Atmos. Meas. Tech. Discuss.,
doi:10.5194/amt-2017-325-RC2, 2017

Atmospheric Measurement Techniques Discussions

Interactive comment on "Comparisons of bispectral and polarimetric cloud microphysical retrievals using LES-Satellite retrieval simulator" *by* Daniel J. Miller et al.

Anonymous Referee #2

Received and published: 27 November 2017

This is a review of the manuscript titled "Comparisons of bispectral and polarimetric cloud microphysical retrievals using LES-Satellite retrieval simulator" submitted to AMTD by Miller et al.

The paper discusses the biases in retrieved drop effective radius and cloud optical thickness using two independent approaches, namely the bi-spectral approach and the polarimetric approach. Both methods are evaluated using simulated measurements based on large eddy simulations and 2D radiative transfer. Biases in retrieval products caused by vertical and horizontal inhomogeneity are evaluated.

The work follows previous work by the same authors, especially that published in Miller

et al. (2016) and Zhang et al. (2012). Those previous papers lacked the focus on polarimetric retrievals, so this paper is a useful addition to those studies. The polarimetric method is the more robust method, as also shown here, but requires multi-view polarization measurements at specific viewing geometries, which makes it not applicable everywhere. The polarimetric method is often seen as a means to validate the bi-spectral retrievals. Therefore, this comparison of the two methods is useful to better understand such comparisons.

However, in my opinion, some of the means of presentation are difficult to interpret and not very effective. Also, while focus is on the effective radius retrievals, the optical thickness retrievals are also evaluated, but some rather surprising outliers in the optical thickness retrievals are not explained. Finally, the authors should provide more references in the results section to put their results in perspective to other relevant papers. Below I will provide more details to these major comments and will follow with some minor comments

Major comments:

1) The conclusions about polarimetric and bi-spectral retrievals are not new. As mentioned in the paper, the bispectral method is already well studied by several papers, including Miller et al. (2016) and Zhang et al. (2012). The polarimetric results are consistent with those by, for example, Alexandrov et al. (2012) and Shang et al. (2015). All of the papers mentioned above are referenced in the manuscript, but mostly in the introduction or conclusions. The authors should provide more references in the results section and put their results in perspective to the 4 papers mentioned above, and other relevant papers. For example, the reduced sensitivity of effective variance at high values, the effects of vertical variation and insensitivity of the approach to optical thickness are all discussed by Alexandrov et al. (2012). The sensitivity to sub-pixel inhomogeneity in the polarimetric approach is discussed by Shang et al. (2015). Retrieval biases in the bi-spectral approach is discussed by Miller et al. Specifically, Miller et al. conclude that biases are especially large in "transition zone" at the cloud edges. I

find it surprising that this is not mentioned here at al. In summary, when discussing the results, please also discuss the appropriate references to set these results in context with these previous studies.

2) The optical thickness retrievals are also evaluated in this study, but hardly discussed. I find it rather surprising that even at large optical depths, large biases occasionally occur. As mentioned, the optical depth retrievals are similarly biased using the polarimetry size retrievals. Looking at equation 4, I am curious what could cause these optical depth biases if not errors in assumed size distribution? It would be informative to further explore this bias in the paper.

3) In figure 5, the effect of the fixed variance of 0.1 on the bispectral retrievals are evaluated. This is done by coupling the bispectral retrievals to the variance retrieved with the polarimetric approach. However, you showed that this retrieved variance often significantly differs from the true value. It performs best in the case around a value of 0.1, which is the value assumed for the bispectral method. So, in this test, often still a 'wrong' variance is used. It is difficult, if not impossible, to deduce solid conclusions from the present results. The authors should couple the bispectral retrievals to the true (2WT) value of variance for each gridbox for this evaluation.

4) Figure 8 convolves a lot of information and is therefore hard to interpret. The aim is to show the effect of pixel size and inhomogeneity on the bi-spectral and polarimetric technique. Here the two methods are compared, making it impossible to tell which technique is biased where and how. The authors concluded that "it is evident that as the spatial retrieval footprint reaches 800 m the sub-pixel inhomogeneity tends to increase and the re(2.13 μm) retrieval suffers from an increasingly high bias relative to the polarimetric retrieval." I do not get this from looking at this figure. Using the colors and open circles of different sizes produces a pretty colorful blob, but individual circles are impossible to spot mostly. I see some large circles with high biases, but have the impression that most are hiding in the colorful blob. The conclusions and abstract state that the methods compare well for high resolutions, but biases appear

at coarser resolution. This conclusion appears to be based on this figure. Looking at figure 5, I see some very large differences between the methods for some cases, so the bispectral method also has issues at these fine resolutions, if not more. Also, the abstract and conclusion states "This bias largely stems from differences related to sensitivity of the two retrievals to unresolved inhomogeneities in effective variance and optical thickness." This suggests that the polarimetric retrievals also have sensitivity to the spatial resolution. They probably have somewhat (as concluded by Shang et al.), but this is not at all evident from this figure and analysis. Please produce figures that more clearly and systematically support these conclusions (or other conclusions). I suggest producing separate plots showing biases from true effective radius values in bi-spectral and polarimetric techniques as a function of H. Possibly the resolution can be on the y-axis and biases can be color coded?

Minor comments:

In figure 3, the cases with tau<3 are removed, revealing a better result. However, I am wondering how the 2D histogram for tau<3 looks like. Do the bulk of these retrievals still perform well, or are they all biased? That is not clear from these plots.

Figure 4 shows that the uncertainty in the retrievals of effective variance is rather high. Firstly, please relate your findings with those found by Alexandrov et al. (2012). Secondly, please discuss the appropriateness of the assumption of a gamma distribution for these LES fields. Is the model producing size distributions that can be well described by a gamma distribution? If not, this could explain part of the spread found in your results. Also, please discuss the possibility of non-parametric size distributions from polarimetry, as presented by Alexandrov et al. (2012; J. Quant. Spectrosc. Radiat. Transfer, 113, 2521-2535, doi:10.1016/j.jqsrt.2012.03.025.)

Figure 9 shows the variation in polarization measurements for sub-pixels in a 800m pixel. For the case including the thin cloud parts, there appears to be a substantial spread, but this is mostly in absolute magnitude. Please note in the text that the polarimetry technique is not sensitive to the absolute magnitude of the measurements, and these variations are therefore not an issue for this technique.

Text edits:

Page 2, line 9: add “which” before “simultaneously” Page 2, line 13: Add “Suomi” in front of “National” (and NPP)

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