Reply to Comment #1.

Following are my reply to the comments.

The reviewer's comments and questions are in bold, and my reply is in blue and normal text.

This work presented the development and evaluation results of a lake-watershed coupled model, called SHUD. The SHUD model utilizes unstructured triangles as fundamental Hydrological Computing Units, and the coupling between lake and watershed units is considered by calculating the groundwater and surface water recharges. In general, the model is useful to the current literature and provides a powerful tool for understanding and predicting hydrological processes in lake basins. However, there are still some issues needed to be clarified to make the paper clearer and more innovative.

1. **The innovation of the SHUD model should be clarified. Is there any innovation in the model development? Or the lake model and the interactions between lake and surrounding grids are similar with other land models (e.g., CLM5)?**

Thank you for your comment.

The SHUD model is an integrated surface-subsurface numerical hydrological model (ISSNHM). The merits of ISSNHMs lie in their temporal-spatial continuum, contrasting with other models like SWAT, TOPMODEL, HBV etc. SHUD employs the finite volume method to solve hydrological partial differential equations on unstructured domains. The detailed innovation of the SHUD model and its performance on watersheds are discussed in the model description paper by Shu et al. (2020).

In the lake-coupling scheme, the lake is also decomposed into triangular mesh domains, and the surface, subsurface, and channel fluxes between the lake and surrounding land are calculated.

The lake schemes in CLM and SHUD model are markedly different (based on the CLM 5.0 technology note):

1. In CLM, the lake is a fraction in a grid cell, described by its depth, extinction coefficient, and fetch, devoid of a physical geometry. Conversely, SHUD-Lake represents the lake as a polygon within a watershed, comprising multiple triangular cells. The lake's volume is a function of its stage and top area.

2. CLM primarily focuses on vertical energy fluxes, particularly the temperature distribution along depth, plus snow accumulation and melt. On the other hand, SHUD only considers the energy term of evapotranspiration.

3. Hydrological aspects are scarcely considered in CLM, portraying the lake hydrology as an impervious non-vegetated unit with a constant water mass, only considering snow hydrology in the lake module. In contrast, SHUD represents comprehensive fluxes between lake cells and land cells, via surface, subsurface, and river reaches.

As a land-surface model, CLM emphasizes vertical energy exchanges between the atmosphere and land surface. As a hydrological model, SHUD-Lake concerns the horizontal water exchanges between the lake and its surrounding land.

The strength of CLM in vertical energy and the strength of SHUD in horizontal hydrological processes suggest a potential for coupling, which could provide a better description of water and energy storage and movement in lakes and watersheds.

We have revised the manuscript to elaborate on the SHUD model and the potential coupling with land surface models.

4. **Does the SHUD model consider the subsurface lateral flow (e.g., groundwater flux) between all the land grids? Or does the current model only consider the lateral subsurface water exchange between lake and the surrounding bank grids? If yes, then the coupling between lake and watershed may be limited from the perspective of groundwater exchange. For example, when the model is applied to 1km or finer spatial resolution, the grids that close to the lake (e.g., 2km) may also have influences on the lake.**

Thank you for your comment.

Indeed, the SHUD model thoroughly considers lateral groundwater fluxes between all land triangular grids. The fluxes are calculated based on hydraulic gradients and mean hydraulic conductivities among a cell and its neighboring cells, as detailed in Shu et al. (2020). Thus, this manuscript primarily focuses on the fluxes among lake, bank, and land cells.

You aptly noted that groundwater fluxes between the lake and surrounding land are bi-directional, depending on the hydraulic gradient between the lake and land. The groundwater head around a lake generally aligns with the lake level, slowing groundwater flow and potentially creating wetlands in flat surrounding lands due to groundwater tables being close to the land surface. In more complex scenarios, land groundwater may recharge into the upstream lake edge, while the lake discharges into land groundwater on the downstream lake edges. SHUD-Lake adeptly captures the groundwater head distribution and flux field around the lake as well as across the entire basin, under sufficient spatial resolution.

5. **The figure 9 seems to show that, subsurface groundwater exchange between lake and band grids and the surface runoff are much smaller than others. I wonder whether we can get similar simulation result when we only consider some simple processes as most lake models do (e.g., precipitation, ET, inflow and outflow). If so, some discussions are needed to illustrate the necessity to consider these small terms.**

Thank you for your comment.

Yes, we have analyzed the water balance. Over the past 40 years, with precipitation as 100 Units, evaporation accounts for 253, River flux in at 153, and surface and groundwater fluxes are 4 and 7 respectively. This sums up to a lake water increase of 16 units. The contributions from surface and groundwater total 11 units, indicating that excluding these contributions would result in a smaller increase in lake water. Though relatively small, the contributions from surface and groundwater are not negligible. Additionally, the mentioned surface and groundwater fluxes are only those entering the lake directly through its boundaries. Due to topographical factors, land surface and subsurface fluxes typically first enter rivers, then flow into the lake through these rivers. Areas directly contributing surface and subsurface fluxes to the lake without passing through rivers are very limited, usually confined to small sections along the lakeshore.

We have incorporated this discussion in the revised manuscript.

6. **Why does the Figure 8 compare the anomaly time series? What about the absolute water level?**

Thank you for your comment.

In short-term simulations, the change in lake water mass is more valuable and reliable than elevation above sea level. According to the SHUD-Lake model settings, the lake is depicted as a bucket determined by lake stage and top area. Without detailed bathymetry (function of lake stage and top area), we can only roughly describe the lake shape (Figure 3). In this paper, the bathymetry for Qinghai Lake is described as the following table:

Elevation (m)	Top Area (km2)
3150	4186
3160	4186
3230	4543

The initial lake stage value in the simulation is 25 meters, implying an initial lake level of 3175 meters in elevation. The rough estimation of lake bathymetry introduces an error in simulating lake surface elevation. Moreover, the DEM and lake level measurements, sometimes based on different datum, exhibit discrepancies.

However, the key target in lake hydrology is not the water level elevation, but the change in lake water volume, i.e., the lake water balance. In the SHUD-Lake model results, the changes in lake water volume are more reliable than the absolute values of lake water level, hence Figure 8 compares the fluctuations in water level.

We have included this discussion in the section 3.1 of the manuscript.

7. The figure caption of Figure 9. The “Qb”seems to be “Qg”

Thank you for your comment.

The correct notation should indeed be "Qg" in the caption. This typographical error has been rectified in the revised manuscript.