551. 481. 215. 1:
551. 326. 85

ON SHORT PERIOD FLUCTUATIONS OF WATER LEVEL OF AN ICE-COVERED LAKE

by

H. SIMOJOKI

Finnish Hydrological Office, Helsinki

Abstract

Short period fluctuations of water level occur continuously in ice-covered lakes. Due to the absence of wind effect during the time of ice-cover the periods are more regular than during the season of open water.

On examining results of records of water level recorders in ice-covered lakes in Finland short period fluctuations are observed in addition to the decrease of water level characteristical for this season.

Oscillation is observed to be partly periodical, partly nonperiodical, as seen in Fig. 1, the figure representing some results of the records of water level recorders of ice-covered lakes. The geographical situation of the lakes is shown in Fig. 2. Regular periodical oscillation is indicated particularly by water level records of Nellimvuono in Lake Inari. A close examination of the observations of water level records of Nellimvuono indicates the same phenomenon to occur in the season of open water as well, suggesting a clear development of seiches with a period of about 3 hours. Short period oscillation is observed also in the limnograms of Lake Päijänne and Lake Pielinen. Moreover, significant nonperiodical fluctuations are demonstrated as well, as observed in the limnograms of Lake Päijänne.

A more exact analysis of limnograms of the same lake indicates a possibility to distinguish, besides local oscillation, a seiches concerning

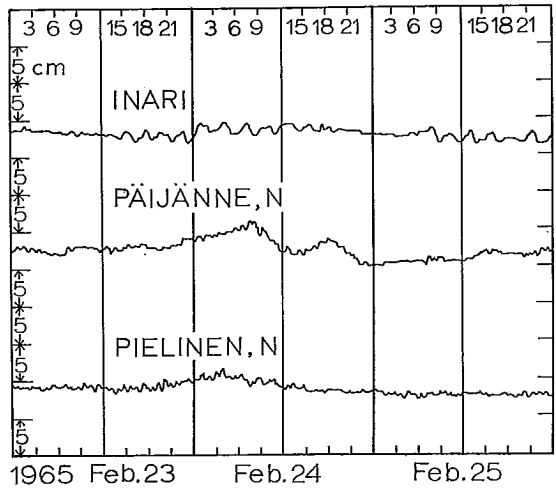

Fig. 1. Limnograms of lakes Inari, Päijänne and Pielinen.

the whole lake basin. However, it is often difficult to decide which part of a lake basin has the predominant oscillation, because lakes in Finland are irregular in shape and abundant in islands, and in addition the water level recording stations are few. Owing chiefly to the great irregularity of the shape of lake basins water level fluctuations caused by the seiches phenomenon remain slight.

Short period fluctuations of water level occurring in ice-covered lakes have been studied in detail using the results obtained from the water level recorder of Lake Saimaa. The recorder is situated in Lauritsala, in a part of Lake Saimaa abundant in islands (Fig. 2). At a distance of 5 km east of the water level recorder there begins a vast square shaped part of the lake with a size of about 20 × 20 km^2. The curve drawn by the recorder is in relation 1:1.

The analysis of observation period covers a period from 1st January to 31st March in 1960, when the lake is naturally covered by ice. In analysing the limnograms all waves ranging 2 mm or more and the period exceeding 20 minutes or more have been considered. Results of analysis have been presented in Fig. 3, the abscissa indicating the period and the ordinate the average number of daily occurrence.

From the diagram it appears that in the lake seiches obviously occurs with periods of about 80 and 45 minutes. The length of the periods suggests uninodal and binodal periods. Selecting from the examined

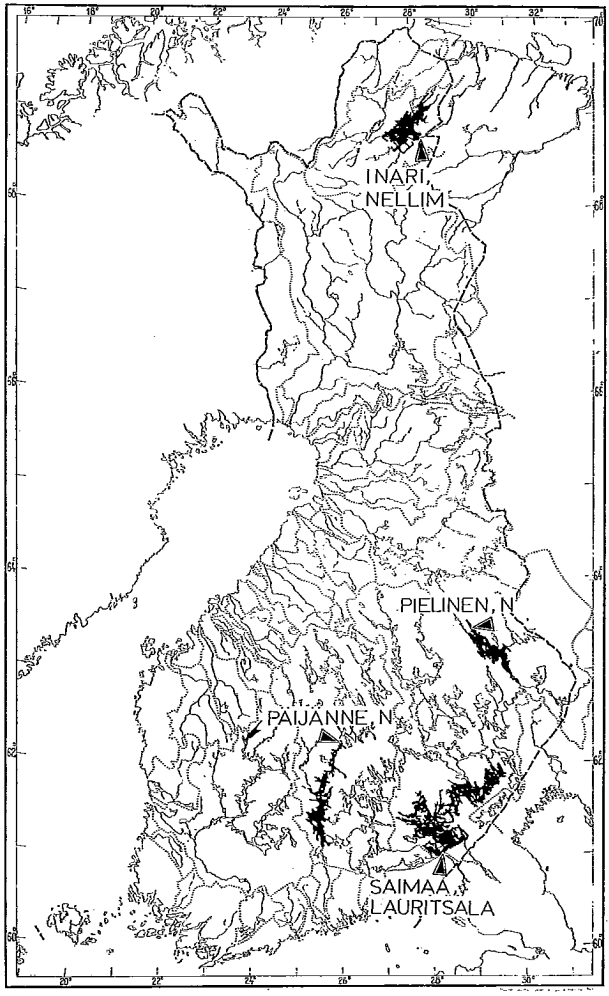

Fig. 2. Situation of water level recorders.

material some individual cases with occurrence of clear wave groups 82 minutes will be obtained for the first mentioned period.

However, the observed waves are rather low. During the 3 month period under examination the maximum height of the wave amounted to 11 mm and during the time in question the wave ranged 5 mm or more 18 times.

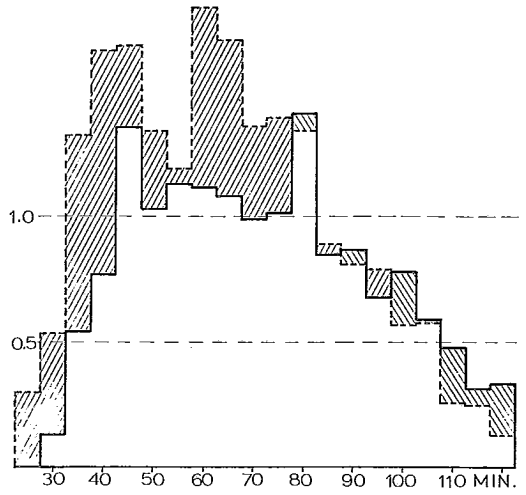

Fig. 3. The frequency of different periods. Continuous line — ice-covered lake, broken line ----- open water.

For comparison a similar analysis was carried out with the results of records of the water level recorder of Lauritsala in Lake Saimaa, during the season of open water, covering a period from 1st September to 31st October in 1959. Results, drawn in broken line, are shown in Fig. 3. The diagram indicates a similar general feature of the distribution as the diagram for ice cover period, but here the eventual occurrence of seiches does not appear as clear as during the season of ice cover. However, in both cases the partial maximum corresponds with the 45 minute period, while the eventual longer period here can not be determined exactly.

Further, the figure demonstrates, as is to be expected, a more frequent occurrence of oscillation during the season of open water than during the period of ice cover. Particularly the occurrence of short period oscillation is more frequent in the first instance. In these conditions the oscillation, although moderate, becomes more regular as wind does not account for oscillation in an ice-covered lake. Hence the material of water level records of an ice-covered lake may well be applied in the study of seiches phenomenon.

Naturally the wave ranges higher during the season of open water. During the period under examination the maximum wave of the recorded oscillation amounted to 40 mm.

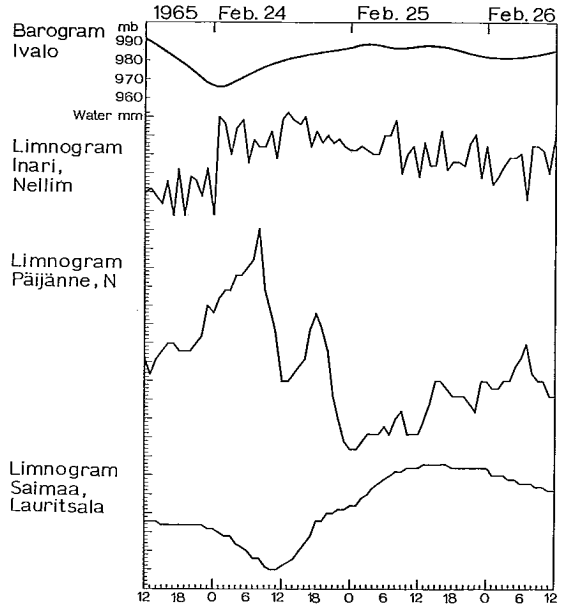

Fig. 4. Alterations of atmospheric pressure and water level.

In some lakes, however, as seen in Fig. 1, the oscillation may, even in winter, be greater than that in Lake Saimaa, demonstrated above. Significant fluctuation of water level during a period of open water as well as ice cover takes place in general in connection with low pressure with occurrence of marked decrease of barometer level.

Short period fluctuations, presented in Fig. 1 and treated in detail in Fig. 4 were caused by low pressure the centre of which was in North Finland in the morning of 24th February, 1965, proceeding rapidly in a south easterly direction (Fig. 5). Besides water level observations in Fig. 4 the barogram of Ivalo is presented. The place is about 40 km from Ivalo water level recorder.

From the Ivalo limnogram it is seen that during the passing of the low pressure centre an oscillation of 26 mm has occured followed by high water exceeding the normal. Along this general alteration local seiches is clearly observed. The water level recorder at the northern end of Lake Päijänne indicates, to begin with, an occurrence of a relatively slow increase of water level; simultaneously a decrease of water level is observed in the southern end of the same lake indicating that the whole

lake has been involved. Decrease in atmospheric pressure was less inclined in the northern end of Lake Päijänne than in Ivalo. The lowest atmospheric pressure occurred in the northern end of Lake Päijänne about 7 hours later than in Ivalo. The peak of the water level was followed by a sharp decrease amounting to 40 mm in 4 hours. In the water level observations of Lake Päijänne seiches is not as clearly demonstrated as in Lake Inari. However, traces of a 5 hour period can be observed. Water level fluctuations in Lake Saimaa are similar to those in Lake Päijänne. Both are characterized by slow alterations. As in the case of Lake Päijänne, the water level recorder placed at the southern shore of Lake Saimaa showed an initial decrease. The increase of water level seen in the limnogram of Lake Saimaa was 26 mm during 21 hour period.

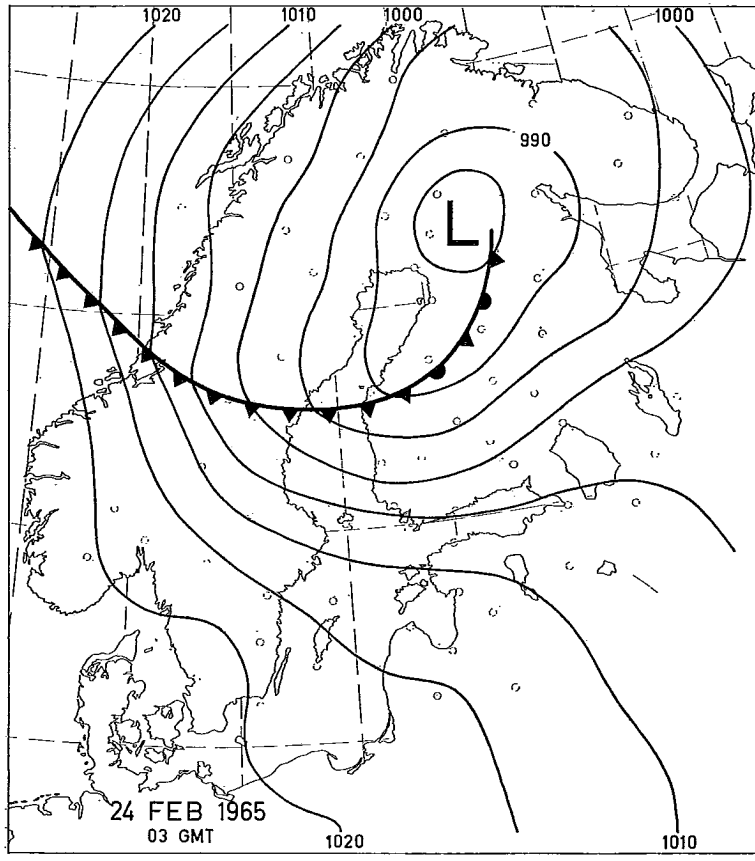

Fig. 5. Synoptic surface chart on Feb. 24, 1965 at 0300 GMT.

The short period fluctuations of water level in ice-covered lakes are chiefly caused by rapid alterations of atmospheric pressure. It will not be necessary to consider the effect of wind. It may indeed be assumed that the wind may cause vibration of the ice cover which in turn may cause motion of the water, but considering the thickness of the ice, about 50 to 60 cm, as well as the limited elasticity of it, this factor does not need to be taken into account.

However, some cases occur which cannot be explained to have been caused by alterations of atmospheric pressure. Apparently other factors should be considered, such as seismic factors and tides, for instance.

The short period fluctuations of water level, accounted for above, are the consequence of corresponding currents in lakes. These again increase the perturbation of water in the lake, being, however, insignificant in winter due to the absence of wind effect. The phenomenon in question affects the heat condition of a lake by increasing turbulence and by accounting for the movement of heat from the bottom to the top.

The phenomenon examined has, in addition, some bearing on the ice cover. At sudden fluctuations of the water level the ice cover may rupture and water may rise over the ice surface. In addition small fluctuations of water level may possibly cause differences in the ice structure.