

## Responses to the reviewer #2' comments

### Reviewer #2:

The authors use one year of data from the Chinese radar wind profiler (RWP) network at six sites at the Tibetan Plateau (TP) to evaluate the evolution of turbulence intensity (turbulence dissipation rate  $\varepsilon$ ) and planetary boundary layer (PBL) height ( $z_i$ ) throughout the day. First, they show the daily variation of these parameters, averaged over the whole year for each daytime hour, at each of these six sites and point out the large differences between the two sites in the North of the TP (with high turbulence intensity) and those in the south and east of the TP (low turbulence intensity). The differences are ascribed to different land cover, but no detail is presented. Next the data from all six stations are averaged per hour and effects of surface-air temperature ( $\Delta T$ ), vertical wind shear (VWS) and cloud cover are discussed. The authors conclude that  $\Delta T$  has the largest influence in the PBL and VWS has the largest influence above the PBL.

*Reply: We appreciate the thoughtful and excellent comments made by the reviewer. We have tried as much as possible to address all the concerns and have revised the manuscript accordingly. The reviewer' comments are written in normal font, and our point-to-point responses to the editor' comments are in blue italics.*

### General comments.

1. In view of the differences between the six sites, in particular as regards turbulence dissipation rate (Fig. 2), what is the justification to average the data over all six sites? Would it not be more reasonable to analyze the data for each site and compare the results? This could provide information on other factors influencing the turbulence characteristics. Along the same lines, cloud cover and especially surface and air temperature vary strongly with season. Why, instead of discussing seasonal variation, are the data averaged over the whole year? Likely, the seasonal variations also vary between the six sites and the data for each site might provide constraints depending on

local conditions which now are hidden in the large amount of data but for different conditions. Furthermore, the effect of cloudy vs clear sky likely affects the deltaT (and the surface and air temperature) and thus would provide more information than looking at all data together. This likely also explains the relatively small difference between cloudy and clear sky  $z_i$  of only 117 m (line 310).

*Response: Per your kind suggestions, we firstly added a discussion on the spatial and temporal distribution characteristics of turbulent dissipation rate ( $\epsilon$ ) at six RWP stations over the Tibetan Plateau (Fig. S1) in section 3.1 of this revised manuscript. Then, the relationships between the subsurface, surface-air temperature difference ( $T_s - T_a$ ), vertical wind shear (VWS) and  $\epsilon$  are examined separately for each RWP station at the heights ranging from 0.5 to 3.0 km, which is shown in Fig. 2, Fig. S2, and Fig. S3, respectively.*

*It has been found that there exists diurnal  $\epsilon$  variation in planetary boundary layer (PBL) at the six RWP stations over the TP in section 3.1. To better reveal the mechanism how a myriad of geophysical parameters affect turbulence under clear- and cloudy-sky conditions, the height-revolved  $\epsilon$  retrievals are further normalized by the average PBL height from section 3.2. The effect of clouds on the vertical structure of turbulence at different RWP stations is given in Fig. S4, and the effects of  $T_s - T_a$  and VWS on  $\epsilon$  (Fig. S5) were further studied.*

*On the seasonal scale, the turbulence at the six RWP stations is characterized by significant variability, which is shown in Fig. S1. To be more specific,  $\epsilon$  reaches the maximum in summer with the highest  $z_i$ , while touches the minimum in winter at Minfeng and Jiuquan. At the remaining four stations, the strongest  $\epsilon$  is found in spring, as opposed to the weakest  $\epsilon$  in autumn.*

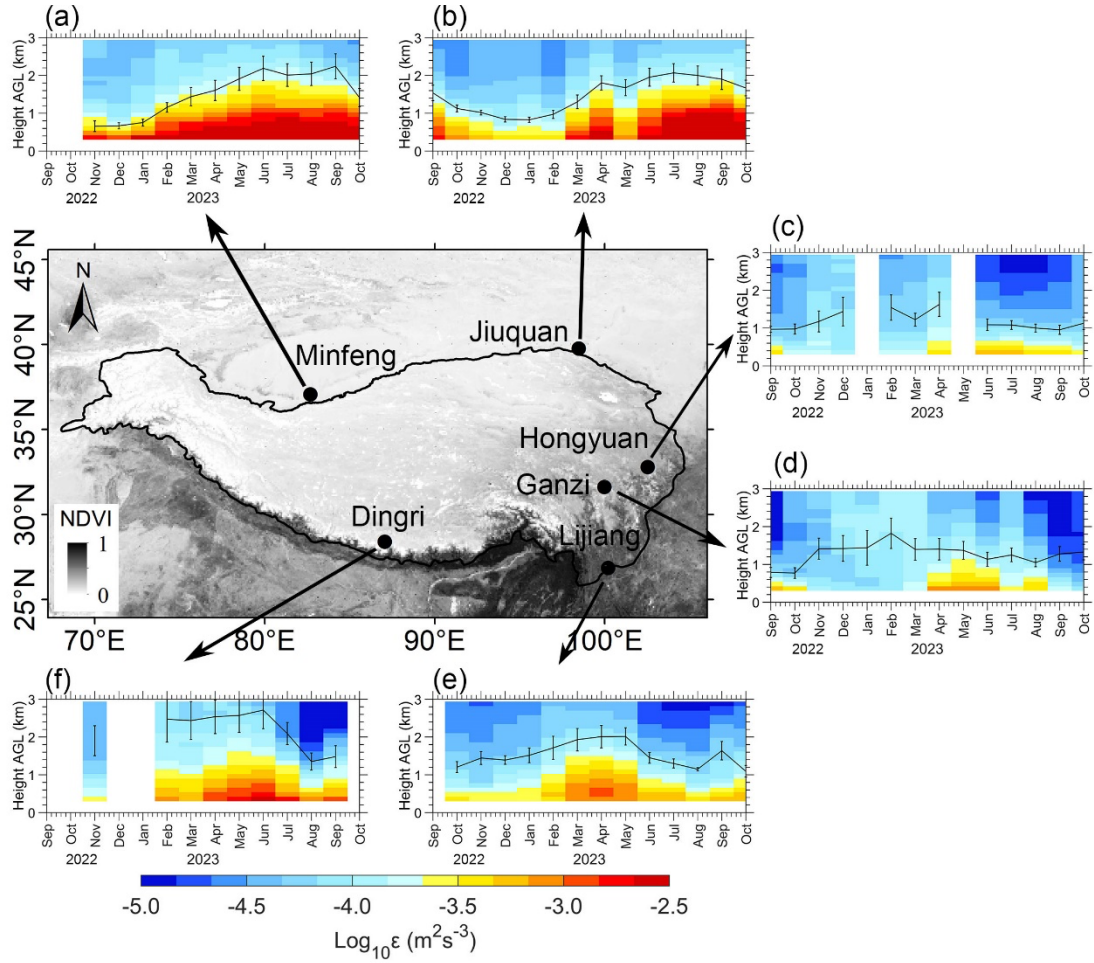


Figure S1. Spatial distribution of the seasonal evolution of the vertical profile of logarithmic turbulence dissipation rate ( $\text{Log}_{10}\varepsilon$  in color shading, unit:  $\text{m}^2 \text{s}^{-3}$ ) at 120 m vertical resolution and 6 min intervals, and hourly mean planetary boundary layer height ( $z_i$ , black line, unit: km) during daytime under all-sky conditions from 0900 to 1700 LST for the period September 2022 to October 2023 as retrieved from the profiling measurements at six RWP stations over the TP. The vertical bars indicate the 0.5 standard deviations for  $z_i$ .

As shown in Fig S2, it can be seen that there is a positive correlation between the  $T_s - T_a$  and  $\varepsilon$  at heights from 0.5 to 3.0 km, indicating that the thermal effect of the  $T_s - T_a$  can promote the development of turbulence under all-sky conditions. However, the relationship varies significantly between each RWP station. The slope values of the regression coefficients for the other five RWP stations, except for Hongyuan are all greater than 0.015. The maximum slope values are observed at Lijiang (0.029) and

Dingri (0.027) in the southern TP, as compared with the minimum slope of 0.007 at Hongyuan. This suggests that near-surface thermal properties have nothing to do with  $\varepsilon$  at Hongyuan in the eastern TP.

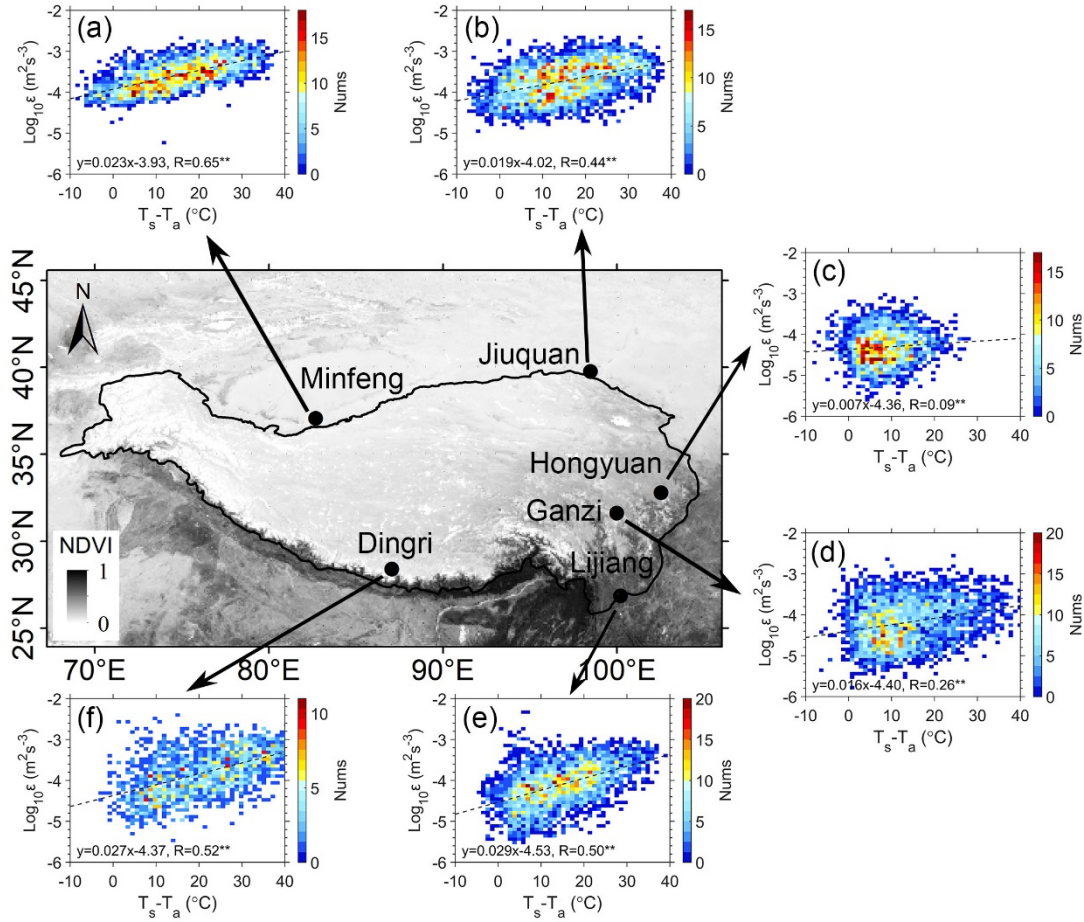


Figure S2. Scatter plots of  $\text{Log}_{10}\varepsilon$  at heights from 0.5 to 3.0 km as a function of  $T_s - T_a$  at six RWP stations over the TP during daytime under all-sky conditions from 0900 to 1700 LST for the period September 2022 to October 2023. The superscript \*\* for R indicates that the regression slope is statistically significant at  $p < 0.01$  level.

The VWS is also found to positively correlate with  $\varepsilon$  at heights from 0.5 to 3.0 km under all-sky conditions (Fig. S3), indicating that the dynamic effect of VWS would promote the development of turbulence. However, the relationship between VWS and  $\varepsilon$  varies significantly among different RWP stations. In terms of the slope value, it can reach 79.34 at Lijiang, followed by Hongyuan (68.56) and Dingri (61.82), and only 6.10 and 10.29 at Minfeng and Jiuquan., Although the slope value at Ganzi is only 9.5,

it can be up to  $41.64$  on the interval of  $0-0.04s^{-1}$  for the VWS. It can be seen that the dynamics of VWS significantly influences the turbulence and is significantly stronger in the southern and eastern TP than in the northern TP.

Figure S4 further shows the distinct spatial variability of cloud effect on  $\epsilon$  across the six RWP stations. Particularly, the turbulence is weakened by clouds within the PBL at Minfeng and Jiuquan in the northern TP, as opposed to the enhanced  $\epsilon$  within the PBL at Ganzi and Lijiang. This suggests that the cloud impact on  $\epsilon$  is much complicated than expected. One of the reasons could be concerned with the cloud life stage, which is not dealt with in this present study. On top of the life stage, the cloud impact on  $\epsilon$ , in combination with  $T_s - T_a$  and VWS, exhibits a distinct altitude dependence, differing by RWP stations (Fig. S5).

The above-mentioned points have been incorporated in this revised manuscript.

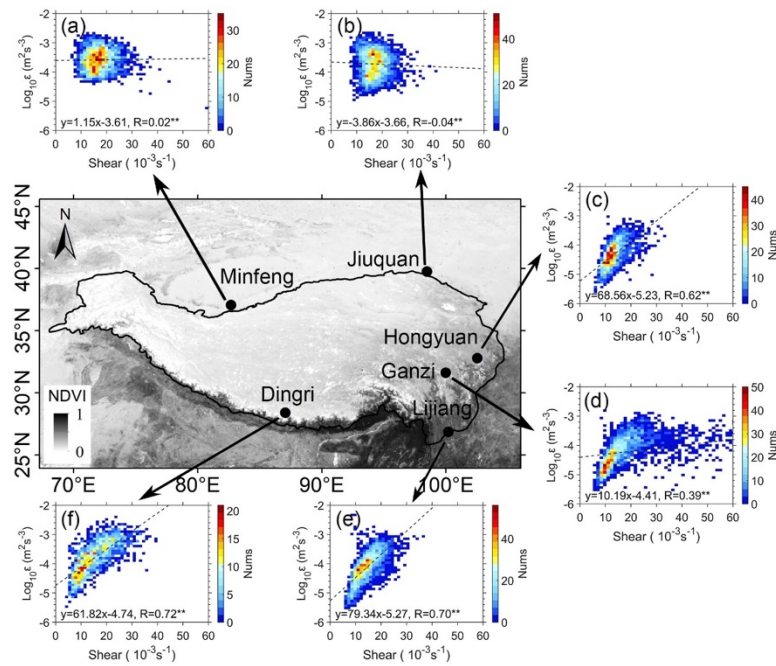


Figure S3. Scatter plots of  $\text{Log}_{10}\epsilon$  at heights from 0.5 to 3.0 km as a function of vertical wind shear (VWS) at six RWP stations over the TP during daytime under all-sky conditions from 0900 to 1700 LST for the period September 2022 to October 2023. The superscript  $^{**}$  for  $R$  indicates that the regression slope is statistically significant at  $p < 0.01$  level.

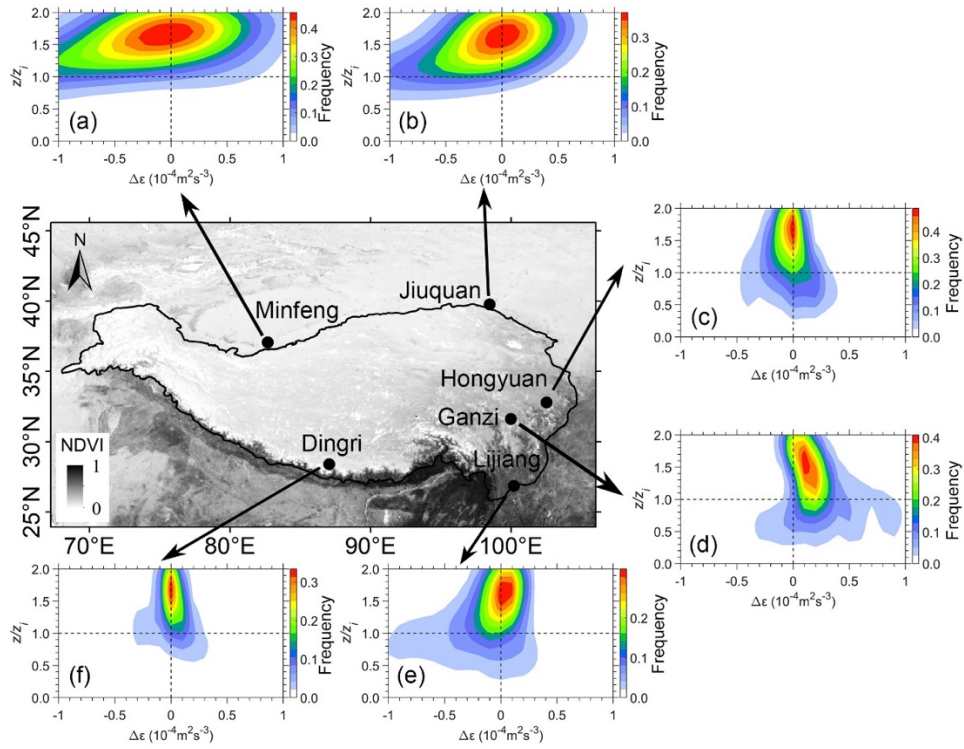


Figure S4. Normalized contoured frequency by altitude diagram (NCFAD) for the difference of  $\varepsilon$  between cloudy-sky and clear-sky conditions ( $\Delta\varepsilon$ ) at six RWP stations over the TP from 0900 to 1700 LST for the period September 2022 to October 2023. Note that  $z_i$  denotes the depth of the PBL, the height ( $z$ ) and turbulence dissipation rate ( $\varepsilon$ ) is normalized by  $z_i$  in order to give a nondimensional vertical coordinate in the form of  $z/z_i$ .

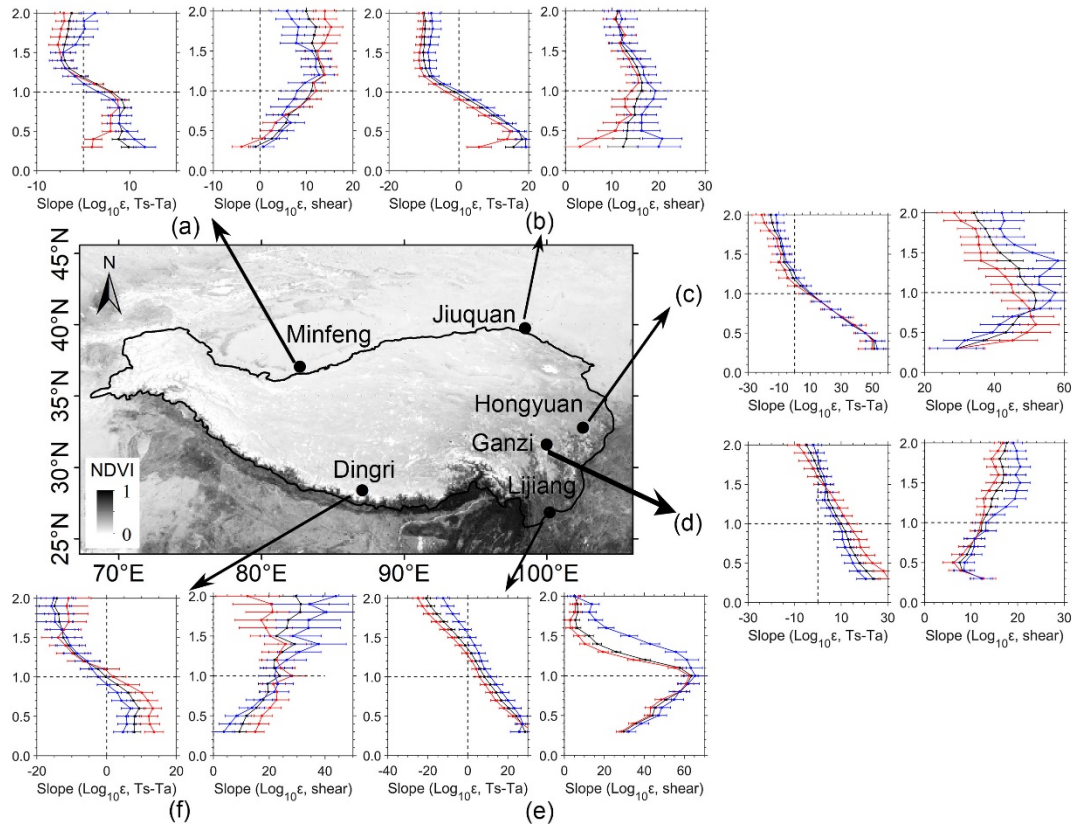


Figure S5. The vertical profiles of least squares regression slope between  $\text{Log}_{10} \epsilon$  and  $T_s - T_a$  and VWS under all-sky (black), clear-sky (red) and cloudy-sky (blue) conditions at six RWP stations over the TP from 0900 to 1700 LST for the period September 2022 to October 2023. Note that  $z_i$  denotes the depth of the PBL, the height ( $z$ ) and turbulence dissipation rate ( $\epsilon$ ) is normalized by  $z_i$  in order to give a nondimensional vertical coordinate in the form of  $z/z_i$ .

2. Another comment is the conclusion the “incapability of analyzing the effect of wind shear on  $\epsilon$  below 0.5 km AGL in the following section” (line 376). With a maximum  $z_i$  of about 2 km (figs. 2 & 4) this implies that  $z/z_i$  needs to be at least  $0.5/2=0.25$ , and preferably should be a function of  $z_i$ . However,  $z/z_i$  is sometimes  $>0$ , sometimes  $>0.2$  (For instance Fig. 6 and caption and text use different measures, but it is throughout the whole MS) and lsq fit seem to be made over different ranges (Fig 6 and Table 2).

*Response: Good point! In this revision, the starting height of  $z/z_i$  has been changed to 0.3, given the minimum value of 0.25. For more details, please refer to Figs.5-10.*

3. The authors define AGL as “above sea level” (line 140) but use AGL also when they mean above ground level. I suggest to define above sea level as ASL and above ground level as AGL and check the paper when each is meant to be used.

*Response: Above sea level is a typo, and it has been corrected to Above ground level in this revision. Thanks.*

4. The authors use “trend” but do not derive any trend. The difference between two data points (line 251) cannot be called a trend, in particular when these data are taken about 1500 km apart and nothing is known about the variation in between, may be just say that in the east the one-year averaged turbulence is smaller than at the western site? Note that “trend” is also used wrongly at other instances to indicate an increase or decrease.

*Response: Per your suggestion, it has been revised to “It is apparent that  $\varepsilon$  exhibits a larger west-east and north-southern spatial discrepancy under all-sky conditions. In terms of the latitudinal variation, the one-year averaged  $\varepsilon$  at the RWP stations in the east part of TP is smaller than in the western part of TP.”*

*Besides, to clarify the characteristics of the vertical profiles of least squares regression slope values between  $\text{Log}_{10}\varepsilon$  and  $T_s - T_a$  and VWS, we have modified the corresponding descriptions in this revision.*

#### **Detailed comments:**

33 spatial discrepancy > do you mean these a large difference between the six stations?

*Response: Yes. It has been clarified as “..exhibits a large spatial discrepancy over the six RWP stations over the TP”*

36 difference in land

*Response: Revised as suggested.*



40 do clouds suppress turbulence? Or does solar irradiation heat the surface which creates a larger  $\Delta T$  and thus turbulence (as is discussed in the paper, see also line 47).

*Response: Per your suggestion, it has been revised to "This could be the cooling effect by cloud that reduces the solar irradiation reaching the surface."*

62 change to: impact on the forecast skill of weather and climate models

*Response: Revised as suggested.*

70/71 hard for radiosondes and ultrasonic anemometers .... of atmospheric .

*Response: Revised as suggested.*

72 elevation larger than 4000 m

*Response: It has been revised to "greater than 4000 m".*

75 change could to can

*Response: Revised as suggested.*

76 change bubbling to thermals of warm air

*Response: Revised as suggested.*

79 change to : understanding the ...

*Response: revised as suggested.*

83 change influential to influencing

*Response: Revised as suggested.*

94 change to: flux promotes the ...

*Response: Revised as suggested.*

103 change to: clouds tend to suppress

*Response: Revised as suggested.*

104 change to: China using fine ...

*Response: Revised as suggested.*

106 change to: compared to clear ...

*Response: revised as suggested.*

108 change to: PBL contributors to .

*Response: Revised as suggested.*

112 change to: in turn influences ..

*Response: revised as suggested.*

115 change “elusive” to “unclear”

*Response: Revised as suggested.*

117/118 change to: Coincidentally, the RWP network in China provides us a valuable ...

*Response: Revised as suggested.*

136 of the RWP

*Response: Revised as suggested.*

137 and detailed information

*Response: Revised as suggested.*

140 ASL (see general comments)

*Response: Revised as suggested.*

144 Dunhuang?

*Response: "Dunhuang" has been corrected to "Jiuquan".*

154 signal to noise

*Response: Revised as suggested.*

182 is this a hypothesis or are these assumptions?

*Response: It should be assumptions, which has been clarified in this revision.*

191 excluding the above

*Response: Revised as suggested.*

192 from the turbulent

*Response: Revised as suggested.*

200 between the Earth's surface and the atmosphere above

*Response: Revised as suggested.*

201 affecting cloud

*Response: Revised as suggested.*

209 profile is greater

*Response: Revised as suggested.*

213 presents

*Response: Revised as suggested.*

240 TP ranges from

*Response: Revised as suggested.*

254 meridional or latitudinal?

*Response: This should be "meridional", and we have revised it as suggested.*

257 reaches values up to

*Response: Revised as suggested.*

258 replace “least magnitude “ with “lowest value”

*Response: Revised as suggested.*

Par. Starting at line 272: is there an explanation why  $z_i$  at Dingri is so much higher than at any of the other 5 sites?

*Response: This point has been added in revised manuscript:*

*“Of the six RWP stations, Dingri is located in the northern foothills of the Himalayas with an altitude of over 4300 m, where the bare land type results in a large surface sensible heat flux. This, together with the lowest atmospheric density, leads to the highest daytime mean value of  $z_i$  up to 2.10 km (Wang et al., 2015).”*

275 replace “both” with “the”

*Response: Revised as suggested.*

277 vegetated terrain at the Ganzi

*Response: Revised as suggested.*

278 the sentence suggests that Fig.1 shows vegetation, but the locations seems to be overlaid on an elevation map

*Response: Revised in the figure caption, per your suggestion.*

280 in the PBL

*Response: Revised as suggested.*

282 the sentence starting with “Thus, “ : some word seems to be missing (spatial variation?) but the sentence does not make sense: is the dissipation relevant to the surface type or does the surface type influence the turbulence?

*Response: You are right. It has been rephrased to “Therefore, we argue that the spatial and temporal variation of daytime  $\varepsilon$  over the TP are affected by the underlying surface type and air density.”*

295 PBL properties?

*Response: Yes, and it has been revised as suggested.*

299-304 it is not mentioned to which sky conditions this applies

*Response: It has been clarified as “under cloud-sky conditions”.*

306  $\varepsilon$  ranges from

*Response: The grammar error has been corrected.*

350-351 does Table 2 show scatter plots or .... please correct and explain what table 2 shows, and also why the lower limit of  $z/z_i$  is 0.2 whereas in the plots you use 0. Obviously the range influences the lsq fits, as the comparison between the eqs in Table 2 and Fig. 6 shows. However, Fig 8 shows that the lowest data point is for  $z/z_i = 0.2$ . Please discuss this in the text, and if no data exist below  $z/z_i = 0.2$ , all figures and text mentioning  $z/z_i > 0$  needs to be corrected

*Response: The range of  $z/z_i$  is revised to 0.3 to 2.0 throughout the revised manuscript. For more details, please see our response to General comment 2,*

361 -364 The data and discussion clearly show the effect of clouds on the turbulence in the PBL. However, the question arises whether clouds reduce the solar irradiation at the surface and thus surface heating and thus deltaT. The extent to which deltaT changes depends on COT and cloud cover. Therefore, I would suggest that deltaT is the governing parameter rather than cloud cover.

*Response: Good point! Yes, you are right. We have revised in the revised manuscript.*

383 As mentioned in the text (see also general comments), VWS influences turbulence within the PBL, but it can be determined only in the upper part (>500 m). Hence the summary sentence on lines 383-384 should more carefully formulated to do justice to the detail presented in the above.

*Response: Thanks for your careful checks, we have modified the corresponding descriptions in this revised manuscript per your kind suggestions.*

Also in the rest of the text, the conclusions on the effect of VWS within the PBL need to be more carefully formulated (see also general comment).

*Response: Per your kind suggestion, we have revised the rest of the paper in the revised manuscript.*

406 decreases with height (remove trend)

*Response: Revised as suggested.*

407 linear variation of the slope from the lower PBL to the top of the PBL. Within the PBL< the slope is positive, above the PBL ...

*Response: Revised as suggested.*

411-413 Fig 8 clearly shows the influence of cloud cover on the  $\Delta T$  and the effect of the surface heating on the turbulence in the lower half of the PBL ( $z/z_i$ )

*Response: revised as suggested.*

421 the slope decreases with height

*Response: Revised as suggested.*

447 buoyant and mechanic forcing

*Response: "buoyant and mechanistic" has been revised to "buoyant and mechanic forcing".*

468 at the Minfeng

*Response: Revised as suggested.*

472-473 similar to comment on line 282

*Response: Revised as suggested.*

487 PBL in clear-sky

*Response: It has been revised to "in the PBL under clear-sky conditions".*

504 remains known or unknown?

*Response: It has been revised to "unknown"?.*