Referee Comment on egusphere-2024-52 ”Development of the MPAS-CMAQ Coupled System (V1.0) for Multiscale Global Air Quality Modeling” by David C. Wong et al.

The CMAQ model has a long history and is widely used across the world for research and regulatory purposes. The paper presents an important advancement of the CMAQ modelling system, going from limited area simulation to global simulation in a coupled setup with the meteorological model MPAS. A unified approach was developed, the Advanced Air Quality Modelling System (AAQMS), that enables the construction of the three different modeling systems: offline CMAQ, two-way coupled WRF-CMAQ, and global coupled MPAS-CMAQ.

The global coupled MPAS-CMAQ was evaluated using two global configurations, one with a uniform mesh for the globe and one with a variable mesh with finer resolution over North America. The study demonstrates good scalability and good performance for the uniform mesh simulations. The performance of the variable mesh case shows limitations with respect to surface ozone predictions in the United States, which have already been noted in simulations with earlier air quality modeling systems.

The manuscript is in general well written and logically organized. The layers of the AAQMS are clearly explained, with the exception of the coupler layer. The description of the unified coupler is not sufficient. It is hard to belief that the coupler does nothing else but data exchange in both directions. The claim that CMAQ inherits map projection, grid alignment, and grid spacing seamlessly in the coupled models needs to be substantiated.

The authors have chosen not to include WRF-CMAQ in the validation as this modeling system has been well documented and evaluated before. However, including WRF-CMAQ in the current evaluation over contiguous US would notably strengthen the credibility of MPAS-CMAQ and especially its performance in the variable mesh configuration. The revision of the manuscript should include a comparison of MPAS-CMAQ to the well-established WRF-CMAQ system for the limited area. In addition, my concerns listed below should be addressed.

Specific Comments:

1.) Section 2.1: It is compelling that MPAS and the CMAQ model are configured with the exact same grid configurations and coordinate systems. Maybe I missed updates in the coordinate system of CMAQ, but as far as I know, CMAQ uses Arakawa C horizontal staggering which previously required interpolation of the wind components to the locations of the CMAQ grid. Also, the coupler used for the WRF-CMAQ system uses the functionality embodied by the MCIP preprocesser that is used in the offline CMAQ. It might appear that CMAQ does not need the wind components since the transport is done in MPAS. However, sea spray parametrizations of sea-salt particle emissions have a wind dependence and would still need wind components for their computation. There are also other additional variables (previously?) required in CMAQ such as the vertical coordinate Jacobian. Please add some more explanation on this.

2.) Figure 2 should display the variable mesh for the refinement over North America that was used in this study.

3.) P4, Line 78: Add a reference for "improve model performance for retrospective air quality applications."

4.) P4, Line 88: Define which processes are solved in the "CMAQ step". A table which lists the processes/solvers would be helpful. Are all the short-lived radicals also transported in MPAS?

5.) Section 3.1: The last paragraph (P6, Line 130-136) should be moved to the beginning of this section. The two major characteristic differences of the two coupled systems will require a different treatment by the coupler. It must be better explained how the characteristic differences in the two coupled systems lead to a different handling by the unified coupler. It is not clear to which extent the coupler supports software interoperability given that WRF-CMAQ and MPAS-CMAQ have different data structures (2-D vs 1-D) and different buffer demand for interpolation.

5.) Section 4.1: It is beneficial that users can balance model performance and model run time for the MPAS-CMAQ modeling. Have lower or higher frequency of the CMAQ call been tested and how is the sensitivity of the modeled ozone concentration field to changes of the frequency?

6.) Figure 5, part b): Show the average bias over the 3-year period separately for spring + summer and fall + winter. It seems that the negative and positive biases during the two periods cancelled out when averaging over the full year.

7.) Figure 6 and P10, Line 248-252: Give an explanation why high ozone over southern Africa in the biomass burning region does not occur in MPAS-CMAQ. Is biomass burning from this region missing in the model?

8.) Conclusion and Future Work: The authors claim that the MPAS-CMAQ coupled model has advantages over the WRF-CMAQ model. While this is correct from a theoretical point of view, the study did not demonstrate a superior model performance of MPAS-CMAQ compared to WRF-CMAQ. If the claim should be kept in the conclusion, then the validation of WRF-CMAQ runs for the CONUS region (Jan and Jul 2016) must be included.

Technical Corrections:

P2, Line 29-30: CMAQ and WRF should have capital letters in the sentence in brackets: “(note that cmaq …)”.

P2, Line 36: Month of publication is usually not given in the citation.