

## ***Interactive comment on “Experimental and model assessment of PM<sub>2.5</sub> and BC emissions and concentrations in a Brazilian city – the Curitiba case study” by Lars Gidhagen et al.***

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Manuscript title (acp-2018-1094): Experimental and model assessment of PM<sub>2.5</sub> and BC emissions and concentrations in a Brazilian city – the Curitiba case study Please find below the comments made by Reviewer 1. Authors’ responses are given after each comment. The references to pages and lines are for the revised manuscript which includes the tracking changes.

Reviewer 1: “The manuscript carried out monitoring and model assessments in a Brazilian city Curitiba focusing on PM<sub>2.5</sub> and Black Carbon emissions. It is an interesting and important research topic, however, there are information details lacking

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in the current manuscript and it is like a report instead of a research paper. There is a large block of text (for example in the discussion and conclusion section) which is difficult for the readers to follow. I would suggest a major revision before we can consider for publication. It is suggested that the authors would improve the manuscript by adding sub-headers at appropriate locations and also organize the tabulated data in form of bar/pie charts. Below are some specific comments:”

Authors’ response: The authors acknowledge the constructive comments made by Reviewer 1. We have tried to improve the manuscript according to the specific suggestions, e.g. by adding sub-headers. Our responses to each of the specific comments are given here below, after each of the comments.

Introduction: 1. “Page 2 line 6: “One Specific SDG indicator, 11.6.2, for meeting this goal is the annual mean level of PM2.5 weighted by population. . .” This sentence seems incomplete. Are the authors trying to bring out that the annual mean level of population weighted PM2.5 reaches a certain value would meet the goal? Please consider re-organize the sentence structure.”

Authors’ response: We have revised the sentence structure to assure it to be understandable, see page 2, lines 6 - 9.

Section 2.1 Study Area: 2. “Page 4 line 1: The authors mentioned there are four automatic stations within the municipality of Curitiba and four in the industrial area of the nearby city of Araucaria and an analysis of PM10 and NO2 from the official monitoring network was performed for three years from 2013 to 2015. The analysis include the data from the four automatic stations within the municipality of Curitiba but does it consider the data from the four stations in the industrial area of the nearby city of Araucaria? If not, what is the reason for excluding them in the analysis? Also please clarify whether there are missing data?”

Authors’ response: The reason why we only discuss the four monitor stations inside the Curitiba municipality was because our assessment had to be limited to his area. De-

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tailed traffic information was available for the Curitiba municipality, this is why our high-resolution model was restricted to the Curitiba municipality, not covering the neighboring Araucaria industrial area. We have stressed this areal limitation of our assessment in the end of Section 2.1 (page 4, line 5), and also at various locations in Section 2.2. The reviewer 1 also asks for a clarification if there are missing data. As for missing data at the four stations inside the Curitiba municipality, there is a column in Table 4 showing “Data capture” during the 2013-2015 period used as reference.

Section 2.2 Study Design: 3. “Page 4 line 7: Please be specific measured data from which stations are validating the emission inventory?”

Authors’ response: In the last paragraph of Section 2.2 we have more clearly stated that the validation of the emission inventory was principally made by comparing street canyon increment at one station in the city center with the modeled impact of local traffic passing the street canyon, this leading to corrected emission factors for road vehicles. We then compared the urban background measurement data in the city center and in a residential area with high-resolution model output (based on the corrected emission factors for road vehicles) together with the long-range impact as determined by the regional model, revealing – as presented in the Result sections - reasonable results for BC but inconsistent results for PM<sub>2.5</sub>.

Section 2.3 Emission Inventory: “The emission inventory are developed mainly based on two economic sectors: industries and on road transport.” 4. “Page 5 lines 5–8: Detailed data for industrial sources are lacking. Please summarize and supplement.”

Authors’ response: We have added a description of the IAP industrial inventory, the type of industries found inside Curitiba and in the Araucária area just southwest of the city (page 5, lines 25-31). A summarized information on industrial PM emissions are found in the result Section 3.5 (page 12, line 14).

5. “It is observed that data has been provided in Tables 1–3 for both public and

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private vehicles. Please supplement bar charts to these tables for better illustration. The data on public transportation are quite detailed but for private vehicles, it is recommended to report the total number/types of vehicles and average speed as now seem there are only emission factors for private vehicles as in Table 3. What about uncertainty analysis?”

Authors' response: We made attempts to produce readable bar charts of Table 1-3, but it was found difficult to obtain the same amount of information presented in a pedagogic way and within a few diagrams. For example the following diagram only covers one of six data columns in Table 2 and we could not find a way of displaying all information in a single or a few bar charts. Moreover, those interested in the modeling part will find the absolute numbers of the emission factors to be useful. We thus believe that showing the tables makes this publication more informative.

We did not perform any uncertainty analysis of emission factors for private vehicles. Due to the much higher emission factors for diesel fueled LDVs and HDVs as compared to gasoline cars (Table 3), it is the percentages of those former type of vehicles that are critical (comment added page 6, line 31-32). As trucks are restricted to operate in the city center, we were suggested by traffic experts in Curitiba to work with 5% of diesel LDV and only 2% of HDV, this for most of the streets inside the ring road (only some transit roads excluded) and in particular for the street where we compared the street canyon model output with measurements. Our street canyon model evaluation resulted in a correction factor for private vehicle emissions, compensating for errors in vehicle fleet composition at this particular street as well as the emission factors taken from the literature. However, at other streets any different fleet composition from what we have assumed, will contribute to an erroneous emission and impact. We are clear in the manuscript that the lack of exact fleet composition for the private vehicles is a weak point in our assessment, e.g., in the Section 5 Limitations, page 18, lines 4-5.

6. “Page 5 line 23: Please describe more details about the VISSIM model and the corresponding input settings and data required for this model.”

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Authors' response: More details of the VISUM traffic model has been added on page 6, line 13-19.

7. "Page 5 line 25: Please provide information on the daily profiles adopted."

Authors' response: A new Fig. 2 has been included, revealing the daily profiles adopted.

Section 2.5 Dispersion Modelling: 8. "The EDGAR-HTAP information include BC and OC emissions from what kind of sources, does the information include those BC release from vehicles and industries or wood burning within state of Parana?"

Authors' response: The EDGAR-HTAP should include those sources, but with a very coarse spatial resolution. We lack information to evaluate how complete the EDGAR-HTAP emissions of BC and OC are for the state of Paraná. We have added some details of the database in Section 2.5, page 8, lines 15-17. We conclude, after comparing the simulated and measure BC levels inside Curitiba, that the long-range BC contribution seems to be underestimated, see Section 4.7, page 16, line 13-16.

9. "It is mentioned that Gaussian Dispersion model incorporates a diagnostic wind model that takes into account surface roughness and building heights. As the building morphologies of the investigated city, are quite complex revealed in Fig 2 (right). Do the authors require inputting surface roughness and building height information or construct the CAD city model for OSPM model? If so, what surface roughness profiles/values and assumptions do the authors made to input in the OSPM model? Please include in the manuscript."

Authors' response: An explanation has been added of how surface roughness was calculated (page 8, line 23-24). The OSPM model uses wind speed at roof level, given by the diagnostic wind model, as input (added text page 9, line 4-5).

10. "Would the justification of choice of BRAMS for regional scale modelling (P.6 line 27-29) be provided? How would be its accuracy compare with other major alterna-

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tives e.g. WRF?”

Authors' response: BRAMS is used together with CCATT model in an operation setup (<http://meioambiente.cptec.inpe.br/index.php?lang=en>) on 50x50 km<sup>2</sup> grid resolution. It was natural to use the same meteorological model for the nesting down to 10x10 km<sup>2</sup> over the Paraná state. It is not likely that using WRF with the same coarse grid resolution (10x10 km<sup>2</sup>) would have implied any substantial improvement in the CCATT model output, especially if one considers the important shortcomings in how CCATT was applied (no secondary PM, lack of detailed industrial BC emissions in the inventory etc). We thus argue that limitations in the regional CCATT model output are more found in the emission inventory than in the meteorological forcing. In addition, the CCATT-BRAMS modeling system, currently in the BRAMS 5.3 version, has more than 20 years of development in Brazil, with refinements and improvements allowing fast computations on multi-processor computers and parameterizations focused on the physical processes of South America.

Section 3 Results: 11. “Page 7 Line 28: There were no PM<sub>10</sub> data reported from station CIC during the campaign period? Does it mean there is no PM<sub>10</sub> release or there are other reasons behind? How about NO<sub>2</sub> data at this station?”

Authors' response: There were technical problems for the PM<sub>10</sub> monitor at the CIC station during the monitoring campaign, therefore no data were available. However, NO<sub>2</sub> levels at CIC stations during the winter 2016 monitoring campaign were lower – 76% – as compared to the mean for the corresponding winter period (August) in 2013, 2014 and 2015. We have added this NO<sub>2</sub> ratio at CIC station located in the more industrial area and close to the ring road, see Section 3.1, page 9, line 23.

12. “Page 7 Line 32: Would the authors please provide more information on the variation in long range transported pollution arriving to Curitiba.”

Authors' response: We have introduced in Section 2.1 Study area a comment and a reference on possible long range contributions from the seasonal biomass burning in

northern and central Brazil (page 4, lines 7-10).

13. “Page 8 Line 21: Please describe what kind of technical failure caused the acquired data during fixed monitoring cannot be used.”

Authors’ response: There was an electronic problem with the pump with the consequence that it was not possible to keep a steady air flow. We could see clear signs of an interrupted air flow in the filter data, with days of data completely lost and with most of the remaining days a lower accumulated PM<sub>2.5</sub> mass at the street level (close to traffic) as compared to at roof level. Due to this circumstance, that we were not sure about the accuracy of the data obtained, we preferred to discard these data.

14. “Section 3.4: It is mentioned that the street canyon dispersion model OSPM produced much smaller magnitude of PM<sub>2.5</sub> and BC compared to measurement and regression analysis has been carried out to obtain correction factors. Please provide some brief information on the way that regression analysis were carried out. Also are the correction factors applicable to other places in Brazil? Have the authors tried other dispersion models such as AERMOD, ADMS or CFD approach, which might improve the magnitude prediction?”

Authors’ response: A sentence has been added on the regression analysis (page 11, lines 32 – page 12, line 1-2). The conclusion from this Curitiba street canyon assessment was that the detailed information on public transport gave, together with emission factors from Europe, fairly accurate emissions. Similar information on public transport should be available in other Brazilian cities (a sentence added in Discussion page 14, line 30-31). However, for the private transport, with uncertainties both in vehicle fleet composition and vehicle technology, there is a risk for large errors and an attempt to determine site specific emission factors can be, like in Curitiba, necessary (sentence added in Discussion Section 4.5, page 15, lines 9-11). No other microenvironment model than OSPM have been used to simulate the dispersion of local traffic emissions inside street canyons in Curitiba. Since the PM<sub>2.5</sub> and BC emission factors were de-

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terminated from the assumption that NO<sub>x</sub> was correctly simulated by the model, it is not likely that the use of different models would have given other results (we have made linear corrections, see Authors' response to next comment).

15. "Section 3.4: Can the change of correction factor for BC for private vehicle emission by a factor of 5 be justified and conclude that it is not contributing by other factors like wrong fleet composition and modeling error? Is the new emission factor checked using an independent dataset of concentration measurement?"

Authors' response: In the assessment of local emission factors, our main assumption was that we found simulated NO<sub>x</sub> contributions to be similar to measured increments. This can be a coincidence, e.g. if dispersion/ventilation is underestimated and the emission factors overestimated. However, since NO<sub>x</sub> emission factors are more tested and more robust in the literature (as compared to PM and BC emission factors), we assumed that the similar results for measured and simulated contributions to NO<sub>x</sub> indicate that all steps in the simulation - including vehicle fleet composition, emission factors, dilution - were OK. If this is the case, then the large difference between simulated and measured BC contributions can't be explained by neither fleet composition nor model errors; instead the difference should have been created by erroneous emission factors. Comparison with independent dataset: Yes, while using the corrected emission factors estimated from the street canyon measurement and model simulations with OSPM, we find reasonable simulated BC contributions from local sources inside Curitiba also when comparing with urban background levels taken from independent stations (MD roof station, SC residential area). The local contribution is reasonable under the assumption that the regional model output of BC is underestimated, which seems possible when we only have the global EDGAR-HTAP database as input to BC emissions. Curitiba's own contribution to urban background BC levels seems to be about half of total measured BC, leaving space for a spatially homogeneous long-range contribution of approximately the same size as the local contribution ( $\sim 1 \mu\text{g m}^{-3}$ ). Note that an earlier measurement campaign at the University campus showed a BC mean level just

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above  $2 \mu\text{g m}^{-3}$  (Polezer et al., 2018) i.e. the same urban background concentration level as for the two stations MD roof and SC of the present campaign.

Section 4 Discussions and conclusions: 16. “This section needs to be better organized around the main conclusions and highlights. At the moment, there is a large block of text with many information which is hard for the readers to follow. Please add sub-headers at appropriate locations to break down the text and also present the important data in form of bar/pie charts instead of tables only. Please also list out important conclusions point by point and include a section on limitations of the study.”

Authors’ response: Nine sub-headers have been added, giving a structure of the Discussion and conclusion section more easy to follow. One text paragraph (concerning the mobile data collected with bikes) has also been moved to fit with this structure. The last sub-header is a point-by-point conclusion list. A new section 5 Limitations has been added.

17. “Please add a sub-section that focus on discussion of comparison between model simulation results and measurement/monitoring data.”

Authors’ response: The comparison of simulated PM<sub>2.5</sub> and BC levels with those measured in the two fixed urban background stations (MD roof and SC) is now part of a new sub-section named 4.7 Spatial distribution of PM<sub>2.5</sub> and BC over Curitiba (comparison between simulated and measured concentration levels), page 15, line 1.

18. “EDGAR-HTAP gives only 0.1deg x 0.1deg resolution. Do you mean local industrial BC emission is low when compared to other BC sources in Curitiba by providing a simulated BC urban background (P.10 line 32-33)? Please justify?”

Authors’ response: Industrial sources to BC emissions in the area just southwest of Curitiba are very coarsely described in the EDGAR-HTAP inventory and they constitute the only input of BC emission to the regional model. We also find the output over Curitiba to be very low, with BC contributions from sources outside the

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Curitiba municipality of 0.06-0.07  $\mu\text{g m}^{-3}$  in average, see Table 8. Local traffic sources contribute, according to the urban model, with a bit more than 1  $\mu\text{g m}^{-3}$  of BC, however monitored mean levels are found above 2  $\mu\text{g m}^{-3}$  both in the city center and in the residential area situated in the outskirts of the city. It is reasonable to think that the limited and coarse input of BC emissions from sources outside Curitiba can explain an underestimated long-range BC contribution. If local sources were behind the underestimated BC levels in the urban background, it would have been reasonable to see more varying levels at different locations (like we saw for PM<sub>2.5</sub>).

Please also note the supplement to this comment:

<https://www.atmos-chem-phys-discuss.net/acp-2018-1094/acp-2018-1094-AC1-supplement.pdf>

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