Atmospheric Measurement Techniques Discussions

Atmos. Meas. Tech. Discuss., referee comment RC2
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Comment on amt-2021-7

Anonymous Referee #2

Referee comment on "Evaluation of satellite retrievals of liquid clouds from the GOES-13 imager and MODIS over the midlatitude North Atlantic during the NAAMES campaign" by David Painemal et al., Atmos. Meas. Tech. Discuss., https://doi.org/10.5194/amt-2021-7-RC2, 2021

This paper presents a comparison of satellite derived cloud optical thickness (tau) and droplet effective radius (re) for liquid clouds using airborne in situ observations and remote sensing retrievals obtained during NASA's NAAMES field campaign (2015-2017). Specifically, Terra and Aqua MODIS tau and re retrievals from the CERES Edition 4 algorithms, and similar GOES-13 retrievals from their SatCORPS algorithm counterparts, are compared against re derived from droplet size distributions measured by the CDP cloud probe and re and tau retrieved from the RSP polarimeter (re from polarimetric observations, tau from NIR reflectance). The comparisons show that the satellite retrievals of re are larger than those obtained from both the CDP and RSP, with GOES-13 having the largest differences; comparisons of tau show better agreement. Biases in both re and tau are further investigated as a function of scene heterogeneity and viewing/scattering angles as possible explanations of the differences.

The paper is really well written – clear, concise, and easy to comprehend. The methodology is sound, and I think it will be a good addition to the body of literature on evaluating satellite cloud optical/microphysical retrievals using airborne observations. My comments are mostly on the discussion of the comparisons and potential causes of disagreement, which I find to be too narrowly focused on sensor spatial resolution (along with the inherent impacts of heterogeneity and 3D effects) and angular sampling at the exclusion of other important players – particularly potential forward model deficiencies beyond the plane-parallel assumption that I identify below. I suggest the authors do a bit more legwork on these before this paper is accepted for publication.

Comments:

- Page 2, lines 56-57: I suggest citing the Witte et al. (2018) paper here, along with implications on this study. (Witte, M. K., Yuan, T., Chuang, P. Y., Platnick, S., Meyer, K. G., Wind, G., & Jonsson, H. H. (2018). MODIS Retrievals of Cloud Effective Radius in Marine Stratocumulus Exhibit No Significant Bias. *Geophysical Research Letters*, *45*(19), 10,656–10,664, doi:10.1029/2018GL079325.)
- Page 3, line 86: Just to clarify, the C-130 only flew 1 to 1.5 hour (60 to 100 minute) flights? Seems short to me, so perhaps I'm misunderstanding.
- Page 3, lines 96-97: This statement on overcounting being thought to equally affect all size bins is an assertion without evidence. Was this verified to be the case? It might be an acceptable assumption, but there's nothing here that makes that case.
- Page 3 line 102: Why is the CIP sampling not the same as the CDP? My understanding is that these two in situ instruments are supposed to complement each other to resolve the full width of the droplet size distribution, and are flown together for that reason.
- Page 4, lines 115-117: Yes, the RSP polarimetric re retrievals may be accurate, at least for the synthetic LES cases considered in Alexandrov. But the key question here, given their use as a benchmark for satellite re retrievals, is whether these retrievals should be consistent with those from total reflectance approaches considering their different vertical weighting functions (e.g., Platnick (2000)). The polarimetric signal is a single-scattering phenomenon and thus is sensitive to the very top of the cloud. Looking at the re profiles in Fig. 3 (and from knowledge of similar profiles from other field campaigns), there is a decrease in re at the very top of the cloud. This decrease may in fact be too small to matter, but the authors don't fully address this other than later in the paper stating that using different tau thresholds (1 and 3) in their averaging of "cloud top" CDP measurements yields only a roughly 0.1μm re change. The single-scattering polarimetric signal may be in large part from the portions of the cloud above even 1 optical depth into the cloud. Please comment on this.
- Page 4, lines 118-121: Radiometric calibration, and relative radiometry between two imagers, can have a big impact on tau retrievals and their agreement between two sensors (see, e.g., Meyer K, Platnick S, Holz R, Dutcher S, Quinn G, Nagle F. Derivation of Shortwave Radiometric Adjustments for SNPP and NOAA-20 VIIRS for the NASA MODIS-VIIRS Continuity Cloud Products. *Remote Sensing*. 2020; 12(24):4096. https://doi.org/10.3390/rs12244096). While the tau retrieval agreement is quite good later in the paper, did the authors assess the relative radiometry between RSP and MODIS/GOES? It's possible that the good agreement is fortuitous and may be masking larger heterogeneity effects.
- Page 6, lines 177-178: See my comment above on the vertical weighting functions of polarimetry versus total reflectance. I guess for 3.7/3.9μm, the difference in weighting with respect to polarimetry is reduced compared to, say, 1.6μm, but this is a little hand-wavy and there may still be differences.
- Page 6, lines 204-205 and Fig 4: I suggest adding error bars to this plot similar to those in Fig. 5. For the MODIS vs CDP plot, can you stratify these results by the MODIS 250m heterogeneity index (Liang et al. (2009), again similar to what is done in Fig. 5)? Also, what about sensitivity to the width (effective variance) of the observed droplet size distribution? The satellite retrievals are making an assumption on veff (later on defined as 0.1) – how do these results stratify as a function of divergence of that veff assumption from the observations? Veff can be calculated from the observed DSDs, so I suggest doing that analysis.
- Page 7, lines 213-215: Using RSP to define the heterogeneity index only provides information in one direction, i.e., along the flight track. Both satellite imagers have footprints much larger than the width of the RSP footprint, so across-track heterogeneity may be missed. Using the MODIS 250m heterogeneity, as I suggest above, would be helpful. Also, following my previous comment, what is the veff retrieved by RSP for these comparisons? Are the RSP veff generally consistent with CDP, at least where the two can be reasonably compared? I see the RSP veff are shown later in Fig. 12, but there is no stratification of CER retrieval differences as a function of

veff deviation similar to what was done for VZA and scattering angle, or even heterogeneity. Veff sensitivity should be a no-brainer to add here.

- Page 7, lines 230-243: Perhaps the MODIS vs GOES re retrieval differences are tied to the rather large central wavelength difference (3.75 vs 3.9μm) and may point to a different forward model issue? Specifically, the liquid index of refraction assumed in the calculation of the cloud single scattering properties – see Platnick et al (2020) for a discussion of re sensitivities to refractive index and temperature (Platnick S, Meyer K, Amarasinghe N, Wind G, Hubanks PA, Holz RE. Sensitivity of Multispectral Imager Liquid Water Cloud Microphysical Retrievals to the Index of Refraction. *Remote Sensing*. 2020; 12(24):4165. https://doi.org/10.3390/rs12244165). Note that paper shows MODIS 3.75μm vs VIIRS 3.7μm re differences on the order of those shown here, though I admit the impacts of heterogeneity are difficult to disentangle. Can the authors at least comment on the implications of this on their MODIS vs GOES results?
- Page 8, lines 255-258: This may be more challenging, but I think you can at least plot the MODIS scattering angle distributions within each GOES scattering angle bin (perhaps as an accompanying box plot). That should indicate scattering angle sampling differences. You should also plot Terra and Aqua MODIS separately, since the scattering angle sampling may be quite different.
- Page 8, line 264-267: While the precipitation likely isn't aliasing into the satellite retrievals, how do the DSDs observed by CDP itself change between precipitating and non-precipitating clouds? If it's significant, it's possible that there may be a correlation with re differences given the assumed veff may deviate more/less from reality.
- Page 9, line 278-279: Besides spatial resolution differences between GOES-13 and 16, what about scattering angle differences? This was pointed to as a key player in the MODIS vs GOES-13 differences, and GOES-13 and 16 weren't viewing from the same orbital location.
- Page 10, lines 323-325: I don't think investigating veff impacts needs to wait for future work, nor does it require using veff as an additional input to the satellite retrievals (i.e., using various veff in the forward models). As I suggested above, you can simply look at re retrieval differences as a function of RSP veff (or CDP veff). You already have these data from RSP, and can calculate veff quite easily from CDP, so the hypothesis at least can be partially tested here. I suggest the authors do this analysis.