

Response to anonymous Referee #1

We would like to thank the reviewer for taking the time to make detailed and useful comments. Details of the changes made are now given in the supplement in reply to the comments made.

General comments:

-Add Liu et al. (2018, 2020) into Introduction.

Liu, R., Liu, S.M., Yang, X.F., Lu, H., Pan, X.D., Xu, Z.W., Ma, Y.F., Xu, T.R., 2018. Wind dynamics over a highly heterogeneous oasis area: an experimental and numerical study. *J. Geophys. Res.* 123, 8418–8440.

Liu, R., Sogachev, A., Yang, X., Liu, S., Xu, T., Zhang, J. 2020. Investigating microclimate effects in an oasis-desert interaction zone. *Agricultural and Forest Meteorology*, 290, 107992.

Thanks for your comment. We have added Liu et al. (2018, 2020) into Introduction: “In addition, several studies have examined the effects of surface heterogeneity on different levels of background winds (Shen and Leclerc, 1995; Liu et al., 2020) and the direction relative to the orientation of the heterogeneity (Wang et al., 2011; Kang and Lenschow, 2014), as well as the spatial and temporal variations of the wind fields (Liu et al., 2018).”

-Line 82: Should describe specifically what kind of model is.

Thanks for your comment. We have described specifically what kind of model in this sentence: “Biermann et al. (2014) and Wang et al. (2015) discovered that the turbulent flux of Lake Nam co, which is surrounded by wet grasslands, is actually

very considerable but often underestimated by a hydrodynamic multilayer model from Foken (1979 and 1984).”

-Lines 151-152: "horizontal grid-spacing of 200 m. A vertically stretched grid with a minimum spacing of 1.1 m was utilized in the surface layer and a maximum of 64.8 m above 2000 m", 200:1.1, very large ratio. Is it ok for simulation?

The irregular grid spacing in vertical direction with very fine grid spacing in the surface layer has been used to simulate the turbulent fluxes for the small eddies. According to the other reviewer’s comment, we have illustrated that horizontal resolution of 200 m in our simulation lies in the near gray zone during the early CBL development (12:30), but is an appropriate resolution for the time of 15:30. Please find the detailed replies in the response for the reviewer #2 of RC3. Moreover, the similar grid spacing ratio for the LEM has been used by Huang et al. (2010) to simulate the effects of surface heat flux anomalies on the formation of deep boundary layer over the Sahara dessert.

Huang Q, Marsham J H , Parker D J, et al. Simulations of the effects of surface heat flux anomalies on stratification, convective growth, and vertical transport within the Saharan boundary layer[J]. Journal of Geophysical Research Atmospheres, 2010, 115.

-Line 171: What’s the real size of Ngoring Lake and Gyaring Lake? Does 30 km width reflect the real lake?

The spreads of Ngoring Lake and Gyaring Lake are 610 km² and 520 km², respectively. Ngoring Lake is the biggest lake in the Source Region of the Yellow River and ranges about 30 km from the south to north (west to east) according to Wen et al. (2015). The 30 km × 30 km × 6 km of lake domain size can represent Ngoring Lake and Gyaring Lake.

Wen L J, Lv S H, Li Z G, et al. 2015. Impacts of the two biggest lakes on local temperature and precipitation in the Yellow River source region of the Tibetan Plateau [J]. Adv. Meteor., 2015: 248031. doi:10.1155/2015/248031.

-Line 249: Please specify the time period of the daytime.

Thanks for your comment. We have corrected the sentence as: “In order to investigate the existence of a daytime (6:30-18:30 LT) lake breeze.....”

-Line 290: Please explain what the “h” means is.

Thanks for your comment. Here “3 h” means three hours. We have changed “..... using the radiosonde with at a 3 h interval.....” to “.....using the radiosonde with a 3 h (hour) interval.....”

-Lines 306-308: Please cite refs that can support this hypothesis.

Thanks for your suggestion. We have modified the hypothesis and cited the reference as: “This may be because the background wind weakens the boundary-layer convection, which inhibits the development of the CBL (Huang et al., 2009).”

-Figure 5: The heights of A1L and A1L_C is the same, why? The vertical coordinate may be z_i ?

In our study, the height of the boundary layer (z_i) was determined using the minimum kinematic heat flux of the simulated results according to Sullivan et al. (1998). There is a very similar surface heat flux (only about $0.1 \text{ W}\cdot\text{m}^{-2}$ difference between the cases A1L and A1L_C) that driven the development of the CBL for the runs A1L and A1L_C, which determines the same CBL height for the both cases. In addition, we have changed the vertical coordinate according to your comment.

-Lines 368 – 372: Why the effects of the heterogeneity on the TKE for the runs with balanced surface heat fluxes are less significant? Have other studies have the same phenomenon?

For unbalanced surface heat fluxes simulations (A1L, A2L, A1LW, A2LW), runs with one or two lakes were initialized using the surface heat fluxes measured at LS (the lake station) for the lake patches and the heat fluxes at GS (the grassland station) for the outside patches. For balanced surface heat fluxes runs (A1L_C, A2L_C, A1LW_C, A2LW_C), the surface heat fluxes measured at GS are allocated according to the proportion of the square of lake patches and outside patches to the model domain. Based on the above approach, surface heat fluxes for the unbalanced runs are larger (about $0.1\text{--}15\text{ W}\cdot\text{m}^{-2}$ for the sensible heat flux and $0.3\text{--}38\text{ W}\cdot\text{m}^{-2}$ for the latent heat flux) than that for the balanced runs. It results the smaller TKE for the balanced runs. In order to present clearly, we have modified the sentence as: “For the runs with balanced surface heat fluxes (A1L_C, A2L_C, A1LW_C, A2LW_C), the effects of the heterogeneity on the TKE are less significant due to the relative smaller surface heat fluxes...” The similar simulation settings are found in the LEM study by Huang et al. (2010). It was found that effects of the surface heat flux anomaly on the CBL changes tended to be small for runs used balanced surface heat fluxes (see Fig. 4 from Huang et al. (2010)).

Huang, Q., Marsham, J. H., Parker, D. J., Tian, W. S., and Grams, C. M.: Simulations of the effects of surface heat flux anomalies on stratification, convective growth, and vertical transport within the Saharan boundary layer, J. Geophys. Res., 115, D05201. doi:10.1029/2009JD012689, 2010.

Lines 399 – 415: Discuss the result with Zhou et al.(2018) and Liu et al. (2020).

Zhou, Y., Li, D., Liu, H. and Li, X.: Diurnal variations of the flux imbalance over homogeneous and heterogeneous landscapes. *Boundary-Layer Meteorology*, 168:417–442. <https://doi.org/10.1007/s10546-018-0358-2>, 2018.

Liu, R., Sogachev, A., Yang, X., Liu, S., Xu, T., Zhang, J. 2020. Investigating microclimate effects in an oasis-desert interaction zone. *Agricultural and Forest Meteorology*, 290, 107992.

Thanks for your comment. Here we added the following statement on line 410: “Zhou et al. (2018) and Liu et al. (2020) investigated desert-oasis microclimate effects by simulations and found background wind has crucial effects on the thermal heterogeneous system. They showed the similar results that the circulations are more pronounced between the hot and cold patches without background wind. As background wind increased, the local circulation is gradually weakened and eventually replaced by horizontal flows over the oasis-desert system.”

-Section 4: What’s the difference between ambient wind, background wind and background flow?

In our text, the ambient wind, background wind and background flow are the same thing, which refer to the runs with both the initial wind and geostrophic wind. We have used the expression - “background wind” throughout the text to avoid confusing.

Specific comments:

-Line 48: The sentence “..., which has improved our understanding of the transfer and spatial and temporal variability of the turbulence” is a bit redundant and it is unclear exactly what point you are making. I would suggest rephrasing.

Thanks for your suggestion. We have rewritten this sentence: “Then turbulence over heterogeneous surfaces was investigated through field campaigns (Wang et al., 2016; Zhao et al., 2018) and numerical simulations (Shao et al., 2013; Liu et al., 2011) in the past few decades, which help us better understand the interactions between the surface and atmosphere.”

-Lines 128 - 133: I would suggest rephrasing the sentence.

Thanks for your suggestion. This sentence was rephrased like this: “The GPS radiosonde data is obtained from the field campaign on July 29, 2012, at 30 m west of Lake Ngoring (near the gradient tower station, TS) and Madoi station (MD) located

30 km east of the lake (34.918° N, 98.216° E, 4279 m AMSL). The eddy covariance data for Lake Station (LS) above the northwest of the lake (35.026° N, 97.652° E) and Grassland Station (GS) (34.913° N, 97.553° E) at 1.5 km west of the lake shore were used.”

-Line 135: There are two “and”, please rephrase the sentence. The same as Line 217, Line 225 etc. Please check throughout the manuscript.

We have rephrased the sentence at Line 135: “The synoptic background at 500 hPa and the distribution of the wind components...” The sentence at Line 217 have rephrased: “the horizontal average $\langle \phi \rangle$ and the turbulent fluctuation ϕ' , so...” The sentence at Line 225 have rephrased: “..., as well as the complex and irregular heterogeneities (Maronga and Raasch, 2013).”

-Line 141: When was the Landsat image acquired?

The landsat image was acquired on 21th August, 2014. We have added the time of this image in the caption of Fig. 1.

-Line 150: Please specific the “135 km×30 km×6 km” means: Length? Width? Height?

We have rewritten this sentence: “The domain size was 135 km×30 km×6 km in the y , x and z direction, respectively, with a horizontal grid-spacing of 200 m.”

-Figure 3: The legend should be “T(K)” in figs 3a and 3b. What’s are the units of w and u in figs 3c and 3d?

We have modified the legend in Figs. 3a and 3b, and added the units (Pa s-1) and (m s-1) of w and u in Figs. 3c and 3d.

-Line 456: “fig.03” should be “Fig.S3”. The same as line 459. Please check “fig” or “Fig” throughout the manuscript and make them unified.

We have changed the “fig. 03” into “Fig. S3”. We have used the unified “Fig” throughout the manuscript.

Technical corrections:

-Line 32: Miss interpunction between "m" and "s⁻¹".

We have modified the unit as: “m·s⁻¹”.

-Line 35: Change “it” to “them”.

We have changed “it” to “them”.

-Line 90: Delete “,” after “heat”.

We have deleted “,” after “heat”.

-Line 119: Should be the entrainment layers of PBL.

We have changed the sentence: “...and the entrainment layers of PBL were investigated, too.”

-Line 122: “data” should be “Data”.

We have changed “data” to “Data”.

-Line 248: “distribution” should be “distributions”.

We have changed “distribution” to “distributions”.

-Line 474: Delete increasing.

We have deleted the “increasing” .