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Title	STUDY OF SEICHE IN LAKE BIWA-KO (III) : SOME RESULTS OF A NUMERICAL EXPERIMENTS BY NONLINEAR TWO-DIMENSIONAL MODEL
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Citation	Contributions of the Geophysical Institute, Kyoto University (1972), 12: 63-75
Issue Date	1972-12
URL	http://hdl.handle.net/2433/178618
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

Kyoto University

Contributions, Geophysical Institute, Kyoto University, No. 12, 1972, 63-75

STUDY OF SEICHE IN LAKE BIWA-KO (III) ——SOME RESULTS OF NUMERICAL EXPERIMENTS BY NONLINEAR TWO-DIMENSIONAL MODEL——

By

Norihisa IMASATO

(Received, September 4, 1972)

Abstract

The possible periods of the seiche in Lake Biwa-ko are given as 255.5, 79.8, 69.1, 51.1, 38.7, 31.9 minutes and so on from the numerical experiments by nonlinear two-dimensional model described in a former paper of the same title (Imasato [1971]). In this paper, some characteristics of the seiches with the period 51.1, 38.7 and 31.9 minutes are discussed. It is found that the seiche with the period 31.9 minutes consists of the four different component oscillations. These periods from the numerical experiments agree well with the observed periods. The amplitude variations of each seiche with the wind direction are discussed, too. From a numerical experiment by using the model with a distribution of wind direction, it is found that the seiche with the period 255.5 minutes is controled by the wind field over the south basin, the seiches with the period 69.1, 51.1 and 31.9 minutes by the wind field over the north basin, and the seiches with the period 79.8 and 38.7 minutes by the wind field over both basins.

1. Introduction

In the former paper of the same title (Imasato [1971]), the possible periods of the longitudinal seiches in Lake Biwa-ko were given by means of the Fourier transform (FFT method) of successive 296 digital values of the computed water surface elevation. Numerical calculation was performed by the nonlinear two-dimensional one-layer model in which the lake is divided into 25×62 square meshes of 1 km intervals. Fig. 1 shows the computed area, where black points indicate the elevation points of meshes. Fundamental equations for the seiche motion are expressed as follows,

$$\begin{cases} \dfrac{\partial Q_x}{\partial t} = -g(h+\eta)\dfrac{\partial \eta}{\partial x} + A_x, \\ \dfrac{\partial Q_y}{\partial t} = -g(h+\eta)\dfrac{\partial \eta}{\partial y} + A_y, \\ \dfrac{\partial \eta}{\partial t} = -\dfrac{\partial Q_x}{\partial x} - \dfrac{\partial Q_y}{\partial y}, \end{cases} \tag{1}$$

where Q is the volume transport through a water column, η the water surface elevation, and h the water depth at the mesh point, and in the terms of A_x and A_y, surface

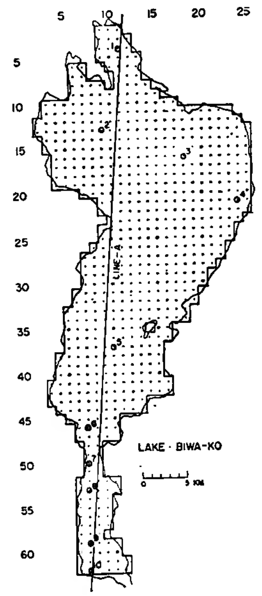

Fig. 1. Computed area of Lake Biwa-ko and arrangement of elevation points(black points).

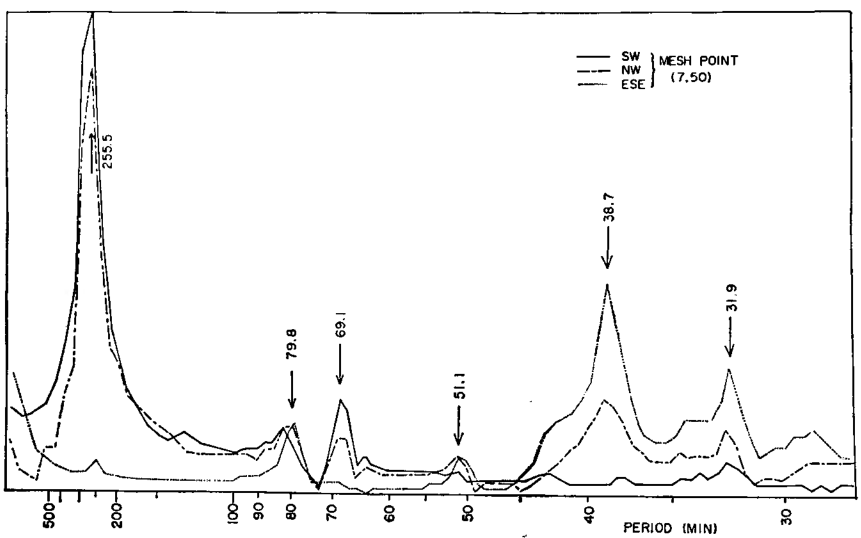

Fig. 2. Amplitude spectra in the mesh point (7, 50) in the case SW, NW and ESE. Arrows show the spectrum peaks which correspond to the periods of seiches.

and bottom stress, the Coriolis' force and inertia term are taken into account. The initial condition is that the lake is rest, and the boundary condition at the wall is that the normal component of velocity is zero, and that the uniform wind with the constant speed 5 m/sec durates to blow over the water surface.

Fig. 2 shows the results of the Fourier transform of the computed water surface elevations at mesh points (7, 50) in three cases of the south-west wind (named the case SW), the east-south-east wind (named the case ESE), and the north-west wind (named the case NW). It is found from this figure that the possible periods of the seiches in Lake Biwa-ko are 255.5, 79.8, 69.1, 51.1, 38.7, 31.9 minutes and so on, which are indicated in the figure by arrows. The characteristics of the seiches with the period 255.5, 79.8 and 69.1 minutes have been discussed already in former papers (Imasato [1970] and [1971]), that is they are uni-, bi- and tri-nodal longitudinal seiche in the whole basin as are shown in Fig. 3, and these results agree fairly well with some observed results in Otsu. Some characteristics of the seiches with the period of 51.1, 38.7 and 31.9 minutes and also the response of these seiches to the wind field over the lake will be discussed in this paper.

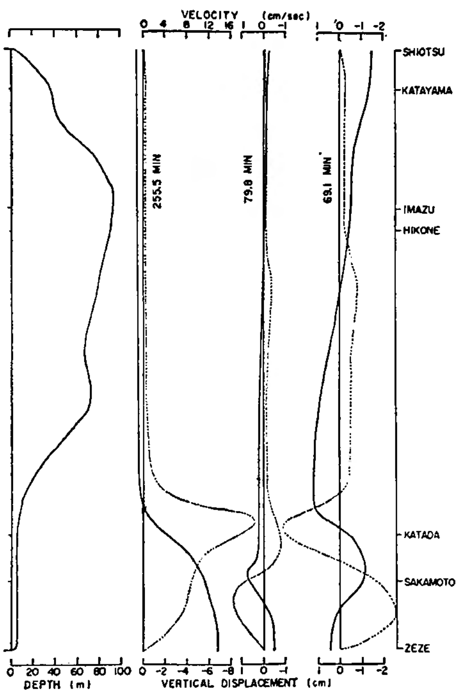

Fig. 3. Vertical displacement (full curve) and maximum velocity (doted curve) distributions of the longitudinal seiches with the period of 255.5, 79.8 and 69.1 minutes along the line A in Fig. 1.

2. Characteristics of the seiches with the shorter period

In this section, characteristics of each seiche from the numerical experiment of the case SW are discussed.

(I) Seiche with the period 31.9 minutes

In the group of shorter period seiches, the most dominant oscillation is one with the period of 31.9 minutes, and some of its characters will be discussed first. If this oscillation consists of only one kind of seiche, phase difference at all mesh points will be π or zero. But the results of the numerical experiments concerning the phase difference show that this seiche seems to consist of the different two kinds of seiches with the phase lag of $\pi/2$ each other. One may be a longitudinal oscillation and another a lateral one. These two oscillations are separated by using the following well-known formula (2),

$$\begin{cases} a\cdot\cos\theta + b\cdot\sin\theta = c\cdot\cos\varphi, \\ b/a = \tan\beta, \end{cases} \tag{2}$$

where phase $\varphi\,(=\theta-\beta)$ and amplitude c are the known values from the Fourier transform of the computed water surface elevation at each mesh point. If phase θ can be known from the distribution of phases in all mesh points, b/a will be determined and therefore the amplitude a and b will be known by Eq. 3,

$$\begin{cases} a = c/\sqrt{1+\tan^2\beta}\,, \\ b = (c^2 - a^2)^{1/2}. \end{cases} \tag{3}$$

Horizontal distributions of amplitude of these two kinds of oscillations are shown in Fig. 4, where (a) describes the distributions of the longitudinal seiche, and (b) these of the lateral one. The longitudinal oscillation is found to be a quinqe-nodal seiche in the whole basin. The longitudinal seiches discussed in the former paper are the oscillations along the line B between Shiotsu and Otsu in Fig. 4 (a). But the quinqe-nodal seiche oscillates not along this line B but along the line C' between Maibara and Otsu. The lateral oscillation consists of three oscillations, that is (i) a uni-nodal bay oscillation in Shiotsu Bay, (ii) a uni-nodal lateral seiche in the north basin along the line D between Kaizu and Maibara in Fig. 4 (b), and (iii) a shelf oscillation on the lake shelf which is well developed off the river mouths of the Yasu and the Hino River. Fig. 5 shows the amplitude distributions of these four seiches along the line B, C', D and E in Fig. 4 with full curves. They express very well the characteristics of these seiches. The lateral uni-nodal seiche between Kaizu and Maibara is remarkable in the north basin. But it is very interesting that amplitude in the mouth of Shiotsu Bay may be larger than in the bay bottom, if the longitudinal quinqe-nodal seiche with this period becomes much larger than the bay oscillation in Shiotsu Bay in any suitable wind field. In this figure, the distributions of the volume transport and the velocity through a water column with these seiches with the

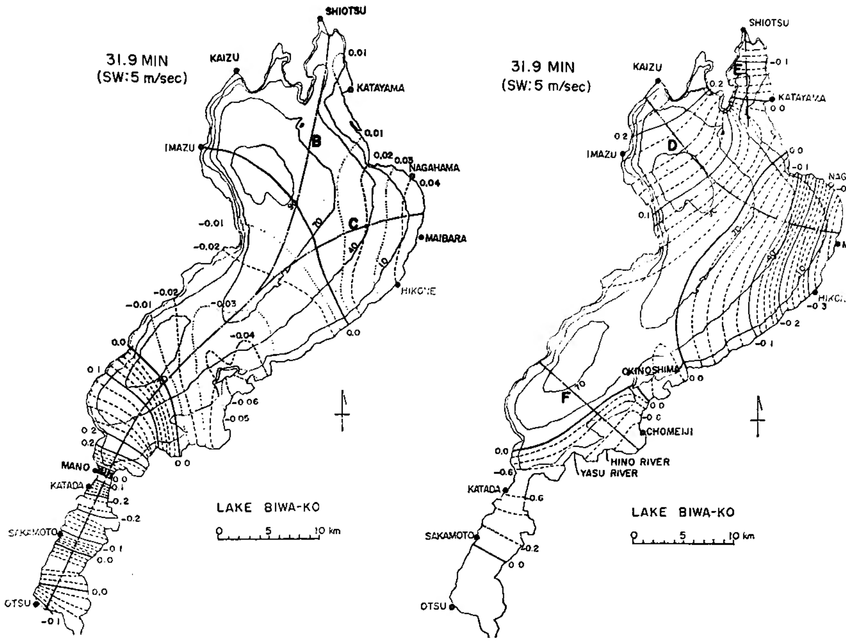

Fig. 4. Horizontal distributions of the amplitude of the seiche with the period 31.9 minutes in the case SW; (a) for the longitudinal seiche (left side), and (b) for the lateral seiches (right side).

Table 1. Amplitude of each component seiche. Among the four component oscillations with the period 31.9 minutes, the amplitude of the bay oscillation in Shiotsu Bay is shown in the line (i), that of the lateral uni-nodal seiche between Maibara and Kaizu in the north basin in the line (ii), the shelf seiche off the coast of Chomeiji in the line (iii), and the longitudinal quinqe-nodal seiche between Otsu and Maibara in the line (iv). The first column shows the amplitudes in cm in the case SW. The 2nd column shows the relative amplitudes in the cases of the four wind directions, and the 3rd column those in the case VII-3. The 4th column shows the places.

PERIOD (MIN) \ CASE	AMPLITUDE (CM)	RELATIVE AMPLITUDE					PLACE
	SW	SW	SSE	ESE	NW	VII-3	
255.5	6.76	1.00	0.90	0.02	0.86	0.72	Otsu
79.8	0.40	1.00	0.94	0.34	0.97	1.60	Otsu
69.1	0.45	1.00	0.78	0.08	0.70	0.45	Otsu
51.1	0.040	1.00	1.50	0.88	2.00	1.21	Otsu
38.7	0.060	1.00	1.42	1.50	1.17	1.73	Otsu
31.9 (i)	0.15	1.00	2.09	2.14	1.84	1.78	Shiotsu
(ii)	0.30	1.00	1.55	1.74	1.40	1.40	Nagahama
(iii)	0.090	1.00	0.98	1.43	1.55	1.82	Chomeiji
(iv)	0.045	1.00	2.03	1.88	1.50	2.16	Otsu

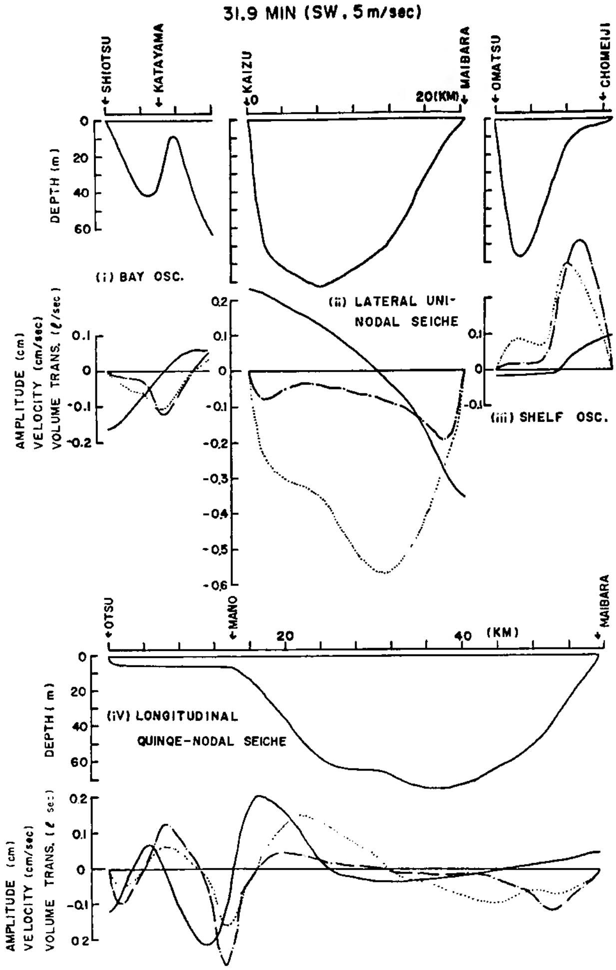

Fig. 5. Distributions of vertical displacement (full curve), maximum velocity (doted curve) and maximum volume transport (chain curve) of each component of the seiches with the period 31.9 minutes.

period 31.9 minutes are shown with doted and chain curves respectively, and the water depth profiles are also shown. As is shown in this figure, volume transport is dominant with the uni-nodal lateral seiche between Kaizu and Maibara, and with the longitudinal quinqe-nodal seiche. The values of the amplitude of these seiches are tabulated in the 2nd column of Table 1.

(II) Seiche with the period 38.7 minutes

From the horizontal distribution of amplitude of this seiche in Fig. 6, this

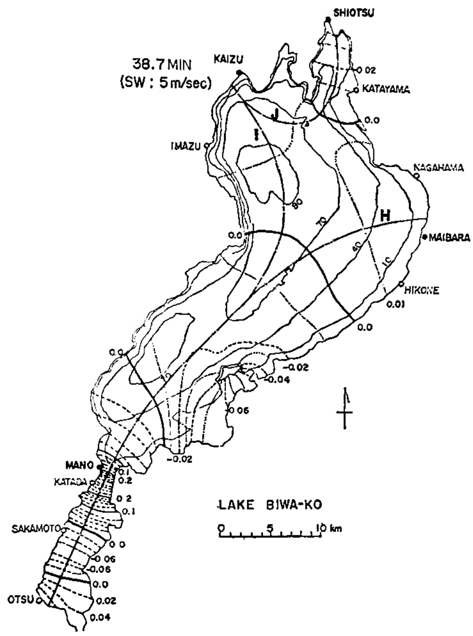

Fig. 6. Horizontal distribution of the amplitude of the seiche with the period 38.7 minutes in the case SW.

oscillation seems to be a quinqe-nodal seiche in the whole basin along the line B in Fig. 4 (a). But the nodal line is not located in the neighbourhood of the narrowest part of channel between the north and the south basin and it is inconsistent with the nature of an odd-nodal seiche such as the seiches with the period 255.5, 69.1 and 31.9 minutes mentioned above. The nodal line in the neighbourhood of Shiotsu Bay seems to belong to a seiche along the line J between Shiotsu and Kaizu in Fig. 6, of which the Merian's period agrees fairly well with this period 38.7 minutes. It may be deduced from these considerations that four other nodal lines make a longitudinal quadri-nodal seiche along the line H between Maibara and Otsu. Therefore, the greater parts of water will oscillate along this line H but there may be a possibility that a part of water may oscillate along the line I between Otsu and Kaizu considering the amplitude distribution in Fig. 6. It is an interesting problem to be investigated in the future. The distributions of the amplitude, velocity and volume transport with this seiche are described in Fig. 7 (b).

(III) Seiche with the period 51.1 minutes

The horizontal distribution of amplitude of the seiche with the period 51.1 minutes is shown in Fig. 8. The distributions of the amplitude, velocity and volume transport with this seiche along the line G in Fig. 8 are shown in Fig. 7 (a). From the figures, this oscillation seems to be a longitudinal quadri-nodal seiche between Otsu and Shiotsu, but the nature of the oscillation of this seiche is different from the

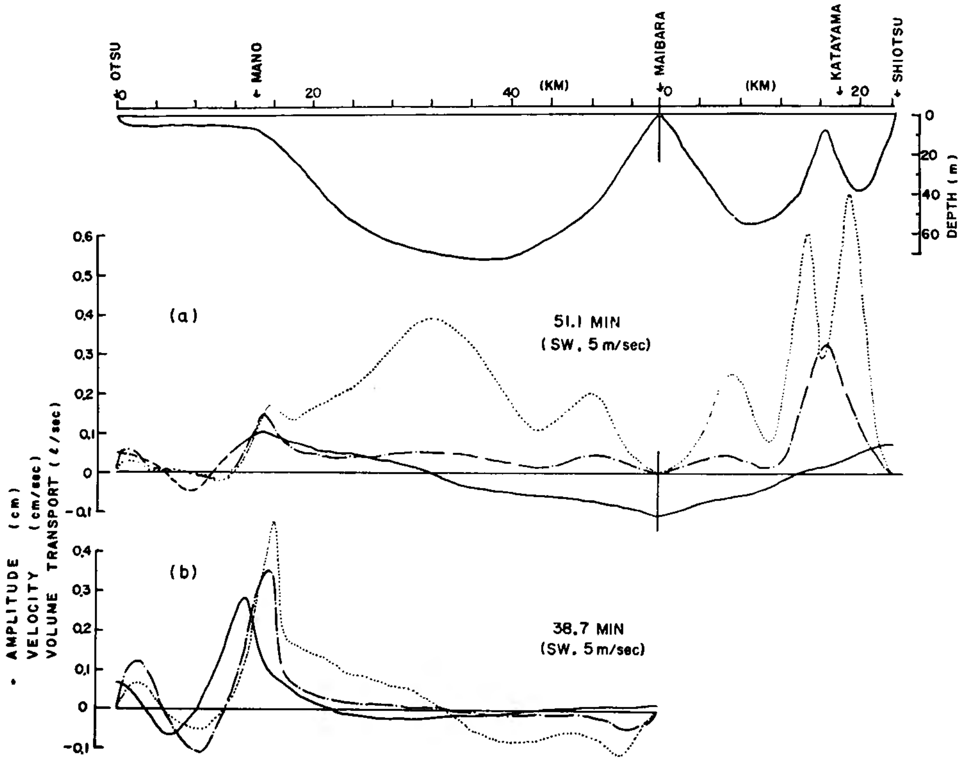

Fig. 7. Distributions of vertical displacement (full curve), maximum velocity (doted curve) and maximum volume transport(chain curve); (a) those of the seiche with the period 51.1 minutes along the line G between Otsu, Maibara and Shiotsu in Fig. 8, and (b) those of the seiche with the period 38.7 minutes along the line H in Fig. 6.

longitudinal seiches with the period 255.5, 79.8 and 69.1 minutes discussed in the former paper (Imasato [1971]), that is, it seems to oscillate from Otsu to Maibara and again from there to Shiotsu. The seiches with a longer period than 69.1 minutes oscillate along the line B, and the 38.7 minutes seiche oscillates along the line C. Therefore, there seems to be a boundary of the changes in the nature of a longitudinal seiche between the 69.1 and 38.7 minutes, that is a change in the direction of the oscillation from the line B to the line C in Fig. 4 (a), and the period of this seiche, 51.1 minutes, may be on the neighbourhood of this boundary. The amplitude distribution in Fig. 8 seems to prove it. Furthermore, it has to be pointed out that the confidence of the distributions of amplitude, velocity and their phases with this oscillation at some mesh points in the south basin is fairly low. Namely, the probability that the amplitude distribution in the south basin in Fig. 8 holds true is fifty-fifty, and therefore this oscillation may not make a standing wave in the south basin, that is, this oscillation may be a uni-nodal seiche along the line G in Fig. 8 between Mano and

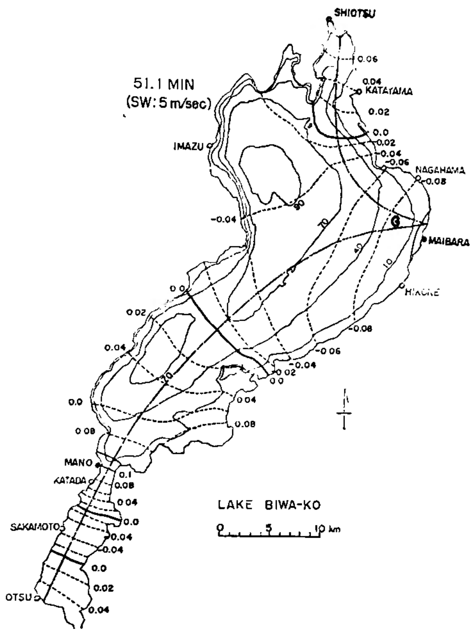

Fig. 8. Horizontal distribution of the amplitude of the seiche with the period 51.1 minutes in the case SW.

Maibara, of which the Merian's period is about 50 minutes.

If the last statement is accurate, the following reasonable consideration will hold true that the longitudinal tri-nodal seiche in Lake Biwa-ko is the oscillation with the period 69.1 minutes along the line B in Fig. 4 (a), the quadri-nodal seiche one with the period 38.7 minutes, and the quinqe-nodal seiche one with the period 31.9 minutes along the line C in Fig. 4(a). Then, the oscillation with the period 51.1 minutes must be considered to be a kind of a local seiche in the north basin along the line G between Mano and Maibara, and between Maibara and Shiotsu, and the south basin with the narrow channel to have a function as an impedance for this oscillation. Although there is a possibility it is true from the amplitude distribution in Fig. 8, where this oscillation has an antinodal line in the neighbourhood of Mano, it is worth mentioning that this period has not been deduced from the observed data in Otsu in 1970.

3. The amplitude variations of seiches with wind fields

According to the change of wind directions, each seiche will change the magnitude of the amplitude. The longitudinal wind will make the longitudinal seiches larger, and the lateral wind the lateral seiches larger. In order to see this amplitude variation, the calculations of three cases are performed. In these cases, the wind directions are chosen to be the south-south-east, the east-south-east, and the north-west, and the cases will be named the case SSE, ESE, and NW respectively. The south-south-east and the south-west wind are the longitudinal wind, and the seasonal winds prevailing in summer in Lake Biwa-ko, and the east-south-east wind the lateral one. The north-west wind is the seasonal wind prevailing in winter in Lake Biwa-ko. The conditions of the calculation are same as these of the case SW except for the wind direction.

The relative values of the amplitude of each seiche in these four cases are tabulated in the 3rd column of Table 1. It is found from the table that the longitudinal seiches with the period longer than 69.1 minutes do not develope in the case of the lateral wind (ESE) to the extent that they do in the cases of the longitudinal wind. The amplitudes of each component seiche with the period 31.9 minutes in the case SW are smaller than those in other cases.

The wind field over the lake is not uniform as we have considered above. Unfortunately, there is scarcely any information about the wind field over Lake Biwa-ko, but it has been said from seamen's experience the main prevailing wind field over the lake is that the south-west wind is blowing in the south basin when the north-west wind is blowing in the north basin. Therefore a numerical calculation (named the case VII–3) was performed under the distribution of wind direction shown in Fig. 9, and a constant wind speed of 5 m/sec over all areas.

The 4th column of Table 1 shows the relative amplitude of the case VII–3 to that of the case SW. The amplitude of the seiches with the period 79.8 and 38.7

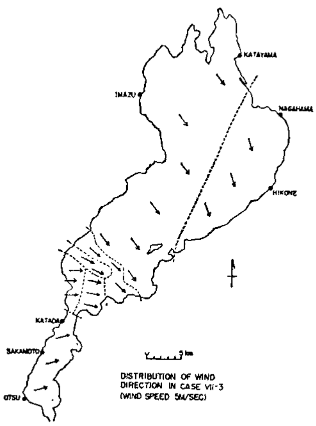

Fig. 9. Distribution of wind direction in the case VII–3.

minutes in this case VII–3 is found to become larger than that in other cases, and that with the period 255.5 and 69.1 minutes smaller. The reason may be that the distribution of the surface stress τ_S agrees with the velocity distribution with these two seiches, and therefore it promotes the development of the even-nodal seiche with the period of 79.8 and 38.7 minutes, but obstructs the water motion with the odd-nodal seiche with the period 255.5 and 69.1 minutes. The lateral seiches with the period 31.9 minutes have the amplitude of the same order as that in the case NW, and this may be considered as proof that these seiches in the north basin are controlled by the wind field over the north basin of Lake Biwa-ko.

Table 2 shows the phases of each component seiche at the mesh point (7, 8) in

Table 2. The phase of each component seiche in the case NW, SSE and VII–3. The letter S means that the phase in the case VII–3 agrees with the phase in the case SSE, the letter N does one with the phase in the case NW, and the letter S–N does that one lies midway between the phases in the case SSE and NW.

PREIOD (MIN) / CASE	255.5	79.8	69.1	51.1	38.7	31.9
NW	−0.27	3.00	0.63	−1.42	0.20	0.59
SSE	2.74	0.29	−2.54	1.78	−2.71	−2.46
VII–3	2.76	1.03	0.55	−1.84	1.73	0.57
	S	S–N	N	N	S–N	N

the north basin in the case NW, SSE and VII–3. The phase of 255.5 minutes seiche in the case VII–3 agrees with the phase in the case SSE and one of 69.1, 51.1 and 31.9 minutes seiche does with phase in the case NW. The phases of the seiche with the period 79.8 and 38.7 minutes lie midway between the phase in the case SSE and the phase in the case NW. It may be deduced from these results that the seiche with the period of 255.5 minutes is controlled by the wind field over the south basin, the seiche with the period 69.1 and 51.1 minutes and the lateral seiches with period 31.9 minutes by the wind field over the north basin, and the seiche with the period 79.8 and 38.7 minutes by the wind field over both basins.

4. Some comparisons with the observed results

In order to establish the results of the numerieal experiments about the seiche in Lake Biwa-ko, observations of water surface elevation have been performed at some points in Lake Biwa-ko. Here in this paper, the experimental results will be compared with the results of the observation in Otsu on February, 1970. Fig. 10 shows an example of the Fourier transform (FFT method), which is obtained from the observed record for about 20 hours beginning from 18 o'clock on February 10th, 1970. The strong seasonal wind of the north-west with the speed of 15∼28 m/sec was durating to blow over the lake for about 49 hours from 3 o'clock on February 9th to 4 o'clock on February 11th. The observed periods indicated by arrows in Fig. 10 are 232.3, 74.1, 66.4, 40.2 and 32.6 minutes. They agree well with the calculated periods, but the period of 51.1 minutes is not distinguished from the figure. This situation is the same as that in other pieces of the observed records. From this fact, the seiche with this period seems not increase enough to be detected in the records in Lake Biwa-ko. The mean periods from the eight pieces of the observed records obtained on February, 1970 are 249.6, 74.1, 65.7, 39.7 and 32.1 minutes, and agree well with the experimental periods.

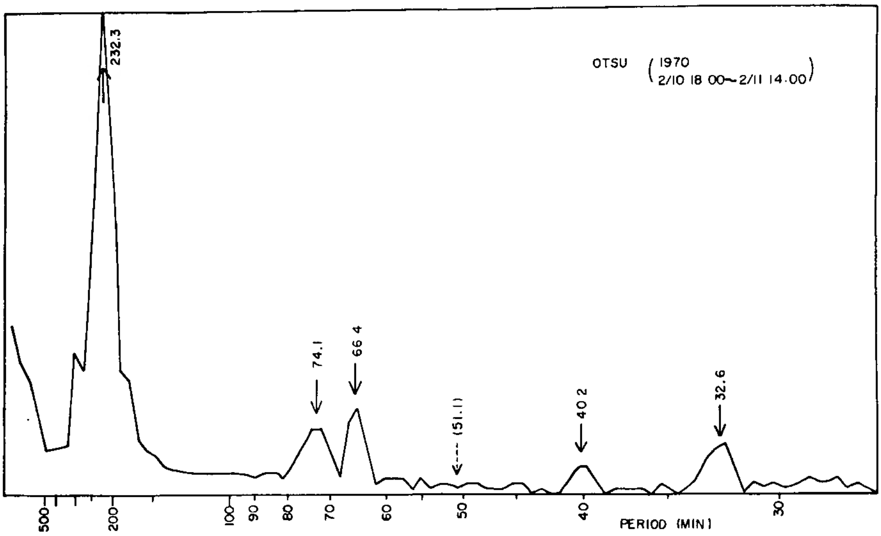

Fig. 10. Observed amplitude spectrum obtained in Otsu for 20hours from 18 o'clock on February 10th to 14 o'clock on February 11th, 1970. Arrows show the spectrum peaks which correspond to the periods of seiches.

5. Conclusion

The possible periods given by the nonlinear two-dimensional numerical experiments are 255.5, 79.8, 69.1, 51.1, 38.7 and 31.9 minutes and so on. The seiches with the period 255.5, 79.8 and 69.1 minutes are the longitudinal uni-, bi- and tri-nodal seiche along the line between Otsu and Shiotsu, and the amplitude and velocity distributions are shown in Fig. 3. Some discussions about these three seiches have been undertaken in former papers of the same title (Imasato [1970] and [1971]).

The nature of the oscillation with the period of 51.1 minutes can not be clearly defined, and is left as a problem for future investigation.

The seiche with the period 38.7 minutes seems to consist of two seiches, i.e. (i) the quadri-nodal seiche between Otsu and Maibara, and (ii) the uni-nodal seiche between Shiotsu and Kaizu. The former is a longitudinal seiche in the whole basin, but its nature is different from that with the period 255.5, 79.8 and 69.1 minutes. The amplitude, volume transport and velocity distributions are shown in Fig. 7(b).

The oscillation with the period 31.9 minutes consists of the four seiches, i.e. (i) the uni-nodal bay oscillation in Shiotsu Bay, (ii) the uni-nodal lateral seiche in the north basin between Kaizu and Maibara, (iii) the shelf oscillation on the lake shelf off the coast of Sabae and Chomeiji, and (iv) the longitudinal quinqe-nodal seiche between Otsu and Maibara. The last seiche is a longitudinal one across the whole basin, but its nature is different from that of the seiches with the period of 255.5, 79.8 and 69.1 minutes and similar to that of the longitudinal seiche with the period 38.7

minutes. The amplitude and velocity distributions are shown in Fig. 5.

The mean periods observed in Otsu are 249.6, 74.1, 65.7, 39.7 and 32.1 minutes, and agree well with the experimental periods of seiche, but the period corresponding to 51.1 minutes can not be found out.

It is found that a particular component seiche develops more than others when the wind field over the lake has some special distribution, and that the lateral wind makes the lateral seiche larger and the longitudinal wind does the longitudinal seiche larger. The seiche with the period 255.5 minutes is controled by the wind field over the south basin, the seiches with the period 69.1, 51.1 and 31.9 minutes by the over the north basin, and the seiche with the period 79.8 and 38.7 minutes by the wind field over both basins.

Acknowledgement

The author expresses his thanks to Prof. H. Kunishi for his encouragements, to Research Assistant S. Kanari for his helpful discussions, to Mr. K. Tanaka for his assistance to the observations, to Mrs. Y. Kajiura and E. Saita for their assistance to the data process. And also he thanks to the Lake Biwa Work Office, Ministry of Construction for the offer of observational wells of water surface elevations in Lake Biwa-ko. The numerical calculation in this article was carried out on a FA-COM 230-60 in the Data Processing Center of Kyoto University. A part of this study was supported by scientific research fund from the Ministry of Education.

References

Imasato, N., 1970; Study of seiche in Lake Biwa-ko (I) — On the numerical calculation by Defant's method, Special Contributions, Geophys. Inst., Kyoto Univ., **10,** 93–103.

Imasato, N., 1971; Study of seiche in Lake Biwa-ko (II) — On a numerical experiment by non-linear two-dimensional model, Contributions, Geophys. Inst., Kyoto Univ., **11,** 77–90.