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Interactive comment on "Aerosol and NO_x emission factors and submicron particle number size distributions in two road tunnels with different traffic regimes" *by* D. Imhof et al.

D. Imhof et al.

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First of all, we would like to thank the referees for their useful comments and suggestions.

Both referees expressed concern about the interpretation of the given threshold value of 5 x $10^9 nm^2$ / cm^3 in Figure 6 to identify one regime with low soot surface area and high number concentrations of nucleation mode particles and a second regime with high soot surface corresponding to a relatively low number concentration of nucleation particles. We would like to emphasize that we do not want to propose the above mentioned threshold value for tunnel situations in general. The changeover seems to be

valid for the Plabutsch tunnel while we do not know the behaviour of the nucleation mode particles in the Kingsway tunnel for higher aerosol surface area concentrations. Different temperatures and different fuel sulphur content in other tunnels would most probably lead to another threshold value. An explaining sentence and the statement that the observed pattern may not be generally applicable will be added to the paper.

Referee 1:

Referee's comment (RC): Page 5135 Lines 11-14: Accurate measurement of the fluxes of inlet and exhaust air is essential to the calculation of particle fluxes. More detail of how the flows were measured (presumably by profiling in at least two directions) and how the measured data were then processed would be valuable.

Authors' comment (AC): Each ventilation shaft of the two tunnels was equipped with an automatically operating flowmeter. The Plabutsch tunnel is divided into five ventilation sections, each of which separated from the adjacent ones. Measurements took place in section No. 3 only supplied by ventilation shaft north (Figure 1a). Since the traffic in the tunnel bore is operated bidirectionally, horizontal air exchange between section 3 and the two adjacent ventilation segments was neglected. In addition to the ventilation shaft measurements in the Kingsway tunnel (unidirectional), Ultrasonic gas flowmeters were positioned at the entrance and at the outlet of the tunnel. Data sets were available on the basis of one-minute values, which were then aggregated to 0.5-hour and 1-hour mean values. Time periods with uncertain or low flow rates were not used for the calculation of emission factors. This will be clarified in the paper.

RC: Page 5141 Line 6: The term "maximum diameter of the nucleation mode" is confusing. At first reading it appears to imply the largest diameter within the nucleation mode, whereas in fact it means the most frequent diameter of the nucleation mode.

AC: According to the suggestion of the reviewer we will replace "maximum diameter" by "modal diameter".

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RC: Page 5146 Lines 5-11: Whilst the reviewer can accept that the regression technique can be used to estimate PM1 values from measurements of total volume, the fact that the volume measurements cease at a diameter of 700nm, means that part of the volume is not included and therefore the estimate of effective particle density is erroneous. Some comment on this by the authors is required.

AC: In Figure 8, we show the correlation between the SMPS particle volume (D = 18 - 700 nm) and the PM1 measured by filter sampling. The fact that a very high determination coefficient (R^2 = 0.93) was obtained applying the volume of particles with D < 700 nm indicates that the volume (D = 0.7 - 1 μm) does not contribute substantially to an improvement of the correlation. Still the effective density of the particles (the slope of Figure 8) should be regarded as an upper limit.

RC: Page 5147 Lines 18-23: No mention is made of the fact that the PM2.5 measurements were made with a TEOM instrument with a heated inlet, whilst the PM1 measurements were made with a gravimetric sampler at atmospheric temperature. Consequently PM1/PM2.5 ratios derived from the measured data will differ from those measured if both instruments had the same sampling characteristics.

AC: We agree with the referee that the different measurement techniques have an influence on the PM1/PM2.5 ratio which is difficult to quantify. The TEOM instruments were operated with a temperature of 40 °C, and the PM1 measurements were conducted within the tunnels with temperatures of about 18 to 23 °C. Therefore the temperature difference between the two mass concentration measurements is not especially high. A clarifying sentence will be added to the paper.

RC: Page 5148 Lines 3-4: The negative PM10 emission factor calculated for LDV may not be statistically significant but, even allowing for the confidence intervals, the emission for PM10 from LDV is smaller than that for PM1. This casts considerable doubt on the error limits attached to the data and the authors need to be more cautious in quoting their emission factors.

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AC: Although we tried various models and conditions, we always got rather low (in most cases even negative and always non-significant) emission factors of PM10 for LDV, which means that there is high uncertainty in the estimation of this emission factor for the Plabutsch tunnel. Possible reasons for this fact might be the high detection limit of the device and the relatively low contribution of LDV to PM10 emissions. The PM10 emission factor for HDV is consistent with results from other measurements and was obtained with a relatively low 95

Referee 2:

RC: Page 5143, line 9-10: in general passenger diesel cars have a much larger [PM]/NOx ratio than heavy duty diesel vehicles, so this cannot explain the higher NOx observations. Perhaps some high polluting gasoline vehicles caused the observation?

AC: The corresponding paragraph will be changed in the paper.

RC: Table 3, page 5147-8: There is no good explanation why the PM1 emission factor for LDV and HDV is 3 times larger at the Plabutsch tunnel. Also, could the authors consider a separation into Gasoline and Diesel emission factors?

AC: As shown in Table 3, a significant difference in the PM1 emission factors (parameters “PM1” for Plabutsch and “PM1 whole” for Kingsway) was only found for LDV and the total vehicle fleet. Since HDV show nearly the same emission factors regarding PM1, a higher proportion of Diesel passenger cars in the Plabutsch tunnel compared to the Kingsway tunnel might be responsible for the different values found for LDV. In addition, we observed that the HDV/LDV ratio for Plabutsch was on average 3-4 times higher than for Kingsway. The higher proportion of HDV at Plabutsch can therefore explain the higher emission factor found for the total vehicle fleet in this tunnel. The low emission factors given in “PM1 section” for the Kingsway tunnel are biased because of the negative slope at the beginning of this tunnel. We did not consider a separation into gasoline and diesel emission factors because we do not know the exact composition of the vehicle fleet with the required time resolution.

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RC: Page 5149, and Table 3: In the paper the authors correctly distinguish among nucleation particles and soot particles. On the other hand, N0.1, N0.3, and N0.7 give a combination of the two. Why did the authors not try to fit two lognormal curves in order to deconvolute nucleation and soot mode. Even if the nucleation mode is strongly dependent on the ambient conditions and presence of soot surface, this approach should reveal robust real world soot number emission factors.

AC: As one can see from Figure 4 the soot mode is hidden by the nucleation mode in the Kingsway tunnel. Although we were able to extract the soot mode by the bi-modal fitting of the particle surface area, there still exists some uncertainty. We used this calculation for the scatter plot depicted in Figure 6. We also computed soot mode number emission factors, but we did not publish them because of the high uncertainty in those calculations. Due to the variability of the nucleation mode in both tunnels the calculation of a number emission factor for nucleation mode particles was not possible. Therefore we selected with N0.1, N0.3 and N0.7 the same quantities which were already published in Imhof et al. (2005) facilitating a comparison of the emission factors derived for various sampling sites.

RC: References: page 5140 line 10: The volatility of traffic related particles has been studied in depth by the Leipzig group. You may want to give credit to Wehner et al 'Volatility of aerosol particles measured next a highway' J. Aerosol Sci. 32.1 S117-8 (2001) and Wehner et al., Atmos. Environ. 38, 6081-6090 (2004).

AC: We will include the reference Wehner et al., Atmos. Environ. 38, 6081-6090 (2004) in the paper.

RC: References: Page 5149: there is a large variety of number emission data in the literature, for example see: Maricq et al., Aerosol Science Technol. 33, 239-260 (2000); Maricq et al., EST 36, 276-282 (2002); EST 36, 283-289 (2002); ACEA programme on the emission of fine particles from passenger cars [2], ACEA 2002; Maricq et al., EST 33, 2007-2015; Vogt et al., EST 37, 4070-4076 (2003); Zervas et al., SAE 2004-01-

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1983).

AC: We will add a few more references and statements but since this is not a review paper, we will not be able to include all studies that have been published so far.

Reference: Imhof, D., Weingartner, E., Ordóñez, C., Gehrig, R., Hill, M., Buchmann, B., and Baltensperger, U.: Real-world emission factors of fine and ultrafine aerosol particles for different traffic situations in Switzerland, Environ. Sci. Technol. 39, 8341-8350, 2005.

Interactive comment on Atmos. Chem. Phys. Discuss., 5, 5127, 2005.