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Interactive Comment

Interactive comment on "Modelling and assimilation of lidar signals over Greater Paris during the MEGAPOLI summer campaign" *by* Y. Wang et al.

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Part I

Response to Referee 1's comments

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General comments

The experiment has lasted for 6 days but the assimilation exercise was performed only for 2 days. My main remark concerns the conclusions of the paper regarding the comparison between both methods for assimilation. Additional test cases should be added to strengthen the conclusions.

Only 2 days out of the 6 measurement days were selected for the assimilation test, because the other days were cloudy and our algorithms do not allow us to assimilate lidar data when there are clouds (see answers to specific comments A et C). Therefore, we can not present additional test cases. For clarity, regarding the conclusion, we have modified the following sentence: "DA tests were performed for 01 and 26 July 2009" to "DA tests were performed for 01 and 26 July 2009, because the other measurement days were cloudy and our algorithms do not allow us to assimilate lidar data when there are clouds".

Specific comments

A) *Regarding the calibration of the lidar signal in paragraph 3.1, there is no evidence that the proposed method improves the calibration of the lidar signal. Indeed you may find a reference altitude that is closer to the laser source, i.e. with a better signal-to-noise ratio but how does it affect the general accuracy of the assimilation procedure when applying this method for the calibration rather than taking a fix range for the* *reference? Please provide numbers for that. Also explain why you have used a least absolute deviation rather than least square method.*

The proposed method for the calibration of the lidar signal is designed to "automatically estimate the normalisation altitude z_{ref} from the lidar vertical profile" (L. 234-235). Such method would be required for operational forecast using the assimilation of lidar signals. In section 3.2, we have stated "Although the molecular zone is often determined visually from lidar vertical profiles, this method is not efficient to treat large amounts of lidar profiles" in this paper (L. 232-234).

In this study, the assimilation exercise is performed for 01 and 26 July, where more cloud-cleaned lidar data are available (in total, there are 6 measurement days: 13 h of measurements on 01 July, 5 h of measurements on 26 July, and less than 3 h of measurements on the other measurement days). The pollution plumes of 01 and 26 July locate mostly in the PBL (about 2 km) (Royer et al., 2011), and lidar data are available below 3 km above the ground (see Figures 4, 8 and 11). Therefore, the calibration/normalisation of the lidar signal was located at an altitude about 3 km above the ground. However, taking a fix altitude for normalising the lidar signal can not work on all measurement days, which depends on the aerosol structure. For example, since an aerosol layer between 2.5 and 3.5 km above the ground was not modelled but observed in lidar measurements at 15:00 UTC on 29 July 2009 (see Fig. 9), taking the altitude of normalisation at 3 km above the ground affects greatly the accuracy of the simulation and assimilation of lidar signals. Our method can avoid this situation.

The following sentences have been added to explain why we used a Least Absolute Deviation (LAD) rather than Least Square method: "It is because we are here interested in the linear regression of lidar signal points at higher altitudes, e.g. the points between 2 and 3 km above the ground. However, it is difficult to know the altitude below which lidar signal points could be cut off for the estimation of z_{ref}. When considering all available lidar signal points, the disturbances are prominently non-normally distributed and contain sizeable outliers (i.e. points at lower altitudes). In such cases,

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the Least Squares method fails and the LAD method performs well (DasGupta and Mishra, 2007)".

B) *In the model evaluation, explain why you think that the model performance goals are met.*

The following sentences have been added into the first paragraph of section 4 to give statistical indices for the PM model performance goal and criterion: "The Mean Fractional Bias (MFB) and the Mean Fractional Error (MFE) are proposed by Boylan and Russell (2006) to evaluate model performances against observations: if both the MFB is in the range [-30 %, 30%] and the MFE is in the range [0, 50 %], the PM model performance goal is met; if both the MFB is in the range [-60 %, 60%] and the MFE is in the range [0, 75 %], the PM model performance criterion is met".

Moreover, I think that the discussion about comparing the aerosol optical depth (AOD) measured by the Sun photometer and simulated by the model is awkward.

Observed and simulated AODs were compared according to the criteria of Boylan and Russell (2006). For clarity, we replaced the following sentence: "The simulated and the observed AOD agree well on 01, 04, 16 and 26 July 2009, according to the criteria of Boylan and Russell (2006)" by "As the MFB and MFE on 01, 04, 16 and 26 July 2009 are respectively in the range [-60 %, 60%] and [0, 75 %], the model performance criterion of Boylan and Russell (2006) is met".

Indeed you are not able to reproduce the AOD variability and the reason you give is unclear. It cant be only a question of vertical mixing in the model. Clearly state in the paper that the model is not able to reproduce the AOD.

The evaluation of the model concerning the AOD was not clearly formulated and was focusing on a specific time correlation. Section 4.2 has been modified to present a global evaluation, as follow: "Table 3 presents statistics for hourly data. As the MFB and MFE on 01, 04, 16 and 26 July 2009 are respectively in the range [-60 %, 60%]

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and [0, 75 %], the model performance criterion of Boylan and Russell (2006) is met, despite a slight underestimation of AOD in agreement with the underestimation of PM_{10} in comparison to Airparif observations (see section 4.1)".

The statistics of comparisons are good using criteria defined in the literature (errors and bias). The time correlation between hourly measured and simulated AOD is also high for 3 out of the days of simulations (between 37 % and 80 %). However, we decided to remove the time correlation from Table 3, because it is based on a limited number of points (between 15 and 22 measurement points depending on the days and the measurement availabilities). This kind of correlation is therefore not very meaningful.

C) *You have to explain again (in 1 or 2 sentences) at the beginning of the section 6 why you retain only 2 days of measurements*.

For clarity, the first paragraph of section 6 has been modified as follow: "DA of lidar observations is performed for two out of the six different measurement days. Only two days are retained because the other days were cloudy and our algorithms do not allow us to assimilate lidar data when there are clouds. There are 13 h of cloud-cleaned measurements on 01 July, 5 h of cloud-cleaned measurements on 26 July and less than 3 h of cloud-cleaned measurements on the other measurement days. Therefore, DA run is performed on 01 and 26 July 2009 because too few data are available during the other measurement days".

D) *In the section 6, I dont consider that you are proposing 2 new algorithms. You are testing 2 different ways of implementing a data assimilation algorithm based on the optimal interpolation.*

You are right. Indeed the two different ways of implementing DA are based on the optimal interpolation DA method. However, they represent distinct variants. For example, we set the background error covariance matrix differently (see section 6.2 and Appendix A). Moreover, their computational costs are quite different. Analysing separately $PM_{2.5}$ and $PM_{2.5-10}$ is more numerically costly than analysing PM_{10}. Therefore,

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we considered them as two algorithms based on the same DA method (i.e. OI). For clarity in the paper, we added "based on the optimal interpolation method" in the conclusion (L. 534-535) and in the abstract (L. 13-14).

It appears that the 2 methods give almost the same results (table 4). You have to clarify this point in your conclusion (starting from Line 479) or you can provide new test cases.

As shown in Table 4, the algorithm where $PM_{2.5}$ and $PM_{2.5-10}$ are analysed separately (referred to as "With DA ($PM_{2.5}$ and $PM_{2.5-10}$)") leads to better scores than the one where only PM_{10} is analysed (referred to as "With DA (PM_{10})") for PM_{10} and leads to similar scores to "With DA (PM_{10})" for $PM_{2.5}$.

This point is stated in section 6.4: "Comparing the two DA algorithms, the simulation with DA ($PM_{2.5}$ and $PM_{2.5-10}$) leads to better scores than the simulation with DA (PM_{10}) for PM_{10} concentrations (see Table 4)" (L. 479-480) and "the simulation with DA ($PM_{2.5}$ and $PM_{2.5-10}$) leads to similar scores to the simulation with DA (PM_{10}) for $PM_{2.5}$ concentrations (see Table 4)" (L. 485-487).

Also this point is stated in the conclusion section: " The simulation with DA ($PM_{2.5}$ and $PM_{2.5-10}$) leads to better scores than the simulation with DA (PM_{10}) because the error variances for backgrounds are set separately for fine ($PM_{2.5}$) and coarse ($PM_{2.5-10}$) particles. The results shown in this paper suggest that the assimilation of lidar observations that analyses $PM_{2.5}$ and $PM_{2.5-10}$ would perform better than the assimilation of lidar observations that analyses PM_{10}, but it is computationally more costly".

E) *The beginning of the conclusion (until Line 478) needs to be modified as well. Include quantitative information on the model performance to simulate actual optical properties*.

The statistics (i.e. RMSE, correlation, MFB and MFE) have been added in the manuscript for the lidar signal comparison. They have been discussed at the end of section 5 as follows: "For all measurement days, we also computed the statistics (i.e.

RMSE, correlation, MFB and MFE) between observed and simulated lidar vertical profiles. The scores are shown respectively in Figures 4, 5, 6, 7, 8 and 9. Overall, RMSEs are below 1.63, the MFB ranges from -38 % to 8 % and the MFE ranges from 3 % to 38 %. Currently, there is no criterion to evaluate the comparisons for lidar signals. The criterion of Boylan and Russell (2006) was designed for PM concentration and light extinction. Because the scores of the lidar signal comparisons are extremely good compared to the criterion of Boylan and Russell (2006) with low errors and bias, the criterion of Boylan and Russell (2006) may not be restrictive enough for lidar signals".

The statistics for aerosol optical properties have been added in the conclusion and the beginning of the conclusion has been modified to: "In order to investigate the ability of the CTM POLAIR3D of the air quality modelling platform POLYPHEMUS to simulate lidar vertical profiles, we performed a simulation over the Greater Paris area for the summer month of July 2009. The results (PM_{10} and $PM_{2.5}$ concentrations) are evaluated using Airparif data. We simulated aerosol optical properties and lidar signals from the model aerosol concentration outputs using the aerosol complex refractive index (ACRI) and the wet particle diameter. The AOD was evaluated using AERONET data: the RMSE ranges from 0.07 to 0.20, the MFB ranges from -58 % to -21 % and the MFE ranges from 29 % to 58 %. According to the criterion of Boylan and Russell (2006), the model performance criterion is met for AOD. Hourly comparisons between simulated lidar signals and lidar observations were described for six measurement days during the MEGAPOLI summer campaign. These comparisons showed a good agreement between GBML measurements and the simulation except for 04 July 2009, where an aerosol layer was not modelled at high altitudes but observed in lidar measurements, and for 21 July 2009, where an aerosol layer was modelled at high altitudes but not observed in lidar measurements. The statistics obtained for the lidar comparison are extremely good compared to the criterion of Boylan and Russell (2006) with low errors and bias: the MFB ranges from -38 % to 8 % and the MFE ranges from 3 % to 38 %. Because the criterion of Boylan and Russell (2006) was designed for PM concentration and light extinction, they may not be restrictive enough for lidar signals. A specific cri-

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terion would therefore need to be designed. Overall, the results show that the optical property module of POLYPHEMUS models well lidar signals".

The sentence "(...) if the aerosol layer is well simulated." is really confusing. I understand that the model is not able to simulate aerosol.

You are right. We have removed the following statement: "if the aerosol layer is well simulated".

Technical comments:

1) *L205. Use PR2 or S, not both*.

All S_{Ray} have been replaced by $PR_{2,Ray}$ in this paper.

2) *Figure 2: I cant see the blue points. Its a black solid line....*

You are right. For clarity, we have replotted Figures 3, 4, 5, 6, 7, 8, 9 and 11 with black solid lines for lidar observations.

3) *Explain all the arguments in equation 14*.

Some arguments were shown at the beginning of section 6.1 before the definition of Equation 14. For clarity, in the latest version, all the arguments in equation 14 have been shown following Equation 14: "where $\mathbf{x}^b$ is the model concentrations, $\mathbf{y}$ is the vector of observations, $H(\mathbf{x}) = \mathbf{L} \cdot S(\mathbf{x})$ is the lidar observation operator, S is a nonlinear operator from the model state $\mathbf{x}$ to the lidar signal state, $\mathbf{L}$ is a linear spatial interpolation operator, $\mathbf{S}$ is the tangent linear of operator S, $\mathbf{B}$ and $\mathbf{R}$ are the matrices of error covariances for backgrounds and observations respectively".

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References

Boylan, J. W. and Russell, A. G. (2006). PM and light extinction model performance metrics, goals, and criteria for three-dimensional air quality models. *Atmos. Environ.*, 40:4946–4959.

DasGupta, M. and Mishra, S. K. (2007). *Least Absolute Deviation Estimation of Linear Econometric Models : A Literature Review*. North-Eastern Hill University.

Royer, P., Chazette, P., Sartelet, K., Zhang, Q. J., and Beekmann, M. (2011). Comparison of lidar-derived PM_{10} with regional modeling and ground-based observations in the frame of MEGAPOLI experiment. *Atmos. Chem. Phys.*, 11:10705–10726.

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