Atmospheric Chemistry and Physics Discussions

Atmos. Chem. Phys. Discuss., referee comment RC2
https://doi.org/10.5194/acp-2022-73-RC2, 2022

Comment on acp-2022-73

Anonymous Referee #2

Referee comment on "An evaluation of the liquid cloud droplet effective radius derived from MODIS, airborne remote sensing, and in situ measurements from CAMP^{2}Ex" by Dongwei Fu et al., Atmos. Chem. Phys. Discuss., https://doi.org/10.5194/acp-2022-73-RC2, 2022

The manuscript documents the validation of MODIS cloud droplet effective radius (Re) during CAMP2eX using in-situ and remotely sensed data. This work is highly relevant as assessments of satellite retrievals for shallow cumulus clouds, where clouds tend to be small and precipitation is frequent, are scarce. While the expectation is that satellite Re significantly departs from observations, having data to support this assertion is essential. This is why Fu et al. is a key study to understand the limitations of MODIS-like retrievals and the implications for climate studies. The authors had to circumvent multiple issues associated with the fact that the sampling strategy was not designed for validating satellite retrievals of cloud properties. I commend the efforts of the authors and the attempts to understand the satellite positive biases. Given the lack of data collocation, the authors mainly report biases, whereas spatial correlations and co-variability are difficult to compute with the CAMP2EX dataset.

While the main message is straightforward and the discussion easy to understand, the number of figures is excessive, making the manuscript a bit difficult to follow. I am providing below a number of suggestions to help polish a few sections and make the manuscript more concise.

- 4, 6, 8, 10: The inclusion of multiple panel figures is repetitive and the information conveyed is quite similar. What matters is: a) clouds have small sizes, precipitation was frequently observed (contrary to what is stated in the manuscript), and MODIS Re is overestimated. I find it particularly hard to understand the excessive interest in cloud top height. From a remote sensing perspective, as long as the focus in on boundary layer clouds, CTH does not matter. The only reason to justify the use of CTH is for exploring the cloud topography and the associated 3D radiative effects. Because no directs comparisons are made between RSP/insitu data and MODIS, my suggestion would be to include PDF for Re, optical depth, radar reflectivity (more below). To

convey information about cloud coverage, one could easily compute cloud fraction from the HSRL using, for instance, 30s segments and this new parameter can be depicted in a PDF. MODIS Re maps are informative so the authors should consider keeping them. In sum, 4 multi-panel figures can be combined into only one: an upper panel for the MODIS maps, and a lower panel with multiple PDFs for each RF.

- Bi-spectral RSP Re is not the same as MODIS. I understand why the authors are using the Bi-spectral RSP retrievals, but they need to keep in mind: 1) at the RSP footprint size, 3D radiative transfer effects are going to be substantial, 2) On the other hand, clear-sky (cloud free) contamination is going to be a much bigger problem for MODIS than RSP, so it is not correct to assume that absolute uncertainties/biases derived from RSP are representative of MODIS, 3) viewing geometry are quite different (see comment #4)
- 7-um Re: It has been shown in several studies that Re derived from the 3.7-um channel is less sensitive to spatial inhomogeneities and 3D radiative effects. Moreover the vertical photon penetration is confined to the uppermost cloud layer with optical depth of 2 or less. 3.7-um Re is also adopted by CERES for deriving radiative fluxes product. Given the increasing use of the 3.7um Re, I would like to encourage the authors to take a look at this product.
- My understanding from Liang et al. and Fu et al. is that the Re correction is for removing the odd behavior of the retrievals near the rainbow. In other words, the correction only applies to satellite scattering angles around 138Ë□-140Ë□. If so, information about satellite scattering angle should be provided. Is it possibly that the bias in MODIS is primarily explained by the rainbow effect? Similarly, if angles around 140Ë□ are observed by Terra MODIS, I am wondering whether Aqua angles differ from Terra. If so, then Aqua Re < Terra Re…possibly, the diurnal cycle of clouds plays a roles…but it would be interesting to investigate Re differences in terms of scattering angle. In any case, the readers need more information about the correction method and why the method is applicable to CAMP2EX.
- Cloud top height (CTH): I cannot understand the rationale for performing the analysis as a function of CTH. I find Fig. 5,7,9, and 11 somewhat misleading because the remote sensors don't retrieve vertical profiles as retrieved cloud properties are representative of those near the cloud top. Moreover, equating remote sensing samples (derived from clouds with different top heights) with the cloud vertical profile is problematic, especially for precipitating shallow cumulus clouds. Another pitfall of the method is that MODIS CTH is likely biased.
- Precipitation: A threshold of 0dBz for precipitation detection is too high (Comstock et al., 2004 (https://doi.org/10.1256/qj.03.187). If the goal is to determine the effect of the bimodal distribution on the satellite retrievals, then, instead of using the maximum reflectivity of the column, one should limit the analysis to the upper cloud layer (e.g. a 100-m layer from the cloud top).
- Cloud fraction: I speculate that the effect of cloud fraction (clear-sky contamination) on MODIS retrievals is substantial. One could test this hypothesis by estimating cloud fraction using ASTER or the 250m MODIS visible channel.

Other comments:

- Line 460-461: From Fig 4, I could not see any correlation between "drizzle" and larger

Re.

- Lines 628-629. While I need to read Miller et al., the same factors could also yield underestimations of Re.
- Line 657: I don't find Fig. 2c a convincing validation of RSP CTH, especially for boundary layer clouds.
- Line 707: Is the rainbow angle in the backscatter direction? If so, then RSP retrievals are always sampled at the backscatter direction. This means that the expected behavior is an underestimation of particle size (illumination effect).
- Line 771-772. Overestimation are only observed for high SZA, otherwise, optical depth is underestimated. Please revise the sentence.
- Figure 15: I see a relationship between delta Re and COT, but no relationship can be observed between transect length and delta Re or COT (Fig. 15 b and c). Does the y-axis of Fig. 15 represent optical depth?