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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 #3

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In this paper, the authors explore the sensitivity of tropospheric ozone and methane lifetime to different factors in three global chemistry-transport models using an emulation process with the goal of identifying the causes of diversity in the model response to changing forcings and climate. This study is an important contribution towards understanding the reasons for model diversity in the evolution of tropospheric ozone and methane lifetime. However, I found that the approach applied here is inadequate to truly understand the reasons for diversity in these non-linear quantities. My main concern (similar to the other two reviewers) is that the sensitivities calculated for each model would depend on the "control" simulation given the non-linear chemistry of ozone and methane. If the models differ in the forcings (meteorology and emissions) to begin

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Discussion paper

with then how do we know that the calculated sensitivity is not due to the initial state. Also, I found the description of the Gaussian emulation approach applied here rather limited to appreciate its usefulness for understanding the reasons for diversity in model response.

Below are some specific comments and suggestions to help strengthen the paper.

L23-25: Clarify if this is referring to controls for climate or air pollution. Controls on NOx emissions in the US (e.g., Clean Air Act) and Europe (e.g., LRTAP) have indeed brought down surface ozone.

L27: Also another ACCMIP paper (Naik et al., 2013) and CCMI models (Zhao et al., 2019 https://www.atmos-chem-phys-discuss.net/acp-2019-281/)

L32: There are large uncertainties in PI estimates of surface ozone as discussed by Tarasick et al. (2019) https://www.elementascience.org/articles/10.1525/elementa.376/

L58: Observational estimates of global ozone are now available from satellites (Gaudel et al. 2019 https://www.elementascience.org/articles/10.1525/elementa.291/). How do the model estimates discussed here compare with satellite estimates?

L100-104: It would help to know how different the base state is in the models. What is the ozone burden, prescribed methane concentration, methane lifetime, surface and lightning NOx emissions, biogenic emissions, wet and dry deposition rates for all species, atmospheric humidity, cloud optical depth, and boundary layer height in the base simulation for all the three models?

L114-115: How are the emulators built for a non-linear system such the O3-NOx-CH4 chemistry? Some description is needed to make the design of emulators transparent for the purpose of this figure.

L142-143: It would be helpful to provide an equation to explain how sensitivity for each variable is determined. As it stands, the process appears too opaque to me.

L151: How different is humidity across the three models for the base run? Is it possible that the three models show large sensitivity of ozone to humidity because such a large (± 50%) perturbation is used? How do the sensitivities for ozone calculated here compare with those calculated by Revell et al. (2018) https://www.atmos-chem-phys.net/18/16155/2018/acp-18-16155-2018.pdf?

L167-169: "and four models showing decreased lifetime" - is the implication here that these four models may have greater sensitivity to humidity and therefore show declining methane lifetime? If so, how do we know that these models are like CAM-chem and FRSGC/UCI CTM in their sensitivities?

L192-194: The chemical loss of methane also depends on the concentration of methane in the models. Are they the same across the models?

L198: How different are the model chemical mechanisms implemented in the models? I would imagine the differences in sensitivities due to NOx are due to the implemented chemical mechanisms.

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