Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-413-RC3, 2018

Atmospheric Measurement Techniques Discussions
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Interactive comment

Interactive comment on "Cloud heterogeneity effects on cloud and aerosol above cloud properties retrieved from simulated total and polarized reflectances" *by* Céline Cornet et al.

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Received and published: 4 February 2018

Review on "Cloud heterogeneity effects on cloud and aerosol above cloud properties retrieved from simulated total and polarized reflectances" by Céline Cornet et al.

Summary: This paper presents a hypothetical study of how 3D radiative transfer effects influence the retrieval of cloud properties and above-cloud aerosol properties based on the multi-angular polarimetric observations. The study starts with forward radiative transfer simulations of POLDER observations for synthetic scenes with absorbing aerosols overlying fractal clouds. Then the simulated radiance and polarization observations are given to a retrieval-simulator to retrieve cloud properties and above-cloud

aerosol properties. Note that in the forward radiative transfer simulations are based on 3-D radiative transfer model, while the retrieval processes are based on the 1-D radiative transfer theory. Therefore, the differences between the retrieval results and the original clouds/aerosols properties reflect the influences of 3-D radiative effects on the retrievals. The results indicate that the microphysics of clouds are less sensitive to the 3-D effects, while other clouds and aerosol properties are more susceptible to 3-D effects.

The topic of this paper is suitable for AMT. The paper is the first one, as far as a I know, to discuss the impacts of 3-D effect on above-cloud aerosol property retrievals. In this regard, it is very important. However, I feel that the current version needs significant improvements before it can be accepted for publication. My major comments and suggestions are listed below.

Major comments/suggestions: " From my perspective, the largest contribution of this paper is that it advances our understanding of how 3D effects influence the retrieval of polarimetric based remote sensing of above-cloud aerosols. However, there is almost no mention about above-cloud aerosols, e.g., their occurrence frequency, global distribution, climate importance, remote sensing methods to retrieve their properties. The background information on above-cloud aerosols is important for the readers to appreciate the importance of this paper. By now, there is a significant volume of literature on this topic, for example, Chand et al. (2009); Zhang et al. (2016);

" In this study, the radiative transfer simulations are done at very high spatial resolution, 50 m. although the results are averaged to 7km to "mimic the radiometer measurements and applied the POLDER operational algorithm". Only retrievals at the 7km are presented and analyzed. The reason for the spatial average understandable. But the high-resolution radiative transfer and retrieval results (if any) should also be presented and analyzed for a couple of important reasons. First of all, the 3-D effects are highly dependent on the spatial scale. At small scale (e.g., 50m) the violation of independent pixel approximation (i.e., smoothing, illuminating and shadowing effects) is more important, while at coarser resolution (e.g., 7km) the plane-parallel bias is more important, as pointed out in many previous studies including Zhang et al. (2012). Therefore, the high-resolution results, in combination with the low-resolution results, are very important for us to gain a comprehensive understanding of the problem. Second, the high-resolution results are very relevant to air-borne instruments, such as RSP and HARP. These instruments have been employed in the recent ORACLES field campaign. These air-borne instruments have spatial resolution on the order of 100m. So the results in this paper are highly relevant. Therefore, I strongly suggest the authors add some results and discussion on the high-resolution radiative transfer and retrieval results.

" This paper focuses on the polarimetric remote sensing technique. But it is somewhat disappointing that there is no discussion on the spectral methods for above-cloud aerosol retrievals (e.g., Jethva et al. 2013 and Meyer et al. 2015). As far as I understand, the radiative transfer and retrieval framework used in this study can be easily extended to the spectral method. I'd encourage the authors to take this opportunity to look into the 3-D effects on spectral based above-cloud aerosol retrievals. But I will leave this to the authors to decide whether they will do this in this study or future work.

" What is not clear from the current paper is how much the retrieval error is due to the 3D effects and how much is due to retrieval algorithm uncertainty. For example, POLDER has a coarse angular resolution and it seems to me this is partly the reason why the above cloud AOD retrieval error is large in Table 3. Also, in the retrieval process based on the Waquet et al. (2013), how much a priori information is given to the retrieval algorithm? Does the retrieval algorithm know, for example, the single scattering albedo of the above-cloud aerosol at each wavelength? In reality, the algorithm certainly does NOT know the aerosol properties. Some discussions are needed to clarify how aerosols are treated in the Waquet et al. (2013) retrieval algorithm and justify the treatment.

" Related to the last point, the AOD retrieval error could be put into a more meaningful context. For example, what is the relative error in AOD retrieval if the assumption of single-scattering albedo of aerosols is wrong in the retrieval algorithm? How is this error compared with the 3-D effects? Such comparison will help us understand the relative importance of 3-D effects in comparison with some other error sources in the retrieval. âĂČ Chand, D., R. Wood, T. L. Anderson, S. K. Satheesh, and R. J. Charlson (2009), Satellite-derived direct radiative effect of aerosols dependent on cloud cover, Nature Geoscience, 2(3), 181-184, doi:10.1038/ngeo437.

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