Response to Referee #1

We thank the referee for their review. Below are the original comments in *italics* with our responses in normal text.

This well-written and well-presented paper is part of a collection describing algorithms and products of the EarthCare mission, and probably makes more sense when read in conjunction with (some) of these other papers. I'm not sure how a paper of this type should be reviewed: is it more about the clarity and quality of the presentation or are criticisms of the algorithm appropriate at this stage meaningful? I guess it's more about the former rather than the latter, and fortunately I don't have much to say about the latter either even if I were to focus on that aspect. So this review is more about questions on matters that were somewhat unclear to me, and may also puzzle other readers not so familiar with the mission or the accompanying papers.

We agree that this contents of this manuscript makes more sense when combined with the rest of the manuscripts describing the EarthCARE. It is a large and complex mission. We thank the referee for suggestions to clarify the presentation.

Questions such as:

-- What is a "frame"? A citation is provided, but can the concept be explained in couple of sentence. Where does the "truth" in the frame come from since there aren't yet EarthCare retrievals of either the L2a or L2b variety? I'd assume some sort of cloud resolving model, (GEM? Fig. 3). So, there are model-generated cloud fields, forward calculations with instrument simulators, and then a cloud retrieval by applying an inversion algorithm on the simulated signals? Does this process corrupt at all the closure effort? What if the RT calculations were applied directly to GEM fields rather than retrevals from the GEM fields, would such an experiment be useful?

The text has been adjusted to indicate what is a “frame”. Basically it is a 6200 km section of the EarthCARE orbit.

The “truth” is as you describe. Forward radiative transfer calculations are applied to high resolution numerical weather prediction (GEM model) output, which are then used as input to instrument simulators. The simulator results are used as input to the entire EarthCARE algorithm process, which are then used by the ACM-RT processor. Radiative closure is performed by comparing output from ACM-RT and processed BBR “observations” consistent with what will be done when observations are available from EarthCARE. Having the high resolution model fields from GEM does afford us the ability to apply the RT calculations directly to the original data. This is indeed a useful experiment as it allows performing a “perfect” radiative closure in which differences should be attributable to instruments and retrievals. Such an analysis is not included in this manuscript but is one of our planned activities.

-- Why are the domains 5x21 km, what's so special about this choice?

The size of the domain for the radiative closure is ~100 km^2 which was driven in part by performance of the BBR which had its nominal performance requirements defined for this sized domain. Instead of using a 10 km by 10 km domain, we decided to use a domain that is larger orbit and smaller across orbit. This is a balance between a domain that is far from the track of the active sensors, for which the scene construction algorithm would have increasing impact on the results, and a narrow but long domain that would make interpretation of the closure difficult. The use of 21 km along orbit rather than 20 km is due to the 7 km period of the horizontal grid used for for retrievals (Eisenger et al, 2023).

We have added text and references to the manuscript to explain this choice.

Eisinger, M., T. Wehr, T., Kubota, D., Bernaerts, and K. Wallace, 2023: The EarthCARE production model and auxiliary products. *Atmospheric Measurement Techniques*, to be submitted.

-- Why is Dx= 0.25 km used for the experiment of Fig. 6, while Dx=1 km used later (line 468). Shouldn't the resolution of the ACM-COM or ACM-CAP retrieval only be used (BTW, do these abbreviations need to be listed somewhere, is it important to know what they stand for?)

The results shown in Figure 6 are RT calculations applied directly to the GEM fields which has a 250 m horizontal resolution. For the EarthCARE retrievals, the data is on a 1 km horizontal grid. Since Figure 6 is used for illustrative purposes of the 3D effect and not quantitative analysis we believe that it is OK to show it at the highest possible horizontal resolution.

-- Why are the signs of SW and LW CREs in Fig. 5 different than what we're accustomed to (negative and positive, respectively).

We thank the referee for catching this error creating the plot in the figure. It indeed is reversed from the CREs computed using the standard definition. Figure 5 and associated text has been corrected and updated.

-- If a radiance closure approach were to be used, what would be the criterion for "pass"?

We do perform radiative closure using radiances but it is not discussed in this manuscript which focuses on the radiative transfer calculations used for the radiative closure. Details of the closure using radiances, including the criteria for a “pass” are discussed in a separate paper focused on the EarthCARE radiative closure processor.

-- If closure is not satisfactory, is there some post-processing provision to "fix" the retrievals to achieve closure (I imagine such a possibly iterative revision would be complicated).

There is not an iterative adjustment of the retrievals to improve the radiative closure in the operational processing of EarthCARE data. However, the radiative closure results are certainly used to inform ongoing improvements of the retrievals for future reprocessing.

-- What an obscure reference for water refractive index (Segelstein). Are the authors aware of Platnick et al. (2020) https://doi.org/10.3390/rs12244165 where the importance of refractive indices is discussed (for inversion, not forward BB calculation).

We are aware of the paper by Platnick et al, 2020 but the reference cited in the manuscript is consistent with the refractive indices used in the Mie calculations described in this manuscript.

-- I don't see a shaded area in Fig. 7 even if the caption of the figure mentions one.

It is there but admittedly, it is faint and given the vertical range of the y-axis quite close to the zero line. We have darkened the shading so it should be more easily seen.

-- Shouldn't the authors comment about the lack of closure possibly being i many cases due to factors other than cloud retrievals, inadequate 1D BB RT, or imperfect 3D BB RT? Like wrong assumptions and input? What if the ice models are not realistic, for example?

We agree that the lack of closure could be affected by a range of factors both within our control, e.g., the radiative transfer modelling, and outside of our control, e.g., surface properties. The goal of this manuscript is to highlight the importance of 3D radiative transfer using the 10 W m^{-2} as a metric. The effect of the input uncertainty on the radiative closure is discussed in the manuscript describing the EarthCARE radiative closure processor.