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Atmospheric Chemistry and Physics Discussions

Interactive comment on "A new method for deriving aerosol solar radiative forcing and its first application within MILAGRO/INTEX-B" *by* K. S. Schmidt et al.

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The reviewer's comments helped identifying inconsistencies in the manuscript. In addition, the reviewer pointed out similar shortcomings as reviewer #2. We will include suggested changes in the revised manuscript as detailed out below.

An important note about the definition of forcing efficiency: We define aerosol forcing efficiency as the forcing normalized by the optical thickness, i.e., RF/AOT, not dRF/dAOT. This distinction is important in understanding the gradient method by Redemann et al. [2006], and this manuscript. Redemann et al. uses the gradient of the net flux (F) under an aerosol gradient, dF/dAOT to derive the forcing efficiency.

(1) "p. 2751, section 20: "We introduced and tested a new method that allows for the simultaneous retrieval of . . . and aerosol forcing efficiencies". The RFEs are not retrieved, they are calculated using the retrieved parameters. Make the corresponding changes in a revised version (e.g., abstract and conclusions)."

We agree; reviewer #1 used the wording "derive" rather than "retrieve", and that's the wording we will use in the revised version. We will stress the fact that our method is not primarily focused on the retrieval of single scattering albedo and asymmetry parameter, but on the derivation of radiative forcing (efficiency) that is constrained by measurements.

(2) "p. 2751, section 20: "This method is useful when . . . (a) the gradient of AOT is too weak.." Similar statements are made throughout the text. How can the RFE be estimated for a homogeneous case (dAOT$\sim$0)? Should one calculate dRF as a function of dAOT assuming that other parameters are fixed? Take a "homogeneous" case from Table 1 and illustrate that."

The answer is related to the comment above (definition of forcing efficiency): All we need for a homogeneous layer is a collocated pair of downward/upward irradiances above and below the layer (that can either be from so-called flux divergence legs with collocated above- and below-layer legs, or a spiral through the layer). We then use our retrieval to get the values of single scattering albedo, asymmetry parameter and surface albedo that best match the four irradiance measurements, where the optical thickness is a necessary boundary condition. The forcing efficiency is then *calculated* by varying optical thickness in the model calculations (from the actual observed value down to zero, i.e., clear-sky conditions). The forcing efficiency is then the gradient dF/dAOT, where F is the net irradiance on top / bottom of the layer, and AOT is optical thickness. Indeed, this is not explained in the text of the manuscript and will be added in the revised version.

(3) "One can retrieve three parameters (SSA, ASP and ALB) using three observational

constraints (e.g., Fabs, F0dw, F1up). The authors retrieved four parameters (SSA, ASPup, ASPdw and ALB) using four observational constraints (Fabs, F0dw, F0up, F1up). Why? Explain selection of the observational constraints and the need for two independent retrievals (ASPup, ASPdw) of ASP."

Indeed, three constraints would be enough to retrieve the surface albedo, asymmetry parameter (ASY) and single scattering albedo (SSA). With four measurements, the problem is over-constrained. Usually the opposite is encountered in atmospheric remote sensing. We chose to retrieve a second value for ASY because that is usually the least well constrained from irradiance measurements and afflicted with the highest error bars. This turns out to be true when looking at Figure 5 where the spread is much larger for ASY than for SSA. We use the two different values for ASY as an indicator for the consistency of the retrieval. If the retrieval works, the two results for ASY should be similar, no matter if it is based on F_up above the layer or F_dn below the layer. A more systematic assessment of the error of the retrieved parameters as a function of the uncertainty in the irradiance measurements is given in the discussion for Figure 5 (Formula page 2743 defines the contour lines). The retrieval also works when minimizing the residual in the formula on page 2743. In this case, only *one* solution for ASY is obtained. However, minimizing the residual takes much longer than the iterative route we took. The error bars shown in, e.g., Figure 8, are all based on the contours as shown in Figure 5.

(4) "The following sentences are not consistent: p. 2734, section 5. “The aerosol single scattering albedo and asymmetry parameter are derived from the upward, downward, and net spectral irradiance above and below the layer by iteratively adjusting these two values in a radiative transfer model until the modeled irradiance converges to the measured irradiance . . ..” p. 2741, section 20. “Figure 4 shows a flow chart of the algorithm where single scattering albedo, asymmetry parameter, and surface albedo are iteratively adjusted until the modeled irradiance converges with the measured irradiance.” Add “surface albedo” in the first sentence and replace “two” with “three”."

We will do that in the revised version.

(5) " p. 2742, section 10. “Repeat loops 1-3 until the values of SSA, ASPup, ASPdw, ALB are stable.” How is “stable” defined?"

Currently, the convergence criterion is set as follows: abs(ssa_i+1 – ssa_i) < 0.001 and abs(asy_i+1 – asy_i) < 0.01. We will add that detail in the manuscript; we will also add indices (i) to denote the different steps in the iteration.

(6) "Figure 4 shows errors in the retrieved SSA, ASPup and ASPdw associated with the AOT uncertainties. Do these uncertainties impact the retrieved ALB? How sensitive are the retrieved parameters (SSA, ASPup, ASPdw and ALB) to uncertainties in the observed irradiances? Perform additional sensitivity tests (similar to Magi et al., 2008) and include corresponding plots (similar to Figure 4)."

Does the reviewer refer to Figure 5, not 4, when talking about the error bars? The uncertainties in the retrieved SSA and ASY do not directly impact the retrieved albedo. Rather, the irradiances with their associated uncertainties determine the error bars of the surface albedo retrieval, as well as ASY and SSA retrieval. Figure 5 shows the error bars of ASY and SSA only; similar plots could be shown for surface albedo. In this paper we chose not to focus on surface albedo; for detailed studies of the sensitivity of the surface albedo to aerosol properties, we referred to Coddington et al. [2007] in section 4. This publication was also based on MILAGRO measurements. There, we also show a sensitivity analysis with respect to the aerosol properties. Here, in this paper, a sensitivity analysis is not necessary because we get to the error bars directly from error propagation, based on the irradiance uncertainties and the contours discussed above. This is explained around Figure 6, and around the formula on page 2743.

On the other hand, we will add a discussion of the Magi et al. [2007 and 2008] papers because they are closely related with the subject of this paper; the first author was not aware of these publications yet. Their findings are also important for the final statement of this paper because they show that the top of layer forcing is close to zero for a large number of conditions.

Did the reviewer want us to include additional plots like Figure 5 (not 4), for surface albedo? That could be added to the manuscript, for example, by showing a 2D plot of residuals of ASY along with surface albedo.

Please let us know if this is what you meant, and we will revise the manuscript accordingly.

(7) "Figure 6 shows AERONET-derived SSA and time series of the retrieved SSA (new method). Add new plots (similar to Figure 6) with other retrieved parameters: AOT, ASP and ALB."

In fact, a time series of ASY is already shown (see Figure 7). We will add a time series of AOD per request of the reviewer.

(8) "The usage of subscript “0” is ambiguous. It specifies (1) irradiances below aerosol layer (e.g., page 2740, line 3 from the bottom) and (2) retrieved values of SSA, ASPup, ASPdw (e.g., page 2743, section 15 and page 2744, section 10). Use different subscripts for the radiative and optical properties."

We will do that, in addition to adding indices to denote the various steps in the iterative retrieval.

(9) "Figure 6 includes the AERONET-retrieved SSA at the Tamihua station. The same symbol (Tamihua AERONET) is applied for two different latitudes. Why?"

The Tamihua station is further west than shown in the plot. The offset was introduced for better legibility (this is explained in the Figure legend, but ambiguously). We will remove the Tamihua station altogether because it is too far away from the aircraft at the time of the retrieval to allow for a comparison.

(10) "Figure 8 has two panels. The right panel is very busy. Modify it. A modified

version of Figure 8 could include three panels."

We agree – the size got diminished by the ACPD formatting. We will try to push for a 1 letter / A4 page representation in the ACP version of this Figure (twice as large as currently displayed). If we cannot do that, we will break up the Figure as suggested by both reviewers.

(11) "Table 1 is not complete. A revised version should include other useful statistics, such as the retrieved ALB, dAOT, distance, uncertainties of retrieved parameters (SSA, ASP, ALB) and RFE. As an example, the authors can use Table 1 from Redemann et al. (2006)."

We will add error bars to the table. Adding additional information as in Redemann et al. [2006] such as distance, dAOT only makes sense for the gradient method. To save space, we will give more information in the text, where applicable. Note that error bars / ranges were given in the spectra in Figure 8.

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