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Interactive comment on "AerChemMIP: Quantifying the effects of chemistry and aerosols in CMIP6" *by* William J. Collins et al.

Anonymous Referee #1

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This manuscript describes the Aerosol Chemistry Model Intercomparison Project (AerChemMIP) - a CMIP6 endorsed MIP. The motivation for this MIP is to quantify the climate forcing and response due to near term climate forcers including tropospheric ozone, aerosols and methane, and N2O in a coordinated manner within the Coupled Model Intercomparison Project (CMIP). Although the contribution of tropospheric aerosols and ozone to climate forcing was recognized since the early 1990s, attribution of climate forcing due to these species within the CMIP framework was not performed until CMIP5. And even within the CMIP5, the radiative forcing due to tropospheric aerosols and ozone was calculated by a combination of methods (offline, double calls) partly because not all models included chemistry-aerosols and partly because all the required diagnostics were not available from CMIP. AerChemMIP represents the first coordinated effort towards quantifying climate forcing and response, and air quality

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impacts from tropospheric aerosols and ozone within the mainstream physical climate model intercomparison project, the CMIP, a major step forward. The manuscript is generally well-written, provides motivation for why modeling centers should participate in this computationally expensive (over 3000 simulation years) MIP, and provides examples of scientific studies that can be conducted beyond the goals of the MIP. However, I note some issues that should be addressed to improve the manuscript.

Given that the multi-model output will be made publicly available for the wider community and users, and the complexity of chemistry-climate models, I suggest indicating that a model documentation/evaluation paper is required for participation in this MIP. This will address two issues - 1) often errors in the submitted data are not revealed until the data is compared against observations; model evaluation and documentation will ensure that the data (or at least the key atmospheric chemistry and aerosol fields) has been looked at before being submitted to the CMIP6 database, 2) each model is unique and data users are not in a position to know the details of all the parameters/processes/chemical schemes that are included in a model; a model documentation paper would be a source of this information.

Some thought needs to be given to the third scientific question that AerChemMIP aims to answer - Can the uncertainties associated with anthropogenic emissions be quantified? Based on section 2.3, it is not clear to me how perturbing emissions by 10% will inform us about the dependence of radiative forcing on anthropogenic emissions. Also, it is not clear why a 10% perturbation is chosen.

Specific and Minor Comments: P1, L3-4: According to Myhre et al (2013), NTCFs are defined as species “whose impact on climate occurs primarily within the first decade after their emissions” and includes methane in addition to ozone, aerosols and their precursors. Suggest revising this sentence to avoid confusion.

P2, L25: Insert “tropospheric” in “...increases in ozone..” and insert “stratospheric in “...decreases in ozone. . .”

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P2, L30: Ozone and O3 are used interchangeably in the text. Recommend sticking with one and specifically "ozone" throughout the manuscript. Same holds for methane.

P3, L3: Please reference a chapter in the IPCC (2014).

P3, L5-7: I am not sure what the authors are trying to convey in this sentence. Is it that the "regional/local" air pollution policies should informed by the projections of air pollutants from CMIP6 models? If so, I am not convinced that this would be possible given the large model diversity in projected atmospheric composition (e.g, Young et al., 2013).

P3. L7-9: This sentence appears to represent an incomplete thought. Please elaborate or cut.

P3, L30: Define the acronym ACCENT here rather than on Page 4, since it is used here for the first time in the text.

P3, L31: This sentence assumes that the relationship between IPCC and CMIP is commonly known. Please clarify how CMIP3 is related to the IPCC Fourth Assessment report.

P4, L11: A few of the newer generation CCMs available now with coupled ocean-atmosphere-chemistry have been documented and can be cited here. For eg., John et al. (2012); Shindell et al. (2013).

P4, L11-13: This sentence is giving short-shrift to the tremendous amount of work done under ACCMIP to assess the performance of CCMs with coupled strat-trop chemistry. The model shortcomings highlighted by ACCMIP studies is being addressed by more detailed analysis within CCMI as noted on http://blogs.reading.ac.uk/ccmi/. Suggest revising this sentence to recognize earlier work regarding the assessment of the performance of CCMs with coupled strat-trop chemistry.

P4, L15-16: I am not sure if the inclusion of time-varying ozone in the climate models has led to an improvement in the climate forcing by stratospheric ozone. What has re-

ally improved since AR4 is the representation of climate forcing by stratospheric ozone in the CMIP5 models. Please revise sentence.

P4, L28-32: Sentence is confusing. Please rephrase.

P4, section 1.2: A key point missing in this section is that the radiative forcings due to short-lived species provided in Myhre et al. (2013) were decoupled from the CMIP5 climate model simulations that provided the basis for IPCC-AR5 chapters on climate change (historical - Bindoff et al., 2013; future - Kirtman et al., 2013; Collins et al. 2013). This made it difficult to relate the temperature responses to radiative forcing due to NTCFs and also to constrain the climate sensitivity. AerchemMIP is designed to fill in this information gap to inform the IPCC-AR6. Suggest adding a sentence to note this point.

P5, L10: CO is the largest sink of OH followed closely by methane . Suggest rephrasing to "...is a dominant sink of the hydroxyl radical (OH), the primary tropospheric oxidizing agent. . ."

P5, L11: References for methane's influence on aerosol oxidation and natural aerosol precursors would be helpful.

P5, L12-13: Methane also influences stratospheric ozone directly by converting reactive chlorine into the reservoir hydrochloric acid HCl (e.g., Pawson et al., 2014).

P5, section 2.1: Diverging multi-model results lead to more questions than answers. An example of model diversity from the multimodel analysis in ACCMIP was the opposing changes in trends in hydroxyl radicals simulated by the models (Naik et al., 2013; Voulgarakis et al., 2013) which did little to alleviate the uncertainty in our understanding of OH trends. Similarly, models that resolve stratospheric chemistry could produce diverging results on the impact of stratospheric ozone depletion on regional climate, reinforcing the uncertainty in our understanding. The issue of diversity in model results should be recognized in the text.

P5, L40: Commas needed after NTCF emissions and CH4.

P6, L5: Need references for SSP3-7.0 scenario. Does this scenario include land-use changes, and if so, do they influence air pollutant emissions?

P6, L15: This in my opinion is the least framed question in the AerchemMIP proposal. It is not clear to me what perturbing emissions by 10% will tell us about the dependence of radiative forcing on uncertainties in anthropogenic emissions. Besides the uncertainty in radiative properties of NTCFs, the uncertainty in the NTCF radiative forcing comes from their spatial and temporal distributions which in turn are a function of their emission estimates. A wide variety of chemistry and physics parameterizations are implemented in CCMs which then lead to diversity in simulated atmospheric composition and therefore radiative forcing, despite implementing the same anthropogenic emissions (e.g., different tropospheric ozone, aerosols, methane lifetimes in ACCMIP). It would help to elaborate what inter-model differences in radiative forcings from 10% increase in anthropogenic emissions will tell us about the uncertainty in radiative forcing induced by emissions. Further, it is not clear from the tables 1-6 which experiments could be used to perform this analysis.

P6, L24-25: Please complete this sentence.

P6, L29: Insert space before 5).

P7, L9-10: Does the CMIP6-specified stratospheric ozone dataset use the CMIP specified forcings? If not, how will this impact results from tropospheric-only chemistry models. Will the stratospheric ozone dataset for future scenarios considered here also use future CMIP6 scenarios.

P8, section 3.1.1: Given that the natural precursor emissions are tied to model meteorology, the perturbed NTCF simulations (hist-piNTCF, hist-piAer, hist-1950HC) will likely simulate different natural emissions compared to that in the historical simulation. Some information on how this natural component will be separated from the anthro-

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pogenic component in the simulated climate response will be helpful here.

P8, L33-34: Some justification for why observed SSTs and sea ice from 1870 to 2014 (available as a forcing from CMIP) could not be used for these forcing calculations, similar to the work of Andrews (2014), should be provided here.

P8,L37-39: Without a reference to RFMIP simulation, this sentence is confusing. Either cut this discussion (as it is being discussed in section 5.1) or provide a reference to RFMIP here.

P9, section 3.2.1: Some discussion of how natural emissions will be impacted in these simulations is needed here.

P10, L10: I probably misunderstand this experiment (ssp370SST-lowLu). The chemistry impacts of land-use changes can only be diagnosed if the precursor emissions (biogenic VOCs, fire emissions, dust) in the model are tied to model land-surface characteristics. If a model does not include land-surface and emission coupling then it is not clear to me how the chemical impacts of land-use changes can be simulated. It would be helpful to clarify this point.

P10, L20-21: How different would the pre-industrial to present-day ERFs be if they were calculated using results (10 year means for PI and PD) from the transient simulations described in section 3.1.2? If the results are similar then this would avoid having to run additional time-slice simulations and considerably pare down the number of requested AerchemMIP simulations.

P12, section 4.2: This section appears to be primarily focused on diagnostics to document aerosol forcing. There is no mention of diagnostics for gaseous NTCF forcings (e.g., ozone). Suggest adding a short paragraph on diagnostics needed to better quantify ozone, methane forcings.

P13, L31: Suggest revising this sentence to: A thorough documentation of natural emissions and 3D fields of reactive gases and aerosols is needed.

P13, L35-36: Need a reference here.

P14, section 4.6: Which simulations will be used to evaluate the skill of models in simulating chemical composition and aerosol radiative parameters? Since modelers are encouraged to increase model output during the AMIP period, would the DECK AMIP simulations be the cornerstone for model evaluation? If so, then it would be helpful to recommend (or even make it a requirement) that each model group evaluate and document chemistry and aerosols in their AMIP simulations, to ensure data quality.

P14, L28-29: The ability of models to simulate climate is measured in terms of how well they simulate global temperature and precipitation. Are there equivalent metrics for the simulation of chemistry and aerosols in the face of large uncertainties and data gaps in observations of short-lived chemicals? Suggest adding examples of robust metrics that could be used to measure the skill of CCMs.

P14, L31-32: A reference to Lee et al. (2013) would be useful here.

P16, Data availability: DOIs should be assigned to each model's output for AerchemMIP so that proper credit can be given to each modeling group providing the data. Are there any plans for assigning DOIs to contributions to AerchemMIP?

P16, L27-28: https://pcmdi.llnl.gov/projects/input4mips/ can be referenced here.

References:

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