CLIMATIC CHANGE AND LONG SERIES OF ICE OBSERVATIONS AT LAKE KALLAVESI

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SUMMARY

The freezing and breakning-up dates of the ice cover of Lake Kallavesi, the longest known series in Finland, are illustrated by the frequency tables. There has been a marked climatic change since the 1880' s.

Ice observations have often been used for elucidation of climatic changes and cycles. Easton's research work is perhaps the best known in its kind. Ice-observation series may cover a longer period of time than observation series obtained instrumentally, such as temperature observations and others. Ice observations, provided they have been made carefully, are free from errors caused by instruments and methods.

For Lake Kallavesi (Fig. 1) there is a continuous series of freezing and breaking-up dates of ice cover beginning in late autumn 1833. The observations bear upon the open lake outside Kuopio. The greatest depth of the lake is 48 meters (Fig. 1). For a long

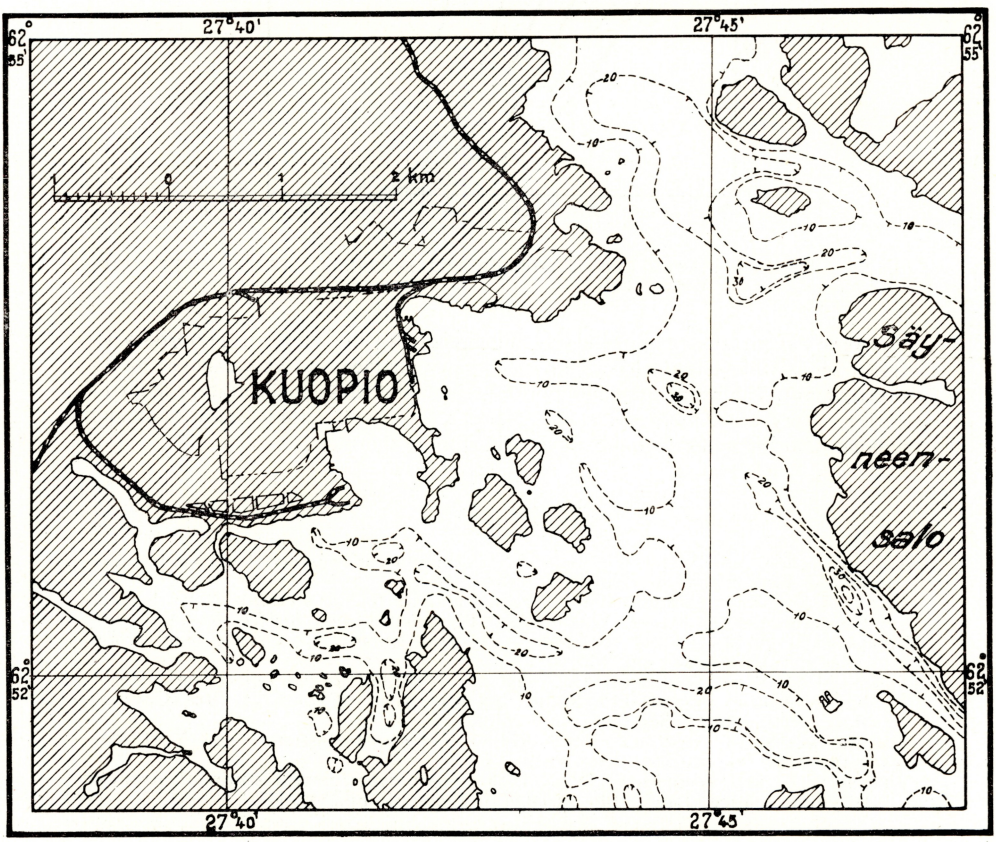

Fig. 1

TABLE 1

The freezing dates of the Lake Kallavesi. Winters 1834-1957.

November	3	1865							
	4								
	5								
	6	1853	1881						
	7	1882	1922						
	8	1895							
	9	1957							
	10	1942							
	11	1857	1928						
	12								
	13	1883	1920						
	14	1835	1842						
	15	1909							
	16	1841	1845	1849	1862	1868			
	17	1859	1876	1903					
	18	1869	1877						
	19	1836	1934						
	20	1861	1872	1892					
	21	1843	1851	1886	1888	1916			
	22	1837	1839	1867	1894				
	23	1889	1891						
	24	1855	1856	1871	1902	1905	1926		
	25	1844	1850	1874	1880	1885	1900		
	26	1860	1956						
	27	1840	1858	1875	1897	1910	1923	1953	1958
	28	1863	1901						
	29	1924	1943						
	30	1898	1911						
December	1	1847	1866	1879	1918	1927	1938		
	2	1893	1904	1946	1955				
	3	1907	1908	1925	1952				
	4	1852	1873						
	5	1899							
	6	1932	1941						
	7	1884	1919						
	8	1896							
	9	1870	1914	1947					
	10	1838	1912	1949					
	11								
	12	1929	1940	1945					
	13	1834	1846	1948					
	14	1906	1931						
	15	1890							
	16	1921							
	17	1913	1939						
	18	1864	1915	1917					
	19	1854	1887						
	20	1954							
	21	1848							
	22	1936							
	23								
	24								
	25	1878	1935	1950	1951				
	26	1937							
	27								
	28	1944							
	29								
	30								
	31								
January	1								
	2								
	3								
	4								
	5								
	6								
	7	1933							
	8								
	9								
	10								
	11								
	12								
	13								
	14								
	15								
	16								
	17								
	18								
	19								
	20								
	21								
	22								
	23								
	24								
	25								
	26								
	27	1930							

TABLE 2

The breaking-up dates of the Lake Kallavesi. Winters 1834-1957.

April	20	1921											
	21												
	22												
	23												
	24												
	25												
	26												
	27												
	28												
	29	1948											
	30	1937											
May	1	1890	1950										
	2												
	3	1925	1930	1953									
	4	1894	1906	1951									
	5	1920											
	6	1943											
	7	1910	1949										
	8	1936	1945										
	9	1848	1886	1919									
	10	1872	1903	1914	1916	1952							
	11	1913	1931	1954									
	12	1836	1860	1897	1911	1933	1934	1945					
	13	1870	1928										
	14	1834	1841	1887	1895	1904	1915	1922					
	15	1844	1863	1882	1883	1905	1947						
	16	1850	1855	1940									
	17	1880	1901	1907	1939	1957							
	18	1842	1868	1879	1924	1935	1938	1944					
	19	1837	1854	1878	1898	1918	1932						
	20	1865	1869	1888	1956								
	21	1851	1889										
	22	1874	1926	1929									
	23	1839	1852	1862	1923								
	24	1835	1840	1846	1849	1853	1858	1875	1885	1891	1896	1912	1927
	25	1881	1892	1908	1955								
	26	1859	1941										
	27	1845	1902										
	28	1861	1884	1899	1900	1917	1942						
	29	1838	1843	1856	1866	1893							
	30	1873	1877										
	31	1847	1857	1864									
June	1	1871	1909										
	2	1876											
	3												
	4												
	5												
	6												
	7												
	8												
	9												
	10												
	11												
	12												
	13												
	14												
	15												
	16												
	17	1867											

time the observations have been carried out by the same persons on account of which the series should be fairly homogeneous. Comparisons with other ice-observation series confirm this opinion.

The freezing date (Z) refers to the point of time at which the lake freezes definitely for the winter season. As there sometimes occur several freezings on account of melting between, the last date of freezing has always been taken into consideration. The date of breaking-up of ice cover (A) refers to the date when the ice has disappeared from the open lake. In general the observations of breaking-up are more reliable than those of freezing.

The observations of winters 1934-1957 are shown in Tables 1 and 2. The records are grouped according to calendar years. The years refer to the spring-part of the winter. Thus, if freezing has occurred before the 1st of January the year refers to the spring-part of the actual winter.

From the values in Table 1 it will be seen that the arithmetical mean of freezing date is November 30. Its dispersion is $\varsigma_Z = 14$ days. The mode falls on November, 27, and the frequency curve is positively skewed. During the 124 years under observation the earliest freezing had occurred in 1864, November, 3, and the latest in 1930, January, 27. The difference in time between these is 85 days. Greatest departures are due to the delay in freezing, owing to the fact that the heat supply of the water must decrease to a certain value before the freezing can take place. Provided this thermal situation has been arrived, and the weather remains relatively warm at the same time, the freezing is delayed.

For the arithmetical mean of breaking-up date of ice cover (Table 2) the date May, 18, is obtained. The dispersion is $\varsigma_A = 9$ days. Thus it is a considerably more regular phenomenon than freezing. The earliest date of breaking-up has been in 1921, April, 20, and the latest in 1867, June, 17. The range of variation has been 58 days. The mode falls on May 24. From the general structure of the Table it is seen that the frequency curve is negatively skewed.

For establishing the alterations in climate the records are divided in two successive groups of 62 winter each. For these the following means are obtained:

	1834-1895	1896-1957
Freezing	Nov. 23	Dec. 3
Breaking-up	May 22	May 14

A survey of these dates indicates that the freezing in the latter period is delayed on an average of 10 days and the breaking-up of ice cover occurs 8 days earlier during the same period.

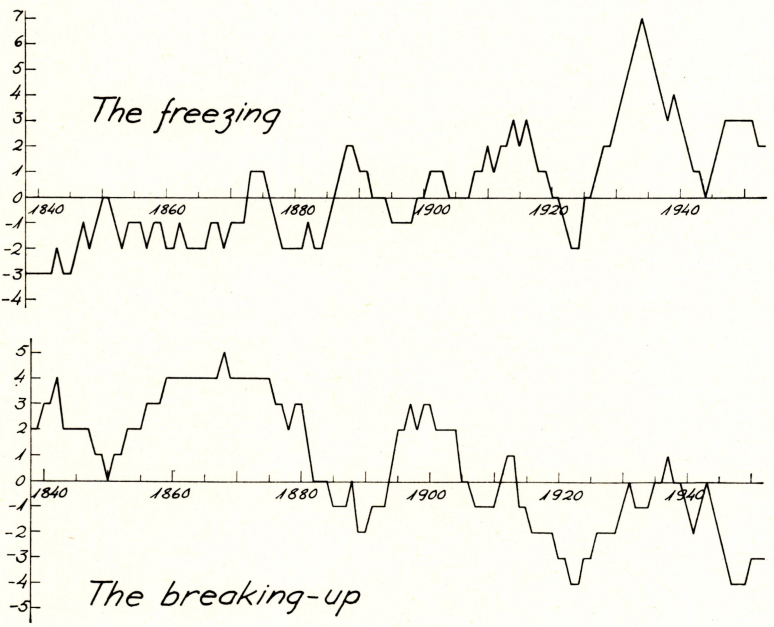

Fig. 2

Following proceedings will be introduced for obtaining a more detailed comprehension on this matter:

The arithmetic mean of the whole observation series of the freezing dates is denoted Z_m and the dispersion ς_Z. The number of cases over a period of 10 years, when the freezing had occurred later than $Z_m + \varsigma_Z$ is marked m and the number of cases over the same period, when the freezing had occurred earlier than $Z_m - \varsigma_Z$ is denoted n. Furthermore, the differences $m - n$ are computed for as many 10-years periods as possible, e.g. for the periods 1834-1843, 1835-1844 etc.

The same method will be applied to the dates of breaking-up. The number of cases over the same period when the breaking-up had occurred later than $A_m + \varsigma_A$ is denoted m and the number of cases when the breaking-up had occurred before $A_m - \varsigma_A$ is denoted n. The course of the differences $m - n$ gives an idea of the possible variations.

The differences $m - n$ for the freezing and breaking-up are illustrated in Fig. 2. It will be seen that the freezing and breaking-up dates have a clear secular course. According to the Figure, there are also fluctuations of a duration of some years, which represent the nature of the general alteration. These results are in good agreement with other climatological elements, e.g., the temperature in Helsinki has a similar course.