Dear Referee #2, thank you so much for reviewing this paper and providing such a thorough and constructive review and comments. Here are our responses to your comments and suggestions point by point (in blue).

This manuscript describes a new coupled model system based on the MPAS meteorological model and CMAQ air quality model. The coupled system with a variable mesh grid has numerous advantages over other model systems such as a consistent transport scheme for pollutants and meteorological variables and the advantages of finer resolution without the need to nest domains, which can introduce interpolation errors. The manuscript is very well written. I recommend publication with only minor changes.

Line 40. I feel like there should be a reference to MPAS somewhere in this paragraph.

The text has been modified as:

"The National Center for Atmospheric Research (NCAR) has recently developed a new global meteorological model, the Model for Prediction Across Scales – Atmosphere (Skamarock et al., 2012) (MPAS-A, hereafter referred to as MPAS),"

and the following new reference is added:

Skamarock, W. C., Klemp, J. B., Duda, M. G., Fowler, L. D., Park, S.-H., and Ringler, T. D.: A Multiscale Nonhydrostatic Atmospheric Model Using Centroidal Voronoi Tesselations and C-Grid Staggering, Monthly Weather Review, 140, 3090–3105, https://doi.org/https://doi.org/10.1175/MWR-D-11-00215.1, 2012.

Line 75. Can you please check this sentence. The sentence states enhancements for physics options and then states "namely the Pleim-Xiu land-surface model" which is a surface model and not physics model.

The physics options were referring to the physics options in the namelist. To avoid misunderstanding, the phrase "physics options" has been revised as "physics models which are associated with specific physics options in the namelist," in the text.

Line 125. Can you provide a bit more detail. Are the soluble and insoluble species in the PM phase? What are the other components needed in MPAS-CMAQ system to model the online aerosol direct effect?

This soluble and insoluble species classification is determined automatically with respect to aerosol species which depends on the version of aerosol scheme used in CMAQ. The other three categories are sea salt, EC, and aerosol water. These five categories are the same as in the WRF-CMAQ coupled model.

Line 185. One of the advantages of the MPAS-CMAQ system is the variable mesh which enables finer scale without the need for nesting grids. This removes the need for interpolation of lateral boundary conditions. However, for the tests performed here, the emissions were interpolated from rectangular grids to the MPAS grid which introduces errors and may counter the gain from not needing nesting. In future work, it would be beneficial to do the emissions processing directly onto the MPAS grid rather than interpolate from other grids.

Global emissions outside of North America rely on HTAP data (https://doi.org/10.5194/acp-15-11411-2015), which is provided on a 0.1 x 0.1-degree grid. To our knowledge there is no consistent source of global emissions data available that could be spatially apportioned to a mesh without interpolation. The 0.1 degree by 0.1-degree grid spacing is generally more of an aggregation of emission estimates rather than interpolation since most of the mesh cells are larger than 0.1 degree by 0.1 degree so there are not many mesh cells that get redistributed in a global MPAS mesh. Within North America regional inventories are directly apportioned to the MPAS mesh using spatial surrogates. This method is limited by both the resolution of the weighting data used in the surrogates and the need to generate new surrogates for every mesh configuration. Also a large number of emission sources in North America are point sources which are mapped directly to the MPAS mesh cells without interpolation.

Line 218. I feel there should be more information on how plume rise is calculated in MPAS-CMAQ since this is a key process where meteorology impacts pollutant dispersion. Is plume rise handled in MPAS or CMAQ? If in CMAQ, what parameters are transferred to CMAQ to simulate the vertical mixing. Does the water vapor in the point source feedback to the meteorology and provide more latent heat?

The plume rise calculation is based on Brigg's algorithm and is performed on the CMAQ side (in the CMAQ offline model as well as the WRF-CMAQ coupled model), taking into account temperature and wind profiles transferred from MPAS and stack information (stack height, diameter, temperature, flow rate, and exit velocity) provided for each point source being modeled. Information on water vapor associated with point source plumes is not available from point source emission inventories and is therefore not part of the information being fed back to the meteorological model.

Line 246. Does the MPAS-CMAQ system include ozone data assimilation in the stratosphere. This may improve the ozone low bias in winter/spring, particularly in free troposphere.

We thank the reviewer for identifying this omission. The new text includes a description of our data assimilation approach in the stratosphere in the Section 4.1:

"CMAQ does not include a full representation of stratospheric chemistry, and the potential vorticity scaling approach that is used in hemispheric-scale CMAQ domains to estimate ozone mixing ratios in the

upper layers (Xing et al., 2016) is not viable over the equator. In MPAS-CMAQ we ingest time-dependent values of stratospheric ozone from the Copernicus Atmosphere Monitoring Service (CAMS) reanalysis product (Inness et al., 2019) where model pressure is less than 300 hPa and model ozone is above 200 ppb."

We experimented with many versions of this approach, including using other ozone products, more traditional definitions of the tropopause height, and FDDA. For better or worse, the bias in the free troposphere was relatively insensitive to the approach taken.

I would recommend larger size for some of the figures (e.g. Figure 7,8), maybe not side by side.

We have increased the size of the figures to provide a clearer view.

Grammar Corrections

Line 29. Change "a" to "an".

Can't find this item. We believe the reviewer asked to change "a Eulerian" to "an Eulerian" and it is done

Line 50. Change "entities" to "objectives"

Done.

Line 230. Remove "has".

Done.

Line 251. Correct MERA to MERRA

Done.

Line 282. Change CAMQ to CMAQ

Done.