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Interactive comment on "Quantifying the bias of radiative heating rates in NWP models for shallow cumulus clouds" by Nina Črnivec and Bernhard Mayer

Anonymous Referee #1

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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.

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

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

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

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

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

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

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

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

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

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

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

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

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

Page 3, Line 20: I suggest adding "and is" in front of "commonly".

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").

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

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

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

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

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

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

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

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

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

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

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).

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

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

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

Page 9, Line 24: I suggest replacing "additionally" by a comma.

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

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

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

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).

Page 12, Line 9: I am not sure what the word "additionally" refers to; some clarification would help.

Page 12, line 12: I suggest replacing "corresponds well with" by "is near".

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

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).

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

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

Page 18, Line 31: I suggest mentioning that, presumably, the one quarter of windows displayed was selected randomly.

Page 19, Line 10: I suggest replacing "besides" by something like "also".

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

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

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

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

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

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

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?