Response to Reviewer #2

Reviewer comments in black and our response in blue text.

Overview

The paper presents MAM4xx, a GPU-enabled version of the MAM4 aerosol model rewritten in C++/Kokkos and coupled to the EAMxx atmospheric model. It describes the code development from the original Fortran-based MAM4. A 33-day aerosol simulation for spring 2016 using MAM4xx within EAMxx is compared with a GEOS-FP simulation and evaluated against observations, including PM2.5, AOD, and AERONET. GEOS-FP uses the GOCART aerosol scheme and is constrained by MODIS AOD satellite observations.

General comment:

The paper's scientific contribution is not yet clear. The main motivation for developing EAMxx–MAM4xx appears to be its ability to simulate aerosol- cloud and aerosol-radiation feedbacks, but this aspect is not examined in sufficient depth.

As part of E3SM, ACI and ARI are the primary rationale to include prognostic aerosols. To simulate ACI and ARI requires reasonable simulations of meteorology (e.g., cloud properties) and aerosol properties (number, size, composition) that influence CCN, INP, and optical properties. When developing a new Earth system model, it is therefore critical to assess meteorological and aerosol components separately before assessing ACI and ARI. The E3SM team has been responsible for the evaluation of meteorology. Some meteorology-focused evaluation studies have been published and other studies are underway. This study represents one aerosol evaluation in the new EAMxx framework. Now that MAM4xx has been implemented and evaluated, assessments of ACI and ARI predictions that the reviewer is looking for are underway by the E3SM team. This includes differences between using prognostic aerosols versus EAMxx simplified prescribed aerosol treatment (SPA). We expect that future publications by the E3SM team will focus on ACI and ARI in EAMxx and we did not want to get ahead of their efforts. A couple of sentences refining the bounds of the paper has been added at the end of the introduction.

The paper describes the porting of MAM4 from Fortran to MAM4xx in detail, and it appears that technical tests were carried out to verify the correctness of the implementation. However, I am not convinced that this alone justifies a scientific publication.

As stated on the GMD website, GMD is "*dedicated to the publication and public discussion of the description, development, and evaluation of numerical models of the Earth system and its components.*" We therefore believe this paper falls within the mission of GMD as it is written. We included material necessary to document the new aerosol model, MAM4xx, and its performance for a case study so that future scientific studies using MAM4xx to address new scientific questions and published in other journals do not need to include a discussion of how or why MAM4xx was developed.

The breakdown of the computational cost of EAMxx–MAM4xx is valuable. However, I would have expected some comparison of the performance changes between MAM4 and MAM4xx. It is interesting to note that aerosol–cloud and aerosol–radiation interactions (ACI, ARI) account for a large share of the MAM4xx overhead. (see first comment)

As suggested by Reviewer #1, we have added a figure depicting the flow chart of the code which partially explains the reason for the computational expense of ACI. The structure is a holdover from the Fortran code where ACI processes are also the largest portion of the total computational burden of MAM4. In addition to the new Fig.3, some text has been modified in Section 3.4 regarding the computational expense. The E3SM team is now exploring options to recode the ACI aspects to improve computational performance as well as examining differences in computational performance on different GPU clusters. The goal of initial port of the code was to ensure aerosol physics operates reasonably, but computational optimizations on GPU clusters was a next step.

Because ACI and ARI appear to be central motivations of the paper, it is a missed opportunity that their impact on the EAMxx simulation is not examined. The paper fails to show the benefit of MAM4xx in MAM4xx.

This comment is similar to the first comment; therefore, we refer the reviewer to our response to the first comment. The E3SM team has already tested the impact of MAM4xx on ACI and ARI within SCREAM and documentation of the results is forthcoming.

Instead, the paper compares the aerosol simulation from EAMxx–MAM4xx with that from GEOS-FP over North America. The claim that GEOS-FP can serve as a reanalysis reference for aerosol should be treated with caution. The paper does not describe the AOD data assimilation method used in GEOS-FP. Although AOD assimilation can improve AOD fields, its positive effect on aerosol composition, especially near the surface, is generally limited. In addition, GEOS-FP should be regarded as a substantially different aerosol model because it uses a different aerosol scheme and, most importantly, different emissions for anthropogenic sources, biomass burning, sea salt, and dust. This likely explains the often large differences between EAMxx–MAM4xx and GEOS-FP, as well as their respective errors against observations.

We agree that GEOS-FP, as with other global aerosol analyses such as CAMS, should be viewed with caution for the reasons the reviewer describes. Had we included an aerosol model that used the modal approach as in MAM4xx, differences would still arise that would be difficult to explain (e.g. due to different meteorology, emissions, treatments of specific aerosol processes). Our purpose was to include at least one other aerosol model as a reference to show that the MAM4xx predictions are within the range of what might be expected from other aerosol models.

The evaluation of EAMxx–MAM4xx against AOD observations in Figs. 13 and 14 should also be shown for the GEOS-FP simulation.

The AOD from GEOS-FP has now been included. The new version of Fig. 14 includes the time series of AOD from the GEOS-FP grid cell that encompasses the SGP site. Two-dimensional monthly averages are now shown in Fig. 15. We decided to include a new figure, Fig. 16, to depict the heat maps for both models. The text has been modified to include discussion associated with the AOD from GEOS-FP.

The evaluation of aerosol size distributions and CNN against campaign data (Figs. 9, 11, and 12) appears relevant to the intended applications. Since GEOS-FP cannot simulate these quantities, it would be helpful to compare the results with MAM4 or another modal aerosol model.

The new figure 13 now includes CCN derived from the CAMS reanalysis (Block et al. 2024) and additional text describing the results. We agree that comparisons with other aerosol models would be useful, but would require careful configuration (grid spacing, emissions, etc.) to obtain a fair comparison the model performance.

Please provide more detail in the figure captions: which line and graph presents which model.

Figure captions have been changed to clarify observations and simulation results in the plots.