

Interactive comment on “Extending the Community Multiscale Air Quality (CMAQ) Modeling System to Hemispheric Scales: Overview of Process Considerations and Initial Applications” by Rohit Mathur et al.

Anonymous Referee #2

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General Comments

This paper provides an overview of the development and some initial applications of a major extension to the off-line Community Multiscale Air Quality (CMAQ) regional chemistry-transport model. Some limitations of regional air quality models are first described and the case is made for the use of hemispheric (or global) air quality models to better address some important research and policy questions. The paper then describes a number of model enhancements that were required to extend CMAQ from its traditional regional-scale configuration to the hemispheric scale, followed by a survey

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of a number of different evaluations and applications using this new model version.

This is a well-written paper that describes hemispheric CMAQ, an important enhancement of a widely used regional air quality model to enable it to be applied for larger spatial scales and longer time scales. The process enhancements that were required to achieve this design goal should be of general interest. A diverse set of six different applications of the new hemispheric CMAQ are then presented. Several of these applications have been presented elsewhere while others are presented for the first time. In the former case, however, additional perspective and discussion are provided.

I recommend acceptance of this manuscript with minor revisions. I have made a number of specific comments and suggestions below related to clarity and completeness that I would ask the authors to consider. I have also included a number of editorial comments and corrections that I hope will improve the final version.

Specific Comments

1. In Section 2 there were a few places where I asked myself "but what about ...?". In order to provide a more complete description of hemispheric CMAQ, I would suggest that some text could be added to address the following points:

* (Section 2.1) There are many regional chemistry-transport models and there are many global chemistry-transport models, but I am not aware of any other hemispheric chemistry-transport models. Could you add some text to explain the rationale for choosing a hemispheric rather than a global extension, and are there any other models that you are aware of that have also taken your hemispheric approach?

* (Section 2.1) Limited-area models require lateral boundary conditions. Although you have greatly expanded your model domain by choosing a hemispheric domain, hemispheric CMAQ is still a limited-area model. However, there is no discussion in the text of the LBC that you have used for hemispheric CMAQ. Also, Figure 1 showed CMAQ sensitivity to ozone lateral boundary conditions for a regional configuration over the

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continental U.S.: has a similar sensitivity test been performed for hemispheric CMAQ to show its sensitivity to LBC specification?

* (Section 2.1) What is the vertical coordinate used by WRF and hemispheric CMAQ?

* (Section 2.2) You recommend here that hemispheric CMAQ should be started from clean tropospheric conditions, and you mention initializing O₃ at 30 ppb throughout the model column for the clean IC case. Do you similarly recommend that other CMAQ model species should be set to a uniform clean value in both the horizontal and vertical? Also, can you mention at least some of the clean IC values used for other CMAQ species (e.g., NO, NO₂, CO, NH₃, SO₂, ...)? And given its complex suite of sources, have you examined how CO responds to a 9- or 12-month spin-up from clean conditions?

* (Section 2.3.1) Is the ARCTAS emissions inventory associated with a nominal base year?

* (Section 2.3.1) Are the GEIA biogenic VOC and lightning NO_x emissions climatological or year-specific?

* (Section 2.3.1) Natural emissions take on increased importance for a global or hemispheric chemistry-transport model. Were sea-salt emissions, biomass-burning emissions, soil NO emissions, or volcanic SO₂ emissions considered by hemispheric CMAQ?

* (Section 2.3.3) What about marine DMS emissions?

* (Section 2.4.3) It could be mentioned here that RACM2 does not include all (any?) of the chlorine, bromine, and iodine species discussed in Section 2.4.2 – this is relevant to Section 3.4.

* (Section 2.5) In essence this section deals with chemical upper boundary conditions. How are other CMAQ model species treated at the top of the model?

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2. It is not made clear in Section 3.1 (p. 15, l. 12) exactly which forms of the two gas-phase chemistry mechanisms were used. Although Sarwar et al. (2013) is referenced (l. 11), I am not sure that the exact mechanism versions used for that paper were also used in this study. For example, I think but I am not sure that a modified version of CB05TU was used in this study that included the modifications described in Sections 2.4.1 and 2.4.2. I am not sure whether or not the version of RACM2 used in this study included the modifications described in Section 2.4.1. The analysis presented in this section does state that two different versions of RACM2 were used, one with the modifications described in Section 2.4.2 and one without those changes, but some additional clarification would be very helpful.

3. In preparing figure panels 13d, 13e, and 13f, was the SCIAMACHY averaging kernel applied to the CMAQ NO₂ fields?

4. In Section 3.5, how were the station trends that are shown in Figure 15 calculated?

5. In Section 3.6 how were the CMAQ SWR fields calculated in conjunction with predicted cloud fields?

6. In Section 3.6 I am not sure that the discussion of Figure 16 is completely correct, in particular the following sentence: "The change in the SWR and AOD for each summer month in the 2001-2010 period was estimated relative to the corresponding year-2000 value, and the relationship between these changes is examined in Figure 16 for both model simulations with and without direct aerosol feedback effects." If this were true, then for East China, which has been experiencing dimming over the past decade, wouldn't most of the observed SWR changes be negative, whereas for Europe and the eastern U.S., which have been experiencing brightening over the past decade,

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wouldn't most of the observed SWR changes be positive? Instead, the difference patterns in Figure 16 seem to be more consistent with the subtraction of the 11-year monthly means; that is, they are centered.

Technical Corrections

The manuscript reads very well but it would still benefit from a careful copyediting to add commas, hyphens, and definite articles in some places but remove them in other places (e.g., change "space and time varying" to "space- and time-varying").

Some acronyms are used but never defined: ECMWF, GFS, ADP, PBL, NOAA, AQS

p. 1, l. 13 WRF is also included as a keyword so it could be defined here on the same page.

p. 2, l. 4 Perhaps "... implementation of the *U.S. National Ambient Air Quality Standards* ..."

p. 2, l. 11 Perhaps "... postulated that in limited-area *chemistry-transport* models, ..."

p. 2, l. 14 Perhaps "... derived from the *global* Integrated Forecasting System of ..."

p. 2, l. 16 hPa is the equivalent SI unit to mb.

p. 2, l. 26 "higher values in the high elevation regions": concentration values or variability values?

p. 2, l. 26 Perhaps "Additionally, higher *contributions from* background levels are estimated"

p. 2, l. 30 "Expectedly" makes me think of "bigly" – perhaps "As expected" would be a better choice.

p. 2, l. 34 Perhaps "... that *other* pollutants with atmospheric lifetimes greater than a

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few days ..."

p. 3, l. 17 Perhaps "Section 2 *provides an overview of the* ..."

p. 3, l. 21 Perhaps "*Lastly*, Section 4 summarizes the current model *status* ..."

p. 4, l. 28 Could give a reference for the NCEP/NCAR Reanalysis data set?

p. 4, l. 31 Check weblink (extraneous blank after "V3.1/"?)

p. 5, l. 8 Perhaps "... closer attention to model *chemical* initialization ..."

p. 5, l. 13 Perhaps "... based on the model *emissions, physics, and chemistry* ..."

p. 5, l. 24 Perhaps "... Clean IC and Profile IC cases by August, *nine months after the start of the simulation*, suggests the diminishing impact of initialization ..."

p. 8, l. 33 Should it be Xie et al. (2013)?

p. 9, l. 23 The Goliff et al. (2013) reference is missing.

p. 10, l. 5 "... in the modelled upper troposphere/lower stratosphere"

p. 10, l. 29 Perhaps "These *hemispheric O₃ fields* can then be used ...".

p. 11, l. 20 There are a number of references to the "Pacific": perhaps some could refer to the "Pacific Ocean" instead.

p. 11, l. 24 "DC-8"

p. 11, l. 25 "... *were* based ... *and* sampled ..."

p. 11, l. 27 There are some unexpected capitalizations, such as Pollution, Spring, Winter, and Continental.

p. 12, l. 33 "Particle Into Liquid Sampler" is the more common usage.

p. 13, l. 23 Perhaps "... air pollutants, *dating* back almost a century"

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- p. 15, l. 15 Perhaps "... are illustrated in Figure 12a for August"
- p. 17, l. 1 Perhaps "... in the Savanna region of Africa both in ..."
- p. 17, l. 2 "SCHIAMACHY" (spelling)
- p. 17, l. 21-22 The Figure 15 caption and labels state that the analysis shown is for the summer months only and not all year as stated in this sentence.
- p. 17, l. 23 Perhaps "...are results from an additional 21-year simulation with CMAQ ..."
- p. 17, l. 28 The "Conclusions" section states a range for the underestimation (p. 20, l. 12) that should be mentioned here.
- p. 18, l. 12-21 As a lead in to the next paragraph, it could be mentioned here that the aerosol optics calculations in WRF-CMAQ include the calculation of AOD.
- p. 18, l. 29 Perhaps "... using regional *monthly averages* ..." and "Eastern U.S."
- p. 18, l. 33 Perhaps "... but AOD at noon (local-time) for model values to be consistent ..."
- p. 20, l. 11 Perhaps "... at U.S. CASTNET monitors, ..."
- p. 21, l. 33 IONS and WOUDC are not networks.
- p. 29 Figure 1 caption: Perhaps "Impact of *ozone* lateral boundary conditions (LBC) ..."
- p. 31 Figure 3: Would it be useful to give associated states or longitudes for these four measurement sites?
- p. 32 Figure 4 caption: Would it be useful to indicate the elapsed simulation time for these two panels; that is, four months and nine months after the start of the simulation?
- p. 33 Figure 5 caption: Does not mention the aircraft altitude time series in the first

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four panels.

- p. 43 Figure 14 caption: Perhaps "... changes in *regional- and monthly-average* modeled ..."

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