

Atmos. Meas. Tech. Discuss., referee comment RC2  
<https://doi.org/10.5194/amt-2021-13-RC2>, 2021  
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## Review of the manuscript amt-2021-13

Anonymous Referee #3

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Referee comment on "Effects of the large-scale circulation on temperature and water vapor distributions in the  $\Pi$  Chamber" by Jesse C. Anderson et al., Atmos. Meas. Tech. Discuss., <https://doi.org/10.5194/amt-2021-13-RC2>, 2021

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### Overview

The manuscript presents a description and analysis of the laboratory experiments performed in order to characterize the thermodynamic properties of the large-scale circulation formed within the turbulent Rayleigh-Benard convection in the  $\Pi$  Chamber. This characterization is based on the measurements of temperature, water vapor and saturation ratio at a number of points in the mid-plane of the chamber under dry and moist conditions. Although the obtained results cannot be directly related to physical processes in the atmosphere, the true relevance of this work is that it provides a valuable context for a few previous laboratory studies at the  $\Pi$  Chamber which focused on cloud droplet activation and condensational growth in a turbulent flow. The experiments are described in detail and the quality of the analysis is very good. I recommend publication after addressing the comments below.

### General comments

In my opinion, the great advantage of the paper is the experimental work done as well as the detailed description of the experiments and the following analysis. As far as I understand, the objective and the motivation for the study was "to measure the spatial and temporal variability in  $r$ ,  $T$  and  $S$  in order to determine how closely the models of reduced dimensionality capture the true variability in the chamber" (line 82). The first aspect was addressed very well, the second only shortly mentioned in the conclusions (line 282).

You concluded that "models capture the essential variability of  $T$ ,  $r$ , and  $S$  in the chamber". Please be more specific about what the models capture. Do you mean the single roll LSC pattern or the PDFs of the fluctuations? I presume that the issue is subject

to ongoing work, however I suggest discussing briefly some implications of your results in the last section, e.g. on the interpretation of the previous findings from the Pi chamber.

I suggest collecting all the information about the instrumental configuration and the execution of the experiments in the methods section. In a few places, I wanted to request additional details but then found them further in the paper (in sec. 3 or 4). For instance: what was the position of the sonic with respect to the hygrometer and whether the paths were coincident (given in line 231), why the inner ring was not used in the moist experiment (given in line 230), how many and what runs were performed (deduced from the figures), how long were the measurement series (given in the figures and their captions).

For the convenience of readers, the strategy of the study may be explained in a straightforward way in one additional paragraph. It became evident to me only after reading the result sections that: the role of the outer ring was to track the orientation of the LSC, the role of the inner ring was to characterize the temperature field in the dry experiment, the traverse was (probably) introduced at the expense of the inner ring to characterize the humidity and saturation fields in the moist experiment, and the crucial assumption is that the behavior of the temperature field does not change significantly between dry and moist conditions (line 228) which can be justified by comparing the terms of Eq. (1). You can consider organizing sec. 2 into subsections about the facility, instrumentation, experimental strategy and influence of path averaging.

## Specific comments

- You seem to use “we” and “our” in two meanings: the authors of the paper as well as the broader research group (e.g. line 6, line 34, line 76). Please avoid such a confusion because it may lead to the misunderstanding of what you did within your present study.
- Please determine whether  $r$  denotes the concentration of water vapor molecules ( $\text{cm}^{-3}$ ), water vapor mixing ratio (per unit mass of dry air, g/kg) or water vapor mass fraction (specific humidity, per unit mass of moist air, g/kg), and use the same term consistently throughout the manuscript. The same symbol should not be used for droplet radius (line 23).
- Please mind the difference between saturation ratio and supersaturation. If  $S$  denotes the former, then the equation in line 23 should read  $dr/dt \sim (S-1)/r$ .
- Lines 58-73. In your thorough introduction you summarize previous studies on the LSC in turbulent RBC and describe the findings concerning mean flow patterns. Has anyone studied higher order moments (variance and skewness) as you did or is your work unique in this aspect?
- Lines 94-98. You specified boundary conditions in terms of temperature. What are they in terms of humidity? Are the walls kept saturated in moist convection experiment?
- Lines 116 and 119. You sampled  $r$  and  $T$  at 1 Hz with your hygrometer and sonic. Does this frequency correspond to the time constant of the instrument (i.e. the effective averaging time is 1 s) or to the rate at which you recorded the data (i.e. the averaging time is smaller but you save a result once in 1 s)? This question is relevant because

both instruments are capable of much faster sampling.

- Lines 119-120. "The sonic temperature sensor operates on the same physical principle as a sonic anemometer, using the Doppler shift in emitted and detected sound waves to derive the quantity of interest, using the known speed of sound." Are you sure the operation principle of your instrument is as described? As far as I know, most sonic anemometers rather than Doppler shift determine the transit times of an acoustic signal in two opposite directions out of which flow velocity and speed of sound can be estimated. The latter depends on air humidity. Hence,  $c$  can be inferred.
- Line 123. How did you calibrated the sonic thermometer - does the procedure involves any adjustments in the instrument itself or did you fit some calibration curve (e.g. straight line) to the recorded values?
- Sec. 2.1. I appreciate the analysis of the influence of averaging along the measurement path on resulting turbulent fluctuations.
  - In addition to spatial averaging, I suggest considering temporal averaging. Assuming, the time in your LES can be interpreted as physical time, the sampling of the "ideal measurement" is 50 Hz whereas the sampling of the real measurement is 1 Hz (see comment 6 first). Taking this into account, spatial averaging should have smaller influence and comparing the spectra (Fig. 6) turns out rather unnecessary.
  - You analyzed the averaging effects only for the central part of the chamber and the paths which are symmetric with respect to the central point. However, in the moist experiment the hygrometer and the sonic seem to be located far from the center for updraft and downdraft (the exact position is not given). Can you explain the choice? The path averaging can possibly exert more influence on the measurements further from the center. I am aware that repeating the LES is rather not feasible but having the timeseries at your 41 points, I would suggest considering asymmetrical and off-axis paths. This will add more points to Fig. 4.
  - Grid boxes in a LES have finite volume. In fact, your single grid box have the volume significantly larger than the measurement volume of the hygrometer and the sonic given in sec. 2. This fact can be used as the argument in favor of your measurements resolving considerable portion of turbulent statistics.
- Lines 178-178. "Due to the positive correlation between the vertical velocity and temperature, either variable can be used to find where the mean updraft is located." Can you provide a reference which proves that?
- Fig. 7. Please add error bars to the points. This should be straightforward as you performed a direct measurement of temperature.
- Line 186. "smaller than the uncertainty in the fit". Please provide a typical value for the uncertainty of the fitted orientation and amplitude. Please comment whether the goodness of fit changes in time.
- Line 187. "azimuthal oscillations". Are they related to the drift in chamber controls which you filter later or are they the inherent property of the LSC? Does this oscillation have the frequency  $f_0$  determined in sec. 4?
- Line 195 and Fig. 10. Please fit the lines and draw them in the plot.
- Line 197. Do you mean the orientation of the LSC is the same for different experimental runs? Does the presence of the traverse in the moist experiment have any influence?
- Line 204. As far as I understand, after the binning of the individual instantaneous measurements you calculated the standard deviation within each bin separately. This implies that, in principle, the measurements from different sensors contribute to each resulting  $\sigma$  value. Please clarify.
- Figs. 11, 12 and the relevant discussion. In my opinion, introducing absolute value of angular position versus updraft is misleading. I suggest using the deviation itself with its sign specifying the side of the chamber. In the figures, please use the entire range  $[-n, +n]$  or consider presenting the data in the form of polar plots. For convenience, you may add additional "updraft" and "downdraft" labels.
- Line 233. Did you perform the moist experiment for only one temperature setting because of the required duration? Is there any specific reason for choosing  $\Delta T = 12$  K?

Please explain the strategy (see general comments).

- Line 233. What was the exact position of the sensors for updraft and downdraft regions in the moist experiment? Was it 30 cm from the center where the inner ring of thermometers was located in the dry experiment? Please provide those details in sec. 2 (see general comments).
- Line 238. Can the circulation frequency be attributed to azimuthal oscillations, sloshing mode or did you mean it is related to the LSC turnover time?
- Figs. 14, 15 and the relevant discussion. Are the fluctuations  $T'$ ,  $r'$  calculated with respect to the time average for each measurement point or with respect to the global mean values in the chamber similarly to  $S$  in Fig. 16?
- Figs. 14, 15 and 16. For better readability, I suggest combing those three figures into one with 3 panels. You can refine x axis range to show the central part of the PDFs.
- Lines 240-261. I suggest providing the results in a table: mean values, standard deviations, skewness of  $T$ ,  $r$ , and  $S$ .
- Line 274. "qualitatively similar". Do you mean their Gaussian-like shape or some other property? Please clarify.

## Minor issues

- Line 12. "consistently" – do you mean at each position? Please clarify.
- Line 60. "near one or two" – do you mean the whole range or two separate values?
- Line 87. "respects" – do you mean "respects" or "aspects"?
- Line 123. "sonic temperature" – do you mean "sonic thermometer"?
- 4 and 5. Please increase the size of the symbols.
- Line 169. Wrong formatting of the unit "cm".
- Line 202. "period of the LSC" is unclear and  $f_0$  is not defined at this point. Please refer to sec. 4 and Fig. 13 here.
- Lines 218, 220, 221, 222. I assume you meant  $n/2$  instead of  $n$  to denote the directions perpendicular to the LSC.
- Referring to equations. The house standard of AMT is Eq. (n).
- Please add DOIs. This enables the reader to access the cited paper through a single click.