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STUDY OF SEICHE IN LAKE BIWA-KO (IV) —OBSERVATION WITH A NEW PORTABLE LONG PERIOD WATER LEVEL GAUGE—

By

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Abstract

A new portable long period water level gauge was designed in order to verify the results of numerical experiments with a computer about the seiche in Lake Biwa-ko, especially about the longitudinal oscillations. Using two water level gauges of this type, an observation was performed for a month in Otsu and Hikone at the same time. The observed periods of seiche agree well with the periods derived from the numerical experiments. The seiche with the period of about four hours is found for the first time in the north basin of Lake Biwa-ko from the frequency analysis of the records in Hikone. The observed amplitude ratio and the observed phase difference between those two observation sites agree with the experimental results about seiche of mode 1, mode 2 and mode 3. But the observed result of seiche of mode 4 disagrees with the experimental result.

1. Introduction

In the previous papers (Imasato [1971] and [1972]), possible periods of seiches in Lake Biwa-ko are found to be 255.5, 79.8, 69.1, 38.7 and 31.9 minutes from the numerical experiments by a nonlinear two-dimensional model, and some characteristics of seiches are discussed. These experimental results agree with the results of the observations in Otsu at the southern end of the lake. The observed periods are 249.6, 74.1, 65.7, 39.7 and 32.1 minutes.

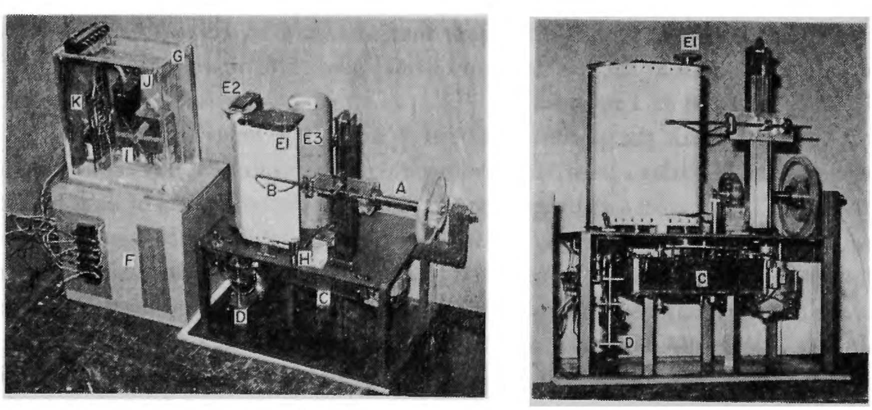
The seiche with the period of about 4 hours has never been confirmed from observations in the north basin and has been considered to be a bay oscillation in the south basin. The reason for this can be attributed to the technique of data analysis in those days. The numerical experiments with a computer indicate that this is a uninodal seiche in the whole basin, and that its amplitude in the north basin is very small. In order to verfy the experimental results about the seiches in Lake Biwa-ko, especially about the longitudinal seiches, a new portable long period water level gauge was designed and an observation was performed in Otsu in the south basin and in Hikone in the north basin at the same time for about a month. In this article, some descriptions will be made about the instrument, and then the results of the observation will be shown.

2. New water level gauge

A portable water level gauge capable of taking a continuous record for a day or for a week has been used in the observations of seiche in Lake Biwa-ko. The latter has a defect of low accuracy in the frequency analysis, and the former has a defect that maintenance of continuous observation is very difficult for observation of such a large basin as Lake Biwa-ko.

Therefore, the new portable long period water level gauge was designed. It was developed from the original type of this water level gauge which had been established many years before by G. Toyohara, H. Kunishi and K. Tanaka of Kyoto University. This original type of water level gauge has two excellent qualities: one is that a recording pen contacts very smoothly with the surface of recording-paper, and the other is that the float with a shape of a flat circular cone responds well to the water surface elevation. In our new type of water level gauge two improvemets have been added: one is that an automatic observation can be performed for approximately 34 days, and the other is that the detection of the phase differences among the records in some observation sites is made possible by accurate time marks for every hour. The instrument of the water level gauge will be briefly described here.

Photo 1(a) and (b) show the new portable water level gauge of which dimensions are 39 cm in height, 28 cm in width and 18 cm in depth, and 10 kg in weight. A is the reduction part of the water surface elevation whose mechanism is well known. The reduction ratio may be chosen arbitrarily, and it is 1/2 in this observation. B is the recording pen which moves smoothly and vertically according to the ascent and descent of the float in an observation well. C is the driving clock, which drives record-paper from the cylindrical box E3 to the roller E2 with the speed of 24 mm/hr through



(a) (b)

Photo 1. The new portable long period water level gauge. A is the reduction part, B the recording pen, C the driving clock, D the micromotor, E1 and E2 the rollers, E3 the paper box, F the power source box, G the fork-clock as a timer and H the marker pen.

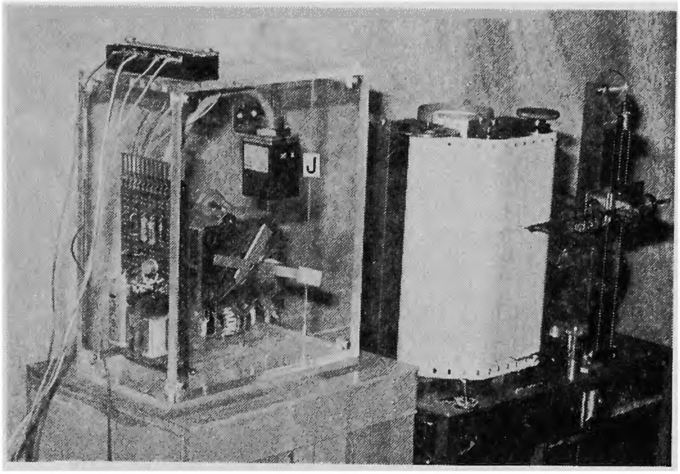


Photo 2. The fork-clock as a timer. I is the clock, J the proximity switch, and K the electronic filter circuit.

the roller E1. The clock is wound intermittently by the micromotor worked by 12V DC. Recording-paper is always pulled by the roller E2, in which a spring is wound intermittently by a micromotor in D with 3V DC. Power sources are dry-batteries in box F. H is a marker pen, which works every hour for about a second with 24V DC. A pulse signal comes from a fork clock G, of which details are shown in Photo 2. In this photo, I is the clock, and J is a proximity switch. When the long hand of the clock I passes under the proximity switch, a signal of about 5 minutes is sent to an electronic circuit K. Passing through the filter, the signal is modulated into a pulse of about a second, and sent to the marker pen H.

This water level gauge expends very little power, and the observation can continue for several months.

3. Observation in Lake Biwa-ko and the results

In order to perform a more complete observation of seiche in the near future using this water level gauge, a preliminary observation with the two water level gauges was carried out in Otsu and Hikone for 32 days from March 12th to April 12th, 1973. Observation wells in Otsu and Hikone were kindly offered by the Lake Biwa Work Office, Ministry of Construction. In Fig. 1, the locations of the observation sites are shown by the mark ⊙. Fig. 2 shows the records of Run-3 beginning from 12 o'clock on March 14th. The upper is the record in Hikone where oscillation of the short period of about 30 or 40 minutes predominates, and the lower is in Otsu where oscillations of about 4 hours and 70 or 60 minutes are dominant. Time marks are recorded on the bottom of the recording-paper.

Twenty-seven pieces of records are digitalized every 2.5 minutes and the amplitude spectra are computed by the FFT method. Some examples of spectra are shown

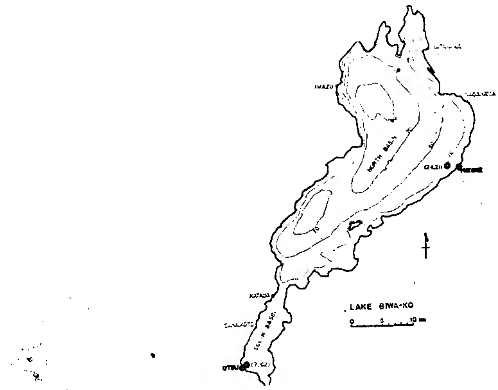


Fig. 1. Map of Lake Biwa-ko. The mark ⊙ indicates the location of the observation sites, and the mark ◎ the position of the mesh point of the numerical experiments in Table 2.

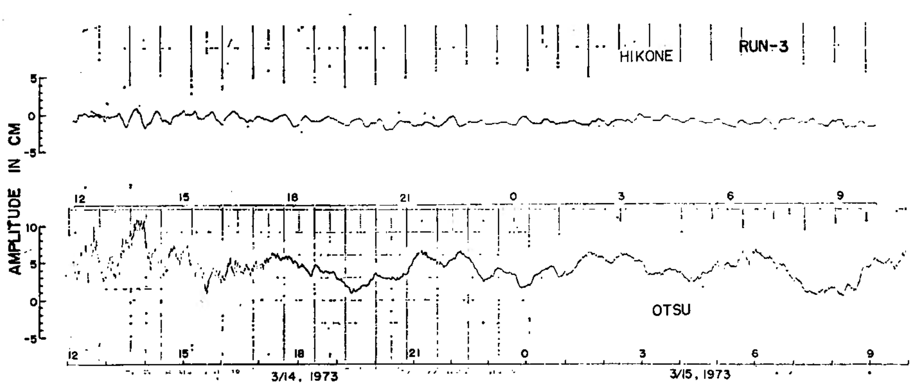


Fig. 2. Examples of the observed records. The upper is the record in Hikone, and the lower in Otsu on March 14th, 1973.

in Fig. 3. In (a) are shown the spectra of Run-3 as an example of a case where the oscillation of about 1 hour dominates, and in (b) those of Run-13 as one where the oscillation of 4 hours dominates. The spectra in Otsu are shown by solid curves and those in Hikone by dotted curves. It is found from this figure that the dominant peaks appear at the periods of about 240, 73, 65, 40, 30 minutes and so on. These periods may be considered to correspond to the period of 255.5, 79.8, 69.1, 38.7 and 31.9 minutes obtained from the numerical experiments (Imasato [1972]). Therefore, oscillations with these periods may be called the oscillation of mode 1, mode 2, mode 3, mode 4 and mode 5, respectively.

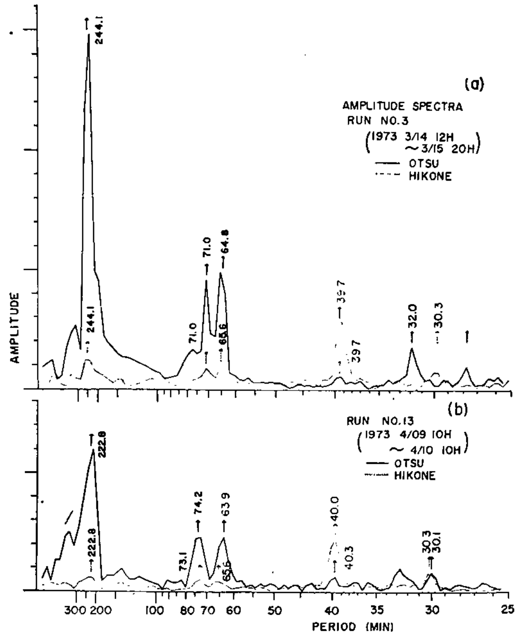


Fig. 3. Examples of the amplitude spectra. Solid curves indicate the amplitude spectrum in Otsu, and dotted curves that in Hikone. Arrows indicate the spectrum peaks of each mode.

The observed frequency spectra in Otsu are very similar with those of 1970 (Imasato [1971] and [1972]). Spectra in Hikone are clearly found to have the same components as those in Otsu. Each amplitude of the oscillations of mode 1, mode 2 and mode 3 in Hikone is smaller than that in Otsu, but that of mode 4 and mode 5 is larger.

4. Discussion

Periods of amplitude spectrum peaks are summarized in Table 1, where a mark * means that the significant peak does not appear around the period of that mode in the spectrum, and a mark — means that data have not been obtained because of trouble with the water level gauge in Hikone. The mean observed periods of each mode are 229.8, 72.7, 65.1, 40.1 and 30.5 minutes. They agree fairly well with the periods from the numerical experiments, but are a little smaller. The accuracy of the observed mean period of mode 1 is not very good in this analysis, because the length of the record used in the frequency analysis has been short.

Table 2 shows the ratios of the amplitude of each mode at the mesh point (7, 62) of the numerical experiments to that at the mesh point (24, 21). These two mesh points indicated by double circles ◎ in Fig. 1 are located near the observation sites,

Table 1. Observed periods of seiche. The mark * indicates that the spectrum has no dominant peak at that period, and mark — that the data have not been obtained due to trouble with the water level gauge.

Run No.	Observations	Mode 1		Mode 2		Mode 3		Mode 4		Mode 5	
		Otsu	Hikone	Otsu	Hikone	Otsu	Hikone	Otsu	Hikone	Otsu	Hikone
1	3/12 15h–3/13 07h	255.8	232.5	71.0	71.0	63.9	64.8	39.7	40.0	32.4	30.1
2	3/13 20h–3/14 12h	232.5	213.1	73.1	*	64.8	65.6	*	40.0	30.1	31.8
3	3/14 12h–3/15 20h	244.1	244.1	71.0	71.0	64.8	65.6	39.7	39.7	32.0	30.8
4	3/17 12h–3/18 03h	232.5	*	71.0	72.1	*	65.6	*	39.4	*	29.8
5	3/18 15h–3/19 04h	232.5	232.5	*	*	66.4	64.8	*	40.6	*	30.1
6	3/18 22h–3/19 11h	222.8	213.1	*	*	69.1	*	*	*	32.0	30.1
7	3/21 00h–3/21 13h	244.1	244.1	71.0	72.1	63.9	*	*	40.0	30.1	30.1
8	3/21 13h–3/22 02h	222.8	222.8	71.0	*	*	67.3	41.3	40.0	30.1	30.1
9	3/24 12h–3/25 12h	*	213.1	74.2	73.1	61.6	*	39.7	39.1	29.2	30.3
10	3/28 20h–3/29 16h	213.1	—	75.2	—	65.6	—	*	—	29.4	—
11	3/29 16h–3/30 13h	232.5	—	73.1	—	65.6	—	40.3	—	30.8	—
12	4/01 17h–4/02 15h	244.1	—	71.0	—	64.8	—	*	—	30.5	—
13	4/09 10h–4/10 10h	222.8	222.8	74.2	73.1	63.9	65.6	40.3	40.0	30.1	30.3
14	4/10 10h–4/11 20h	232.5	232.5	73.1	72.1	*	63.9	*	41.3	30.8	30.6
15	4/11 14h–4/12 11h	213.1	*	79.9	*	64.8	*	*	40.3	30.1	30.3
		231.8	227.7	73.0	72.1	64.9	65.4	40.1	40.0	30.6	30.3
Mean Period (min.)		229.8		72.7		65.1		40.1		30.5	
Period from Numerical Experiments (min.)		255.5		79.8		69.1		38.7		31.9	

Table 2. Ratios of the amplitude of seiche in the mesh point (7, 62) to that in (24, 21) in the numerical experiments.

Case	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
SW	11.62	11.36	1.18	6.02	0.341
SSE	11.47	11.48	1.20	7.90	0.545
ESE	9.63	14.43	2.88	5.69	0.309
NW	11.48	9.79	1.24	7.26	0.583
Mean	11.05	11.77	1.62	6.72	0.445
VII-3	12.68	10.83	3.19	2.14	0.252

i.e. Otsu and Hikone respectively. In the last line of Table 2, the amplitude ratio in the case VII-3 of the numerical experiments, where a nonuniform wind field is given, is shown for reference.

Table 3 shows the observed ratios of the amplitude of each mode in Otsu to that in Hikone. The observed ratio of mode 1 agrees fairly well with the experimental one shown in Table 2. The ratios of the other modes, however, do not agree enough with the experimental ones, especially the amplitude of the seiche in mode 4 in the north basin is much larger than that in the south basin contrary to the result of the experiment. The disagreement in the amplitude ratio, however, can not be definitely evaluated in the present step of our investigation. The difference in amplitude ratio by the

Table 3. Observed ratios of the amplitude of seiche in Otsu to that in Hikone.

Run No.	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
1	—	5.14	3.32	0.177	0.265
2	—	*	3.48	*	0.968
3	12.52	5.22	4.78	0.187	0.595
4	*	4.04	*	*	*
5	9.58	*	2.83	*	*
6	8.15	*	*	*	—
7	11.35	5.87	*	*	0.785
8	—	*	*	0.207	0.704
9	*	3.69	*	0.357	0.887
13	10.52	4.80	5.84	0.280	1.055
14	12.34	6.28	*	*	—
15	*	*	*	*	0.932
Mean	10.74	5.01	4.05	0.241	0.774

Table 4. Observed phase differences of seiche between Otsu and Hikone in radian.

	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5
Observed Mean Phase Diff.	2.80	0.34	2.41	1.19	—
Theoretical Phase Diff.	π	0	π	0	—

factor 2 might be seen to be allowed. In this sense the observed results do not necessarily contradict those of numerical experiments except the oscillation of mode 4.

Table 4 shows the observed mean phase differences between Otsu and Hikone. Phase differences of mode 1, mode 2, and mode 3 agree with those expected from the numerical experiments. On the other hand, the phase difference of mode 4 disagrees with the experimental one.

The origin of these disagreements on the oscillation of mode 4 is not clear. There is, however, the possibility that there may exist another mode of oscillation different from that of the longitudinal seiche derived from the numerical experiments in the former paper (Ismasato [1972]).

The results of the numerical experiments indicate that the oscillation of mode 5 consists of four oscillations, and the real wind field over the lake always changes with space and time. Therefore, the observed phase difference of mode 5 is considered to have little meaning.

5. Conclusion

The new portable long period water level gauge was designed in order to verify the results of numerical experiments about the seiches in Lake Biwa-ko. This water level gauge is able to automatically record the water surface elevation for 34 days. It needs power sources of 24V DC, but expends very little power so that it is possible to continue an observation for several months with dry-batteries. Accurate time marks from the fork-clock every hour make it possible to detect the phase differences of any component seiche among the records in some observation sites.

Using two water level gauges of this new type, the preliminary observation of seiche was performed in Otsu and Hikone in Lake Biwa-ko at the same time. From the frequency analysis of the records in Hikone, the oscillation of mode 1 with the period of about 4 hours is found for the first time in the north basin of Lake Biwa-ko. The observed periods of seiche agree well with the periods derived from the numerical experiments. The observed results of the amplitude ratio and phase difference support the results of the numerical experiments about the longitudinal seiches of mode 1, mode 2 and mode 3. But the observed result of seiche of mode 4 disagrees with the experimental result, and it seems that there may exist another mode of oscillation with this period.

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