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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Eddy covariance measurements and parameterisation of traffic related particle emissions in an urban environment" *by* E. M. Mårtensson et al.

E. M. Mårtensson et al.

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We would like to thank the referee for the time she/he has spent to carefully read the manuscript and for the positive comments. The comments are no doubt important, and we will give our response below. We have done clarifications and corrections in text.

Main comments

1. See also the answer to referee 3. It is hard to underestimate the importance of the footprint area during flux data analysis, and reviewer is right in highlighting specific on the footprint area. We would like to note that footprint area experimental validations especially in urban area are very limited in literature. Very few reported studies are of

empirical-numerical type and they have very challenged practical applications. From the practical side: on imposing a known footprint area formula to the specific urban terrain, it is unavoidable to introduce uncertainties if physical characteristics variability inside the area is neglected. Therefore, our approach to select sectors by their physical properties was adopted as potentially the most successful approach in defining the footprint area and analyzing the flux dataset.

The footprint was not calculated in any details. We have used our experience from such models to estimate the approximate size of the foot print in order to decide over which radius from the tower that we should include data points from the traffic data base grid. Any attempt to calculate specific footprints corresponding to individual flux data points would be meaningless. The shape of the footprints is not triangular, but each wind sector is naturally triangular in its form. The limited spatial resolution of the database does not allow us to combine its grid points into realistically shaped footprints. The connection to footprints was the guess on how far away, to what radius; the surface contributes significantly to the flux. All considered this is probably good enough, and the best realistic approach. Nevertheless, given the limitations of the footprint models, a comparison of selected sector distance versus available N. Kljun (http://footprint.kljun.net/varinput.php) footprint model is included in the current version of the manuscript. This model is for dynamically homogeneous terrain. A more detailed verification of the footprint models is out of scope in this manuscript. This exercise has not changed the choice of sectors used for the data analysis. The model agrees approximately with our estimates, where we sorted data from different wind directions into the sectors characterized by the traffic database.

Reviewer says that “is likely to increase the uncertainty of the number" and "likely increase uncertainty of the number of vehicles”. Increased uncertainty relative to what value? No comparables are provided by reviewer. Reviewer suggests that a well-defined footprint formula exists which can be imposed in the sampling area - to which we respectfully disagree. We are tackling two problems here: (1) footprint area definition (very limited reports in literature with practical applications) and (2) aerosol flux analysis and definitions of aerosol source function in urban area (only one paper so far, Dorsey et al, Atmos. Envir.). The later can be solved strictly speaking only after the very detail answer is available to the former. However, to resolve the footprint area problem, numerous flux measurements such as reported in this study are needed to be done. There must be iteration process to resolve both, and we can only hope that after many years done by many groups an answer will emerge. This manuscript provides an attempt to characterize fluxes where footprint areas are defined based on surface physical properties, distance from the sampling tower and wind direction rather than a “blind” mathematical equation as a function of tower height and distance from the tower and totally ignoring specific terrain properties.

2. The database gives traffic activity, total number of kilometers the cars drive in an area per time unit, not only the number of cars. Hence, the number of cars, and their speed, both contributes to the traffic activity. This information is based on traffic counts (made by the traffic authority of the city) at different sites during several years. As written in the text the cars emit more particles at higher speeds. This effect cannot be distinguished with our data set, and may contribute to the data scatter.

3. Such separation could be easily done using aerosol size distribution measurements. During this campaign, unfortunately, no such measurements are available. However, nucleation is a process when clusters are formed from vapor, which in turn is from traffic or industry emissions, when the nucleation event are detected the particles have already reached the detection limit, a diameter of 3nm, the measured aerosol spectra is the subsequently growth of particles. As the referee point out the number concentration can be dominated by these particles, this is however not an emission. The focus in this study was to analyze the dominant integrated aerosol source in urban environment. In other words - how many particles are emitted from the city to the higher elevations of atmosphere where they can be transported horizontally to areas outside the city, to regional environment, regardless if it is primary or secondary aerosol, whether comes

from chimney, traffic, or smoking - here we interested in total number of aerosols larger 11 nm. Of course, it is interesting to know a secondary aerosol fraction in total particle number, but it is out of scope of this paper.

Detailed comments

4. Where u and v are the longitudinal and transverse horizontal wind components.

5. The fraction of particle loss due to Brownian diffusion and gravitational settling is calculated for the tube and flow used in the current study. The flow was 7.0 l min.-1 and the total tube length was 3.83m, of which 0.5m were horizontal and the rest vertical, with a diameter of ij inch. Reynolds number is R=419 that is $<$2000, representing a laminar flow. For particles with Dp=11nm this will give a loss of ˜8%, and less for larger particles. The counting efficiency of 50 % is for Dp=11nm, which is what is considered the lower cut for the CPC 3762. If the particle loss in the tube is included for Dp=11nm, the counting efficiency will approximately be 0.5*0.92=0.46. As the increase in the counting efficiency is very steep around 11 nm, together with the decreasing penetration in the tube for larger particles, the lower limit for the particle size is close to 11 nm. No size distributions are available at the measurement site, but it can be assumed that the peak of combustion particles is often at about 40-50 nm where the tube losses are already reduced to a few percent. We will write about this in the manuscript.

6. Obukhov length is a surface layer scale, with dimension meter. It is a relation between parameters characterizing dynamic, thermal and buoyant processes in the surface layer. The equation is L=-Tustarˆ3/kgw'T', where k=0.4 is the von Kármán constant, ustar is the friction velocity and g is gravitational acceleration. Hence, it expresses a competition between mechanical and convective mixing. The Obukhov length is zero for neutral stratification, and positive for stable and negative unstable stratifications.

7. Where Fm is the measured flux and F is the flux after correction for the underestimation due to low response time.

ACPD

5, S4059–S4064, 2005

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8. The distance between Hornsgatan and Rosenlundsgatans is 840 meter and between Rosenlundsg and the tower the distance is 2500 meter, thus between Hornsgatan and the tower the distance is 3340 meter. Will be included in the manuscript.

9. No size resolved data is available from this period.

Add: The difference between the cutoff size, 11nm for the tower and 7 nm for the street and roof, will to a minor part be the reason for the lower concentration at the tower, the reason for this is that the number concentration peaks above 11 nm (Gidhagen et al, 2003).

10. Add: Wind speed, should be horizontal wind speed. Where u and v are the longitudinal and transverse horizontal wind components of the horizontal wind vector.

11. As mentioned at page 5547 line 5 and line 15 the response time for the CPC is 0.4 s, the signal from the CPC is logged through a pulse-to- analogue voltage converter and through one of the Gill R3 external analogue signal input lines at 20 Hz. We note that due to the smearing, the sequential concentration data points are not independent in 20hz time series. CPC has too slow time response to provide resolved in time concentration data at 20Hz frequency. However, it is no problem to get 20 Hz data from a CPC. The important thing is to note that the variations faster than 0.4 s are noise, as we show in the wN spectra. This problem however, we deal with in detail, and we correct the fluxes for the limited sensor responses.

12. No, in this figure, it is an average of all fluxes from that particular average wind direction with both daytime and nighttime included. The number fluxes (half hour averages) can differ between the sectors; still they are all from that particular wind direction. However, when we calculate the flux, we use a time scale of 30 min page 5546 line18, to include the larger eddies contributing to the flux. The wind direction is in the same way as the flux an average over 30 min. There can be an uncertainty, if the wind direction change during this period, but there is no alternative, since we would face larger problems if we calculated fluxes over shorter periods, causing underestimates of the

ACPD

5, S4059–S4064, 2005

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flux since we would neglect the larger eddies.

13. Yes, and even if the machinery is new, the emissions can be large compared to normal vehicles. However, we do not know anything about the amount of, or the age of the off-road machinery. Nevertheless, on Page5559 and line 15, we try to do an estimate of how large the flux from the area, due to off road machinery is.

14. Page 5557 line 18. The average background concentrations are between 2500 and 3500 cm-3 around 03.00. Should be At three o'clock the average background concentration is around 3000-4000 cm-3

15. In Figure1 legend: .eight days sample. Should be: eight days, Julian Day 105-112 (15 - 22 of April), sample

In Figure3 legend: Aerosol number concentration, Should be: Aerosol number concentration for two weeks, Julian Day 78-91, (19 of March to 1 of April)

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 5541, 2005.