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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Global sensitivity analysis of chemistry-climate model budgets of tropospheric ozone and OH: Exploring model diversity" *by* Oliver Wild et al.

Anonymous Referee #1

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The manuscript presents an analysis of the response of tropospheric ozone and OH to a number of different factors across three different global chemistry models. A number (order 80) of sensitivity experiments varying factors such as specified emissions, deposition rates and atmospheric humidity are specified and Gaussian process emulation is used to extend the model response across the full parameter space. Sensitivity of the model tropospheric ozone burden is found to be dominated by humidity, while two of the three models also show the prescribed variations in humidity also dominate the response of OH. Interestingly, the third model shows almost no response of OH to the imposed variations in humidity and, correspondingly, has a larger variation deriving from other factors such as surface emissions of NOx and isoprene, and lightning NOx.

The manuscript is very well written and the results and conclusions are clearly laid out. The findings of the importance of the effect of water vapour for tropospheric OH and ozone and that one of the three models shows a radically different sensitivity for OH are certainly of great interest to the global chemistry modelling community as the causes of the diversity across models is a long-standing problem. The only significant comment I would have is that given the somewhat arbitrary specifications for some of the ranges over which the different factors are varied, it is very difficult to put these results into context. It is shown that varying water vapour by $\pm$ 50% is the dominant factor affecting ozone and OH, but how does the range of $\pm$ 50% compare to the actual variability across models? While emissions, including lightning NOx, have well defined and regularly discussed ranges across models and other processes such as boundary layer mixing are very poorly constrained, a range for water vapour across models should be more easily quantified and given the importance of the process found here it should be more clearly justified. From a quick look at Figure 7 of Lamarque et al. (Geosci. Model Dev., 6, 179–206, 2013) I think a variation of $\pm$ 50% might be too large.

My other minor comments are given below.

Lines 32: While I understand the need for brevity here, I do find the statement that 'changes in surface O3 since the preindustrial era are systematically underestimated (Stevenson et al., 2013)' to be a bit of an over-simplification of the situation. Recent work under TOAR (Tarasick et al., under review) and work with oxygen isotopes (Yeung et al, Nature, doi:10.1038/s41586-019-1277-1, 2019) have found new reasons why the increase in tropospheric ozone may not be as large as shown by the early surface measurements. I am not suggesting an exhaustive discussion here, but just some acknowledgement that there is uncertainty.

Line 109 – 110: How do you approach increasing wet deposition rates for a species such as HNO3?

Lines 176 – 177: In both Figures 5 and 6 the very different response of OH in GISS to

humidity is highlighted, but because humidity is only displayed as a percentage change relative to the baseline it is not possible to ascertain whether the behaviour of GISS is due to some fundamentally different response of the chemical scheme to water vapour or whether the response is due to the models being in a different part of the parameter space. Given the importance of water vapour, is it possible to provide some absolute comparison of water vapour across the three models? I'll also note that while the full range of NOx emissions are plotted for these two figures, water vapour is only plotted as $\pm$ 20% while the range of the sensitivity experiments is $\pm$ 50%.

Lines 198 – 202: In discussing Figure 7 and the different response of GISS, there is speculation that GISS may have a very different treatment of NOy chemistry because of the more widespread sensitivity to surface NOx and isoprene emission, particularly in the tropics. The quantity plotted here is the percent variance of CH4 loss that can be assigned to each of the different factors. Since water vapour in the GISS model explains almost none of the variance in the tropics, doesn't the variance have to be assigned somewhere else. Is, in some absolute measure, methane loss in the GISS model more sensitive to NOx and isoprene emissions than the other two models or does it only assign more of the response to NOx and isoprene emissions because of the negligible contribution from water vapour?

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