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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Air pollution near arterial roads: An experimental and modelling study" *by* José Ignacio Huertas Cardozo and Daniel Fernando Prato Sánchez

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For a more comprehensive understanding of the author's response, we invite the Referee to see it in the supplement material.

Air pollution near unpaved roads: An experimental and modelling study

Reply to reviewer 2 Jan 2018

General remarks. This is an experimental and modelling study of pollutant dispersion from unpaved arterial roads. As written, and as described by the other reviewer, the manuscript is in danger of being misunderstood, and a careful re-write will be required

before it can be considered for publication in ACP. Reply: We thanks comments from our reviewer and appreciate his effort providing comments to improve our manuscript and our work.

Specifics comments. Specific Comment 1.Title and abstract: should prefigure the main work of the paper more accurately. Please include the word "unpaved" before "arterial roads". Reply: Ok. Manuscript was modified.

Specific Comment 2. Abstract. Please make it clear that the particle measurements in the study are 24-hour average mass concentrations. I don't see how emission mass rates were measured – please delete. Reply: Ok. Manuscript was modified

Specific Comment 3. Abstract, Line 12. Please state whether these "plots of pollutants concentration" are measured or experimental. If they are experimental, please repeat the temporal averaging time. Reply: Ok. Manuscript was modified

Specific Comment 4. P2, Line 20. You say "an important number of works" but only cite one work – please amend to make consistent. Reply: Ok. Manuscript was modified

Specific Comment 5. P2, Line 30. The diffusivity differences between CO and NOx are trivial with respect to dispersion under turbulent mixing at a roadside. Also, CO and NOx disperse in the same plume, having the same density, not in plumes of different density, so I don't think this sentence is helpful. I suggest you delete. Reply: Ok. Manuscript was modified We did not delete the whole sentence because it is relevant. We are emphasizing that, quantitatively, the dispersion of particles is not exactly the same as the dispersion of any gas phase pollutant.

Specific Comment 6. P2, Line 32. Here, and thoughout, you must make it clear which size fraction you are discussing. Reply: Ok. Manuscript was modified

Specific Comment 7. P2, Line 34. Gaussian models are not heuristic, see Seinfeld and Pandis, Atmospheric Physics and Chemistry, 2nd ed., Ch. 18. Reply: Ok. Manuscript was modified

Specific Comment 8. P2, Line 37. This paragraph does not add anything to the manuscript and could be read as a criticism of the understanding of fluid dynamics of previous pioneers in the field. I suggest it is deleted. Reply: Ok. Most of the paragraph was deleted.

Specific Comment 9. P2, Line 44ff. There are many more studies of computational fluid dynamics for urban and rural roads than cited here. You should distinguish RANS approaches from large eddy simulations and provide more citations. Your primary data to evaluate the model are 24-hour averages; please provide a discussion of why "state-of-the-art" CFD is the best method to interpret such long-time averages. Reply: Ok. Manuscript was modified

Specific Comment 10. P3, Line 7. If the point of the previous paragraph was to introduce the idea of working with a commercial CFD package, then that package should be named here. Reply: Ok. Manuscript was modified. We used Fluent v17 from ANSYS.

Specific Comment 11. P3, line 16. Please re-write this bullet to state what the model is (not just "state of the art") and what it does (something more useful than to resolve a known issue with the Gaussian solutions). Reply: Ok. Manuscript was modified

Specific Comment 12. P3, Line 21. Define symbols or direct reader to a list of symbols. Reply: Ok. Manuscript was modified

Specific Comment 13. P3, line 24. Disambiguate TPS and TSP – are these the same or something different? Please provide horizontal scale bounds on the statement about "constant fraction" because as written it appears to break the laws of physics (or those laws conspire to match precisely the different loss processes affecting PM2.5 and TSP). Reply: Ok. Manuscript was modified It should be TSP (total suspended particles).

Specific Comment 14. P3, Line 25. Please provide the reader with some idea of the threshold applied that allows an impact area to be defined. Reply: Ok. Manuscript

was modified. The environmental impact area generated by the use of the roads was defined as the area at both sides of the road where short or long-term average concentrations exceeds national air quality standards for any of the pollutants under consideration. We used thresholds of 100 and 300 ug/m3 for 24 h and annual averages of TSP concentrations, respectively, and thresholds of 50 and 100 ug/m3 for 24 h and annual averages of PM10 concentrations, respectively.

Specific Comment 15. Figure 1. Horizontal scales are given but not a vertical scale. The caption should draw the reader's attention to the non-uniform length scale. Reply: Ok, Figure 1 was modified

Specific Comment 16. P3, Line 29. Strictly, vegetation can be a source of primary (mostly coarse) aerosol particles composed of pollen, spores, or plant fragments. This sentence should be written more carefully. Reply: Ok. Manuscript was modified We selected a region in which the unique particulate matter (TSP, PM10 and PM2.5) emission source was the road. We selected areas covered with pastures and assumed that on these areas the emission of primary aerosol particles such as pollen, spores or plant fragments were negligible.

Specific Comment 17. P3, Line30ff. These sentences are rationale for the study and should be in the Introduction. When re-written in the correct place, this paragraph should carefully distinguish between sources which dominate the mass size distribution of roadside aerosol, and those which dominate the number size distribution. Reply: Ok. Manuscript was modified

Specific Comment 18. P3, Line 38. Please state at which positions relative to the road which measurements were made, at which temporal resolution, and with which measuring equipment. Reply: Ok. Manuscript was modified That information is provided later in the manuscript. We added the sentence: Section 2.1 will describe the experimental work conducted in this study.

Specific Comment 19. P4, Line 4. Please state that you will discuss model calibration in a later section. Reply: Ok. Manuscript was modified

Specific Comment 20. P4, Line 28. Explain to the reader what changes to get emissions for TSP and PM10 from equations 1-4. Reply: Ok. Manuscript was modified. The emission factor Ef changes for TSP and PM10.

Specific Comment 21. P5, Line 1. Please provide the temporal resolution of met data. Delete "primary and secondary". Reply: Ok. Manuscript was modified

Specific Comment 22. P5, Line 17. Report briefly the definition of diameter derived from the microscopy (e.g., equivalent area, longest axis, etc). Reply: Ok. Manuscript was modified. We reported observable mean diameter.

Specific Comment 23. P5, Line 17. Figure 2d reports apparently size in mm, not micrometres. Reply: Ok. Manuscript was modified. Figure 2d was modified. Specific Comment 24. P5, line 18. Rosin-Rambler (abstract) or Rosin-Rammler? Reply: Ok. Manuscript was modified

Specific Comment 25. P5, Line 35. Are these two different references? If so, they should be disambiguated. Reply: Ok. Manuscript was modified. They are two different references.

Specific Comment 26. P6, section 4.2. Whether an accompanying model description paper is available or not, sufficient detail of the modelling approach should be given to allow the reader to understand the model set-up and experiments. Please describe the model discretization and turbulent closure as a minimum. Please provide some justification for the size of domain and for the boundary conditions chosen. Please provide details of model spin up to steady state. Please explain how 1 hour steady state models are to be compared to 24-hour average measurements. Please describe what microphysics, if any, is included in the model. Reply: Ok. Manuscript was modified The information requested about the implementation of the CFD model is included later in the section under the subtitle: Implementation of the NR-CFD model.

We used the standard k-ε turbulence model

We used a 1500-m-long, 60-m-high and 10 m-depth computational domain. Computational domain dimensions were selected as the minimum required for the boundaries not to interfere with dispersion under the emission conditions studied. Even though the simplicity of the geometry allows 2D simulations, particle dispersion is highly affected by turbulence and therefore 3D simulations are required.

We used a condition of symmetry (zero gradient normal to boundary) at the upper ceiling. Pressure outlet was used as boundary condition at the exit and a periodic boundary condition was used for the lateral walls. On the surface downwind from the road, we considered the Air–particulate matter–ground interaction and used the boundary condition that traps the particles arriving at the surface (ANSYS, 2012a). We expressed the entry of air into the computational domain as a speed profile of a fluid on a flat surface using Equation 6, which describes a neutrally stratified atmospheric boundary layer (Panofsky and Dutton, 1984; Zanneti, 1990). . . . . .

Steady state vs. transient simulations: Particle dispersion is a natural phenomenon that varies with time. To determine its impacts on human health and the environment, average short-term (∼1 day) and long-term (∼1 year) ground-level concentrations are needed. As the modelling of transient-state particle dispersion via CFD for 1 day and certainly for one year is computationally prohibitive, we simplified the problem by using short-interval modelling, where it could be assumed a steady state condition. In practice, 1-hour intervals are appropriate, as meteorological data are reported in this way.

To obtain pollutant concentrations over extended periods of time, we calculated for each hour i the values of input parameters to the NR-CFD model (average emission rate, wind speed, wind direction). Then, pollutant concentration (Ci,j) is obtained for each hour and position (j) downwind from the road. Finally, average daily and annual values are obtained for each distance from the road ((C_j) ÌĚ). If particulate matter emission remains constant, average values are obtained by Equation 10 where fk,q is the frequency at which speed Uk, appears in the wind rose for each wind direction (q).

$C_j=\sum\sum f_{(k,q)}C_{(k,j)}$ (10)

For winds flowing in directions other than perpendicular to the road, we maintained the magnitude of wind speed unaffected and computed its contribution to particulate matter concentration at receptor j as if the receptor j were located at an equivalent distance from the road (xe) (Figure 4, Equation 11).

$x_e=x / \mathrm{Cos}(\theta)$ (11)

Further details on the implementation of the NR-CFD model are reported in (Huertas et al., 2018).

Specific Comment 27. P6, Line 34ff. I don't believe that readers will accept you can model all kinds of vehicle induced aerosol with a single 'quartz' model tracer following a Rosin-Rammler size distribution. It would be much more persuasive to stick to modelling the suspended silt that makes up the vast majority of the mass concentration in the hi-vol samples. Reply: Ok. Manuscript was modified. We deleted all mentions to other types of particles in this section.

Specific Comment 28. P7, Line 9. Finally, we learn that the model is FLUENT, set-up with a variety of standard settings. Please completely re-order the description of the modelling to start with the name of the commercial modelling system and describe the important set-up parameters as asked for above. Reply: Ok. Manuscript was modified.

Specific Comment 29. P8, Line 1. The calibration procedure is not clear. Calibration implies that some parts of the measured data were used to refine model parameters and then the calibrated model used to simulate a different part of the data. Please explain. Reply: Ok. Manuscript was modified. We did that, except that all experimental data was used to adjust the model. Then the calibrated model was used to study dispersion of gases, vertical profiles of concentration etc. We re-wrote the paragraph

to make it clear.

Specific Comment 30. Figure 5b. How long are the long-term averages? Please make all captions self explanatory. Reply: Ok. Manuscript was modified

Specific Comment 31. P8, Line 11. If the measurements are averages please also plot standard deviations (or, better, plot medians and quartiles). Reply: Ok. Manuscript was modified. Figure 5 was modified.

Specific Comment 32. P8, Line 16. Please report numbers using standard scientific notation. RMSE should have associated units. Reply: Ok. Manuscript was modified

Specific Comment 33. P8, Line 26, It is a basic property of the Gaussian plume model that downwind concentrations are proportional to the emission rate, so Figure 6a is not needed. Figure 6b is more interesting, but only if some description of the model is provided that would account for non-linear behaviour with emission rate. Since the concentration further downwind is exactly proportional to emission rate for the CFD simulation, it is more pertinent to ask what is causing the spread near the source. Reply: Ok. Manuscript was modified Figure 6a was deleted It also shows that near the road (x*<1) C* is highly disperse. We believe that the spreading effect is caused by the perturbations that the vertical flow of particles emitted from the road causes to horizontal incoming wind flow. Those mixing flow effects disappear downwind when the mix-flow becomes again uniform and parallel to the ground surface.

Specific Comment 34. Figure 6b and 6d. I am not sure how "zero" can appear on a logarithmic scale. This will be confusing, especially for junior scientists, and should be removed. Reply: Not Ok. Figures 6b and 6d are semi-log plots. On the x-axis we used log scales and they ranges from 0.1 to 1000. On the y-axis we used normal scales and they ranges from 0 to 10.

Specific Comment 35. P8, Line 30ff. It is, again, a standard result from Gaussian plume models that the concentration at a point varies inversely with wind speed. This para therefore shows what a good job Gaussian plume modelling does of capturing the time-average concentration profile downwind of a source, which has been demonstrated many times before. Again, the behaviour of the CFD for x* <1 is more interesting. Reply: Ok. Manuscript was modified We removed the paragraph from the manuscript.

Specific Comment 36. P9. If deposition is negligible and coagulation and condensational growth are not applicable/ accounted for, then the ratios of size fractions are bound to remain constant. Reply: Yes. That is the point of the subsection entitle PM10 and PM2.5 concentrations downwind

Specific Comment 37. P10, Line 10. It is not intuitive to expect a Gaussian vertical distribution from AERMOD. This would be the case for a chimney but not for a ground source. Reply: Ok. Manuscript was modified. We removed this word from the paragraph.

Specific Comment 38. P10, Line 46ff. Please explain why the model results for gas phase tracers are very much smoother than those for TSP. Reply: Ok. Manuscript was modified.

Specific Comment 39. P11, Line 23. This material should be much earlier on when the concept of 'area affected' is introduced. It is important to state what averaging time is used in the air quality standard you are using, and to compare similar modelled and measured averaging times. Reply: Ok. Manuscript was modified This section is located at the end of the document because the determination of the road impact area is an application of the model.

Specific Comment 40. P12. The conclusions should be re-written in light of the revisions suggested by the referees. Reply: Ok. Manuscript was modified

Specific Comment 41. References. If Huertas and Prato is "in press" please provide the journal name. Reply: Ok. Manuscript was modified

Specific Comment 42. Throughout: please could the font size and line spacing be

made consistent. Reply: Ok. Manuscript was modified

Best Regards Dr. José Ignacio Huertas School of Engineering and Science-EIC Automotive engineering research center- CIMA (http://cima.tol.itesm.mx/) Tecnológico de Monterrey (http://www.itesm.edu/) Phone: (52) 81 8358 2000 Ext 5293

Please also note the supplement to this comment:
https://www.atmos-chem-phys-discuss.net/acp-2017-753/acp-2017-753-AC2-supplement.pdf

Interactive comment on Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2017-753, 2017.