ACP Review

Title: *Quantifying the bias of radiative heating rates in NWP models for shallow cumulus clouds*

Manuscript: acp-2018-1247

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Overall assessment: *Minor revision*

Summary

This manuscript reports on radiative biases that can be expected to occur when NWP models neglect detailed solar and infrared 3D radiative transfer (i.e., all NWP models all of the time). Results for full 3D transfer are compared to the Independent Column Approximation (ICA), which an NWP model would employ if it resolved domains as well as the LES fields used here, and a highly parametrized radiation scheme which an NWP model would use if its resolution was substantially less than that of the LES fields. The extent of experiments and analyses is adequate for ACP. The authors are experts in this area of work, and there are no obvious signs of either technical or interpretative issues. The manuscript is, however, a bit long... but this might be of no concern for a largely electronic journal (though it might compromise the number of people who read the entire document?). I recommend this manuscript be published after minor revision. A few points follow.

General comments

1. Note that much of the issue addressed here is the ability of an NWP model, run at a resolution >> 0.025 km) to adequately provide the information needed to do the benchmark 3D radiative transfer computations. It was assumed that variables such as mean cloud water content and cloud fraction have been produced perfectly by the NWP model (i.e., in total agreement with the LES). This is unlikely to be the case, and those errors could easily rival, or exceed, errors due to use of either the ICA or the simple model. Moreover, my sense is that most NWP models with resolutions near 3 km would neither attempt to get sub-grid cloud fractions nor invoke the max-rand overlap (MRO) rule... I suspect they would assume grid-cells to be either full or free of cloud water? If this assumption is wrong, perhaps the authors could provide a reference to support their claim.

2. Following from point 1... It would have been interesting to see ICA results as one progressively backs-off full LES resolution (i.e., starting at 0.025 km and going up to ~2.5 km) without making assumptions about the nature of unresolved clouds; just cell-

filling if some cloud exists. Obviously, cloud fractions will increase and mean cloud water contents will decrease, but is this what well-resolved NWP models do?

3. My expectation at first was that the authors were going to report on LES sensitivities when 3D radiative transfer models were used interactively. The analyses were, however, strictly diagnostic. Interactive studies were referenced at the top of pg. 3. Why werenôt they performed and reported on here?

Minor comments

1. pg. 1; L24: Iôm not sure that the work here ñhighlights the importance of an improved representation of clouds even at the resolution of todayôs regional (limited-area) numerical modelsò. Perhaps the (conditional) radiative errors are minor in the overall energy budget and the NWP model wonôt even respond to them in a significant way?

2. It would be useful to mention the resolution of the LES in the abstract.

3. pg. 2; L22: This should be ñBakerò, not ñBarkerò (reference list, too).

4. Title of Section 2.2: The assumption is that the NWP model gets this correct. It probably wonôt, and that could represent the majority of error! Moreover, if it gets cloud fraction and mean water content correct, why not assume that it does better than MRO and use something better than that in the simply model (like decaying exponential overlap)?

5. pg. 6; L13: Given the length of the explanation for the delta-Eddington and the simple model, it seems that Bugliaro et al.ôs equation could be stated explicitly.

6. Section 2.4: Note that the McICA method is equivalent to the ICA when the full LES field is available to be sampled. When it is not available, additional assumptions are needed for the stochastic cloud generator... it would be interesting to see how it performs using some standard settings.

7. pg. 9; L10: Why were standard conditions used as opposed to the LESôs temp, vapour, etc.?

8. pg. 9; L18: 65,536,000 photons seem like over-kill for domain-average fluxes! Perhaps you could mention typical Monte Carlo uncertainties for HRs in cloudy layers?

9. pg. 9; L23: I presume that ñcloud cover of 52.3% placed over landò was a typical condition given that it was highlighted often?

10. Fig. 4: Would this be a reasonable thing for an NWP model to do for SW radiation: Use the ICA (with a stochastic cloud generator) for SZA < 45 deg. and switch to a

simpler (faster) 1D model for SZA > 45 deg.? Judging from this figure that might yield possibly tolerable errors???

11. Section 3.3: Since 1D and ICA errors depend weakly on srf alb, perhaps this section could be reduced much in length (especially if youôre looking to reduce overall length)?

12. Fig. 7: Are these RMSE values for every grid-cell in the ñcloud layerò?

13. Fig. 8: For better comparison, the y-axes on the two rightmost columns should match: -70:30 for the centre column and -20:50 for the right column.

14. Fig. 9: While the RMSE values look disconcerting, at times, it might not be an issue for the dynamics (cf. the abilities of GCMs to consume substantial radiative ñnoiseò produced by the McICA method).

15. pg. 19; L8: ñ...demonstrates the general need for statistics.ò seems like odd terminology?

16. Discussion near pg. 21; L15: Could there also be an underlying effect involving LWC variability as a function of mean LWC? What if the 1D model made some reasonable assumption about variance of LWC across layers (in addition to assuming that the NWP predicted both cloud fraction and mean LWC perfectly with the MRO)?

17. pg. 23; L13: I think that ñKablick III et al. (2011)ò can be simply ñKablick et al. (2011)ò... the III need be used only in the full reference.

18. pg. 23; L15: McICA is equivalent to the ICA when the subgrid-scale generator is perfect. It never is, but increasing levels of complexity can be easily added with confidence (e.g., accounting for correlations in sfc alb and LWP or Re and LWC)... this cannot be said for Tripleclouds.