Referee comment on "Dynamic sub-grid heterogeneity of convective cloud in a global model: Description and evaluation of the Convective Cloud Field Model (CCFM) in ECHAM6-HAM2" by Kipling, Stier, Labbouz and Wagner

General comments

The authors of this manuscript expand and test the cumulus convection scheme that is based on the multi-plume scheme from Arakawa and Schubert (1974) as implemented by Wagner and Graf (2010, CCFM). In particular a sub-cloud parcel description is included as well as cloud droplet number concentrations for each updraft. Parameter sensitivity experiments are documented and the simulations are compared to observations. The diurnal cycle over tropical land is improved over the ECHAM default Tiedtke-Nordeng convection parameterization in terms of phase but with a too small afternoon peak. To get a reasonable climate in clouds and energy balance the CCFM scheme needed to be tuned in terms of sub-cloud properties rather strongly (parcel perturbation dT=2.8K, parcel initiation at 350m).

There are two overarching issues with the text.

1. Two base models ECHAM/ECHAM-HAM confusing

   The convection parameterization Tiedtke-Nordeng and CCFM are in the manuscript compared based on sometimes ECHAM-HAM and standard ECHAM. ECHAM-HAM add a two-moment modal aerosol scheme. But the big relevant difference is the microphysics scheme (two-moment and one-moment respectively). That explains rather different behaviour of clouds and radiative fluxes and as a result even the diurnal cycle. I suggest the authors to decide of one base model to show in the main manuscript and move the other plots to the supplement or an appendix. Maybe with the aim at aerosol/convection interactions the ECHAM-HAM should be the primary choice.

2. Explanation of results

   In section 4 several interesting results are presented but such as the sensitivity to the sub-cloud parameter choices, the two convection parameterizations and the "HAM" model component. Explanations are often missing. I do expect from a model developer paper at least an idea why a diurnal cycle changes or clouds are shifting in magnitude and location. I will note a few examples below, but this effort is really important to advance the understanding of parameterizations.

In general, this paper is scientifically interesting. Given a more thorough discussion of results and work on the presentation as outlined in this review this paper can add to the understanding of convective parameterization and I can recommend publication in ACP.

Specific comments

3. Line 57, Introduction: "most paramterizations of this type prescribe the cloud spectrum empirically"

   Here you refer to parameterization of the type AS74 as mentioned a few lines above. AS74 though uses a kernel for the interaction of cloud types within the cloud spectrum. They are therefore "dynamic" and not "empirical". Please find a better formulation.

4. L137, Section 2.2.2: “parcel of air from a configurable level”

   This is the paragraph where you describe the tuning setup for the sub-cloud parcel. You need to add the Table 1 and the text explaing the initiation level from L226 in section 6 “Method”.

5. L138, Section 2.2.2: “2.8K”

   This value that gives the best results is a rather big value. Typical temperature perturbations used in conveciton schemes are around 1K. Therefore you need to refer to a comparison to other schemes - for example the Tiedtke/Nordeng value used in ECHAM. And then later when discussing Figure 6 you need to explain why such a large value is necessary phyiscally.

6. L146, Section 2.2.2: ”initial parcel radii”

   When you say “initial”, does that mean that the parcel radii are allowed to change with height? If not, remove “initial”. If yes, describe how.

7. L198, Section 2.2.3: “1000 steps is reached” (replace by “are”)

   Here and in the conclusion you need to mention the speed of the model runs when comparing Tiedtke/Nordeng with CCFM. How much slower does CCFM run? Is there a more efficient technique?

8. L261, section 4.1: “les liquid and ice when CCFM is used”

   Delete “and ice”. Same in L263. Figure does not support that statement for ice.

9. L272-274, section 4.1 and Figure 2:

   Here you need to mention quantitatively that ECHAM-HAM has 3x less IWP that ECHAM. And please try to explain this drastic phenomena beyond the qualitative speculation that the different cloud schemes are responsible.

   You also should explain why there is more LWP sensitivity in ECHAM-HAM due to convection scheme. When looking at fig 2 and 3, it is interesting to note that liquid water in CCFM is significantly located at the lowest model level, while in Tiedtke-Nordeng much is above the boundary layer. This needs to be mentioned in the text and explained.

   This phenomena might be related to the description of shallow convection. Please describe the shallow convection used in CCFM (or lack of as in AS74).

10. L282, section 4.2.1 “CCRM show a negative cloudy bias ... Tiedtke-Nordeng shows a clear positive bias ...” (add “negative” and “positive” for clarity)

    Please explain this.

11. L291, section 4.2.1 “too little cloud .. due to suppression by low-level inversions”

    This explanation is rather unclear. Low-level inversions help stratocumulus.

    One speculation would be that the higher parcel initiation (L-2, L-3) favour deeper updrafts and therefore less shallow convection. Less shallow convection then leaves more moisture in the sub-cloud layer with allow more stratocumulus to be formed (more low cloud).

    An analogous argument can be made with dT in figure 6. High temperature perturbation allow deeper updrafts ... .

12. Figure 8

    Mention the difficulty of CCFM in CRE and explain. Too much low cloud?

13. Figure 12a

    There are two modes in cloud bse updraught velocity. Please explain. Does that represent shallow and deep convection?

Technical corrections

14. L146, Section 2.2.2
    “model is run for a range of”
    replace by
    “model is run for a number of”
15. L151, Section 2.2.2
    “cloud-base radii from r1 to max(r,max; z,PBL) where”
    replace by
    “cloud-base radii from r1 to r,max(z,PBL) where”
16. L187, Section 2.2.3
    ”where the coefficients”
    replace by
    ”where the coefficients are”
17. L359-360, Section 4.2.3
    ”As noted aboev, Tiedtke-Nordeng also ... configuration.”
    This sentence can be deleted as it has been mentioned already above.
18. L368, Section 4.2.3
    ”cloud-base radius and updraught velocity”
    replace by
    ”cloud-base radius and the updraught velocity”
19. Figure 2
    All LWP figures should have same color scale for easier comparison.
20. Figure 3
    All LWC figures should have same color scale for easier comparison.