Response to Referee #1

General comments:
The authors model the atmospheric boundary layer and aerosol dynamics above a pine forest in Finland, in order to examine the effect on vertical transport of aerosols, and how this impacts on the interpretation of flux measurements. They find that the vertical transport of particles within and above a forest canopy can be strongly dependent on the aerosol dynamics and measured fluxes deviate from dry deposition. This is an important result and deserves publication in ACP. I would, however, recommend proof reading the manuscript, as I found the language difficult to understand at times, meaning that the points the authors were trying to make were not always clear. I would also like to see a description of the measurements that were used in the model.

We will make effort to make proof reading and improve the language/presentation.

The study relies mainly on the model simulations and the measurements were used either to initialise the model or for evaluation of model outputs in terms of predicted particle size distributions (Fig. 1) and meteorological variables such as surface heat fluxes (Fig. 2). All other results were based on the model runs. We will emphasize this more clearly in the revised MS. For the input data used in the model we refer to Zhou et al. (2014); here we provide a short description of the station and the measurements presented in the MS.

The SMEAR II (Station for Measuring Forest Ecosystem-Atmosphere Relations) field measurement station is located in Hyytiälä, Southern Finland (61° 51' N, 24°17' E, 181 m asl). The station is located in the area covered mainly by pine-dominated forests. The dominant height of the stand near the measurement tower was about 20 m in 2013. Description of the site in micrometeorological context at SMEAR II station can be found in Rannik (1998) and more detailed description of the station and the measurements can be found in Hari and Kulmala (2005).

Turbulent fluxes of momentum, heat, CO_2 and H_2O were measured by means of the eddy covariance technique. The system, located at 23 m height above the ground on the top of a scaffolding tower, included an ultrasonic anemometer (Solent Research HS1199, Gill Ltd., Lymington, Hampshire, England) to measure the three wind velocity components and the sonic temperature, a closed-path infrared gas analyser (LI-6262, LiCor Inc., Lincoln, NE, USA) that measured the CO_2 and H_2O concentrations. The data were sampled at 21 Hz and a 2D rotation of sonic anemometer wind components and filtering to eliminate spikes were performed according to standard methods (e.g. Aubinet et al., 2000). The high-frequency flux attenuation was corrected by using empirical transfer functions and co-spectral transfer characteristics (Mammarella et al., 2009).

Aerosol size distribution (from 3 nm to1 μm) measurements were performed using Differential Mobility Particle Sizer (DMPS) system. The aerosol was sampled from inside the forest at 2 m height. Details of the DMPS measurement system are presented in Aalto et al. (2001).

Minor comments:

Page 19376, line 10: “However, the fact that the model is not able to reproduce the fine details of the particle formation events does not affect the generality of our results.” Could the authors qualify this? If the modelled nucleation modes were not “as clear”, and the particle growth overestimated, I would have thought this could have an impact on the aerosol dynamical term. Are the authors able to quantify this impact, and thus assure the reader that the same conclusions apply?

The aerosol dynamical term is dependent on the amount of condensing vapours available and the quantitative results would differ if the model was better tuned to reproduce the observed particle growth patterns. This can be seen also from our presented results where the aerosol dynamical terms differ between different days. We will present the respective sensitivity analysis in the revised MS.

However, we meant that our qualitative conclusions were not affected by the quantitative differences between our simulations and measurements and we believe the conclusions hold.

Page 19376, line 23: "a single mode with the maximum particle amount at around 200nm", remove "with the maximum particle amount".

To be removed during revision.

Page 19377, line 13: "The aerosol concentration inside and above forest was homogeneous at noon and small vertical concentration gradients could not be observed from color presentation 15 in Fig. 4a.". This is presumably from the model results. Are there any measurements to validate this (even from published results)?

Yes, this is from model results. We do not have such measurements of the concentration profile from the SMEAR II site. However, the modelling studies (e.g. Rannik et al., 2009) as well as measurements at some other sites (e.g. Pryor et al., 2013) have shown relatively small particle concentration gradients within and above forest due to efficient mixing, with particle concentration differences within and above forest from a few (for about 100 nm particles) up to a few tens (for about 10 nm particles and smaller) of percents depending on particle size. The colour presentation in Fig, 4a is not able to resolve such differences in vertical along with much larger differences as the function of particle size.

Here we present the vertical profiles for the same time period as in Fig. 4 for selected particle sizes. The figure indicates agreement with the references given above.

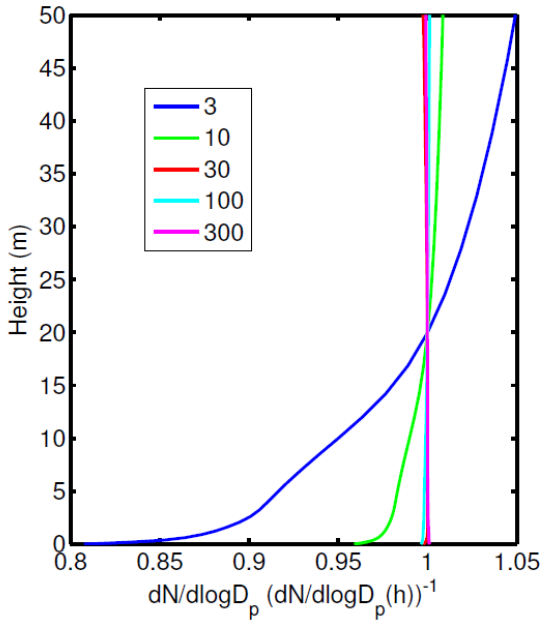

Figure C1. Normalised (with the value at the canopy top) concentration profiles on 07 May at 12:00 LT for a range of particle sizes (in nm).

Page 19377, line 18: Why "not shown"?

We think the figure does not add new information and therefore it was excluded from the MS. Here we present it also for the evening time 21:00 LT to illustrate the same qualitative features (not to be included in the revised MS).

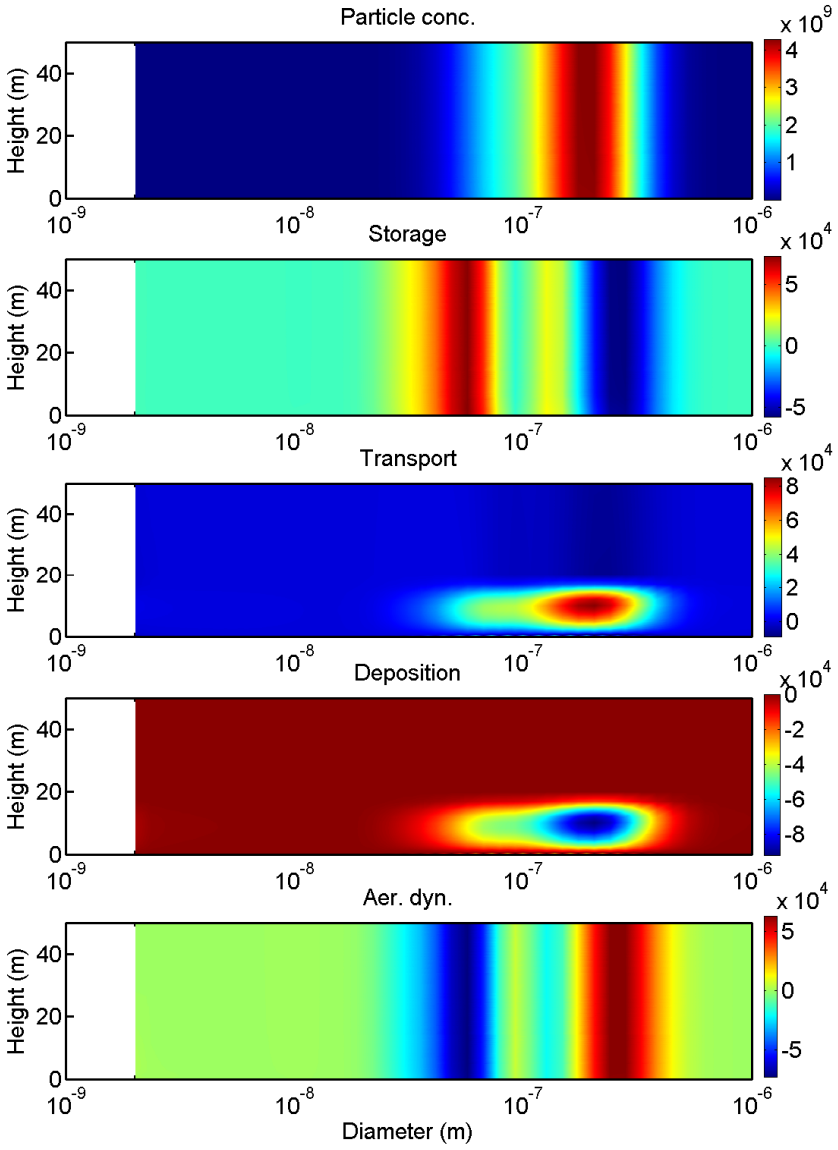

Figure C2. Vertical profiles of aerosol (a) number concentration (#m^{-3}) and conservation terms: (b) storage change (#m^{-3} s^{-1}), (c) transport (in #m^{-3} s^{-1}), (d) deposition (in #m^{-3} s^{-1}), (e) aerosol dynamical (in #m^{-3} s^{-1}) on 07 May at 21:00 LT for particle size range from 2nm to 1 μm.

Page 19378, line 3: "normalized to local concentration" – are these modelled concentrations?

Correct, we include this clarification in the revised MS.

Page 19378, line 22: "Note however that the concentration of small particles was very low in the evening" – will this affect the accuracy of the results?

We believe not. However, to observe/verify such a behaviour with experiments would be extremely difficult (or virtually impossible) because of large uncertainties involved in observations of particle

concentrations and especially fluxes in case of small particle counts. Therefore the note was made to draw the attention to low concentration.

Page 19381, line 11: "exceeding deposition more than ten times" – do you mean exceeded by a factor of more than ten? Use this term instead, as "more than ten times" could be interpreted to mean more than ten occasions.

Correct, it was meant that the downward transport velocity exceeded the deposition velocity by a factor of more than ten. To be corrected in the revised MS.

Table 1: The median values are a lot closer to unity than the averages, suggesting the latter are affected by outliers. Could the authors comment on whether this affects their conclusions?

It is true that the medians are closer to unity than the averages. This means that the averages are affected by the values deviating much from the average values. Those values are not however outliers (in terms of likely being erroneous values) but within the model context the "true values" that correspond to certain conditions occurring in the ABL. Such conditions certainly take place in case of strong horizontal advection and resulting vertical mixing conditions. Note that our assumption on the night-time vertical profiles of concentrations corresponds mainly to "no horizontal advection" situation (except day 1, see p. 19374 l. 26 onward), therefore leading rather to underestimation of the impact of advection and vertical mixing. Therefore we believe our conclusions hold.

Page 19384, line 6: "The dominant condensing compounds, OH oxidation products of monoterpenes, resemble a similar profile as monoterpenes and model simulates strongest growth of nucleation mode particles at the same height." – I'm afraid I didn't quite understand this sentence; could the authors make it a bit clearer. Also is there concentrations and/or profile data for monoterpenes? If so, please show it, or at least reference it.

We meant that the condensational growth rate is mainly driven by the oxidation products of monoterpenes and therefore the aerosol dynamical term – the condensational growth term – is expected to follow the monoterpene concentration profile in vertical. Below (Fig. C3) we present an example of the concentration profiles for monoterpenes. Since monoterpenes are emitted by forest and transported to the higher ABL, the concentration maximum occurs within forest (height 20 m). The vertical transport of monoterpenes in combination with oxidation into condensing compounds leads to variation of the aerosol dynamical term with height, which in turn affects (differentially in height) the aerosol size spectrum and induces vertical transport of particles. We will refine this reasoning in the revised MS.

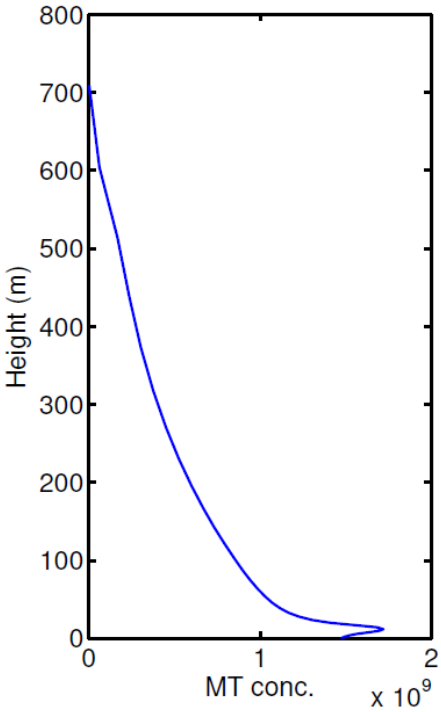

Figure C3. Vertical profiles of monoterpenes (MT) concentration on 07 May at 12:00 LT according to SOSAA simulations.

Page 19384, line 17: "The concentration time change, when summed up from the surface up to the measurement level, is called the storage term and commonly accounted for in estimation of the net ecosystem exchange of carbon dioxide from the EC flux measurements." – A reference would be useful here. Also correct "in estimation".

A reference to be added is Foken et al. (2012).

Figure 2: A label for the colour scale is needed for (a). Please clarify: SMEAR is the measurements?

A label to colour scale shall be inserted. SMEAR means Station for Measuring Ecosystem-Atmosphere Relations, a station located in Hyytiälä, Southern Finland. The station shall be introduced along with description of measurements used in the study.

Figure 3: Correct bottom axis label of (a) "Diameter". Where is nucleation on (b)?

To be corrected prior to submission of the revised MS. The nucleation at 2 nm particle size is out of scale as explained in the figure title. This is to improve presentation for other sizes.

Figure 6: Positive velocity means downward? Please clarify.

The positive values of the exchange velocities mean downward transport, see eq. (8).

Figure 7: There is a lot of variability with diameter in aerosol dynamics and transport timescales. Is there any measure of uncertainty?

For given conditions at a specific time moment (particle size spectrum and its vertical profile, atmospheric mixing and availability of condensing vapours) the aerosol dynamics and transport are deterministic physical processes and in our 1.5-order model representation without uncertainty (stochastic variability) estimates. However, the conditions are dynamical and the aerosol dynamical

and transport time scales change respectively as the function of time (which is illustrated by different patterns at 12:00 and 21:00, respectively).

The accuracy of the results relies however on the physical correctness of the model. If to translate the model results into real world, then at each single time moment the results are uncertain due to limited ability of the model to reproduce the exact atmospheric state of meteorology and of its content. However, the same large variability with diameter would be expected as this is determined by the size spectrum and availability of condensing vapours (which determine coagulation and condensational growth, strongly varying with particle size), and their vertical profiles (which determine the transport).

References

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