Referee's Report: On the interaction between marine boundary layer cellular cloudiness and surface heat fluxes

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Summary:

In this study, the authors use three dimensional cloud system resolving simulations to investigate the interaction of closed and open-cellular mesoscale marine low clouds with their correspondent surface fluxes of latent and sensible heat, as well as sea-salt aerosol. The relative contributions of the component dynamical fields for each flux type are diagnosed in simulations with interactive fluxes, and simulations using spatially homogeneous fluxes prescribed from the interactive runs are used to demonstrate that enhanced sensible fluxes are key to the maintenance of the open-cellular state. While the study is generally well written and furthers understanding of the dynamics of open-cellular convection, some additional analysis would be nice, and the figures require substantial modification. Publication in ACP is recommended after major revisions addressing the issues below.

General Comments:

1) Role of sensible heat flux in maintaining the open cell state: The simulations conducted and time series provided in Fig. 13 do a nice job of showing how a reduction in sensible heat flux leads to a cooler, moister surface layer with a lower lifted condensation level (LCL) and increased rain rate, eventually leading to a sharp increase in number of rain areas, downscaling cell sizes and desynchronization of convection. However, time series also show that the sharp changes in organization only occur in the final six hours of simulation S_{hybrid}. The LCL decreases substantially early on in the simulation, and yet the dramatic shift in organization doesn’t appear to occur until thirty hours in. Nothing in the text, Fig. 13, or any of the other figures provides a means to understand the reason for this delay, and further, it is not clear that the base simulation S_{open} would not undergo a similar transition if run for an additional 24 hours. The authors correctly point out that none of these simulations are in equilibrium (though simulation S_{closed} may be approaching it); thus, at best, the simulations suggest the desynchronization and rapid growth in number of rain areas is prevented by the higher sensible flux for the 36 hour length of the simulations S_{open} and S_{open}''. If the specific mechanism or criterion could be established for the onset of growth in the number of rain areas, this would significantly strengthen the results. Attention to the average properties and depth of the surface mixed layer might be useful here, and in general, some additional attention to the vertical structure of the boundary layer might help clarify what is going on. Analysis of the time evolution of histograms for column LCL or column rain rate might be helpful, as well.

2) Synchronization of convection: While the magnitude of domain-wide oscillations certainly seems to damp more in the final six hours of S_{hybrid}, it would be nice to have a way to gauge this process. Perhaps looking at anomalies of the various quantities by separating the domain into quadrants and showing that anomalies by quadrant decorrelate with each other would do this. Additionally, strong correlations between the anomaly time series in each quadrant of the base simulation S_{open} would reinforce the idea that the processes really are synchronized domain-wide in persistent open cell convection.
3) Figures: The majority of the figures, especially multi-panel plots of various quantities, domain-wide, attempt to do far too much. Redundant axis and contour labels result in quite a bit of wasted white space. Vector field layers in multi-panel plots of this type are simply inappropriate, as printing the paper in color at normal size renders such fields illegible, and thin contours are not much better. While enlarging the document by 1600% on a laptop allows the figures to be reasonably appreciated, this brings even a reasonably high spec machine to its knees, making it very difficult to make use of the paper at all. These are perhaps reasonable in the SI, but not elsewhere. Specific comments on the figures are given below.

Specific Comments:

- 1 Introduction
  - How is closed-cellular mesoscale organization different from the organization of precipitating trade cumulus, where cloud arcs are the result of cold pooling? E.g. Seifert and Heus, 2013 (ACPD).
- 3 Simulations
  - For clarity, is the FT aerosol concentration initialized identically to that in the boundary layer?
- 4 Results and discussion
  - Simulation names: A more descriptive, somewhat less hieroglyphic naming approach would be easier to follow in the text, obviating the need to constantly refer back to Table 1.
  - Based on LWP trace in Fig. 3 for run S_{closed}, it seems possible that the boundary layer has decoupled around hour 18. How does the degree to which the boundary layer is coupled project on surface flux correlations with cellular structure in the closed simulation?
  - P18863L3: What causes the opacity reduction in cell centers? Have the effective radii of cloud droplets there significantly changed?
  - P18865L15-20: Does the conclusion regarding detrainment include the effects of the imposed large scale divergence? From Fig. 5, it appears that while closed cell entrainment is approximately 5mm/s, the open cells, based on a 130m drop in z_i from hours 20-36, are entraining at $w_e = dz_i/dt - w_{ls}$ = -0.0023-(-3.75e-6*1000) = 0.0014 m/s.
  - P18874L13-29: An attempt at a simple aerosol budget would be nice here. What fraction of the aerosol activate? What is the estimated loss rate due to collision coalescence?

- P18876L7-25: The role of the balance between entrainment and large scale subsidence seems worth mentioning here, as well.
- P18877L3-14: It is a nice result that the small scale variability of fluxes seems to have limited impact on the statistics of the boundary layer evolution as a whole. However, since the domain-mean fluxes are determined by the net result of interactions between the fine scale dynamical fields and the surface, the circulation still must be resolved (which, based on results of UKMO modeling, seems to require roughly 1km resolution) or parameterized adequately (potentially quite difficult).

- Figures
  - Fig. 6: For clarity, recommend stacking panels vertically and stretching plots horizontally, increasing separation between individual peaks in the anomaly time series.
  - Fig. 7: This figure is very difficult to use and hard to read. As the full time series for each of the plotted variables have already appeared in Figs. 4e, f and 6b, recommend choosing a representative six hour period to allow easier examination over a shorter number of cycles; alternatively, compositing over the peaks in rain rate might give a clearer picture of the leads and lags the figure is trying to display.
  - Fig. 8: The vector fields, even in this best case usage against a mostly white background, are quite difficult to use at the given density for the panel size. Also, the main idea in the text discussing the figure on P18867 seems to be the divergence. As such, perhaps a better alternative would be to use a filled contour plot of divergence using a jet color map with white contours of rain rate for 1 mm day^{-1}. A second panel could use a contour of surface temperature of 289 K to show the asymmetry of cold pools due to the mean surface wind. If the original plotting choices are preferred, cropping down to a single domain quadrant would perhaps make the vector field usable.
  - Fig. 9: The discussion of P18867L25-P18868L19 cannot be easily understood without extreme magnification of the figure. Perhaps focusing on a single quadrant of the domain would enlarge these features enough to appreciate the patterns; even so, the residual wind field is quite difficult to see; a separate shaded contour plot of surface divergence would be more helpful.
  - Fig. 10: Much as in Figs. 8 and 9, there is simply too much going on here. Vector field in panels (a) and (b) is illegible at any reasonable printing size. The needless repetition of the contour color scale and horizontal/vertical axis labels uses extra white space that could be used to enlarge panels and improve readability. As above, perhaps choose a single quadrant to show.
  - Fig. 11: As in Fig. 10, recommend choosing a single quadrant.
  - Fig. 14: Vector fields are illegible. Recommend same strategy as in Fig. 8.
  - Fig. 17: Panels (a) and (c) are essentially useless: simply relying on text to describe the case as non-precipitating and overcast should be sufficient.

Technical Comments:

- Text:
  - P18859L24: perhaps "…parameterized using the Community Atmospheric Model scheme…" rather than "…described with…"
  - P18866L23: prefer 'jumps' over 'hikes' to describe elevated surface water vapor
- Figures:
  - All multi-panel figures: move panel letters to upper left from bottom left corners.
  - Fig. 3: Delete redundant right hand y-axes, they take up unnecessary space and are distracting. Consider only including x-axes labels for bottom row.
  - Fig. 4: Perhaps find a way to visually indicate which panels correspond to which simulation, e.g. the simulation name with a left brace or bracket grouping the top row for S_{closed} and the second and third rows with S_{open}
  - Fig. 5: Delete redundant right hand axis
  - Fig. 7: depending on final presentation, delete redundant color bars.
  - Figs. 9, 10: Legend for contour intervals wastes space, recommend simply listing contours and colors in caption. Since fields are at synchronous times in all panels, list time/date once at top of figures and delete from all other field titles to save space
  - Fig. 13: Delete redundant right hand y-axes. Consider only including x-axes labels for bottom row.
  - Fig. 14: Regardless of final form, delete contour legends and simply list in caption.
  - Figs. 15, 17, 18: Delete redundant right hand y-axis.