Atmos. Chem. Phys. Discuss.,
https://doi.org/10.5194/acp-2017-415-AC2, 2017

Atmospheric Chemistry and Physics Discussions

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

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Received and published: 21 August 2017

Response to Anonymous referee #2

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Discussion paper

1 General remarks

First of all we wanted to thank you for taking your time to go through the manuscript in detail. Your contribution is very much appreciated. Answers to the specific comments are given below. We appended a differential version of the manuscript as supplement.

- *The paper is very short and could do with more material. To start with it should inform the reader about the theory of streets. Line 51/52 is insufficient. The authors tend to be in a hurry to tie the paper up and not deal with details like teasing out the extent to which horizontal photon transport contributes to the results (Line 190). I would have appreciated more analysis. A few choice simulations to focus on various issues would greatly add to the impact of the paper.*

  The introduction on the theory of cloud streets was also a concern for reviewer #1 and we added a paragraph to the introductory part as well as to the description of the model and simulation setup.

  We agree that it would be really interesting to study the effects of atmospheric heating. One could probably artificially increase the radiative heating rates and hopefully see a stronger signal in order to understand as to what extent and which mechanism is changing the cloud shapes. However, we do not think that the set of simulations with the chosen setup allows for further, quantitative analysis of the effects of atmospheric heating rates. The feedback through surface fluxes is most certainly the primary effect and has precedence in this study. We therefore added the study of atmospheric heating rates to the outlook of the paper.

- *The influence of 3-D longwave cooling should be discussed.*

  Indeed, we compute the thermal radiative transfer also in 3D but we expect the impact of 3D effects not to be important for the formation of cloud streets because thermal radiative transfer does not infer any asymmetries (i.e. is rotational symmetric). We added a paragraph to the model description.

- *I liked the intuitive sketch (Fig. 5) but would appreciate a similar sketch pertaining to the dynamics of streets that might help understand the amplification/offsetting of the radiation - particularly the length scales in question.*

  We are not sure if we understand your request. If you mean a figure such as for example in Gronemeier et al. (2016), fig. 3, we feel that, in our case, it does not add a lot to the explanation pertaining the radiative/wind feedback. The length and time scales vary with zenith and azimuth angles and surface heat capacity and we could not come up with a simple sketch that would improve the display of our ideas.

- *The congruence with the quote by Weckwerth (1997) and subsequent sentences (line 210 - 217) really needs some deeper thought and analysis.*

  I think the theoretical foundations concerning as to where the limit of buoyancy vs. shear-stretching lies, are limited. Anyway, it is encouraging to see that the LES simulations reproduce the observations (Woodcock (1942); Priestley (1957); Grossman (1982)). We rewrote the paragraph.

- *Please comment on how static heterogeneities might play out over land, where the 3- D solar radiation influence is significant. Particularly when the wind advects a boundary layer that includes the net effect of upstream static (and dynamic) heterogeneity. The scale of the patches and the advective wind will be important. This links in to my request to tie the discussion more tightly to the dynamic theory of streets.*

  Static heterogeneities and their influence are in part tackled in Avissar and Schmidt (1998); Patton et al. (2005); Rieck et al. (2014). Furthermore, Gronemeier et al. (2016) investigated the interplay of static surface heterogeneities and radiatively induced, dynamic heterogeneities. While studying this interplay is clearly a very interesting and important aspect, we feel that there is probably not much potential gain in yet another study with idealized setups. We mention in

the outlook of the paper that we hope to study the effects of 3D radiative transfer in a more realistic setup within the High Definition Clouds and Precipitation for Climate Prediction (HD(CP)2) project.

- *Finally, the paper contains some testable hypotheses that I urge the authors to pursue with data since it will add much value to this line of research. (I'm not saying this should be done in the current paper.)* Thanks, I agree. Specifically, as noted in the point above, we very much look forward to checking whether we can reproduce the effects in a realistic setup and compare that to satellite observations. Another strategy we will try is to look for statistically significant organization of cloud streets in high resolution satellite imagery. Specifically whether the cloud streets follow the solar azimuth angles.

2 Specific Comments:

- *Line 267: I think you mean "simulations" rather than data.*

  Indeed, corrected.

- *Line 272: Again please include more theoretical explanation of dynamically induced cloud streets.*

  We added an additional paragraph to the introduction and rephrased this particular sentence.

- *When you use the phrase "surface heterogeneities" in the text, please be clear that this is a dynamical heterogeneity.*

  Yes, I went through the text and added clarifications where possible.

- *The LWP threshold > 1 for the cloud mask is much too rigid but I expect has little to no bearing on the results other than how it will bias the quoted cloud fractions. An optical depth threshold might be more useful/relevant anyhow.*

  Indeed, I checked and as you expected, it changes the cloud fraction usually by less than 1% and neither has an impact on the selection of time-steps nor on the autocorrelation ratios.

Many thanks,

Fabian Jakub

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