Response to Reviewers

We appreciate the thorough consideration of the manuscript from both reviewers. We have incorporated the comments into the manuscript without exception. We are gratified that both reviewers found the analysis and level of detail presented in the manuscript as “clear” and “very good”.

Our responses below are shown with the specific comment from the reviewer in red and our response directly below in blue.

Referee 1

General comments:

The authors investigate the structure of large-scale circulations (LSCs) in turbulent Rayleigh-Benard convective with aspect ratio 2, and in the presence of multiple scalars (temperature, water vapor mixing ratio, and saturation ratio). This study is motivated by the Michigan Tech Pi chamber, a unique facility to study interactions between aerosols, turbulence, and cloud microphysics. While the Pi chamber has yielded many valuable insights, the effects of spatial heteorogeneity in the chamber on the scalar fields has not been investigated in detail. The authors present clear evidence of LSCs in the chamber, which have a non-negligible influence on the skewness of temperature, water vapor mixing ratio, and saturation ratio. The manuscript is clear, well-written, and of an appropriate focus and scope for AMT. I have some specific comments below I recommend that the authors address, but these should not be a barrier to publication.

Specific comments:

1. r is defined as both droplet radius in l. 23 and water vapor mixing ratio in l. 53. I would suggest a change in notation.

- We agree with the reviewer. We have changed r so that it solely defines the water vapor mixing ratio. The droplet radius is now defined as R.

2. The saturation ratio is used several times (ll. 22, 35, 82, 92) before it is actually defined in Equation 2; I would suggest defining it the first time it is used.

- We have added the definition in the second paragraph.

3. l. 103 What approximation of the Clausius-Clapeyron equation is used to calculate saturation vapor pressure? I'm guessing that it is probably based on an empirical fit that accounts for the variation of the latent heat of vaporization with temperature, but more detail would be beneficial.

- We have used the Magnus equation to calculate the saturation vapor pressure. This approximation accounts for the variation of the latent heat of vaporization with temperature. We have added this point to the manuscript.

4. Fig. 2 caption "temperature calibration of the sonic temperature" sounds redundant; consider rewriting.

- The caption of Fig. 2 has been changed to now say “calibration of the sonic temperature”.

5. l. 146 "The grid spacing is 3.125 cm" in reference to the LES. Is this only for the horizontal grid spacing, or also the vertical grid spacing? So the LES grid is 64x64x32 points? This seems very coarse to me, and it doesn't appear that the authors are using bin microphysics (which has a significant computational cost)? Why not run at a higher resolution? Have grid convergence tests been done to demonstrate that this resolution captures turbulence satisfactorily within the Pi chamber?

- The LES grid is 64x64x32 points. Both the horizontal and vertical grid spacing of 3.125cm. The LES grid spacing is chosen such that the spatial scale is at least 30 times the Kolmogorov length scale - and lie in the inertial range according to Monin and Yaglom (2013). The turbulent dynamics - energy dissipation rates, TKE and large scale oscillations - from the simulations have been matched with the experimental values (Thomas et al. JAMES 2019). We have added this clarification to the manuscript where the LES is introduced.

6. l. 147-150 Discussion of 50 min spinup and 70 minutes of data analyzed from the LES. It is helpful to have these listed in dimensional values, but from a fluid mechanics perspective what matters is the number of independent samples (or integral timescales) that one is spinning up and averaging over. Can these values also be reported in the text?

- The 50 min spinup and 70 min of data are 30 and 42 times greater than the period of the LSC respectively. We have added this to Section 2.4.

7. l. 201 High pass filter "with a cutoff of around 5 minutes" Is it possible to give the exact temporal filter width here, rather than giving an approximation? Also, what is the filter kernel that is used here (e.g. is iit a spectral cutoff filter, Gaussian, box filter, or something else...)?

- The filter used is a spectral cutoff filter with a center of 3.3145 and width of 0.82846. We have included the width and center values in line 201.

-8. l. 202 Discussion of the period of large-scale circulations. The authors presented evidence that the amplitude of the LSC varies with the temperature difference between the top and bottom walls, but what about the frequency of the oscillation? I'm assuming this is discussed in the literature, so it would be useful to highlight previous studies here.

- The frequency of the LSC is dependent on the temperature difference between the top and bottom plates of the chamber (See Niedermeier et al., 2018). We have clarified this in the manuscript in Section 3 and we have added additional references to support the finding.

Technical corrections:
None needed, to my knowledge.
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