with CAMSRA respectively. Especially the use of the MACC reanalysis data is questionable. This product has already been identified as less accurate compared to CAMSRA in other studies (e.g. Inness et al. (2019)) and is, as far as I am aware, not supported anymore because it is replaced by the CAMSRA system. Thank you for pointing these out. We will elaborate on our choice in the appropriate section.

The inclusion of the MACC reanalysis has historical reasons. The MACC reanalysis is still well known in the wider community. Although its lower accuracy compared to CAMSRA has been recently shown. To assess whether and how the improvements to the CAMS assimilation system affect the reanalysis results in our focus area, we kept the analysis of the MACC reanalysis after switching to the newer CAMSRA as it became available. CAMSRAQ has been specifically chosen to test whether a higher spatiotemporal resolution will also show better results in our focus area. The more general inter-comparison studies (eg. Huijnen et al. (2020)) did not look into the seasonal cycle in detail but compared sea-

sonal averages. These seasonal averages, however, suggest a similar performance of CAMSRA and TRC-2 in our focus area, therefore we assume our selection to be representative for the state-of-the-art global reanalysis products.

Thank you for pointing out the comprehensive JRA-55 reanalysis which is very interesting in terms of climatological studies due to its length. With a horizontal resolution of T319 it may not perform substantially better than CAMSRA. As we have shown, only the regional reanalysis ensemble (CAMSRAQ) performs reasonably well through all seasons. Furthermore, according to the JRA-55 handbook (Section 4.1.10 and 5.1) the atmospheric mixing ratios of ozone are only available in 6-hourly temporal resolution and interpolated to pressure levels (e.g. 1000 hPa). Both disqualify the JRA-55 as substitution for observational data in our case, because the computation of POD_y requires 1-hourly $[O_3]$ input.

- For CAMSRAQ, the period of 2014-2018 is used to compute the daily mean ozone climatologies compared to the period 2003-2012 for the MACC and CAMSRA products. The authors should discuss if and how this relatively short period affects the computed climatologies (also with respect to observations which cover an even longer period) also considering the anomalous summer of 2018 as the authors show in their Fig. 6b. Thank you for pointing this out. We will elaborate on this in the final revision.

The length of the CAMSRAQ is indeed too short to compute a reliable climatology in a purely statistical sense, though interannual variability in the reanalysis may be considered to be somewhat lower than in actual ground-level observations (e.g., systematic errors in instruments). In statistical terms, a systematic underestimation of the CAMSRAQ cannot be demonstrated, only suggested. Assuming that background ozone concentrations are indeed increasing, the reanalysis based climatologies are biased towards higher annual average ozone concentrations at ground-level than the observational climatologies. This does not affect the main issue of the global reanalyses not reproducing the seasonal cycle.

- In the results Section the authors show the divergence of reanalysis products from generalized ozone climatology for northern Fennoscandia spatially (Fig. 4 and accompanied text in line 167-179). The main analysis of this subsection mainly focuses on the seasonal skill scores (from RMSE) which can also be derived from Fig. 3, rather than the spatial patterns in the divergence. Furthermore, the need for presenting these spatial patterns appears to be limited also because they do not play a prominent (if any) role in the Abstract and Conclusions. The authors should more strongly motivate and discuss these spatial patterns or remove Fig. 4 and combine the text with the analysis presented in line 147-166. Thank you for your suggestions. We may consider removing Fig. 4 and combine the text as suggested or use it for elaborate on the implication of our findings on biome (spatial) level.

Minor comments

- page 1, line 1: “regional or global” → “regional and global”. We follow the suggestion.
- page 3, line 74: “such as a” → “such as”. We follow the suggestion.
- page 6, Fig. 2 label: “6.6. ppb” → “6.6 ppb”. We corrected the typo.
- page 6, Fig. 2 label: “The magnitude ... late summer”. In my opinion this does not belong in a label also because it is repeated in the main text. We follow the advice and remove the additional information in the caption.
- page 6, line 140: “In the following”. Add subject. ?
- page 7, line 146: “ozone reanalysis product” → “ozone reanalysis products” We fix this typo.
- page 7, line 161: “This indicates an insufficient vertical resolution of these models”. What is the vertical resolution of these datasets (e.g. the height of the surface layer)? To be included in the methods (Table 2). We update Table 2 accordingly. MACC and CAMSRA vertical levels amount to 60 levels and are the same as for Integrated Forecast System (IFS); the level thickness at surface is 10 m. For CAMSRAQ, the vertical levels vary for each ensemble member, data is given at the actual surface level.
- page 7, line 166: “observation” → “observations” or “observed”. We correct the spelling to *observations*.
- page 8, Fig. 3: I suggest using same xticks as in Fig. 2 for better comparison between the two. We adjust the xticks as suggested and update the figure in the next revision of our manuscript.
- page 8, Fig. 3 label: “The global ... low [O₃].” . In my opinion this does not belong in a label also because it is repeated in the main text. We follow the advice and remove the text from the caption.
- page 8, line 167: The term “tropospheric ozone background” has been used throughout the manuscript (at multiple instances before and after this line). As this study deals with the ground-level ozone climatology I ask the authors to consider the terminology “ground-level ozone background” to avoid ambiguity. Thank you for pointing this out. We have changed the term as suggested through out the manuscript.
- page 9, Fig. 4: The colorbar-label is cut off. For (a) and (b) also the xlabel “Longitude” is cut off just short. For all other Figures the sublabels are located above the panel while for this Figure they are located below the panel. Furthermore, the labels could benefit from some extra dpi if possible. As suggested by the referee, we consider removing this figure from the manuscript.

- page 10, line 183-185: “given in ... of ppb”. Can be removed. We remove these sentences, as suggested.
- page 12, line 233: Remove closing bracket. Done.
- page 12, line 236: “an RMSE” → “a RMSE”. Done.
- page 12, line 239: “Conclusions” → “Discussion & Conclusions”. Done.