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Key Points:
- Decline of water level of YY during 1975–1997 was mainly attributed to decreased recharge from land runoff
- The impacts of human activity on the water level decline of YY aggravated after 2005
- The aridity index over the drainage basin was closely linked to the changes of water level of YY

Supporting Information:
- Supporting Information S1

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What Caused the Decline of Water Level of Yamzho Yumco During 1975–2012 in the Southern Tibetan Plateau?

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Abstract Variability of water balance in closed lakes in the Tibetan Plateau (TP) can be a useful indicator of climate change. While most of lakes over the TP have been expanding, especially in the inner TP, the Yamzho Yumco in the Southern TP faced a significant water level decline in 1975–2012. This study focused on attribution of the water level changes to various factors with the help of a physically based and a statistical model for the water balance of the lake, along with observed precipitation and lake surface evaporation data. Results showed that climatic conditions dominated the changes in water level until 1997, and human activity through the construction and operation of a hydropower station started to play a strong role after 1998. The lake level has gone up and down due to changes in precipitation-generated recharge and evaporation over the study period. The water level decline in 1975–1997 was mainly due to low level of the recharge from precipitation and land runoff. However, the drastic decline of water level in 2006–2012 was far from the reach of the climatic conditions. It was indeed caused by the intensified influence of the building and operation of a nearby hydropower station. It was also found that the water level change during the whole period (1975–2012) followed the aridity index for the basin, especially before 1989. This provides an effective way to predict future changes of lake level, if reliable projections for future climate change and human activity are available.

1. Introduction

The Tibetan Plateau (TP) has complex terrain and cryosphere conditions (Lin et al., 2018; Zou et al., 2017), as well as dynamical and thermal structures (Morrill, 2004; Yang et al., 2014), causing unique features of water cycle in the region (Qian et al., 2011; Sang et al., 2016; Yao et al., 2013). Facing the aggravating impacts of climate change with global warming, hydroclimatic process throughout the TP has been significantly changing during recent decades (Chen et al., 2015; Yao et al., 2019) and attracted extensive attention worldwide. Among all drainage basins in the TP, closed lakes compose an important part of the terrestrial water resources system, and the water changes in them can be a useful indicator of climate change (Lei et al., 2017; Li et al., 2014; Yang et al., 2017; Zhang et al., 2017a). Thereby, many studies focused on detecting the changes of water budgets in closed lakes in the TP, as well as exploring the dynamics and attributing their physical causes (Song, Huang, Ke, et al., 2014; Zhang et al., 2017b, 2017c).

The scarce observed data caused great difficulty for the hydroclimate studies in the TP (Ma et al., 2015; Cuo et al., 2014). For solving the problem, previous studies alternatively used remote sensing data, reanalysis data, and limited field investigations to detect the change in hydroclimatic process and its physical causes in the TP (Kropáček et al., 2012; Tong et al., 2014). Overall, the changes of water budgets in closed lakes in the whole TP indicated obviously temporal variability and spatial heterogeneity (Kang et al., 2010; Lei et al., 2014; Yang et al., 2017). Water levels of many lakes in the Changtang Plateau and the central and northern TP increased over recent decades, while the lakes along the Himalayan Mountains and in the Southern TP showed stable variations or weak decreasing trends (Song, Huang, Richards, et al., 2014; Lei et al., 2017; Zhang et al., 2011; Jiang et al., 2017; Sun et al., 2018; Wu et al., 2017).

It is generally accepted that these results are associated with sizable uncertainties, mainly due to the unquantified uncertainties and errors of these data sources, which cannot accurately describe the seasonal variability of major hydroclimatic variables (Koster et al., 2017; Tong et al., 2014). Especially, they cannot meet the needs of investigating the variability in hydroclimatic process at local scales, which represents a considerable challenge.

Located in the Southern TP, the lake of the Yamzho Yumco (YY) is one of the “three holy lakes” of Tibet (Zhao et al., 2016), and its water level drastically declined by more than 5.00 m over the last four decades (Chu et al., 2012), differing from the stable variations or weak decreasing trends in other lakes in the surrounding region. For example, the declining rate of water level of YY was about 10 times of those in the Peiku Co and Puma Yumco in the Southern TP (Jiang et al., 2017; Sun et al., 2018). The decline in water storage of YY has disastrous influence on the fragile ecological systems, as well as the agriculture and livestock development in the basin. The abnormal phenomenon has been attracting extensive concerns. Previous studies mainly attributed the water decline of YY to the climatic variability, that is, due to precipitation decrease and evaporation increase (Li et al., 2014; Wang & Dou, 1998). However, the results may be not reliable due to the limited observed data. Moreover, these studies have neglected the impacts of human activities (especially the operation of the pumped-storage hydropower station in the basin) on the lake, without which the change of water level of YY may not be completely explained. Therefore, by collecting more observed hydroclimatic data including evaporation data over the last four decades, the objective of this study is to reexamine the changes of water level of YY. The key question to be clarified is as follows: Are the lake level changes caused by climatic variability or human activity, or both?

2. Data and Methods Used

2.1. Study Area

The YY Basin (28.27–29.20°N, 90.34–91.08°E), with an altitude above 4,400 m above sea level, is located in the northern foot of the Himalayas Mountain (Figure 1) (Li et al., 2014). It has an area of 6,100 km^2 and a water surface area of about 600 km^2, with a water storage of about 150×10^8 m^3. The basin is mainly covered by scrub grassland, due to semiarid climatic conditions. The glacier/snow coverage, occupying about 3.6% of the whole area, is mainly distributed in the west and southwest parts of the basin (Figure S1 in the supporting information). Over the last decades, there was a rapid deglaciation process in the west part of the basin, whereas the stable glacier status dominated in its southwest part (Zhao, 2014). In addition to the direct supply of precipitation over lake surface, the water of YY was more supplied by the baseflow and surface flow from land precipitation (including both rainfall and snowmelt), and the glacier meltwater also contributed a small part (Lutz et al., 2014; Wang & Dou, 1998). On its north, the Yarlung Tsangpo River (the upper reach of the Brahmaputra River) flows through to east, with an elevation difference of more than 800 m between them. Thus, it is rich in hydropower resources. The YY pumped-storage hydropower station was established in 1989 and has been operating since 1997 (Zhe et al., 2017) for providing power in the central Tibet, which had potential influence on the variability and changes of water budgets in the lake due to the water pump discharge. But unfortunately, there lacked observed data to quantify this effect.

2.2. Data Used

We collected monthly precipitation and temperature data measured in 1975–2012 at four meteorological stations (namely, Gyangtse, Konggar, Nagarze, and Baidi, as shown in Figure 1) in and around the YY Basin and took their averages as the areal precipitation (temperature) in the basin. Note that other data sources (i.e., remote sensing data and reanalysis data) have considerable bias to describe the seasonal variation of precipitation and its annual magnitude in the TP (Zhu & Sang, 2018) and thus were not used here. Differing from previous studies in which the potential evaporation was estimated by using different methods and data from remote sensing and reanalysis, here we obtained the data of water surface evaporation measured from an evaporation pond (with the diameter of 20 m) at the Baidi station in the lake, which directly presented the actual evaporation from the lake. Measuring water evaporation from such a big pond is often considered one of the most direct and accurate method. This was confirmed by a comparison between this measurement and an independent estimate based on the Penman-Monteith method at the Nagarze station (shown in Figure S2), which showed close agreement between the two. The daily water level was measured at the Baidi station, with the same period as that of water surface evaporation and precipitation data. The lengths, consistency, and completeness of all data records have been checked for ensuring the reliability of results. Besides, the monthly streamflow data measured at the Wengguo runoff station (shown in

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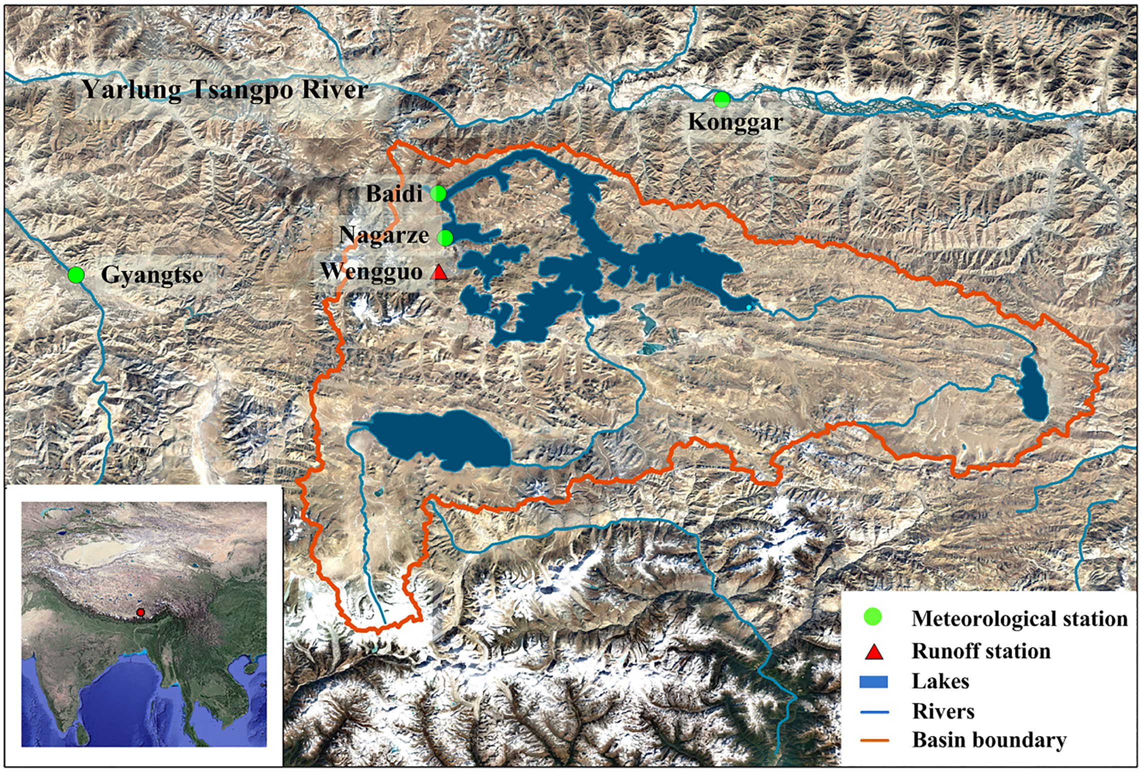

Figure 1. Basic situation of the Yamzho Yumco (YY) Basin in the Southern Tibetan Plateau, as well as the Wengguo runoff station and four meteorological stations in and around the lake.

Figure 1) were collected to estimate the glacier meltwater, as a main contributor to the water budgets of YY. We further collected the Land-Use and Land-Cover Change (LUCC) data (DCRES, 2017) in five periods (1990, 1995, 2000, 2005, and 2010, Figure S1), to investigate the changes of land surface situations (including the ice/snow coverage) among different periods in the YY Basin.

2.3. Methods Used

To ensure the accuracy of results, we used both a physically based water balance model and a multiregression statistical model to simulate the monthly water level variability in the lake and examined the accuracy of results at annual scale.

2.3.1. The Water Balance Model

The factors that influence the water balance of YY include precipitation P_l over the lake, evaporation E_l from the lake surface, and land runoff depth R_l from the basin to the lake. The water balance in the lake is thus described as follows:

$$L(t) = L(t-1) + P_l(t) + R_l(t) - E_l(t) + e \tag{1}$$

where $L(t)$ and $L(t-1)$ are the water levels in month t and $t-1$, respectively, and e is error caused by uncertainties in the terms represented in the model and other factors which were not represented. The observed P_l and E_l data were from the Baidi station.

The land runoff depth R_l includes the precipitation-generated land surface runoff (R_p, including both rainfall and snowmelt), baseflow (R_b), and glacier meltwater (R_g), that is, $R_l = R_p + R_b + R_g$. Here, the monthly simulated data from the Variable Infiltration Capacity model (Zhang et al., 2014), with a 0.25° spatial resolution, were used to estimate the R_p and R_b, as a basis of analyzing their contributions to the water budgets of YY. The observed streamflow at the Wengguo runoff station included the glacier meltwater R_g and the other two components (R_p and R_b) in its drainage basin. Here the difference between the observed streamflow data at this station and the sum of the simulated land runoff R_p and R_b data from the Variable Infiltration Capacity model was taken as the estimated R_g. The estimated R_g had a high correlation with the basin average temperature (with the correlation coefficient of 0.72). Therefore, a linear regression between the two was established to estimate R_g data during 1996–2005. For amending the above estimated R_l data, they were further adjusted using a scale factor (with the value of 0.784 here) based on the observed water budgets of YY before 1989.

2.3.2. The Multiregression Model

We also established a multiregression statistical model to simulate the monthly water level variation of YY. After analyzing the correlation between the water level and precipitation over land surface of the basin, it was established that the water level in a month had close relationship with the precipitations in the 2 months before (Figure S3). Thus, a multiregression model was established as follows:

$$L(t) = L(t-1) + P_l(t) - E_l(t) + c_1 \times P_s(t-1) + c_2 \times P_s(t-2) + w \quad (2)$$

where c_1 and c_2 are two parameters reflecting the generating efficiency of runoff by land precipitation P_s and w represents the influence of many random factors. The second-order regressive process approximately reflects the contribution of precipitation and runoff on land surface to the changes of the water level of YY.

The observed data in the first 15 years (1975–1989) were used to calibrate the parameters and determine the specific formulas in the above two models. Both the Nash efficiency coefficient and correlation coefficient were used to quantify the accuracy of the simulation results. Then, the observed data in 1990–1997 were used to verify models' performances. By considering the simulation results of the physically based water balance model and that of the multiregression model, more confidence for the study can be obtained.

Based on the results of the established water balance model (in equation 1), we can investigate the influences of the above five variables (i.e., P_l, E_l, R_p, E_b, and E_g) on the changes of the water level of YY, reflecting the effects of climatic variability. Especially, the above simulation mainly considered the climate-induced variability of water level. That way we can basically estimate the influence of nonclimatic factors such as human activities (especially for the operation of the YY pumped-storage hydropower station) by comparing the difference between the simulated and observed water level after 1997. Note that the influence of the human activities cannot be directly clarified due to the lack of water pump discharge data.

3. Results and Discussion

3.1. Variability of the Water Level of YY

The annual water level of YY significantly declined by 5.12 m during 1975–2012, with a declining rate of 0.14 m/year, visually beyond the observed natural variability. There was a local bottom value of 17.45 m in 1997 and a peak value of 19.68 in 2005. Visually, the water level changes can be divided into three periods: significantly decline in 1975–1997, increase in 1998–2005, and then decline in 2006–2012 (Figure 2). Differently, observations of precipitation and lake surface evaporation indicated periodic variations at decadal scales, without significant trends. For the annual temperature, it kept increasing in the whole period, especially after 1997. The water level displayed obviously seasonal variability, with the lowest level in June and the highest level in October. Monthly precipitation mainly occurred from June to September in the region, averagely accounting about 88% of the mean annual precipitation (Figure S4). The seasonal variation of lake surface evaporation had two peak values in May–June and October (Figure S4). The monthly distribution of precipitation in the three periods did not show difference, but that of lake surface evaporation was lower in 1998–2005 compared with the other two periods (Figure S4). Therefore, precipitation in rainy seasons directly caused the water level increase from June to October, and high lake surface evaporation dictated water level decline in dry seasons. Besides, the stable seasonal variations of precipitation and lake surface evaporation (except 1998–2005) in the whole period could not cause such significant decline of water level of YY.

The difference of water levels between October and June and between June and October in the previous year (Figure 3) was further analyzed. They basically reflected the changes of water level in rainy and dry seasons, respectively. It was found that the water level difference (WLD) in dry seasons kept negative values and increasingly decreased with year, although that in rainy seasons fluctuated with year and remained stable. The phenomenon implies that the water supply from precipitation and runoff inflow cannot offset the

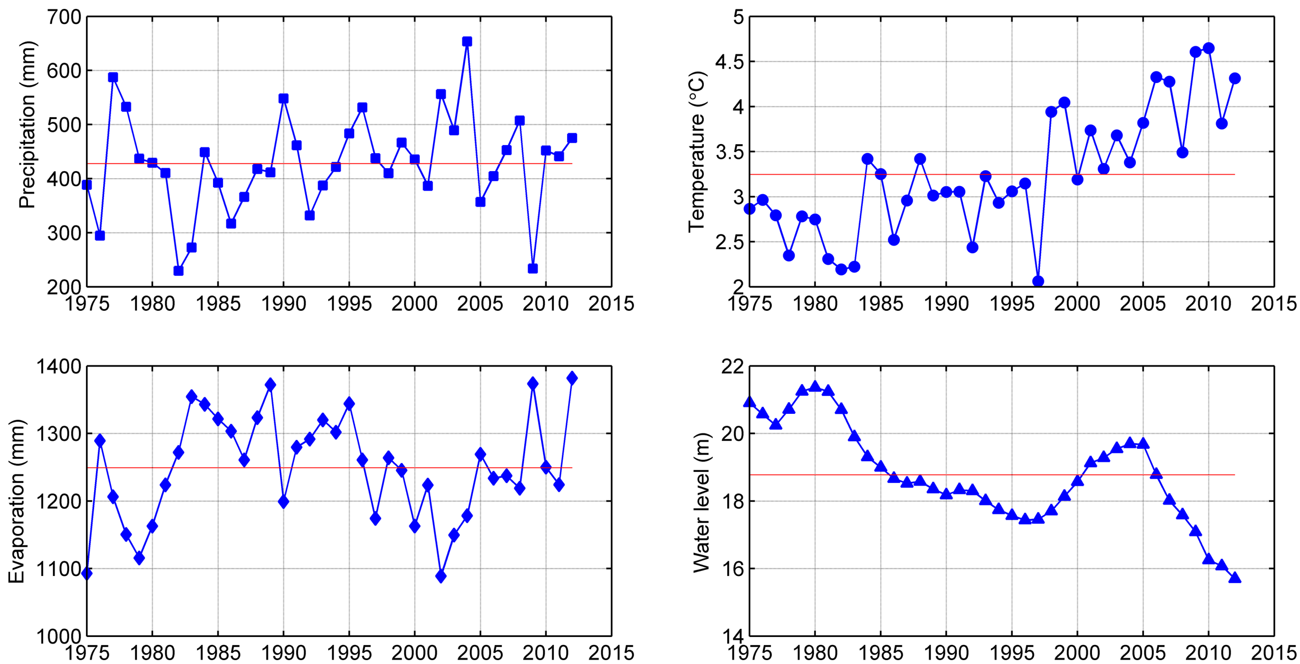

Figure 2. Interannual variations of annual precipitation, temperature, lake surface evaporation, and water level during 1975–2012 in Yamzho Yumco (YY) in the Southern Tibetan Plateau. The red lines show their mean values (425 mm, 3.25 °C, 1,249 mm, and 18.8 m for the four variables) during the whole period (1975–2012) considered.

water loss by evaporation in dry seasons. By computing the accumulated time series of the WLD in dry seasons, it also clearly presents the continuous decline of water level since 2005, obviously differing from the precipitation fluctuation in the same period and the variation of WLD in the former period.

Overall, the drastic decline of water level of YY in the period of 2006–2012 cannot be fully explained by the water balance expressed in equation 1. This means that a nonclimate-induced variability may have played an increasing role in the water level changes, which was discussed in the following section.

3.2. Factors in Determining the Water Level Changes

The estimated land surface runoff, baseflow, and glacier meltwater, as well as their sum, are shown in Figure 4 (left), where the Nash efficiency coefficients for the water balance model (and the multiregression model) were above 0.80 in 1975–1997. The results of two models closely followed each other and presented the decline-increase-decline step changes of water level (Figure 4, right). It shows that the land surface runoff and baseflow in the YY Basin, which were mainly influenced by precipitation (shown in Figure 2), fluctuated with year, with an annual mean of 574.1 and 121.4 mm, respectively, but having no significant trends. However, the glacier meltwater (with the mean value of 76.7 mm) kept increasing in the whole period, which was most likely due to the temperature increase (shown in Figure 2). The total land runoff (with the mean value of 772.2 mm) was mainly determined by the land surface runoff (contribute 74.4%), and the baseflow and glacier meltwater contributed 15.7% and 9.9%, respectively. Because of them, the total land runoff indicated fluctuation (due to precipitation variability) and increasing trend (due to the increasing glacier meltwater).

Some previous studies reported that the land surface runoff, baseflow, and glacier meltwater contributed 67%, 23%, and 10%, respectively, to the total land runoff in the region (Lutz et al., 2014; Wang & Dou, 1998), being similar to the above results. The relative difference may be due to the uncertainties of different data sets used. Besides, the variation of the Normalized Difference Vegetation Index (Figure S5) indicated that the LUCC conditions in the basin became greener and then remained stable after 1995, being similar as revealed by the LUCC maps in five periods (shown in Figure S1). Considering the stable fluctuations of precipitation and potential evaporation in the basin, and the stable land-use and land-cover conditions, it was less likely that they have caused the abrupt changes of land runoff. To

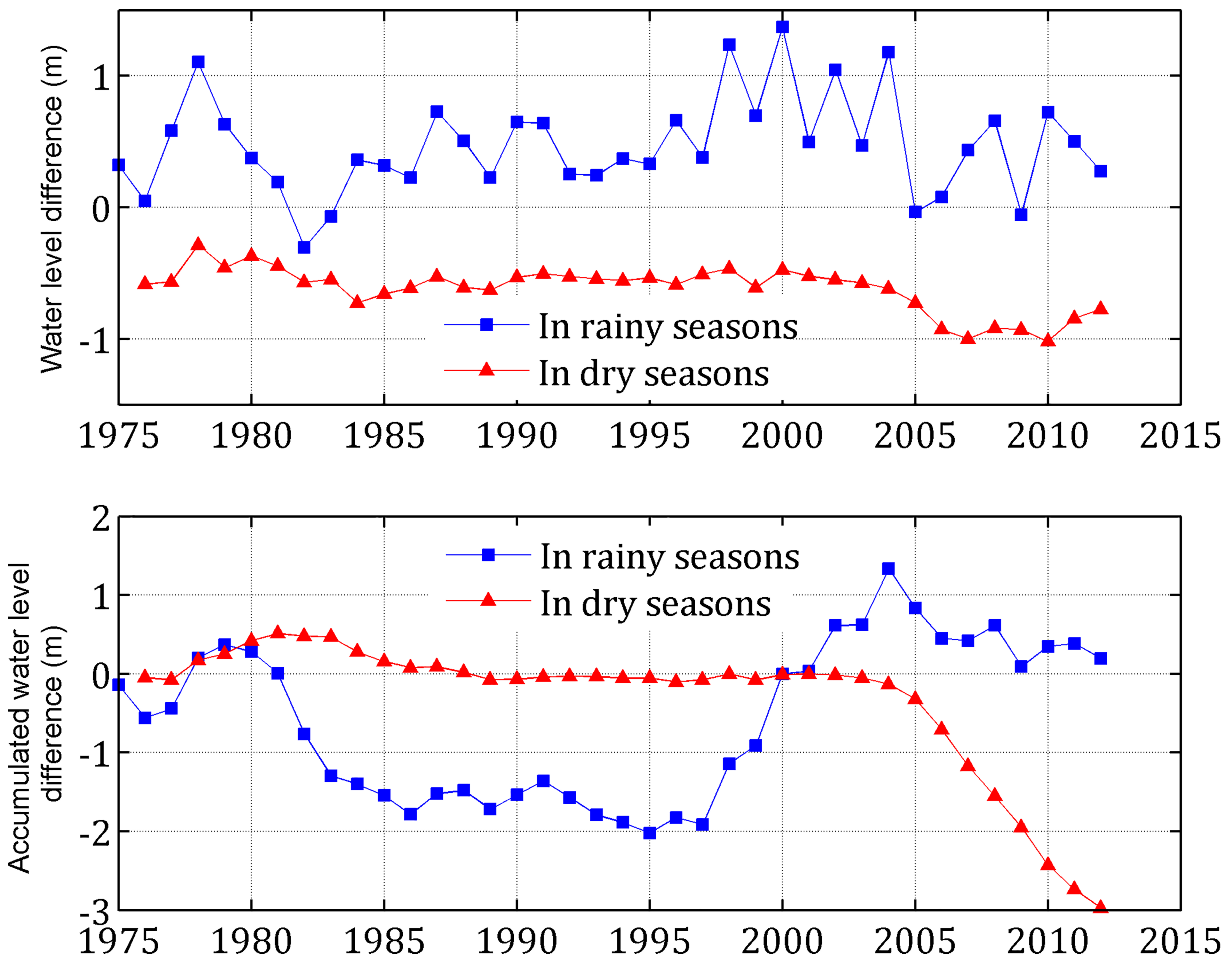

Figure 3. Differences of water level in rainy and dry seasons (up) and their accumulations during 1975–2012 in the Yamzho Yumco (YY) in the Southern Tibetan Plateau. The difference of water level in rainy season was calculated from the difference of water level between October and June and that in dry seasons were calculated from the difference of water level between June and October in previous year. For computing the accumulation of water level difference, their mean values during 1975–1997 were first removed.

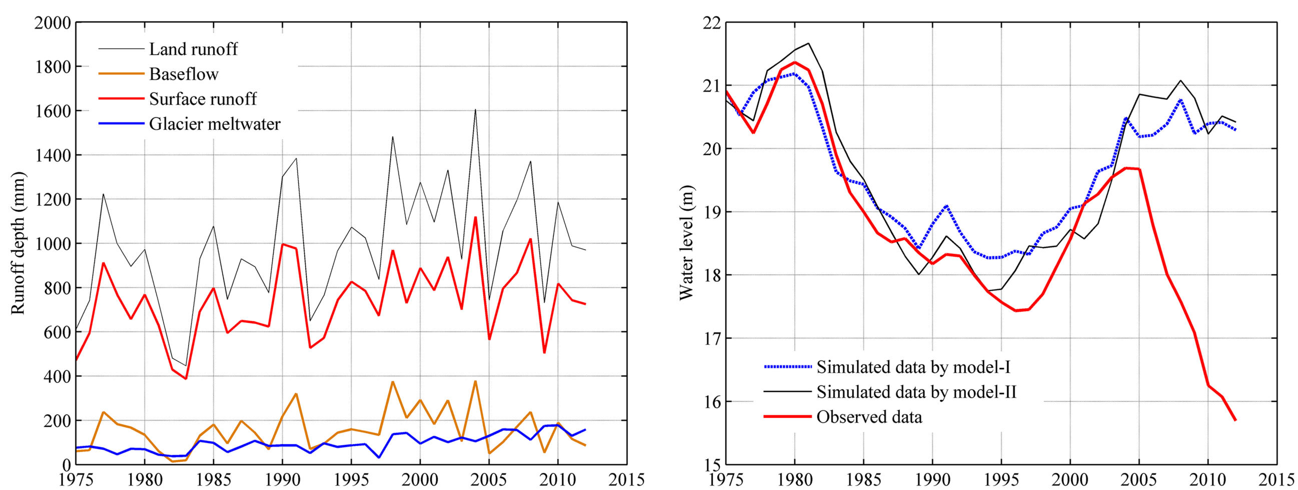

Figure 4. Estimated land runoff depth and its three components (left) in the Yamzho Yumco (YY) basin and the simulated annual water level of YY (right) using the water balance model (Model I) and the multiregression model (Model II) during the 1975–2012.

Table 1
Changes of Precipitation P_l, Evaporation E_l, Surface Runoff Depth R_p, Baseflow R_b, Glacier Meltwater R_g and Human Activities (HA), and Their Contributions to the Changes of Water Level (L) in Three Periods in the Yamzho Yumco (YY) in the Southern Tibetan Plateau

Period		Observed change in L	Simulated change in L	Changes of factors							Errors
				P_l	E_l[a]	R_p	R_b	R_g	HA[b]	Total	
1975–1997	Magnitude (m)	−3.46	−2.58	−0.36	−0.33	−1.16	−0.52	0.03	—	−2.34	1.12
	Ratio (%)			−15.4	−14.1	−49.6	−22.2	1.3	—	100.0	28.9
1998–2005	Magnitude (m)	2.22	2.73	0.33	0.42	0.83	0.65	0.39	−0.51	2.11	0.11
	Ratio (%)			15.6	19.9	39.4	30.8	18.5	−24.2	100	5.0
2006–2012	Magnitude (m)	−3.98	0.11	−0.03	−0.18	−0.13	−0.13	0.57	−4.09	−4.04	0.06
	Ratio (%)			−0.7	−4.5	−4.5	−3.2	14.1	−101.2	100	1.5

[a]Considering the negative effect of the evaporation E_l to the water budgets of YY, its opposite values (including both magnitude and ratio) are shown here.
[b]Considering that the operation of the YY pumped-storage hydropower station occurred after 1997, the influence of human activities on the changes of water level before 1997 was not discussed here.

roughly investigate the effects of glacier meltwater, we also extracted the glacier areas from the LUCC maps in the basin in five periods (Figure S1) and found that they did not change much either. The smallest area covered by glaciers was 225 km^2 in 1990, compared with 234–235 km^2 during the recent four periods. Therefore, the positive effect of glacier meltwater seems to be weak for the water level increase, and it cannot be the cause for the water level decrease after 2005. Based on the above considerations, the estimated land runoff and its three components were thought to be reasonable.

Comparatively, the simulated and observed water levels had relatively large difference (about 3.7%) in the 1990s, which may be partly due to the construction of the YY pumped-storage hydropower station in 1989–1997. Further, the simulated water level was increasingly higher than the observed ones after 2003, with a difference up to 4.60 m in 2012 (Figure 4, right). Repeated adjustments of parameters always led to the simulated water level higher than the observation. The systematic difference may reflect the effects caused by nonclimate factors. One such candidate can be the water loss due to the construction (since 1989) and operation (since 1997) of the YY pumped-storage hydropower station. Thus, it was thought that the simulation results by the two models until 1997 were acceptable and reliable, and the difference between the simulated and observed data after the 1997 could have been caused by the operation of the hydropower station.

To clarify the physical causes of the changes in the water level, we analyzed the changes in precipitation P_l, evaporation E_l, land surface runoff R_p, baseflow R_b, and glacier meltwater R_g in each subperiod and further quantitatively estimated their respective contributions to the change of the water level using the established model. Table 1 shows their contributions to the changes of the water levels in the three periods. The decline of water level in 1975–1997 was mainly caused by the low precipitation (account for 15.4%), low land surface runoff (account for 49.6), and baseflow (account for 22.2), pulsing the negative effect of high lake surface evaporation (account for 14.1%), offsetting the weak positive effect of glacier meltwater (account for 1.3%). It implies that the lower than average precipitation level (shown in Figure 2) in the whole YY basin was not enough to keep the water balance in the lake. In the period of 1998–2005, more recharge from precipitation (account for 15.6% and 39.4% in lake and from land surface), together with more baseflow (account for 30.8%) and increasing glacier meltwater (account for 18.5%), caused the increase of water level, and the low evaporation also accounted for 19.9%, offsetting the water loss caused by human activities (account for 24.2%). In this period, the lake surface evaporation decreased compared with that in the former period, which was mainly due to a decrease in wind speed and a decrease in net total radiation in the region, although temperature kept increasing (Woolway et al., 2019; Zhang et al., 2007). During 2006–2012, the positive effect of the increasing glacier meltwater (account for 14.1%) basically could offset the negative effect of P_l, E_l, and land runoff, causing the stable variation of the simulated water level, while its significant decrease was mainly caused by the human activities.

Overall, the results in Table 1 are different from previous studies, in which precipitation was thought as the primary factor (account for 88.9%) for the increase in water storage, and the glacier meltwater

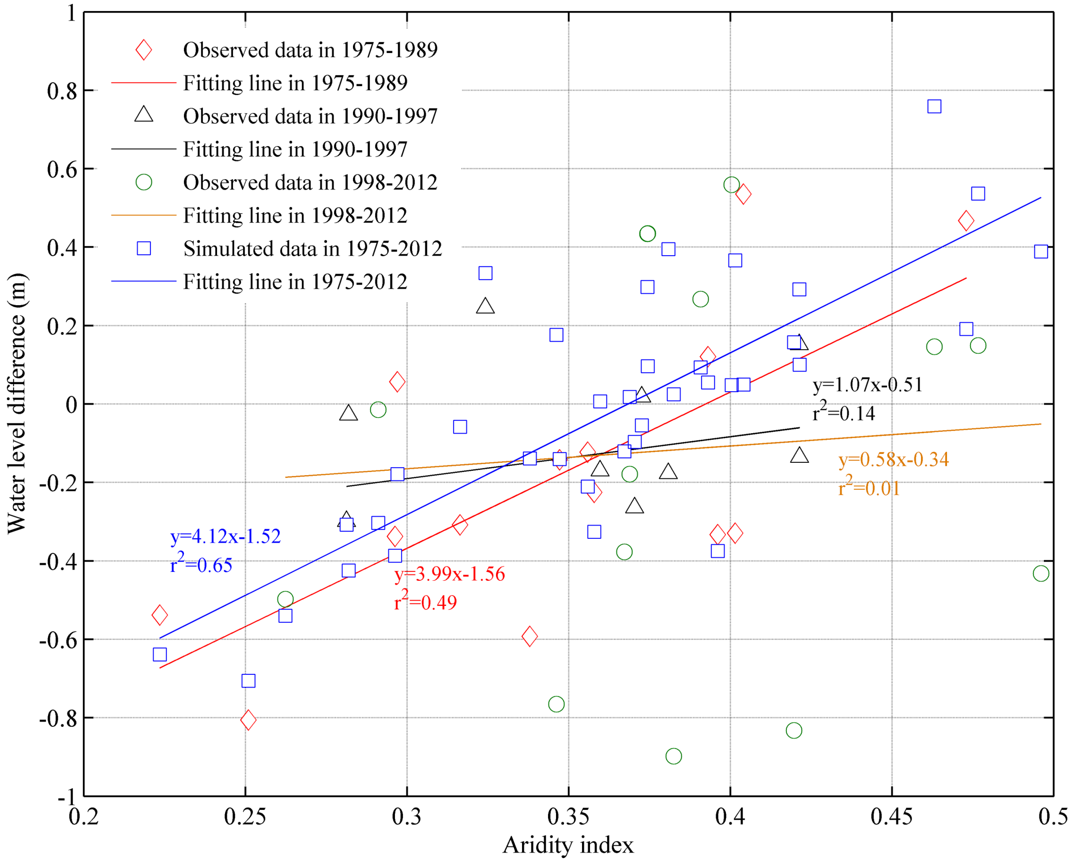

Figure 5. Scatter diagram showing the relationship between the aridity index for the basin and the water level difference during 1975–2012 in the Yamzho Yumco (YY) in the Southern Tibetan Plateau. The aridity index was defined as the ratio between the annual precipitation and potential evaporation in certain year. The water level difference reflected the difference of annual water level in the year and that in previous year, and it was mainly determined by the water surplus or deficit in the corresponding year, quantified by the aridity index.

accounted for 8.9%, but E_l accounted only for 10.1% of the lake shrinkage in 2004–2012 (Li et al., 2014). However, from Figures 2 and 3 we clearly see the similar precipitation and evaporation in the two periods of 1980–1995 and 2005–2012, and they could not be taken as the cause for the drastic decrease of water level only in the latter period. As a result, it was thought that the positive effect of recharge from precipitation and the negative effect of lake surface evaporation could have been equally important in maintaining the water balance in the lake. Moreover, the aggravating influence of the nonclimatic effect which was probably due to human activities after 2005 should be emphasized. Comparatively, the water level decline in 1975–1997 was mainly due to the lower recharge from precipitation and land runoff, but the drastic water level decline in 2006–2012 was likely caused by the intensive influence of human activities.

To further verify the reasonability of the results, we used an aridity index (AI) (Arora, 2002) to present the water budget in the YY Basin. Here the AI was defined as the ratio between annual precipitation P_s and potential evaporation E_l in the basin. It is generally known that the interannual variability of annual water balance is governed by the relative availability of water (precipitation) versus energy (potential evaporation) processes, quantified by AI, and modulated by the physical underlying surface process (Carmona et al., 2014). Assuming a weak influence of human activities in the YY Basin, the AI can reflect the relative water surplus or deficit at annual scale, which basically determines the increase or decrease of water level compared with that in previous year. Generally, high AI value would lead to the increase in water level, and vice versa. On the contrary, the deflected relationship between the AI and water level variability could be due to the influence of human activities.

In Figure 5, the AI and WLD calculated from the observed data do show fairly close relationship in 1975–1989, as expected. Higher AI value corresponds to bigger WLD; especially, the AI value above 0.4 can basically ensure the positive water balance in the lake. However, the AI-WLD relationship was much weaker in 1990–1997 (especially in 1998–2012) compared to that in 1975–1989, implying that the change of water level in the latter periods was not only determined by the nature hydroclimatic variability. As a result, the influence of human activities, as described in Table 1, cannot be neglected. Comparatively, the AI and simulated WLD in the whole period of 1975–2012 displayed a similar close relationship as in the first period of 1975–1989, with consistent fitting lines, which means that the changes of the simulated water level were mainly determined by nature hydroclimatic variability. Therefore, the simulation results of water level by the established water balance model were thought reasonable, and they mainly reflected the variability of water level under the natural hydroclimatic conditions.

The humidifying tendency in the region during recent decade, coupled with the glacier meltwater due to temperature increase, would be favorable to the recovery of water level in the lake. However, considering the variability of water level of YY for the 21st century, the aggravating drying tendency in arid and semiarid areas (covering the YY Basin) worldwide under 2 °C global warming target has been expounded in many previous studies (Huang et al., 2017). Focusing on changes in hydrological cycle, in a warmer climate, more rain is needed, and many regions will get more precipitation, but they are not enough to keep pace with the growing evaporative demand (Sherwood & Fu, 2014). Thereby, the decreasing AI value would more likely cause negative water balance in the lake, and more human activities would further worsen it. Under this scenario, the water level of YY would continue to decline for a long time, and the conflict between the protection of ecological system and the water resources utilization in the region would be aggravated.

4. Conclusions

A significant declining trend of the water level of YY during 1975–2012 has been identified, while there were subperiods when a recovery of the water level occurred. Using observed precipitation and lake surface evaporation data, and a water balance model as well as a multiregression model, this study attempted to attribute the changes of water level to various physical causes. Results showed that various physical components of the water balance played different roles in different periods of time, and these physical causes combined could not explain the drastic decline after 2006.

It was found that the negative effect of lake surface evaporation and the positive effect of precipitation (include both precipitation over the lake and runoff from the surrounding land surface) were commensurate, and their relative difference caused the increase or decline of water level of YY in different periods, in which the glacier meltwater kept its positive effects. The water level decline in 1975–1997 was mainly due to the low level of the recharge from precipitation and land runoff; in 1998–2005, the water level increase was caused by enhanced precipitation over the lake and recharge from land surface runoff, while human activities also contributed to a part to the water level decrease. The drastic decline of water level in 2006–2012 was far from a balance by the hydroclimate factors and processes considered. It could have been caused by the aggravating influence of human activities through the operation of the hydropower station.

The AI describing the major natural factors (precipitation versus potential evapotranspiration), affecting the water balance in the basin, was found to be a useful indicator for the water level variability of the lake, which was especially true for the period before 1990 when the influence of the hydropower station did not play a significant role in determining the water level of the lake. This provides a possibility to make a rough prediction of the water level change with simple calculations of the index for the basin. However, a more reliable prediction of future water level changes will require not only accurate prediction of precipitation, evapotranspiration, and runoff but also reliable estimate of more human activities including the operation of the hydropower station.

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