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An Increasing Annual Rainfall in Japan and Its Possible Causes

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Abstract

An increasing annual rainfall in Japan is statistically discussed. This variation in rainfall was paralleled with hydroelectric potential output data and flood damages in Japan, in the long run. Finally, a relationship between the rainfall and the eleven-year sunspot cycle is tested, although it is concluded the eleven-year sunspot cycle is of little importance. A hypothesis of an inerease trend of water vapour in the atmosphere for a possible cause of the generally warm and rainy years on the world-wide scale is suggested.

From tremendous materials, the author [1] deduced the existence of a recent tendency of *generally warm rainy years* in the Far East. The late Dr. E. Brückner, formerly Professor of Geography at the University of Bern, also pointed out a long succession of cycles — a series of generally warm and dry years alternating with a series of generally cool and rainy years. So far as the Far East is concerned, the recent decade is characterized by warm and rainy years.

At first, the average of the annual totals of precipitation at six representative weather stations over Japan (Nagasaki, Kyoto, Tokyo, Niigata, Miyako and Hakodate) in the 69 years, 1886 to 1954, has been computed for each year. Then the averaged annual totals of precipitation have been taken as a measure of the annual totals of precipitation over Japan. By means of 10-year running averages of precipitation, the climatic changes in precipitation have been illustrated in Fig. 1. The average annual volume of precipitation decreased at about 1890 and at about 1940. The recent gradual increase of annual precipitation is really of great practical value for economical life in Japan [Arakawa [1], Takahashi [2]]. Table 1 shows the hydro-electric *potential* output (in KWh) over Japan in chronological order. This variation in *potential* output was paralleled with an increasing annual rainfall, as shown in Fig. 1. The correlation coefficient between the annual totals of precipitation and the annual hydro-electric *potential* output is +0.833. The required regression equation is put into algebraical forms,

$$\Delta y=0.042\cdot\Delta x,$$

where Δy is the departure from the normal of the annual hydro-electric *potential* output in per cent and Δx is the departure from the normal of annual total of precipitation in *mm*.

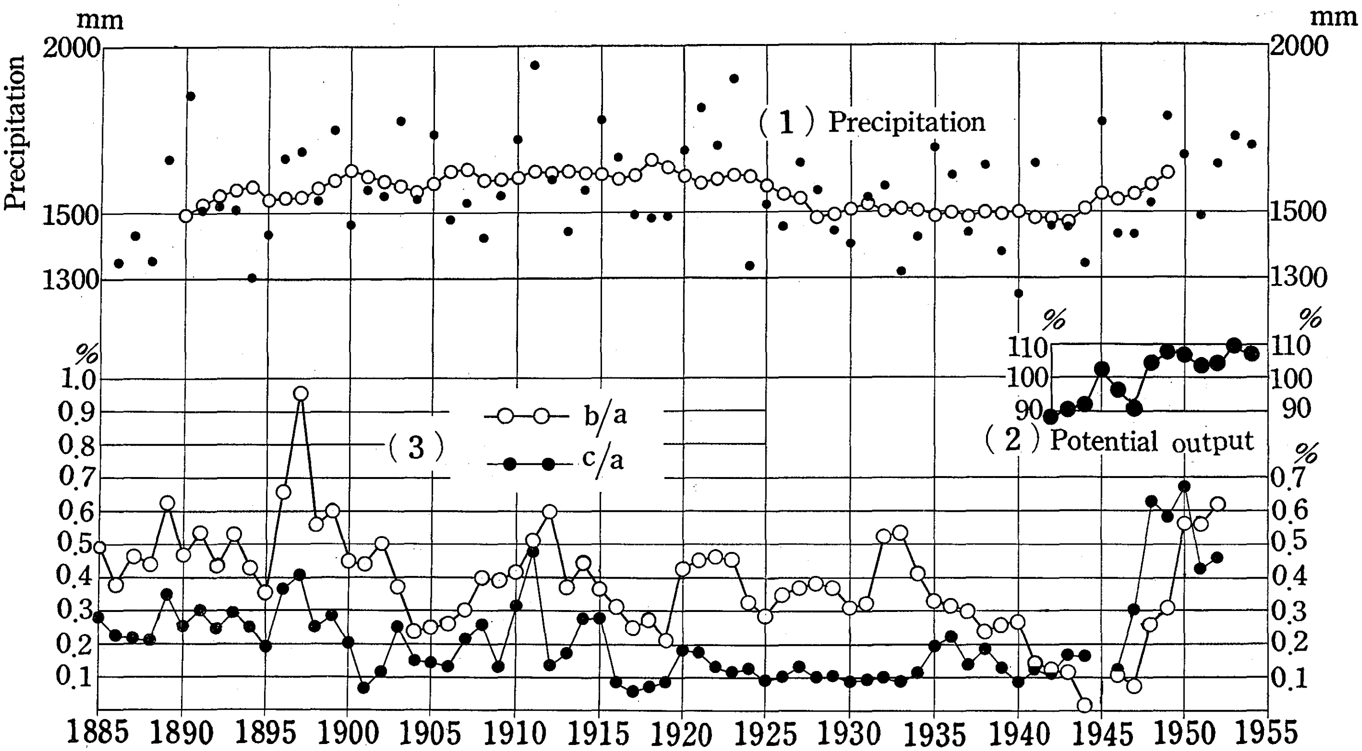

Fig. 1. (1) 10-year running means of precipitation in mm over Japan, 1886～1954. Dots are the mean annual totals of precipitation in chronological order.
(2) Hydro-electric *potential* output (in per cent) in chronological order.
(3) b/a and c/a in chronological order.

Table 1. Hydro-electric potential output in Japan.

Year	Hydro-electric *potential* output	
1942	35,385,719 KWh	87.94%
1943	36,611,763	90.99
1944	37,101,632	92.21
1945	41,068,245	102.06
1946	38,707,787	96.20
1947	36,406,815	90.48
1948	42,050,416	104.51
1949	43,272,386	107.54
1950	42,991,238	106.84
1951	40,381,301	100.36
1952	42,044,546	104.49
1953	44,080,324	109.55
1954	42,985,660	106.83
Mean	40,237,439	

Authority, Ministry of International Trade and Industry, Japan

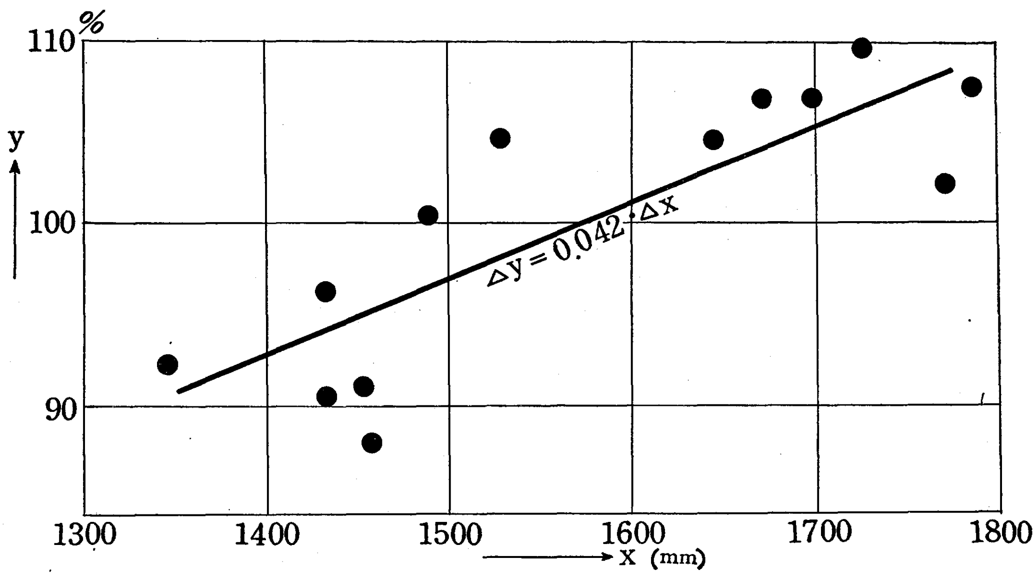

Fig. 2. Relationship between annual precipitation in *mm* and annual hydro-electric *potential* output in per cent in Japan.

For reference, I would like to quote some financial data. In Table 2,

$$\frac{b}{a} = \frac{\text{Financial expenditure for building of dikes to land from being washed away}}{\text{National income}},$$

$$\frac{c}{a} = \frac{\text{Financial expenditure for recovery from damages done to land}}{\text{National income}},$$

Table 2. Some financial data.

a : National income ;
b : Financial expenditure for building of dikes to land from being washed away ;
c : Financial expenditure for recovery from damages done to land.

Year	*b*/*a*	*c*/*a*	Year	*b*/*a*	*c*/*a*
1878	0.326%	0.191%	1916	0.310%	0.086%
1879	0.232	0.131	1917	0.249	0.059
1880	0.259	0.156	1918	0.274	0.073
1881	0.219	0.125	1919	0.210	0.085
1882	0.355	0.210	1920	0.426	0.182
1883	0.403	0.222	1921	0.452	0.177
1884	0.496	0.267	1922	0.462	0.133
1885	0.489	0.280	1923	0.454	0.117
1886	0.378	0.225	1924	0.326	0.127
1887	0.464	0.217	1925	0.285	0.092
1888	0.441	0.212	1926	0.350	0.104
1889	0.625	0.348	1927	0.369	0.133
1890	0.467	0.253	1928	0.382	0.102
1891	0.535	0.301	1929	0.369	0.104
1892	0.437	0.246	1930	0.311	0.089
1893	0.531	0.295	1931	0.322	0.095
1894	0.427	0.250	1932	0.524	0.101
1895	0.354	0.192	1933	0.534	0.088
1896	0.656	0.366	1934	0.413	0.116
1897	0.955	0.407	1935	0.329	0.195
1898	0.558	0.251	1936	0.316	0.224
1899	0.600	0.285	1937	0.300	0.140
1900	0.449	0.203	1938	0.238	0.186
1901	0.442	0.067	1939	0.257	0.131
1902	0.503	0.117	1940	0.267	0.088
1903	0.372	0.252	1941	0.145	0.125
1904	0.237	0.150	1942	0.128	0.113
1905	0.248	0.144	1943	0.116	0.169
1906	0.260	0.133	1944	0.018	0.167
1907	0.302	0.216	1945		
1908	0.398	0.259	1946	0.108	0.127
1909	0.392	0.132	1947	0.075	0.304
1910	0.415	0.315	1948	0.260	0.630
1911	0.511	0.478	1949	0.310	0.582
1912	0.597	0.137	1950	0.560	0.673
1913	0.372	0.173	1951	0.560	0.428
1914	0.444	0.277	1952	0.621	0.462
1915	0.366	0.277	1953		0.586

Authority, Ministry of Construction, Japan.

are tabulated in chronological order. The greater parts of *b* and *c* were spend for recovery and/or protection from flood damages done to land, so these figures will give some indications on the secular change of rainfall over Japan.

The general interest in the causes of the increasing annual rainfall is, of course, very intense in Japan ; for erratic rainfall and disastrous drought are recurrent features over most of Japan, and precipitation is almost the sole natural resource that Japan can rely on.

Many people ask if sunspots do not cause large weather changes. The late

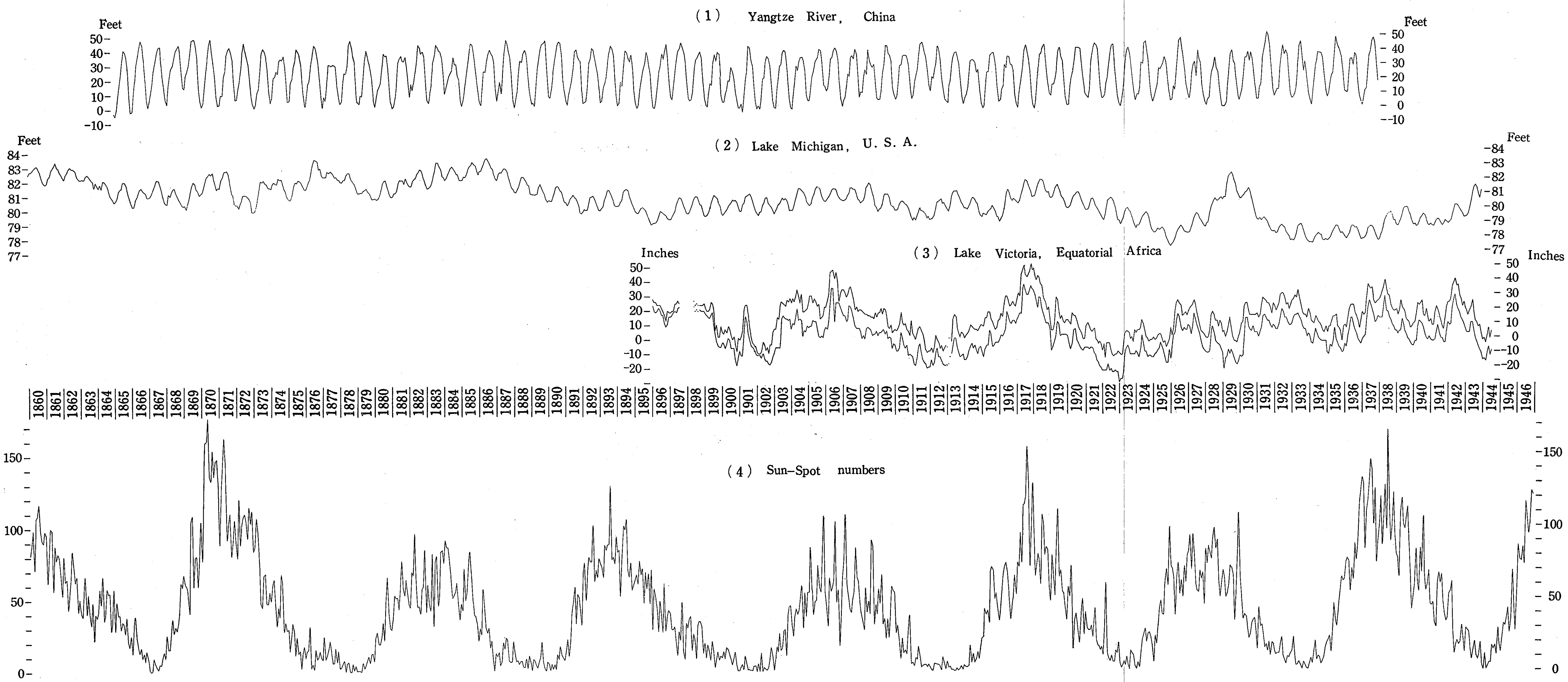

Fig. 3. River levels, lake levels and sunspots.

(1) Monthly means of water levels at Hankow, China, in feet above zero level [HAYAMI, 1938 and 1940]
(2) Monthly means of water levels at Milwaukee, Wis. in feet (500 ft +) [World Weather Records, 1947]
(3) Maximum and minimum readings of the lake gauge at Kisumu, Uganda, in inches above zero level [World Weather Records, 1947]
(4) Monthly sunspot numbers

Dr. W. Köppen [3] found definite evidences of higher temperatures for tropical regions at times of minimum sunspots than at times of maximum, but the average temperature difference associated with the eleven-year cycle did not exceed 1°C. Dr. C.E.P. Brooks [4] found that the sunspot cycle of nearly eleven years seems to be the cause of changes in the levels of Lake Victoria in equatorial Africa for the period 1896~1927. The late Dr. Kullmer [5] [6], formerly of Syracuse University, found remarkable latitude shift of the storm track in the United States in double Hale solar cycle. Literature on this subject is enormous, but critically examined, it may be reduced to the above three articles.

There appears to be a fairly close relationship between the sunspot number and the rainfall in certain parts of equatorial Africa, especially the plateau of Lake Victoria, as shown by Dr. Brooks. The eleven-year cycle in the solar activity and the series of monthly readings of the gauges on Lake Victoria in equatorial Africa, Lake Michigan in the United States and the Yangtze River in China, are illustrated in Fig. 3 over longer periods. A close relationship between sunspot number and the rise and fall in the levels of Lake Victoria does not appear to be confirmed, especially in the latter half of the period, which Brooks did not treat of in his paper. From the precipitation data for Lake Michigan [World Weather Rocord, 1947] and for the Yangtze River [Hayami, [8] in the temperate latitudes, it is quite hard to see just what connection sunspots as such have with precipitation.

Thus it is concluded the eleven-year sunspot cycle is of little importance in explaining the secular changes of precipitation. As for the cause of the climatic changes of precipitation, we know nothing. Emphasis should be placed on interrelationships between the general circulation of the atmosphere and the precipitation, which may be found by means of synoptic and dynamic climatological studies. With such studies as basis of understanding, prediction of precipitation in question may follow.

I would like to suggest a hypothesis that an increase in temperature of the earth's atomsphere may be causing an increase in the concentration of water vapour in the atmosphere. A significant increase in the concentration of water vapour would noticeably raise the surface temperature of the earth because of the "green-house effect," which, in turn, may be causing such an increase of water vapour until a *certain limiting period* comes up. Thus our interest may be directed toward an increase of atmospheric water vapour as a possible cause of the rising temperature and increasing precipitation on the world-wide scale, although in the light of the uncertainty both of physical knowledge and of statistical analysis, the question of the trend of water vapour in the atmosphere remains an open subject.

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