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Atmospheric Chemistry and Physics Discussions

Interactive comment on "Radiative impacts of cloud heterogeneity and overlap in an atmospheric General Circulation Model" *by* L. Oreopoulos et al.

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This paper addresses the question as how the radiative impact of clouds in an atmospheric GCM depends on assumptions regarding cloud overlap and subgrid-scale variability in condensate amount.

Qualitatively, the basic results are obvious to those who know the subject well. Within the applicability limits of the Independent Column Approximation, the radiative effects of a single cloud layer are maximized by distributing the cloud condensate homogeneously - basically because cloud SW albedo and LW emissivity both depend weaker than linearly on the condensate amount (or cloud optical depth). This also applies to a multi-layer cloud field in a GCM grid column. Thus, if the cloud field as a whole is made more heterogeneous, either by making the individual cloud layers more inhomogeneous, or by adjusting the overlap closer to maximum overlap, so that the cloud condensate in a GCM grid column is packed into a smaller part of the column, domain-mean cloud radiative effects (CRE) become weaker: that is, a positive change in SW CRE and a negative change in the LW CRE.

The question then is, how sensitive the SW and LW CRE are to these assumptions. Although this question has been addressed before in some studies, especially for cloud fraction overlap, the present study has the asset that the authors use in their tests two different cloud schemes in the GEOS-5 AGCM. This allows at least a case study of to which extent the sensitivities depend on the properties of the GCM cloud field. Another useful aspect is the consideration of observation-based vs. globally constant decorrelation lengths (although this was also discussed in Barker (2008b; paper cited in the manuscript).

SPECIFIC COMMENTS:

* One of the main results of the current work is that the impact of cloud fraction overlap is rather strongly cloud scheme -dependent, while the impact of cloud heterogeneity is more robust - provided that a similar specification of cloud heterogeneity is used for both cloud schemes, which is the case here.

The strong cloud scheme dependence of the impact of cloud overlap is explained in the paper in terms of greatly different cloud fraction frequency distribution for the two cloud schemes. I wonder if there is any simple physical explanation for the similar cloud heterogeneity effects for the two cloud schemes?

Judging by Figs. 2, 3 and 10, I would guess there is some compensation between different factors. McRAS-AC has substantially higher global-mean cloud fraction than CTL, which would suggest that the heterogeneity effects also be larger for McRAS-AC. However, in fact, in Figs. 2 and 3 the effect of cloud heterogeneity on SW CRE is slightly smaller for McRAS-AC (the difference between EXP4 and EXP3 being 6.3 Wm-2 for CTL and 5.2 W m-2 for McRAS-AC). Perhaps this is due to clouds being optically thinner? Note that there is not much difference in the global mean CREs in spite of the larger total cloud fraction for McRAS-AC.

* A previous study that addresses pretty much the same questions as this one (namely, the radiative flux sensitivities to cloud fraction and cloud condensation overlap and the degree of subgrid-scale variability) is Barker and Räisänen (2005). Among other things, this study shows, like the present manuscript, that the decorrelation length for cloud fraction overlap is more important than that for condensate. This study should be cited in the present work.

* The first paragraph of the Introduction is perhaps too much "written for the specialist". It is completely void of references. For example, "optical depths that have been greatly adjusted" could/should augmented by references (e.g., Tiedtke's (1996) optical depth tuning factor 0.7).

* I find the sign convention used in Figs. 2, 3 and 4 counter-intuitive. If one has a reference case (REF) and several experiments (EXP) in which the model parameters are modified, the normal way of expressing the effect of the modifications would be as EXP-REF, not REF-EXP as apparently used here. Thus I strongly recommend to change the signs of the differences in Figs 2-4. This would also reduce the need for the now rather lengthy explanation of the sign convention on p. 12302. Another foolproof way of handling this would be to give the CRE values as they are, without subtracting the reference case.

* p. 12296, line 8: The assumption of horizontally homogeneous effective particle size should be discussed a bit more. Physically, it implies that horizontal variations in condensate amount result from variations in droplet/ice crystal number than their sizes. If there is a positive correlation between particle size and condensate amount (which at least aircraft observations tend to suggest) the radiative impact of subgrid-scale variability in condensate amount is reduced (Räisänen et al. 2003; Barker and Räisänen 2004).

* Would it be possible discuss how the assumptions on subgrid-scale cloud structure influence the radiative heating rates? E.g., represent a comparison between zonal-mean heating rates between selected experiments (e.g., EXP4 or EXP8 vs. EXP1).

* In Fig. 11, does the lowest cloud fraction bin also include cloud-free cases? If yes, they should rather be separated from the cases with small but non-zero (0-0.05) cloud fraction. Completely cloud-free layers are irrelevant for cloud overlap.

* Figure 12 suggests that completely cloud-free grid columns occur almost never, whichever cloud scheme is used. Is this the correct interpretation?

TECHNICAL COMMENTS:

* p. 12291, line 4: this should be "essentially"

* p. 12291, lines 14-15: it is not clear what is meant by that the "McICA noise ... is of similar length ..."?

* p. 12293, line 15: this should be "may also be important"

* p. 12294, Eq. (5): Am I right assuming that the mean value of the rank (i.e., the overbar quantities) is always 0.5?

* p. 12294, lines 4, 13 and 14: "Relative strength" seems like an odd wording in the case of condensate. "Relative magnitude?"

* p. 12297, fist line: remove the comma (,) before "potentially"

* p. 12300, Eq. (12a): "all" might be a better notation than "cld" for a mixture of clear and cloudy skies.

* In Table 2, it is not clear what is meant by "heterogeneous clouds" (you could refer to Eq. (9)). It is even less clear what is meant by "weaker cloud heterogeneity". This information can only be found on p. 12304, line 23. The tables should be self-explaining.

* Fig. 1, in the first line of the caption, remove either the degree sign or the word

"degree".

REFERENCES

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