Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., author comment AC1
https://doi.org/10.5194/acp-2021-552-AC1, 2022

Reply to RC1

Andrea Mazzeo et al.

Author comment on "Evaluation of the WRF and CHIMERE models for the simulation of $PM_{2.5}$ in large East African urban conurbations" by Andrea Mazzeo et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2021-552-AC1, 2022

General Comments:

Overall, this paper uses a sound scientific approach that supports its main conclusion that the coupled WRF-CHIMERE model is suitable as a tool for air quality management in East Africa. It could be improved with more in-depth discussion of some results and clarification/correction of several minor items.

Specific Comments:

- *I couldn't tell from the text if anthropogenic emissions inputs to the model had any diurnal variations. Only annual total emissions are mentioned, possibly indicating that constant emission rates are used for each pollutant. This could have a major impact on correlation to hourly data.*

A > The anthropogenic emission inputs have been temporally disaggregated using factors included in the CHIMERE pre-processor "emisurf2016". These coefficients are divided by emission sector and permit to save the total mass of the original emissions (provided in the emission inventories) but to divide this total according to the diurnal variation. This system, largely used in atmospheric chemistry modelling, permit to allocate e.g., more emissions from road transport in the peak of the morning and afternoon rush hours than in the other hours of the day preserving the original total value of the emissions. A New line highlighting this aspect has been added at **233-234**.

- *Not entirely clear how statistical measures are averaged (lines 336-338). Are measures calculated for each site and then those values for each domain are averaged (e.g., the 5 Relative Humidity NRMSE values for the 5 KEN2K weather stations are averaged to produce the KEN2K NRMSE value?) Or are the observed and modelled data for all the sites within a domain used together to calculate the average measure?*

A > The statistical analysis both for WRF and for CHIMERE has been done calculating the statistics for each station individually and the averaging all stations together so that e.g., the 5 values of the individual relative humidity NRMSE are averaged to produce the final NRMSE value for the domain. The calculation has been done on the original hourly values from observations and model outputs and consider hourly values from the model only if the corresponding hourly observation is present. According to comments made by reviewer 4 and 5, MNB and RMSE have been substituted by MFB and MFE in the validation of WRF and CHIMERE.

- *It would be helpful to specify how wind direction statistics were calculated. Since wind direction is a circular variable, calculating means, RMSE, etc. is different than for linear variables. Also, I'm not sure that normalized measures, MNB, NRMSE make sense for wind direction.*

A > The statistics presented originally in the manuscript has been calculated as follows (see supplement):

As the review suggests these operators can be used for linear variables such as temperature and relative humidity but they haven't the same meaning for what concern circular variables like in the case of the wind direction. Moreover, they rely also on the number of observations point included in the denominator and the final value can be misleading. For this reason, the statistical analysis in the new manuscript has been changed and the MNB and RMSE values substituted with mean fractional bias and error (MFB and MFE) originally used only for the validation of CHIMERE. Moreover, for WRF we also use the Index of Agreement calculated as follows (see supplement):

- *In the discussion of statistical evaluation of meteorological parameters it would be helpful to include criteria for what constitutes "good agreement" (line 361), "acceptable agreement" (line 443), etc.*

A > These qualitative terms have been deleted and the paragraphs modified to include quantitative statements.

- *Table 3 needs to include units for each meteorological variable. Shouldn't the MNB for KEN2K wind speed be negative?*

A > The statistics of Wind Speed for the domain KEN2K have been modified due to the presence in the observations of data from a station that after further analysis, was found to be suspect. In absence of precise information on the possible cause for this (the mean wind speed in that particular station was 45 m s^{-1} with only few data available during the month) we have excluded that station from the statistical evaluation and performed the calculation again. The new values are in line with expectations.

- *There are conflicting statements about model performance for wind speed and direction. Lines 426-427 claim that the Nairobi and Kampala show higher agreement than Addis Ababa, but line 431 says that Kampala is the worst performing of the three cities.*

A > The conflicting statements have been addressed and the new paragraph can be found at lines **486-508.**

- *In Table 4, why are the Mean MOD $PM_{2.5}$ values different for Daily and Hourly? And it seems strange that the hourly NRMSE values are lower than the daily NRMSE.*

A > The Values in Table 4 have been checked and re-calculated. The initial difference between daily and hourly values of modelled $PM_{2.5}$ was present in Nairobi (roadside site) and Addis Ababa. The reason of the mismatch was related to the treatment of the Nan values by the python code used for the calculation of the statistics. The issue has been addressed and the averages re-calculated.

- *In Figure 8 the data for Nanyuki show what appears to be a nearly constant baseline $PM_{2.5}$ concentration of around 2 to 2.5 μg m^{-3}. Why would this be occurring?*

A > The observations used to validate CHIMERE performance for Kenya comes from previous work by Pope et al., 2018 [1]. In that work the site of Nanyuki was chosen as

rural spot in a location of minimum local air pollution influence. The data from Nanyuki has been used for the calculation of the net urban increment subtracting the rural background concentrations of Nanyuki from the urban concentrations in Nairobi.

The average concentrations around 2 μg m^{-3} in the period between the 4th and the 11th are the levels of the rural background in absence of any external influence from meteorological parameters and in absence of local sources. The peak of concentrations visible is the other days are between 4 and 15 μg/m^3 that is in any case a low value in comparison with the concentrations from the urban area.

The difference in the baseline concentrations is given by the big difference between the days with possible transport of pollutants from days where this phenomenon is not visible, but it is exaggerated by the low scale of the concentrations (0-16 μg m^{-3})

- *The $PM_{2.5}$ data from Figure 9 and Figure 8 don't seem to agree. For the period March 3 – March 10, Figure 9 reports a daily concentration of 53-55* μg m^{-3}*each day. In Figure 8, however, the hourly concentrations for that same time period hover around 2.2* μg m^{-3}*and never exceed 4* μg m^{-3}*.*

A > $PM_{2.5}$ data provided in Figure 8 are hourly concentrations comparing model outputs and concentrations. $PM_{2.5}$ provided in Figure 9 were daily cumulative totals obtained by summing all the concentrations observed in Nanyuki during each day. The average concentrations during the period between the 4th and the 11th of March are around 2.2 μg m^{-3}, 2.2 * 24 hours = 52.8 μg m^{-3}. The Figure has been modified and the cumulative concentrations substitute with daily average concentrations to not confuse the reader and provide more consistent information.

- *In presenting data table results, the text is often mainly just stating the values that are already shown in the tables. (e.g., sections 3.1.2, 3.2.1, 3.2.2) These sections could be condensed and/or modified to include additional description and discussion of what the data values mean. For example, why might model performance for wind speed and wind direction vary for airport vs. urban locations, why is there such a strong correlation between model and observation in Nanyuki, what are possible reasons for differences in model performance between the different domains?*

A > The reasons for the different behaviour in the model performance between Kenya, Uganda and Ethiopia has been explained in the text with a new paragraph between line **586-593** *"The performance of CHIMERE vary between the domains of Kenya, Uganda and Ethiopia. The performance of the model has been optimised during the validation for the simulation of hourly concentrations of $PM_{2.5}$ in Kenya and the same configuration applied to the domain of Uganda and Ethiopia to compare the reliability of the model. The difference in performance can be connected to different reasons: In first place, the difference in the sampling methods used for the two sites in Kenya against the measurements taken in the U.S. Embassies of Kampala and Addis Ababa. A second element of differentiation can be connected to the location of the observation sites in the cases of the U.S. Embassies and/or the possible influence of local sources not accounted in the emission inventories."*. The motivation for the higher agreement between model and observation in Nanyuki has been added with a new paragraph at lines **599-604**: "*Finally, the site of Nanyuki is the location where the agreement between model and observations is highest. This site was chosen by Pope et al. (2018) as rural spot in a location of minimum local air pollution useful to calculate the net urban increment subtracting the rural background concentrations of Nanyuki from the urban concentrations in Nairobi. Is therefore intended by their work that the average concentrations in that site were low. The model reproduces this low level or contamination close to the reality and to results to be able to reproduce also peaks of contamination in particular days of February probably generated elsewhere (see Section 3.2.2)".* The difference in the location of the

observations can have an influence on the change in directions and speed recorded in the observations. These rapid changes given by the open spaces (airport) or the building canyon effects of urban areas cannot be captured by WRF that take in account of a coarser differentiation of the land use between urban and not urban areas. New paragraph in line **501-508**.

Technical corrections: *Throughout the manuscript the authors mention "low air quality index". This could be interpreted as a low numerical value of the air quality index, indicating good air quality, but from the context it seems the authors are instead describing poor, or low, air quality. It would be better to use a different word than "low".*

I found the initial paragraphs of section 2, Materials and Methods, to be unnecessary (lines 104-127). They provide a partial summary of emissions, observational data, and model simulations, but since it is not a complete description, the reader is left with many questions. There are separate subsections that do provide all the pertinent details and they are much easier to follow. I would suggest removing lines 104-127 and incorporating that information into the subsections as appropriate.

A > following the suggestion of the reviewer the initial paragraph of section 2 Material and Methods has been shortened and the content already mentioned elsewhere deleted.

- *Clarify in section 2.2 that CHIMERE is run only for the 6x6 and 2x2 km domains. This is somewhat implied in the discussion of boundary conditions (line 174), but not clearly specified. It is not until section 3 (lines303-304) that it becomes clear.*

A > The clarification that CHIMERE has been used to run only the 6 km and 2 km domains has been added at the beginning of the paragraph that now says: *"The configuration adopted in this work to run simulations over the domain at 6 and 2 km uses initial and boundary conditions from the global three-dimensional chemistry-transport model (LMDz-INCA, (Hauglustaine et al., 2004)), both for gaseous pollutants and for aerosols for the most external domain at 6 km of resolution while for the most internal domains at 2 km of resolution, the boundary conditions are calculated from model outputs of the parent domains."* Lines **157-164***.*

- *It might be clearer to mention the rural Nanyuki, Kenya site (lines 285-287) immediately following the description of the urban Nairobi, Kenya site (lines 280-281).*

A > The paragraph has been modified in agreement to the suggestion: *"For the city of Nairobi, data from urban background were provided by the roadside site at Tom Mboya Street in Nairobi (1.28° S, 36.82° E) while data from rural background were provided by the site of Nanyuki, Kenya (0.01° N, 37.07° E) both obtained from the field sampling campaign performed by Pope et al., (2018)."* Lines **300-303**.

- *Symbols and text on figures with maps (Fig 1, Fig 3, Fig 7, Fig 11) were too small to read without zooming in to at least 200%. I was left searching for tiny triangles, numbers, and coloured dots.*

A > Figure 1 has been modified in order to make the markers on three cities more visible to reader. Figure 3 has been modified and the size of each map increased in order to make all the observation points more visible to the reader. Figure 7 has been deleted because it provided the same information visible in Figure 3 and finally Figure 11 has been modified to make the coloured indications and labels more evident for the reader.

- *Table 2 – units on Elevation written as "(m a. g. l)" are unclear. I interpret this as meters above ground level. "Above ground level" would imply monitoring sites aloft. I suggest just using "(m)" because elevation of ground sites can be assumed as height*

above sea level.

The Table 2 unit has been modified accordingly.

- Line 392 – does "small mean bias" refer to MB or NMB, and is it only for temperature peaks or all temperature measurements? There is similar ambiguity about the use of "mean bias" of relative humidity in line 406

A > originally the sentence was referred to the absolute bias calculated between the observed mean values of model and observations. The statistical analysis has been modified and the MNB deleted from the analysis so that in the new manuscript when the word bias is used it's referred always to the absolute difference between mean observational and modelled values.

Line 414 – change "…sampled, a better …" to "…sampled. A better …"

A > The text has been modified accordingly.

Line 436 – not clear what is meant by "both observation sites". The text seems to be describing results at Addis Ababa which only has a single site.

A > The text has been modified accordingly.

- *Would be helpful to add a sentence after line 332, stating the frequency of weather station data observations. From Figure 4 it seems to range from every 3 hours to every 6 hours. Table 4 needs to include units for $PM_{2.5}$ (presumably micrograms/m3, but not specified).*

A > A new line has been added to specify the variable frequency of the observations: ". *While for the case of WRF observations with frequency variable from 3 to 6 hours are available from the UK Met Office database for different locations […]* "Lines **270-271** In Table 4 has been the units for $PM_{2.5}$ have been also added (μg/m^3)

Line 524 - 526, Eq. (2) and Eq. (3) are missing parenthesis in the denominator around (Co+Cm)

The parenthesis has been added in the new manuscript.

- *Table 5 is never referred to in the text.*

A > The table has been referred in the text in the paragraph of analysis of the general statistics of MFB and MFE.

- *Line 598-599. Figure 7 is mentioned twice, but text seems to be describing Figure 8. Figure 7 seems to be almost the same as Figure 3c. Not sure why it is needed.*

A > The paragraph refers to Figure 8, the text has been modified accordingly. Figure 7 has been deleted; the information was included already in figure 3c. A new figure has been introduced according to the suggestion of reviewer 4 to show additional hotspots of $PM_{2.5}$ concentrations inside the KEN2K domain.

- *Figure 9 should use a date format consistent with other figures in the paper. (Figure 9 writes dates as YYYY-MM-DD, while other figures use DD/MM/YY)*

A > Figure 9 has been modified accordingly.

- *Lines 674-680. Could also consider the impact of precipitation on particulate levels.*

A > The paragraph has been modified to take in account of the possible presence of precipitation modelled or observed in those days when we see and model big changes in concentrations in Nanyuki. The new paragraph is at line **737-747**.

- *Line 689, change "constituencies where analyzed" to "constituencies were analyzed"*

A > The text has been modified accordingly.

- *Line 690-691, text mentions relative population density and references Figure 11, but Figure 11 does not include any population density data.*

A > The text has been modified and correct.

- *May want to mention that the AQI levels are for hourly measurements, while the WHO limit used is for a daily average.*

A > The information has been added at line **773-776**.

- *In Figure 11, the concentration scale for the plot on the right is set at 50 µg m^{-3}, which is lower than the maximum concentrations. It would be better to use a scale that encompasses the entire concentration range.*

A > Figure 11 have been modified and the colour scale now range from 0 to 80 that is the highest mean modelled value found in the map.

- *Line 737-738, Figure caption mentions "top right" and "bottom right" maps, but only one is shown.*

A > The Figure caption has been modified accordingly.

References:

- Pope, F.D.; Gatari, M.; Ng'ang'a, D.; Poynter, A.; Blake, R. Airborne particulate matter monitoring in Kenya using calibrated low-cost sensors. *Atmospheric Chemistry and Physics* **2018**, *18*, 15403-15418, doi:10.5194/acp-18-15403-2018.

Please also note the supplement to this comment:
https://acp.copernicus.org/preprints/acp-2021-552/acp-2021-552-AC1-supplement.pdf