

Manuscript: EarthCARE Cloud Profiling Radar Observations of the Vertical Structure of Marine Stratocumulus Clouds – Point to point response to reviewer 1 comments

We are grateful to reviewers for their insightful comments, which have helped us improve the clarity and impact of our study. In the remainder of this document comments from the reviewer are in black and our responses are in red.

General Comments:

This paper presents some early performance characteristics of the EarthCARE cloud profiling radar with regard to detection of hydrometeors in marine stratocumulus clouds. EarthCARE performance is shown to be a notable advance over CloudSat in respect to detection sensitivity and surface clutter suppression. Marginal improvements in the detection of precipitation (drizzle) are shown as well. The paper is timely - EarthCARE is new and a good reference specific reference relative to StCu is warranted. The presentation is generally of a high quality and the methods are appropriate. I only have a few minor comments listed below to be addressed.

We would like to thank the reviewer for the positive, general comments.

Specific comments:

Line 240: 2.5 km should be 1.7 km. See Tanelli et al. 2008, Table 1.

Corrected. I think you meant line 40 instead of 240.

Line 128: add 'the' before 'model'.

Added.

Subsection numbering is messed up. There are two 2.1 and two 2.3 sections but no 2.2!

Corrected.

Figure 4: I think you could probably make this figure more compelling. I think it would help to add both an EarthCARE and CloudSat example of a thin non-precipitating cloud with cloud top at or below 1 km. There are lots of examples where CloudSat has only one or two bin of reflectivity where EarthCARE might see significantly more detail. I think you envision your panel A as showing a marginal cloud but this is actually a fairly thick StCu.

Thanks for the suggestion. We added two additional examples to the supplement along with some descriptions to illustrate the potential differences observed by the two sensors for such clouds.

Line 220: note that this field campaign included coordinated under flights of EarthCARE here.

We added “, which included coordinated underflights of EarthCARE for validation purposes.” after the 1st sentence of this paragraph.

Lines 240-247: This paragraph describes model results. Does it belong here? I would put this back in your section 2.3 (the one that discuss the model results).

We would like to thank the reviewer for his logical suggestion. The text and associated figure (Fig. 6 in the original manuscript) have been moved to section 2.3 (model results).

Lines 248 – 276. You might want to include a sentence or two before this discussion to describe why you are showing these results. I think you are trying to identify a multi-variable relationship with precipitation that goes beyond a simple reflectivity threshold. I also think your results show that this is hard to do and there is likely inherent uncertainty in cloud/precipitation identification. Maybe add a little discussion of that fact.

Completely agree. At the beginning of this part, we added “Ambiguities exist when it comes to partition cloud and drizzle with single-frequency radar reflectivities (e.g., Xu et al., 2019). The variability associated with microphysics, dynamics and the fact that reflectivity is dominated by the large drops in the radar volume all contribute. Therefore, using a threshold of Z_{MAX} for drizzle detection is subject to uncertainties. Combining model outputs and EarthCARE observations allows for some exploration of the possibility to identify a multi-variable relationship beyond a simple threshold of reflectivity.”

Additional discussions are also added near Line 276 in the original manuscript – “The observed NH_{MAX} of cloud-only and light drizzling profiles is close to 0.5. We know from ground-based and airborne radar observations (Kollias et al., 2011; Remillard et al., 2013; Fan et al., 2018) that the NH_{MAX} of cloud-only and light drizzling profiles is usually near the cloud top. Thus, the PTR limits our ability to diagnose the absence of drizzle particles using the NH_{MAX} value. As the size and number concentration of drizzle particles in the profile increases, Z_{MAX} increases and NH_{MAX} decreases but the PRT has reduced the dynamic range of the NH_{MAX} compared to those from the model simulations without the PRT (Fig. 3). Further effort would be devoted to combining other observations that could afford additional constraints such as Doppler velocity and path integrated attenuation (PIA).”

Line 280: What CloudSat years. The MDS changed by about 6 dB over the course of the mission which would significantly influence the pdf's in figures 8 and 9.

We used CloudSat CPR observations collected in 2007 and 2008, during the early period of CloudSat in space, when the CPR sensitivity was high.

Figure 9: I'm confused about two aspects of this figure. The CS pdf's don't show detections smaller than about -26 dBZ (related to question above). There is no reason that EarthCARE

should detect more -15 dBZ clouds than cloudsat at altitudes above 750 m – but panels b and c show this. Why? Is it just that the time period sampled is different?

There are detections with $Z_{max} < -26$ dBZ, though it is not apparent in the figure because we plotted the probability and the number of Z_{max} smaller than -26 dBZ is very small compared to the number with Z_{max} greater than -26 dBZ. For example, there are 1886 profiles that have $Z_{max} < -26$ dBZ relative to 332420 profiles with $Z_{max} > -26$ dBZ in the category of $750 < H_{max} < 1000$ m (Fig. 9c).

For the second question, we think it is likely mainly due to the different large-scale circulation, SSTs, and inversion strength during 2007-2008 and 2024-2025. The slightly weaker inversions and warmer than average SSTs in 2024-2025 tend to favor deeper boundary layer and more mixed stratocumulus-cumulus clouds that carry larger liquid water path, whereas the colder SSTs combined with strong inversions in 2007-2008 favor overcast Sc with overall less precipitation.

Line 320: So CS misses 20% of the EC precip detections at this height bin. Can you also add for reference what fraction of EC radar shots contain precip?

Yes, the fraction of EC and CS radar that contain precipitation with the height of Z_{max} in 3 different categories can be found in the caption of Fig. 9. We also added “The fraction of precipitating Sc observed by EC-CPR and CS-CPR is respectively 11.4% and 10.2%, summing the three height categories in Fig. 9. Overall CS-CPR misses the precipitation detection in Sc clouds by about 10.5%.” to the manuscript.

Section 3.2: You should add a bit more analysis to this section. First it would be useful to include the total fraction of radar shots with a StCu hydrometeor detection in each of the two regions for both EarthCARE and CloudSat. Second I would add a plot that shows the vertical profile of the hydrometeor detection fraction from each sensor.

Sure. We added “The Sc cloud fraction (fraction of columns with a detection) as observed by EC-CPR and CS-CPR is approximately 40% (44.8% in SEP and 36.7% in SEA) and 20% (23.6% in SEP and 19.2% in SEA), respectively.”

The suggested plot is added as the panel (c) in Fig. 8. It is done by summing the probability at each height bin in panel (a) and (b).

Referencing in the intro is a little thin. Here are some (not a comprehensive list) to add:

Thanks for pointing us to these important references. They are added along with some others.

Tanelli et al., "CloudSat's Cloud Profiling Radar After Two Years in Orbit: Performance, Calibration, and Processing," in IEEE Transactions on Geoscience and Remote Sensing, vol. 46, no. 11, pp. 3560-3573, Nov. 2008, doi: 10.1109/TGRS.2008.2002030

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Wood, R., D. Leon, M. Lebsock, J. Snider, and A. D. Clarke (2012), Precipitation driving of droplet concentration variability in marine low clouds, *J. Geophys. Res.*, **117**, D19210, doi:10.1029/2012JD018305.

L'Ecuyer, T. S., W. Berg, J. Haynes, M. Lebsock, and T. Takemura (2009), Global observations of aerosol impacts on precipitation occurrence in warm maritime clouds, *J. Geophys. Res.*, **114**, D09211, doi:10.1029/2008JD011273.

Mülmenstädt, J., Salzmänn, M., Kay, J.E. *et al.* An underestimated negative cloud feedback from cloud lifetime changes. *Nat. Clim. Chang.* **11**, 508–513 (2021). <https://doi.org/10.1038/s41558-021-01038-1>