

# ***Interactive comment on “Synergy processing of diverse ground-based remote sensing and in situ data using GRASP algorithm: applications to radiometer, lidar and radiosonde observations” by Anton Lopatin et al.***

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This paper is a comprehensive report of taking GRASP aerosol retrievals of lidar and lidar-like measurements to the next level. It had been previously established that GRASP retrieval software could be adapted to retrieve vertical aerosol properties when applied to simultaneous measurements of lidar and AERONET. These previous retrievals used the total column angular sky-scattering measurements and the total aerosol optical depth from AERONET to constrain the vertically-resolved backscattering lidar measurements. The present paper shows two things: 1) AERONET and lidar

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do not need to be coincident in time to produce viable retrievals. This allows nighttime lidar measurements to be inverted together with day time AERONET measurements. 2) There is sufficient information in the vertically-resolved measurements of spectral backscattering alone to produce reasonable retrievals in a simplified GRASP inversion. Furthermore, if the lidar is more complex with measurements of profiles of multi-wavelength backscattering and extinction with depolarization, and this is adequate to resolve complex aerosol layering in the atmosphere, even without benefit of AERONET measurements for constraint.

My overall assessment is that the study is worthwhile, even though i have concerns, and the paper eventually publishable. I have no need to remain anonymous. This is Lorraine Remer writing.

Length, organization and readability: Right now the manuscript is very long with over 40 figures. Each case is presented methodically, with repetitive description elements. This systematic approach in some ways keeps the presentation consistent and clear but reading it does become tedious. I'm not going to insist on a re-organization, but I am going to suggest considering alternative presentation ideas. Perhaps combining the plots of each case into a single 4-panel figure, so that you have one plot per case study: Figures 1,2 and 3 become a 4-panel figure 1; Figures 16 and 17 become another 4-panel figure; Figures 24, 25 and 26 become a 4-panel figure, and then maybe you don't also need Figure 27 and it can be eliminated. And so on.

But overall the writing is satisfactory, mostly the descriptions are clear and the English is fine. The figures are clear and informative.

Questions and concerns: 1. There is an underlying assumption necessary to use evening and morning (daylight) AERONET measurements with the middle-of-the-night COBALD measurements. That is, there is no change in aerosol properties from evening to morning (line 524). Then I look at Figure 1. How can that assumption be justified when the evening and morning AERONET size distributions have shifted a

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couple of microns to coarser particles over night? Not only has a dust event arrived over night, but the particles are different sizes. Do the refractive indices change also? Why aren't the AERONET values shown in Figure 3? Something similar happens in Figure 4. Maybe also in Figure 7. Not so much in Figure 13.

Exactly which parameters are constrained and which are free parameters to be retrieved? Is it just a temporal smoothing? I just don't see the assumption holding in some of these cases given the comparison of size distributions with AERONET.

I am not convinced that the assumption holds. It also bothers me that all three size distributions that include vertical profiles look alike in Figure 1, but do not look like either AERONET size distribution retrievals. The authors assume that the retrievals are accurately retrieving the aerosol properties and then describe the figures as though the "evening", "night" and "morning" retrieved properties are describing changes in the real aerosol that is happening overnight (lines 641 – 646). To me, I see no validation of this "multi-pixel" technique applied to these data when vertical profile measurements are not coincident with AERONET.

2. Is there MPL at night? Wouldn't it make sense to take baby steps? Joint retrievals of MPL and AERONET during the day. Non-simultaneous retrievals of MPL at night with AERONET morning and evening. Maybe at several times during the night. I would show this before I jumped in to do a non-simultaneous retrieval with a new instrument-data type (COBALD) that I could not compare with a simultaneous joint retrieval.

3. Figure 2, Figure 5, etc. Is there no lidar during night? Does it make sense to compare the COBALD multi-instrument retrieval with the same time lidar backscattering? That would help to validate what is going on here. Maybe the lidar at night would pick up that high altitude layer that the evening and morning miss. Right now it looks to me like a retrieval artifact.

4. Why do the size distributions in Figure 1 created with vertical profiles (MPL and COBALD both) look the same, but that AERONET alone does not? What is the verti-

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cal profile information doing to the retrieval that accentuates the coarser range of the coarse mode and diminishes the finer range of the coarse mode?

5. In the end, I am much more comfortable with the single instrument retrievals than I am with the non-simultaneous multi-instrument retrievals. It is somewhat surprising how well the unconstrained COBALD measurements perform, but not so surprising about the complex lidar. Still by combining instruments at different times you could be introducing more uncertainty than it is worth.

6. Still, all of the actual examples are in dust-dominated regimes. Before the authors conclude that all is well, they need a paragraph in their conclusion expressing that fine-mode dominated aerosols or multiple layers with different aerosols could pose problems. This is especially so since the retrieval was set up to constrain real and imaginary parts of the refractive index to be the same in the fine and coarse modes.

7. Table 2 needs to be more informative somehow. It needs to clarify which data sets are combined in retrieval to create what is termed “evening”, “night” and “morning” in the figures. For example, “night” involves both COBALD and the AERONET measurements. That is unclear in Table 2. This is really important because the paper is so long it will be read in multiple sittings. So by the time somebody is looking at the figures and results, they have forgotten how the retrievals are set up. There needs to be an easily referenceable table to pull it all together.

Minor comments

Page 2. Need references to describe the advanced lidars

Page 2. Need references to describe the “blind zone”.

Line 118. Contraction. “didn’t” and other places. Usually in formal journal articles we do not use contractions, but that is a stylistics thing with the journal. I use contractions all the time.

Line 249. “component” should be plural “components”

Lines 274-275. BRDF and BPDF need to be written out and/or defined

Line 276. Make sure Dubovik et al. 2020 is in the reference list. Right now I believe the citation refers to Dubovik et al. 2019 in the list.

Line 307. Insert “the” into “of THE retrieval”

Line 329. “could defined” needs to be either “could be defined” or “could define”

Line 471. “visible-IR” should be “visible-NIR”, but NIR needs to be defined some place as near infrared.

Line 471. “daily perform” should be “perform daily”

Line 473. Besides fixed elevation angle, if you include principal plane inversions, then you have to add “fixed azimuth angle”

Lines 630 – 633. I did not understand. Try saying, “Not shown here, but . . .” What is meant by “GRASP retrievals of only almucantar and TOD data do not demonstrate such difference”? Isn’t this what the AERONET green lines in the figure are? Is there something different between “GRASP retrievals of AERONET measurements” and AERONET retrievals as displayed in the figures?

Line 736. Strongly should be stronger.

Lines 912- - 915. I’m still unconvinced.

Line 1063. Figures range should be 24-36, not 23-35.

Line 1172 – 1173. Maybe because the multi-instrument retrieval introduces noise because assumptions are not being met.

Figure 38b. how much noise was introduced in the panel shown?

Lines 1235 – 1238. I think the authors mean “coarse spherical” not “coarse non-spherical” when they discuss the second most abundant aerosol type.

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