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STUDIES ON WATER STAGE FLUCTUATION OF YAMZHO LAKE IN XIZANG

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ABSTRACT: Yamzho Lake, with a drainage area of 6,100km^2, is the largest closed interior lake in the southern part of the Qinghai-Xizang Plateau. The elevation of the lake stage is 4,440m, lake storage is about 16 billion m^3. Water recharge mainly depends on rainfall, melting water from glacier area, taking up 16%. In the drainage basin about 2% of the area is covered with glacier. Seasonal range of variation in the lake stage is small, usually less than 0. 6m. The biggest water level in a year appears in September or October, not in July or August of the rainfall concentrated period, because of the lake's self-adjustment. The lowest lake level occurs in May, June or July. In wet years the stage fluctuation has clear periodicity, in dry years the lake level tends to fall down around the year. There is a close correlation between rainfall and water level variation. Based on the analysis of the patterns of the lake level fluctuation during the recent 100 years, according to the measuring and investigation data, the fluctuation range of the lake level varied at 4 to 5 meters, and the water level has been gently descending at the rate of 0. 6m/100 years.

KEY WORDS: Yamzho Lake, lake stage fluctuation, Qinghai-Xizang Plateau, climatic change

I. GENERAL SITUATION ABOUT THE DRAINAGE BASIN

Yamzho Lake is the largest closed interior lake to the south of the Yarlung Zangbo River and the north of the Himalayas. Its drainage basin is located at 90° 08′ to 91°45′ east longitude, 28°27′ to 29°12′ north latitude. The Ganbala Mountain, as the demarcation line, is between the Yamzho Lake and the Yarlung Zangbo River, the nearest distance between them is at Zhamlong, where the water level difference is up to 840m. To its east there is Zhegucuo basin, and to its southeast and south there is the Himalayas. The lake is contiguous to Puma Lake to southeast and the Nianchu River in its west adjacent

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to it, with the snow capped Karela Mountain as watershed.

To its northwest, Yamzho Lake is separated, from the Manqu River, a tributary of the Yarlung Zangbo River, by a low hill. There are several lake lets distributed on the top of this hill. Based on estimation, Yamzho Lake was originally a exorheic lake, its water ran to the Manqu River through Yase Gap, then to the Yarlung Zangbo River. Because of dry climate the lake level fell down and disconnected with the Manqu River and became a closed interior lake. In the Yamzho Lake, Chiguo Lake and Puma Lake region —— the largest lake region in south of Xizang, Bajiu Lake basin inserts in the southwest of Yamzho Lake basin, and Chen Lake is embeded in Yamzho Lake basin since its water recharge is small, and their water level difference is over ten meters (Fig. 1). The change of the lake region clearly reflects the lake basin changes with climate.

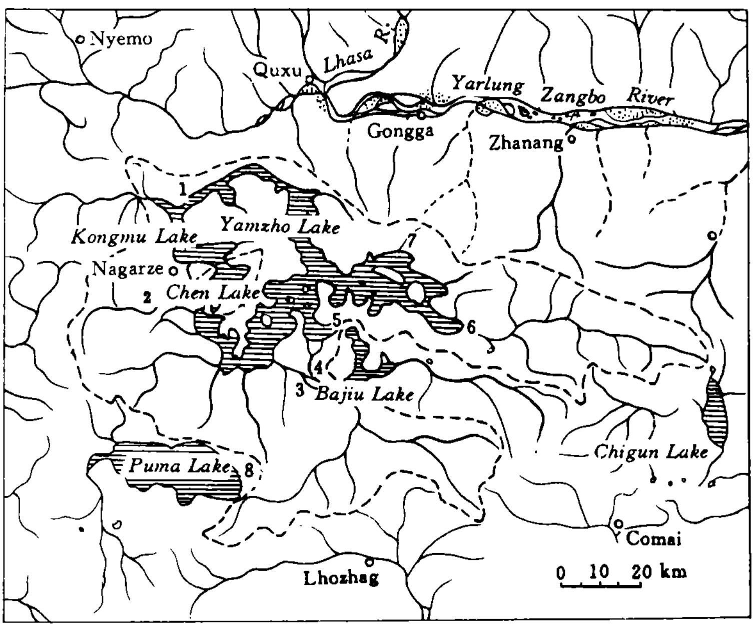

Fig. 1 Location of Yamzho Lake basin
1. Baidi 2. Wengguo 3. Kadong 4. Rongduo
5. Tiela 6. Quguozhong 7. Dongla 8. Dui

The Yamzho Lake basin covers an area of 6,100 km^2, among which water area is 621 km^2. The elevation of the lake water level (the Yellow Sea as base-level) is 4,440 m. The lake basin is extraordinarily irregular with winding lake shore line. There are islands scattered in the lake. Perimeter of the lake is

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about 400km. Lake storage is about 16 billion m^3. The lake is deeper in north, the deepest depth is 55 m, in the east of Zhamlong, The main rivers entering into the lake are Kamalin River, Kadongjia River, Linqing River, Xiangda River, Puzong River and Kaluxong River from west, southwest to east, respectively. The rivers in the north are usually very short, carrying small quantity water and most are seasonal rivers.

Yamzho Lake is located inside the rainfall shade area of the Himalayas' north hillside, so it is very dry, average annual precipitation is only about 350 mm, but average annual evaporation from water surface is over 1,250 mm, average annual temperature is 2.6℃.

II. SITUATIONS ABOUT THE LAKE WATER RECHARGE

Vapour transferring to Yamzho Lake depends on the warm and humid current from the Bay of Bengal through Manqu inlet and valley of Luozanu and Luozaxia Rivers, which cut over the Himalayas, in the south of the lake basin. Vapour transferred can not reach the northeast of the lake because of continuous ridges of mountains, so it is very dry. There are glaciers covering the watershed in the west of the lake, with an area of 110 km^2. There is also a large area of ridges capped with snow around the year. They are all sources for lake water recharge. But rainfall is the main water recharge source. Water from glaciers which make up 2% of the total lake drainage area, is 1% of the total recharge water to the lake.

There is a meteorological station at Nagarze built in 1961 in this lake basin, rainfall data from 1961 to 1992 are available. There are also eight hydrological stations built around 1974 at Baidi, Wengguo etc., complete hydrological data are available too (Table 1).

In the lake drainage basin precipitation is nearly the same at different stations except Baidi, where annual rainfall is 20% higher than that at Nagarze. By analysis of the rainfall information the annual rainfall at Nagarze station can represent the situation in the lake basin.

III. PATTERNS OF VARIATION IN THE LAKE STAGE

The record of the Yamzho Lake stage began in 1974, there are 19-year

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complete stage data available from 1974 to 1992. The highest water level recorded was 4441. 6 m (in 1980), the lowest was 4437. 88 m (in 1990), the range of fluctuation was about 3. 76 m. Historical highest water level (according to investigation) was 4442. 5 m (in 1963), the largest range of stage fluctuation was 4. 26m.

Table 1 Precipitation in the lake drainage basin

Station	Precipitation (mm)	Duration (years)	Period
Nagarze	353. 4	31	1961—1968,1970—1992
Baidi	411. 6	17	1975,1977—1992
Wengguo	346. 6	10	1983—1992
Kadong	352. 4	13	1976—1978,1983—1992
Rongduo	327. 5	10	1983—1992
Quguozhong	326. 9	11	1976—1978,1985—1992
Dongla	354. 4	5	1983—1987
Dui	363. 8	9	1976—1978,1985—1990

1. Patterns and Characters of Annual Lake Stage Fluctuation

In general in wet or moderate wet years such as in 1974 and 1978 (Fig. 2) from May or June, the beginning of rainfall season and the ice and snow melting period, the lake stage begins slowly rising, then quickly going up during the rainy season of July and August. Because of the lake's self-adjustment, highest lake level doesn't appears in July or August, but in September or the first ten days of October. From then on the lake stage begins falling till May or June of the next year. The characters of the fluctuation of the lake stage are as follows: stage rising period is short with great variance, stage falling period is long with small variance. Like river stage, variance in the lake stage is cyclical with single peak around a year, but range of the lake fluctuation is more gentle.

In dry years such as in 1976, 1982 and 1983, lake level fell down around the years, water running to the lake decreased since less rainfall occurred during those years. No lake level rising period appeared. The highest lake level was on Jan. 1, the lowest was at the end of Dec. This reflects the special pattern of Yamzho Lake stage variation.

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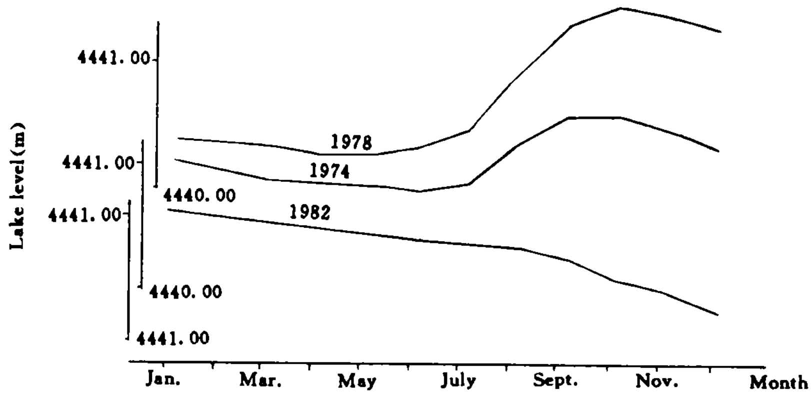

Fig. 2 Process of monthly mean lake stage in dry, normal and wet years

In this paper for variation in lake stage two basic indexes were used, one is the difference of annual highest and lowest lake stages, the other is the difference of the lake level at the beginning and the end of a year. Variation of Yamzho Lake stage by the second index was given in Table 3. The range of the lake stage fluctuation was between −0.87m and +0.80m, the range of the difference of the highest and the lowest levels in a year was between 0.39 m and 1.23 m(Table 2), the average was below 0.6m, only one year has the range of over one meter, which was in 1978, with the value at 1.23 m. All those data showed that the fluctuation of Yamzho Lake stage was small.

The relation of the lake stage variation with rainfall was shown in Fig. 3. Rainfall data were collected from Nagarze Station, which can represents the real situation in the lake basin. In 1978 rainfall was 505.0mm, which was 1.43 times of the average annual rainfall in this area, lake stage rose up 1.23 m, in 1982 precipitation was only 150.7 mm, which was 43% of the average annual rainfall, lake stage fell down by 0.87 m, the difference between the highest and the lowest level was also 0.87 m, and lake stage descended around this year.

The curve in Fig. 3 can be represented by the following equation:

$$\triangle H = 0.27(P - 140)^{1.48} - 90$$

where $\triangle H$ is the range of the lake level fluctuation (cm), P is annual rainfall (mm).

This equation and the curve in Fig. 3 also showed that the lake storage changed with rainfall. When rainfall was equal to a certain value P_o, the $\triangle H$

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Table 2 Patterns of the lake stage fluctuation

Year	Date of highest level appeared	Date of lowest level appeared	Variation in a year (m)	Variation between years (cm)
1974	09. 28	06. 15	0. 66	
1975	10. 03	07. 19	0. 40	−11
1976	01. 01	12. 31	0. 56	−34
1977	10. 08	05. 19	0. 68	−33
1978	11. 11	05. 03	1. 23	+47
1979	09. 12	06. 16	0. 68	+53
1980	09. 12	05. 13	0. 49	+13
1981	08. 27	12. 25	0. 40	−13
1982	01. 01	12. 30	0. 87	−54
1983	01. 01	12. 30	0. 67	−80
1984	09. 15	06. 24	0. 45	−60
1985	09. 13	07. 01	0. 40	−26
1986	01. 01	12. 30	0. 40	−37
1987	09. 27	06. 30	0. 81	−15
1988	09. 28	06. 14	0. 58	+ 4
1989	01. 01	07. 19	0. 42	−21
1990	10. 01	06. 19	0. 72	−17
1991	09. 26	06. 02	0. 72	+15
1992	09. 05	07. 11	0. 39	− 3

Table 3 Variation of Yamzho Lake stage in different years

Year	Level at the beginning of a year (m)	Level difference ΔH (cm)	Year	Level at the beginning of a year (m)	Level difference ΔH (cm)
1974	4441. 04	+ 3	1984	4439. 49	−33
1975	4441. 06	−26	1985	4439. 15	−28
1976	4440. 80	−56	1986	4438. 87	−40
1977	4440. 25	+17	1987	4438. 47	+21
1978	4440. 42	+80	1988	4438. 68	− 9
1979	4441. 22	+20	1989	4438. 59	−40
1980	4441. 41	− 5	1990	4438. 19	+15
1981	4441. 37	−33	1991	4438. 34	+10
1982	4441. 04	−87	1992	4438. 44	−27
1983	4440. 16	−67			

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$=0$, we call this P_0 as balance rainfall. If rainfall in this lake basin was over this value, $\triangle H$ was positive, otherwise $\triangle H$ was negative. P_0 was 384mm from the curve in Fig. 3 and 380 mm calculated from the equation. Then based on this P_0 the fluctuation of the lake stage can be predicted. Obviously for different lake stage, $\triangle H$ represents different changes in lake storage, so at different lake levels there should be a special P_o for $\triangle H=0$, respectively. In this paper the range of the lake level fluctuation was relatively small and the period concened was not very long, this error was omitted here.

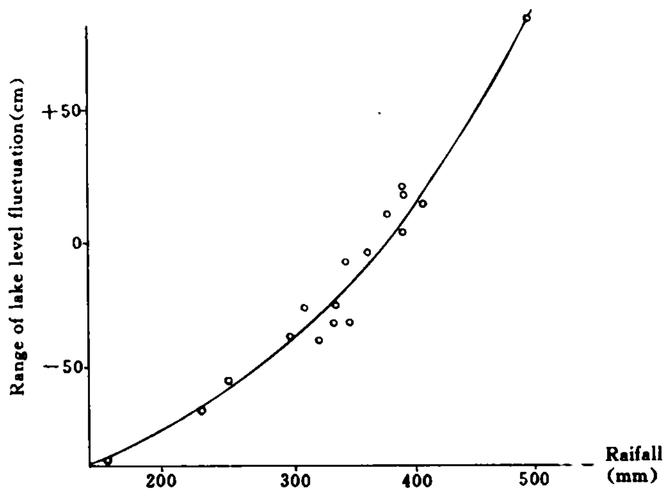

Fig. 3 Relationship between lake stage fluctuation and precipitation

2. Character of Yamzho Lake Level Fluctuation Between Years and Affecting Factors.

By investigation and measurement the change of Yamzho Lake level during the recent 100 years was shown in Fig. 4. The range of variation was about 4—5 meters, rising period alternates with falling period. The longest lake level rising period was 14 years (from 1923 to 1937), and the longest falling period was also 14 years (from 1963 to 1977). The overall tendency of the lake stage was slightly falling down, the rate was at 0.6m/100 a. The author holds that this overall falling tendency was caused by the decrease in rainfall and the rising in atmospheric temperature based on analysis.

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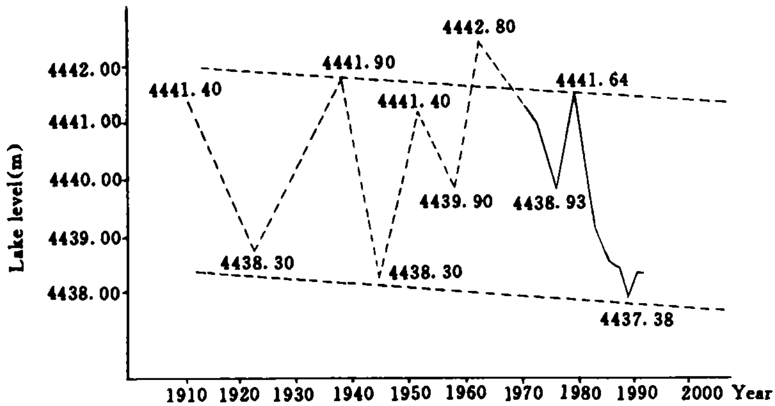

Fig. 4 Change of the lake level during the recent 100 years

Table 4 Range of the lake stage fluctuation during different periods

Order	Year		Range of variation in lake level (m)	Years	Reference
	Beginning	Ending			
1	1912	1923	−2.60	11	Data during1912−1973 was from investigation, those during 1974 − 1992 from measurement
2	1923	1937	+3.10	14	
3	1937	1945	−3.60	8	
4	1945	1952	+3.10	7	
5	1952	1959	−1.50	7	
6	1959	1963	+2.60	4	
7	1963	1977	−2.57	14	
8	1977	1980	+1.71	3	
9	1980	1992	−3.34	12	

There were nine lake level rising and falling periods alternately from 1912 to 1992 (Table 4). A single period usually lasted 7 to 14 years, only the sixth and the eighth periods lasted 3 to 4 years. This objectively reflected that the continuous wet period was becoming shorter. The range of the lake stage fluctuation during those nine periods was 1.5 to 3.6 meters. Based on the balance rainfall P_o and taking reference to the analysis of rainfall in the neighboring Nianchu River valley the variation in the lake stage was tested and verified. From 1956 to 1959, Yamzho lake level fell down to the lowest because less rainfall occurred during this period, 1962 and 1963 were wet years, average $P=441.7$mm, it was over P_o, the lake stage began rising, and in addition, a large amount of water from the burst Puma Lake ran to Yamzho Lake, the level rose up by 0.77 to 0.8 meters and reached the highest of 4442.5 m in history.

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From 1964 to 1976, a long period of less rainfall, average $P=343.2$mm, less than P_o, then the lake stage fell down. The lowest level in this period was 4439.93, occurred on May 19,1977. From 1977 to 1979, the average $P=434.7$mm, higher than P_o. In 1978 rainfall amounted to 505.0 mm, the lake level rose up and the highest lake stage of 4441.64 m in this period appeared. From 1981 to 1992, a long continuous period with less rainfall than P_o, average $P=321.1$mm, lowest lake level of 4437.8 m in this period occurred, which was also the lowest in history.

Average rainfall from 1961 to 1992 in Yamzho Lake drainage basin was 353.4 mm. This value was below the balance rainfall P_o. So for the 30 years of rainfall data available it was drier and the lake level fell down. By statistical analysis during this period rainfall in 1980 was lower, then falling in lake stage was obviously. Rainfall departure during the recent 30 years was shown in Fig. 5. The curve showed that for most of the years precipitation was less than P_o. This was in coincidence with the overall declining tendency of the lake stage.

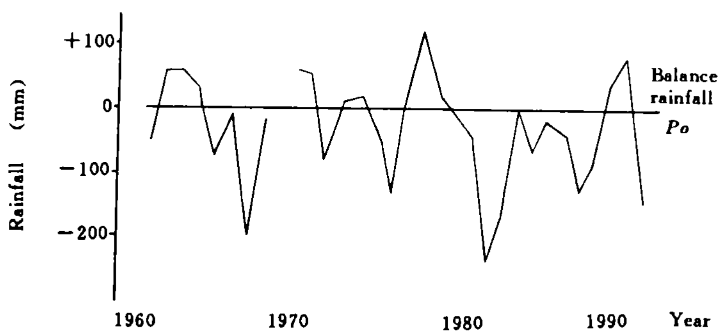

Fig. 5 Rainfall departure during 1960 to 1992

For further testifying the declining tendency of the lake stage, temperature change was analysed (Table 5). From the 30—year meteorological data available the average annual temperature was rising, the rate was at 0.2 to 0.3℃/10 a, the annual lowest temperature was also rising, the rate was slightly higher. The annual highest temperature was relatively constant.

In large-scale area such as Lhasa, Zedang, Rikaze and Damxung from 1960 to 1990 temperature was also rising, only the rate was slightly smaller than that in Yamzho Lake area (Fig. 6). The rising of the temperature in Yamzho Lake district directly reflected that the climate became warmer and rainfall declined, which were consistent with the falling of the lake stage.

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Table 5 **Temperature at Nagarze meteorological station** (℃)

	1962	1963	1964	1965	1666	1967	1968	1969	1970	1971
Average	2.3	1.5	2.9	2.0	2.9	2.0	1.7		2.7	2.2
Highest	19.5	18.7	21.8	21.2	21.6	19.9	19.7		21.8	20.7
Lowest	−24.9	−24.3	−21.5	−20.5	−24.6	−20.2	−25.0		−21.5	−20.8
	1974	1975	1976	1977	1978	1979	1980	1981		
Average	3.1	2.8	2.9	2.8	2.8	2.4	1.9	2.5	2.4	2.4
Highest	22.5	20.1	19.3	20.0	19.4	18.8	19.8	21.4	19.3	20.5
Lowest	−19.9	−20.2	−23.4	−21.6	−22.9	−22.9	−23.2	−22.7	−21.9	−22.7
	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Average	2.5	2.4	3.5	2.7	2.4	2.7	3.2	3.1	2.7	2.9
Highest	20.9	21.8	20.5	21.1	21.5	22.6	21.5	21.6	21.6	19.0
Lowest	−20.2	−22.4	−18.6	−20.5	−20.1	−21.4	−17.3	−19.4	−19.4	−19.8

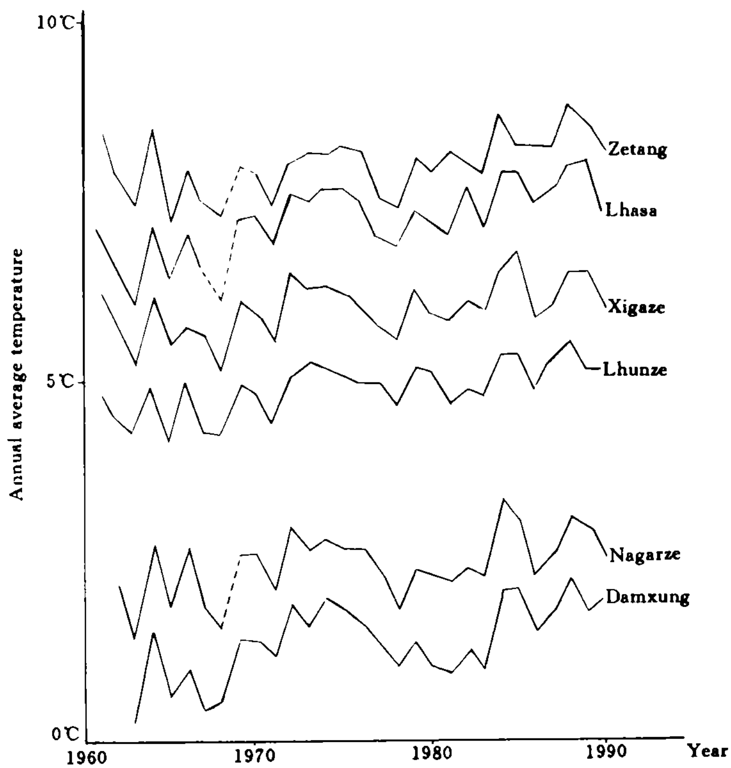

Fig. 6 Processes of annual average temperature at representative stations

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IV. CONCLUSION

There are three characters in the fluctuation of Yamzho Lake stage: 1) Variation in lake stage was closely related to rainfall, and had clear periodicity around a year and between years. 2) Because the lake's self-adjustment range of level fluctuation was smaller than rivers, the dates of the highest and lowest levels and the range of level fluctuation during a long period were all different from rivers. 3) Based on the analysis of the recent 30-year data measured and the recent 100 years' data investigated, it can be concluded that the overall lake fluctuation tended to fall down with a rate at 0. 6m/100 a.

Yamzho Lake is the largest closed interior lake in the south part of Qinghai-Xizang Plateau. The fluctuation of the lake stage was controlled by climate. Rising in temperature and declining in rainfall were reasons that the lake stage was falling down. The average temperature in Qinghai-Xizang Plateau in 2030 will rise by 2℃ to 3℃ by forecasting, this will undoubtedly aggravate the falling tendency of the lake level. So more attention should be concentrated on the fluctuation of the lake level since it has great effects on the study of climate in Qinghai-Xizang Plateau, the whole China, even Asia.

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