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NOTES ON THE CLIMATIC VARIATIONS CONCLUDED FROM THE DATES OF THE FIRST COMPLETE FREEZING OF LAKE SUWA IN JAPAN.

By S. FUJIWHARA, TOKIO.

As is obvious, freezing of a lake takes place as the result of accumulated cold during the preceding weeks. Hence, as the measure of the general climatic feature of successive winters in the surrounding district, the period of the first complete freezing of the lake surface is more preferable to those rather accidental periods of the first ice, frost or of the first descent of thermometer below the freezing point.

There is a nearly continuous record of the dates of the first complete freezing of the surface of Lake Suwa,¹ (135° E, 36° N) in Japan, during the periods, 1444—1872 and 1893—1912. A few years ago, the present author² noticed the possible relation between the freezing of the lake and the latitude variation in view of the nearly coincidence of the periods and phases of both the phenomena. As far as Fig. 1 is concerned, the dates of the first complete freezing made fluctuation with two periods, one being six or seven years and the other nearly the half of it. Freezing occurred very late in the warm winters of 1896, 1903, and 1910, and happened rather late in 1900 and 1906. Freezing took place very early in 1898 and 1904, while it occurred rather early in 1902 and 1908.

Chandler's period of the latitude variation is 14 months, and it makes out a seven years period, when combined with the period of the annual revolution of the earth round the sun. In an actual case, however, the interval of the recurring of the same phase is not strictly seven years but is sometimes six years.

¹ The lake has nearly circular form, with a diameter of nearly 3 km and a depth of 8 m. The temperature of the water in the lake becomes as high as 25° C. in summer and sinks to 0°—4° C. in winter. Nearly every winter the surface of the lake is covered with ice and affords a good skating rink to the sporting people of Tokyo. After two or three days of the first complete freezing of the surface, a big characteristic fissure of ice, called «Miwatari», is produced and from its position, shape, and direction, people have been accustomed to judge the climate of the approaching summer. In this respect the state of ice was reported to the government every year since 1444. The records of ice have been kept at the temple of Suwa and also at the Jaturugi shrine in this district.

² S. Fujiwhara, on the same subject, *Journal of Meteorological Society of Japan* V. 31, p. 400.

A new agitation will commence a new phase of oscillation, and if its amplitude is great, it will be enough to disturb the old weak phase. For the sake of convenience such a type of variation may be called »temporary periodic type«.

It is not yet certain that the above variation of ice periods belongs to this type or to the permanent periodic type. If it is temporary, then the ordinary methods of periodigram or method of integration are of no use in order to analyze its periods. So that the following method was adopted as the first step of investigation.

In Fig. 1, we can see that the recurring of relatively late freezing occurred once with an interval of two years, twice with one of three years, four years and seven years, but it never occurred with a five and six years interval. We can thus count the number of recurring of relatively late freezing as well as relatively early freezing in that long duration since 1444 for each interval such as 2, 3, 4... years. If there were no particularity with any individual interval, then the number of recurring, i. e. frequency, must be greater for the two years interval and gradually diminish as the interval increases, and will tend to zero asymptotically as is clear from the theory of probability.

In Fig. 2 are shown two curves of frequency of the late and early freezing of Lake Suwa, for each interval during 429 years, i. e. from 1444 to 1872, the ordinate being the number of recurring and the abscissa the length of the interval. Generally speaking, these two curves follow the exponential law of distribution of frequency as discussed above, while individuality for each interval is too great to be explained simply as an accidental matter. The frequency is highest for the three years interval, and a little less for the four years one. It sinks low at the five years interval and rises again at the six and seven years interval. Thus further we can also recognize swells at 11 and 14 years intervals. Whatever is the true meaning of such a thing, we can see the fact that the climatic tendency to be repeated with a three or four years interval and also with a six or seven years interval was very remarkable during those 429 years in the Suwa district in Japan.

Natural tendency of thought will lead us to connect the results appeared in

Fig. 2. Frequency for each interval in years of recurring of early and late freezing of Lake Suwa during 429 years.

— · — Early freezing.
 - - - × - - - Late " "
 Curve ought to be in the case of equal opportunity for each interval.

Fig. 1 and 2. The Bigelow's period of tertiary solar activity is 3.7 years and it must correspond to the greatest frequency at the three and four years intervals in Fig. 2. It is, however, still an open question that which one of the latitude variation and climatic change is the cause of the other. We can also imagine the case that there is some agent which is the cause of both. Anyhow, the fact is that both have the same tendency to repeat the same phase with the period of some six or seven years and their phases nearly coincided during 1896—1910.

The swell for the 11 years interval in Fig. 2 must be due to the principal phase of the solar activity. In Bigelow's investigation it is also shown that the influence of the tertiary harmonic variation of the solar activity on the earth's atmosphere is far stronger than that of the principal variation.

We shall close this short note now in pointing to the fact that there were spells of very warm winters from 1506—1518, from 1800—1805 and also from 1865—1869. In these winters the lake was not covered with ice.

P. S. According to the investigation by Mr. J. V. Eriksson in the ice periods of Swedish lakes for the period of from 1811 to 1916, there took place rather late freezing of these lakes in the years 1865, 1867—1869, which correspond to the years at maximum phase of eleven years period. In 1843, 1845, and 1854 Lake Suwa was not covered with ice, and Sweden experienced also very late freezing of the lakes in these three winters, which correspond also the maximum phase of eleven years variation. The recurring of the same phase after each four years is conspicuous in the smoothed curve u_2 of Mr. Eriksson, but there is no trace of six or seven years periods in it.