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Atmospheric Chemistry and Physics Discussions

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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We thank the reviewers for their useful comments on the following manuscript:
Journal: ACP
Title: Modelling and assimilation of lidar signals over Greater Paris during the MEGAPOLI summer campaign
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Interactive Discussion

Discussion Paper

Part I

Response to Referee 2's comments

Specific Comments:

1) *I fully agree with points A, B and D, presented on 25 November 2013, by Anonymous Referee 1.*

Please see answers to comments A, B and D of Anonymous Referee 1.

2) *Several citations of the paper are too old or missing and need to be updated.*

Several citations were updated, e.g. the citation Kelly et al. (2011) was added at L. 30, the citation Holben et al. (1998) was added at L. 147 and Balgovind et al. (1983) was added L. 449. For defining the lidar equation, we prefer to keep the original references.

3) *AOD should be given the meaning of these initials. However, AOT should be replaced by AOD everywhere in the paper.*

You are right. We replaced "Aerosol Optical Thickness (AOT)" by "Aerosol Optical Depth (AOD)" (L. 51). All AOTs were replaced by AOD everywhere in this paper.

4) *Page 6, L176-177. It is completely unclear how the aerosol water content is calculated. What are the input values to ISORROPIA to do this calculation? Is ISORROPIA I or II used. In any case, more recent citations to ISORROPIA (by Nenes et al., and Fountoukis et al.) should be provided.*

For clarity, L. 176-177 is modified to the following statement: "The aerosol water content is calculated from the thermodynamic model ISORROPIA (Nenes et al., 1998a,b) which models the phase state (i.e. gas, liquid, solid) of inorganic aerosol species (i.e. ammonium, sodium, chloride, nitrate, sulfate) in equilibrium with gaseous precursors.

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The inputs of ISORROPIA are temperature, relative humidity (RH), gaseous precursor concentrations and inorganic aerosol concentrations. Because of the large amount of water vapour in the atmosphere, the ambient RH is assumed to be unaffected by the deliquescence of aerosol particles in ISORROPIA (Nenes et al., 1998a) and equals the water activity (referred to as a_w). The aerosol water content is estimated by the ZSR relationship (Robinson and Stokes, 2002),

$$W = \sum_i \frac{M_i}{m_{oi}(a_w)}, \quad (1)$$

where a_w =RH, W is the aerosol water content concentration, M_i is the molar concentration of species i (mol m^{-3}), $m_{oi}(a_w)$ is the molality of an aqueous solution of species i (mol kg^{-1})".

In this paper, ISORROPIA I was used. As crustal species (Ca, K, Mg) are not present in our simulation, ISORROPIA I and ISORROPIA II should produce identical results (http://isorropia.eas.gatech.edu).

Nenes et al. (1998a) and Nenes et al. (1998b) are provided to cite ISORROPIA (I).

5) *Page 7, L199. Explain why lidar signals at higher levels arr attached to higher uncertainties*.

For clarity, "lidar signals are attached to higher uncertainties at high altitude" has been modified to "lidar signals are attached to higher uncertainties at high altitudes because of a higher signal-to-noise ratio".

6) *Page 9, L277. Replace "boundary layer" by "Planetary Boundary Layer (PBL)"*.

At L. 305, "boundary layer" was replaced by "PBL", and "Planetary Boundary Layer (PBL)" was introduced at L. 123.

7) *Provide geogr. coordinates for all stations examined (lat., long., height a.s.l.) as well as do not use capital letters for stations names*.

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We have added geogr. coordinates for all stations examined, e.g. "Saclay (48.7° N, 2.14° E, 30 m a.s.l.)" at L. 136, "Paris (urban station, 48.87° N, 2.33° E, 50 m a.s.l.)" and "Palaiseau (suburban station, 48.70° N, 2.21° E, 156 m a.s.l.)" at L. 151-152. Moreover, we do not use capital letters any more for stations names in the latest version of this paper.

8) *To my opinion the correlation between measured and simulated signals are not successful, especially for certain days (without DA). When DA is used, then things are better (in most cases). Authors should apply DA techniques to all simulations shown in this paper and extract conclusions*.

In this paper, we simulate lidar signals from the model aerosol concentrations. Therefore, the accuracy of the model aerosol concentrations impacts the one of simulated lidar signals. Some days are better modelled than the others. For example on 04 July, there is an aerosol layer between 2 km and 3 km which is not modelled. This layer impacts the lidar signal at lower altitudes (see section 5 and Fig. 5). However, the statistics of comparisons are good.

The statistics (i.e. RMSE, correlation, MFB and MFE) have been added in the manuscript for the lidar 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 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

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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.

You are right: when DA is used, we simulate signals better (see Fig. 11). It means that DA corrects the model aerosol concentrations (the closer to the truth the model aerosol concentrations are, the better the lidar signals are simulated).

We performed DA runs only for 01 and 26 July, because of scare measurements and/or presence of clouds on the other days. Please see answers to comments A and C of Anonymous Referee 1 for more details.

9) *Abstract needs to be more specific and less general. Correlation coefficients calculated *without and with DA) should be discussed*.

To be more specific, the following statement of the abstract: "POLYPHEMUS correctly reproduces the vertical distribution of aerosol optical properties and their temporal variability" was replaced by "Overall, POLYPHEMUS reproduces well the vertical distribution of lidar signals and their temporal variability, especially for 01, 16, 26 and 29 July 2009. Discrepancies on 04 and 21 July 2009 are due to high-altitude aerosol layers, which are not well modelled".

Moreover, the following sentences were added in the abstract: "One algorithm analyses PM_{10} (particulate matter with diameter less than 10 μm) concentrations. Another analyses $PM_{2.5}$ (particulate matter with diameter less than 2.5 μm) and $PM_{2.5-10}$ (particulate matter with a diameter higher than 2.5 µm and lower than 10 µm) concentrations separately. The aerosol simulations without and with lidar data assimilation are evaluated using the Airparif (a regional operational network in charge of air quality survey around the Paris area) data base to demonstrate the feasibility and the usefulness of assimilating lidar profiles for aerosol forecasts. The evaluation shows that data assimilation (DA) is more efficient at correcting PM_{10} than $PM_{2.5}$, probably because $PM_{2.5}$ is better modelled than PM_{10}. Furthermore, the algorithm which analyses both

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$PM_{2.5}$ and $PM_{2.5-10}$ provides the best scores for PM_{10}. The averaged RMSE of PM_{10} is 11.63 $\mu g\,m^{-3}$ with DA ($PM_{2.5}$ and $PM_{2.5-10}$), against 13.69 $\mu g\,m^{-3}$ with DA (PM_{10}) and 17.74 $\mu g\,m^{-3}$ without DA on 01 July 2009. The averaged RMSE of PM_{10} is 4.73 $\mu g\,m^{-3}$ with DA ($PM_{2.5}$ and $PM_{2.5-10}$), against 6.08 $\mu g\,m^{-3}$ with DA (PM_{10}) and 6.67 $\mu g\,m^{-3}$ without DA on 26 July 2009".

10) *Units should be provided in all figures (Y-axis in "m"). All X-axis should read "Lidar signal* $\times$ *10^3)*.

The Y-label in Figures 2, 4, 5, 6, 7, 8, 9 and 11 were changed to "Altitude, m". However, in Figures 4, 5, 6, 7, 8, 9 and 11, we use "Normalised lidar signal" for the X-label, instead of "Lidar signal $\times$ 10^3", because simulated and observed lidar signals in these figures have been normalised in the molecular zone.

11) *Table 3 should also contain units (Obs. mean, Sim. mean and RMSE in ug/m3). More details are given in the attached annotated manuscript)*.

Units (Obs. mean, Sim. mean and RMSE in ug m^{-3}) were added in Table 4. However, there is no unit for Obs. mean, Sim. mean and RMSE in Table 3, because AOD has no unit.

12) *Provide an additional figure, as Fig.1 showing the methodology of the paper(methodology-input-output)*.

As suggested, a figure of the description of lidar signals modelling was provided in the latest version of this paper. Moreover, the following statement was added at the beginning of section 3: "Figure 2 describes the methodology used for lidar signal modelling from the outputs of the air-quality model and for comparisons to measurements (aerosol concentration measurements, AOD data and lidar vertical profiles)".

13) *The dotline of PR2 signals in all figures, should be less bold, to show better the existing signal variations*.

We have replotted PR_2 signals in all figures with black solid lines, in order to better

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show signal variations.

Technical comments:

This section is for the other comments in http://www.atmos-chem-phys-discuss.net/13/C9408/2013/acpd-13-C9408-2013- supplement.pdf.

1) “is devoting to evaluating” was replaced by “aims at evaluating” (L. 85).

2) The sentence “... about 25% (Raut et al., 2009). It is mostly ...” was modified to “... about 25% (Raut et al., 2009) which is mostly ...” (L. 82).

3) The title of section 2.1, “Presentation of the model”, was replaced by “POLAIR3D model”.

4) “high vertical resolution” was modified to “increased vertical resolution” (L. 133).

5) “(the black track in Fig. 1)” was changed to “(black track in Fig. 1)” (L. 300).

6) “lidar observations” was replaced by “the lidar observations” (L. 359).

7) “The background error variances (PM_{10})” was replaced by “The background error variances of PM_{10} concentrations” (L. 456).

8) “July 2009” was modified to “of July 2009”.

9) “... would reproduce correctly lidar signals ...” was replaced by “... models well lidar signals ...” (L. 533).

10) For clarity, “That depends on whether PM_{10} is analysed or $PM_{2.5}$ and $PM_{2.5-10}$ are both analysed” is modified to “One algorithm analyses PM_{10} concentrations. Another analyses $PM_{2.5}$ and $PM_{2.5-10}$ concentrations separately” (L. 535-536).

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11) “laboratory” is modified to “Laboratory” (L. 553).

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