Authors' Response to Editor's Report

Changes of Anthropogenic Precursor Emissions Drive Shifts of Ozone Seasonal Cycle throughout Northern Midlatitude Troposphere

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We are grateful to the editor and to the referees for the time and effort that they invested in their second reviews of our paper. This response has been prepared in consultation with all coauthors.

Editor's Report

Comments to the author:

Dear authors,

your revised submission have been re-evaluated by the reviewers. While many points have been adequately addressed, in particular referee 1 suggested that the issue of discussing possible reasons for discrepancies of model results is still not sufficiently addressed, and pointed to several co-authors on the author list should have this expertise. Referee 2 in a comment to the editor referred to a 'missed opportunity'. I therefore suggest that you integrate a paragraph on reasons for mismatch of model and observations trends into this paper. While I do not expect original new research, a reflection on model evaluations as found in the literature, and what it means for the subject of this paper would enrich the paper. I am looking forward to receive your revised manuscript.

Author's response

We are grateful for the suggestion. The last paragraph of our paper has been modified as indicated below, and an additional reference has been added. New discussion integrated into the new paragraph is indicated in red text:

The seasonal cycle of ozone reflects the annual variability of the sources and sinks of ozone; thus its accurate simulation is expected to present a stringent test for models. Given the paucity of the observational ozone record, both spatially but more importantly temporally, improved confidence in our understanding of changes in the seasonal ozone cycle must primarily come from improved agreement between different model simulations. Our analysis has focused on changes in anthropogenic and biomass burning emissions, which were prescribed from the same source to the extent possible for all models; however, there were differences in implementing the prescribed emissions into the models, mainly from VOCs due to individual requirements of the chemistry scheme within each model. In addition, the representation of natural emissions (e.g. biogenic VOCs emitted from vegetation) differed between individual models, giving variation in the natural to anthropogenic emission ratios between models. Thus, remaining differences in emissions between models may cause some of the inter-model differences. More generally, Griffiths et al. (2020) suggest that differences in the simulation of ozone from CMIP6 models could be due to inter-model variations in the treatment of chemical and physical processes including dynamic transport, stratosphere-troposphere exchange, photolysis, deposition, convection and boundary-layer schemes. There is a need to go beyond direct model-observation comparison studies; for example, multi-model perturbed parameter ensembles can be used to intercompare the sensitivity of models to different input parameters and/or parameterizations (Wild et al., 2020). Notably, in this work we document relatively large seasonal cycle shifts that are common to the entire northern midlatitude baseline troposphere; given the magnitude of these shifts, which we attribute to changing precursor emissions, it may be difficult to independently determine the effects of other factors, e.g. changing climate (Fowler et al., 2008; Clifton et al., 2014), on the northern midlatitude ozone seasonal cycle.

Reference not originally cited in manuscript

Wild, O., Voulgarakis, A., O'Connor, F., Lamarque, J.-F., Ryan, E. M., and Lee, L.: Global sensitivity analysis of chemistry–climate model budgets of tropospheric ozone and OH: exploring model diversity, Atmos. Chem. Phys., 20, 4047–4058, https://doi.org/10.5194/acp-20-4047-2020, 2020.