amounts. In June 4.81 inches fell on consecutive dates from the 18th until the 30th; the greatest amount in any 24 hours during this period was but 1.10 inch and the least 0.06 inch, but the effect is clearly apparent in Figure 3 and in the numerical values of Table 1. Evaporation is not only greatly reduced by continuous cloudy rainy weather, but the run-off is much greater because the vegetative cover of the basin becomes thoroughly wetted and sheds water so much the quicker and with less loss from interception and absorption.

The rainfall record for 1917 is much similar, the annual deviation from normal being −1.89 inches. Here again annual figures are not significant; one should consult the monthly deviations as shown in Table 2. These show that rainfall was decidedly below normal in March, moderately below in July, and decidedly below in both November and December. The detailed record of rainfall made at Entebbe shows that March had but 3 rainy days, April had 23, of which 18 *were consecutive*; May had 19, 13 *consecutive*.

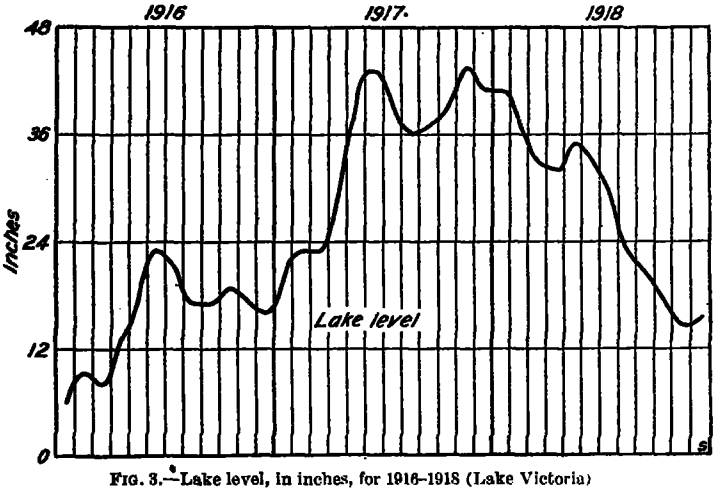

FIG. 3.—Lake level, in inches, for 1916–1918 (Lake Victoria)

June had 7, scattered throughout the month, and July had but 0.02 inch for the entire month; August 15 rainy days, 5 *consecutive;* September, 12, 6 *consecutive;* October, 10, 5 *consecutive;* November and December had few rainy days and they were scattered throughout the month.

By following the curve of Figure 3 it will be seen that the lake rose practically uninterruptedly from January to June in perfect congruence with the rainfall. The lack of rain in July, only 0.02 inch is manifest in the drop in the curve for July and August. More rain, favorably distributed sent the lake up to a second maximum in November equal to the first maximum in June.

A period of deficient rainfall set in in November, 1917, continuing uninterruptedly for 14 months, then followed 2 months of normal rains and again a deficient period, this time lasting without a break for 11 months. The lake level was, of course, falling during these periods of deficient rains and reached in March, 1922, the lowest point ever recorded, viz, 18.5 inches below its normal level. The lake level will of course rise in response to a return of the rainfall to normal. The high water of 1917 might be explained in one or more ways as independent of the rainfall; first, the discharge over Ripon Falls might have been greatly retarded through channel obstructions during 1916 and 1917, or, second, prevailing southerly winds during these same years may have driven the water to the northern end of the lake—the neck of the bottle; but it is preferred to believe that the response of the lake to the natural rainfall and run-off has been such as might have been expected and that it is unnecessary to have recourse to changes in solar radiation to explain the variations in level as described.

Through the courtesy of Mr. R. Z. Kirkpatrick, chief hydrographer of the Panama Canal, the editor has been supplied with monthly values of observed evaporation from a 4-foot pan floating in Lake Gatun, Canal Zone, Panama, an artificial body of water formed by damming the Chagres River. The lake has an area of 164 square miles. The 11-year mean evaporation from this lake is roughly 60 inches, of which 44 per cent occurs during the dry season—January to April, inclusive, and the remaining 56 per cent occurs during the remaining months of the year. During the year of sun-spot minimum, 1913, evaporation from the lake was 108 per cent of the 11-year average; during the year of spot maximum, 1917, evaporation was 102 per cent of the average. The least evaporation was 87 per cent in 1921 and the greatest 109 per cent in 1918. There is here no suggestion of a sun-spot influence upon evaporation.

DISCUSSION BY C. E. P. BROOKS [2]

I am glad to see this review, although I do not entirely agree with your remarks.

The rainfall for Uganda employed in the original memoir were the best I could do at the time, and I was very glad to receive the more extensive figures given by Mr. Phillips, director, Cairo Hydrological Service (Nature, London, 113:440).

I have already had an opportunity of considering the *effect of this modification*, in an unpublished paper on the subject written at the request of the Uganda Literary and Scientific Society. I have unfortunately no spare copies of this paper, but may quote the following expression of my revised views:

> Since the level of the lake shows so close an agreement with the number of sun spots, the latter must have a dominating influence on one or both of the prime factors which influence the lake level, namely, rainfall and evaporation. A comparison of the average rainfall over the lake plateau, according to Mr. Phillips, with the sun spot numbers shows that the rainfall is generally high when sun spots are increasing and low when sun spots are decreasing. The change in the average sun spot number from one period of 12 months (July to June) to the succeeding 12 months shows a good agreement with the rainfall amounts * * * the correlation coefficient being +0.64, which indicates good but by no means remarkable agreement. The correlation coefficient between plateau rainfall and the change in the level of Lake Victoria is +0.91, indicating a very close agreement. Since the level of the lake depends on the rainfall and the rainfall depends on sun spots, it is evident that the level of the lake would show agreement with sun spots even if there were no other factor. To measure this agreement between lake level and sun spots through rainfall we multiply together the two correlation coefficients given above, i. e., $0.64 \times 0.91 = 0.58$, and this would be the correlation coefficient between lake level and the sun spots if no other factor than rainfall had to be taken into account. But the connection between lake level and sun spots is much closer than this; it gives a correlation coefficient of +0.87. Therefore some other factor in the lake le besides rainfall must be closely connected with sun spots, and * * * this factor must be evaporation.

[2] A copy of the foregoing having been furnished Doctor Brooks, he makes the following comment.

The agreement shown between the level not only of Lake Victoria but also of Lake Albert, and sun spots is so remarkably good that some intimate connection between the two variables must certainly be accepted, and this is the primary contention of the geophysical memoir referred to. By making use of the scattered reports of explorers previous to the installation of lake gages the lake-level curve can be carried back another eight years, and still it agrees with the sun-spot curve. Data for 1923 also support the agreement. Assuming a correlation of 0.8 for the 36 years 1888–1923 (between level of Lake Victoria and sun-spot numbers) the probable error works out as only $\pm .04$, and the coefficient is 20 times the probable error, which amounts almost to absolute certainty. To reduce the number of "occasions" to the six or seven maxima and minima amounts to assuming beforehand the truth of what you wish to disprove.

Working out the partial coefficients roughly we obtain lake level, sunspots, rainfall constant, $r = +0.92$; lake level, rainfall, sunspots constant, $r = +0.80$.

The first figure, 0.92 is practically the same as the crude coefficient between lake level and rainfall. This means that the level of the lake is determined almost entirely by two factors—rainfall, and sunspots—independently of their effect on rainfall. It is difficult to see any other means than evaporation through which the latter effect can operate. The run-off from the lake is so small (only about 6 per cent of the rainfall) that its variations can not appreciably affect these relationships.

The conclusion drawn from the data is therefore solely that the level of the lake is determined almost entirely by the balance between rainfall and evaporation. At first the chief effect was attributed to the latter, but Mr. Phillip's rainfall figures show rainfall to be of equal importance. Variations due to run-off, seepage, etc., are necessarily relatively unimportant, but they were so far from being ignored that on page 342 of the Memoir an attempt is made to calculate them. I therefore can not understand why I am accused of having "set aside one of the fundamental laws of hydrology * * *." Actually this elementary law was present in my mind throughout.

The use of temperatures at Entebbe for calculating evaporation would be irrelevant for two reasons. In the first place at stations on the edge of large bodies of water the sun-spot cycle of temperature variations is greatly modified by the incidence of lake or sea breezes, so that they are not a fair indication of the temperature of the mass of air blowing over the lake or sea, and, in the second place, with higher land temperatures some distance inland the wind movement would be greater and this would increase the evaporation disproportionately to the rise of temperature.

THE FREQUENCY OF WINDS OF DIFFERENT SPEEDS AT FLYING LEVELS BETWEEN NEW YORK AND CHICAGO: A FURTHER ANALYSIS OF THE RECORDS OF THE AIR MAIL SERVICE[1]

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551.55 (73)

[Weather Bureau, April 4, 1924]

The effect of winds of different speeds on the performance of aircraft in regular service over a given route was examined in some detail by the authors in an earlier paper.[2] Because of the importance of this factor of wind frequency in aircraft operations it has been considered desirable to extend the analysis of the previous paper, particularly as regards the New York-Chicago route, in order to confirm or modify the earlier conclusions. The records of the air mail for the fiscal year 1923 have therefore been examined and combined with those for the fiscal year 1922, as previously determined, and the results of this more complete analysis are considered in the paragraphs which follow.

The flight data upon which the analysis is based were taken directly from the operating records of the air mail and cover the two-year period from June, 1921, to May, 1923, inclusive. Table 1 presents the number of flights by month and by season, the average speed maintained and the percentage of flights completed to the total number possible. This table corresponds to Tables 1 and 2 of the earlier report, to which reference should be made for a description of the route and of the general method of computation.

Table 2 presents the data corresponding to those of Tables 9 and 11 of the former report. Of particular interest is the last line which gives the wind factor as determined for the two consecutive years.

[1] Presented before American Meteorological Society at Washington, D. C., Apr. 30, 1924.

[2] The Wind Factor in Flight: An Analysis of one Year's Records of the Air Mail. Mo. WEATHER REV., March, 1923, 51: 111–125.

TABLE 1.—*Flights made between New York and Cleveland and between Cleveland and Chicago, June, 1921, to May, 1923, inclusive*

	January	February	March	April	May	June	July	August	September	October	November	December	Spring	Summer	Autumn	Winter	Annual
	Number of days available, excluding Sundays and holidays																
	51	46	54	50	52	52	50	54	50	52	50	51	156	156	152	148	612
	Number																
New York-Cleveland	42	36	43	46	49	51	50	52	49	49	39	44	138	153	137	122	550
Cleveland-Chicago	46	39	50	48	51	52	50	54	50	52	45	46	149	156	147	131	583
Chicago-Cleveland	47	40	51	48	51	52	50	54	49	52	42	45	150	156	143	132	581
Cleveland-New York	40	38	44	45	49	51	50	52	49	50	39	47	138	153	138	125	554
	Percentage of possible																
New York-Cleveland	82.3	78.3	79.6	92.0	94.2	98.1	100.0	96.3	98.0	94.2	78.0	86.3	88.5	98.1	90.1	82.4	89.9
Cleveland-Chicago	90.2	84.8	92.6	96.0	98.1	100.0	100.0	100.0	100.0	100.0	90.0	90.2	95.5	100.0	96.7	88.5	95.3
Chicago-Cleveland	92.2	87.0	94.4	96.0	98.1	100.0	100.0	100.0	98.0	100.0	84.0	88.2	96.2	100.0	94.1	89.2	94.9
Cleveland-New York	78.4	82.6	81.5	90.0	94.2	98.1	100.0	96.3	98.0	96.2	78.0	92.2	88.5	98.1	90.8	84.5	90.5
	Average speed (m. p. h.)																
New York-Cleveland	90.4	87.8	89.3	89.6	96.6	89.6	88.4	90.0	89.6	88.6	86.1	89.7	91.8	89.3	88.1	89.3	89.6
Cleveland-Chicago	89.6	86.8	87.6	89.4	95.6	90.2	87.7	89.1	88.9	86.6	87.4	88.1	90.9	89.0	87.6	88.2	88.9
Chicago-Cleveland	107.1	106.5	105.0	104.5	94.9	93.3	96.6	95.5	98.7	104.5	106.2	105.7	101.5	95.1	103.1	106.4	101.5
Cleveland-New York	113.5	117.4	111.8	108.8	102.2	98.1	93.5	95.8	98.8	105.8	105.2	111.9	107.6	95.8	103.3	114.3	105.2