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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Particle number, particle mass and NO_x emission factors at a highway and an urban street in Copenhagen" *by* F. Wang et al.

F. Wang et al.

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We would like to start with expressing our gratitude to the reviewers and the editor for taking the time to carefully read our manuscript and for their relevant comments, we all agree with and which definitely will result in an improved paper. We have in the following answered all comments and will make changes in the manuscript according to the reviewers' suggestions.

Anonymous Referee #1

COMMENT: Page 19548 In section 2.1. The positions of urban kerbside and background sites are given. The kerbside measurement is taken 3 m away from the 6 lane H.C. Andersens Boulevard and the urban background measurement is a roof top mea-

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surement in proximity to the 6 lane Norre Alle. In comparison to the H.C. Andersens Boulevard with 55600 vehicles per day. In terms of vehicles per day, how busy is the Norre Alle and are contributions from this local traffic source evident in the data?

RESPONSE: Norre Alle is close to our urban background station has a traffic flow of about 36000 veh./day. However, the station is located on the roof of a 20 m high building. Therefore, the direct influence of Norre Alle to the background station is limited. Previously conducted receptor analysis has shown, that the traffic contribution at the background station (originating from several sources not only Norre Alle) is only about 16%-18% compared to the kerbside station. Please see also the height of the morning rush hour peaks for Urb-Ks and Urb-Bg in Figure 6 and the response to comment Page 19554, Line 3, second part.

COMMENT: Page 19552, Line 14. Reports that traffic volume was not measured at the urban roadside site and instead there is a reliance on a pattern measured by the Copenhagen municipality one a year for 1-2 days. What measures were put in place in your calculation to ensure that the urban HDV/LDV emission factors were not under/over estimated due to the incorrect split between the heavy and light duty vehicles of the fleet measured during the campaign? Furthermore, how sensitive are the HDV/LDV emission factors to this split between light and heavy duty vehicle counts?

RESPONSE: From other (partly automatic) traffic observations at other locations downtown Copenhagen we know that the traffic pattern is quiet stable and regular. Unfortunately, we do not have more data on this road. We agree that the LDV and HDV emission factors are very sensitive to changes in the traffic share HDV/LDV. This issue will be addressed by a sensitivity study added to the revised version of the manuscript. We altered the HDV counts by 20% and this resulted in a change of the HDV emission factor of max. 17%.

COMMENT: Page 19554, Line 3. Reference is made to the street canyon effect and authors such as Jones and Harrison indicate that wind direction is an important con-

ACPD

9, C8727–C8736, 2009

sideration when measuring traffic emission factors at the London Marylebone Road. Can the Urb-Kb be correctly defined as a canyon considering the open park located across the road? Also when selecting the data to measure a roadside increment, how sensitive is wind direction to this “street canyon” effect . . .

RESPONSE: It is correct, that H.C. Andersens Boulevard close to Urb-Kb is a one-sided street and that the wind direction is a crucial parameter. Based on flow and dispersion models (WinOSPM) and from wind tunnel studies we know, that due to the flow pattern around the buildings for a one-sided street the street pollution is transported to the side where the buildings are located. In our case the measuring station was located at this side, where the buildings are, following that this station observes the emitted street pollution nearly independently of wind direction. The location of the measurement station was chosen for this reason. In the revised version of the manuscript we will replace the term “Street canyon effect” that might indeed be misleading.

COMMENT: . . . and are local sources, e.g. the train station, evident in the data when taking into account wind direction which may be elevating the average emissions measured at this site?

RESPONSE: This is correct as an urban street monitoring station is affected by 3 major source contributions: 1) contribution from the local street next to the station, 2) contribution from other local sources (e.g. other streets, train station, non-traffic sources) and 3) regional / long range transported pollution from outside the city. The basic idea with taking the difference (kerbside minus background station) is that the local street contribution (1) is isolated. This assumes that the contributions (2+3) are similar at the two stations (kerbside and background station). Our calculations and conclusions are based on the assumption, that the background station is influenced by sources (2+3) in the same way as the kerbside station is. This assumption will be clearly formulated and be discussed with possible errors in a revised version of the manuscript.

ACPD

9, C8727–C8736, 2009

COMMENT: Page 19555 Line 8. The lowering of the boundary layer may also contribute to an elevation of concentration at night.

RESPONSE: We agree, that the night peak might be influenced by changes of the boundary layer at night. This argument will be considered in a revised version of the manuscript.

COMMENT: Page 19556 Line 17. Dyno and chase studies in the PARTICULATE programme also show the onset of a nucleation mode at 100 kph, i.e. the speed of the traffic on the Highway.

RESPONSE: Thanks for this comment. We will include a relevant reference concerning this comment.

COMMENT: Page 19557 Line 20 onwards. The change in particle size distribution is considered with distance from the highway by comparing the measurements at the background site when the wind blew away and towards the site. When selecting measurement data according to wind directions 105 to 225, there are two roads, namely the Bondehojvej road and Roskildevej highway which air will pass over before reaching the background site. Can the arguments made in this section can be extended to justify the positioning of the background site?

RESPONSE: Roskildevej has a substantial traffic intensity of about 17500 veh./day, but is however located more than 1 km south of our two stations. The contribution from Roskildevej will be about the same at both the Hw-Ks and Hw-Bg stations and can be considered as a general background, that is "neutralized" by taking the difference Ks minus Bg later after Section 3.6. The road Bondehøjvej has very minor traffic of only 2400 veh./day and should not have any relevant contribution at our stations compared to the highway itself. The Hw-Bg station has a distance of about 200m to Bondehøjvej, that is considered as far enough to avoid a direct influence. We will add the traffic volumes and this argumentation to the revised version of the paper.

ACPD

9, C8727–C8736, 2009

COMMENT: Page 19566, Line 20 and Page 19566, Line 21. States, “the emission factors for HDV decreases with vehicle speed since engines run more efficiently on highways." The literature, e.g. Imof et al (2005), Morawska et al (1999), Kristensson et al (2004), Jones and Harrison (2006), all suggests that as fleet speed increases from 50 to 100 kph the emission factors also increase for both LDV and HDV. Morawska did measure similar PN emission factors for fleet speeds of 60 and 100 kph, but this was for LDV; HDV PN emission factors showed a rise in value with speed. Laboratory and chase experiments also make this claim from the reports given by PARTICULATES http://www.lat.eng.auth.gr/particulates. Can the authors provide references to support this argument? Furthermore, does this contradict the statement on page 19561 line 15, stating that Mode 1 has obviously high concentrations due to high traffic speeds?

RESPONSE: Here we are talking in the beginning about emission factors of NOx, which decrease with vehicle speed (at certain range, likely speed >50 km/h?). For particle number emission factors, we obtained the result, that emission factors are lower at highway for both HDV and LDV. It might be due to the fact, that particles less than 10 nm were not measured, and clearly at the highway site there were more dominant particles around 10 nm observed.

COMMENT: Page 19563, line 13. For equation 3, please check the consistency of the units used on either side of the equals sign. Are extra constants needed to account for the different measured values, e.g. comparing hours and seconds.

RESPONSE: We have correctly considered the difference between units, e.g. 1h=3600s, but did not show the unit conversion in the equations. In the revised version of the paper we will give the units of N as (vehicle s-1) to avoid any misinterpretation.

COMMENT: Page 19564, Line 1. It is stated that the WinOSPM model simulates pollutant dispersion in street canyons. How well did the model simulate the dispersion at the H.C. Andersens Boulevard site which appears to be asymmetric with buildings along just one side of the canyon?

ACPD

9, C8727–C8736, 2009

RESPONSE: You are right also here we will avoid the term “street canyon” in the revised manuscript. WinOSPM is very well capable of handling irregular street canyons with variable building heights or asymmetric streets. Please be referred also to our earlier comment (P.19554, l. 3).

COMMENT: Page 18564, Line 9. The term “multiple linear regression”. Be aware that purists statisticians may point out that is simply just “regression”.

RESPONSE: We consider the term “multiple linear regression” as justified, since there are two explanatory variables (nLDV and nHDV) and a response variable.

COMMENT: Page 19565, Line 28 onwards to the end. This description needs just a little more clarification. It is difficult to understand what the fitted curve is and consequently the final argument.

RESPONSE: We clarified the description. The fitted curve represents the concentration in different modes obtained by lognormal fits, and we will change the sentence as: However, there are differences between the sum of the three modes (diameter >10 nm) obtained by lognormal fits and the measured data.

Technical Corrections

COMMENT: Throughout the paper where there is an emission factor, please make it clear that the emission factor units are per vehicle. For NOx g/vehicle/km; for particle number particles/vehicles/km; for PM2.5 mg/vehicle/km.

RESPONSE: Have many thanks for this useful comment. In a revised version of the manuscript we will carefully consider the units of emission factors used.

COMMENT: Page 19552, line 1. Consider adding a synonymous word to flow to the sentence, "The average daily traffic flow during the..."

RESPONSE: Yes. We will do this. We will write: “The average daily traffic intensity during the measurement campaign at the highway is 55 600 vehicles per day.”

ACPD
9, C8727–C8736, 2009

COMMENT: Page 19552, line 15. Consider making the phrase, "...and for buses a bit lower" moreformal.

RESPONSE: Thanks for the comment. This will we changed to: “The average traffic speed is about 40–50 km h−1 for light duty vehicles and is expected to be lower for buses”.

COMMENT: Page 19555, Section 3.5.1 "nighttime" -> "night-time".

RESPONSE: This will be changed in a revised version of the manuscript.

COMMENT: Page 19557, Line 4. Should read "...even at distances...".

RESPONSE: This will be changed in a revised version of the manuscript.

COMMENT: Page 19561, Line 12. The sentence starting “The number concentration...” needs to be checked for clarity and tense.

RESPONSE: We agree, this sentence is not clear and will be changed to: “The number concentration in mode 2 located at about 19nm at the urban site dominated during the morning rush hour (07:00 LT) and almost doubles the one in mode 3 located at about 59nm at the urban site. During the afternoon rush hour, this number concentration in mode 2 decreases again only being little higher than that in mode 3.”

COMMENT: Page 19561, Line 14. The sentence starting “Mode 1 takes inappreciable contribution at...” needs to be checked for clarity.

RESPONSE: We agree again and will change the sentence to: Mode 1 centred at 10nm has only very small contribution at the urban site independently of the time of the day.

COMMENT: Page 19565, Line 28. Should read, “However, the fitted curves...”

RESPONSE: This will be changed in a revised version of the manuscript.

Anonymous Referee #2

ACPD

9, C8727–C8736, 2009

COMMENT: In general, my main concern relates to the method for estimation of the emission factors. Firstly, in addition to the primary road next to the Copenhagen urban area kerbside station (the H.C. Andersons Boulevard), there are also some other roads close by, which would also contribute to the measured particles, however they were not accounted for (only traffic at the main road is accounted for).

RESPONSE: This comment was addressed in a similar way by reviewer 1. We address the following answer to both reviewers: This is correct as an urban street monitoring station is affected by 3 major source contributions: 1) contribution from the local street next to the station, 2) contribution from other local sources (e.g. other streets, train station, non-traffic sources) and 3) regional / long range transported pollution from outside the city. The basic idea with taking the difference (kerbside minus background station) is that the local street contribution (1) is isolated. This assumes that the contributions (2 + 3) are similar at the two stations (kerbside and background station). Our calculations and conclusions are based on the assumption, that the background station is influenced by sources (2+3) in the same way as the kerbside station is. This assumption will be clearly formulated and be discussed with possible errors in a revised version of the manuscript.

COMMENT: . . .In addition, the traffic flow rate was not monitored in the study, but the Copenhagen municipality data was used. This data by itself is not comprehensive, only one or two days of monitoring. Without good quantification of the traffic flow rate, estimates of the emission factors are not very accurate. Additionally, if the background stations are too close to the roads in question, which may be the case here (at 200 m impact of the road is still present), the contribution from traffic is underestimated, and so are the emission factors.

RESPONSE: This comment was also addressed by reviewer 1. We agree to the relevance of this comment and address the following answer to both reviewers: From other (partly automatic) traffic observations at other locations downtown Copenhagen we know, that the traffic pattern is quiet stable and regular. Unfortunately, we do not

ACPD
9, C8727–C8736, 2009

have more data on this road. We agree, that the LD and HD emission factors are very sensitive to changes in the traffic share HD/LD. This issue will be addressed by a sensitivity study added to the revised version of the manuscript. We altered the HD counts by 20% and this resulted in a change of the HD emission factor of max. 17%.

COMMENT: Abstract, first paragraph, sentence: “In this study we further estimate. . .”. What does “further” refer to? Has already some work been published based on this research?

RESPONSE: We would like to express, that apart from analysis of the data in terms of spatial and temporal trends, we also estimated the emission factors. We will rewrite the abstract in a revised version of the manuscript to make this much clearer. No scientific paper has been published based on this data so far, only a technical report presenting details about the campaign and the data without deeper analysis (See our reference “Ellermann, T., et al.”).

COMMENT: Introduction Second paragraph, sentence: “In comparison, Jayaratne et al (2005) demonstrated a box model. . . “. This statement is incorrect, as Jayaratne did not use a box model, but carbon dioxide as a tracer in determination of particle number emission factors from heavy duty diesel emissions. This method is similar to the one employed by the authors of the manuscript: instead of CO2, they used NOx to account for dilution. A box model was used by another group of authors for estimating vehicle emission factors of urban fleet: Jamriska et al 2001, “A model for determination of motor vehicle emission factors from on-road measurements with a focus on submicrometer particles” in Science of the Total Environment. This model was later used by for example Morawska et al, 2005, “Quantification of particle number emission factors for motor vehicles from on road measurements” in Environmental Science and Technology.

RESPONSE: This is right, that Jamriska et al. (2001) demonstrated the application of a box model. This fact will be corrected in a revised version of the manuscript.

ACPD

9, C8727–C8736, 2009

COMMENT: Second paragraph, sentence: “Most of the above mentioned studies are based on a short period of several hours or several days of measurements. . .”. Most but not all. For example the measurement duration at each of the sites in the above mentioned study by Morawska et al, 2005 was about three months, which is longer than in this work.

RESPONSE: We agree. This is right and will be changed in the revised text.

COMMENT: Fourth paragraph. The aim of the work should be better formulated. Is this study aimed at improving methods for emission factor estimation (as it could be deducted from the comments expressed by the last sentence of paragraph two of the introduction), or at obtaining data on highway emission factors? If the later (which I think is the case), there needs to be better emphasised the need for this kind of knowledge.

RESPONSE: We fairly agree on this comment. In a revised version of the manuscript, we will rewrite the introduction and you will find an improved formulation of the aim of this work, which is in first order - as you mentioned – to obtain and present data on highway emission factors, compare them to emission factors from other locations and put them into a literature context.

Interactive comment on Atmos. Chem. Phys. Discuss., 9, 19545, 2009.