

We would like to thank the Reviewer for his/her comments which helped us to improve our manuscript. We have modified the text according to the suggestions made and provide below responses to the comments.

General comments

“This paper aims to provide a description of the vertical structure of the intense Mediterranean dust outbreaks. It is clearly written, the overall presentation is well structured and clear, and the paper addresses scientific questions fully within the scope of ACP/AMT special issue on ChArMEx. Generally the analysis is interesting but it appears that the use of CALIOP-CALIPSO data set to describe the vertical distribution of dust events, with an extended spatial coverage over the Mediterranean area, is the main new contribution of the paper.

As extensive research has been carried out on Mediterranean dust outbreaks, based on ground-based (AERONET) and satellite observations, the paper should be more focused on what is really new in the data set and associated analysis. For example the analysis presented in Section 4.1. (2-D geographical distributions of desert dust episodes frequency and intensity) is not fully novel as nearly all the conclusions have been already reached in Gkikas et al. (2013). Even if the period of study is extended and the identification of desert dust method slightly improved (use of both MODIS-terra and Aqua, QA-weighted level-3 data, threshold on cloud fraction), the modifications are relatively minor. The main novel aspect of the paper is the analysis of vertical structure of the intense desert dust episodes with CALIOP, so I suggest to emphasize this part of the paper. In the present paper only two figures are related to this aspect.”

We agree with the Reviewer that the vertical structure of Mediterranean desert dust (DD) episodes is the main new contribution of the present paper, with respect to the paper by Gkikas et al. (2013), which first introduced the satellite-based identification algorithm. In this context, we also agree with the Reviewer’s suggestion to further emphasize this part of the analysis, since the obtained results in Section 4.1 (2-D geographical distributions of desert dust episodes’ frequency and intensity) do not reveal remarkable differences compared to the corresponding ones presented by Gkikas et al. (2013). Therefore, also in line with the indications made by Reviewers 2 and 4, we made an effort to strengthen the part of the paper dealing with the vertical structure of DD episodes, while trying to get the manuscript more balanced with respect to the partition of its analysis to the: (i) geographical distribution of DD episodes’ features, (ii) evaluation of the satellite algorithm and (iii) description of episodes’ vertical structure.

We would just like to note that devoting a considerable part of our analysis to the above mentioned tasks (i) and (ii) was made intentionally for the following reasons:

- (a) the satellite-based algorithm is applied in the present study over a more extended time period (almost double) than in Gkikas et al. (2013). We believe that this is important because it confirms the dust episodes regime across the entire Mediterranean basin. Even if this may seem trivial, it is not so, since the work by Gkikas et al. (2013) has been the first, yet the single one to date, which appropriately described this regime, at a complete spatial coverage. Therefore, basically it was not guaranteed that the regime could not change over the time, which is proven by the obtained results in the present paper.
- (b) the evaluation of the satellite-based algorithm is largely improved in terms of robustness by:
 - (1) considering much more, actually all the currently existing AERONET stations within the study region, and
 - (2) using more aerosol optical properties.

- (c) issues related to the MODIS Level 3 AOD sub-grid spatial representativeness and homogeneity, affecting the agreement between MODIS-AERONET AODs, are accounted for and addressed in the present study (Figure 5).
- (d) the comparison of the satellite algorithm's outputs against ground PM₁₀ data is more detailed here (e.g. success scores, dust contribution, mean and median levels are reported) than in Gkikas et al. (2013).

Moreover, apart from the previous reasons there is one more, which is the same or even more important. It is that in the present revised manuscript, also based on a relevant comment of Reviewer 4, we applied a second methodology (METHOD-B) for the identification of DD episodes in our algorithm, which does not exist in Gkikas et al. (2013). According to the new methodology, the defined thresholds in the algorithm for the various aerosol optical properties are calculated from the non-dust affected Level 3 retrievals. The results of this methodology and those of the default one are compared and discussed in the revised manuscript, which constitutes a novelty in this paper.

Following, however, the Reviewer's comment, in the revised manuscript more emphasis is given to analyzing the Mediterranean desert dust outbreaks' vertical structure. More specifically, we have identified desert dust outbreaks of different geometrical characteristics for which the satellite algorithm's outputs, PM₁₀ concentrations and CALIOP-CALIPSO lidar profiles are all together available concurrently. The obtained results are discussed in the new section 4.4 introduced in the revised manuscript. The scope of this analysis, triggered by the poor-to-moderate agreement between the algorithm outputs and PM₁₀ concentrations in the western Mediterranean, is to give a better insight on how dust outbreaks' vertical distribution can affect the level of agreement between columnar AOD retrievals (MODIS) and ground PM₁₀ concentrations. This analysis was made by implementing both vertically resolved data retrieved by the CALIOP-CALIPSO, in conjunction with ground PM₁₀ measurements (representative for the lowest part of the planetary boundary layer) and MODIS AOD retrievals (representative for the whole atmospheric column).

Finally, another new point in the revised manuscript, giving more emphasis to the vertical structure of Mediterranean dust outbreaks, is that we have reproduced the three dimensional plots of Figure 9, displaying dust outbreaks 3D characteristics (both for dust records and total backscatter coefficient values), but considering all the available CALIOP-CALIPSO dust lidar profiles. The results, presented in Fig S6 of supplementary material, help to investigate the modifications of vertical distribution of CALIOP retrievals under intense desert dust outbreaks. The main findings are discussed in the revised manuscript (lines: 855-882).

"It is surprising that section 4.2, which is centered on the evaluation of the satellite algorithm (combining MODIS and TOMS/OMI) against AERONET and PM10 measurements represents the longest part of the paper. The analysis and results are interesting but they seem quite disconnected to the main topic and objective of the paper, i.e. vertical structure of intense dust outbreaks, as stated in the abstract. In other words, a lot of effort (and figures) is put in certifying the ability of the satellite algorithm to identify desert dust episodes although it is not clearly announced as a main objective of the paper."

We agree with the Reviewer that in the original manuscript, a quite significant part of the manuscript was dedicated to the comparison of the satellite algorithm's outputs against AERONET and PM₁₀ data. This was made just for the reasons explained in our previous reply. However, in order to reduce the length of this part of the manuscript we have made some major modifications. More specifically,

Figure 6 of the original manuscript was moved to the supplementary material (Figure S3 now) and just a short reference to this figure is made in the main body of the revised text (Lines: 556-563). Also, Figures 8 and 9 (in sect. 4.2 of original manuscript) were moved to the supplementary material (Figs. S4 and S5) while the sections “Ångström exponent and effective radius” and “Single scattering albedo and asymmetry parameter” of the original manuscript are now merged to a shorter single section entitled “Size optical properties, single scattering albedo and asymmetry parameter”. Nevertheless, we would like to point out that some results related to the performance of the satellite algorithm are kept in the revised paper because in our opinion they are critical and have been not presented in Gkikas et al. (2013). For example, the results of Figure 5 deal with the issue of level 3 AOD sub-grid spatial variability, which is essential when attempting comparisons of MODIS satellite against local surface-based AOD data like AERONET ones. Also, the results of Figure 7 (revised manuscript), highlight the validity of the defined thresholds for α , AI , FF and r_{eff} (green boxes in the flowchart) used in the satellite algorithm for the desert dust aerosols’ identification, which is essential since there are not any specific objective and commonly accepted thresholds in literature. Yet, in Figure 8 of revised manuscript, are given the success scores, referring to the performance of the satellite algorithm, the dust contribution as well as the mean and median levels of PM_{10} concentrations, under dust episodes conditions.

“In order to clearly reflect the contents of the paper, the title should indicate that analysis focus on intense desert dust outbreaks. I suggest: “Mediterranean intense desert dust outbreaks and their vertical structure based on remote sensing data”.”

We agree with the Reviewer’s comment and the title has been modified according to his/her suggestion.

“My recommendation is to publish this paper after some appropriate changes: (i) taking into account the fact that too much conclusions are identical to Gkikas et al. ACP 2013 in sections 4.1 and 4.2 (despite the slight modifications regarding methods, time period, and sensors) and (ii) reinforcing analysis on its main objective and scientific interest, i.e. analysis of CALIOP vertical distributions of intense desert dust events in section 4.3.”

Done, see our responses to previous comments.

Specific comments

“1. P 27682, lines 21-22: “The main target of the present study is to describe the Mediterranean desert dust outbreaks’ vertical structure over the period from March 2000 to February 2013.” This sentence should be reformulated since the analysis of CALIOP retrievals presented in section 4.3. cover the period 2006-2013.”

Done.

“2. In section 2.1.2 EP/TOMS and OMI-AURA, the period considered for each satellite data as well as their respective spatial resolution should be provided.”

Done (Lines: 247-250).

“3. Figure 1 of the paper has already been published in Gkikas et al., ACP 2013 (figure 2).”

We prefer to keep Figure 1 in the present manuscript just to avoid making readers to go back and consult the paper by Gkikas et al. (2013).

“4. Figure 7: it is not necessary to provide results for both MODIS-Terra and Aqua, as they are very similar.”

We agree and removed Figure 7-ii in the revised manuscript.

“5. Results presented in Table 2 and page 27701 lines 20-24 are not clearly described.”

We have modified the relevant part of the manuscript in order to describe more clearly the corresponding results. Please, see lines 647-653.