Response to comments by Anonymous Referee #1

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General comments

The paper presents a refinement of the EXPAND model to evaluate the population exposure to air pollutants. It gives a thorough description of an up-to-date approach to evaluate exposure in urban areas keeping into account pollutants concentration and human time activity variability in time and space. The model development proposed consists mainly in the integration of different modules to describe pollutants emission, atmospheric dispersion, population time activities and exposure.

A few details need to be clarified to complete the modelling system description and some aspects of the presented application over Helsinki area need to be discussed in more detail to better identify and possibly quantify the simulation limits.

It would be advisable to enhance the final summary of data and models applied that can be considered local and need to be replaced to enable the application of the proposed methodology in regions characterized by different climatic and social conditions.

- ✓ Yes, we will include a discussion on how to extend the use of this model for other regions.

Specific comments

Section 2.2.1

Pag. 2340 Lines: 10-11 Are emissions estimated using pollutant dependent emission profiles for each vehicle category? Are those profiles Finland specific or are they generally applicable to the European vehicle fleet in different locations?

- ✓ Yes, we use pollutant dependent emission profiles for each vehicle category. The emission factors are based on European emission factors, but we have taken into account the age distribution of Finnish vehicles fleet. We will describe this more clearly in the revised version.

Lines: 15-22 The meaning of these sentences is not very clear. Does the mentioned evaluation aim to analyse the emission variation from 2005 to 2008? No specific result concerning this item is presented in the rest of the paper.

- ✓ We do not intend to analyse the emission variation, but to obtain more reliable emissions for the years 2008 and 2009. Since the total vehicular exhaust emission values are available for 1005, 2008 and 2009 from LIIPASTO system (Mäkelä, 2002), we assumed that the total emissions in 2008 and 2009 for each traffic link will vary proportionally to the total vehicular exhaust emissions.

Pag. 2341 Lines: 3-5 It would be worth specify if the mentioned resuspention emission model is strictly specific for the Nordic countries or if can be applied even in regions where road sending is episodic and can generally be neglected.

✓ The resuspension model used is not specific for the Nordic countries. It can be applied anywhere; however, some local experimental data is needed for its application. We will specify these conditions in more detail in a revised manuscript.

Section 2.2.3

Pag 2342 Lines 8-10 The impact of the choice to neglect small-scale wood combustion on model results should be better evaluated and possibly quantified. It is not clear if the whole residential heating contribution has been neglected and why. Are public and private buildings located within the city core heated by natural gas boilers or district heating facilities possibly included among point sources?

✓ The small-scale wood combustion contributed 23% to PM2.5 emissions in the Helsinki in the 2009 case study. See figure below.
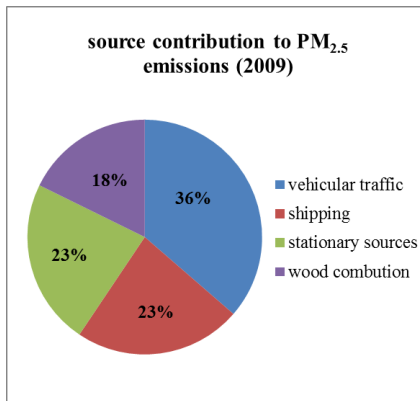

Figure. Source contribution to PM2.5 emissions in Helsinki, 2009.

✓ According to the statistics of Finland, the amount of natural gas boilers in Finland is very low (see figure below). It should be similar for the Helsinki Metropolitan Area. The district heating facilities are indeed the highest contribution to the heating but those are included in the stationary sources inventory.
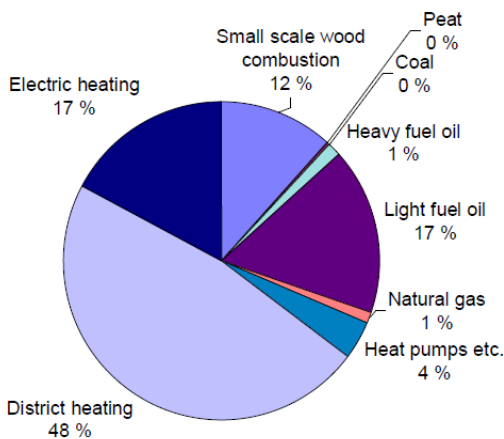

Figure: energy sources in Finland (Statistics Finland, 2004)

Section 2.3

Pag 2342 Lines: 25-26 Does LOTOS model simulation, used to evaluate long range transport contribution, include Helsinki emissions or have they been excluded? In the former case some emission contribution could be double counted, even if the limited regional model resolution would smooth the effect.

✓ The emissions used in the LOTOS-EUROS computations account for sources in Helsinki. However, by assuming the same grid-cell where the background station Luukki is located, the influence of local sources is very small. Several previous studies have showed that the influence by local sources at this station is on the average less than 10 %; therefore, no double counting will rarely take place.

Section 2.4

Pag. 2344 Lines: 4-5 Is the information referred to shops and recreational activities limited to working people or does it include statistics concerning the presence of costumers in shops, etc.?

✓ The people included in "other activities" are not working; they are recreational users/costumers. The employees at those shops are included in the work environment. Unfortunately there is no readymade statistics for this information. The data was evaluated by using time use survey data, which includes data about how much time (in minutes) people are spending in shops or restaurants. We have used the number of employees to evaluate how many people visit in shops and restaurants. The more people working in certain shop the more clients the shop will have. We have utilized also statistical information about how many times per week people are shopping. Combining this data we get activity in shops and restaurants.

Section 3.1

Pag. 2349 Lines: 13-15 157t PM2.5 emissions from wood combustion with respect to 322t from traffic seems quite low with respect to the estimation of house heating contribution to PM emissions in other European areas. Could you provide a little more detail about this evaluation? The referred paper is in Finnish.

✓ Currently there is a project ongoing financed by the Finnish entities to improve the estimation of such sources, but results are still uncertain. The inventory available from the Helsinki Region Environmental Services Authority (evaluation only published in Finnish) is based on registration data of small houses (type of heating systems in the city area), questionnaire of wood use in different heating systems (amount of wood used) and emission factors of sauna stoves, masonry heaters and boilers.

What is the fraction of total PM2.5 emissions due to wood combustion? It can provide a first estimate ion of the emission error/underestimation caused by neglecting this contribution.

✓ We have mentioned in section 3.1 the contribution of wood combustion to PM2.5 in Helsinki: 23%. The new revised draft we could add the figure presented in 3.1.

Section 3.4.1

Pag. 2354 Lines: 2-3 The infiltration factor has been previously introduced as Finf<=0 (page 2345). Could you explain how can it assume values larger than one?

✓ The reviewer is correct, the infiltration factor can never be assumed higher than one. The reason the current version is stating values larger than one is because the authors were discussing indoor to outdoor concentration ratios (i/o); which can be higher than 1. The EXPAND model actually considers i/o instead of Finf in order to accommodate indoor sources. In this particular study, we do not assume indoor sources and, therefore, the i/o will be the same as Finf.

✓ We will revise: 1) section 5 adding the use of i/o in the model; 2) revise the lines 2-3 accordingly

Section 3.4.2

Pag. 2354 Lines: 12-14 Can you give an estimate of the uncertainty due to the small scale combustion contribution?

✓ At the moment we can only say that we are missing 23% of the emissions, but because the spatial distribution of this data is not known, we cannot estimate the real impact of the wood combustion. What we can foresee is that it would have higher impact than the stationary sources since the emission height is closer to surface levels.

Section 4

Pag 2355 Lines 1-9 It would be useful the introduction of a table resuming the improvements introduced in the new version of the presented model, e.g. through the comparison with the previous version features.

✓ This is a good addition to the paper, we will revise.

Lines:13-14 Stationary sources and shipping have been considered for 2009 simulations only (page 2340, lines 4-5).

✓ We will revise

Lines: 15-18 The fraction of PM2.5 emission neglected should be possibly mentioned.

✓ We will revise

Pag 2357 Lines: 12-17 Data and models that need to be provided to make the proposed methodology applicable elsewhere should be better specified to make easier to understand the possible need of local investigations concerning e.g. emission details, infiltration factors,...

✓ We will revise