General comments

In the presented work the authors analyze a 21-day period of atmospheric measurements in the Po Valley, Italy. In particular, the authors present the measurements obtained by different *in situ* and remote sensing instruments and compare them mainly in a qualitative way, presenting the results separately. In this sense, a more quantitative approach should be tried in some analyses. For instance, in the analysis of the effect of RH on the aerosol linear depolarization ratio (δ_a) , a correlation analysis between the RH at surface level and the values of δ_a at the lowest altitudes would offer more information about this process.

According to the authors, "The main objective of this paper is to investigate the transport of desert dust in the middle troposphere and its intrusion into the planetary boundary layer (page 1, line 4)". In order to fulfil this objective it would be desirable a more detailed analysis of the events where the aerosol concentration increases at surface level and how the dust layer interacts with the PBL. However, the whole 21-day period is presented in a single figure (figure 2, lidar; figure 4, in situ).

A great part of this work is based on measurements of a lidar system. However, the lidar signals have not been properly processed. The calculations regarding the lidar measurements must be revised (see specific comments).

Finally, the authors must carry on a thorough revision of the language.

Specific comments

1. Page 4, line 20: **"***In the following discussion, we will make use of backscattering ratio (R)*". Why do the authors use R, which depends on the molecular terms, rather than β_a, which only depend on aerosols?

2. Issues regarding the depolarization measurements

Page 4, from line 21**:**

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minutes with a vertical resolution of 7.5 m extending, on average, up to 7 km. In the following discussion, we will make use of backscattering ratio (R) and aerosol depolarization (δa) , defined as (Browell et al., 1990; Cairo et al., 1999):

$$R(r) = \frac{\beta_a(r) + \beta_m(r)}{\beta_m(r)}$$

$$\delta_a = \frac{\beta_{a_{perp}}}{\beta_{a_{par}}}$$

$\beta_m(r)$ represents the backscatter coefficient from molecular contribution while $\beta_{a_{perp}}$ and $\beta_{a_{par}}$ represent the backscattered signal components from aerosol light scattering, with polarization respectively perpendicular and parallel to the polarization of the emitted light. The inversion of the LiDAR signal is accomplished with the Klett method (Klett, 1985; Fernald , 1984), finding a suitable region of the profile that is supposed to be free of aerosol to calibrate the signal, and using piecewise constant extinction-to backscattering ratio (LiDAR ratio, L) values. We make use of different values for L following what reported in literature: desert dust (identified by $\delta_a(r) > 10\%$) is characterized by L equal to 50 sr (Müller et al., 2007) while for low depolarizing aerosol we assume the values typical for anthropogenic aerosol, L∼60–70 sr (Murayama et al., 1999; Ferrare et al., 2001; Fiebig et al., 2002). In addition we considered different values for water cloud ($L = 20$ sr) and ice clouds ($L = 30$ sr)

(Chen et al., 2002; O'Connor et al., 2004). A more detailed description of the methods used to perform the inversion of LiDAR data, together with a through uncertainty analysis, performance in conditions close to the SPC site and additional experimental set-up details, are given in Cairo et al. (2012) and Rosati et al. (2016) and its supplementary material.

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For the determination of the lidar ratio Rosati [2016] uses the volume linear depolarization ratio, defined as: $\delta \equiv \frac{\beta_{a\perp}+\beta_{m\perp}}{\beta_{a\parallel}+\beta_{m\parallel}}$ (called DR by Rosati [2016]). This parameter indicates the total depolarization effect of the atmosphere (molecules + aerosols), and can be determined in a straightforward way[1] as the calibrated ratio of the elastic signals:

$$\delta = C\,\frac{P_\perp}{P_\parallel}$$

This parameter can be estimated prior to the signal inversion and can be used as a *rough* indicator of the presence of dust.

Unlike δ, the aerosol depolarization, $\delta_a \equiv \frac{\beta_{a\perp}}{\beta_{a\parallel}}$ (more commonly called aerosol -or particle- linear depolarization ratio), is an intensive property of the aerosols. In order to estimate this parameter we first need to perform the inversion of the signal. Because of this, in a first instance, I could not get to understand how the authors use δ_a to determine the lidar ratio prior to the signal inversion. However, in page 4, line 29 the authors claim: *"…desert dust (identified by δ_a (r) > 10%) is characterized by L equal to 50 sr (Müller et al., 2007)…"*. This is the same criterion used by Rosety [2016], although Rosety [2016] used δ instead of δ_a. Because of this, the most likely explanation is that the authors have mixed up both parameters (δ and δ_a).

Another example of this is found in page 6, line 29: "*At 532 nm, values of aerosol depolarization around or higher than 30 % are generally associated with layers of nearly pure mineral dust while smaller values (around 8–10 %) are often detected in*

[1] Strictly speaking we should take into account the optical properties of the system, especially the diattenuation properties and misalignment of the receiving optics [Freudenthaler, 2016; doi:10.5194/amt-9-4181-2016]

correspondence of mixture of mineral dust and non-depolarizing particles". Nevertheless, the authors barely find aerosols with δ_a > 20 % (e.g., Fig. 1). This is another indication that the authors are actually using δ instead of δ_a.

Page 7, line 3: "*The reader should notice that the lower depolarization values that we observe respect what usually found in literature (especially for the dust layers) are more likely linked to the calibration process, and in particular to the difficulty in individuating completely aerosol free layers in the vertical span of the adopted LiDAR system (from ground to 7 Km)*." Again, I think that these differences are because the authors are comparting two different parameters (δ and δ_a). The authors should revise their calculations to see if this is the source of disagreement. If, after this, the calibration stills play an important role in this disagreement, the authors should describe its effect in a more detailed way.

In the corrected version the authors must indicate, unambiguously, which depolarization parameter are using. The volume depolarization ratio, δ, can still be used as a rough indicator of the presence of dust in the determination of the lidar ratio values. However, for aerosol classification in section 3 I strongly recommend using the aerosol linear depolarization ratio (δ_a), since it is an intrinsic property of aerosols and does not depend on the molecular terms.

3. Page 6, line 16. "*For simplicity, dust on emissive areas is considered to be injected uniformly below 1000 m a.g.l., therefore only trajectories crossing this height are included in the footprint-emissions coupling*". Is this a common procedure? Is there any previous work that backs this procedure?

4. Page 7, line 5: "*The LiDAR classification, based on the statistical distribution of the overall observed δ_a and R values, is also applied here to overcome such limitations*." However, in Fig. 1 it can be seen that the only parameter used for aerosol classification is δ. Because of this, we could get more information with a histogram of only δ values. Also, the figure should only show relevant δ values: more than half of the current figure corresponds to δ values (over 0.25) with almost no associated case.

5. Page 7, line 13:

1. low values of δ_a (< 3 %); based on the above references, these particles may be composed of anthropogenic pollution and, for higher values of R, by droplets, and are defined as non-depolarizing.

2. high values of δ_a (> 10 %); according to the previously mentioned literature, this can be consider as a threshold value for mineral dust or mixed dust particles. This class is defined as depolarizing.

3. intermediate δ_a values (3 %< δ_a <10 %) which, based solely on R and δ_a, cannot be considered as indicative of a dominance of a defined aerosol type unless coupled to a more thorough correlation with additional observations. We will refer to this type as intermediate depolarizing.

The authors are comparing their results to other references although they have previously said that their results might not match them due to calibration issues (again, this is likely due to a confusion between δ and δ_a). If δ is finally used for the classification (although I strongly recommend δ_a), the threshold values should be derived from a statistical analysis of its values.

6. Figure 3. The relevant data in fig. 3 covers less than half of the total area and is hard to visualize. The figure should be redesigned for better interpretation. Also, it could be improved if the surface temperature were plot in an independent panel.

7. Page 8, line 29 "*Meteorological evolution is integrated with the aerosol optical variability from LiDAR (see Fig. 2) and with ground aerosol 30 number concentration and volume size distribution (estimated as the volume of a sphere of diameter corresponding to the volume-equivalent particle diameter) at SPC and CMN (see Fig. 4)*" Meteorological parameters, lidar measurements, and in situ measurements are presented separately in different figures. They do not seem to be integrated.

8. Page 10, line 18 "*According to FLEXPART, the import of mineral dust persists until the morning of 23 June, when dust presence is not unambiguosly inferable from observations but the aerosol mask still indicates the presence of intermediate depolarizing particles below 2000 m. The second desert dust event predicted by FLEXPART shows the same timing with respect to observations but, while the APSS and the OPSS indicate a similar dust burden for the two desert aerosol advection events, the dust load indicated by the model(between 3 and 5 µg m−3) appears lower respect to the previous events*". In addition to limitations of the model, differences between estimations of FLEXPART over the SPC site at 1-2km and 3-4km and surface-level measurements at SPC (different altitude level) or CMN (different location) might be partly caused by aerosol time-space variability. Have the authors considered a comparison against lidar-derived dust concentration? (These can be retrieved with the POLIPHON method by Mamouri [2014[2]]).

9. Figure 7. This figure does not seem to add any information to what can be seen in Fig. 6 and what is on the text. I think it can be removed.

10. Issues regarding section 7

Name of the section: "Effect of aerosol hygroscopic growth on aerosol particles light scattering and depolarization" -> Effect of aerosol hygroscopic growth scattering and depolarization

Page 12, line 19. "*LiDAR data (Fig. 2) frequently show, during early morning hours, a shallow layer of non-depolarizing aerosol below 300 m height, more easily visible during days characterized by desert dust and mixed dust events*". Below 300 m the overlap of the lidar is not complete. Despite the authors claim that "*Experimental correction allows the reconstruction of the LiDAR backscattering profile down to around 100 m, with an acceptable uncertainty* (4-17)", they also say that "*The reader should notice that the lower depolarization values that we observe respect what usually found in literature (especially for the dust layers) are more likely linked to the calibration process, and in particular to the difficulty in individuating completely aerosol free 5 layers in the vertical span of the adopted LiDAR system (from ground to 7 Km)* (7-5)" The question is: to what extent can we trust depolarization measurements below complete overlap?

Figure 11 and Figure S2. For this kind of study it might be more appropriate to show the aerosol and humidity profiles at 5:00 UTC as regular plots (not color plots).

[2] doi:10.5194/amt-7-3717-2014

Page 12, line 29: "*The study, extended separatedly on the whole dust events 30 period (20–23 June and 29 June – 2 July, lower panel of Fig. S2, supplementary material) and in the remaining dust free days (upper panel of Fig S2, supplementary material), indicates in both case a depolarization decrease in the lower layers, visible starting from RH>60%*". In Fig. 11 and Fig. S2 we can see that in cases with presence of dust the depolarization decreases with RH. But this can be seen as the opposite: elevated dust layers (within dry hot air-masses from the Sahara) uncoupled from the PBL result in a decrease in the RH. In order to state that the dust depolarization properties are affected by the humidity, the authors should prove that a noticeable amount of dust actually reaches the lower altitudes where RH > 60 %. For instance, for the case used as example (30 June), at 5 UTC (time of the sounding) we do not see an especially high concentration of coarse particles at surface level compared to, for instance, 1 July (Fig. 4). Also, it would be interesting if the authors showed, in addition to the RH profile, the temperature profile for 30 June. This way we could see it a thermal inversion between the dust and the lower layers keeps them uncoupled. Finally, on 1 July we can see aerosols classified as dust reaching the surface (it is also the day with highest coarse-mode concentration at surface level). Although no soundings might be available at those times, it would be interesting to compare the depolarization values at the lowest altitudes available and the relative humidity at surface level.

Other comments, language errors, and typos

Although some language mistakes have been noticed, the following list is not complete. Because of this, a thorough revision of the language must be made.

- Common language error (1): Before a certain characteristic (e.g., concentration, depolarization, size…) the noun is usually singular (e.g., particle size, aerosol depolarization, ion concentration), not plural (e.g., particles size, aerosols depolarization, ions concentration).
- Common language error (2): Before a date (e.g., 30 June) you do not have to write "the" (e.g., the 30 June).
- δ_a should be called aerosol (or particle) linear depolarization ratio instead of the ambiguous "Aerosol depolarization". δ should be called Volume linear depolarization ratio
- 4-7: "For the most part of the year". -> For the greater part of the year
- The lidar ratio is referred as both L (e.g. 4-28) and LR (e.g., 6-24). This has to be fixed.
- 5-29 "High accuracies" -> high accuracy.
- 8-29 "small particles concentration" -> small particle concentration (see common language error (1)).
- Figure 2: "not depolarizing aerosol (yellow), depolarizing aerosol (orange) and intermediate aerosol (brown) properties". Rewrite this phrase so that it makes sense.
- 9-19 "*…intensification of mineral dust burden or, as suggested by **???** a corresponding increase in black carbon concentration observed at CMN (see also Cristofanelli et al. (2016)), by mixing with pollution from the regional PBL (Cristofanelli et al., 2009).*" Rewrite to make it more clear.
- Figure 4. Title of panel a): "Dp = 420 nm" -> 297nm< Dp < 420 nm
- 10-19 "unambiguosly" -> unambiguously
- Figure 8. "…evolution of aerosol particles volume size distribution" -> …evolution of particle volume-size distribution (see common language error (1)).
- Figure 10. "… LiDAR aerosol particles depolarization …" .-> volume linear depolarization ratio (in case of δ) or particle linear depolarization ratio (in case of δ_a)
- 11-33 "wide range of aerosol type" -> wide range of aerosol types
- Figure 10. The label of the horizontal axes should be "hour" in all panels not "hours" or "day".
- 12-20. "*see for instance 00:00-06:00 UTC of the 19 June and between 00:00-08:00 UTC of 30 June*" -> see for instance 00:00-06:00 UTC on 19 June and between 00:00-08:00 UTC on 30 June (see common language error (2)).
- 12-31. "*…indicates in both case a depolarization decrease in the lower layers, visible starting from RH>60%.*" -> …indicates in both cases a decrease in the depolarization of the lower layers for RH>60%.
- 14-27 *"…basing on in situ measurements…"* -> based on *in situ* measurements