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(1) **Wallis, B. C.** Georgraphical aspects of climatological investigations. Scott. geogr. mag., Edinburgh, July, 1914, **30**: 356-369.
(2) **Wallis, B. C.** The rainfall régime of Australia. Scott. geogr. mag., Edinburgh, Oct., 1914, **30**: 527-532.
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(4) Discussion of (3) above, pp. 323-325.

"MONSOON" RAINFALL.[1]

By B. C. WALLIS, North Finchley, England.

The total volume of the precipitation in certain parts of India is apparently so extraordinary that it has caught the special attention of geographers and teachers, and the term "monsoon" rainfall has tended to imply a very special type of rainfall which is intimately related to the southwest monsoon wind. Later investigations demonstrated the fact that the Abyssinian rainfall which caused the Nile flood was sufficiently similar to the Indian rainfall to be called "monsoon" rainfall. The summer rainfall in Abyssinia * * * [has an intensity of 300 per cent] agreeing with a general high rainfall intensity which is reached by those places which have vertical sunshine when the sun is, as it were, journeying southward from the Tropic of Cancer. The rainfall intensity lags behind the sun, so that at a certain place south of lat. 23½°N. the maximum intensity which has been following the sun northward is reenforced by the sun's second passage through the zenith. A precisely similar phenomenon is to be noted in the Southern Hemisphere just north of the Tropic of Capricorn.

Now the pluviometric coefficients for Indian rainfall tend to show precisely the same magnitude of rainfall intensity during the same months as in northern Africa A rough glance at the monthly and annual rainfall maps of the world in [Bartholomew's] Atlas of Meteorology shows a similar rainfall intensity in northern Australia—where the term "monsoon" rains is used—and also in the belts of similar latitude in South America.

Hence it follows that the maps [published in the original whence this is excerpted] lay bare one of the factors in connection with monsoon rains in India; the incidence of rainfall intensity [as expressed by Angot's "pluviometric coefficients"] is a question of latitude and is a world phenomenon, not a purely local Indian fact. "Monsoon" rainfall, as the name of a phenonenon which is most typically exemplified in India, refers entirely, when regarded in relation to the southwest monsoon, to the *quantity* of the rainfall and not to its incidence during the summer months. Quantity of precipitation appears, therefore, to be a matter of *local* importance due to elevation, prevailing winds, and nearness to the sea as well as to the average temperature of the air.

Eastern Asia and eastern America.—It is usual to extend the term "monsoon rainfall" to include the summer rains of northern China and southern Japan. A similar investigation to that of the preceding paragraph indicates that the summer rains of these portions of eastern Asia resemble in incidence of intensity, but not in total quantity, the rainfall which is characteristic in areas of similar latitude to the northeast of the United States.

Here, again, the term "monsoon" is applicable to quantities of rain which coincide in period with the onshore winds of the monsoon; and this fact is related to the special nature of the temperature changes to which reference has been made in the first section of this paper.[2]

Summer savanna rainfall.—Summer savanna rainfall in the Sudan and Rhodesia is * * * almost entirely a question of (*a*) a small total annual precipitation and (*b*) a high summer rainfall intensity which is a question of latitude in relation to the force of solar radiation; and apart from the smaller amount of the total annual precipitation summer savanna rainfall is equivalent to "monsoon" rainfall.

[1] *Extracted from* B. C. Wallis. Geographical aspects of climatological investigations. Scott. geogr. mag., Edinburgh, July, 1914, 30: (365, 368-369).

[2] Wallis, B. C., op. cit., p. 356-363.

ON THE USE OF "AVERAGE," "MEAN," "GENERAL."[1]

By HUGH R. MILL, London.

In considering the distribution of rainfall * * * we need to use terms with a definite meaning, and I hope that I may be excused for assigning definite meanings to familiar English words instead of importing classical terms which, despite a grander display of syllables, can mean no more. For convenience I use the term *mean* as indicating the sum of any number of figures divided by that number, reserving the word *average* for the mean of a number of figures representing values in order of time. Thus the mean of 30 annual rainfall values is spoken of as the average rainfall for 30 years. The mean of a number of uniformly distributed figures representing the distribution of rainfall in space I speak of as the *general* rainfall of the area concerned; thus the mean depth of rainfall over England for any day, month, or year is the *general rainfall* of England for that particular day, month, or year. The mean of the general rainfall of England for 30 years is expressed as the *average general rainfall* of England for 30 years. A line passing through points having the same rainfall is an isohyetal line, or *isohyet*—the term having been already introduced is retained on account of its similarity to isotherm and isobar. The line joining successive positions of the center of an atmospheric depression or cyclone is the *track* of the depression. The isohyetal lines representing the distribution of rainfall in a shower may be termed the *splash* of the rainfall, and the isohyets representing the rainfall of one or several days for a considerable stretch of country along the track of a depression, which is the generalization of a succession of splashes, may be called the *smear* of the rainfall of that depression.

[1] *Extracted from* [H. R. Mill]. On mapping rainfall. British Rainfall, 1907. London, 1908. 47: 36-43.
See also H. R. Mill. Map studies of rainfall. Quart. jour. Royal metl. soc., London, No. 146, April, 1908, 34.

TEMPERATURE AND SPRING WHEAT IN THE DAKOTAS.

By THOMAS A. BLAIR, Observer.

[Dated, Weather Bureau, Wagon Wheel Gap, Colo., Jan. 8, 1915.]

In a previous article (1) a short study was made of the relation between rainfall and the yield of wheat in the great northwestern spring-wheat region comprising the States of Minnesota, North Dakota, and South Dakota; and the conclusion reached that the total precipitation of May and June, without regard to its distribution, is, in most years, the most important factor in determining the yield in the two Dakotas, but not in Minnesota. At the same time, attention was called to the fact that there is an evident relation between temperature and yield. A further study of this relation leads me to modify the above conclusion so far as to state that the mean temperature of June exercises an equally important influence on the yield in the Dakotas.

TABLE 1.—*Temperature and wheat yield in the Dakotas, 1891-1913.*

Year.	North Dakota.				South Dakota.			
	Mean temperature, June.	Departure.	Yield.	Departure.	Mean temperature, June.	Departure.	Yield.	Departure.
1891	....	....	....	....	64.2	−2.1	15.2	+4.0
1892	60.5	−2.6	12.2	+0.1	63.9	−2.4	12.5	+1.3
1893	67.4	+4.3	9.6	−2.5	70.3	+4.0	8.5	−2.7
1894	68.8	+5.7	11.8	−0.3	70.6	+4.3	6.6	−4.6
1895	59.7	−3.4	21.0	+8.9	63.7	−2.6	12.0	+0.8
1896	65.6	+2.5	11.8	−0.3	67.0	+0.7	11.2	0.0
1897	61.7	−1.4	10.3	−1.8	65.0	−1.3	8.0	−3.2
1898	62.6	−0.5	14.4	+2.3	67.3	+1.0	12.4	+1.2
1899	62.2	−0.9	12.8	+0.7	66.4	+0.1	10.7	−0.5
1900	66.9	+3.8	4.9	−7.2	69.4	+3.1	6.9	−4.3
1901	61.6	−1.5	13.1	+1.0	66.3	0.0	12.9	+1.7
1902	58.0	−5.1	15.9	+3.8	62.6	−3.7	12.2	+1.0
1903	62.4	−0.7	12.7	+0.6	65.0	−1.3	13.8	+2.6
1904	61.4	−1.7	11.8	−0.3	64.5	−1.8	9.6	−1.6
1905	59.7	−3.4	14.0	+1.9	64.4	−1.9	13.7	+2.5
1906	62.0	−1.1	13.0	+0.9	63.9	−2.4	13.4	+2.2
1907	61.9	−1.2	10.0	−2.1	64.2	−2.1	11.2	0.0
1908	60.4	−2.7	11.6	−0.5	63.7	−2.6	12.8	+1.6
1909	62.9	−0.2	13.7	+1.6	66.9	+0.6	14.1	+2.9
1910	67.3	+4.2	5.5	−6.6	68.3	+2.0	12.8	+1.6
1911	66.9	+3.8	8.0	−4.1	73.4	+7.1	4.0	−7.2
1912	61.8	−1.3	18.0	+5.9	64.8	−1.5	14.2	+3.0
1913	65.8	+2.7	10.5	−1.6	69.6	+3.3	9.0	−2.2
Average	63.1	....	12.1	....	66.3	....	11.2	....

It is well known that cool and wet weather best promotes the development of wheat until the time of heading, after which more sun and less rain are needed (2), (3). As wheat is seeded during April in these States, the spring type of weather should be prolonged through June for the best results. But June is sometimes a very hot month in the Dakotas; it may even bring the highest temperatures of the year, and the mean may exceed the normal for July, which is ordinarily the warmest month. It is to be expected, then, that these hot Junes should have a marked deleterious effect on the wheat yield, and the following table and charts are intended to exemplify this effect.

In North Dakota, out of the 22 years studied, only 4 show departures of the same sign, and in each case one or both of the departures is small. The correlation coefficient, as calculated from this table, is −0.67, with a possible error of 0.08, evidence of a well-defined inverse relation between temperature and yield. A similar comparison in my previous article, between yield and combined precipitation of May and June gave 5 years with departures of unlike sign and a positive coefficient of 0.63, with a possible error of 0.05. Referring to the chart showing combined effect of temperature and precipitation, we notice that the yield has never been above normal when the temperature was above normal, but has three times been above when the precipitation was below. On the other hand, it has only four times been less than normal when the temperature was less and an equal number of times when the precipitation was greater. Similar comparisons, using the mean temperatures for May and July instead of June, show no such correlations. For May there are 10 years with departures of the same sign, and the correlation coefficient is +0.02; for July 8 years and a coefficient of −0.19. Evidently June is the critical month in the influence of temperature upon yield, and that influence is very marked, being of about the same importance as the combined May and June rainfall.

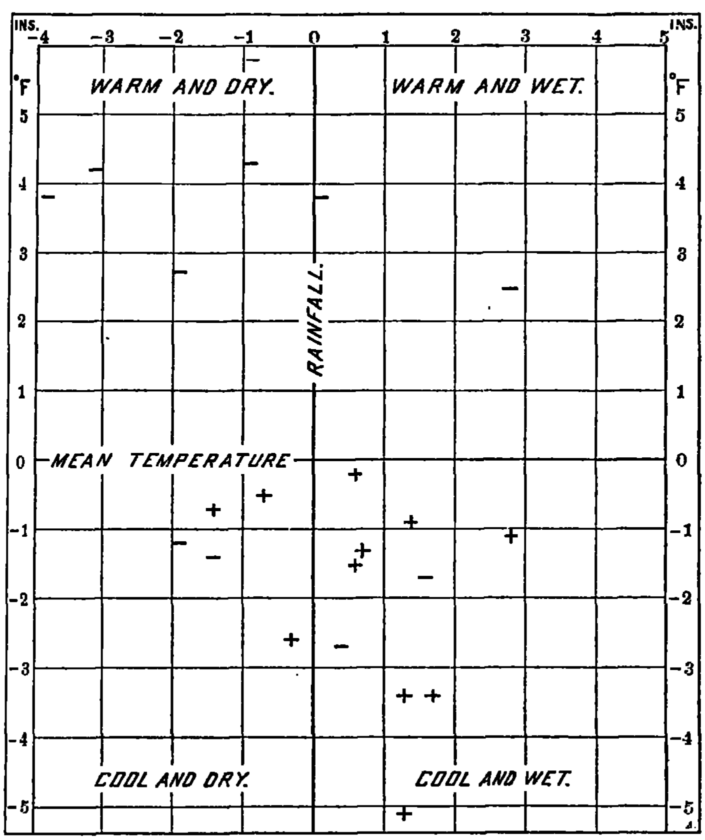

FIG. 1.—Chart showing the combined effect of temperature and rainfall upon the wheat yield of North Dakota. Rainfall departures are from the averages for May and June; temperature departures are from the average for June. Yield is above (+) or below (−) the average.

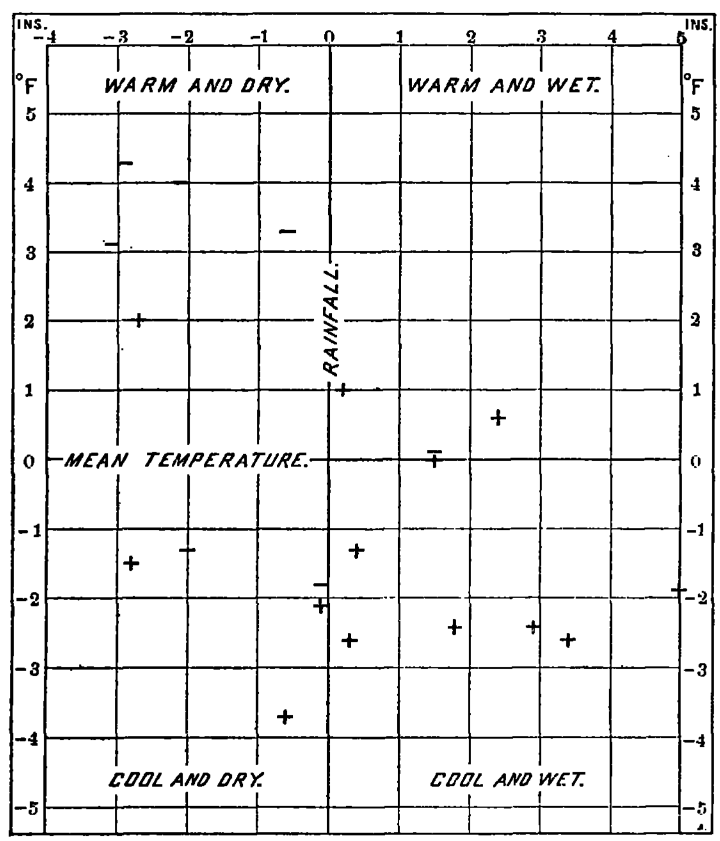

FIG. 2.—Chart showing the combined effect of temperature and rainfall upon the wheat yield of South Dakota. Rainfall departures are from the averages for May and June; temperature departures are from the average for June. Yield is above (+) or below (−) the average.

In South Dakota 5 of the 23 years have departures of like sign; but in this case also the departures are small, and the correlation coefficient is greater than in North Dakota, being −0.73, with a possible error of 0.07. The coefficient expressing the relation between precipitation and yield was previously found to be 0.59, and the possible error 0.06. Of the 5 years with departures of like sign, 3 are with temperature and yield both above normal and 2 with both below. Likewise there are 5 years when precipitation and yield fail to show their expected relation, 1 wet year with a small yield, and 4 dry years with high yields. In this State, also, May and July temperatures are apparently without significance in this connection. In both States the cool and wet years are undoubtedly the most favorable, but in South Dakota the greatest yield was in a cool and dry year. On the whole, the cool and dry years appear somewhat more favorable than warm and wet years, but the number of observations of these conditions is rather limited. Similar tables for Minnesota gave small coefficients and indicated no definite correlation.

Considering only calendar months, the rainfall of May and June and the mean temperature of June are the important weather factors, and they are of about equal importance, affecting the wheat crop of the Dakotas.

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AN EIGHT-DAY MECHANICALLY RECORDING RAINGAGE.[1]

By CHARLES F. MARVIN, Chief of Bureau.

[Dated, Weather Bureau, Washington, D. C., Jan. 23, 1915.]

The tipping-bucket raingage permits of a great refinement and accuracy of record, and is probably the best device available for securing rainfall records at the regular Weather Bureau stations. There is, however, a widespread need for a thoroughly reliable gage of ample capacity, complete in itself, involving no troublesome electrical arrangements for registration, and finally providing a record covering a considerable period of time. Early in 1913 the author undertook to design a weekly gage of the float type to meet such requirements; a model was constructed, and the success of the tests has since justified the purchase of a number of these gages for use in the Weather Bureau service. They will find an extended use in the studies of rainfall in connection with many projects wherein the *rate* of rainfall is an important factor.

Wind shields of the Nipher type are provided, which we hope will assist in obtaining the true catch even on occasions when the wind velocity is considerable.

Description.—The photograph reproduced in figure 1 shows the complete gage. The circular collector, *A*, is exactly 8 inches inside diameter across its sharpened (beveled) brass rim, and is surrounded by the rectangular wind shield, *B*. This shield is nearly 21 inches square at its upper edge and curves downward and inward to the copper cover, *C*, to which it is screwed. The cover is about 15 inches square inside and supports the 8-inch collector, the two together forming the top. The cover is ordinarily hinged to the top plate of the support, *E*, and is locked in position by a small bolt. The support, *E*, which is a little over 2 feet high, is made up of two iron castings; the upper casting carries the recording apparatus and the top, and the lower one forms the base for the receiver, *D*. The two castings are connected at the center by a 1¼-inch pipe, which also serves to inclose a small brass counterweight. The posts of the support, *E*, are four small iron pipes, which are screwed into the upper casting at its corners and fastened to the lower casting by means of set screws. The lower ends of the corner posts form feet for the gage.

Figures 2 and 3 illustrate the recording apparatus in detail. The registration is a record of the motion of a float upon the surface of the water in the receiver, *D*. To eliminate inaccuracies and uncertainties, the float is suspended by means of a fine flexible brass chain, such as jewelers use, permanently attached to one end of the drum, *H*. When the float rises, the chain is wound up by the pull of the counterweight suspended from a length of silk cord, also fastened to and wound up on the drum, *H*. The chain and cord run in a shallow screw thread cut in the drum, the chain winding up as the cord unwinds, and vice versa. The chain eliminates possibilities of variation of length, such as would be caused by moisture and stretching should a cord be used, and its permanent attachment to the drum, *H*, makes slipping impossible.

The cam shaft, *I*, carrying the drum, *H*, turns once for each one-half inch of rainfall and revolves a cylindrical cam, *K*, made to turn with the shaft, *I*, but free to slide endwise at the same time. The pen and pen lever are shown at *S* and *L*, respectively. The pen carrier, *T*, is mounted on the long screw, *N*, and guided by the rod, *U*. The motion of the pen is somewhat complex, but the arrangement is one that affords the maximum of clearness of records of excessive rates of precipitation, and at the same time the minimum of size of record sheets. Nearly all other automatic gages with records on a large scale require very large sheets that must be changed after a relatively moderate amount of rain has been recorded thereon. In this gage the rise of the float in the manner already explained rotates the cam, *K*, which in turn causes the pen to oscillate laterally over an extreme range of one-half inch on the record sheet. This amount of motion, over and back, represents one-half inch of rain. The record sheet has one-tenth-inch rulings, each subdivision represents 0.05 of an inch of rainfall and permits of very satisfactory estimates to hundredths of inches. The apparent impossibility of any kind of accumulative error in this gage makes its records more reliable than gages of the tipping-bucket type.

The adoption of an oscillating motion for the pen permits a large amount of precipitation to be recorded in a narrow band one-half inch wide across the record sheet. The remainder of the sheet is made available for additional record simply by causing the pen carrier to move laterally by the action of the clock, at the rate of one-half inch per revolution of the drum. Thus each day's record (one revolution of the drum) occupies only a transverse space on the record sheet one-half inch wide. Each sheet provides a record for eight days. The reason for adopting an 8-day record is that four sheets will suffice for a full record for each and every month. Instruments using only 7-day or weekly record sheets require five sheets for a month's record with only little on one of the sheets. The record cylinder, *F*, is 6 inches in diameter outside, and $5\frac{7}{16}$ inches in length over all, and it is made to revolve on the axle, *R*, by a clock which is entirely

[1] *See* Weather Bureau Instrument Division Circular E, 3d ed., App. 2. Washington, 1915.