Atmos. Chem. Phys. Discuss.,
doi:10.5194/acp-2017-415-RC1, 2017

Atmospheric Chemistry and Physics Discussions
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Interactive comment

Interactive comment on "The Role of 1D and 3D Radiative Heating on the Organization of Shallow Cumulus Convection and the Formation of Cloud Streets" *by* Fabian Jakub and Bernhard Mayer

Anonymous Referee #1

Received and published: 27 May 2017

This paper discusses results from a series of LES simulations of shallow nonprecipitating convection focusing on the role of 3D radiative transfer and the coupling with the surface processes. Overall, I feel this is a nice study and it should be eventually published. However, he analysis is very superficial and does not really give justice to the tremendous amount of computation that went into producing the dataset. I provide general comments below where some suggestions of additional analysis are given, and subsequently follow with detailed specific comments.

General comments:

1. One of key aspect of the roll-type shallow convection is the presence of low-level shear associated with the Ekman boundary layer. This is really not mentioned in the

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introduction and I feel this is an essential omission. I think the shear explains the key impact of the mean wind as documented in Fig. 4. I have more points on that aspect in the specific comment section below, but a discussion of numerical studies (starting with Mason and Sykes QJ 1982, p. 801) as well as observational studies have to be brought in the revision (Weckwerth at el. is just mentioned in passing without any reference to the dynamics). There is also a wealth of theoretical studies on the stability of shear flows in unstable stratification focusing on the development of roll-type circulations, starting with Asai (JMSJ 1970, p. 129). I understand that the authors specialize in the radiative transfer and not in the atmospheric dynamics, but the poor treatment of the dynamical aspects needs to be corrected. My suggestion is the authors trace back citations to the papers listed above and provide an appropriate discussion on the role of boundary-layer shear in determining the organization. Overall, I feel the dynamics is the key, and radiation provides just a small (although quite interesting!) modification. But I feel that unequivocally separate the two is difficult.

2. The model setup is described with insufficient detail. For instance, sending the reader to the description of the land surface model in Heus et al is not appropriate. The C_skin parameter in Table 1 is not explained and I did not know what it really meant. In the discussion of model results this becomes obvious: this is the depth of the well-mixed layer of water that responds to radiative and surface heat fluxes. This is critical to the specifics of the simulation as the shadow on the surface is only important through its effect on the surface sensible and latent fluxes, doesn't it? Ocean response to the shadow can be argued to be quite small at spatial and temporal scales this study is concerned with, whereas land surface would respond quite rapidly. Similarly, significant wind moves the cloud and its shadow, and the surface may not have time to respond. These aspects of the model need to be presented in detail so the reader is aware of the surface response in various simulations. Are the surface momentum fluxes (i.e., surface friction) included in the model setup? If so, what is the surface drag (or whatever parameter is used to describe surface roughness) for the momentum? For instance, to mimic the difference between land-surface (small C_skin) and the ocean

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(large C_skin), the surface drag should also be changed (larger over land and smaller over the ocean). This aspect should be at least mentioned in the description of the model as the surface drag affects the shear across the boundary layer.

3. I would like to see more analysis of bulk properties of the cloud field to put model results into perspective. For instance, the authors should show evolution of the cloud cover for various simulations, BL depth (differences in the cloud mean size evident in Fig. 1 suggests to ma that BL is deeper in the upper panel as clouds seem larger), depth of the cloud field, wind profiles across BL in various simulations, etc. etc. Differences in those bulk properties can affect organization of shallow convection as well and better isolating them from the effects of 3D radiation would be desirable. At the moment, the authors provide very speculative discussion of the model results (see specific comments) and I think some of the bulk differences may be used to better explain the results as well.

4. As far as I can tell, shallow convection organization develops gradually and the time scale is relatively long (hours; this can also be better quantified in the analysis). In nature, the sun is moving around, so both the azimuth and zenith angles are slowly changing. So the idealized setup may be questioned if one has to wait long time for the organization to develop. This aspect needs at least to be recognized in the manuscript.

Specific comments:

1. The title needs revision. "The role"... "on" is not correct. "In" would be better, but replacing "role" with "impact" would be more appropriate.

2. L. 92: "resolution" has to be replaced with "grid length".

3. L. 96: I do not understand "...layers of the surface model are soaking (30% vmr)". Please rephrase. Is the Bowen ratio the same in all simulations? This affects buoyancy flux that drives the boundary layer dynamics.

4. L. 111. Lower sun means lower energy input, hence later convection development,

correct? I would also think that this leads to different evolution of the boundary layer depth, an aspect that might be important as well.

5. I suggest adding a table with simulation acronyms and apply them throughout the text for an easy reference.

6. Do various simulations have different destabilization rates across the lower troposphere? This may have some impact on convection as well. See major point 3 above.

7. Fig. 2 is too small. Consider splitting into separate figures or use vertically-stack panels.

8. L. 136. Is this the wind direction, or shear? What is “along track”?

9. I feel Fig. 4 is the key result of the study. But some aspects are really not mentioned in the discussion. i) The spread between simulations with different C_skin narrows with the C_skin increase. Does this suggest some dynamical effects through surface fluxes? ii) The correlation ratio is much larger for the strong wind case, no doubt because of the role of Ekman shear across the boundary layer.

10. I found the discussion in section 3 speculative and not supported by the analysis. For instance, Fig 5 can be supported by the analysis of model data. That said, my problem is that changes in the surface fluxes do not translate immediately into changes of the boundary-layer structure. The argument is likely correct for the surface layer, but I am not sure how rapidly these changes are passed higher up. Another aspect is the role of secondary circulations that can either support or suppress development of roll-type convection. The discussion on lines 185-190 seems to suggest that the authors think this happens, but I suggest using model data in an attempt to document that. For instance, are there any systematic differences in the updraft/downdraft structure between sunlit and shadow part of the cloud? One should investigate that.

11. How the wind (and thus the boundary layer shear) is maintained? Again, major point 2 above.

12. L. 210 – 217. Can these speculations be supported by appropriate analysis of model data (e.g., shear, boundary layer depth, etc).

13. Suggestion for the future: one can apply different surface roughness to explore the impact of shear. Also, one can vary Coriolis parameter (including a change of sign to mimic the southern hemisphere) to better separate dynamical and radiative effects.

14. L. 245-250: I am sure there are more recent references that show observational estimates of the relevant scales than Kuettner 1959.

15. I found the conclusion section too brief and not providing the justice to the wealth of results the authors have. In particular, dynamical aspects are really not discussed at the appropriate detail level throughout the text and thus in the summary section.

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