Response to Comments by Reviewer 1

General Comments

Comment: This manuscript summarizes experiments that compare dry deposition schemes available in the CMAQ model. The conclusion that careful diagnostic grid-scale and land use specific dry deposition variables should be adopted especially for model intercomparison purposes is an important message of this work. In general, I think this manuscript presents a reasonable analysis with many valuable details that will be of interest to the relevant community.

Response: We would like to thank the reviewer for the overall positive assessment of our manuscript and the constructive suggestion to consider revising Section 3.1. Our responses to reviewer comments are shown below in italics while changes incorporated into the revised manuscript are shown in bold font.

Comment: My major comment is really related to what I felt was a lack of focus in the earlier parts of the manuscript: There is a lot of text in this paper (throughout the Methods and Section 3.1) that spends time explaining differences in their simulations with the output from model experiments in Appel et al. (2021). I was a bit confused by this. The main purpose of this manuscript is to compare the M3Dry and STAGE dry deposition schemes in an internal CMAQ implementation from 2016. To give this manuscript a more targeted focus, I would have suggested just to evaluate their model implementation directly without commenting so much on the indirect evaluation through the Appel et al. (2021) implementation. Likewise, I was a bit confused why there are so many tables and figures focused on evaluating 2010 model output, when none of this output is relevant to the dry deposition scheme discussion that uses only the 2016 model experiment (from Sections 3.2 onward). A great deal of unnecessary (and seemingly unrelated) text could be avoided if the focus was simply on the 2016 model experiments to begin with. This focus would also help remove many tables and figures (e.g., avoiding at least Table 2b, 3b, and many panels throughout Figure 1a-2b) to tighten the content.

To illustrate my point, one of the sentences early in the conclusion section mentions that lateral boundary conditions are a driver of the main differences between the present simulations and those from Appel et al. (2021). Why is this relevant to the internal comparison of CMAQ dry deposition schemes? Following this one (and only) mention in the conclusion, the remaining two and half pages of summary discuss, appropriately, only on the 2016 dry deposition scheme comparison. I highly recommend a substantial revision of the earlier sections of this manuscript so that it focuses on the relevant 2016 simulations only, and perhaps deemphasizes all the comparisons with Appel et al. (2021). In my opinion, all this extra material detracted from the motivation of the paper. Otherwise, perhaps I missed something important, and the authors could provide better motivation for why all this analysis was included.

I really don't have many other substantial comments. Sections 3.2 and 3.3 contain a great deal of valuable information about dry deposition modeling in CMAQ, with implications for other models as intercomparison projects, that I believe could be of interest to many readers of ACP.

Response: After considering the reviewer's comments, we agree that a restructuring and partial reduction of the material presented in Section 3.1 would help with the flow of the manuscript. We have therefore shortened Section 3.1 by removing any model performance results of the Appel et al. (2021) CMAQ simulations from the tables and figures in this section and also from any associated discussion.

Furthermore, we have also eliminated the RMSE time series previously shown in Figures 2a and 2b since they contained similar information to what was already shown in Figure 1 and the tables. These changes have hopefully made Section 3.1 more focused and easier to read.

While we agree that discussing the performance of the CMAQ simulations performed for this study in the context of the comprehensive Appel et al. (2021) CMAQv5.3.1 evaluation study is not directly related to the diagnostic comparison of the CMAQ M3Dry and STAGE AQMEII4 simulations, we believe that doing so is still desirable within the context of the overall AQMEII4 activity to document how different model configuration choices and input files affect the CMAQ results contributed to this activity. Forthcoming AQMEII4 analyses targeted for the same ACP special issue for which this manuscript is intended will perform model evaluation across all participating models and will benefit from having access to a more detailed analysis of the CMAQ M3Dry and STAGE model results than will be possible to perform in those multi-model studies. To balance this motivation for keeping these comparisons with the justified concern raised by the reviewer that doing so as part of Section 3.1 would result in a less focused manuscript, we decided to move all of the figures, tables, and discussions related to comparing the AQMEII4 CMAQ simulations to the Appel et al. (2021) CMAQ simulations, to the supplemental material. The following text has been added to the beginning of Section 3.1:

"Comparisons of modeled and observed MDA8 O_3, SO_2, NO_x, $PM_{2.5}$, SO_4^{2-}, NO_3^-, OC, and EC concentrations at AQS monitors, MDA8 O_3, SO_2, NO_x, and $PM_{2.5}$ at NAPS monitors, and precipitation and wet deposition of SO_4^{2-}, NO_3^-, and NH_4 at NADP NTN monitors are presented in Figure 1 and Tables 2 – 3. This section summarizes the performance of the M3DRY_2016, STAGE_2016, M3DRY_2010, and STAGE_2010 base case simulations. To provide context for these results, a comparison to the model performance of 2016 CMAQv5.3.1 simulations from a recent comprehensive evaluation study (Appel et al., 2021) and the differences in model configurations driving differences in model performance can be found in the supplemental material (Figures S1 – S7 and Tables S2 – S3)."

Regarding the reviewer's concern that model evaluation results in Section 3.1 are provided for both 2010 and 2016 while the diagnostic analysis in Sections 3.2 and 3.3 focus on 2016, we again note that having CMAQ performance documented for all simulations contributed to the AQMEII4 activity and analyzed in forthcoming multi-model analysis manuscripts will be beneficial for such manuscripts. We have therefore retained the 2010 model evaluation results in Section 3.1, but have also added the following text to the beginning of Sections 3.1 and 3.2, respectively, to provide more clarity on the different choice of years in both sections.

"Even though the diagnostic analyses presented in subsequent sections of this manuscript are focused on 2016, this section documents model performance results for both 2010 and 2016 because results from the 2010 simulations will be included in forthcoming AQMEII4 analyses."

"To avoid repetition, all analyses in these sections focus on the CMAQ AQMEII4 simulations performed for 2016 because the differences between the M3Dry and STAGE CMAQ simulations for 2010 were very similar to those for 2016 and because the sensitivity simulation quantifying the impacts of using a different LU classification scheme was performed for 2016."

<u>Minor comments:</u>

Line 171: First introduction of “VEGF” – please define.

Response: Thank you for catching this omission, the definition has been added in the revised manuscript.

Line 494-496: “…treats cells with more than 10% water as either all land or all water depending on whether the fractional water coverage is below or above 50%”. I had trouble following this sentence. Could it be reworded or broken up to help with its clarity?

Response: The relevant section has been reworded as follows in the revised manuscript, hopefully providing greater clarity:

“For grid cells with water fractions between 10% and 50%, the water fraction is reset to zero and the non-water categories are renormalized to 100%. For grid cells with water fractions exceeding 50%, the water fraction is reset to 100% and the fractions for non-water categories are set to zero. No renormalization is performed for grid cells with water fraction coverage below 10%.”