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GEOPHYSICAL MEMOIRS No. 20.

This Memoir completes Volume 2.

VARIATIONS IN THE LEVELS OF THE CENTRAL AFRICAN LAKES VICTORIA AND ALBERT

BY

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Published by the Authority of the Meteorological Committee.

LONDON:
PRINTED & PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased through any Bookseller or directly from H.M. STATIONERY OFFICE
at the following addresses: Imperial House, Kingsway, London, W.C.2, and
28 Abingdon Street, London, S.W.1; York Street, Manchester;
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1923

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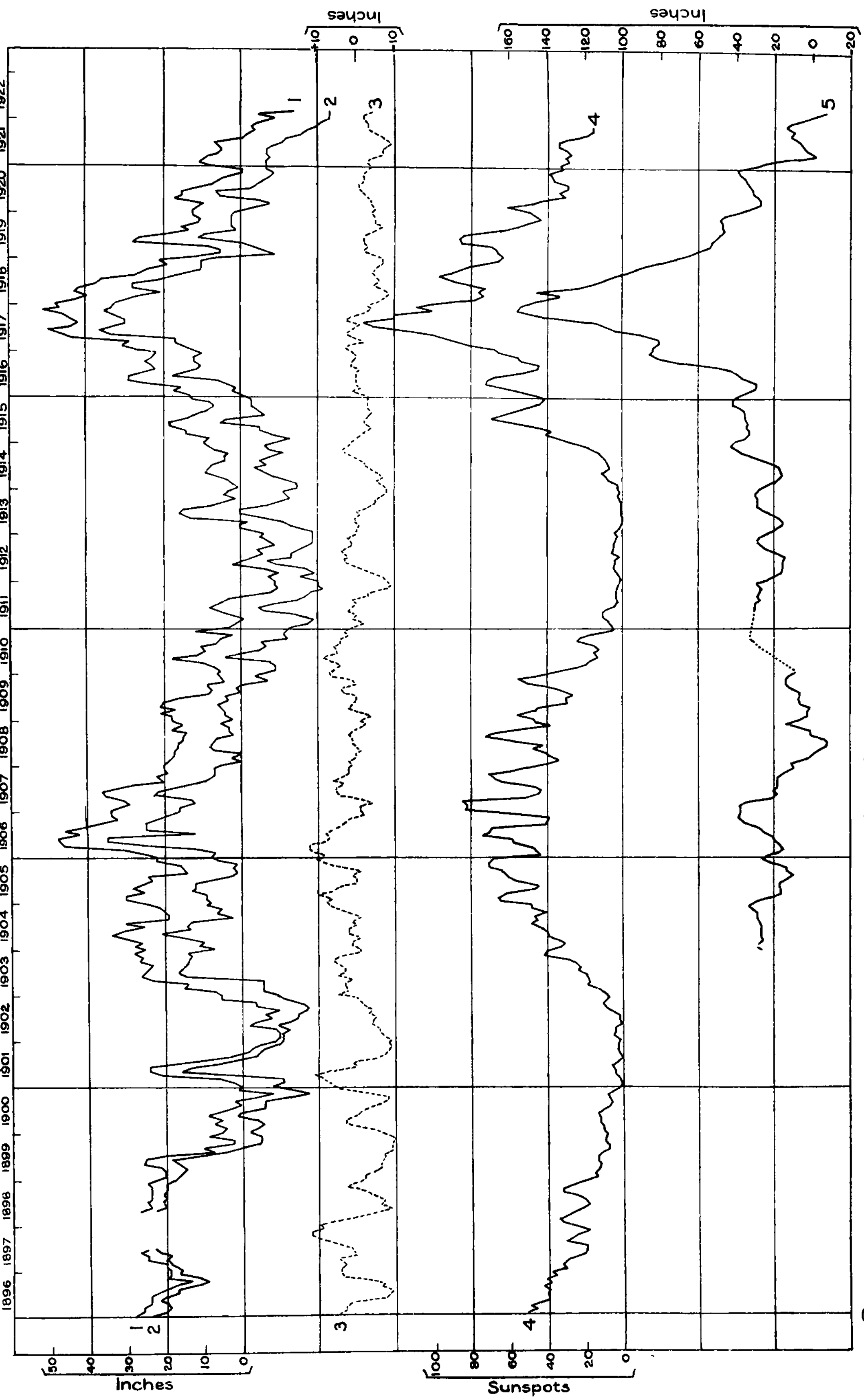
Plate I. — Lake levels, Rainfall and Sunspots.



Curves 1 & 2. Maximum and Minimum readings of the Lake gauge on Lake Victoria in inches above Zero Level.
Curve 3. Rainfall in Uganda; deviations from normal summed in overlapping periods of six months.
Curve 4. Monthly Sunspot numbers. Curve 5. Mean level of Lake Albert in inches above Zero Level.

H.M.S.O. Press, Kingsway, W.C.2.

Ps 4085/710. Wt. 32747A D.8682/736. 625 7/23.

VARIATIONS IN THE LEVELS OF THE CENTRAL AFRICAN LAKES VICTORIA AND ALBERT.

LAKE VICTORIA, which lies across the Equator in Central Africa, and is the second largest body of fresh water in the world, is of very great meteorological interest because of the remarkable way in which its level changes in sympathy with the variations in the number of spots visible on the sun. A brief note of this connection appeared in 1916[1], but since that date much more information has become available. The variations of level are of economic importance because Lake Victoria is the principal source of supply for the upper waters of the Nile. Lake Albert lies further north and is much smaller; the Victoria Nile from Lake Victoria enters it after passing through Lake Kioga, and it receives also the Semliki river draining Lake Edward.

The lake-level data for Victoria are obtained from the gauge maintained by the Lake Engineering Division of the Uganda Railway at Kisumu, at the head of the Gulf of Kavirondo on the east of the lake. This gulf is a small inlet connected with the main body of water by a narrow channel; it has no large river flowing into it, and is in every respect suitable for the purpose of observations of level. Daily observations are available, but the figures which have been utilised are the highest and lowest readings each month. These figures from the beginning of 1896 to March, 1922, are plotted in curves 1 and 2. These curves are referred to the present zero on the lake gauge at Kisumu, which is given as 3726·15 ft. above mean sea level. In the early years the series is incomplete, and the data have been pieced out to some extent by the records of other gauges. Lake-level gauges were first installed at the end of 1895, and observations were commenced at three stations on 1st January, 1896. The one which is taken as representing Kisumu is that at Port Victoria, at the south-western end of Berkeley Bay, an inlet of moderate size on the north-east shore of the lake. Observations were taken regularly once a day until the end of July, 1897, when the Sudanese mutiny caused an interruption. In May, 1898, observations were resumed at the gauge at Luba's, near the outflow of the lake into the Nile; unfortunately only the monthly means of these readings are available, and the readings for May to September were first corrected to the mean level of the Kisumu gauge, and then maximum and minimum readings were interpolated by means of the average range during these months[2].

On 1st October, 1898, observations were recommenced at Port Victoria; it appears that the gauge had not been disturbed and the new observations were directly comparable with the earlier ones. These readings were continued until 31st July, 1899, when the gauge was moved to Port Ugowe (Port Florence) at the head of the almost land-locked Kavirondo Gulf. The time occupied by the removal was 23 days; the new zero was computed from the observations at Luba's and Port Alice (Entebbe) during the period, but there is a possible error of two or three inches. The figures given for August refer only to the dates 23rd to 31st. On 1st October, 1900, the name of the gauge was changed from Port Ugowe to Kisumu, but the site was not altered, and from 23rd August, 1899, the records have been continuous. The present zero is 19 ft. 11 in. below the bench mark at Port Florence.

The extreme fluctuations in each month are probably of the nature of waves, and the change from the comparatively open situation at Port Victoria to Kisumu at the head of Kavirondo Gulf had the effect of accentuating these fluctuations appreciably, just as the ordinary tidal waves of the sea are accentuated in long, narrow gulfs. Consequently, the monthly range after the change was greater than that before, but the mean level was probably not affected. The upper curve (1) shows the maximum readings and the lower curve (2) the minimum readings. The readings on which the curves are based are given in Table I.

[1] *Meteorological Office Circular*, No. 3, Aug., 1916, p. 4.

[2] For a description of the early history of the lake-gauges *see* Garstin, Sir W., *Report on the Basin of the Upper Nile.* Appendix 3, by H. G. Lyons; *On the Variations of Level of Lake Victoria.* Cairo, 1904.

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TABLE I.—MAXIMUM AND MINIMUM READINGS OF THE LAKE GAUGE AT KISUMU, KAVIRONDO GULF, LAKE VICTORIA, IN INCHES ABOVE ZERO LEVEL.

—		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year (Mean)
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1896.	Max.	**28**	26	26	24	24	24	22	20	17	13	20	19	19·6
	Min.	24	20	19	20	22	20	17	17	12	**9**	11	16	
1897.	Max.	19	20	20	25	25	27	25	—	—	—	—	—	
	Min.	16	17	19	20	19	22	23	—	—	—	—	—	
1898.	Max.	—	—	—	—	(27)	(24)	(25)	(24)	24	24	24	25	
	Min.	—	—	—	—	(23)	(20)	(21)	(20)	21	20	20	20	
1899.	Max.	22	20	20	21	**26**	25	20	7	10	2	2	9	11·9
	Min.	18	17	16	15	17	19	11	4	− 1	− 4	− **5**	− **5**	
1900.	Max.	5	4	7	5	**9**	7	3	0	2	− 4	− 8	1	− 1·9
	Min.	− 2	− 4	− 6	− 3	1	0	− 6	− 6	− 6	−13	−**18**	−12	
1901.	Max.	0	2	6	21	**24**	**24**	17	8	2	− 2	− 3	− 5	3·1
	Min.	− 8	−**11**	−**11**	2	16	13	5	0	− 4	− 5	− 6	−10	
1902.	Max.	− 9	−10	−10	− 9	− 2	− 4	− 8	− 6	−10	− 4	− 4	**5**	− 9·7
	Min.	−11	−11	−11	−13	−10	−13	−15	−15	−17	−**18**	−16	−12	
1903.	Max.	7	7	15	14	23	26	25	24	23	27	26	**28**	12·9
	Min.	−**10**	− 6	− 6	− 6	− 6	14	16	15	14	14	13	14	
1904.	Max.	25	28	26	29	**34**	30	25	31	19	19	20	21	18·1
	Min.	7	11	10	15	21	13	14	13	**2**	6	5	9	
1905.	Max.	25	**30**	**30**	25	28	26	23	24	14	15	16	22	15·0
	Min.	8	9	9	13	12	12	7	2	**1**	2	**1**	6	
1906.	Max.	22	26	31	46	47	**48**	42	46	40	26	32	34	28·7
	Min.	8	**7**	12	24	35	35	12	25	25	25	22	19	
1907.	Max.	34	32	29	31	35	**36**	32	27	20	22	19	20	20·9
	Min.	16	16	12	13	23	22	18	14	9	**7**	**7**	**7**	
1908.	Max.	**20**	19	18	17	17	16	16	15	15	14	18	15	10·3
	Min.	5	**0**	2	**0**	7	8	7	6	2	3	3	5	
1909.	Max.	18	18	**21**	17	**21**	20	15	8	7	9	4	5	7·6
	Min.	2	4	4	5	6	3	5	0	1	0	− **7**	− 4	
1910.	Max.	6	5	7	10	**18**	11	9	10	6	5	2	12	0·9
	Min.	− 5	− 9	− 9	− 7	4	0	− 5	− 7	− 5	−**12**	−11	−**12**	
1911.	Max.	3	1	− 1	3	6	**8**	5	3	− 2	− 8	−10	− 9	− 7·3
	Min.	−13	−18	−19	−14	− 6	− 4	−10	−15	−17	−18	−**21**	−20	
1912.	Max.	− 9	− 7	−10	− 6	**2**	− 1	− 3	− 7	− 5	− 9	− 7	− 5	−10·5
	Min.	−**20**	−15	−19	−17	−10	− 7	−13	−13	−16	−18	−19	−19	
1913.	Max.	(− 6)	(0)	(0)	− 2	13	**16**	15	7	4	1	4	3	− 2·6
	Min.	(−**19**)	(−18)	(−13)	−11	− 5	0	0	− 6	−10	−13	−12	−11	
1914.	Max.	0	2	3	5	**9**	8	7	4	4	3	7	**9**	− 1·9
	Min.	−**15**	−**15**	−13	− 9	− 6	− 4	− 7	− 5	− 8	−11	− 7	− 6	
1915.	Max.	9	8	14	14	**18**	**18**	13	11	8	6	7	12	3·6
	Min.	− 9	−**13**	− 8	− 5	− 5	5	3	− 6	− 5	− 3	− 3	− 3	

TABLE I.—*continued.*

——		Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year (Mean)
		in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1916.	Max.	13	17	15	23	**29**	**29**	26	22	23	25	23	22	15·3
	Min.	− **1**	2	1	3	6	18	15	11	10	12	12	10	
1917.	Max.	27	31	29	44	47	50	44	42	44	46	**51**	47	34·6
	Min.	**13**	15	17	17	34	37	33	30	30	33	36	34	
1918.	Max.	**48**	43	40	43	42	38	36	28	26	24	19	21	27·3
	Min.	33	30	26	21	28	28	21	17	14	**10**	**10**	**10**	
1919.	Max.	12	5	5	9	**28**	26	18	13	15	11	10	12	7·6
	Min.	6	− **9**	− 6	− 3	1	11	9	1	2	2	2	2	
1920.	Max.	12	11	9	**17**	15	15	11	7	5	3	− 1	− 1	2·7
	Min.	1	− 4	− 8	− 4	5	6	− 2	− 4	− 6	− 8	− **9**	− 7	
1921.	Max.	8	**10**	8	5	4	5	6	− 1	− 2	− 4	− 3	− 5	−4·6
	Min.	− 7	− 7	− 8	− 7	− 7	− 8	−11	−12	−16	−17	−20	−**21**	
1922.	Max.	− 9	− 5	−14	—	—	—	—	—	—	—	—	—	—
	Min.	−23	−23	−23	—	—	—	—	—	—	—	—	—	—

One would naturally expect a close connection between the level of the lake and the rainfall over the basin ; to test this a selection of stations with the longest or earliest rainfall records was made and the deviations from the monthly normals at each station were combined into a single series (Table II.). Ten stations in Uganda were employed, but as, at the majority of these, observations did not commence until 1901 or 1902, the departures previous to the latter year are based on comparatively few records. The mean rainfall over the whole of Uganda calculated from these stations has an average of 50·71 in. (1288 mm.). The monthly figures are given in Table IV., together with the monthly means of the lake-levels ; from this table it appears that while the rainfall shows a semi-annual variation in excess of the annual term, the lake-levels show the annual term much in excess of the semi-annual. In order to take this into account, as well as to allow for the retardation of the rainfall in reaching the lake, the rainfall deviations have been summed in overlapping totals of six months, the totals being entered to the last of the six. In the last line of Table IV. is given the mean level of Lake Albert, based on fourteen complete years' observations of lake gauges at Butiaba, on the eastern shore. The average levels for the individual months at Lake Albert are shown in Table III.

From Table IV. it appears that the six-monthly rainfall sums reach a minimum in February and March and a maximum in August and September. The level of Lake Victoria is at a minimum in October to March, from which point it rises to a maximum in June. It will appear from considerations put forward later that from June to September evaporation is very active, and that the rapid fall during these months is to be attributed to this cause.

At Lake Albert the annual maximum of level is reached some months earlier, in November and December. The heaviest rainfall at Butiaba occurs in the months April and May, and again from August to October, while since Lake Albert lies entirely north of the Equator, the radiation received from the sun and probably also the evaporation is least from November to February. The maximum level in November and December is thus due to the accumulation of the August to October rainfall, and the diminished loss by evaporation.

It has not been considered necessary to apply any correction for annual range to the figures plotted in Plate I., since the long-period changes greatly exceed the annual variations in magnitude.

TABLE II.—AVERAGE RAINFALL OVER UGANDA (DEPARTURES FROM MONTHLY AND ANNUAL NORMALS).

——	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1895 ..	−0·26	−0·29	+0·76	+7·09	+5·50	−1·95	−0·55	−0·22	−0·25	−0·13	+4·74	+0·32	+14·76
1896 ..	+0·12	−2·27	−0·25	−1·54	−2·93	−0·93	−1·09	+1·21	−1·49	0·00	+5·55	−0·38	− 4·00
1897 ..	−0·58	+0·28	−0·67	+0·52	+0·34	+0·84	+0·24	+3·34	+4·22	+2·77	+0·18	−1·28	+10·20
1898 ..	+1·00	−1·57	−1·08	−2·24	−3·97	+2·11	+0·07	+0·16	+0·70	−0·06	+0·36	−1·08	− 5·60
1899 ..	−2·00	−0·12	−2·55	−0·52	+0·07	−2·35	−1·77	−2·35	−2·09	−0·94	−0·95	−0·13	−15·70
1900 ..	+0·92	+2·69	+1·30	−0·95	−3·45	−1·21	−1·76	+0·27	−0·42	−1·07	+2·44	+5·05	+ 3·81
1901 ..	−0·69	+2·57	+0·88	+0·33	−0·74	−2·06	−0·44	−2·02	−1·65	−1·25	−1·17	−1·58	− 7·82
1902 ..	−0·97	+0·02	−1·03	−1·21	+0·71	−1·11	−2·18	+1·52	−1·32	+0·80	+1·18	+0·36	− 3·23
1903 ..	+2·27	−1·50	−0·11	+0·60	−0·59	+4·30	+0·65	−1·46	+1·72	+0·98	−2·64	−0·40	+ 3·82
1904 ..	+0·84	+0·49	+1·89	−1·33	+0·61	−0·41	−0·89	+1·05	+0·36	+1·30	+2·29	+2·52	+ 8·72
1905 ..	+0·92	−1·08	+3·80	−2·36	−0·22	−0·84	+0·79	+0·03	+1·21	+2·41	+3·04	+2·55	+10·25
1906 ..	−0·95	+2·55	+2·62	+2·03	−0·58	+1·55	−0·13	+0·99	−0·03	+0·96	−2·44	−0·88	+ 5·69
1907 ..	+0·07	+1·27	−3·05	+3·87	+3·05	−0·15	−0·07	−0·97	−0·15	+0·87	+1·96	+0·36	+ 7·06
1908 ..	−1·12	+0·12	−2·39	+1·00	+1·52	+0·51	−0·08	+0·93	−1·86	+0·30	−0·66	−0·22	− 1·95
1909 ..	+0·39	−1·77	+1·10	+3·32	−1·56	−1·17	−0·16	+1·82	+1·75	−0·58	−1·13	+4·06	+ 6·07
1910 ..	+1·40	−0·31	+0·95	+0·87	+2·00	−0·33	+1·83	+0·59	−0·82	+0·89	−0·26	+0·44	+ 7·25
1911 ..	−0·24	−1·82	+1·95	+0·04	+1·54	−0·91	−0·88	−0·81	−2·02	−0·40	−3·19	−1·79	− 8·53
1912 ..	+0·69	+0·19	+0·27	+1·42	−0·20	+0·41	+0·27	+1·19	+0·49	−0·90	−0·06	+0·56	+ 4·33
1913 ..	−0·82	+0·64	−0·13	−0·11	+0·02	−0·51	−0·28	−2·29	−1·97	−0·51	−1·87	−1·49	− 9·32
1914 ..	−0·29	−0·63	−0·14	−2·57	−0·59	+0·66	+0·78	+0·11	+1·50	−0·45	+1·60	−1·34	− 1·36
1915 ..	−0·68	−0·88	+0·94	−1·59	−0·52	+0·60	−0·80	−1·91	+0·57	−0·71	−0·73	+0·85	− 4·86
1916 ..	−0·55	+1·13	−0·57	−0·06	−0·82	+0·68	−0·63	0·00	+2·07	−0·59	−1·16	+0·06	− 0·44
1917 ..	+0·65	+1·71	−2·88	+1·98	+0·58	+0·30	−1·42	+0·79	+0·43	+0·64	−2·62	−2·05	− 1·89
1918 ..	−0·30	−1·77	−1·72	−0·63	−0·37	−0·59	−0·51	−1·03	−0·89	−1·55	−1·79	−1·03	−12·18
1919 ..	−1·04	+2·54	+0·45	−2·22	−0·55	−0·97	−1·63	−0·53	−0·89	−0·82	−0·12	−0·86	− 6·64
1920 ..	−0·52	−1·72	+0·22	−0·68	+0·26	+0·58	+0·24	−1·16	−1·41	−0·34	+0·04	−0·07	− 4·56
1921 ..	−0·65	−0·73	−2·44	−2·93	−0·59	−0·25	−1·85	−0·26	−0·21	−0·46	0·00	−0·32	−10·69
1922 ..	−0·98	−0·07	−2·25	—	—	—	—	—	—	—	—	—	—
Mean ..	2·17	3·06	4·60	7·35	5·82	3·58	2·48	3·80	4·60	4·76	5·16	3·33	50·71

TABLE III.—MEAN READINGS OF LAKE GAUGE AT BUTIABA, LAKE ALBERT, IN INCHES ABOVE ZERO LEVEL.*

——	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1904	—	28	26	27	27	27	27	28	29	29	32	34	—
1905	29	22	17	17	18	17	14	11	14	14	20	25	18
1906	23	17	16	18	20	21	26	27	32	37	39	39	26
1907	38	38	35	21	19	21	19	19	19	17	13	10	22
1908	11	6	1	− 1	− 4	− 7	− 8	− 5	1	1	8	14	1
1909	—	3	3	2	7	8	7	7	13	15	15	13	—
1910	9	—	—	—	—	—	—	—	31	33	—	—	—
1911	—	—	—	—	31	31	30	28	29	28	27	29	—
1912	25	20	17	16	16	16	15	19	24	27	29	27	21
1913	23	20	17	16	18	22	27	29	29	29	30	29	24
1914	27	23	19	17	17	18	19	24	29	35	40	43	26
1915	41	36	33	33	35	34	35	35	35	38	42	42	37
1916	38	33	29	29	33	37	40	43	54	71	81	86	48
1917	84	83	80	81	90	103	108	113	128	145	156	154	110
1918	149	141	132	146	123	116	110	105	99	93	86	79	115
1919	71	64	58	53	52	50	48	46	47	47	48	46	53
1920	40	32	27	27	28	31	31	33	34	35	38	39	33
1921	29	24	9	− 2	2	4	5	7	11	9	14	11	10
1922	5	− 2	− 8	—	—	—	—	—	—	—	—	—	—

*The zero of the gauge is at 2028·1 feet above M.S.L. The figures from 1904 to 1910 were read from old wooden gauges, and are not so reliable as the later readings.

TABLE IV.—MONTHLY NORMALS OF RAINFALL AND LAKE LEVELS.

——	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
RAINFALL—													
Normal ..	2·17	3·06	4·60	7·35	5·82	3·58	2·48	3·80	4·60	4·76	5·16	3·33	50·71
Sum for six months ending with the named month	23·82	23·08	23·08	25·67	26·33	26·58	26·89	27·63	27·63	25·04	24·38	24·13	25·35
HEIGHT* OF LAKE VICTORIA—													
Normal monthly maximum.	12·7	13·2	13·2	17·2	21·9	21·2	18·0	14·7	12·4	11·0	10·7	12·7	14·9
Normal monthly minimum.	0·5	−0·6	−0·5	2·8	8·7	10·4	6·5	3·4	1·3	0·1	−0·5	0·4	2·7
½ (max.+min.)	6·6	6·3	6·3	10·0	15·3	15·8	12·3	9·1	6·9	5·5	5·1	6·5	8·8
HEIGHT† OF LAKE ALBERT (mean monthly)	44·1	39·9	35·0	33·6	33·4	34·5	34·9	36·1	39·7	42·7	46·0	46·0	39·4

* In inches above the zero level of 3276·15 feet above M.S.L.
† In inches above the zero level of 2028·1 feet above M.S.L.

Turning now to Plate I., we find that it shows very clearly that while the level of Lake Victoria undoubtedly depends to some extent on the accumulated rainfall, the connection is generally small. The fall of level in 1896 was preceded by a dip in the rainfall figures, and the big rise of 1901 was preceded by a rainfall maximum, while there is also some parallelism in 1906 and 1911, but the great rise culminating in 1917 is entirely unconnected with any increase in the rainfall, which remained practically normal throughout.

In curve 4 we have the monthly sunspot numbers.[1] For the purposes of the figure these were smoothed by taking the mean of each three successive months, allocated to the middle one. Here we do see a really remarkable connection, brought out not only in the major features of the curves, but in many of the minor features as well. Taking the period from 1915 to 1920, we have maxima on both curves in June, 1915, May, 1916, a single sunspot maximum in August, 1917, corresponding with a double lake-level maximum (June and December), a maximum in both curves in May, 1919, and a sunspot maximum in January, 1920, corresponding with a lake-level maximum in March. In general, it appears that there is a lag of one to two months in the effect of the solar conditions on the lake levels. The lowermost curve (5) shows the level of Lake Albert at Butiaba. This lake is much more variable in level, the total range exceeding 160 in., so that it is represented in the figure with a vertical scale only half that of curves 1 and 2. The sunspot maximum of 1917 is again connected very markedly with a rise in the level of the lake, but the preceding maximum of 1906 is not so well defined. These early observations at this station are, however, admittedly unreliable.

It is interesting to express the relationship between the level of Lake Victoria on the one hand and the rainfall and sunspots on the other hand numerically in the form of correlation coefficients. In 1916 a direct correlation between the mean annual lake-levels and the annual sunspot numbers (1896 to 1915) gave a result as high as $+ 0 \cdot 80$. It is now possible to calculate the correlations on the basis of monthly instead of annual means and to take account also of rainfall. The mean lake-level has been taken as the mean of the maximum and minimum for each month; for rainfall the six-monthly sums have been used, and for sunspots the unsmoothed relative numbers. In addition to the direct correlations, partial coefficients were

[1] *Meteorologische Zeitschrift*, Vol. 19, 1902, p. 195 (1749–1901); Vol. 39, 1922, p. 326 (1902–1920); Vol. 38, 1921, pp. 118, 216, 307; and Vol. 39, 1922, pp. 19, 125 (1921–1922).

calculated showing the connection between lake-levels and rainfall, the sunspot numbers being constant, and between lake-level and sunspots, rainfall being constant. The results were worked out for the period 1899 to 1921 and also for the period with more reliable figures, 1902 to 1921. The former period gives 276 sets of observations and the latter 240, so that the probable errors are extremely small. In Table V. the suffix 1 indicates lake-level, 2 indicates rainfall, and 3 sunspot numbers; the usual notation is employed, 12·3 meaning correlation coefficient between lake-level and rainfall, corrected for sunspots and so on. In the third line the coefficients deduced from the annual means are added for comparison.

TABLE V.—CORRELATION COEFFICIENTS BETWEEN LAKE LEVELS, RAINFALL, AND SUNSPOTS.

—	r_{12}	r_{13}	r_{23}	$r_{12\cdot3}$	$r_{13\cdot2}$
1899–1921	+·26	+·74	+·12	+·25	+·72
1902–1921	+·29	+·81	+·08	+·39	+·82
1902–1921 .. .. (Annual figures.)	+·39	+·87	+·12	+·59	+·90

From Table V. it appears that while the level of Lake Victoria depends to some extent on the rainfall, the relation to sunspot numbers is much more close, the corrected coefficient reaching + 0·82 for the period 1902 to 1921, even when monthly figures are considered, in spite of the fact that no lag is allowed for, while the annual means, which to some extent compensate for the lag and also tend to smooth out irregularities, give a corrected coefficient as high as + 0·90. These are remarkable figures, and indicate a very close connection between the lake-levels and the radiation from the sun. Such a connection can only be through evaporation.

From the monthly coefficients (1902–1921) we can deduce the relationship—

$$L = 0\cdot36R + 0\cdot36S,$$

where L is the departure in inches of the lake-level from the normal level for the month (*see* Table IV.), R is the departure of the general rainfall in inches over Uganda in six months from the normal, and S the departure of the relative sunspot number from 35, the average number.

Now, the area of Lake Victoria is somewhat over 26,000 square miles, and the area of its basin, including the lake itself, is about 92,000 square miles. If all the water which fell over the basin drained into the lake in such a way that at any time the water present represented the rainfall of the preceding six months, and also if nothing were lost from the surface itself by evaporation and the run-off remained constant, a total rainfall in excess of the normal by 1 in. would cause a deviation of the lake-level from normal to the extent of 92/26 = 3·54 in. Actually we find that the change of level is only 11 per cent. of this, or 0·36 in.; the remaining 89 per cent. is made up of increased evaporation from the soil and vegetation and increased run-off. It is interesting to compare these figures with the data given by Sir William Garstin[1] for the outflow from the lake at Ripon Falls, which averages only 18×10^9 cubic metres a year, while the normal rainfall over the basin and lake amounts to approximately 300×10^9 cubic metres, giving a run-off of only 6 per cent. of the rainfall. The remaining 94 per cent. represents evaporation from the soil and vegetation and from the surface of the lake. The figure of 89 per cent. obtained from the regression equation includes some loss by increased run-off and seepage. The increased run-off can be calculated from the observations at Ripon Falls, and amounts to only about 0·5 per cent. of the rainfall; the increased seepage cannot be calculated, but

[1] loc. cit., p. 168. The run-off varies from 500 to 650 cubic metres per second, or 16×10^9 to 20.5×10^9 cubic metres a year.

is probably small. After allowing for these factors, enough agreement remains to show that evaporation is responsible for by far the greatest loss of water in Uganda, and also that—*other things being equal*—the evaporation is nearly, but not quite, proportional to the rainfall.

The chief factor in the amount of evaporation, however, is not rainfall but solar conditions. The researches of W. Köppen and others have established beyond doubt that there is a close connection between sunspots and tropical temperatures, the latter being 1·1° F. higher at spot minimum than at spot maximum. It is reasonable to conclude that the higher the temperature the greater the evaporation; hence at spot minimum evaporation will be increased and the level of the lake will fall, while at spot maximum evaporation will be decreased and the level of the lake will rise. This relationship, as we have seen, is so intimate that it gives correlation coefficients of between 0·8 and 0·9.

Although lake-gauge measurements do not begin until 1896, certain earlier data are available in general terms from the descriptions of explorers. These have been summarised by H. G. Lyons, who gives the following table. In the third column remarks on the sunspot numbers are added for comparison.

TABLE VI.—EARLY RECORDS OF LEVEL OF LAKE VICTORIA.

Date.	*Lake Level.*	*Sunspots.*
1878	Very high in north-east during August and September	Minimum 1878.
1884–1886	Drought in north-east	Maximum 1883 to 1884.
1888–1890	General fall on southern shore	Minimum 1888 to 1890.
1891	Low	
1892	Very high, heavy rainfall, tendency to rise	Sunspots numerous; Maximum in 1893.
1895	Very high	

On the whole this table bears out the conclusions drawn from the lake gauges, with the exception of the high level in 1878, which was associated with heavy rain and occurred at a sunspot minimum. The records for 1884 and 1886 refer to a failure of the rains and not the level of the lake. From 1888 to 1895 the agreement with sunspot numbers is complete.

DIURNAL VARIATION OF LEVEL AT KISUMU.

For the past few years the lake-gauge at Kisumu has been read twice daily—in the morning and evening. The precise hours are not stated. These readings show that the level during the evening is persistently higher by a few inches than that during the morning. During the five years 1917 to 1921 the mean difference was 3·9 in.; it was greatest in February (5·0 in.), and least in July and October (3·0 in.), but the annual variation was not very marked. The mean difference from December to April was 4·4 in., and from June to October 3·4 in.

This diurnal variation is probably largely due to the influence of land- and lake-breezes, which, owing to the great area of Lake Victoria, are well developed. During the night and early morning the land breezes tend to blow the surface water away from the shores on all sides, accumulating it in the open part of the lake. During the day, on the other hand, the lake-breeze tends to drive the water before it, and it collects against the shore, raising the level there at the expense of the centre of the lake. Such an effect would be well developed in a long, narrow inlet like Kavirondo Gulf. The months when the effect is best shown—December to April—are, in general, those with least rain, and also to some extent those in which the diurnal range of temperature is greatest. The difference between the mean daily maximum and mean daily minimum temperatures at Entebbe exceeds 16° F. from September to February, while from April to July it is less than 15° F. The monthly figures are given in Table VII.

TABLE VII.—DAILY RANGE OF LAKE LEVEL AND TEMPERATURE AND MONTHLY RAINFALL.

——	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Daily range of lake-level, inches.	4·0	5·0	4·6	4·4	3·8	3·4	3·0	3·4	4·2	3·0	3·6	4·2
Daily range of temperature (Entebbe) °F.	16·3	16·5	15·0	13·8	13·3	13·8	14·7	15·7	16·9	17·4	16·6	16·3
Monthly Rainfall (Uganda), inches.	2·17	3·06	4·60	7·35	5·82	3·58	2·48	3·80	4·60	4·76	5·16	5·33

It is probable that if the variations of lake-level were systematically investigated with the aid of an autographic gauge, various other types of fluctuation would come to light, especially "seiches," and probably also true tidal waves. At present, however, the amount of material available is insufficient for an investigation of these more minute fluctuations.