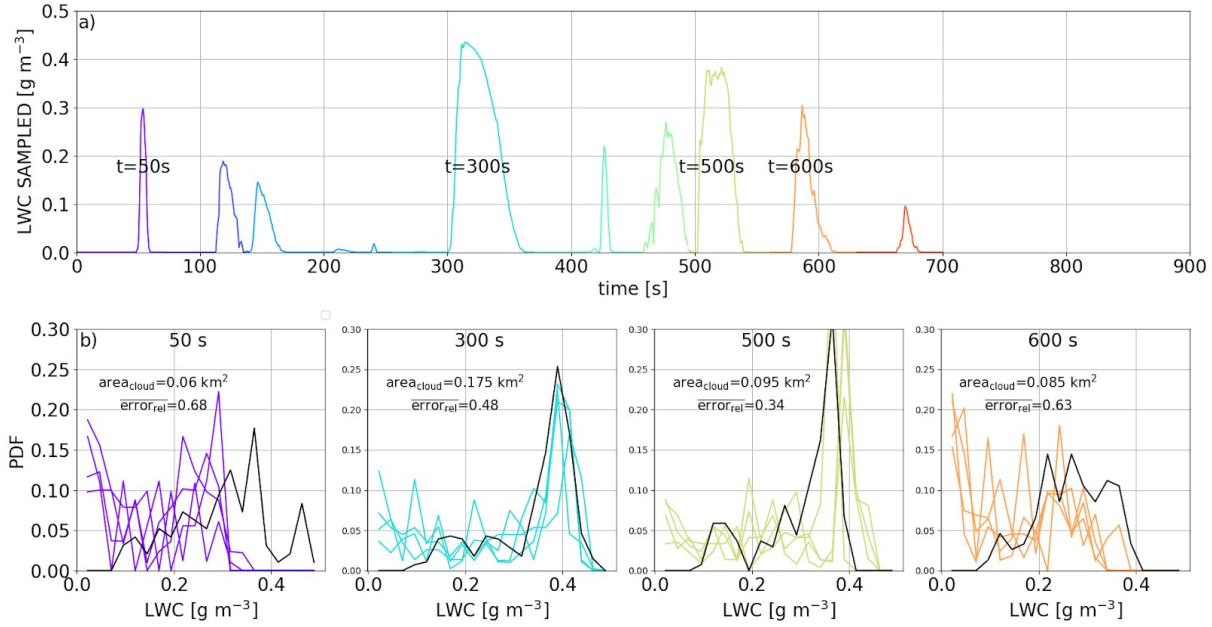
We wish to thank the reviewer for his/her careful review. Below are our responses (in red) to the comments (in black) on a point-by-point basis. The new text in the manuscript is indicated in quotation marks.

After providing an access review for this article previously, I have now reread it in some more detail. The approach described here is certainly worth pursuing, but I still think the manuscript would greatly benefit from the inclusion of some exploration of the time-evolving case with multiple RPAs. This could be a proof of principle to show that it is possible to characterise the time-evolution of the cloud.

We intend to investigate GPR mapping using a much larger number of RPAs; however, exponentially more computer resources were needed and, unfortunately, we were not able to go beyond two RPAs for this study. Nonetheless, this manuscript shows that two RPAs and GPR mapping are needed to adequately characterize cloud heterogeneities on small enough scales to quantify important parameters such as total LWC.

We are currently optimizing the simulations to conduct the cloud mapping with several (up to 6) RPAs in a dynamic environment to define temporal scales as a function of the number of RPAs.

For the time-evolving case, some of the transects in the mature phase (e.g. transect 4 and 7 in figure 15) might resemble the full PDF, but these could be "lucky" transects. Moreover, since the analysis is on single transects here, there does not seem to be an advantage over using single passes with a traditional approach.



We have augmented Fig. 15 with additional simulations to show the robustness of the sampling strategy (that the results are not "lucky").

In principle, many of these exploration techniques can also be applied to traditional aircraft; however the main advantage of using RPA is that multiple platforms can be coordinated simultaneously.

The abstract should at least mention that a single RPA isn't enough to accurately reconstruct individual clouds.

We have updated the abstract to state that a single RPA is not sufficient to accurately reconstruct individual clouds using an adaptive sampling strategy and advanced mapping techniques.

We have added in the abstract :"While a single RPA coupled to GPR mapping remains insufficient to accurately reconstruct individual clouds, two RPAs with GPR mapping adequately characterize cloud heterogeneities on small enough scales to quantify important parameters such as total LWC."

I also think the focus on only 3 clouds (even if these clouds are sampled from multiple starting points) is a weakness of the study. Clouds tend to vary considerably in terms of their shape, especially when they contain multiple updraught cores, so it is hard to see if the results here are generally robust. Showing the LWC convergence for at a few more clouds in the same class size as N2 and N3 would help to establish robustness.

The three clouds used in this study (N1, N2, N3) have not been chosen arbitrarily. We conduct an extensive analysis of the cloud population simulated in the LES to carefully choose the clouds for this study (Figure 4), and show that the three clouds are representative of the cloud population. In addition, they also show similarities with the clouds sampled in Zhao and Austin (2005). Each of the clouds have non-circular cross-sections with fractal edges, illustrating the capability of the GPR mapping.

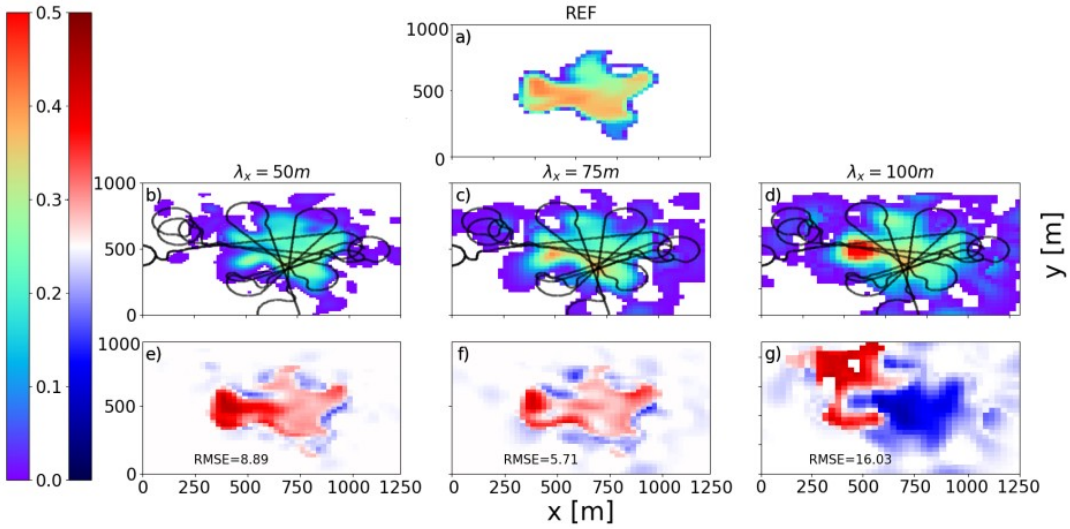
Random sampling of the clouds via different entry points has a similar effect as using multiple clouds by generating unique trajectories that capture the fractal nature of the clouds. Figure 13 establishes the robustness of sampling the different sizes of clouds and the limits of the sampling strategy and length scales.

The length scales for GPR currently seem to be chosen by trial and error, but will depend on both the cloud scale and how well the cloud has been sampled. Note that 75m seems to give a good PDF of LWC, but the LWC RMSE is relatively high. It would also be worth pointing out that clouds are fractal objects, and that this is one of the reasons an ellipse/circle reconstruction fails (another reason is that a transect may not pass through the actual centre).

The length scales are tested for different types of clouds and the value of 75 m remains the most suitable to reconstruct a LWC field, whatever the size of the cloud. And indeed we are well aware of the fractal nature and use Figure 9 to clearly demonstrate that an ellipse/circle reconstruction does not work well. In the discussion of Figure 9, we add in the text that clouds are fractal objects "Clearly, none of these relatively simple methods are able to accurately reconstruct the cloud cross section (Fig. \ ref{volume_transect}),particularly related to the fractal character of the borders of cloud cumulus."

As mentioned earlier, the target for the center of the clouds is weighted by LWC from GPR mapping and is recalculated after each transect through the cloud.

Regarding the high value of the RMSE for a length scale equal to 75 m (f),the simulated cloud and the reconstructed one were not overlayed properly. We thank the reviewer for catching this. The figure has been rectified as shown below(and has also been updated in the manuscript).



There is another comment on the discussion which mentions the effective resolution of the strategy is 164m. This interpretation does not look right to me, but it would still be good to discuss the practical limitations on resolution that the RPAs may have.

As discussed in responses to the previous review:

The mixing time stated Baker et al.1984, provides a target temporal resolution for assessing the evolution within the cloud. . As noted by the reviewers, for the simulations shown in Figure 11, this scale analysis suggests that total LWC needs to be measured within temporal scales of ca. 200 sec (using a 100 m length scale defined in Bodenschatz et al., 2010).

We can also assess mixing length scales (L) using the follow expression (Taylor, 1935),

$L \sim w3 / \varepsilon$

Updrafts (w) in trade wind cumuli are typically > 1 m/s (Katzwinkel et al., 2014), resulting in length scales > 1000 m (which are often larger than the cloud itself). This scale analysis suggests that spatial scales in clouds are driven by gradients in updraft, which mostly occur at the cloud edges. Therefore, to estimate total LWC, the identification of cloud edge and fractal morphology of the cloud is most important.

Overall, I think some major revisions would really strengthen the article, and make it suitable for publication. Besides these general comments, I have included a list of minor issues below; these are mostly simple to address though.

General notes:

- Subfigure labels are missing on most plots. corrected

- A non-uniform aspect ratio is used in some figures (e.g. figure 9)

- Some fonts are often too small (e.g Fig 1, 5-6, 8 and 14-15) Fonts sizes have been increased

- Figure 6: The black lines in b. are hardly visible The black line has been enlarged

- Figure 7: It is hard to compare the LWC in the reconstructed cloud with the LES field here, though figure 9 clarifies this.

The color palette was chosen to better visualize the measurements made during the first transect and for the entire exploration.

- I think the "(1-\sigma)" notation for standard deviation is confusing. Is the mean +/- the standard deviation meant?

The notation «(1-\sigma)» has been changed by ±.

Line-by-line:

- l3: Earth (capitalise) corrected

- l15: "allows to track" → "allows tracking" corrected

- l24" "oceanic surface" → "ocean surface" corrected

- l25: remove "annual" corrected

- l29: "climatic" → "climate" corrected

- l34: "The studies on these processes" → "Studies of these processes" corrected

- l43: "(i.e. the Fast-FSSP (Brenguier et al., 1998) to the HOLODEC" → "(e.g. the Fast-FSSP (Brenguier et al., 1998) and the HOLODEC" corrected

- l47-49: “Some measurement field campaigns have allowed a re-sampling in clouds with aircraft (Burnet and Brenguier, 2007) and with sensors suspended below a helicopter during the CARRIBA campaign (Siebert et al., 2006, Katzwinkel et al., 2014).” → This sentence is not clear.

We have modified this paragraph to clarify that in-situ sampling strategies are still too limited to reconstruct a horizontal cloud cross section with conventional equipment.

“Observations from research aircraft such as Burnet and Brenguier (2007) or with sensors suspended under a helicopter (Siebert et al., 2006, Katzwinkel et al., 2014) have conducted multiple transects through an individual cloud with a lower frequency (a maximum of five transects). It has been shown that airplane transects without cloud mapping induce a bias in cloud sampling by oversampling the cloud core (Hoffmann et al., 2014). In addition, this manuscript illustrates the importance of extending the transects with GPR mapping to capture the fractal nature of clouds.”

- l52: “in detail” (singular) corrected

- l64: “ microphysic” → “ microphysical” We have removed the term “microphysical”.

- l68-72: “ Section 3 highlights the results of the LES case study with an overview of the cumulus field...We then select one cloud representative of each category and analyze the evolution of their macrophysical and thermodynamical properties, by comparing the exploration strategy and the capacity of the RPAs to reconstruct the microphysical and macrophysical fields for static and dynamic cases.” → Both of these sentences are unclear, in particular “an overview of the cumulus field” and “analyze...by comparing the exploration strategy” (which suggests the exploration strategy for static cases is different from that for dynamic cases, it is unclear how “comparing” refers back to “analyze”).

We have attempted to clarify this paragraph:

“Section 3 highlights the results of the LES case study with a description of the cumulus field. We first classify individual simulated clouds into three categories based on their volume. We then select individual clouds representative of each category and analyze the evolution of their microphysical, macrophysical and thermodynamical properties using an adaptive exploration strategy for static and dynamic cases. . ”

- l78: “the period between 22 to 23 June of the Phase 3 of the BOMEX campaign characterized” → “the period 22-23 June of phase 3 of the BOMEX campaign. These days are characterized” corrected

- l81: “LESs” → Rephrase (the plural form is confusing) corrected

- l85: “Well-represented” does this mean the simulations are in line with the intercomparison case? As this is pointed out later, I would leave it out here. We agree and we have removed ”well-represented”.

- l87: “is initialized... decreases” → make plural corrected

- l89 and elsewhere: asl → ASL corrected

- l93: " the piecewise parabolic model" → I think this has not been introduced.

We have simplified the description of the simulation set-up.

"The classical configuration for LES (detailed in Lac et al. (2018)) is used here."

- l98: using a single moment scheme may be appropriate in this case, but there is not really a justification given.

We agree, but the reason for using a one-moment scheme is that no aerosol size distributions were measured during the BOMEX campaign to initialize a two-moment microphysical scheme.

In addition, since these RPAs did not measure aerosol size distribution, we chose to stay with the use of a one-moment scheme to compare with previous BOMEX simulations (Siebesma et al., 2003).

- l104 "four times" The LES simulation was conducted just one time for both domain sizes."

- l108: "outputted" → "stored" corrected

- l109 and elsewhere: "high-resolution" corrected

- l115: It is worth noting the onset of convection is delayed and much more active in Meso-NH. Added "(20 minutes delay in Méso-NH; however, convection results in a similar intensity)".

- l117: Put the year 2003 in parenthesis. corrected

- l124: "cloud entire life cycle" → "entire cloud life cycle corrected

- l126: "the function of time" → "a function of time" corrected

- l130: "isolates..defines" → "isolate...define" corrected

- l132: it is unclear if/where faces, edges, or corners respectively are used in the tracking algorithm

We re-phrased this sentence: " For each cloudy cell, the method identifies the neighboring cells connecting by their face, edge or corner "

- l150: "RPAS" → "RPA" corrected

- l175: It is worth pointing out here that the few clouds in class 3 contribute disproportionally to cloud volume, mass-flux and heat and moisture transport.

We have added a sentence mentioning the importance of these cumulus clouds in the mass transport budget in the boundary layer.

"Despite the small number of clouds classified in class 3, they have a disproportionate role in the transport of moisture and heat in the boundary layer since their mass flux is more than an order of magnitude larger than the clouds of class 0 and 1. "

- l180: "the minimum and maximum lifetime...over their lifetime" → rephrase

We have rephrased this sentence:

" For each class, the minimum (maximum) lifetime is calculated by averaging the smallest (largest) 10th percentile, and the minimum cloud base height (cloud top height) is calculated by averaging all the minimum cloud base heights (cloud top heights) of each cloud during their lifetime."

- l184: the smaller clouds may sometimes be remnants where tracking has failed, which would explain their higher cloud base.

We agree.

- l187: "vertical extension and variations" → what is meant by variations here?

We meant variability in vertical extension -- 'variation' is not needed so we have removed it.

- l193: "The standard deviation is 200 times greater than the average flux for cumulus class 0, while it is only 1.37 times greater than the average mass flux for class 3." → I am a bit sceptical of the first result. Maybe leave this out, as it is not supported with further data or figures. The large standard deviations could be the result of using large bin sizes for the classes.

Indeed, the large deviation is related to the relatively large bin size for class 0, which also has shorter cloud lifetimes. We have removed this sentence.

- l205: "are followed" → "is followed" corrected

- l215: "summit" → "top" corrected

- l220 and 344: "maturity" or "its mature phase" corrected

- l226: "has permitted [to describe the→ the description of] heterogeneities [of→ in] the horizontal and vertical structure of cumulus clouds, in particular with respect to LWC" → Horizontal structure only seems to be described later in the article. corrected

- l244 and elsewhere: "the cloud N2" → "cloud N2" corrected

- l249: “and 4% of grids have a LWC near 0.40 g per m^3” → this description is imprecise

We have clarified this sentence to read:

“... and 4 % of cloud grids have a LWC that approaches the adiabatic value of 0.4 g per m^3.”

- l252: remove parentheses corrected

- l253: Does the LWC really approach the reference distribution (without reconstruction, at this point)? It seems like high LWC is still oversampled. The description also doesn’t make it clear the PDFs for the later transects are cumulative.

The PDF distribution of LWC approaches the reference distribution but values are still overestimated at the end of exploration (but much less than with only one transect). The RPA aims for the cloud center, which is recalculated after each transect. In a static case; this leads to an oversample of the cloud center. In a dynamic environment; the frequent resampling of the cloud center allows it to follow its evolution.

We have added that the calculation of LWC distribution has been done with GPR mapping in the caption of Figure 7.

We have completed the term of PDF by a cumulative reconstructed PDF by the sentence ”Note that reconstructed PDF is the cumulative PDF which also takes into account previous transects.”

- l255: “and representing 15% of the cloud cross-section” → This is unclear

We clarify this point in the manuscript:

“15% of model grids in the cloud cross section exhibit vertical wind equal to 0.8 m.s-1, corresponding to the peak of gaussian distribution in the cloud.”

- l258: “above-mentioned” corrected

- l267-268: “For following...Gaussian” → “Below...GPR” corrected

- l272: \lambda_t = \infinity: do you simply mean temporal variation is not taken into account?

Yes, \lambda_t = \infinity means that we do not consider time in the GPR mapping. We have added a sentence in the manuscript to clarify this point.

“For the static case, $\lambda t = \infty$ means that an earlier observation is considered to have the same weight as the last measurements (temporal variation is not taken into account).”

- l287: “with Rosette pattern” → “with a Rosette pattern” corrected

- l288: “is compared” → “are compared” corrected

- l289: Since this is at one altitude only, the units of LWC_{tot} seem incorrect (it may be in gram per meter vertical extent).

The lwctot corresponds to the mass of liquid water contained in the layer of the cross section. The volume of each cloud grid (25 m on each side, 15625 m^3) is multiplied times the number of grids in the cross-section and by each grid LWC to arrive at a total mass of liquid water represented by the layer.

Similarly, trying to derive this without GPR or an ellipse/circle fitting method (the “method_transect”) seems strange. Looking at figure 7, it may be based on a grid here, but that makes it very dependent on the grid spacing used in that grid.

Indeed the “method transect” uses an grid averaged value corresponding to the observations by the RPA. Figure 7 highlights the advantage of using GPR to reconstruct the cloud with a smaller fraction of grids. There is some dependence on grid size, however; Neggers et al., 2003 show that a grid size of less than 50 m is sufficient to characterize microphysical properties of the clouds.

- Equation 1: Use n_{bin} for the number of bins.

The term was modified.

- l312: “Table 2 highlighting a significantly improved mapping the cross section by using the GPR method.” → “Table 2, highlighting a significantly improved mapping of the cross section by using the GPR method.” corrected

- l321: I don’t understand the meaning of “pattern-limited” here. It should still be possible to perform many transects in the smaller cloud and get a good reconstruction, though \lambda may need to be reduced.

The term "pattern-limited" corresponds mainly to the constraint that the U-turn outside the cloud is at least 100 m (corresponding to the turn radius of the RPA). If the size of the cloud approaches the turn radius of the RPA, the RPA can no longer effectively sample the cloud.

- l329: “with time and space” → “with time and in space” corrected

- l329: “and reaches 0.1 by the end of the HFS.” → this is unclear to me

The sentence has been removed.

- l331: comma missing before “tracking”

We do not see tracking in this line

- l338: “continues” → “continue” corrected

- l345: “resembling to” → “resembling that of” corrected

- l348: “ improve the ability to reconstruction of” → “improves the ability to reconstruct” corrected

- l350: “ either via a better sampling strategy of leg adding a second RPA.” → “either via a better sampling strategy or by adding more RPAs.” corrected

- l354: “non-precipitating” → “weakly precipitating”/“without surface precipitation” corrected with “without surface precipitation“

- l356: “derived from the observations in” → “, where the simulations are based on observations during” corrected

- l363: “its growth phase, maturity, and dissipation phases”: remove “phase” corrected

- l366: remove spurious “its” corrected

- l373: “assuming a circular” → “assuming circular” corrected

- l391: “ with a different trajectories RPA” → this is unclear. This sentence mentions both “ To optimize the dynamic exploration of a cloud” and “in improving our ability to observe the cloud life cycle”, which makes it too long.

We rephrase this sentence:

‘To optimize the dynamic exploration of a cloud, at least two RPAs are necessary. To improve our observations of the cloud life cycle, an improved coordination between the RPAs is also necessary to avoid risk of collision and also to couple with different optimized adaptive trajectories.”