# Point-by-point responses to reviewers' comments

We thank both reviewers for their detailed and constructive comments and suggestions. Following these comments and suggestions, we have

- done additional computations and provided more statistics in the discussion in Figure 7;
- added a paragraph in Section 2 to better descript the buoyancy term (BT) and shear term (ST) calculation method;
- added two panels to Figure S1;
- added a satellite image to show organized structures (cellular convection) in Figure 1.

Our revisions are indicated in the revised version with tracked changes. Below are our point-by-point responses (in blue).

Comment on acp-2022-221

Anonymous Referee #1

Comments on "Triggering effects of large topography and boundary layer turbulence over the Tibetan Plateau on convection"

General Comments:

The manuscript tries to analyze the diurnal variations and formation mechanism of low clouds at different elevations based on ERA5, the satellite cloud classification products and data sets from automatic weather stations from June to August of 2010-2019 in China. The author further discuss whether there exist triggering mechanism for convection over the Tibetan Plateau (TP), and whether there is an association among low air density, strong turbulence and ubiquitous "popcorn-like" cumulus clouds. The authors select two typical large topography regions (TP and Rocky mountains) to analyze the triggering effects of large topography and related dynamical structure within the boundary layer on convective clouds. Some interesting results have been obtained. I suggest that this manuscript could be accepted after minor revision.

Specific Comments and suggestion:

The writing of this manuscript needs to be improved. Such as the title maybe should change to "Triggering effects of large topography and boundary layer turbulence on convection over the Tibetan Plateau "

Done.

L110-113: The author used 0.25° x 0.25° ERA5 reanalysis data to calculate the buoyancy term (BT) and shear term (ST) in the TKE equation for each grid. How to interpret this method compared with traditional calculation of BT and ST in a micro-scale micrometeorology especially on the large TP terrain with strong heterogeneity? On the other hand, is it reasonable to used M-O similarity theory in this grid?

Thank you for your comments. Of course, there exists uncertainty for the ERA5 reanalysis flux data especially on the large TP terrain with strong heterogeneity. However, in situ eddy covariance observations are too sparse to meet the needs of this study. Thus we use ERA5 reanalysis data to calculate the BT and ST. It is only an approximate calculation method of surface flux by using M-O similarity theory. Recent study (Xin et al., 2022, https://rmets.onlinelibrary.wiley.com/doi/epdf/10.1002/joc.7589) showed the bias errors of fluxes are generally smaller in ERA5 than in ERA-Interim. The Root mean square error between ERA5 flux data and in situ eddy covariance observations at eight sites over the TP are ranged from 21.82 W $m^{-2}$ to 46.73 W $m^{-2}$. We think this accuracy can meet the needs of this study. More studies need to evaluate the uncertainties of ERA5 flux data over the TP in future.

L150: "Figure 2 (a)" should change to Figure 2. In fig 2 caption "The monthly mean" should be "The summer mean"(June to Aug ).

Done.

Line 241 and 259: which is the relationship of BT and ST between calculated form the point measurement (such as soda) and from the ERA5 gird?

Compared to the 0.25° x 0.25° ERA5 reanalysis data, we think point measurement (such as soda) can reveal more local microscale information especially for the heterogeneous land surface.

Move the text in line 290-294 to line 203, and add more descriptions to show why the author select TP and Rocky Mountain as two typical large topography regions in subsequent paragraphs.

Thanks for your suggestion. We add more descriptions to illustrate this issue in line 228-234.

Line 297: Please show the range of latitude and longitude for TP and Rocky Mountain. Same for line 303.

Done.

Comment on acp-2022-221

Anonymous Referee #2

General

This paper analyses cumulus cloud cover over China with a focus on the difference between the Tibetan Plateau and regions with less topography. Finally, results are compared with the North American region. It is found that topography has a triggering effect which is more pronounced over the Tibetan Plateau than over the Rocky Mountains because of the larger impact of subsidence in the latter region. This is in principle an interesting topic, but I find that the presentation needs much improvement before its publication. My major concerns and some minor points are described below.

Major revisions

The considered topic is not new and the differences to existing literature should be better described. New findings should become clearer. Especially, the differences to Wang et al. (2020) need to be explained who also studied the Tibetan cloud cover. Figure 6 is shown in the same way in Wang et al. (2020) but this is not mentioned. What is new here?

Figure 6 (a) is basically similar to the Figure 1 (a) in Wang et al. (2020). We add a paragraph in line 306-313 to show more new findings in Figure (b)-(d).

I have difficulties to understand the principle idea. Why should the TKE budget at the surface play the most important role for cloud cover? I can follow that the near-surface buoyancy flux is important and also the near-surface shear stress is important for the PBL height, but there are many other impact factors influencing clouds such as aerosol, large scale forcing etc. Also, there are other sources of turbulence especially at cloud top and condensation level which might have an impact.

The main purpose of introducing TKE budget equation is to show the specific forms of buoyancy and shear terms (BT and ST), and then we use ERA5 reanalysis data to calculate BT and ST. Here we do not think all the terms in TKE budget equation play an important role for cloud cover. We agree with your comments that other factors (e.g. aerosol, large scale forcing) also play a key role in clouds formation and development. As shown in Figure 3, compared to the Rocky Mountains, the obvious large scale ascending motions over the TP are in favour of clouds formation and development. We also discussed the variations of PBLH-LCL on clouds. Please refer to the relevant paragraph for more details. Other factors such as aerosol are not mentioned in this study, further data analysis is needed to elucidate the role of these factors.

Before equation (3) occurs, it must be clearly said that in the following the determination (iterative scheme) of the surface fluxes is explained. But the equations are incomplete. The characteristic temperature scale (theta_star occurring in the Obukhov length) must be involved, otherwise the system cannot be solved and neither friction velocity nor heat flux can be determined. I guess, equation (6) is for heat? Equation (7) does not involve humidity, which is in contrast to equation (3).

Thank much for this comment. Yes. The heat flux is derived from $\theta_*$ by using M-O similarity theory. Here we directly use ERA5 reanalysis sensible heat flux product, and then use equation (3) to derive $\overline{w'\theta'_v}$. The equation (6) is for momentum rather than heat, here we do not show the $\phi_h$ for heat. We add a subscript v for θ' in equation (7).

It is several times repeated that there are organized structures (cellular convection) (e.g. in lines 162, 163, 231). What is the basis for this conclusion? I expected at least a satellite image showing the typical cell structure and the cumulus clouds which are described as 'popcorn-like'.

Thank you for your suggestion. We add a co-author Ruixia Liu who supports high resolution satellite Gaofen 4 images to show the organized structures (cellular convection) for shallow convection.

When the goal is to compare results in China with those in North America then a similar Figure 2 should be shown for North America.

Figure 2 are derived from in situ measurements LCC in China, we do not show a similar figure in North America due to lack of this kind of data in North America. For comparing, we also plot Figure 7 (e) and (f) to show the summer mean LCC derived from cloudsat satellite data at local time 2:00 pm in Eastern Asia and North America.

Please explain results showing wind vectors in Figure 4. There is no unit given, but at present I must conclude that mean vertical velocities are in the order of 4 m/s (at least the same order as horizontal wind). But they should be close to zero. Or what is the reason for the permanent strong upward wind over the Tibetan Plateau?

The length of wind vectors in Figure 4 cannot denote the actual wind speed due to the different orders of magnitude for the horizontal or vertical velocities, thus we delete the legend in Figure 4. In order to highlight the large scale ascending or descending region in Figure 4, we extend the vertical velocities by 100 times. Figure 4 show the summer mean large scale vertical velocities, TP as a heat source in summer, there is strong upward wind over the TP, which correspond the convergence in middle troposphere (about 500 hPa) and the divergence in upper troposphere (about 200 hPa).

The definition of the PBL is unclear. In Figure 4, it seems that over long distances LCL and PBL are at the same level. But usually, shallow cumulus at least is part of the PBL.Cloud base is at LCL but the rest of the cloud above it.

Here we directly use the PBLH product from ERA5 reanalysis data. We agree your comments. Sorry for the unclear figure 3 captions. Figure 4 only show the summer mean PBL height and LCL at local time 2:00 pm, thus over long distances (e.g. eastern China) LCL and PBLH are almost at the same level.

Figure 8: According to the figure, the authors seem to consider deep convection. But this is not clear from the beginning of the paper. ‘Cumulus convection’ is referring to shallow convection as well. Please specify already in the introduction, which kind of convection is considered. Figure 8 would give a wrong impression when the paper addresses also shallow convection.

Yes. We discuss and analyze both the shallow and deep convention in this study. Figure 5 show the spatial distribution of day time variations of cloud top height in summer, which reflect the evolution from shallow convection to deep convection over the TP. Compared to the eastern China, higher median cloud top height in summer implies that deep convection are more likely to occur over the TP.

Mínor revisions

Line 54: why does decreasing RH favors the formation of clouds?

Sorry for the mistakes. It should be “increasing”.

Line 96: replace ‘obscured’ by ‘covered’

Done.

Line 150: add that the figure is based on reanalysis

Done.

Line 152: what is an ‘in ribbon’ pattern?

For the purpose of expressing more clearly, we delete the words “ribbon pattern”, and revise the sentence.

Line 152: better show a map with the Tibetan Plateau and Yangtze River valley or add this explanation in an existing figure

Thanks for your suggestion. We add a sentence in Figure 2 caption.

Figure 3: Explain all abbreviations (ASL, AGL and others). Show this figure also for North America.

We have revised all abbreviations, and added necessary explanation. Using ERA5 LCC data, we add Figure S1 to show the diurnal cycle of LCC in summer in East Asia and North America in supplementary material. It should be noted that there exists some differences between the LCC from ERA5 and in situ measurements due to the different definition and model deviation. ERA5 defines low clouds as those between surface and the height at 80% of the surface pressure (or the lowest ~2 km).