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ARMAGH OBSERVATORY LEAFLET No. 10

METEOROLOGY AT ARMAGH OBSERVATORY : GENERAL NOTES AND A STUDY OF RAINFALL

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The present work has been carried out at the suggestion and with the help of Dr. E. M. Lindsay, Director of Armagh Observatory. To him I would like to express my very sincere thanks.

Meteorological observations were commenced at Armagh Observatory in the year 1794, four years after the Observatory was founded. Since then they have been continued without interruption. The early records contain readings of the barometer, internal and external thermometers, the direction of the wind and general remarks on the weather. This series ended in 1825. From then onwards a new series started and in 1867 a first class Meteorological Station, one of five in the British Isles, was set up by the Board of Trade. This included a building for the instruments to the east of what was then known as the polishing room. The station was discontinued as a first class one in 1883 and although some attempts were made in 1918 to restore it as such, it has since remained a second class meteorological station. The former meteorological rooms are now the Observatory workshop and dark room.

Apart from the actual observations the early records provide interesting and at times vivid reading. There are several references to waterspouts, although in the past 100 years no such phenomena have been observed, or at least recorded here. There are many descriptions of thunderstorms, though often these are far from the neighbourhood of Armagh, referring even to parts of England. Reports of people and animals being struck by lightning are numerous. We are told, for example, for July 26, 1821, that " this day in the afternoon a horse was killed near Coal Island, by the lightning. The tail was separated from the body of the horse, and found about 40 yards distant, as if cut off. The lightning appeared to have risen out of the earth, from the holes appearing about the place, and the direction of the mould cast up, by the explosion."

Thunderstorms are usually localized affairs so that it is not to be expected that in a relatively thunder-free climate any small area should frequently experience a heavy storm. This apparently did occur in June 1817 and the following description of it will be at least of local interest. " On the night of the 23rd of this month June, a storm of thunder and lightning took place, at Armagh, such as is very unusual in this climate. It appears as if the first cloud had extended from Caledon to the Vicar's Cairn, in as much as a cow was killed about a mile on this side of Caledon, and about the same time two children in a house

near the Cairn were struck (but not killed), and the *house* in which they were, *injured* by the lightning.—This cloud emitted frequent sparks from its edges; which sparks probably did the damage sustained. The lightning emitted from this cloud became visible at Armagh, about half after eleven o'clock at night. And the thunder became audible about 12. From that time to one o'clock, the cloud approached the town, accompanied with very heavy rain. The western edge of the cloud kept to the east of the cathedral, and about one o'clock struck a house in Primrose Lane and produced sensible effects on a gentleman in English Street (Mr. W. Carrol). From that, the cloud kept to the east and north of the town, striking Drumilly House; and the house of Mr. Marks, north-west of Loughgall, about one mile.

" This cloud was succeeded by another, producing greater thunder, but heading more to the east and north-east of the town. From 12, to three o'clock in the morning, the lightning and thunder were almost incessant, being at least 30 peals every hour. The nearest to my house (foot of Scotch Street) had 5 seconds between the lightning and noise; which was about one in the morning. A great number of peals had 15 sec between noise and lightning. But the most sonorous thunder, as to the continuance of the peal, had about 30 sec. The lightning was most vivid, being zigzag and forked, and the effects of terror and want of sleep were general on the people coming to the market next day. A sulphurious smell was very perceptible in my house, and the windows shook by the concussion of the air. The thunder clouds were evidently *negative,* when near Caledon and Newtown-Hamilton; as both flash and report, to many observers in that line, were instantaneous. Whereas at Armagh, it would appear, the cloud nearest the town was *positive;* and that the distance of the cloud was merely its altitude."

Other phenomena besides meteorological are to be found recorded in these earlier days. For an April month we find " Beech leaves out " ; " Brown Butterfly " ; " Swallows seen " ; " Primroses and Blackthorn in great blow " ; " Ash in leaf " ; " White Lilac in flower " ; " Lilac in flower " ; " Cuckoo heard " ; " Oak leaf out , Corncrake heard ". By contrast, in a more " modern " age, we find in the Remarks Column for May 30, 1919 " Aeroplane passed over steering West and flying high. 10.35 a.m.". How many meteorological observers would record any of these phenomena now!

The present paper, however, is confined to the rainfall at Armagh. It is hoped to deal in future with other meteorological phenomena and it may be possible to utilize some of these very early records, though it seems doubtful that they can have much statistical value.

In discussing the rainfall records consideration has been given only to the observations made since the year 1840. There are records from the year 1816 but there is no indication as to how they were obtained, as regards the type of rain-gauge or its position. Also only totals for each year are available. The first individual daily records appear on January 1, 1836. The records for 1836-39 are not complete and often when there were remarks on the fall of heavy rain no entry was made of the amount. The exact types of gauges cannot at present be

traced but there was a reference on January 1, 1838 that "the machinery of the Brofsleys raingauge is not to be depended on. I have therefore removed it and substituted the common method of measuring the water". From September 8, 1839, when an additional "globe" gauge, afterwards referred to as the "round" gauge, was introduced, the record for each day up to the present has conscientiously been kept by one or more gauges. The types of gauges, their position and intervals of operation are listed in Table 1. The symbols denoting the different types are in brackets.

Table 1

Raingauges in Use at Armagh Observatory

Type	Position	Date
Square (S1)	Observatory Roof	Jan. 1836—March 1861
Round (R)	" "	Sept. 1839—March 1874
Square (S2)	Front Lawn	Nov. 1853—Dec. 1884
Kew (K) Automatic	" "	May 1874—Dec. 1884
"	Instrument Lawn	Jan. 1885—Present
8-inch (I)	" "	Jan. 1885—Present

It is to be expected that, with so great a variety of gauges, placed sometimes in unsatisfactory positions, discordant results would be obtained and discontinuities would occur when one type of gauge was replaced by another. The observatory roof is a narrow strip, 41′ 6″ x 7′ 2″, bounded the whole length of the north and south sides by slates sloping to an angle of 45°. A dome and a building housing the Robinson anemometer further increase the errors due to shelter and eddy currents. The exact positions on the front lawn are not stated but a photograph taken in 1890 shows the square (S2) and Kew instruments to be in a satisfactory site at that time although since then the growth of surrounding trees would be expected to affect their registering. The sites of the Kew and 8-inch gauges on the instrument lawn meet the requirements of the Meteorological Office (see e.g. *Meteorological Observer's Handbook*, 1939, p. 3).

An attempt has been made to reduce the observations recorded since 1840 to a single uniform system. The 8-inch gauge has been taken as the standard and all others reduced to the system of the 8-inch. Fortunately, as can be seen from Table 1, there is sufficient overlapping of types and positions to assure a fair measure of confidence in such a reduction. The 8-inch and Kew have been recording side by side for over 65 years; the Kew and Square (S2) in adjacent positions for over ten years; the Square (S1) and Round both on the roof for over twenty years; each of the latter overlaps the Square (S2) on the lawn for over seven and twenty years, respectively.

The conversion factors to transform from one raingauge system to another have been found by taking the ratios of the total annual rainfalls over the overlapping periods. The mean ratio was found by ascribing to each year a weight equal to the number of days of rainfall, that is according to the number of comparisons or observations. The values found are given in Table 2 together with their probable errors and the number of observations.

Table 2

Conversion Factors to reduce Raingauges K, S1, S2, and R to the System of the I

Type and Position	Ratio	Probable Error	No. of Obs.
Kew (K) and 8-inch (I) on Instrument Lawn	K/I=1.038	0.006	7463
Kew (K) and Square (S2) on Front Lawn	K/S2=1.035	0.011	2569
Round (R) on Roof and Square (S2) on Front Lawn	R/S2=1.172	0.066	4387
Square (S2) on Front Lawn and Square (S1) on Roof	S2/S1=1.309	0.037	1586
Round (R) and Square (S1) on Roof	R/S1=1.543	0.078	4462

It was obvious that after 1918 a discontinuity occurred in the ratio of the Kew to the 8-inch gauge. It was clear what had caused this. On January 3, 1919, the Kew gauge had been dismantled for repair and overhauled (incidentally by Dr. F. J. Whipple, then Director of the Meteorological Office, who had been paying a short visit to the Observatory). This resulted in the ratio of the two gauges becoming almost equal. Previous to this there was internal consistency in the ratios and the natural value to adopt is that obtainable from these earlier years. It will be seen from Table 2 that, within the limits of error, the ratio of K/I equals that of K/S2. In other words, we can, without any correction, regard the rainfall from Nov. 1853 to the present as being on the same system. There is internal consistency among the ratios of S2/S1 but discontinuities in the cases of R/S2 and R/S1. In the former case by sub-dividing into the intervals 1853—59, 1860-69 and 1870-73 the corresponding ratio values are 1.132, 1.179 and 1.212 (small weight). The first of these has been chosen as the most likely for converting R to S2. In the interval 1854—59 inclusive the mean of all three gauges has been taken with of course the values of the Round and Square on the roof multiplied by the appropriate factors to convert them to the system of the Square on the lawn. Between 1840 and 1853 the means of the Round and Square on the roof converted to the Square on the lawn system have been used. Table 3 gives the average rainfall for ten-year periods obtained by the above method.

Table 3

Mean Annual Rainfall over Ten-Year Periods from 1840—1949

Interval	Rainfall	Interval	Rainfall
1840-49	30.94 inches	1900-09	32.09 inches
1850-59	30.19 „	1910-19	32.34 „
1860-69	32.47 „	1920-29	33.95 „
1870-79	31.77 „	1930-39	32.44 „
1880-89	31.75 „	1940-49	33.30 „
1890-99	30.97 „		

The values of Table 3 are plotted on Figure 1 (full line). The graph shows a pronounced upward trend. While this may be regarded with some suspicion it is difficult to see how so systematic an error with time can account for it. Considering the curve from 1874 onwards when the Kew and 8-inch gauges were operating there is still a definite tendency towards increasing rainfall.

From Table 3, it can be found that, averaged over the past 110 years, the average annual rainfall at Armagh is 32.02 inches. In view, however of the apparent systematic increase with time a more suitable period for averaging would be the past forty years. From this we get an average yearly rainfall of 33.01 inches.

The monthly values of the rainfall, again averaged over ten-year periods, are given in Table 4.

Table 4

Monthly Values of Rainfall averaged over Ten-Year Periods

Yr.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1840-49	3.13	2.36	2.23	1.92	1.98	2.52	2.78	2.51	2.29	3.24	3.05	2.75
1850-59	2.95	1.92	1.83	2.35	2.24	2.57	2.94	2.97	2.35	2.48	2.53	3.00
1860-69	3.18	2.44	2.63	2.08	2.60	2.41	2.37	3.17	2.45	3.40	2.95	2.85
1870-79	3.34	2.20	1.90	1.90	1.85	2.24	3.28	2.90	3.24	3.67	2.53	2.74
1880-89	2.48	2.30	2.22	2.23	2.34	2.23	3.45	2.92	3.07	2.54	3.20	2.74
1890-99	2.22	1.81	2.10	1.92	2.18	2.84	2.95	3.95	2.45	2.75	2.79	3.01
1900-09	2.76	2.14	2.67	2.19	2.78	2.24	2.68	3.84	2.40	3.02	2.76	2.62
1910-19	2.68	2.84	2.20	2.09	2.46	2.66	2.37	3.31	2.19	2.74	2.94	4.20
1920-29	3.45	2.63	1.87	2.12	2.49	2.10	3.08	4.06	2.84	3.36	2.90	3.03
1930-39	3.13	1.88	1.85	1.81	2.19	2.61	3.90	2.91	2.74	3.46	2.94	3.01
1940-49	3.44	1.99	2.41	2.14	2.36	2.46	3.27	3.02	2.98	3.12	2.70	3.37
Mean	2.97	2.23	2.17	2.07	2.32	2.35	2.92	3.23	2.64	3.04	2.84	3.03

In January 1944, for an unknown reason, the rainfall was not recorded on eleven days. The monthly rainfall is calculated from the twenty days' observations and by assuming the same average rate of rainfall for the missing days; an assumption which is justified by the observer's comments in the Remarks Column. This seems to be a better procedure to adopt than simply to discard the observations of this month.

The highest and lowest recorded figures of rainfall for each month for the period 1840-1950 are set out in the following table.

Table 5

	Jan.	Feb.	Mar.	Apr.	May	June
Wettest	6.72	4.53	4.40	4.28	6.16	5.63
	(1948)	(1910)	(1903)	(1880)	(1916)	(1897)
	July	Aug.	Sept.	Oct.	Nov.	Dec.
,,	7.09	7.04	5.70	8.18	6.44	7.15
	(1896)	(1892)	(1946)	(1870)	(1890)	(1914)

	Jan.	Feb.	Mar.	Apr.	May	June
Driest	0.39	0.13	0.35	0.03	0.07	0.18
	(1881)	(1932)	(1929)	(1842)	(1884)	(1942)
	July	Aug.	Sept.	Oct.	Nov.	Dec.
,,	0.16	0.54	0.10	0.98	0.46	0.55
	(1878)	(1940)	(1894)	(1904)	(1945)	(1844)

Table 6 gives a comparison in the mean number of days per month with 0.04″ of rain or more (classified by the Meteorological Office as " wet days ") between the fifty years 1850-1899 and the fifty years 1900-1949.

Table 6

Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1850-59	14.6	10.6	9.4	10.3	9.2	10.5	12.1	12.9	9.0	11.8	9.9	14.1
1860-69	13.9	10.8	13.9	10.2	11.4	10.7	9.9	12.9	11.7	14.0	10.8	13.5
1870-79	14.0	9.9	9.9	9.4	10.0	10.9	13.2	12.9	12.6	14.7	11.7	10.7
1880-89	12.6	12.1	11.2	10.7	12.3	10.2	15.7	12.1	12.1	12.4	14.2	14.7
1890-99	12.7	10.0	12.4	12.1	10.6	12.3	11.0	15.4	12.1	11.9	11.8	15.0
Mean	13.5	10.7	11.3	10.5	10.7	10.9	12.4	13.2	11.5	12.9	11.7	13.6
Period	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1900-09	13.4	11.6	13.7	12.7	13.3	10.2	11.9	14.2	10.5	15.1	11.5	13.8
1910-19	13.1	14.0	11.4	12.1	11.8	11.9	11.1	13.8	9.6	12.4	14.3	18.9
1920-29	17.3	13.3	11.5	11.8	13.0	10.7	14.7	17.4	12.9	13.8	14.0	15.7
1930-39	15.3	12.0	12.8	11.5	12.0	12.8	15.0	12.6	12.8	15.5	13.1	14.4
1940-49	15.1	11.5	10.9	11.8	11.7	12.6	13.6	14.1	14.2	13.0	13.8	15.9
Mean	14.8	12.5	12.0	12.0	12.3	11.6	13.2	14.4	12.0	13.9	13.3	15.7

Figure 1 (broken line) shows the yearly number of days exceeding 0.04" of rain averaged over ten-year periods during 1840-1949. As in Figure 1 (full line) there is a pronounced upward trend. Here again this tendency to increasing figures is still apparent from 1880 onwards when the two reliable raingauges were already in operation.

Finally an attempt has been made to find if there is any correlation between rainfall at Armagh and the sunspot cycle.

The values of the relative sunspot numbers (Wolf's numbers) have been taken from a paper by Brunner (*Astronomische Mitteilungen* Nr. 145 by W. Brunner, Zurich 1945). To smooth out irregularities of individual cycles a Mean Eleven-Year Sunspot Cycle has been derived. Starting with the year 1840 the mean relative sunspot numbers have been found for the phases of 0, 1, 2, ... etc. years from the year of sunspot minimum, covering a period of ten sunspot cycles (110 years). The corresponding mean values of the rainfall have been found. The result is given in Table 7.

Table 7

Mean Relative Sunspot Numbers averaged over Ten Cycles and corresponding Mean Average Rainfall at Armagh

Years from Minimum	0	1	2	3	4	5	6	7	8	9	10
Rel. Sunspot Number	5.7	14.2	43.2	73.8	89.0	85.2	78.5	48.8	35.4	23.4	13.5
Rainfall	30.32	31.73	31.97	32.09	31.23	35.38	32.65	31.38	31.63	32.49	31.96

The values of Table 7 have been plotted in Figure 2. The mean Sunspot Curve shows the well known rapid rise to maximum and slower fall to minimum. The comparison of the two curves is remarkable for the interruption in the rise of rainfall at sunspot maximum followed by a sharp rise one year after maximum. There is also a trend upwards when the cycle is approaching its end. It is well known that the suspected relation between precipitation and sunspots varies considerably with the locality. (*See* e.g. R. E. DeLury *Journ. Roy. Astr. Soc. Canada,* 19, p. 293, 1925, and *Dominion Obs. Reprint* No. 32). The pattern in Figure 2 is, however, remarkably similar to that found on the other side of the Atlantic, for the island of Anticosti (*cf.* DeLury, *loc. cit.*).

Armagh Observatory,
October 20, 1951.

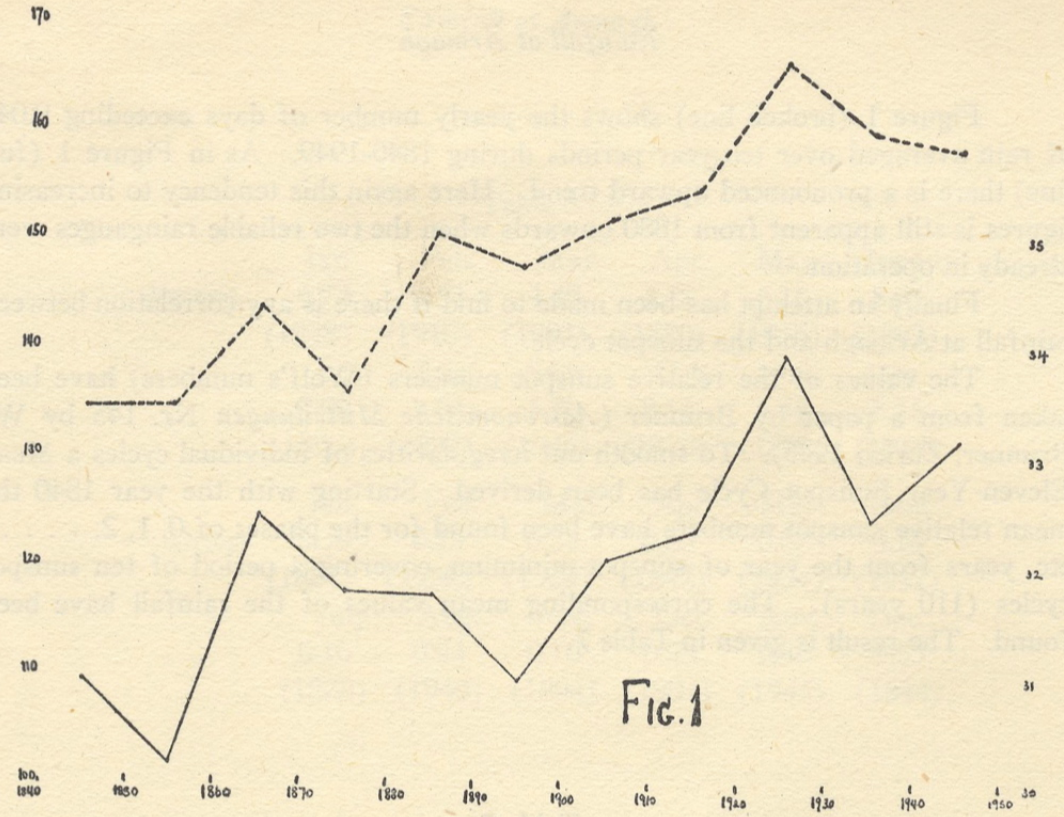

FIG. 1

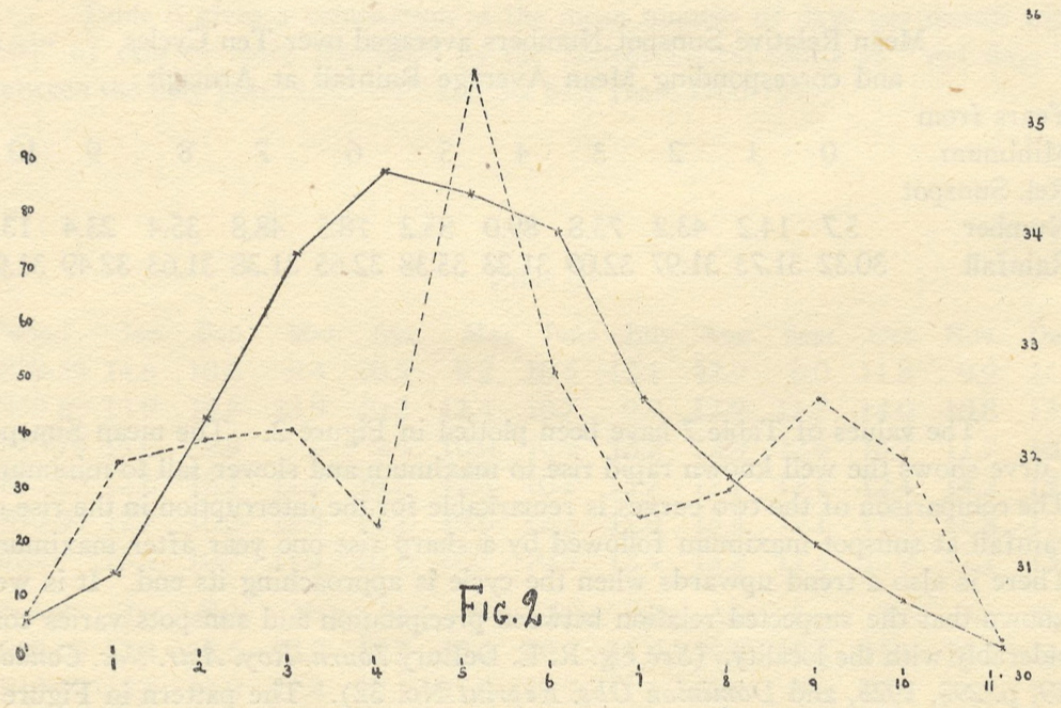

FIG. 2

Figure 1. Average Yearly Rainfall over ten-year periods (full line and right-hand scale)
Yearly number of wet days (0.04" of rain or more) averaged over ten-year periods (broken line and left-hand scale).

Figure 2. Mean Relative Sunspot Numbers and corresponding Mean Average Rainfall averaged over Ten Cycles. (Sunspot curve—full line with crosses and left-hand scale, Rainfall curve—broken line with dots and right-hand scale).