

Interactive comment on “Comparative evaluation of the impact of WRF/NMM and WRF/ARW meteorology on CMAQ simulations for PM_{2.5} and its related precursors during the 2006 TexAQS/GoMACCS study” by S. Yu et al.

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We thank the anonymous referee #2 for the constructive and helpful comments, the incorporation of which has led to a substantially improved manuscript.

Reviewer #2(Comments):

Major comments:

This numerical modelling work examines the operational performance of two CMAQ simulations, with one using meteorological data provided by WRF-NMM (NMM-CMAQ) and the other using data provided by WRF-ARW (ARW-CMAQ). The performance characteristics of each simulation are methodically presented. While the performance results are presented neatly, the manuscript fails to discuss the reasons for the differences in performance between the two simulations. The sensitivity of the CMAQ modelling system to different meteorological fields in relation to air concentrations of PM_{2.5} and its related precursors is demonstrated. This result is to be expected and calls for reasons for the differences. The manuscript is in need of more interpretation in light of the simulated meteorology. Even though an operational evaluation of the model for a case study is of interest, it does not in itself represent a substantial contribution to scientific progress within the scope of ACP. The manuscript is a bit too descriptive; it needs more interpretation and explanation of the results before I can recommend it for publication.

We thank the reviewer for the comments and suggestions. I agree with the reviewer that there is a need for more interpretation in light of the simulated meteorology. To address the reviewer's concerns, we have added additional results in terms of differences in the simulated meteorology have been added in the revised manuscript. The following sentences and paragraphs have been added in the revised manuscript “As shown in Yu et al. (2011), the mean temperature of the ARW model is slightly lower than that of the NMM model on the basis of comparisons with WP-3 measurements. This may be one of the reasons which cause different model performances of ARW-CMAQ and NMM-CMAQ for PM_{2.5} and its related chemical composition.”. The addition of few more pertinent details on the NMM and ARW dynamical cores have been included in the revised manuscript as follows: “These two dynamic cores cannot be merged because each dynamic core corresponds to a set of dynamic solvers that operates on a particular grid projection, grid staggering and vertical coordinate (Skamarock, 2005). As summarized by Skamarock (2005), operational results indicated that the significant differences between these two dynamic core forecasts are more the result of different physics but not dynamical core designs. The NMM core is a fully compressible hydrostatic NWP (Numerical Weather Prediction) model using mass based vertical coordinate, which has been extended to include the non-hydrostatic motions (Janjić, 2003), whereas the ARW core is a fully compressible, Eulerian

nonhydrostatic model with a run-time hydrostatic option available. The NMM core uses a terrain-following hybrid (sigma-pressure) vertical coordinate and Arakawa E-grid staggering for horizontal grid, whereas the ARW core uses a terrain-following hydrostatic-pressure vertical coordinate with vertical grid stretching permitted and Arakawa C-grid staggering for horizontal grid. As summarized in Yu et al. (2011), the physics package of the NMM (ARW) includes the Betts-Miller-Janjic (Kain-Fritsch (KF2)) convective mixing scheme, Mellor-Yamada-Janjic (Asymmetric Convective Model (ACM2)) planetary boundary layer (PBL) scheme, Lacis-Hansen (Dudhia) shortwave and Fels-Schwartzkopf (RRTM) longwave radiation scheme, Ferrier (Thompson) cloud microphysics, and NOAH (Pleim-Xiu (PX)) land-surface scheme. In this study, both WRF-ARW and WRF-NMM are employed to provide meteorological fields for CMAQ (the notations ARW-CMAQ and NMM-CMAQ will be used hereafter to represent these two configurations). NMM-CMAQ uses the lowest 22 layered vertical grid structure of the 60 hybrid layers in WRF-NMM meteorological fields directly without vertical interpolation through the use of a common vertical coordinate system. On the other hand, the WRF-ARW model has been employed to generate meteorological fields for CMAQ because the WRF-ARW meteorological model is compatible with CMAQ like MM5 before. For the NMM-CMAQ run, the results from the target forecast period (0400 UTC to next day's 0300 UTC) based on the 1200 UTC NMM-CMAQ simulation cycle over the domain of the continental United States (see Figure 1a of Yu et al. (2011)) are used, whereas the ARW-CMAQ model with 34 vertical layers was applied over a domain encompassing the eastern United States (see Figure 1b of Yu et al. (2011)) and was run continuously over the whole period.

Given the fact that both models use different map projections and grid staggering, it is difficult to make the WRF-ARW grid coverage identical to the WRF-NMM coverage. Several steps are taken to ensure that both the models are set up as consistently as possible so that the comparison of the two models is meaningful. First, the meteorological fields of ARW were padded by 5 cells in both x and y directions around the original meteorological domain when the meteorological fields were processed using Meteorology-Chemistry Interface Program (MCIP) to create the CMAQ-ready files. This helps match the larger NMM domain and smaller ARW domain sizes, and is able to use the emission data from the NMM-CMAQ forecast model. Second, the point source emissions were redistributed to the 34 layers according to the ARW meteorological fields on the basis of those from the NMM-CMAQ model. In addition, the ARW-CMAQ uses the same area sources such as the mobile and biogenic sources as those in NMM-CMAQ. Therefore, the total emission budgets for both models are the same. In both ARW-CMAQ and NMM-CMAQ, the lateral boundary conditions are horizontally constant and are specified by continental "clean" profile for O₃ and other trace gases; the vertical variations are based on climatology (Byun and Schere, 2006). For both models, the thickness of layer 1 is about 38 m and the vertical coordinate system resolves the atmosphere between the surface and 50 hPa although each model uses different number of vertical levels. ”

Below are some more specific comments (some editorial).

P32033, L20: Please explain what is meant by 'differently'?

Thanks. To address the reviewer's concern, the following sentences have been added in the revised manuscript "For example, sulfate is produced from both primary and secondary sources but elemental carbon (EC) is emitted from the primary sources. Differences in the composition of particles produced by different sources lead to spatial and temporal heterogeneity in the composition of the atmospheric aerosols."

P32034, L18: The manuscript presents the sensitivity of the CMAQ modeling system to different meteorological fields in relation to air concentrations of PM_{2.5} and its related precursors. Why is the purpose of the manuscript twofold?

We agree with the reviewer's comment and have revised the discussion as follows: "The purpose of this paper is to comparatively examine the impact of these two different meteorological fields on CMAQ simulations for vertical profiles of PM_{2.5}, its chemical composition and precursors on the basis of the extensive measurements obtained by aircraft and ship during the 2006 TexAQS/GoMACCS field experiment, especially, for three types of plumes (power plant plumes, Houston and Dallas urban plumes and Ship Channel plume) over the Houston-Galveston-Brazoria and Dallas-Fort Worth (DFW) metropolitan areas. The influence of these two different meteorological fields on spatial and temporal variations of PM_{2.5}, and its chemical composition over the eastern U.S. is also evaluated against the observations from the surface monitoring networks (AIRNOW, IMPROVE, CASTNet and STN) during the 2006 TexAQS/GoMACCS study. "

P32035, L5: The WRF model has been around for some time now, so I would suggest deleting 'new'.

We agree with the reviewer and have revised the manuscript accordingly.

P32036, L5: Please delete 'the' before 'CMAQ'.

We agree with the reviewer and have revised the manuscript accordingly.

P32037, L15: What is the Part 1 paper?

Thanks. This has been changed to Yu et al. (2011) in the revised manuscript.

P32038, L24-25: Please explain what is meant by 'majority of the observed daily PM_{2.5} concentrations with a factor 2'? Please give the percentage.

Thanks for your comments. To address the reviewer's concern, we have revised the manuscript as follows: "Figures 1a and 1b clearly indicate that both ARW-CMAQ and NMM-CMAQ models reproduced the majority (78%) of the observed daily PM_{2.5} concentrations within a factor of 2, especially for the concentration range of 10 to 35 $\mu\text{g m}^{-3}$."

P32039, L11: Why 'slightly consistent'?

It should be “consistently slight”. The new sentence “...had consistently slight underestimations of PM_{2.5}...” has been used in the revised manuscript.

P32039, L21-22: Please explain what is meant by ‘majority of the observed daily PM_{2.5} concentrations with a factor 2’? Please give the percentage.

The percentages have been added in the revised manuscript. The revised sentence read as follows: “The scatter plots of Figure 3a indicate that at the IMPROVE, CASTNet and STN sites, both ARW-CMAQ and NMM-CMAQ captured a majority of observed SO₄²⁻ (65% (ARW-CMAQ), 74% (NMM-CMAQ)), NH₄⁺ (60% (ARW-CMAQ), 69% (NMM-CMAQ)), PM_{2.5} (66% (ARW-CMAQ), 72% (NMM-CMAQ)) concentrations within a factor of 2.”

P32041, L22 to P32042, L3: Presumably, this can be checked using results of the simulations.

Since the observations of PM_{2.5} at IMPROVE and STN sites are 24-h samples, the diurnal evolution of observed PM_{2.5} cannot be checked.

P32043, L15-19: Because SO₄²⁻, NO₃⁻ and NH₄⁺ are sensitive to NH₃, is the overestimation of NH₄⁺ reflected by an overestimation of SO₄²⁻ and/or NO₃⁻?

This will be dependent on the relative amounts of SO₄²⁻, TNO₃ and TNH₄ and temperature. In TNH₄ rich regions, an overestimation of SO₄²⁻ will definitely put too much TNH₄ into the aerosol phase (NH₄⁺) and cause the overestimation of NH₄⁺. On the other hand, in TNH₄ poor regions, an overestimation of SO₄²⁻ will not cause the overestimation of NH₄⁺ because there is not available NH₃ to react with SO₄²⁻ to produce NH₄⁺.

P32045, L6: Please delete ‘the’ before ‘similar’.

We have revised the sentence following the reviewer’s suggestion.

P32047, L28: Please delete ‘the’ before ‘consistent’.

We have revised the sentence following the reviewer’s suggestion.

P32048, L10-13: Maybe, but this is not shown.

Thanks. We agree. This sentence has been deleted in the revised manuscript.

P32059, Figure 3a: Right column, middle, should be NO₃⁻.

We have revised the sentence following the reviewer’s suggestion.