Referee comments

We thank the Referees for their valuable comments on our manuscript. We made a revision to the manuscript based on the comment of the Referees, and we think that it improved the quality of the manuscript significantly.

Referee #1

The manuscript reports a comprehensive study of urban air quality in Helsinki, Finland. The work was carried out at two supersites using a bunch of instrumentation: traffic pollutant dominated measurement site and urban background station less affected by traffic. Interestingly, the urban station is less that one hundred meters further from the major traffic roads than the traffic station, but the observations were quite different. I have a few minor comments before its final publication.

Throughout the manuscript, measurement uncertainties should be added.

Answer: Information about the measurement uncertainties has been added to the experimental section for the instruments whose data has been shown in this paper. The paragraphs below are added at the end of each instrument section.

AMS

The uncertainties of the AMS measurement arise from several factors. One source of uncertainty is the used effective nitrate response factor which is determined by the calibration of the AMS. Also, the use of default RIE for the calculation of total OA concentration is a source of uncertainty as a single RIE value for organics may not represent thousands of different organic compounds found in particles. The fact that the lower size range of the AMS is 50 nm has only a minor effect on the measured concentrations since the majority of PM1 mass is in particles above this size. The calculation of CE based on the chemical composition of measured aerosol is an additional source increasing the uncertainty as it uses nitrate, ammonium and sulphate concentrations in the calculation. The overall uncertainty of the AMS measurements can be estimated to be about 20–30 %.

ACSM

The uncertainties related to the ACSM measurements are like those described for the AMS above. However, the measured concentration of chloride and ammonia were very low during the campaign so especially for these two components the measurement uncertainty is clearly higher. The estimation for the uncertainties is 50 % for ammonia and >50% for chloride.

GC-MS/FID

The detection limits for the different VOCs varied between 0.2 and 16 ng m^{-3}. Average uncertainty was 2.8, 25 and 18 ng m^{-3} for terpenoids, aromatic compounds and C6-C15 alkanes, respectively.

NAIS

The total particle concentrations measured by the NAISs have been observed within ±50 % of the reference CPC concentration at 4–40 nm sizes (Asmi et al., 2009).

CPCs

The uncertainties of the CPCs are typically within 10% concentrations of the ambient aerosol ranging from a few thousands up to 100 000 particles cm^{-3} (Schmitt et al., 2020). In both CPC types, butanol (n-Butyl alcohol) was used as a working fluid and data was collected at 1 min time resolution.

MAAP

At traffic Supersite the measured BC concentration was most of the time above the detection limit of the MAAP so the measurement uncertainty is mostly due to the uncertainties in the sampling like particle losses in the sampling lines. The uncertainty of the MAAP results can be estimated be around 10–15 %. At UB Supersite the measured BC concentration was more frequently near or below the detection limit. This can cause larger uncertainties for the BC measurements at UB Supersite.

AQ Urban

The measured LDSA concentration was typically above the detection limit of the AQ Urban instrument (1 μm^2 cm^{-3}).

DMPS

The particle number size distributions from 20 to 200 nm determined by the mobility particle size spectrometers are typically within an uncertainty range of around ±10%, while below and above this size range the uncertainty increases. For particle sizes above 200 nm, 30% uncertainty has been reported (Wiedensohler et al., 2012).

Picarro

The measured CO_2 and CH_4 concentrations were above the detection limit of Picarro at both sites. The uncertainty of these two gases is low (10 %) but for the measured CO concentrations the uncertainty can be larger.

EC/OC analyses

The uncertainties of the EC/OC analysis are ~15 % (Cavalli et al., 2023).

Line24-27, long sentence, please reword it.

Answer: The sentence has been reworded.

L94-95, Please add references for the mentioned figures.

Answer: The references have been added for the mentioned figures:

Figure 1. Stationary measurement locations and the driving route of the Aerosol and Trace-gas mobile laboratory. The Traffic Supersite is showed in the map as an orange balloon with a figure right bottom. The side street is showed as a blue balloon and the figure is right middle. The UB Supersite is showed as a red balloon and with a figure right top.

Section 2.2.1 Please make it clear if the intracavity Nd-YAG laser was used in the AMS. If laser was used, the RIE for BC should be mentioned too. How well does AMS-derived BC compare to other BC results?

Answer: The intracavity Nd-YAG laser was used in the AMS and this detail has been added to text. However, refractory BC (rBC) measured by the SP-AMS was not presented in the paper. Sentence clarifying this has been added to the manuscript:

However, rBC concentrations are not shown in this paper since the BC size emitted by traffic is partially below the transmission efficiency of the SP-AMS.

Although the rBC results are not presented in the paper, SP-AMS was calibrated for rBC. A RIE value is 0.09 for rBC was obtained. Also, the correlation between BC measured with MAAP and rBC measured with AMS was good (R^2=0.83) at Traffic Supersite. The slope between rBC (AMS) and BC (MAAP) was 0.66 which means that AMS gave lower rBC values compared to BC values measured with MAAP. It seems that the

measured rBC values measured with AMS are closer to BC values measured with MAAP during lower PN concentrations. Probably part of the traffic related BC particles is too small to be measured with SP-AMS.

L141, are you saying the transmission efficiency for the particles in the size range of 76-650 nm is 50%? This is not true, as the transmission efficiency is nearly 100% in the size range of 60 – 400nm.

Answer: It was said in Ng et al. (2011) that in the ACSM the transmission efficiency for the particles in the size range of 76-650 nm is 50% (Liu et al., 2007), however, it was not specified what kind of diameter (vacuum/aerodynamic?) it was. For clarity, the sentence has been rewritten:

which exhibits nearly 100% transmission efficiency from approximately 70 to 500 nm (aerodynamic diameter, e.g. Canagaratna et al., 2007; Jayne et al., 2000).

Since AMS and ACSM use similar aerodynamic lenses, the text above was moved to the paragraph describing the SP-AMS operation and in the ACSM chapter it is said only:

that is similar to the aerodynamic lens used in the AMS.

Line 163, consist->consists

Answer: Word has been corrected as suggested by the referee.

Line195-204, are the data used anywhere in the manuscript?

Answer: CI-API-TOF-MS data is not shown in this paper, and this is now mentioned in the manuscript.

Section 2.2.1. The section does a good job describing the instrumentations. For a quick grab of the idea of this section, it could also be nice to tabulate all the instruments used at the traffic superstation. You can also add additional instruments not listed in Table S2 at UB station.

Answer: The instruments at the Traffic Supersite have also been tabulated and the table has been added to the supplement.

L376, Add a period at the end of bracket.

Answer: Period has been added as suggested by the referee.

L385, it is unclear how the traffic frequencies were counted.

Answer: More detailed description about traffic frequency counting has been added to the manuscript:

Traffic frequencies are continuously counted by the City of Helsinki. Inductive loop sensors are installed below the asphalt surface for each driving lane. As the magnetic field of a vehicle passes over the inductive loop, it generates signals that are then recorded. The traffic frequencies were measured about 500 m from the station, but after the measurement point traffic directed to the city centre is divided into two other main streets before the Traffic Supersite. The average number of vehicles passing the Traffic Supersite during workdays was 17 000 per day which is about 40 % less than at the point where traffic frequencies were measured.

L410, which instrument was PN measurement from?

Answer: It was added that the PN measurements were carried out with a CPC with a cut-off (D_{p50}) of 5.4 nm.

L422 Is SP-AMS derived BC concentration comparable to MAAP results.

Answer: The BC concentrations measured with AMS and MAAP correlate well. However, the measured rBC concentrations with AMS are lower compared to those measured with MAAP probably due to the small size of traffic related particles containing black carbon (see the answer for the comment above).

L459, Please add reference(s) for your argument.

Answer: References have been added:

Hellén, H., Praplan, A. P., Tykkä, T., Helin, A., Schallhart, S., Schiestl-Aalto, P. P., Bäck, J., and Hakola, H.: Sesquiterpenes and oxygenated sesquiterpenes dominate the VOC (C_5–C_{20}) emissions of downy birches, Atmos. Chem. Phys., 21, 8045–8066, https://doi.org/10.5194/acp-21-8045-2021, 2021.

Hakola H, Taipale D, Praplan A, Schallhart S, Thomas S, Tykkä T, Helin A, Bäck J and Hellén H (2023): Emissions of volatile organic compounds from Norway spruce and potential atmospheric impacts. Front. For. Glob. Change 6:1116414. doi: 10.3389/ffgc.2023.1116414.

L472, can you guess the sources of a-pinene? In addition to the background concentrations, is it from regional or long-range transport?

Answer: Information about the sources of a-pinene has been added to the manuscript:

Due to the short lifetime of α-pinene it is not long-range transported, and sources are expected to be local/regional. α -pinene has also anthropogenic sources related to human activity (e.g. cleaning and hygiene products).

L531, ...are due to..

Answer: We think that the Referee is referring here to the sentence: "The higher LSDA concentration... is due to the higher concentration" so we think that the sentence is correct, and no changes were made.

Section 3.1.6 PMF did a nice job in distinguishing six organic factors. A few more words describing the Tr-LVOOA, LVOOA and LVOOA-BB would also help to understand these three factors and their sources.

Answer: More description of the PMF factors has been added:

A source apportionment of organic aerosols was conducted on the AMS data collected at the Traffic Supersite. PMF solution consisted of 6 factors: OA with a significant signal at m/z 60 ($C_2H_4O_2^+$) and 61 ($C_2H_5O_2^+$), Tr-OOA; low-volatility oxygenated OA (LV-OOA) with a large signal at m/z 44 (CO_2^+); hydrocarbon-like OA (HOA) mostly composed of $C_XH_Y^+$ fragments; biomass burning OA (BBOA) with characteristic m/z 60 ($C_2H_4O_2^+$) and m/z 73 ($C_3H_5O_2^+$) signal peaks; semi-volatile oxygenated OA (SV-OOA) with high signal at m/z 43 ($C_2H_3O^+$), and LV-OOA-BB that had also a high signal at m/z 44 but as well a significant signal at m/z 60 (Fig. S9 and S10). LV-OOA represents primarily regional or long-range transport emissions, while the pronounced m/z 60 signal in LV-OOA-BB strongly indicates its biomass burning origin. In contrast, the exact source of Tr-OOA remains uncertain. It is likely linked to vehicular emissions based on its mass spectra and a diurnal profile that closely aligns with HOA, the factor representing primary traffic-related OA. The PMF results have been shown earlier in Barreira et al. (2024) which studied the light absorption characteristics of organics.

Additional corrections

1. The one-hour averages have been recalculated due to some mistakes in the start and end times of the measured components. The error in one-hour average data did not cause any meaningful changes to the average values shown in Table 1 and Table S3 or the correlation coefficients mentioned in text. However, these small changes have been corrected. The corrected data has been uploaded to Zenodo.

2. The text has been read throughout, and several long sentences have been shortened.

3. The Abstract has been changed so that no abbreviations are used.