Review of “Combined sun-photometer/lidar inversion: lessons learned during the EARLINET/ACTRIS COVID-19 Campaign” by Tsekeri et al.

This article discusses the use of the GRASP/GARRLIC algorithm applied to lidar and AERONET Sun Photometer measurements acquired during May 2020 over Europe. These measurements, acquired by sensors in the ACTRIS network, were used to derive profiles of fine mode aerosol size distribution and concentration for selected cases that considered to be dominated by anthropogenic aerosols. The original intent of the paper was to monitor the spatial and temporal characteristics of anthropogenic aerosols during the COVID lockdown to study the impacts of this lockdown on these aerosol properties. However, the lack of suitable conditions and other constraints on the lidar measurements prevented the acquisition of sufficient data to address these objectives. Instead, the article focuses on the methodology used to implement the algorithm and the results of the retrievals for a few cases. The paper describes the selection of cases that to be dominated by anthropogenic aerosols, describes the lidar and Sun photometer that were selected and used in the retrieval algorithm, the retrieval algorithm methodology, comparison of retrieval results with other lidar and Sun photometer measurements/retrievals, and issues to be addressed in the use of the algorithm and the interpretation of the results. The paper is generally well written.

As stated above the paper focuses on the methodology of the GRASP/GARRLIC algorithm and the application of this algorithm to retrieving fine mode aerosol size distribution and profiles of fine mode aerosol concentration and the assumed to be anthropogenic. This intent was for this methodology to be application to data acquired by similar lidars and Sun photometers in this network. However, in practice, this methodology appears to have limitations that appear to restrict its use. More importantly, the actual implementation of the algorithm is not clearly presented as described in the comments below. I would not recommend publication until and unless the authors adequately address the comments below.

1. The paper indicates the purpose of the algorithm is to focus on the retrieval of fine mode anthropogenic aerosols. Line 159 indicates that cases with fine mode natural aerosols were filtered out and line 109 indicates that back trajectory and emission sensitivity analyses were used to *verify* the absence of fine mode dust or smoke particles. This word *verify* implies that other means, such as the lidar data, were the primary method used to identify and screen out natural aerosols. However, line 220 seems to indicate that these model simulations were the primary means to exclude natural aerosols. Therefore, it would be helpful to clarify exactly how the cases of anthropogenic aerosols were identified. Furthermore, section 3.1 indicates that the lidar depolarization measurements were used to screen out cases of dust aerosols. However, line 91 indicates that fine mode dust has low depolarization; if that is the case, how were cases with fine mode dust identified and removed? How were cases with fine mode aerosols produced by biomass burning (i.e., smoke) identified and

removed? Was it assumed that if the backtrajectories did not appear to come from regions of fires, that the aerosols were not comprised of smoke?

2. Section 3.4 indicates that a-priori knowledge in the form of smoothing constraints is required for these aerosol retrievals. Section 4.1 describes the optimization of the "setting" or smoothing parameters used by the GRASP/GARRLIC algorithm as well as the sensitivity of the algorithm to the initial guess of the input parameters. It is not clear how the initial guesses of the input parameters are determined; likewise, it is not clear how these smoothing constraints are determined and how the retrieval results depend on these smoothing constraints. What are the ranges of the parameters that are input? In addition, it appears that the "optimum" retrieval is selected from several acceptable solutions based on the least amount of smoothing and the absence of unphysical oscillations in the retrieved parameters. Since lines 276 sand 300 indicate that the latter criterion is based on a qualitative and subjective manner, it seem that this would make it difficult to implement over a network of lidars in a consistent manner. Also, if the acceptable solutions depend on the initial guesses, how does one know what range of initial guesses is acceptable, so that the solutions are acceptable? How does one separate the process of determining the appropriate smoothing parameters from the process of determining the appropriate range of the initial guesses of the input parameters?
3. Speaking of smoothing parameters, section 4.1.1 indicates that these smoothing parameters may vary for different atmospheric states. Why? It is also stated that a global optimum combination of setting parameters was not possible, due in part to the low (<0.15 fine mode AOD at 500 nm.) What is meant by different atmospheric states? Does this mean different AOD amounts? Different fine mode size distributions? Different fine mode aerosol compositions? This seems to relate to the initial guesses for the input parameters discussed above. How can a robust retrieval method be implemented if it depends on the atmospheric state?
4. Lines 311-333. Here it is stated that the information content in the lidar measurements is extremely low relative to the information content in the sky radiances from the Sun photometer so that the addition of the lidar data is not expected to have a strong impact on the derived aerosol microphysical properties. However, that is apparently contradicted by the statements in lines 380-384, which suggest that the difference in the retrieved effective radius compared to the standard AERONET retrievals is because of the higher information content in the lidar measurements, particularly at 355 nm. Has there been any study done to examine the extent to which the lidar measurements provide additional aerosol size distribution information above the sky radiance measurements?
5. Section 4.2 and Figure 10 discuss and show the use of the SCC backscatter and extinction profiles to help evaluate the corresponding profiles calculated from the GRASP/GARRLIC retrieved aerosol properties. Line 335 indicates that these SCC profiles were computed using a pre-defined lidar ratio characteristic for each scene. How was

this lidar ratio determined for each scene? What is the uncertainty in this lidar ratio and how would this uncertainty impact the use of these SCC profiles for evaluation of the GRASP/GARRLIC backscatter and extinction profiles?

Other Comments:

1. Line 63. "…comprised of thirty-three permanent…" instead of "…comprised by…"
2. Line 78. This discussion should be modified to indicate that ground-based lidar detection suffers from these overlap constraints. Airborne and satellite lidars do not have these problems when measuring near-surface aerosols.
3. Line 166. A laser repetition rate of 20 Hz is actually a low rep rate; there are lidars that use lasers with kHz rep rates.
4. Section 3.4 indicates that the retrieval output includes the columnar aerosol volume size distribution, and that the algorithm currently assumes a fixed atmospheric profile. It sounds like the fine mode (total?) aerosol size distribution (and aerosol composition?) are assumed to be constant with altitude. Is this correct? If so, this needs to be clearly stated. Were the lidar multiwavelength profile measurements of aerosol backscatter (and aerosol extinction if available) examined and used to identify cases that may satisfy this assumption? What is done to account for cases where the aerosol backscatter profiles increase with increased relative humidity causing a change in aerosol size but not necessarily concentration?
5. Related to the previous question, section 6.2 discusses the assumption of a homogeneous layer within the lidar overlap region. Since a significant fraction of the column aerosol optical thickness and concentration can reside in this region, this assumption should be mentioned earlier in the discussion.
6. Line 290 and Figure 3a. Should be rectangle instead of rectangular.
7. Line 388. It is suggested that the difference in the aerosol size distribution retrieved using the GRASP/GARRLIC method and the standard AERONET retrieval method may be due to an incorrect estimation of the molecular scattering contribution. Were different density models used to determine the sensitivity of the retrieved aerosol size distribution to the model density to test this hypothesis?
8. Line 339 is missing some references.
9. Line 400. The selection of suitable cases to combine the lidar and Sun Photometer measurements used spatial and temporal collocation criteria of maximum of 30 min and 1 km. These criteria appear inconsistent. Even with low (~3 m/s) wind speeds, one would expect aerosols to travel several kilometers during a 30-minute period.
10. Table 4 lists several different smoothing constraints including those for real and imaginary refractive index. Does the retrieval technique rely on a-priori assumptions of refractive indices, and if so, how are these determined?

11. Figure 5. What are the units for the parameters plotted on the x and y axes in each of these graphs?