Response to comments #1

We would like to thank the referee #1 for their constructive and useful comments. This document contains the authors' responses to comments from reviewer #1. Each comment is discussed separately with the following typesetting:

*Reviewer's comment

Author's response

Changes in the manuscript.

*Review for manuscript Comparative assessment of GRASP algorithm for a dust event over Granada (Spain) during ChArMEx-ADRIMED 2013 campaign. Authors provide comparison of inversions of lidar and sun photometers observations using three different algorithms: LIRIC, GARLIC, AERONET operational algorithm, and demonstrate that results are similar. Such comparison is useful, showing that approaches are consistent. On another hand, similarity in results is hardly surprising, because all three algorithms are based on the same principles. Possibility to use two sun photometers at different heights is interesting, because it helps to analyze possible biases due to geometrical overlap effects. I think manuscript can be published after some revision.

General comments:

*The main question is what we can conclude from this comparison? Authors write: "Results obtained here show that the combination of lidar and sun photometer data can provide improved and more complete column-integrated data compared to AERONET retrieval." I think this statement is unsupported. The difference between methods is inside the inversion uncertainty. This is just comparison and can not be considered as validation.

The comparison presented here between GRASP versus other algorithms (i.e. AERONET and LIRIC) and with airborne in-situ measurements shows the potential to retrieve aerosol microphysical and optical profiles, and also to obtain fine and coarse mode aerosol refractive index and single scattering albedo which is not possible with the current AERONET inversion. Also, the advance versus LIRIC is that GRASP does not assumes as starting point the results of AERONET inversion.

*In conclusion they write: "As a future outlook, it will be of great interest to expand the present analysis covering different scenarios including a major variety of aerosol types and loads during campaigns with airborne measurements in order to validate the new improvements". Yes, it is always useful to consider more situations; still it is not validation.

We agree with the referee that the results presents are just an evaluation for two study cases. To perform evaluations of the configuration sun-photometer + lidar signals, we plan to use a synthetic database provided by global models. Initially we will work with GEOS-5 aerosol fields and computing sky radiances using VLDORT radiative transfer code. A complete evaluation using this scheme is in course, but outside the scope of this manuscript.

We add (section 5, page 11, line 19): The analysis presented here is useful as a primary evaluation of the GRASP algorithm using sun-photometer and lidar signal to retrieve aerosol microphysical properties, both integrated along the vertical column and as vertical profiles. The use of a second sun-photometer located over the local atmospheric boundary layer can be very relevant for the study of the properties of aerosol layers with features really different than the atmospheric boundary layer aerosol. However, the presented analysis is representative of Saharan dust transport to south Europe and still it is necessary to use a more complete dataset that includes different aerosol loads and types. In future studies, we could try to use of the combination of one lidar with two sun-sky photometers at different height to try improve the retrievals in the cases with different aerosol layers. In addition, in order to validate the presented GRASP scheme, in the future it is planned to use global aerosol models (e.g. GEOS-5) following an approach similar to Whiteman et al., (2017).

*Expected advantage of combining lidar with sun photometers is ability to profile intensive particle properties, such as effective radius, refractive index, Angstrom exponent. Authors provide profiles of volume and backscattering, so it is difficult to conclude if they observe height dependence of intensive parameters.

The focus of this work was to evaluate GRASP retrieval algorithm against the well-established AERONET inversion retrievals and independent in-situ airborne measurements during Charmex campaign. GRASP is in continuous development and there are intensive parameters profiles that the referee mentions that are not still available and therefore their evaluation is not possible. However, we focused on SSA and Scattering – Angström Exponent, and also other intensive properties such as mean value of backscatter - Angström exponent (β-AE) and Color Ratio (CR).

*Authors write “For 17th June, vertical profiles of SSA are sensitive to the different aerosol layers with different aerosol types illustrating the capabilities of GRASP for detecting different aerosol layers with different composition.” But from fig.7, 8 I can conclude in the height range ~1.8 – 2.7 km backscattering is very low, so variation of SSA in this range is probably just artifact. The same is true for fig.9, variations of AE in this range are probably not real. Do authors have depolarization measurements? Height variation of particle depolarization ratio could provide some information.

We agree with the reviewer that in the mentioned layer the aerosol load is low (~5 $\mu m^3/cm^3$ in the range ~1.8 – 2.7 km a.s.l.) and, hence, SSA and AE values could be affected by a large uncertainty. However, the layer below 1.8 km a.s.l.

showed a moderate concentration (~17 μm³/cm³) and the SSA and AE profiles still reveal a different composition to that of the layer above 2.7 km a.s.l..

We add (section 4.2, page 10, line 21): On 17th June, in the range ~1.8 – 2.7 km a.s.l. the aerosol load was low (~5 μm³/cm³) and, hence, SSA and AE values could be affected by larger uncertainties. However, the layer up to 1.8 km a.s.l. showed a moderate concentration (~17 μm³/cm³) and the SSA and AE profiles still reveal a different composition with a different composition to that of the layer above 2.7 km a.s.l.

We added the depolarization ratio (δ) quicklook to Figure 2. These figures point out that on 16th June there was a unique layer while on 17th June, there were two main layers: an aerosol layer close to the surface and a decoupled one between 2.7 and 5.5 km a.s.l.. The depolarization ratio evidences that there was an aerosol type below 2.7 km a.s.l. and a different one above this altitude up to 5.5 km a.s.l..

We add (section 4, page 6, line 13): "measurements of δ evidence that there was an aerosol layer below 2.7 km a.s.l. and another aerosol layer above this altitude up to 5.5 km a.s.l.."

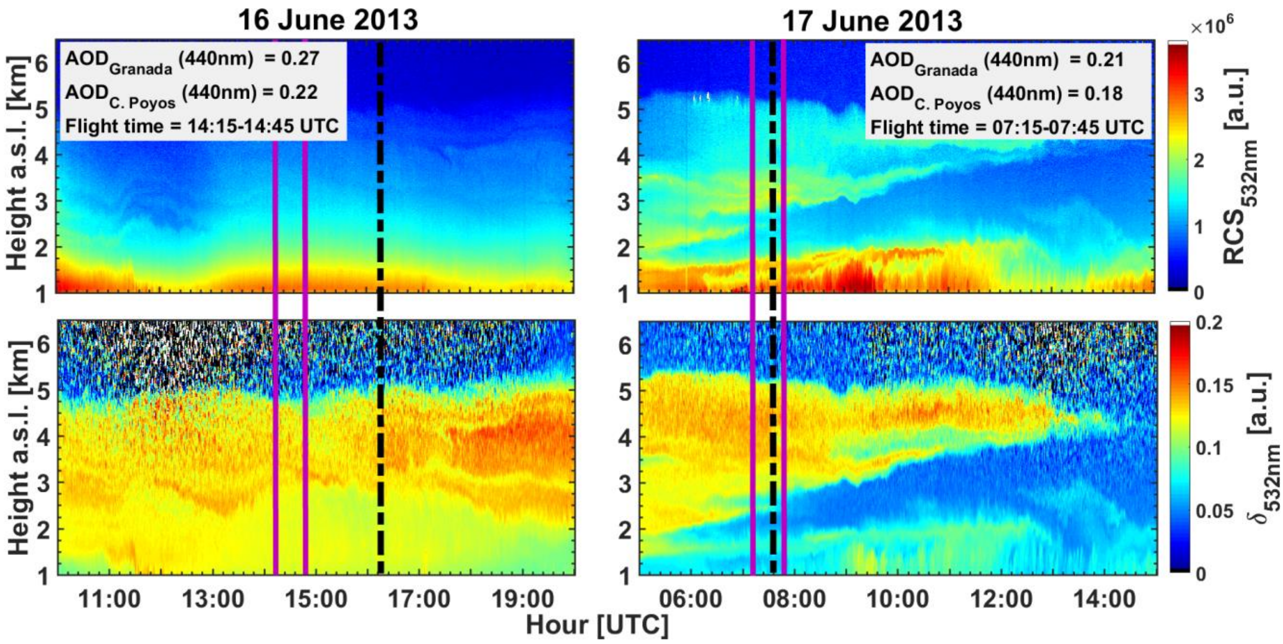

Figure 1. Temporal evolution of the lidar range corrected signal (top) and the depolarization ratio (bottom) at 532nm on 16th (left) and 17th (right) June, 2013. The two purple lines indicate the lidar analyzed interval. The black dashed line indicates the sun-photometer measurements.

Specific comments:

*Fig.3. In Granada imaginary part has spectral dependence typical for dust, while In Cerro Poyos no. Why? PSD look similar. Is it possible to provide vertical profile of imaginary part?

We thank the referee for this comment as we did not notice before. We added the following comment in the manuscript. For the moment, GRASP do not provide vertical profiles of refractive indices.

We add (section 4.1, page 7, line 28): At Cerro Poyos we did not find the spectral dependence of the IRI typically associated to mineral dust. The AOD at 440 nm were around 0.18 - 0.27 and we used AERONET level 1.5 products, therefore, these values have large uncertainties (> 50%; Dubovik et al., 2000). The lack of spectral dependence can be just an artifact of the inversion. However, it is worthy to note that at Cerro Poyos the PSD shows a mode in the coarse mode size range around 1 µm. As there is still discussion in the scientific community about dust RI and about the differences in dust particles between different sources (e.g. Colarco et al., 2014), results can suggest possible differences in dust RI between long range transported and mixture with local dust injections (the area is very dry in summer, thus favoring local mineral dust resuspension) and local pollution.

*Information about airplane measurements would be useful. Did it ascend by spiral? How much time did it take for one vertical profile?

During the CHARMEX campaign the flights ascended or descended performing a spiral trajectory during 30 min. We have added in Figure 2 the flight time for both days.

We add (section 2.3, page 5, line 1): These flights ascended or descended performing a spiral trajectory during 30 min.

*Fig.6, 17 June, Granada, 355 nm. Why Klett is not given for ~1.8 - 2.5 km? If it is 0, it still should be shown. Why Klett at 355 is not shown below 1.6 km while Grasp retrievals are given? The same questions are for Cerro Poyos.

On 17th June for this range at 355nm the values were 0. We changed the figures and now we show these values.

We add (section 4.2, page 9, line 17): Below 1.6 km, the Klett retrieval at 355 showed unrealistic values probably associated with instrumental problems. However, for GRASP this problem does not appear and seems to be canceled due to the use of the combined data of lidar and sun-photometer.

*References take about 50% of the text volume. Probably too much.

In the revised manuscript, we have reduced the number of references.