Responses to the interactive comments on “The effect of low density over the “roof of the world” Tibetan Plateau on the triggering of convection” by Referee#3

(Authors)

Thanks for your comments on the manuscript.

At first, we illustrate the main purpose and innovation of this study. As mentioned by referee #2, this manuscript presents an interesting approach to looking at variations in convective activity over large orography, based on the corresponding variations in air density at the surface. The observation data show that there is stronger thermal turbulence and higher frequency of low cloud formation over the eastern and central TP which provides a basis for our study of whether there is a relationship among the formation and evolution of frequent convective clouds, low air density, and turbulence generation over the TP. We consider this from two aspects: climate statistics and large-eddy simulation (LES).

Specific comments:

l 79 : “interrelation between turbulence and convective motion” : what do you mean here ? This is too vague, and should be better introduced. What has been done before and what is different here.

Thanks. We have rephrased the sentences. Our intention is to emphasize the effect of thermal turbulence on cumulus convection.

l70-71 : very vague. Delete or rephrase. It is not very clear from the introduction what are the “scientific issues”

Please see the first paragraph.

L114-116 : Why is that? Any idea?

The above statistical results from climate data are closely related to the scientific issue discussed and studied in this manuscript. The above phenomenon is explored with the LES experiments, and our main points are as follows: Larger $\overline{w'\theta'}$ at high elevation (or low density) regions increase the moisture transport from the subcloud layer into the cloud layer, which favors cloud formation. Therefore, with the same relative humidity as a low elevation region, more low cloud exists over the TP.

Fig1a : Are there blue dots under the red ones? It looks like it. Consider using transparency to make the figure more readable and to fully demonstrate your point.

Thanks for your suggestion. We have changed the transparency of the dots, and first plot the dots with low RH_{2m} (RH_{2m} < 72%) which makes figure 1 (a) easier to interpret.

L 154: define the cloud cores here. How do you get them from the model?

The cloud core is defined as the grids with liquid (or ice) water content greater than zero and the virtual potential temperature θ_v greater than average potential virtual temperature $\overline{\theta}_v$ at the same height. The results of the cloud core are derived from the three-dimensional liquid water content, ice water content, and θ_v output fields.

L157-158 : justify and explain physical meaning of this assumption.

L158-159 : confusing: : :. Is your model general or only applying to your specific study. Clarification needed. And the sentence must be rephrased.

For the convective boundary layer case of this study, as shown in Figure 2 (b), a_{cc} = 0% before LST 12:00, thus M = 0 m s^{-1} according to Eq. (3). The cloud core has just appeared at about 13:00 LST when dh/dt is on the order of 10^{-1} m s^{-1}, while w_{cc} is on the order of 1 m s^{-1}. Therefore, when a_{cc}<1%, dh/dt is at least about one order of magnitude larger than M according to Eq. (3) so we can ignore M when we use Eq. (2) to calculate w_e. M is equal in magnitude to w_e in the developmental stage of cumuli due to larger a_{cc} (after about 15:00 LST), thus M cannot be ignored in that case.

The Dutch Atmospheric Large-Eddy Simulation (DALES) model is an effective tool for studying the shallow cumulus clouds that can form on top of dry rising thermals in the subcloud layer and thus is suitable for studying the scientific issues in this manuscript. This manuscript mainly discusses the growth rate of the convective boundary layer and the effect of thermal turbulence on the formation and evolution of cumulus in daytime, so we mainly focus on the effect of surface heating especially for varying air density.

L 161: how do you know? How where they calculated?

As shown in Figure B2(c), from 10:00 LST to 13:00 LST, the maximum $w_s \approx 3$ hPa hour$^{-1} \approx 10^{-2}$ m s^{-1}. dh/dt and w_e are about one order of magnitude larger than w_s, thus dh/dt mainly depends on w_e rather than w_s. Here we use eq. (2) to calculate w_e.

Subsection 4.1: Equations are used out of context without discussing the underlying assumptions and the situation to which they apply. This should be done everytime it is releveant. It is also unclear what is the goal here. Is it to build equation (6)? Under what assumptions and for what purpose?

In subsection 4.1, the main point we want to illustrate is, compared to the high ρ case, the growth rate of h increases faster for the low ρ case due to larger $\overline{(w'\theta_v')_s}$. According to the Eq. (1), with the same RH_0, larger RH_h and more favorable conditions for saturation occur for small ρ compared to large ρ. (Sorry, there is a mistake in line 194-195, the four LES experiments should be (CON, 1.2ρ_{CON}, 1.4ρ_{CON} , 1.7ρ_{CON}) rather than (CON, 1.4$\rho_{CON}RH$0.05, 1.4$\rho_{CON}RH$0.15, 1.4$\rho_{CON}RH$0.3)). Whether or not the penetrative convection can form cloud is related not only to the strength of ascending motion within the thermal but also to relative humidity (reflected by RH_h). The goal of introducing Eq. (1) is to show the relationship between the relative humidity at the top of the surface layer RH_0 and the relative humidity at the top of the mixed layer (ML) RH_h. We have stated the assumptions of Eq. (1) in line 137-138. In most cases, these assumptions are reasonable and within the CBL, the water vapor mixture ratio q_T is invariant (or slightly decreases) with increasing height and adiabatic temperature lapse rate $\partial T/\partial z = -\gamma_d$.

L199: There is a lack of discussions of the BL structure in the observations and the model, and a figure like Fig B2 should be in the main part of the paper, and compared with the model results. Make it clear that penetrative convection means here dry convection making it through the inversion and then possibly forming a cloud. Or remove this sentence as more explanations follow it anyway.

Thanks. The related content has been revised, and we have added discussions of the BL structure in the observations and the model results.

L213-214: unclear, be more explicit.

The local CBL height h_{local} for a specific point (x, y) is defined as the lowest level for which the local virtual potential temperature gradient is larger than 2 K km^{-1}, and the penetration depth d_t for this specific point (x, y) is defined as the difference between h_{local} and h.

Section 4.3: this section must be better organised and clarified. More hindsight is needed to avoid only going back and forward from a specific sub-result to one of several cherry-picked models from the literature. What is the reference you are comparing to?

Where are the results from the different schemes? If you decide to not show them this must be made very clear.

Thanks. We have revised section 4.3 to further clarify our point and better explain the climate data shown in Figure 1.

L 454-455 : This surely cannot be the resolution, but must be the domain size. Specify the corresponding resolution and justify the choice of the model top.

Thanks for your suggestion. The descriptions of domain size and resolution are inaccurate. The LES were performed on a numerical domain of 128 x 128 x 150 grid points. The horizontal and vertical resolutions are 50 m and 40 m, respectively. In our LES experiments, the maximum cloud top height is about 4.5 km in the afternoon, thus we think 6 km is a reasonable value for the model top.

Technical :

Only a few comments here as it is not relevant at this state, again not exhaustive at all (cf. My general comments) l133 : “We analyse in detail the results of control experiment ...” : be more precise by adding “In this section ...” l137: it’s “water vapor mixing ratio” Eq. (2) : partial derivatives should be used here (no Large scale BL advection is assumed as far as I understood) L 456 : replace by 14 hours, this is more readable.

Thanks. We have made the suggested changes. As shown in Figure B2 (d) and (e), we have taken into account large-scale advection in the LES experiments. Of course, here the height-based vertical coordinate may be more appropriate due to different pressure at the same height for different LES experiments.

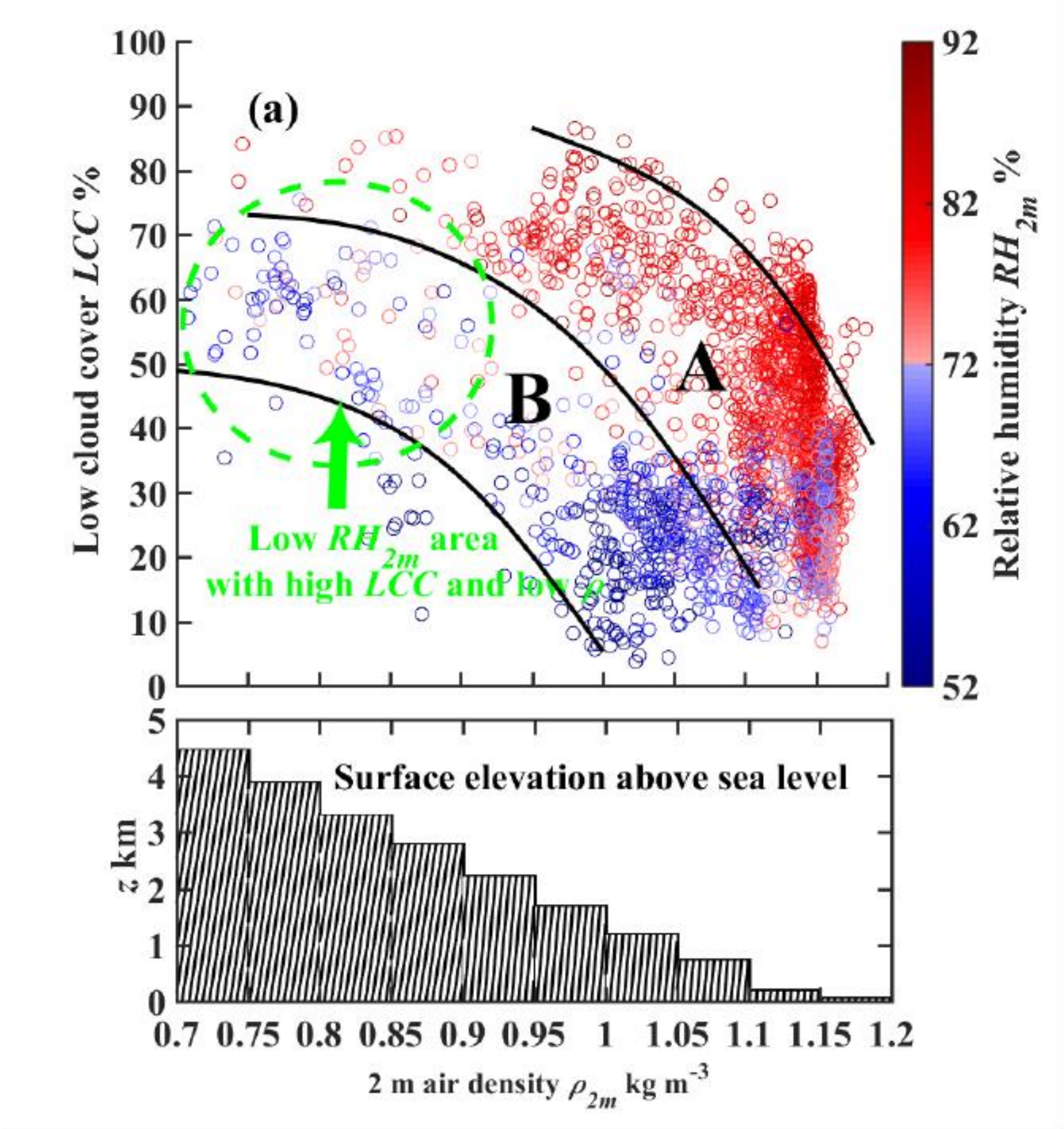

Fig. 1 (a) The relationships among monthly means of *LCC*, ρ_{2m} and RH_{2m} observed by the AWS in summer. The samples are divided into two groups: RH_{2m} > 72% (red dots) and RH_{2m} < 72% (blue dots). Region A and region B generally correspond to RH_{2m} greater than and less than 72%, respectively. The histogram shows an approximate relationship between ρ_{2m} and surface elevation above sea level *z* at the bottom of Figure 1 (a).