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Hydrology and Earth System Sciences
Discussions

HESSD

Interactive comment

Interactive comment on "Thermal regime, energy budget and lake evaporation at Paiku Co, a deep alpine lake in the central Himalayas" *by* Yanbin Lei et al.

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This paper reported the seasonal changes of lake water profile, lake levels, surface heat budget, and evaporations by three years in-situ observation data. They showed very interesting characteristics representing lake environment in southern edge of the TP, that gives us the hints to understand basic processes of heat/water budget of mountain lakes under Indian monsoon climate. As authors introduced in the introduction, lakes on the TP are changing. It is very important to reveal that how the global environment change could modify the lake environment through land-atmosphere interaction. The contents showed basic timelines of observed data with estimated heat budget and evaporation amount, and natures could be easily captured by figures.

Response: We are grateful to the reviewer's comments. We will consider these comments carefully. The main responses to these comments are shown as the following:

However, many key mechanisms are discussed by speculations without in-depth examination/comparisons to previous studies in the TP. This is because the study did not set clear objectives. Therefore, the title is also uncoordinated. For instance, do authors concern about the lake area (level) changes of Paiku Co? Figure 10 shows that lake level show small seasonal variation (within 1m), but do you think this is critical? Or, authors investigated large evaporation rate instead of previous studies? Readers can not understand how the Fig. 10 differs from other lake or even from ground in the TP. If the HESS request level of paper as scientific article instead of "report", I would like to suggest that paper needs fundamental revisions with clear objectives and results based on additional in-depth analysis.

Response: The main objective of this study is to quantify lake evaporation throughout the year based on energy budget method (Section 3) and its impact on seasonal lake level changes (Section 4.4). Until now, lake evaporation during the late autumn and early winter is not typically investigated on the TP because it is difficult to install and maintain measurement platform due to the harsh natural conditions and the influence of lake ice. As a result, how lake evaporation affects seasonal lake level changes remains unclear due to lack of comprehensive observation of lake water budget. We will add one paragraph in the introduction about endorheic lake level seasonality on the TP. 'Compared with numerous studies of inter-annual to decadal lake changes, seasonal lake level changes and the associated hydrological processes on the Tibetan Plateau (TP) are still less understood. Phan et al. (2012) showed that seasonal lake level variations in the southern TP are much larger than that in the northern and western TP. In-situ observations gave more details of seasonal lake level variations (Lei et al., 2017). One striking feature is the different amplitude of seasonal water level variations, that is, deep lakes usually exhibited considerably greater lake level variations than shallow lakes. For example, Zhari Namco and Nam Co, two large and deep lakes on the central TP (Wang et al., 2009, 2010), exhibited significant water level increase by 0.3∼0.6 m during the summer monsoon season and a similar magnitude of lake level reduction by 0.3∼0.5 m during post-monsoon season between 2010 and 2014. For the two nearby small and shallow lakes, Dawa Co and Bam Co, although there was a similar pattern of lake seasonality, the amplitude of seasonal lake level variations was considerably smaller than the two large and deep lakes (Lei et al., 2017).' The main causes for the different amplitude of lake level changes are still not investigated in previous studies, which is the main topic of our study. We will change the title of the paper to: 'Contrasting hydrological and thermal intensities determine seasonal lake level variations Ìű A case study at Paiku Co in the central Himalayas' Lake level changes of Paiku Co (Fig. 10) and other lakes will be shown in a new figure (Fig. 11) to show the different amplitude of seasonal lake level changes. Previous studies about lake evaporation on the TP have been reviewed and compared in Section 4.3.

For the lake dynamics by means of hydrometeorology, following points need to be examined. 1) Water temperature profiles were almost homogeneity during Oct.- June (non-monsoon season), and author explained by "fully mixing" without any analysis. Please proof it physically using surface wind speed and variability conditions and water mixing theory. It is curious that such mixing occurred suddenly. In the central TP, large diurnal wind changes are found in winter due to the coupling of upper strong STJ and boundary layer development. Any relation to the seasonal change of atmospheric circulation ?

Response: The thermal structure of Paiku Co has been addressed in the section 3.1. Lake water temperature profile can be taken as a proxy of lake water mixing. In summer, the lake water is stratified according to the dramatic temperature gradient between surface and bottom. In October, the lake stratification is weakened due to the decreased temperature gradient. The water temperature isobaths show that lake mixing was deepened gradually from early October to later October. Since the late October, the lake water is totally mixed because the vertical temperature gradient suddenly disappeared. If the lake water can not completely mixed, the temperature gradient should always exist. As we have addressed in the main text, the lake mixing is mainly forced by wind disturbance and water convection. This is also the classic theory of lake water circulation, which has been addressed in many publications and books (i.e. Wetzel, 2001). Clear Lake stratification at Paiku Co occurred in late June or early July, which corresponded to a significant reduction in wind speed. The timing of the stratification breaking down occurred in late October, which corresponded well to significantly increased wind speed. The potential relationship with atmosphere circulation will be discussed.

2) Seasonal change of water level should be explained by seasonal change of water budget, including precipitation, river runoff/inflow and surface water inflow. Even there are lack of areal in-situ measurements, some parameters could be estimated by previous studies or literature. This also links to Av calculation as mentioned in 3). I could not see precipitation records, but the Rn sequence demonstrated that rain season is not clear compare to southern Himalayas and central plateau. If the impact of monsoon is small with fair/non-freeze weather, location of the lake may represent local dry climate behind the Himalayas where lee-side subsidence prevails, and that would characterize evaporation rate at Paiku Co.

Response: We do not focus on all components of lake water budget in this study. The main purpose of this study is to quantify lake evaporation and its impact on seasonal lake level changes. Therefore, precipitation, river runoff and other surface water inflow is not shown. We agree that the impact of monsoon precipitation is small in this dry area and location of lake represent local dry climate behind the Himalayas where subsidence prevails. We will add this point in the revision.

3) To consider the heat budget of the lake, especially for the condition of thermocline, advection of cold (snow/glacier-melt) water associated with river/surface inflow need to be considered. This paper only compares the heat budget at water surface, and

conclude the evaporation as a ley parameter to affect lake level seasonality. Is there no effects of glacier melt water (they are illustrated in Fig. 1a) or monsoon precipitation inflow to establish lake temperature profile and lake level seasonality? Diurnal change of river level according to the glacier melt is observed by previous studies. There are some indication at the bottom temperature of northern point in Fig. 3b. At L115, please proof that Av can be ignored. Authors should not avoid those issues to analyze if they focus on the water cycle and environmental changes on the TP as introduced in Chapter. 1.

Response: We will add one paragraph in Section 2.3 to evaluate the impact of Av on the lake energy budget. Av can be estimated according to total river discharge (Fig. 1) and the water temperature difference between river and lake. Lake water temperature was almost same to river water temperature between April and June, but 2-4oC higher between July and December. As a deep lake, total river discharge to Paiku Co was about 800-900 mm water equivalent to lake level and accounted for 2-2.5% of total lake water storage. The river discharge can accumulatively decrease lake water temperature by ∼0.1 oC in a year. Therefore, as a deep lake, the influence of river discharge on the total lake heat storage at Paiku Co is very small and can be neglected. Therefore, we do not consider the influence of Av on the lake energy budget in this study.

Minor comments: There are no previous studies in Paiku Co. ? Need reviews.

Response: We will review previous studies at Paiku Co. We did not do this because we have reviewed it in a previous publication about Paiku Co. Lei, Y., Yao, T., Yang, K., et al.: An integrated investigation of lake storage and water level changes in the Paiku Co basin, central Himalayas, J. Hydrol., 562, 599–608.

Water temperature sensors in the upper profile are shaded? Or, how deep the insolation can penetrate the water at the target lake?

Response: We do not think water temperature sensors in the upper profile are shaded.

As we have illustrated in section 2.2, the first water temperature sensors are fixed below buoy at the water depth of ∼0.5 m. The other sensors were fixed on the rope which was tied to an anchor at the lake bottom. The transparency of the lake is not measured until now.

L176AAËŸ Small water temperature gradient is explained by cold air temperature. This is strange. Air temperature change is due to latent heat from the surface or advection. Enough radiation could increase the water temperature even the air temperature is cold with weak winds.

Response: We will discuss it in more detailed in the revision.

L175-180 Those are speculations, not results.

Response: We will discuss it in more detailed in the revision.

L138 “input data were averaged at weekly interval. Does heat budget screened by the wind direction by instantaneous data then averaged?

Response: Wind speed and direction is not used during the calculation of energy budget and lake evaporation.

Units in Fig. 10 are mm/d, cm and it is m3/s in Table 3. Please unify them to capture accurate water balance.

Response: Thanks for pointing out this. We will unify them in the revision.

Title of 3.3 “Lake hydrometeorology” is vague.

Response: We will change it to ‘Air temperature and humidity over the lake surface’

L215ãËŸAAËŸ “There was a 1.5 month lag between lake surface temperature and air temperature.” Is not clear. Response: We will change it to ‘between the maximum surface water temperature and maximum air temperature’.

I could not understand the meaning to show the Fig.6.

Response: We will consider it further to remove or leave it.

L230 “Downward shortwave radiation at Paiku Co had an annual average of 251.8WÂ°um-2 (Fig. 7), which is slightly higher than the TP average due to its lower latitude (Yang et al., 2009).” What is the TP average? Effects of Indian monsoon is stronger in southern TP in general, and cloudy weather may reduce the insolation. Or, the observation represent local weather in the valley?

Response: Mean annual precipitation at Paiku Co is about 150-200 mm. So we agree that the observation represent local weather in the valley.

L230-237 Discussions are not clear due to mixture of seasonal change and annual average. Why the rainy season is not clear?

Response: As we have shown in Fig. 7, the rainy season is not clear because the precipitation at Paiku Co is low.

L17, L248" “a deep lake”. Many discussion attribute the characteristics to the depth of lake without examination. Manly lakes over the TP are shallower than the target lake? Please review that how the depth of lake over the TP characterize the lake temperature condition.

Response: As we have shown in section 4.3, seasonal changes in lake evaporation is related to the mean lake water depth and the lake heat storage. The mean water depths of the lakes have been mentioned in Section 4.3. Deep lake can store more energy in spring and summer and release more energy to the overlying atmosphere, which can have dramatic impact on the season pattern of lake evaporation.

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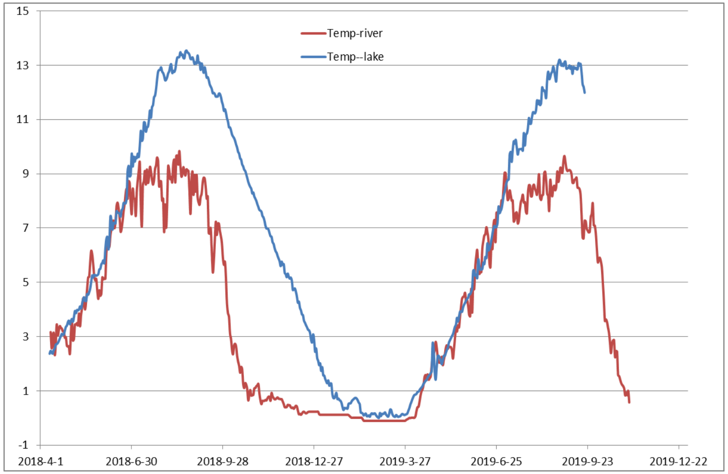

Fig.1 Comparison of water temperature (ºC)between Bulaqu river (red line) and Paik Co (blue)

Fig. 1. Comparison of water temperature between Bulaqu river (red line) and Paik Co (blue)