Atmos. Chem. Phys. Discuss., 11, C4245–C4251, 2011
www.atmos-chem-phys-discuss.net/11/C4245/2011/

Atmospheric Chemistry and Physics Discussions

Interactive comment on "Simultaneous retrieval of aerosol and cloud properties during the MILAGRO field campaign" *by* K. Knobelspiesse et al.

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Received and published: 3 June 2011

I sincerely appreciate your efforts to review this paper.

My response to specific comments follows, where the reviewer comment is in quotes.

"The initial values of the cloud distribution are determined by using a lookup table (LUT). Using the single scattering approximation, the polarized reïňĆectance Q is directly obtained from the single scattering proper ties. The measured Q is then matched to the LUT in order to ïňĄnd initial cloud size distribution parameters. The authors claim that the polarized cloud reïňĆectance is insensitive to multiple scattering as a justiïňĄcation for this procedure. This is not true, polarized reïňĆectance is less sensitive to multiple scattering than total intensity (as it is also stated in Goloub et al. 2000), but

still multiple scattering can not be neglected for clouds. Why is the single scattering approximation used to generate the LUT? I guess it would not take much effort to use the multiple scattering doubling and adding code to generate it and this would yield more accurate initial values."

As I reread Goloub et al 2000, I realize that they did not use the word "insensitive" like I did. So I corrected the manuscript to reflect that polarized reflectance is sensitive to multiple scattering, but to a much smaller degree than total reflectance. I believe that multiple scattering can indeed be used to determine the initial guess in an optimization for optical properties of cloud droplets using polarization. I use the approach described in Goloub's equation 4. These single scattering computations were only used to determine the initial value of cloud size distribution parameters prior to optimization, and yes, they were used to simplify the methodology of the paper. Cloud optical properties in the final result were determined using full multiple scattering. Indeed, the change between initial values and final result (6.25 to 6.82 for effective radius, 0.075 to 0.028 for effective variance) are small enough to indicate that multiple scattering has a minimal effect. I also suspect that multiple scattering will modify the observed reflectance gradually as scattering angle changes, while the location and width of the rainbow will not be significantly altered. This was one of the reasons I removed the low angular frequency trend before determining the initial cloud size parameters, and is further justification for the use of single scattering properties to determine initial conditions.

One additional piece of evidence I'm attaching is a figure from a colleague of mine, Mikhail Alexandrov. Alexandrov, along with Brian Cairns, Claudia Emde, Bastiaan van Diedenhoven and Andrew Ackerman is preparing a manuscript called "Characterization of cloud droplet size distributions based on polarized reflectance measurements by the Research Scanning Polarimeter: Sensitivity Study". He plotted the possibility of retrieving cloud droplet size parameters using single scattering phase functions. The attached figures show the relationship between these retrieved parameters for simulations including cloud multiple scattering. As you can see, the retrieved values of both effective radius and variance are nearly identical to the originally simulated values.

[please see attached figures]

"On p. 6382 the authors state that the modelled Q is generally lower than the measured Q. Is Q modelled here using multiple scattering? If the single scattering approximation is used, this could explain the deviation."

Q is modeled using multiple scattering. I believe this deviation is related to either multiple scattering effects, or the use of our simplistic description of the cloud size distribution.

"How are the cloud scattering phase matrices treated in the doubling-and-adding radiative transfer code? The phase matrix needs to be expanded in a Legendre series with thousands of terms to accurately represent the forward scattering peak and features like the cloud bow. Accurate calculations would be computationally too expensive to be used in an optimal estimation type retrieval. The authors should clearly state which approximations are made in the radiative transfer calculations."

The scattering phase matrices are calculated on an angular grid (not directly as a Legendre or a generalized spherical function series since the calculations as a function of angle are more efficient (cf. discussion in W. A. de Rooij and C. C. A. H. van der Stap, “Expansion of Mie scattering matrices in generalized spherical functions,” Astron. Astrophys. 131, 237–248, 1984.) The angular resolution of the calculations is 0.2° within 5° of forward and backscatter. Tests of required angular resolution have been run with uniform 0.2° resolution and varying angular resolution over the side scattering angular range and it was found that for the RSP data angular resolution of 0.5° at side scattering angles is adequate. RSP has a 14 mrad Instantaneous Field Of View with 14 mrad drag smear giving an apodized view of 1.6° full width and 0.8° full width at half maximum. We believe this method is sufficient for cloud droplets.

The phase function is then renormalized for the multiple scattering calculations. It was

found comparing calculations with 120 quadrature points (for which resolution errors are reduced to a maximum of order ~1E-6) and no renormalization against those with renormalization that the accuracy of the renormalized calculation had reached its minimum for 30 quadrature points and that the error against the exact calculations caused by renormalization was ~0.1%. For cloud scenes, the number of quadrature points required to keep modeling errors below observational errors required the use of nearly three times as many points. The increase in number of quadrature points corresponds to a significant increase in computing time. That said, I was still able to perform these calculations on my 2.4 Ghz Intel Core 2 Duo Mac laptop without problems. Creating an operationally ready algorithm was not the intent of this paper, but doing so would involve putting some effort into optimizing the software for speed, and the use of much faster machines. Considering the narrow swath (and thus much more limited data stream) of an orbital scanning polarimeter, an algorithm fast enough for operational purposes is probably feasible.

"Size distributions should be speciïňAęed more precisely (e.g. radius grid resolution and cutoff-values used for Mie calculations) "

The size grid can be adjusted and for these calculations the size range is 0-20 μm with a grid spacing of 1.5625E-4μm. The range is chosen to ensure that 99.99% of the size distribution is included in the calculation. This information was added to the text.

Technical corrections:

Thank you for identifying these errors, which I have modified accordingly in my manuscript.

Other changes:

1. Equation 8 had a typo: the error covariance matrix, CT should have an inverse sign above it. This was corrected.

2. There were many references to the launch of APS. Many references to this launch

were changed to reflect the unfortunate spacecraft launch failure.

3. Figure 3 was updated to include a more accurate calculation of the aerosol extinction coefficient.

Interactive comment on Atmos. Chem. Phys. Discuss., 11, 6363, 2011.

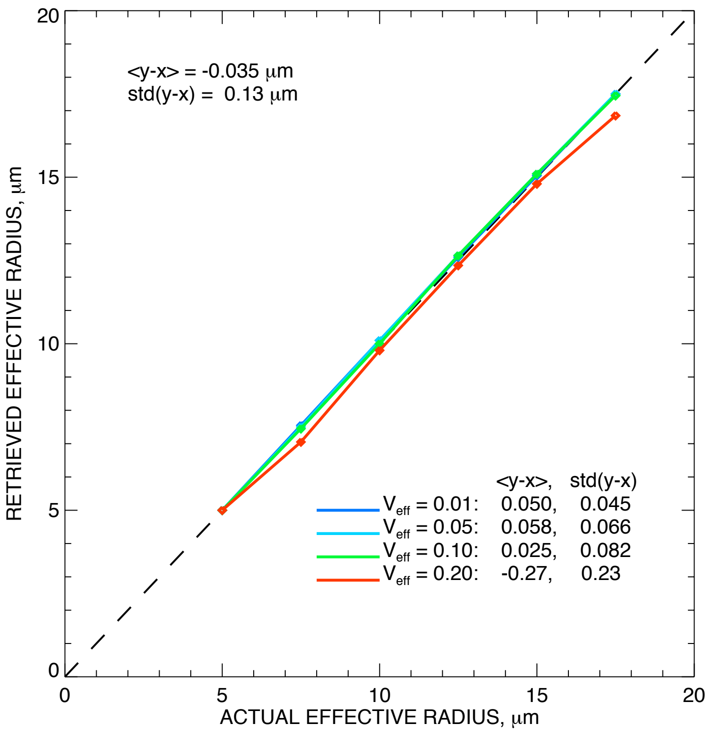
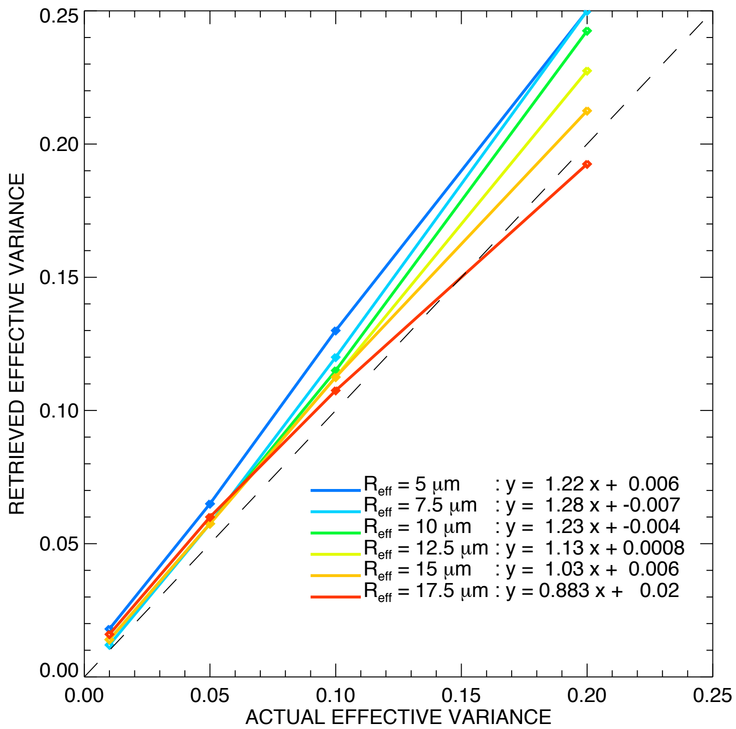


Fig. 1.



0.25
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0.10
0.05
0.00
0.00
0.05
0.10
0.15
0.20
0.25
RETRIEVED EFFECTIVE VARIANCE
ACTUAL EFFECTIVE VARIANCE
R_{eff} = 5 μm : y = 1.22 x + 0.006
R_{eff} = 7.5 μm : y = 1.28 x + -0.007
R_{eff} = 10 μm : y = 1.23 x + -0.004
R_{eff} = 12.5 μm : y = 1.13 x + 0.0008
R_{eff} = 15 μm : y = 1.03 x + 0.006
R_{eff} = 17.5 μm : y = 0.883 x + 0.02

Fig. 2.