**Final response to the Interactive comment by the anonymous referee #1 on "Quantifying the bias of radiative heating rates in NWP models for shallow cumulus clouds" by Nina Crnivec and Bernhard Mayer;**

*Referee's comments in blue, our answers in black;*

In my opinion, this is a good paper worthy of publication. It explores in unprecedented detail the effects of small-scale cloud variability and horizontal photon transport on the accuracy of radiation schemes used in current numerical weather prediction models. The paper presents many noteworthy observations (just one example is the observation that the relative importance of small-scale variability and horizontal transport varies with altitude within the cloud layer). The paper often offers insightful explanations to the observed behaviors, although in some cases this was not possible due to the complexity of the problem and would have required dedicated sensitivity studies. Moreover, the paper also offers guidance for future improvements, for example by suggesting that future corrections for small-scale variability and horizontal transport effects may not need to consider variations in surface albedo. Overall, the methodology is sound and the presentation is clear. I do have a list of suggestions for very minor changes in wording, but none of them is critical.

We thank the anonymous referee #1 for a general approvement of our study and a thorough examination of our text. We have taken into account most of the suggested corrections, which improved the quality of our text. Below please find a list of our replies to the original comments of the anonymous referre #1. Note that the page and line numbers correspond to the ones in the previous file version and might differ slightly in the new (corrected) version of the manuscript.

Page 1, Line 8: I suggest adding "the" between "imitate" and "poor".
Done.

Page 1, Line 12: I suggest adding an "s" at the end of "part".
Done.

Page 1, Line 12: I suggest adding "the" between "and" and "net".
Done.

Page 1, Line 15: I suggest adding "a" in front of "bias".
Done.

Page 1, Line 19: I suggest adding "the" between "while" and "underestimation".
Done.

Page 1, Line 23: I suggest replacing the word "predominantly" with something like "clearly", "much", or "visibly".
Done, changed to "clearly".

Page 2, Line 6: I suggest changing "to" to "into".
Done.

Page 2, Line 10: I suggest adding a comma between "column" and "computationally".
Done.

Page 2, Line 22: The word "competent" does not fit here. Depending on the intended meaning, "powerful" or "complex" could be more suitable.

Done, changed to "proficient".

Page 3, Line 2: I suggest adding "the" between "neglects" and "cooling".
Done.

Page 3, Line 3: I suggest changing "a" to "an".
Done.

Page 3, Line 10: I suggest adding "the" in front of "operational".
Done.

Page 3, Line 12: I suggest adding a comma after "scheme".
Done.

Page 3, Line 20: I suggest adding "and is" in front of "commonly".
We left this as it was, as "NWP radiative solver" refers to the "two-stream method with maximum-random overlap assumption for partial cloudiness", and not only to the "maximum-random overlap assumption".

Page 3, Lines 26-27 (and elsewhere): I suggest capitalizing the "s" at the beginning of "section" when it is used as the name of a specific section (for example, "Section 3").
Done.

Page 4, Line 25: I suggest adding an "s" at the end of "definition".
Done.

Page 4, Line 26: I suggest adding a comma after "step".
Done.

Page 6, Line 14: I suggest changing "scene is varied" to "scenes varies".
Done.

Page 6, Line 15: I suggest moving the word "approximately" just behind "of".
Done.

Page 6, Line 16: I suggest adding "es" at the end of "thickness".
Done.

Page 7, Line 4: I suggest adding "the" between "mimic" and "poor".
Done.

Page 7, Line 6: I suggest adding "the" between "over" and "cloudy".
Done.

Page 7, Line 11: I suggest adding "the" in front of "LES".
Done.

Page 7, Line 4 of the footnote: I suggest adding a comma after "four".
Done.

Page 8, Line 9: I suggest adding "the" after "diagnosed".
Done.

Equations (10) and (11): The averaging should be indicated by overbars (as in Equation (11)) or by some other symbol in all three equations. Alternatively, the word "bias" could be replaced by "error" (if the equations mean to refer to individual cases, not overall statistics).
Done.

Page 9, Line 15: I suggest adding "the" after "varied".
Done.

Page 9, Line 17: I suggest adding "the" in front of "surface".
Done.

Page 9, Line 23: I suggest adding "an" in front of "intermediate".
Done.

Page 9, Line 24: I suggest replacing "additionally" by a comma.
We left this as it was, as we also discuss the dependence on SZA in the subsequent sections etc.

Page 9, Line 28: I suggest adding a comma behind "biases".
Done.

Page 10, Line 10: I suggest adding a comma behind "cooling".
Done.

Page 10, Line 19: I suggest adding "is" in front of "completely".
Done.

Page 10, Lines 25-27: At this point, readers may wonder about the contribution of the lower portion of nearby clouds intercepting some of the photons that escaped through cloud sides, which may increase 3-D heating rates even without surface reflection (especially in cases of high total cloud cover). It could help to mention that the surface impact is thought to be dominant, because the effect weakens significantly as the surface albedo is reduced from 0.25 to 0.05 (as discussed in Section 3.3).
I presume that for overhead sun and the cloud scene with total cloud cover of 50 %, presented in this paragraph, the individual clouds are separated well enough, so that the strong forward scattering on cloud droplets would orient most of the scattered radiation directly towards the surface, and the “interception effect by nearby clouds” should be small. We decide to leave this story out of the discussion at this point, because the paper is already quite long.

Page 12, Line 9: I am not sure what the word "additionally" refers to; some clarification.
Done, by inserting “(but not the ICA)”;

Page 12, line 12: I suggest replacing "corresponds well with" by "is near".
We decided to leave this as it was.

Page 14, Line 1: I suggest adding a comma after "assumption".
Done.

Page 14, line 12: I suggest replacing "3.1 and 3.2" by a comma, or deleting the word "previous" (and still adding the comma).
Done, comma added;

Page 14, Line 28: I suggest adding "that" between "implies" and "more".
Done.

Page 15, Line 21: I suggest replacing "on" by "for".
Done.

Page 18, Line 31: I suggest mentioning that, presumably, the one quarter of windows displayed was selected randomly.
Yes, but also the original (total) windows, the results of which are shown in the thermal spectral range were selected randomly, I think this is clear.

Page 19, Line 10: I suggest replacing "besides" by something like "also".
We decided to keep the original version.

Page 21, Lines 15 and 28: I suggest adding a comma in front of "we".
Done.

Page 21, Line 18: I suggest adding a comma in front of "it".
Done.

Page 22, line 11: I suggest adding a comma in front of "each".
Done.

Page 22, Line 29: I suggest adding "the" in front of "destabilization".
Done.

Page 23, Line 14: I suggest adding a comma in front of "and".
Done.

Page 23, Line 23: I suggest replacing "which" by "that".
Done.

Finally, it could be interesting to comment somewhere on any impact by the assumption that surface temperature (hence the upward flux) is the same in 1-D, ICA, and 3-D cases. Would the differences in downward fluxes impact surface temperatures sufficiently to cause significant differences between 1-D, ICA, and 3-D surface temperatures (and upward fluxes), or would wind drift and other factors make this difference negligible?
This is indeed an interesting question. The paper in its current form, however, involves strictly diagnostic analysis of radiative biases. The effect of these biases on the evolution of atmospheric flow will be a topic of a subsequent study, after an appropriate parameterization is developed.