We thank the reviewers for their useful comments on the following manuscript:
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Title: Assimilation of lidar signals: application to aerosol forecasting in the mediterranean basin
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Part I

Response to Referee 1's comments

General comments

It is not clear to me why and how this simple and partly misleading lidar information leads to forecast improvements. More explanations are required.

This paper is based on the algorithm developed by [Wang et al., 2014]. As mentioned in the abstract, it presents a new application of assimilating lidar signals (range corrected lidar signals, i.e. PR^2) to aerosol forecasting. The algorithm for assimilation of lidar signals was described in detail in [Wang et al., 2014]. For clarity, the following sentences are added in Section 2: "[Wang et al., 2014] developed an aerosol optical property module to simulate the aerosol optical properties (AOD, backscatter and extinction coefficients) and lidar signals (PR^2) from the model aerosol concentration outputs. They also detailed the OI approach for assimilating lidar signals from the model aerosol concentration outputs" (P. 9 L. 27-29 and P. 10 L. 1) and "Concentrations can be impacted by lidar DA far from the place where lidar signals are assimilated, because analysed mass concentrations are transported by winds and diffusion (turbulence)" (P. 11 L. 7-9).

Details

1) *Page 13066, lines 20-22: The model is able to interpret attenuated backscatter, i.e., this complex mixture of backscattering and extinction? Otherwise, if the model interprets attenuated backscatter as backscatter then the use of the lidar data can lead to very bad results, i.e., when ignoring the extinction effect on the range-corrected lidar signals. We need more details how the lidar data are used! Reference to Wang et al. (2013) is not sufficient.*

Yes, our model, POLAIR3D of the air quality modelling platform POLYPHEMUS, is able to simulate attenuated backscatter. [Wang et al., 2014] have developed an aerosol optical property module in POLAIR3D to model aerosol optical properties (e.g. backscatter and extinction coefficients) and lidar signals (range corrected lidar signals) from the model aerosol concentration outputs (see Fig. 2 in [Wang et al., 2014]). For clarity, the following sentences are added in Section 2: "[Wang et al., 2014] developed an aerosol optical property module to simulate the aerosol optical properties (AOD, backscatter and extinction coefficients) and lidar signals (PR^2) from the model aerosol concentration outputs. They also detailed the OI approach for assimilating lidar signals from the model aerosol concentration outputs" (P. 9 L. 27-29 and P. 10 L. 1).

The reference "Wang et al. (2013b)" is updated to "Wang et al. (2014)" at P. 8 L. 12 and L.16.

2) *Page 13067, line 19: The modelling domain covers western and part of eastern Europe, only!! This is strange (sorry for this emotion, but I was a bit upset)! How can you provide high-quality aerosol forecasting in the Mediterranean Basin if the Mediterranean is not totally covered by the model? The most interesting and highly polluted area (and thus source of aerosols even in the central and western Mediterranean) is the Eastern Mediterranean! Why is this part excluded? Please give detailed information.*

The assimilation experiment was designed to assess the improvements of assimilation of lidar signals for real-time forecasting over western Europe (http://cerea.enpc.fr/en/prevision.html). As shown in Fig. 1, validation data are sparse. The french network (i.e. BDQA) provides most validation data. For clarity, this paper's title is modified to "Assimilation of lidar signals: application to aerosol forecasting in the west mediterranean basin".

3) *Page 13069, line 20 to page 13070, line 25: Even as a modeller, please do not ignore the reality! So, please provide an improved Table 1 and Figure 1! The list of participating stations in Table 1 is incomplete. CUT, Limassol, Cyprus measured this 9-12 July episode in the framework of the project as well. I asked them by e-mail! Even if not included in this paper and model study, the reality (full list of network stations) should be reflected in Table 1. CUT, by the way, is also one of the stations with 1640nm photometer channel, thus one of the modern AERONET stations. Please provide a better Figure 1, showing the full Mediterranean and then insert, may be, a box with the modelling domain. To be clear here, I will not accept this paper, if Table 1 and Figure 1 are not improved according to my suggestions!*

The lidar stations Limassol (i.e. CUT), Messinia and Payerne are now included in Tab. 1. For clarity, the following statement is added at P.12 L.7-9 and in the caption of Tab. 1: "Data received by Payerne and Messinia stations are not available. Also, data received by Limassol station are not used in this paper, because Limassol is outside of the model domain" and "Limassol was not included, because it is outside of the model domain. Payerne and Messinia were not included, because data were not available". Also, as suggested, Figure 1 is improved as follows:
1. Limassol, Messinia and Payerne lidar stations are included.
2. The full Mediterranean is shown.

3. A rectangle to show the modelling domain is inserted.
For clarity, the caption of Fig. 1 is modified as follows: "Map of the different measurement sites providing measurements between 9-12 July in the domain of interest (the rectangular area delimited by the black box). The red triangles show the locations of French air quality network (BDQA). The cyan squares show the station locations of the EMEP-Spain/Portugal network. The cyan triangles show the locations of stations around Barcelona. The green squares show the locations of EMEP-Europe stations. The green diamonds show the locations of AERONET stations. The dark blue/black star markers show the locations of ACTRIS/EARLINET stations. The black star markers show lidar stations without data between 9-12 July or outside of the forecast domain. The yellow star marker shows the location of the Corsica lidar station. The dashed line shows the latitude of 44° N which is used to split the French stations in Sect. 5.1".

Again, does the model explicitely use the backscatter AND extinction information, or is the attenuated backscatter just interpreted as backscatter? Please state that clearly!.

We used the attenuated backscatter. Please refer to answers to comment 1) of Anonymous Referee 1.

4) *Page 13070, line 23: The lidar color plots are rather poor, contain almost no information. Almost nothing is seen in these figures, some plumes, mostly decreasing signals, no PBL tops. Why are the lidar data so poor? Are the lidars so bad? I am really surprized that such low quality observations can lead to improvements of aerosol fortecasts.*

We re-plotted Figures 2 and 3 with hourly-averaged vertical profiles of PR^2, to better show the atmospheric structure. Also, the captions of Figures 2 and 3 are respectively modified to "Hourly-averaged range corrected lidar signals (PR^2) from 06:00 UTC 9 July to 06:00 UTC 12 July at Athens, Clermont-Ferrand, Evora, Granada, L'Aquila and Potenza lidar stations" and "Hourly-averaged range corrected lidar signals (PR^2) from 06:00 UTC 9 July to 06:00 UTC 12 July at Barcelona, Bucharest, Corsica and Madrid lidar stations". Indeed we cannot easily visually determine the PBL top at some stations (e.g. Athens) in Figures 2 and 3. But the PBL top can be easily visually determined at Evora, Barcelona and Bucharest stations. That is likely because of the different overlap of the different lidar systems and different atmospheric conditions at stations.

Although the PBL top is not sometimes easily visually determined due to the overlap problem, lidar observations provide aerosol information at high altitudes, which improves the aerosol simulation using DA.

5) *Page 13071, line 12: Why do you use 355 nm AOD? The AOD at 340 nm (used to get the 355 nm AOD) is not just free of uncertainties, because strongly controlled by Rayleigh extinction (and correction of this effect). Why not using 500 or 532 nm AOD? Please explain! May be the reason is, ... as it is often found in measurement-model inercomparisons... , the modelled AOD matches much better the measurements at short wavelengths than at 500, 532, or 550 nm AOD? Please explain, why you use this a bit complicated wavelength (even the Angstroem exponent*

is uncertain at these short wavelengths).

In our opinion, the wavelength 355 nm is not attached to more significant concentrations than 532 nm. Although extinction coefficients include a strong contribution of molecules at this wavelength, they can be easily corrected by calibration uncertainties. As shown in [Chazette et al., 2010], AERONET gives a maximal absolute uncertainty of about 2% for AOD, which is wavelength dependent. Moreover, in the current implementation of our DA algorithm, only one wavelength may be used. This is mentioned in the following statement at P. 8 L. 12-13: "[Wang et al., 2014] developed for the first time DA algorithms to directly assimilate normalised range corrected lidar signals (PR^2) at one wavelength (i.e. 355 nm)". Measurements were performed at 355 nm at most stations, because the lidar measurements at 355 nm are eye-safe (e.g. aviation near the city) and more sensible to aerosol pollution. Keeping the wavelength of AOD match with the one of lidar reduces the computational cost in simulations.

Again, Cyprus (CUT, AERONET/EARLINET station) belongs to AERONET too. Again, Figure 1 is really bad, even Crete (in the center of the Mediterranean) is almost not on the map. As mentioned, please improve Figure 1 significantly.

CUT (34° 40' N, 33° 02' E) is one of AERONET stations. However, it is out of our modelling domain ([15° W, 35° E] × [35° N, 70° N]). It is why CUT AERONET station is excluded. FORTH CRETE (35 N, 25 E) does not provide the Level 2.0 (cloud-screened and quality-assured) AOD data for the year of 2012. Please refer to the AERONET website `http://aeronet.gsfc.nasa.gov/new_web/aerosols.html`. Therefore, FORTH CRETE is excluded. For clarity, the caption of Fig. 1 has been modified as follows: "Map of the different measurement sites providing measurements between 9-12 July in the domain of interest (the rectangular area delimited by the black box)...".

6) *Page 13073: How can lidar data in terms of attenuated backscatter with all the problems introduced by overlap problems in the near field (in the lowest 500-1500 m above ground) improve ground-based PM2.5 and PM10 forecasts? Please explain. I have no idea, how this is possible.*

To avoid overlap problems, the lidar data below chosen altitudes were not used in this paper (see Figures 2 and 3, the overlap altitude depends on the lidar system). Assimilating lidar data improves aerosol mass concentrations at high altitudes (above the overlap altitudes), e.g. 1000-3500 m above ground level. The improved aerosol concentrations at high altitudes are transported to the ground by diffusion (turbulence) and winds during the simulation of the chemistry-transport model, leading to improvements of ground-based concentrations. This is now explained in section 2: "Concentrations can be impacted by lidar DA far from the place where lidar signals are assimilated, because analysed mass concentrations are transported by winds and diffusion (turbulence)". This impact of DA on concentrations nearby the locations of lidar is shown in Section 5.1 and 5.2. The ground-based PM_{10} and $PM_{2.5}$ stations can be impacted by assimilation of lidar data: "Against the observations at BDQA stations on the southern side of 44° N (dashed line in Fig. 1), ... The improvements of DA are more significant by comparisons to measurements at BDQA stations southern of 44° N than at all BDQA stations. These southern stations are impacted by DA of the Corsica, Spain and Portugal lidar data" and "the surface stations around Barcelona are also strongly influenced by the Evora and Madrid lidar sites due to wind fields, because Barcelona is on the leeward side of these lidar sites during the lidar campaign in July 2012 (see Fig. 6). The improvements due to lidar DA associated with a long-range transport pollution from Evora and Madrid are also validated". About this point, please also refer to [Wang et al., 2013] and [Wang et al., 2014] who have demonstrated the usefulness of assimilation of ground-based lidar data for aerosol forecasts.

7) *Page 13076: line 5-28: What is now the most important lidar information when using attenuated backscatter? Please state! Is it the observed aerosol layering (geometrical properties) or the optical properties of aerosols which may be used to estimate volume and mass concentrations of the particles? Please provide more details on this! And again, how did you overcome the large uncertainties in the lidar data in the lowest tropospheric heights?*

In our case, we assimilate PR^2, instead of extinction, backscatter coefficients or mass concentrations estimated by the optical properties. Therefore, both the optical and geometrical properties of aerosols are important for assimilation of lidar signals. To avoid overlap problems (uncertainties in the lowest tropospheric heights), the lidar data at each station below chosen altitude were not used in this paper (see Figures 2 and 3). For example, the lidar data at Athens station below 600 m a.g.l (see Fig. 2) were not used. In this section, we discussed the choice of the assimilation altitude range: "First, as the normalisation of range corrected lidar signals is done at high altitude, the lower the altitude is, the higher the error in the simulated lidar signal is" and "Second, the numerical computations of the lidar operator H and its tangent lidar operator H (see Eq. 1) are very costly". Therefore, we need a moderate assimilation altitude range.

8) *Pages 13077 and 13078: There are no explanations why the forecasts improve, all the results do not help. The reader will almost learn nothing without further information.*

For clarity, the following sentences are added in Section 2: "[Wang et al., 2014] developed an aerosol optical property module to simulate the aerosol optical properties (AOD, backscatter and extinction coefficients) and lidar signals (PR^2) from the model aerosol concentration outputs. They also detailed the OI approach for assimilating lidar signals from the model aerosol concentration outputs" (P. 9 L. 27-29 and P. 10 L. 1) and "Concentrations can be impacted by lidar DA far from the place where lidar signals are assimilated, because analysed mass concentrations are transported by winds and diffusion (turbulence)" (P. 11 L. 7-9).

9) *Figure 7: What is the truth? (what is the true curve or the curve most close to the reality)? May be I missed the point?.*

Figure 7 shows the time evolution of the RMSE (root mean square error) and the correlation of aerosols, rather than the aerosol mass concentration evolution. There is no "truth". There are statistics calculated against observations to estimate how the simulation performed, i.e. how close they are to observations. The lower the RMSE is and the higher the correlation is, the better the simulation for aerosol forecasts is.

10) *Figures 10 and 11: Again, what are the true curve?*

Please refer to answers to comment 9) of Anonymous Referee 1.

11) *Figures 12 and 13: I do not see any improvement when using these attenuated backscatter data from lidar!*

The improvements shown by scatter plots in Fig. 12 are not very significant. However, the statistics (RMSE, correlation and bias) show improvements. It is discussed in section 5.3 as follows: "The PM_{10} correlation and RMSE are slightly improved. During the assimilation and forecast periods (72 h), the RMSE averaged over all six experiments is $6.9\,\mu g\,m^{-3}$ without DA and $6.3\,\mu g\,m^{-3}$ with DA (see Tab. 4). Compared to the simulations without DA, DA ("Lidar DA") increases the correlation from 58 % to 63 % (see Tab. 4). Meanwhile, the Mean Bias Error (MBE) decreases from 3.1 to $2.3\,\mu g\,m^{-3}$ (see Fig. 12)." (P. 21 L. 6-10).

According to the statistics in Fig. 14, the improvements are not significant for all AOD. However, AODs are significantly improved in the simulation with DA for high AOD observations. This is discussed and explained in section 5.4 as follows: "As shown in Fig. 14, AODs are significantly improved in the simulation with DA for high AOD observations (few cases). When the observed AODs are larger than 0.4 ($N = 262$), the RMSE (resp. MBE) is 0.23 (resp. 0.2) without DA against 0.20 (resp. 0.13) with lidar DA. It is because large AODs could be associated with transport of particles above the boundary layer, which is not well simulated by the model (probably due to large-scale model uncertainties) but followed by the lidars [Wang et al., 2014]. It may also be that assimilation of lidar signals improves the estimation of aerosol mass concentrations more efficiently when aerosol concentrations are high, e.g. during air pollution events, that is when the lidar signal is strong" (P. 22 L. 4-12).

Part II

Response to Referee 2's comments

General summary:

Some points that needs to be addressed concern the generality of the results given that only one case study was presented, as well as the impact of changing the boundary conditions on the DA results.

As shown by [Roustan et al., 2010] who have performed sensitivity analysis for aerosol and gas-phase concentrations over Europe using the model used in this paper (POLAIR3D/POLYPHEMUS), simulated concentrations of PM are sensitive to boundary conditions (BC). Depending on the global scale model used to provide BC and on the simulated period/year, changing BC could improve or deteriorate aerosol forecasts. If BC are improved, aerosol forecasts may be improved in the simulation without DA, and the impact of DA may be less important. However, depending on period/year and place, changing BC may also deteriorate aerosol forecasts leading to a higher impact of DA. Because simulations of PM strongly depend on other input data, e.g. meteorological fields [Dawson et al., 2007] and emissions [de Meij et al., 2006, Napelenok et al., 2006], the impact of DA may also be more or less important if other input data are changed. The modifications of DA would vary with period/year and place. Therefore, for simplification, this paper presents only one set of input data.

Specific Comments:

1) *p.5 l.127: Could also add these to the list of references on lidar DA:*
Campbell, J.R., Reid, J.S., Westphal, D.L., Zhang, J., Hyer, E.J., Welton, E.J., 2010. CALIOP aerosol subset processing for global aerosol transport model data assimilation. Journal of Selected Topics in Applied Earth Observations and Remote Sensing 3, 203-214. doi:10.1109/JSTARS.2010.2044868.
Zhang, J., J. R. Campbell, J. S. Reid, D. L. Westphal, N. L. Baker, W. F. Campbell, and E. J. Hyer, 2011: Evaluating the impact of assimilating CALIOP-derived aerosol extinction profiles on a global mass transport model, Geophys. Res. Lett., 38, L14801, doi:10.1029/2011GL047737.

These two citations are added as follows: "lidar extinction coefficients [Campbell et al., 2010, Zhang et al., 2011]" (P. 7 L. 25-26).

2) *p.6 l. 177 Are the boundary conditions on dust derived from the EMEP inventory? Please explain. In the case of the regional models, DA results strongly depend on boundary conditions (BC). For example, it would be interesting to investigate how the use of different BCs (from global models, or different inventories, or different reference year, etc.) would influence the DA results. Please comment on this in the text.*

Boundary conditions (BC) are climatological conditions obtained from averaging BC from the MOZART4 model over the years 2004-2008. This point was stated at P. 9 L. 16-19 as follows: "Boundary conditions are climatological conditions obtained from averaging boundary conditions from MOZART4 (Model for OZone And Related chemical Tracers version 4) [Emmons et al., 2010] over the years 2004-2008". Moreover, we explained at P. 9 L. 20-26 as follows: "Anthropogenic emissions of gases and aerosols are generated with the EMEP inventory for 2009... In the simulation, Saharan dust is only forced by boundary conditions".

In regional models, the simulation strongly depends on input data, e.g. BC [Roustan et al., 2010], meteorological fields [Dawson et al., 2007] and emissions [de Meij et al., 2006, Napelenok et al., 2006]. BC are often obtained from the global models. Therefore, they strongly depend on the uncertainties of global models. In this paper, BC are from the MOZART4 model over the years 2004-2008. They are not specific BC for the month of July 2012. However, if specific BC are used, concentrations may be better modelled and the impact of DA would then be less important. However, because uncertainties on global models and BC are high, it is not certain that concentrations may be better modelled. Furthermore, uncertainties are not only limited to BC but also to meteorological fields and emissions. For clarity, the following statement is added at P. 11 L. 10-16: "In regional models, uncertainties are linked to input data and parameterizations, e.g. initial and boundary conditions [Roustan et al., 2010], meteorological inputs [Dawson et al., 2007] and emissions [de Meij et al., 2006, Napelenok et al., 2006]. DA may be used to improve input data as initial conditions as done in this paper using observations. Replacing other input data, such as BC or emissions by another set of data which are also uncertain, may either improve or deteriorate the aerosol simulations depending on period/year and place, leading local variations in the impact of DA.".

3) *p.8 l.232 Were the observations averaged over 1 hour? Did you try different averaging intervals? What about in the vertical?*

Yes, the lidar observations were averaged over one hour. In this paper, we did not try different averaging intervals. However, [Wang et al., 2014] assimilated data every 10 mins at the scale of Paris, because averaging or assimilation intervals depend on the modelling scale. They are larger in this paper (simulations over Europe) than in the simulation over Paris. In the vertical, assimilated data were interpolated from the high resolution lidar profiles (see Tab. 1).

4) *p.9 l.275 The analysis of the case study using backward trajectory can only go so far as far as the species attributions: can the authors use different tools (for example global aerosol models) to assess what type of aerosols were likely present at the lidar stations during the campaign period?*

We focus mainly on the forecast of aerosols, e.g. mass concentrations of PM_{10} and $PM_{2.5}$. We checked if Saharan dust strongly impacted the continent of Europe P. 14 L. 1-10. In this paper, backward and forward trajectories are used to show the impact area of assimilating lidar data P. 14 L. 20-24. They are not used to assess the aerosol types. This is done using POLAIR3D/POLYPHEMUS. For clarity, the following statement is added at P. 14 L. 11-12: "To check that the penetration of the Saharan dust plume over the continent of Europe was limited and to assess where analysed concentrations are transported to after assimilation, ...".

5) *p.10 l.306 Would you have had the same improvements if more dust was already present in the BCs? The influence of the BCs should not be neglected. This is part of assessing the goodness of the background.*

Yes, we believe we would have had the same improvements if more dust was already present in BC, because the penetration of Saharan dust plume over the continent of Europe was limited and did not affect most of the ground-based concentrations, as discussed in section 3.3. Using BC from another global models may not improve the simulations as all global models are attached to uncertainties. This paper presents the first application of assimilating lidar signals. It was expected to demonstrate the usefulness of lidar network for aerosol forecasts. Therefore, only one set of input data is tested. Assessing the impact of uncertainties on DA may be the topic of further papers.

6) *p.11 l.321 : Add "should" before 24-hour".*

At P. 16 L. 12, "should" was added before "24 h".

7) *p.11 l.324 : Why did you choose 60 hours for the total forecast length?*

Actually, we took 108 hours as the forecast length. Since improvements are not significant after 60 hours, we showed only the first 60-hour forecast in this paper.

8) *p.12 l.374 What is the vertical resolution of the data? Did you perform any averaging? If yes, did you look at the sensitivity to the choice of averaging interval (the same question applies to the temporal averaging, see question above). Why did not not assimilate from the surface? Are there intrinsic problems with the use of the ground-based lidar observations close to the surface? Please comment.*

The vertical and temporal resolutions of the data are shown in Tab. 1. Moreover, they are detailed at P. 12 L. 11-13 that "The vertical resolution of measurements ranges from 3.25 m to 30 m (depending on the lidar system). The temporal resolution of measurements ranges from 30 s to 300 s (depending on the lidar system)". Assimilated data were interpolated with a time resolution of 1 hour from high temporal resolution lidar profiles. We did not perform any averaging in the vertical.

We did not assimilate lidar data from the ground level, because data are not available between the surface and several hundred meters due to overlap problems (see Figures 2 and 3). Please see answers to comments 6) and 7) of Anonymous Referee 1.

9) *p.13 l.404 Please summarize the results in a table, section 5.1 is hard to read. Please do the same for sections 5.2 and 5.3.*

For clarity, we summarised the statistics of sections 5.1, 5.2 and 5.3 in Tab. 4.

10) *p.13 l.417 How do you assess the significance of the improvements?*

For clarity, the following sentence "Against the observations at BDQA stations on the southern side of 44° N (dashed line in Fig. 1), ... The improvements are significant" is modified to "Against the observations at BDQA stations on the southern side of 44° N (dashed line in Fig. 1), ... The improvements of DA are more significant by comparisons to measurements at BDQA stations southern of 44° N than at all BDQA stations" (P. 20 L. 8-9).

11) *p.14 l.431 From these results it appears that the radius of influence of the lidar measurements is rather small. Could you comment on how what type of density of lidar stations would be desirable? Where would having more lidar stations bring the highest benefits? It is probably situation-dependent. Could you comment on using a denser network such as the ceilometer network?*

The radius of influence of the lidar measurements is not very small. As tested in this paper (see section 4.2), the assimilation correlation length should be less than 200 km. We took 100 km as the reference assimilation correlation length which defines a radius of influence of about 500 km by the Balgovind approach (similar to exp(-x/L), x stands for the distance and L stands for the assimilation correlation length).

[Wang et al., 2013] have investigated the number of required lidars and how to define an optimal lidar network for PM_{10} forecasts over western Europe using synthetic data. They have studied lidar networks of 12 stations, 26 stations and 76 stations. 76 lidar stations lead to the best scores (RMSE and correlation). Moreover, [Wang et al., 2013] have investigated the optimal locations of lidar networks. They found that spacing regularly the lidars improves PM_{10} forecasts over Europe. Since [Wang et al., 2013] used synthetic data (i.e. the vertical profile of aerosol mass concentrations), the results should be generalised to the ceilometer network.

What type of accuracy is needed from the lidar measurements to have a significant impact on the surface PM concentrations?

Lidar measurements as those performed here are accurate enough to have a significant impact on surface PM concentrations. Since uncertainties in the lidar signal are low (less than 5 %), reducing uncertainties in the simulation and changing the algorithm used for assimilating lidar signals may further improve surface concentrations.

12) *p.15 l.478 Can this be generalized?*

Yes, but it also depends on the modelling scale, the vertical resolution, the density of lidar network etc. Moreover, most validation observations were provided by the French network (i.e. BDQA) in this paper.

13) *p.15 l. 484 Remember the possible role played by the BCs, you only experimented with one set of BC and one case.*

Please refer to answers to comments 2) and 5) of Anonymous Referee 2.

Figures

Figure 2-3 It would be good to see the model equivalent of the lidar PR2 before and after assimilation alongside the observations.

Such comparisons are shown in Fig. 11 of [Wang et al., 2014]. They were used to validate the improvements at high altitudes. In this paper, we focus mainly on the validation using surface PM measurements to study the impact of assimilating lidar signals at ground level.

Figure 13 Could you also show the time series for AOD at a few stations rather than only the scatterplot. Are the obs matched to forecast time?

As you suggested, a figure of the time series of observed and simulated AODs at two stations Rome and Bucharest is added in the paper. Also, the following statement is included in section 5.4: "Figure 13 shows the time evolution of the AOD measurements and AODs of the 36-hour forecasts without DA and with DA at AERONET stations Rome (41.84° N,12.65° E,130 m a.g.l.) and Bucharest (44.35° N, 26.03° E, 93 m a.g.l.). The impact of assimilating lidar signals lasts about 36 hours, which corresponds to the findings of sections 5.1 and 5.2".

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