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C. E. P. BROOKS, D.Sc., AND THERESA M. HUNT

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1. THE AVERAGE ANNUAL RAINFALL.

A KNOWLEDGE of the distribution of rainfall in different latitudes is important for many problems of physical and dynamical meteorology, but it is many years since an independent investigation into this distribution has been made. The figures recently published by G. Wüst[1] are merely a combination of those published by earlier authors[2] nearly all of which are based on Supan's chart of world rainfall[3] issued in 1898. Since that year improved rainfall charts have become available for the greater part of the world, and it appeared that the time was fully ripe for a redetermination of the figures.

The first step was to determine the zonal distribution of the average annual rainfall. The method adopted for this purpose was simple. For each country the best available chart of average annual rainfall was selected, and was either considered separately or combined with other charts to give a rainfall map of the whole continent. The different countries of Europe and Asia were dealt with individually; the continents of North and South America, Africa, and Australia were treated as units, the procedure in this respect being merely a matter of convenience. Some of the maps were on Mercator's projection and were divided into "squares" of one degree of latitude by one degree of longitude, by ruling straight lines across them. In some other maps with curved co-ordinates it was found more convenient to divide the surface into "square degrees," *i.e.* squares the four sides of which were each equal to one degree of latitude. Each "square" was then mentally subdivided into tenths, and the number of tenths between each pair of isohyets was estimated by eye.

The combined figures for a strip of five degrees of latitude across each country or continent were then treated in two ways, which are best made clear by an actual example. Spain, between 40° and 35° N., forms a good illustration.

The sums of the areas, in degree squares and tenths, between the different isohyets in this five-degree strip were found to be as follows:

Rainfall in cm. . .	Below 40	40-60	60-80	80-100
Area in degree squares	3·9	14·4	2·8	0·7

No isohyet of 20 cm. was shown on the rainfall chart from which the measurement was made; as the isohyets rise regularly by steps of 20 cm. to 100 cm., it was assumed that an isohyet of 20 cm. would have been

[1] Verdunstung und Niederschlag auf der Erde. *Berlin Zs. Ges. Erdk.*, 1922, p. 41.
[2] See p. 146.
[3] *Petermann's Mitt.*, *Gotha*, 1898. *Ergänzsb.* **26**, H. 124.

inserted had it been necessary, in other words, that the rainfall nowhere fell below 20 cm. The figures between different isohyets were next combined to give the total areas which received more than various amounts of rainfall:

Lower limit of rainfall in cm. . . .	20	40	60	80
Area in degree squares above this limit	21·8	17·9	3·5	0·7

The first figure, 21·8 degree squares, gives the total area of the strip.

These figures were plotted on squared paper, divided in inches and tenths, with the area as ordinate and the lower limit of rainfall as abscissa, and a smooth curve drawn through the plotted points (Fig. 1).

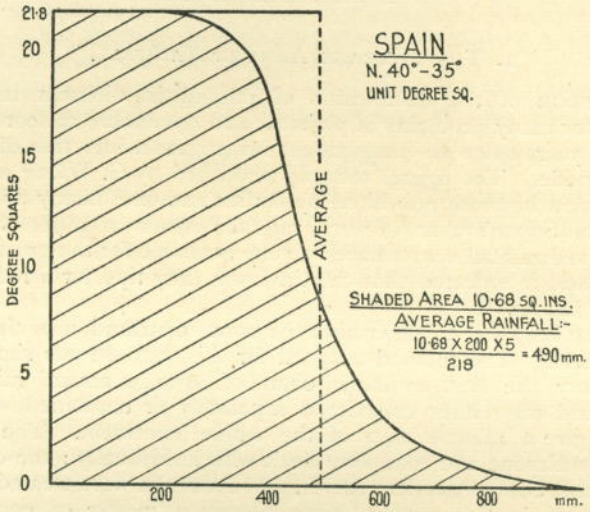

FIG. 1.—Illustrating calculation of average rainfall.

At the top this curve passes smoothly into the horizontal line representing the total area (21·8), and at the bottom it passes smoothly into the horizontal axis.

The next step was the measurement of the area between the curve and the horizontal and vertical axes, shaded in Fig. 1. This measurement was made with a planimeter and checked by counting the number of squares. In this example the area was found to be 10·68 square inches. One inch along the ordinate represents an area of 5 degree squares, and one inch on the abscissa a rainfall of 20 cm. The average rainfall over the area of 21·8 degree squares represented by the diagram is therefore $\frac{10{\cdot}68 \times 5 \times 20}{21{\cdot}8}$ cm. or 490 mm.

As a check the average rainfall of the area between each pair of isohyets was taken as midway between the values of the isohyets, and the average for the whole strip was calculated arithmetically, and was found to be 496 mm.

The differences between the figures given by the two methods were in general slight, of the order of one or two per cent. The chief exception occurred where there was a large area above the highest isohyet marked on the map. Thus if there were isohyets for 1000 and 2000 mm., and a large area with more than 2000 mm., by the graphical method the average rainfall over this area was determined by the general slope of the smooth curve, and especially that part of it between 1000 and 2000 mm. In the arithmetical method, the average rainfall of the area enclosed by the isohyet of 2000 mm. was taken as 2500 mm., *i.e.* 2000 mm. plus half the difference between the two highest isohyets, 1000 and 2000 mm. Discrepancies also sometimes occurred when the steps between the two highest isohyets on the rainfall charts were large. With both these types the graphical method gives a figure for the average rainfall which is smaller and almost certainly more accurate than that given by the arithmetical method.

In northern Africa and parts of Asia there were several five-degree strips in which the rainfall according to the charts is everywhere below 250 mm. Over these strips the average rainfall was taken as 125 mm. It is probable that in the Aïr and Ahaggar massifs the average rainfall rises to just above 250 mm., but, on the other hand, there are probably extensive areas in which the "average" of the extremely rare falls is below 50 mm. a year. The average of the whole strip is more likely to be below than above 125 mm., but in the absence of any means of arriving at a closer determination it seemed best to take the half-way figure between 0 and 250 mm. An error of 25 or even 50 mm., though large relatively, is small in absolute amount.

For the Antarctic continent data were almost entirely lacking. We know of only two definite measurements, Port Circoncision (Petermann Island), 65° S., 265 mm. in eleven months, and the German Antarctic Expedition, drifting in an average latitude of 69° S., 118 mm. Even these are probably subject to a considerable error, owing to the difficulty of measuring snowfall with a high wind, but in default of anything better they had to be accepted. It was assumed that the amount decreases slowly towards the interior, and the figure for the pole was taken as 50 mm. These figures were plotted on squared paper and a smooth curve drawn through them, from which an average was computed for each five-degree zone. Although the errors in these figures are probably large relatively, they are not likely to be important in absolute measure.

The figures for the different five-degree strips of the various maps considered are not printed, but are available for reference at the Royal Meteorological Society or the Meteorological Office. The authorities are listed in Appendix I. The combined figures for the whole of the five-degree zones over the land are shown in Table I., which gives also the area of land within the zone, in units of 10,000 square kilometres, and the total volume of water, in units of 100,000,000 cubic metres, contained in the precipitation which falls over that area in a year.

Over the oceans rainfall data are very scanty, and the existing maps have been mostly compiled from a consideration of the frequency of rain combined with a few observations of the rate of fall. The figures for the Atlantic were computed (in the same way as those for the land areas) from a map by G. Schott.[4] The figures for the Pacific and Indian Oceans were similarly obtained from a revised chart by Süring.[5] Some further comments about these figures seem desirable.

For the Atlantic some figures were obtained during the cruise of the *Meteor*.[6] The observations cover only 196 days, but being direct measure-

[4] Geographie des Atlantischen Ozeans. 2. Aufl. Hamburg, 1926.
[5] Hann-Süring. Lehrbuch der Meteorologie. 4. Aufl. Leipzig, 1926.
[6] *Washington, D.C., Mon. Weather Rev.*, **57**, 1929, p.61.

TABLE I.—Rainfall over the Land. Zones.

Zone.	Area.	Average rainfall.	Volume of water.
	10,000 km.^{2}	mm.	10^8 m^3.
90° – 85° N.	...	...	...
85° – 80° N.	29	113	260
80° – 75° N.	106	134	1,424
75° – 70° N.	233	152	3,545
70° – 65° N.	609	222	13,550
65° – 60° N.	720	378	27,231
60° – 55° N.	656	475	31,154
55° – 50° N.	803	499	40,181
50° – 45° N.	845	520	43,941
45° – 40° N.	801	505	40,420
40° – 35° N.	764	573	43,784
35° – 30° N.	790	603	47,625
30° – 25° N.	794	726	57,643
25° – 20° N.	713	620	44,182
20° – 15° N.	616	680	41,911
15° – 10° N.	508	978	49,704
10° – 5° N.	525	1,273	66,821
5° – 0° N.	469	1,553	72,860
0° – 5° S.	535	1,900	101,643
5° – 10° S.	506	1,131	57,235
10° – 15° S.	441	1,222	53,888
15° – 20° S.	500	965	48,247
20° – 25° S.	504	770	38,801
25° – 30° S.	427	531	22,698
30° – 35° S.	296	503	14,875
35° – 40° S.	117	717	8,390
40° – 45° S.	60	843	5,061
45° – 50° S.	37	713	2,637
50° – 55° S.	20	961	1,921
55° – 60° S.	1	1,295	129
60° – 65° S.	5	300	150
65° – 70° S.	182	(173)	(3,149)
70° – 75° S.	620	(68)	(4,216)
75° – 80° S.	464	(55)	(2,552)
80° – 85° S.	293	(52)	(1,524)
85° – 90° S.	98	(50)	(490)

ments they form a useful check on those derived from Schott's chart. They are set out in Table II.

TABLE II.—Rainfall Observations on the *S.S. Meteor*.

Latitude.	No. of days.	Amount.	Calculated annual total.	Value from Schott.
		mm.	mm.	mm.
10° N. to 8° S.	69	224	1185	1250
8° S. to 13° S.	29	6	75	320
15° S. to 34° S.	98	160	600	545
Whole area	196	390	726	830

TABLE III.—RAINFALL OVER THE OCEANS. ZONES.

Zone.	Area.	Average rainfall.	Volume of water.
	10,000 km.²	mm.	10^8 m³
90° – 85° N.	98	(125)	(1,225)
85° – 80° N.	264	(125)	(3,300)
80° – 75° N.	379	(125)	(4,737)
75° – 70° N.	441	(271)	(11,930)
70° – 65° N.	248	514	12,716
65° – 60° N.	314	832	26,096
60° – 55° N.	545	1,113	60,607
55° – 50° N.	557	1,744	97,101
50° – 45° N.	663	1,747	115,846
45° – 40° N.	842	944	79,500
40° – 35° N.	1,001	1,188	118,891
35° – 30° N.	1,086	1,062	115,217
30° – 25° N.	1,177	1,019	119,954
25° – 20° N.	1,337	946	126,470
20° – 15° N.	1,500	1,124	168,605
15° – 10° N.	1,656	1,302	215,422
10° – 5° N.	1,670	1,570	262,170
5° – 0° N.	1,744	1,648	286,986
0° – 5° S.	1,678	1,472	246,847
5° – 10° S.	1,691	1,292	218,391
10° – 15° S.	1,723	1,142	196,442
15° – 20° S.	1,615	1,012	163,646
20° – 25° S.	1,546	910	140,633
25° – 30° S.	1,543	957	147,460
30° – 35° S.	1,579	1,047	165,403
35° – 40° S.	1,649	1,157	190,707
40° – 45° S.	1,583	1,266	200,335
45° – 50° S.	1,471	1,163	171,013
50° – 55° S.	1,340	1,005	134,710
55° – 60° S.	1,201	910	109,291
60° – 65° S.	1,029	(500)	(51,450)
65° – 70° S.	676	(200)	(13,520)
70° – 75° S.	54	(100)	(540)
75° – 80° S.	22	(75)	(165)

The agreement is as good as could reasonably be expected, except between 8° and 13° S., where the *Meteor* observations cover only 29 days, which probably fell in an unusually fine period.

Thanks to the enterprise of the Dutch Meteorological Institute there are abundant data of the frequency of rainfall over the Indian Ocean, and probably the zonal values of rainfall for this ocean are reasonably accurate. For the Pacific, meteorological data of any description are very rare, and from the figures entered on Süring's chart it appears that he has employed rainfall measurements on islands to assist in constructing his maps. On small low islands the rainfall is not likely to differ much from that in the surrounding oceans; but, in mountainous islands such as the Samoa group, the rainfall is purely local. It is possible, therefore, that the area included within Süring's highest isohyet, 2000 mm., is too great, and that the estimated zonal rainfalls over the Pacific are higher than they should be. We subsequently found that our calculated zonal values for all the oceans agree fairly well with those of Kerner (see page 146), whose determinations for the Pacific were based partly on the salinity, and that G. Wüst regarded Kerner's figures as too high, because they upset the balance between precipitation and evaporation. However, if we concentrate the whole of Wüst's correction on the Pacific figures, it would certainly make them too low, so that there seemed no alternative to accepting Süring's map as it stood.

As a check on the values over the oceans as a whole, the average rainfalls in the different zones were compared with those collected by W. G. Black, which were based on actual observations obtained with the "marine rain-gauge" which he invented. Black gives for different latitudes in the Atlantic, Indian, and Pacific Oceans and "Austro-Chinese Seas"

TABLE IV.—Rainfall over the Earth.

Zone.	Average rainfall.	Zone.	Average rainfall.
	mm.		mm.
90° – 85° N.	(125)	0° – 5° S.	1575
85° – 80° N.	(122)	5° – 10° S.	1254
80° – 75° N.	(127)	10° – 15° S.	1157
75° – 70° N.	230	15° – 20° S.	1002
70° – 65° N.	306	20° – 25° S.	875
65° – 60° N.	516	25° – 30° S.	864
60° – 55° N.	764	30° – 35° S.	961
55° – 50° N.	1009	35° – 40° S.	1127
50° – 45° N.	1059	40° – 45° S.	1250
45° – 40° N.	730	45° – 50° S.	1152
40° – 35° N.	922	50° – 55° S.	1004
35° – 30° N.	868	55° – 60° S.	910
30° – 25° N.	901	60° – 65° S.	(499)
25° – 20° N.	833	65° – 70° S.	(194)
20° – 15° N.	995	70° – 75° S.	(76)
15° – 10° N.	1225	75° – 80° S.	(56)
10° – 5° N.	1499	80° – 85° S.	(52)
5° – 0° N.	1626	85° – 90° S.	(50)

the amounts of rainfall measured on specified numbers of days (including rainless days), and these have been divided into ten-degree zones and reduced to totals for 365 days. The total number of days on which observations were taken was 2170, or about six years. The details are shown in Table V B., but here it is of interest to note that the average rainfall between 50° N. and 60° S. from Black's observations is 1065 mm., while that given by our figures over the same area is 1166 mm. The agreement appears reasonably good; much better, in fact, than with Wüst's corrected figures, which for the same zones give an average of only 776 mm.

The details for the Atlantic, Pacific, and Indian Oceans are given with those for the land areas in Appendix I. The mean values for five-degree zones over the whole water area are shown in Table III. The Arctic Ocean north of 75° N. and the Southern Ocean south of 60° S. were difficult problems, and the only method which suggested itself was to extrapolate from the known data. The zonal means already obtained for both land

and sea were plotted on squared paper, and the oceanic figures were then extrapolated by means of a smooth curve. The process was, of course, little removed from guesswork, and was only resorted to in order to complete the figures for the globe.

The final values for the five-degree zones over the whole earth (land and sea areas combined) are shown in Table IV.

The average annual rainfall over the whole globe is found to be 975 mm., and the volume of water 4971×10^{11} cubic metres. For the land and sea separately the figures are: land, average rainfall, 659 mm., volume of water, 994×10^{11} cubic metres; sea, average rainfall, 1107 mm., volume of water, 3977×10^{11} cubic metres.

The figures for the different latitudes are set out graphically in Fig. 2.

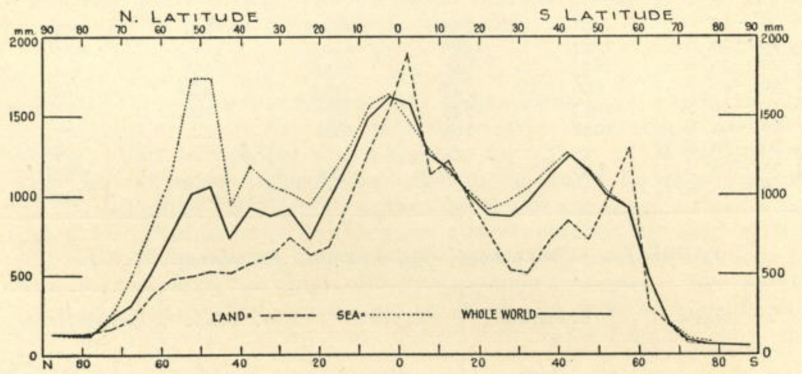

FIG. 2.—Variation of average annual rainfall with latitude.

The land data, shown by the broken line, rise to a marked maximum of nearly 2000 mm. just south of the equator, with a secondary maximum in 50° to 60° S. latitude. There is no corresponding maximum in the northern hemisphere where the amounts increase almost continuously from pole to equator.

The data for the oceans, shown by the dotted line, give three maxima. The chief falls in the storm belt of 50° N., but the equatorial zone (0-10° N.) is almost equally high. The south temperate maximum in 40-45° S. is less strongly developed.

It is interesting to notice that while the sub-tropical deserts of the southern hemisphere lead to a clearly marked minimum in latitude 30° S., there is little trace of the corresponding minimum in the northern hemisphere. The dryness of the great deserts of North Africa and Arabia is counterbalanced by the heavy monsoon rainfall of southern and south-eastern Asia.

The continuous line shows the averages over the world as a whole, and in general shows similar features to the curve for the oceans.

For comparison with the results of previous investigations, Table sV A. (land) and V B. (oceans) have been prepared, the data for this purpose being combined in ten-degree zones. For the continents, Murray's figures were based on a chart constructed by Buchan, partly from figures collected by Loomis. Those of Bezdek, Fritsche, and Kerner were obtained by different methods from Supan's well-known world chart. Bezdek merely measured the rainfall along every tenth parallel of latitude, and interpolated between each pair of parallels to give the average of the zone

TABLE V A.—COMPARISON WITH PREVIOUS ESTIMATES. LAND.

Zone.	J. Murray.[7]	J. Bezdek.[8]	R. Fritsche.[9]	F. Kerner.[10]	Brooks-Hunt.
	mm.	mm.	mm.	mm.	mm.
90° – 80° N.	337	...	340	...	113
80° – 70° N.	353	...	259	...	147
70° – 60° N.	371	407	348	321	307
60° – 50° N.	546	572	504	489	489
50° – 40° N.	565	677	508	497	513
40° – 30° N.	551	732	522	520	589
30° – 20° N.	673	705	786	575	676
20° – 10° N.	950	1037	947	961	815
10° – 0° N.	1964	1702	1716	1638	1406
0° – 10° S.	1881	1735	1812	1751	1526
10° – 20° S.	1227	1325	1100	1125	1086
20° – 30° S.	655	987	638	563	661
30° – 40° S.	696	747	573	550	563
40° – 50° S.	1053	745	870	790	795
50° – 60° S.	1041	795	1021	...	977
60° – 70° S.	990	...	300	...	(176)
70° – 80° S.					(62)
80° – 90° S.					(52)

TABLE V B.—COMPARISON WITH PREVIOUS ESTIMATES. OCEANS.

Zone.	F. Kerner.[11]	G. Wüst.[12]	W. G. Black.[13]	Brooks-Hunt.
	mm.	mm.	mm.	mm.
90° – 80° N.	...	(150)	...	(125)
80° – 70° N.	...	(290)	...	(203)
70° – 60° N.	650	480	...	691
60° – 50° N.	1300	960	...	1432
50° – 40° N.	1600	1170	700	1232
40° – 30° N.	700	510	840	1122
30° – 20° N.	300	220	1340	980
20° – 10° N.	850	620	1350	1217
10° – 0° N.	1900	1400	2250	1608
0° – 10° S.	1300	950	1490	1382
10° – 20° S.	900	660	1350	1079
20° – 30° S.	700	510	840	933
30° – 40° S.	1200	880	640	1103
40° – 50° S.	1250	920	450	1215
50° – 60° S.	950	700	460	960
60° – 70° S.	...	(290)	...	(380)
70° – 80° S.	...	(150)	...	(93)

[7] Murray, John. On the total annual rainfall on the land of the globe, and the relation of rainfall to the annual discharge of rivers. *Edinburgh Scot. Geog. Mag.*, **3**, 1887, p. 65.

[8] Bezdek, Josef. Die Verteilung des Niederschlags nach den geographischen Breiten. *Budapest, Bull. Soc. hongr. Géog.*, **22**, 1904, Abrégé, p. 95.

[9] Fritsche, Richard. Niederschlag, Abfluss und Verdunstung auf dem Landflächen der Erde. Diss. Halle, 1906.

[10] Kerner, Fritz v. Revision der zonaren Niederschlagsverteilung. *Wien, Mitt. K. K. Geog. Ges.*, **50**, 1907, p. 139.

[11] Kerner, Fritz v. Eine neue Schätzung des Gesamtniederschlages auf dem Meere. *Met. Zs. Braunschweig*, **36**, 1910, p. 167.

[12] *Loc. cit.* footnote 1.

[13] Black, W. G. Ocean rainfall by rain-gauge observations at sea. General and special oceans, 1864–75–81, Edinburgh, *s.a.*

which they enclosed. Kerner measured also the intervening fifth parallels; he did not give zonal values, and those quoted here were calculated from his figures. The mean for the zone 70° to 60° N., for example, is one quarter of 70° N., 60° N., and twice 65° N. Fritsche measured actual areas with a planimeter. For temperate regions these earlier computations agree sufficiently well with ours, but in both polar and equatorial zones there are wide discrepancies. These are, in our opinion, due partly to the additional information which has become available in recent years, and partly to the closer isohyets of the maps which we employed. For the Arctic and Antarctic zones Murray's and Fritsche's figures are certainly too high, but ours may be somewhat too low. For the equatorial regions there can be little doubt that the earlier world maps exaggerated the area with a very heavy rainfall, with the result that all the early zonal figures between 20° N. and 20° S. latitude are too high.

For the oceans our figures agree fairly well with those of Kerner except between 40° and 10° N. Kerner employed Supan's crude and incomplete charts for the Atlantic and Indian Oceans and calculated the figures for the Pacific on the basis of certain assumptions regarding salinity. This is probably why his values for 30° to 20° N. are so low. Wüst did not make independent calculations except for polar regions, but he multiplied all Kerner's figures by the factor 0·734, because his figures for the balance of precipitation and evaporation required such a reduction. As previously stated, while Kerner's figures and ours may be somewhat too high, we think Wüst's correction excessive. The figures for evaporation over the oceans—which Wüst also reduced considerably from the observed figures—are probably no more reliable than the estimates of rainfall.

2. The Monthly Values.

The second step was to divide the zonal values of average annual rainfall, obtained by the methods described above, among the different months. The direct method was impracticable, in the first place because for large parts of the globe, including all the oceans, monthly charts of rainfall are not yet available; and secondly because, if such charts had been constructed, the labour of measuring them would have been prohibitive. Accordingly an indirect method had to be adopted.

Over the continents the five-degree zones were divided into a number of segments, each of which covered ten degrees of longitude, and in each segment, as far as possible, a representative station was selected. Preference was given to stations employed in the *Réseau Mondial.* For these stations the mean monthly and annual values of rainfall were written down, with estimated figures for segments in which no stations could be found. The figures for each month for all the segments of a zone were then added together, and reduced to percentages of the total for the year. For the extreme northern and southern zones, where stations are few and records short, the percentage values so obtained were smoothed by means of the first two terms of a Fourier series, but for most of the zones the figures ran sufficiently smoothly without this additional process. Finally, the annual figures for the land zones, given in Table I., were divided among the months according to these percentage values. The resulting figures are shown in Table VI.

For the oceans the method adopted was essentially similar, but more extensive smoothing was necessary because of the paucity of data. The monthly means for all islands, except those near the coast, were written down under the appropriate zones, and weighted according to their isolation and other factors. The means for each zone so obtained were then analysed into Fourier series, of the form

$$R = a_0 + a_1 \sin t + b_1 \cos t + a_2 \sin 2t + b_2 \cos 2t.$$

The ratios of the coefficients a_1/a_0, b_1/a_0, etc., found for each zone were

TABLE VI.—MONTHLY MEANS OF RAINFALL FOR THE LAND.

Zone.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm
85° – 80° N.	9	8	8	8	8	10	15	13	10	8	7	9
80° – 75° N.	11	10	8	6	6	9	13	16	16	15	13	11
75° – 70° N.	11	12	12	10	9	11	15	18	18	15	11	10
70° – 65° N.	13	10	11	10	14	23	31	29	28	22	17	14
65° – 60° N.	26	22	22	19	25	31	43	47	46	39	30	28
60° – 55° N.	26	21	22	22	30	47	56	71	61	48	39	32
55° – 50° N.	34	29	34	30	37	46	55	55	48	49	42	40
50° – 45° N.	35	29	34	36	46	55	61	55	45	44	41	39
45° – 40° N.	35	31	38	43	47	50	48	41	46	44	44	38
40° – 35° N.	44	41	56	54	51	46	52	47	49	47	44	42
35° – 30° N.	53	48	51	49	46	58	66	56	47	38	40	51
30° – 25° N.	27	29	36	54	64	102	119	115	79	47	28	26
25° – 20° N.	21	15	18	23	58	88	104	105	80	50	31	27
20° – 15° N.	18	9	8	11	43	90	116	114	101	80	54	36
15° – 10° N.	21	13	14	29	77	117	150	172	157	114	73	41
10° – 5° N.	55	36	47	63	115	158	180	156	139	130	109	85
5° – 0° N.	150	127	132	157	159	137	109	106	97	115	123	141
0° – 5° S.	189	186	214	234	201	146	121	94	91	110	144	170
5° – 10° S.	167	162	178	132	82	25	20	19	38	66	103	139
10° – 15° S.	200	191	185	114	61	38	28	24	29	67	110	175
15° – 20° S.	220	187	128	46	18	9	6	8	19	50	101	173
20° – 25° S.	133	107	97	55	45	48	31	26	36	43	60	89
25° – 30° S.	71	71	64	40	37	33	23	23	27	40	45	57
30° – 35° S.	34	36	43	45	54	54	48	42	38	38	37	34
35° – 40° S.	41	43	55	69	76	74	67	63	63	62	57	47
40° – 45° S.	59	57	62	75	88	94	87	74	63	60	62	62
45° – 50° S.	57	58	60	62	63	64	62	60	58	56	56	57
50° – 55° S.	88	89	87	84	81	78	74	71	71	74	79	85

then plotted on squared paper and smooth curves drawn through them, the different figures being weighted according to their reliability. Values of the coefficient ratios for each zone were read off these curves and the monthly figures of rainfall over the oceans were calculated from these smoothed coefficients. The results cannot be regarded as giving more than a qualitative impression of the distribution of rainfall over the oceans throughout the year, though they are probably as good as could be obtained at present. The monthly means for the oceans are shown in Table VII, and the monthly means for the whole globe in Table VIII.

Isopleths of the annual variation of rainfall over land and sea are shown in Figs. 3 and 4, and over the globe as a whole in Fig. 5, the vertical scale representing the latitude and the horizontal scale the twelve

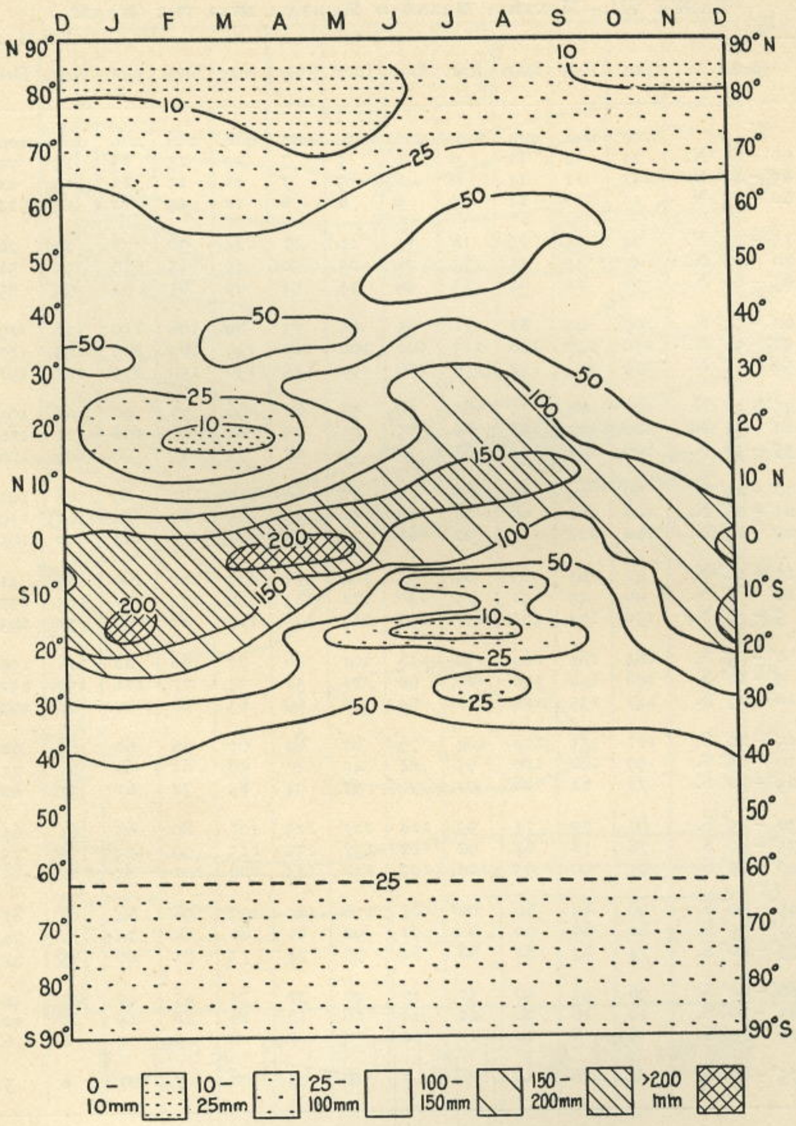

FIG. 3.—Annual variation of rainfall over the land.

months. Fig. 3 shows several interesting points. The annual migration of the belt of heavy tropical rainfall north and south with the sun is clearly brought out by the arched form of the shaded band, and the almost complete dryness of the sub-tropical regions in the late winter of the corresponding hemisphere by the stippled areas below 100 mm. a year. In the northern hemisphere the summer rainfall of high latitudes is also brought out, but in the southern hemisphere this point could not be made for lack of data.

TABLE VII.—MONTHLY MEANS OF RAINFALL OVER THE OCEANS.

Zone.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
90°–85° N.	11	11	11	9	6	5	7	11	15	15	13	11
85°–80° N.	11	11	11	9	6	5	7	11	15	15	13	11
80°–75° N.	11	11	11	9	6	6	8	12	14	12	13	12
75°–70° N.	24	24	23	18	13	12	17	24	30	31	29	26
70°–65° N.	47	45	41	33	26	25	32	45	55	59	55	51
65°–60° N.	78	71	64	53	46	44	54	69	85	92	91	85
60°–55° N.	107	95	82	71	65	65	73	89	106	119	122	119
55°–50° N.	170	147	126	113	106	106	115	135	163	183	193	187
50°–45° N.	176	153	132	116	109	109	115	130	150	175	191	191
45°–40° N.	100	88	75	65	59	58	61	66	76	90	101	105
40°–35° N.	126	117	101	86	75	73	75	83	97	108	121	126
35°–30° N.	106	101	94	85	76	69	67	73	83	96	104	108
30°–25° N.	99	94	89	86	79	72	66	69	77	89	98	101
25°–20° N.	108	101	90	78	65	52	45	49	63	84	101	110
20°–15° N.	112	122	117	92	61	45	56	84	108	114	108	105
15°–10° N.	41	61	69	62	65	104	171	224	219	160	85	41
10°–5° N.	90	49	41	75	130	171	187	182	174	171	163	137
5°–0° N.	136	164	181	191	192	183	155	117	82	67	77	103
0°–5° S.	184	184	164	139	118	101	86	71	66	82	118	159
5°–10° S.	148	142	132	119	96	71	52	54	77	111	139	151
10°–15° S.	127	135	129	112	94	78	69	63	66	72	88	109
15°–20° S.	111	131	128	104	76	62	62	67	66	60	63	82
20°–25° S.	99	120	120	95	64	45	47	59	65	62	61	73
25°–30° S.	72	81	88	92	96	97	94	85	72	61	57	62
30°–35° S.	67	70	77	93	114	127	123	105	80	65	61	65
35°–40° S.	78	78	84	99	122	137	135	115	90	73	71	75
40°–45° S.	91	90	93	104	127	142	144	126	101	83	80	85
45°–50° S.	90	89	86	92	104	118	121	113	98	84	83	87
50°–55° S.	80	85	90	90	91	92	91	87	80	74	71	74
55°–60° S.	74	83	88	88	82	77	74	73	71	68	65	67
60°–65° S.	36	43	50	52	47	40	37	39	43	42	37	34
65°–70° S.	12	16	20	22	20	16	14	16	18	19	15	12
70°–75° S.	6	8	10	11	10	8	7	8	9	9	8	6
75°–80° S.	4	6	8	8	7	6	5	6	7	7	6	5

Owing to the extensive smoothing necessary, Fig. 4 has a more orderly appearance and fewer points of interest. The most striking is the winter rainfall in temperate latitudes of both hemispheres and in the sub-tropical part of the northern hemisphere, and the arched belt of heavy rainfall near the equator. Fig. 5, as would be expected, generally reproduces the features of Fig. 4, except in about latitude 50° N., where the large dry areas over the continents cause the rainfall over the whole earth to be about 50 mm. a month less than that over the oceans alone.

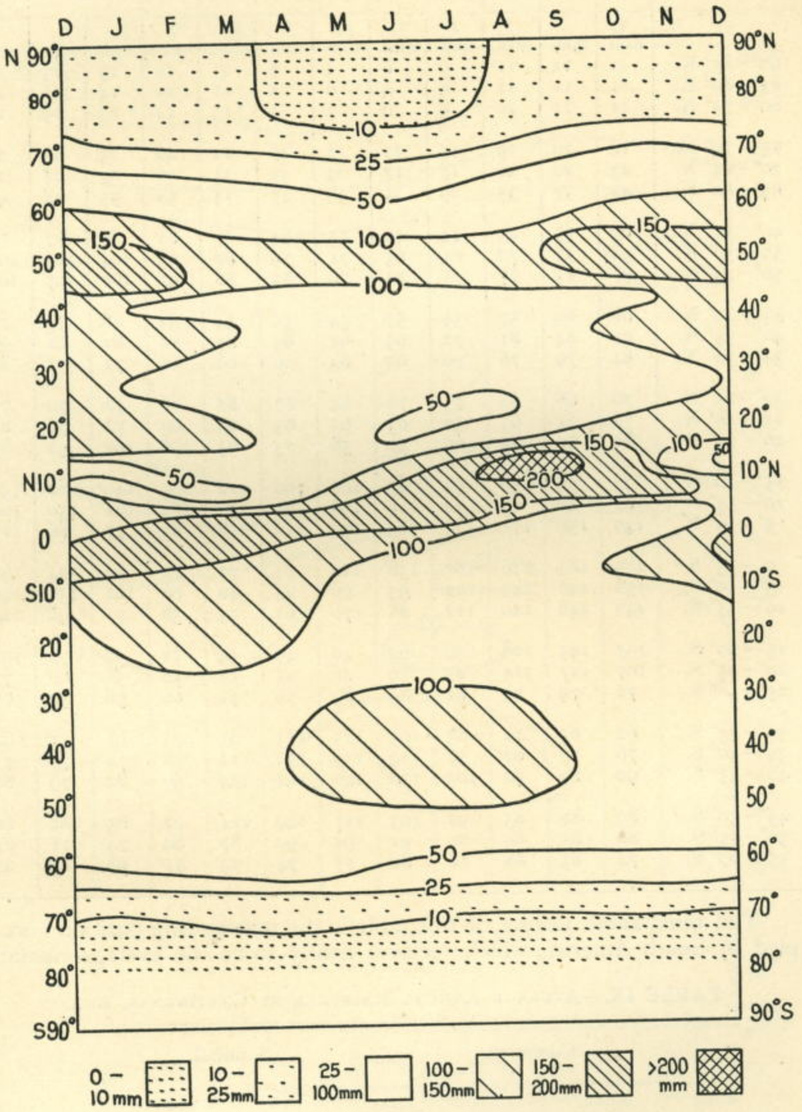

FIG. 4.—Annual variation of rainfall over the oceans.

3. The Rainfall of the Continents.

From the working sheets the average annual rainfall over the various continents was readily calculated and the resulting figures are shown in Table IX.

TABLE VIII.—MONTHLY MEANS OF RAINFALL OVER THE WHOLE EARTH.

Zone.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
90° – 85° N.	11	11	11	9	6	5	7	11	15	15	13	11
85° – 80° N.	11	11	11	9	6	6	8	11	15	14	12	11
80° – 75° N.	11	11	10	8	6	7	9	13	14	13	13	12
75° – 70° N.	19	20	19	15	12	12	16	22	26	25	23	21
70° – 65° N.	23	20	20	17	17	23	31	33	36	33	28	25
65° – 60° N.	42	37	35	29	31	35	47	54	58	55	48	45
60° – 55° N.	63	55	49	44	46	55	64	79	81	80	77	71
55° – 50° N.	90	77	72	64	65	71	79	88	95	104	104	100
50° – 45° N.	97	83	77	71	74	79	85	88	91	101	107	106
45° – 40° N.	68	60	57	54	53	54	55	54	62	68	73	72
40° – 35° N.	91	84	81	72	65	61	65	67	76	82	88	90
35° – 30° N.	84	79	76	70	63	64	66	66	68	71	77	84
30° – 25° N.	70	68	68	73	72	84	87	88	78	72	70	71
25° – 20° N.	78	71	65	59	63	65	65	69	69	72	76	81
20° – 15° N.	85	89	85	69	56	58	73	93	106	104	92	85
15° – 10° N.	36	50	56	54	67	107	166	212	205	149	82	41
10° – 5° N.	82	46	43	72	126	168	185	176	165	161	150	125
5° – 0° N.	139	156	171	184	185	173	145	114	85	77	86	111
0° – 5° S.	185	184	176	162	138	112	94	77	72	89	124	162
5° – 10° S.	152	146	143	122	93	60	44	46	68	101	131	148
10° – 15° S.	142	146	140	112	88	70	61	55	58	71	92	122
15° – 20° S.	137	145	128	90	62	49	49	53	55	58	72	104
20° – 25° S.	107	117	114	85	59	46	43	51	58	58	60	77
25° – 30° S.	72	79	83	81	83	83	79	71	62	56	54	61
30° – 35° S.	62	65	72	85	105	115	111	95	73	61	57	60
35° – 40° S.	76	76	82	97	119	133	130	111	88	72	70	73
40° – 45° S.	90	89	92	103	126	140	142	124	99	82	79	84
45° – 50° S.	89	88	85	91	103	117	120	111	97	83	82	86
50° – 55° S.	80	85	90	90	91	92	90	87	80	74	71	74
55° – 60° S.	74	83	88	88	82	77	74	73	71	68	65	67

The remarkable feature of this table is the outstanding position occupied by South America, which receives nearly twice the average rainfall

TABLE IX.—AVERAGE ANNUAL RAINFALL BY CONTINENTS, ETC.

Continent.	Rainfall.	
	mm.	in.
South America	1350	53·1
Australasia	719	28·3
Africa	711	28·0
Asia	646	25·4
Europe	618	24·3
North America (with West Indies)	601	23·7
Australia and Tasmania . .	456	18·0

of any other continent. At the other extreme is the island continent of Australia, taken as a unit, with an average of only 456 mm. The remaining continents, in spite of their great diversity, have surprisingly uniform

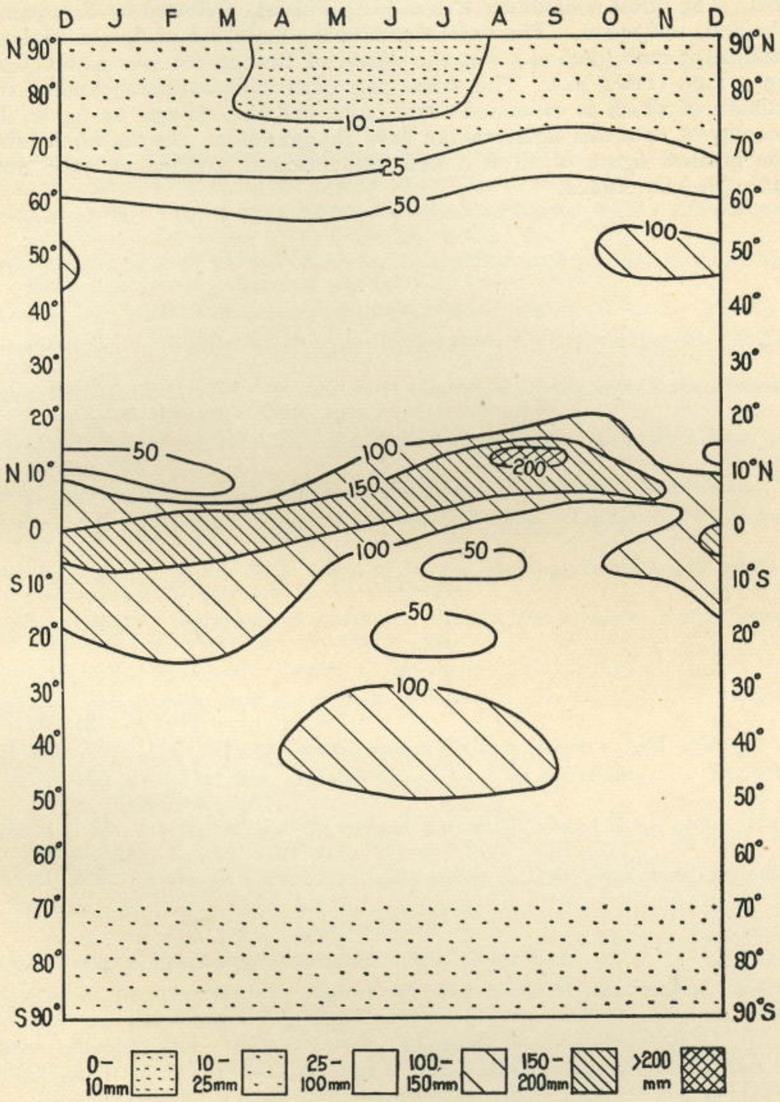

FIG. 5.—Annual variation of rainfall over the world.

rainfalls, but the high position of Africa is something of a surprise. The heavy rainfall of the equatorial belt fully compensates for the sub-tropical deserts. The average rainfall of the oceanic islands, as would be expected, is very heavy, no less than 2086 mm. (82·13 in.).

In Appendix II. the figures for some of the individual countries of

Europe and Asia, and some groups of islands, etc., are given as a matter of interest. Figures in brackets are estimates based on a small amount of data. The rainiest country in Europe is Switzerland, with Scotland second, and Ireland third; Norway, curiously, comes well down on the list. The driest is naturally Russia (with Poland), followed by Roumania, Finland, and Spain. The wettest part of the mainland of Asia is Malaya, with 2453 mm. (96·6 in.), but the island of Borneo receives as much as 2999 mm. (118·1 in.). The driest part of Asia is naturally Arabia, the rainfall of which is estimated as 172 mm. (6·8 in.), though owing to the scarcity of data this figure cannot have any precision. In the whole table the greatest figure of all is a well authenticated average of 4300 mm. (169·3 in.) for Samoa.

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[TABLE

APPENDIX II.—Mean Rainfall by Countries.

Country.	Rainfall. mm.	Rainfall. in.
Antarctic—		
Graham Land	275	10·8
South Orkneys	403	15·9
Arctic—		
Arctic Archipelago (N. of 70° N.)	(135)	(5·3)
Franz Josef Land	(250)	(9·8)
Greenland and Grant Land	257	10·1
Novaya Zemlya	(470)	(18·5)
Spitsbergen	(214)	(8·4)
Asia and E. Indies—		
Arabia	(172)	(6·8)
Asia Minor and Persia	267	10·5
Central Asia and China	(652)	(25·7)
Ceylon	2037	80·2
East Indies—		
Borneo	2999	118·1
Celebes	2266	89·2
Java and Madoera	2807	110·5
Sumatra	2863	112·7
Smaller Islands	1411	55·6
Formosa	2150	84·6
India (with Nepal and Bhutan)	1166	45·9
Indo-China	1759	69·3
Japan	1666	65·6
Korea	935	36·8
Malaya	2453	96·6
Philippines	2307	90·8
Russia in Asia	277	10·9
Australasia—		
New Guinea	3194	125·7
New Zealand	1426	56·1
Europe—		
Austria *	1034	40·7
Balkan Peninsula (except Greece)	930	36·6
Belgium	831	32·7
Corsica	1008	39·7
Denmark	614	24·2
England and Wales	894	35·2
Finland	573	22·6
France	843	33·2
Germany	705	27·8
Greece	721	28·4
Europe—*continued*—		
Holland	699	27·5
Hungary *	786	30·9
Iceland	903	35·6
Ireland	1100	43·3
Italy	979	38·5
Norway	931	36·7
Portugal	801	31·6
Roumania *	571	22·5
Russia and Poland *	452	17·8
Sardinia	627	24·7
Scotland	1278	50·3
Spain	573	22·6
Sweden	649	25·6
Switzerland	1684	66·3
Oceanic Islands—		
Bismarck Archipelago	2475	97·4
Fiji Islands	2629	103·5
Galapagos	(500)	(19·7)
Hawaiian Islands	2332	91·8
Kerguelen	852	33·5
New Caledonia	1094	43·1
New Hebrides	2502	98·5
Samoa	4300	169·3
South Georgia	(1500)	(59·1)
West Indies	1382	54·4

* Boundaries of 1914.

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