Interactive comment on "Overview of SLOPE I and II campaigns: aerosol properties retrieved with lidar and sun-sky photometer measurements" by Jose Antonio Benavent-Oltra et al.

Anonymous Referee #1 Received and published: 17 March 2021.

We would like to acknowledge the work done by the referee in the revision of our manuscript. We appreciate his/her effort and contributions to improve the quality of the paper. Our responses to the reviewer's comments are detailed below. Our answers to reviewer are shown in bold and the changes inserted in the manuscript are noted here in italic and between quotation marks. The changes in the new version of the manuscript are noted in blue.

Reviewer's comment

Author's response

Changes in the manuscript.

General comments:

This paper aims to provide an overview of the aerosol optical and microphysical properties during SLOPE I and II field campaigns in Granada using the GRASP remote sensing retrieval algorithm. GRASP retrievals were validated with in-situ measurements (with nephelometer, aethalometer, SMPS, CPC, and APS) performed at the Sierra Nevada Station and airborne flights (nephelometer, aethalometer). This study shows that GRASP retrieval algorithm can provide a valuable addition to the in-situ measurements and climate models.

The point-to-point responses to the Referee #1's comments are summarized below:

Abstract:

Line 20-22: Sentence needs rewording.

Following reviewer suggestion we have rewritten this sentence as follows:

(sect. Abstract, line 21-24): "The SLOPE I and II campaigns were developed along summer 2016 and 2017, respectively, combining active and passive remote sensing with in-situ measurements at the stations belonging to AGORA observatory (Andalusian Global ObseRvatory of the Atmosphere) in the Granada area (Spain)."

Line 35: "study the aerosol properties profiles" ? – This sentence needs rewording.

We have rewritten this sentence as follows:

(sect. Abstract, line 35-38): "Finally, desert dust and biomass burning events were chosen to show the high potential of GRASP to retrieve vertical profiles of aerosol properties (e.g., absorption coefficient and single scattering albedo) for different aerosol types."

Line 38: “simultaneous in situ measurements”. Please introduce the instruments here.

We add the instruments:

(sect. Abstract, line 39-40): “*… GRASP show good agreement with simultaneous in-situ measurements* (nephelometer, aethalometer, Scanning Mobility Particle Sizer and Aerodynamic Particle Sizer) *performed at Sierra Nevada Station …*”

Specific comments:

“In situ” or “in-situ”, please be consistent.

We use in-situ throughout the document.

Line 61: “while they have”

Corrected

Line 65: “provide information”, instead of “have information”:

Corrected

Line 114: “very variable” – without the world “very”:

Corrected

Line 149: “that operates”:

Corrected

Lines 160-161: “that performs…atmosphere” – needs rewording:

Following reviewer suggestion, we have rewritten this sentence as follows:

(sect. 2.1, line 168-169): “MWR is a passive remote sensor that performs unattended measurements of the temperature brightness of oxygen and water vapor in the atmosphere.”

Line 191: How about at 20 μm diameter?

The coincidence errors are provided by the manufacturer (TSI 2004; https://www.wmo-gaw-wcc-aerosol-physics.org/files/aps_3321.pdf) and they are only provided for diameters of 0.5 and 10 μm.

Line 193: For consistency purposes, can you stick on just radius or diameter?

We appreciate this comment and we have changed the diameters by radius along whole document.

Line 194: It would be nice to provide a brief explanation what Q value is.

Following reviewer suggestion, we have rewritten and added a brief explanation of Q value as follows:

(sect. 2.2, line 202-208): "Since SMPS and APS measurement principles are based on mobility and aerodynamic particles properties, conversion from aerodynamic to mobility diameter is needed to combine both measurements. In this sense, both measurements could be related by a factor Q (Sorribas et al., 2015) that depends on chemistry and aerosol shape. Due to the absence of information of both properties, Q-value=1 has been assumed for conversion from aerodynamic to mobility size distribution (mobility diameter equal to aerodynamic diameter)."

Line 208: "divide the sampled air" instead of "de":

Corrected

Line 225: From lidar? It would be nice to mention the instrument here.

We agree and include "from lidar" in the sentence:

(sect. 3.1, line 239): *"…corrected signal at 355, 532 and 1064 nm* from lidar*, the AOD and sky radiance…*"

Line 227: Is this a necessary condition to run GARRLiC?

There are different configurations to run GRASP/GARRLiC, however each configuration have different conditions to be run and this specific restriction is not applied to all configurations. In this sense, in this work we used the configuration proposed in Lopatin et al. (2013) with daytime lidar measurements, clear-sky conditions and solar zenith angles larger than 40º. However, there are different papers that run GRASP with different conditions (e.g., Benavent et al., 2019, Lopatin et al., 2021).

Line 240: "between minimum", without "a":

Corrected

Line 246: What does relative residual mean? What was its magnitude at the current case?

Relative residual mean is a parameter related with the differences between the measurements used as input and the same observations but derived from the retrieved aerosol scenario. This parameter is provided for each GRASP retrieval and it is useful to quantify the quality of the retrievals (Torres et al., 2017) since it gives information about the goodness of the retrieved aerosol properties to

reproduce the input measurements. In this work, we obtain different values for each retrieval, however we have only used the retrievals with a relative residual < 15%.

Line 255: “pressurized”:

Corrected

Line 258: What is the uncertainty on the measurements from using temperature obtained from MWR, instead of having a temperature sensor outside the aircraft?

The MWR uncertainty might have some variability according to the weather conditions (cloud-free or cloudy), ranging from 1.8 K to 3 K (Bedoya et al., 2019). These values were obtained during an intense campaign where radiosondes and MWR were compared. In this manuscript, we presented the MWR profiles since no other sensor was available on the airplane and also for taking advantage of the 24/7 operation of the instrument. We have added the following sentence:

(sect. 2.1, line 173-175): “The uncertainty of the MWR temperature profiles varies according to the weather conditions (cloud-free or cloudy), ranging between 1.8 K and 3 K (Bedoya et al., 2019)”

Line 295: Have you tried to run GRASP in 1-mode? A related paper to cite here is Kezoudi et al, 2020, where the authors used 1-mode size distribution ("We constrain the investigation in this study to one dust mode because the UCASS observations at Cyprus show a dominance of coarse-mode dust particles throughout the atmospheric column...").

As the reviewer indicates, there are cases when 1-mode configuration is used: (1) only sun-sky photometer measurements (e.g., Torres et al., 2017), (2) combining sun-sky photometer and only one lidar wavelength measurements (e.g., Román et al., 2018), (3) it knows beforehand the type of aerosols is predominant (e.g., Tsekeri et al., 2017, Kezoudi et al., 2020). However, the 2-mode configuration is recommended when combining sun photometer and multi wavelength lidar measurements (e.g., Lopatin et al., 2013). GRASP 2-mode configuration can discern between different aerosol modes in the vertical and it is able to provide vertical profiles of intensive aerosol properties such as single-scattering albedo or lidar ratio for fine and coarse mode. For all these reasons and that we do not know beforehand which type of aerosols is predominant for each retrieval, in this work, we only run GRASP in 2-mode configuration.

Line 323: Can you please elaborate on the purpose of the differences?

We appreciate this question because we have realized that these differences do not provide more information than that provided by the correlation coefficient (R=0.9) which shows the good agreement of the extinction coefficient between GRASP and in-situ measurements.

Line 369: You probably mean "Box-Whisker"?

Yes, we mean Box-Whisker and we have corrected it accordingly.

Line 375: "of non-absorbing particles"… e.g. dust

We have rewritten this sentence as follows:

(sect. 4.2.1, line 389-390): "These relatively large values of SSA for all wavelengths indicate a small concentration of absorbing aerosol particles (e.g., mineral dust)."

Line 380-382: Any reference for this?

We have added the following references that study the variability of absorption Angstrom exponent for different particle chemical compositions.

(sect. 4.2.1, line 396-397): " … *in AAE can be explained by the differences in particles chemical compositions* (e.g., Russell et al., 2010; Cazorla et al., 2013; Liu et al., 2018), … "

Line 389: that come from the Atlantic brings...

Corrected

Line 416: *patterns (plural):

Corrected

Line 420: How about the altitudes, any references?

Following reviewer suggestion, we have added the altitudes where the largest values are observed:

(sect. 4.2.2, line 436-437): "*… are observed* for the altitudes below 2 km a.s.l. *(40, 35 and 4 Mm^{-1} for α, σ_{sca} and σ_{abs}, respectively).*"

Line 425: *reveals:

Corrected

Line 426: Does this stand for all the aerosol types?

In this case we refer to the statistical overview median value of all aerosol types measured during SLOPE I and II campaigns.

Line 429: Please elaborate on that, give some threshold values for both.

AERONET classify the SSA as high-quality product only if it is retrieved under an AOD value at 440 nm above 0.4 (Dubovik et al., 2002; Sinyuk et al., 2020). We have shown good agreements between in-situ measurements and GRASP retrievals even for low aerosol loads. However, we consider this discussion is out of this section scope and following also referee 2 suggestion we have rewritten sentence L426-429 on the new manuscript version as:

(sect. 4.2.2, line 443-445): "Thus, GRASP retrievals show the capability of this code to characterizing aerosol absorption coefficients with vertical resolution, that it presents a step forward to aerosol characterization."

Line 430: What do you mean with "intensive" properties?

The extensive properties can be directly related to aerosol number concentrations whereas the intensive properties, which do not depend on aerosol amount, can determine the dominant particle size, type and shape (spherical and non-spherical).

Line 435: obtained from where? Here? In Muller et al?

We agree that this reference should come before and we have accordingly rewritten this sentence as follows:

(sect. 4.2.2, line 449): "*... on both chemical composition and particle shape* (Müller et al., 2007), *which explains the variability in the retrieved ....*"

Line 436: … to the ones observed…:

Corrected

Line 440: at these levels which are dominated…

Corrected

Line 439-442: Reword this sentence please, it is too big.

We agree and following reviewer suggestion we have rewritten these sentences as follows:

(sect. 4.2.2, line 454-457): "This pattern agrees with the assumption of higher anthropogenic aerosol loads at these altitudes which are dominated by fine mode particles. Furthermore, it agrees with the low mixture of transported mineral dust with anthropogenic pollution at altitudes above the atmospheric boundary layer top."

Line 446: *pollutants:

Corrected

Line 448: were occurred/observed, instead of "registered":

Corrected. We have changed it and we have also added "were occurred":

(sect. 4.2.3, line 463): "During the SLOPE I and II campaigns were occurred two extreme events with AOD_{440} ~ 1.0."

Line 457: *in the morning:

Corrected

Line 459: "in our region"? Do you mean in Europe? Spain? Granada?

In this case "our region" means in Granada area. We have changed it and we have added "…previously in Granada…" instead "…previously in our region…" as follows:

(sect. 4.2.3, line 474): "… *it has been observed* previously in Granada…".

Line 460: affect both the intensive…

Corrected

Line 464: *in the aerosol layer:

Corrected

Line 469: *as shown in Bevanent:

Corrected

Line 474: “very similar”, please provide some numbers.

We have realized that this phrase is incorrect because this sentence said the total scattering and really, we are talking about the scattering coefficient profiles. The aerosol optical depth values are higher than 0.4 but not similar. For this reason, we have removed this sentence from the document.

Line 477: “as expected for mineral dust particles”, any potential reason for that?

Mineral dust could present Fe oxidation states (as hematite, Fe_2O_3) with large absorptive properties, especially in the ultraviolet range compared to larger wavelengths (Liu et al., 2018). Valenzuela et al. (2012) show mean SSA values around 0.91 during desert dust events in Granada that indicate the absorption from mineral dust particles.

Line 478: *are supported:

Corrected

Line 501: “due to the few cases”, is this the reason? If there were more cases, then would the agreement be better?

We appreciate this question because we cannot confirm that the better agreement of coarse mode is due to the few cases with predominating fine particles. For this reason, we have added the following sentences:

(sect. 5, line 513-516): “The volume concentration comparison shows better agreement for coarse mode (R=0.83) than for fine and total modes. The range of values for fine mode is small due to the few cases (15 % of cases) with predominating fine particles, therefore, we cannot conclude the agreement of GRASP retrievals and in-situ measurements for fine mode.”

Line 506: *for both scattering:

Corrected

Line 521: *of these events:

Corrected

Figures:

Figure 1: It would be nice to show information about the altitude

We agree with the referee suggestion to show information of aircraft altitude. Therefore, we have decided to represent one of the flight trajectories during the SLOPE II campaign where the colored line indicates the altitude of the aircraft.

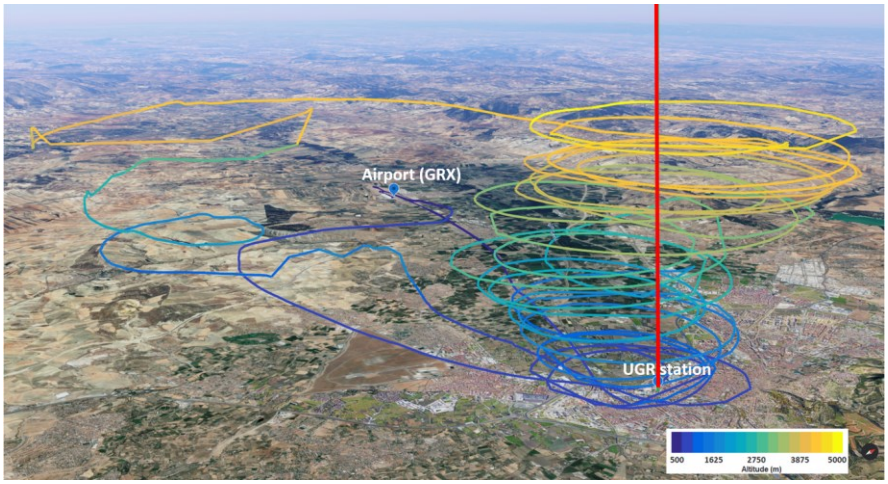

Figure 1.Map illustrating UGR station. The colored line indicates the trajectory of the aircraft and its altitude during the SLOPE II campaign. The red line indicates the vertical of lidar measurements. © Google Earth

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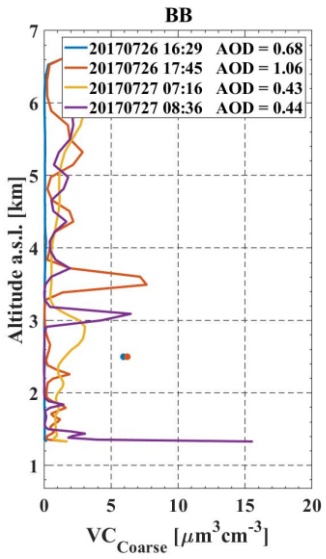
Figure 10b: The scale in x axis should be adjusted to the corresponding magnitude. This is too large and lines cannot be seen clearly.

We adjusted the scale in x axis of Figure 10b.



References:

Bedoya-Velásquez, A.E., Navas-Guzmán, F., de Arruda Moreira, G., Román, R., Cazorla, A., Ortiz-Amezcua, P., Benavent-Oltra, J.A., Alados-Arboledas, L., Olmo-Reyes, F.J., Foyo-Moreno, I., Montilla-Rosero, E., Hoyos, C.D., Guerrero-Rascado, J.L. Seasonal analysis of the atmosphere during five years by using microwave radiometry over a mid-latitude site. Atmospheric Research, 218, pp. 78-89, https://doi.org/10.1016/j.atmosres.2018.11.014, 2019.

Benavent-Oltra, J. A., et al.: Different strategies to retrieve aerosol properties at night-time with the GRASP algorithm, Atmos. Chem. Phys., 19, 14149–14171, https://doi.org/10.5194/acp-19-14149-2019, 2019.

Cazorla, A., Bahadur, R., Suski, K. J., Cahill, J. F., Chand, D., Schmid, B., Ramanathan, V., and Prather, K. A.: Relating aerosol absorption due to soot, organic carbon, and dust to emission sources determined from in-situ chemical measurements, Atmos. Chem. Phys., 13, 9337–9350, https://doi.org/10.5194/acp-13-9337-2013, 2013.

Dubovik, O., Holben, B., Eck, T., Smirnov, A., Kaufman, Y., King, M., Tanre, D., and Slutsker, I.: Variability of absorption and optical properties of key aerosol types observed in worldwide locations, J. Atmos. Sci., 59, 590–608, 2002.

Kezoudi, M., Tesche, M., Smith, H., Tsekeri, A., Baars, H., Dollner, M., Estellés, V., Weinzierl, B., Ulanowski, Z., Müller, D., and Amiridis, V.: Measurement report: Balloon-borne in-situ profiling of Saharan dust over Cyprus with the UCASS optical particle counter, Atmos. Chem. Phys. Discuss. [preprint], https://doi.org/10.5194/acp-2020-977, in review, 2020.

Liu, D., Taylor, J. W., Crosier, J., Marsden, N., Bower, K. N., Lloyd, G., Ryder, C. L., Brooke, J. K., Cotton, R., Marenco, F., Blyth, A., Cui, Z., Estelles, V., Gallagher, M., Coe, H. and Choularton, T. W.: Aircraft and ground measurements of dust aerosols over the west African coast in summer 2015 during ICE-D and AER-D, Atmos. Chem. Phys., 18(5), 3817–3838, doi:10.5194/acp-18-3817-2018, 2018.

Lopatin, A., et al.: Synergy processing of diverse ground-based remote sensing and in situ data using the GRASP algorithm: applications to radiometer, lidar and radiosonde observations, Atmos. Meas. Tech., 14, 2575–2614, https://doi.org/10.5194/amt-14-2575-2021, 2021.

Román, R., J. A. Benavent-Oltra, J. A. Casquero-Vera, A. Lopatin, A. Cazorla, H. Lyamani, C. Denjean, D. Fuertes, D. Pérez-Ramírez, B. Torres, C. Toledano, O. Dubovik, V. E. Cachorro, Á. de Frutos, F. J. Olmo, and L. Alados-Arboledas: Retrieval of aerosol profiles combining sun photometer and ceilometer measurements in GRASP code, Atmospheric Research, 204, 161–177, https://doi.org/10.1016/j.atmosres.2018.01.021, 2018.

Russell, P. B., Bergstrom, R. W., Shinozuka, Y., Clarke, A. D., DeCarlo, P. F., Jimenez, J. L., Livingston, J. M., Redemann, J., Dubovik, O., and Strawa, A.: Absorption Angstrom Exponent in AERONET and related data as an indicator of aerosol composition, Atmos. Chem. Phys., 10, 1155–1169, https://doi.org/10.5194/acp-10-1155-2010, 2010.

Sinyuk, A., Holben, B. N., Eck, T. F., Giles, D. M., Slutsker, I., Korkin, S., Schafer, J. S., Smirnov, A., Sorokin, M., and Lyapustin, A.: The AERONET Version 3 aerosol retrieval algorithm, associated uncertainties and comparisons to Version 2, Atmos. Meas. Tech., 13, 3375–3411, https://doi.org/10.5194/amt-13-3375-2020, 2020.

Sorribas, M., Olmo, F.J., Quirantes, A., Lyamani, H., Gil-Ojeda, M., Alados-Arboledas, L., Horvath, H.: Role of spheroidal particles in closure studies for aerosol microphysical-optical properties. Quarterly Journal of the Royal Meteorological Society. 141 - 692, pp. 2700 -2707, 2015.

Torres, B., Dubovik, O., Fuertes, D., Schuster, G., Cachorro, V. E., Lapyonok, T., Goloub, P., Blarel, L., Barreto, A., Mallet, M., Toledano, C., and Tanré, D.: Advanced characterisation of aerosol size properties from measurements of spectral optical depth using the GRASP algorithm, Atmos. Meas. Tech., 10, 3743-3781, https://doi.org/10.5194/amt-10-3743-2017, 2017.

Tsekeri, A., Lopatin, A., Amiridis, V., Marinou, E., Igloffstein, J., Siomos, N., Solomos, S., Kokkalis, P., Engelmann, R., Baars, H., Gratsea, M., Raptis, P. I., Binietoglou, I., Mihalopoulos, N., Kalivitis, N., Kouvarakis, G., Bartsotas, N., Kallos, G., Basart, S., Schuettemeyer, D., Wandinger, U., Ansmann, A., Chaikovsky, A. P., and Dubovik, O.: GARRLiC and LIRIC: strengths and limitations for the characterization of dust and marine particles along with their mixtures, Atmos. Meas. Tech., 10, 4995-5016, https://doi.org/10.5194/amt-10-4995-2017, 2017.

Valenzuela, A., Olmo, F.J., Lyamani, H., Antón, M., Quirantes, A., Alados- Arboledas, L.: Analysis of the desert dust radiative properties over Granada using principal plane sky radiances and spheroids retrieval procedure. Atmos. Res. 104–105, 292–301, https://doi.org/10.1016/j.atmosres.2011.11.005, 2012.