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Heavy Rainfalls and the Lunar Cycle

F. A. BERSON and E. L. DEACON

C.S.I.R.O., Division of Meteorological Physics, Victoria, Australia

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ABSTRACT. Heavy rainfalls during the monsoon seasons at Djakarta (1864–1945) and Mangalore (1901–1950) are found to occur more frequently at certain epochs of the lunar synodic cycle than at others. The effect is not of high statistical significance, but the results are sufficiently suggestive and in line with evidence from U.S.A. (Brier and Bradley 1964) to warrant a much more extensive study of Indian rainfall statistics. The indications that the lunar effect is much stronger in years of below average sunspot number, here and in U.S.A., may help in the elucidation of underlying processes.

Following the reports of Bradley, Woodbury and Brier (1962) and Adderley and Bowen (1962) of marked variations in the incidence of heavy rainfall within the lunar synodic cycle, both in U. S. A. and New Zealand, it was thought that an examination of the rainfalls for two tropical stations, for which the data were to hand, might prove of interest. There was the possibility that useful indications might emerge from single station data if these were for places where heavy rainfalls were much more frequent than in the areas studied by the above mentioned authors.

For Djakarta (Batavia) complete rainfall data were available for the period 1864-1945 from the annual publications of the Royal Magnetic and Meteorological Observatory, Batavia. The summer monsoonal rains, heaviest in January and February, were studied for the months December to March which receive 60 per cent of the annual total of 69·5 inches.

Fig. 1 shows the cumulative frequency distribution of the daily rainfalls exceeding 0·1 in. in the two-month periods around solstice. This curve suggested a value of 1·5 in. (38 mm) as about the lower limit of a seemingly homogeneous population sample so that daily rainfalls exceeding 1·5 in. are first dealt with.

These heavy rainfalls for Djakarta were then tabulated in relation to the lunar synodic cycle of 29·53 days divided into ten parts. This relatively coarse subdivision was dictated by two considerations: the limited amount of the data and the persistence in rainfall series which causes a fine subdivision to give little, if any, increase in significant information over a coarser one. In examining this point it was found that the autocorrelation exhibited by 3-day totals of rainfall (approximately normalised in distribution by taking the cube root following Stidd, 1953) was suitably small; for one lag the correlation coefficient averaged +0·18 for the December—March seasons in a trial period of 6 years (1939-1940 to 1944-1945).

In Fig. 2 these heavy rainfalls are shown as percentage deviations from the mean in relation to the lunar cycle. It should be noted that no moving means have been used in the present work as they introduce spurious periodicities. This graph has three maxima of which only two are well marked: the larger of these is shortly before full moon and the other a little after new moon. This last coincides in timing fairly well with one of the two maxima exhibited by the U.S. data (Bradley *et al., loc. cit.*) but the other is earlier in phase by about 2 synodic decimals.

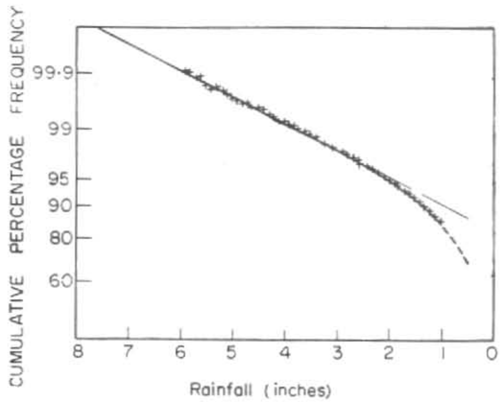

Fig. 1. Frequency distribution of daily rainfalls exceeding 0·1 inch at Djakarta : months of Dec and Jan 1864-1945—probability paper plotting

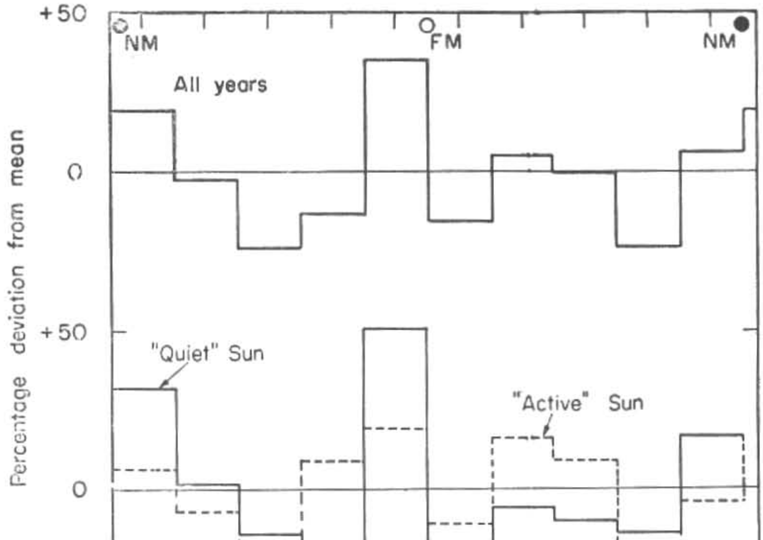

Fig. 2. Percentage deviation from mean of the precipitation at Djakarta on all days having a rainfall exceeding 1·5 inches in months Dec-Mar (inclusive) 1864/5 to 1944/5, in relation to ten divisions of the lunar synodic cycle

(Years of above median sunspot number denoted : Active Sun; below median: Quiet Sun)

To gain some idea of the statistical significance of the variations of heavy rainfall in the lunar cycle the frequencies of occurrence, as set out in Table 1, were studied. These frequencies lend themselves more readily to statistical treatment than is the case for the rainfall amounts. At the same time it seemed worthwhile to see if there was any indication that the strength of the lunar cycle variation depends on the general level of solar activity. This was prompted by Berkes' (1954) remarks on an investigation of Budapest rainfall in relation to lunar phase. He said, "To test the lunar variation in precipitation we divided all the data between 1887-1942 into two parts from various points of view. Even and odd years, decades before 1915 and after, as well as separating according to winter or summer—all gave curves of a similar character. The most interesting result was given by separating the years of greatest and least solar activity..............". This he held to demonstrate some solar influence at work. In the present study the data were divided into two parts: one part (denoted Active Sun) was for years of Sunspot Relative Number greater than the median value for the period the observations covered; the remainder was called the Quiet Sun part.

From the frequencies given in Table 1 the values of χ^2 for departure from uniformity were calculated and the values of the significance level P given in the last column are those appropriate if effects of persistence may be neglected as seems justified by the slight persistence extending from one decimal phase to the next as mentioned above. It is apparent that there is no significant evidence of a lunar effect in years of Active Sun. For the years of below median sunspot number the value of $P=0 \cdot 06$ is suggestive of a real variation but not fully conclusive.

To see whether lighter rainfalls than 1·5 in./day displayed any variation in the lunar cycle the frequencies of daily rainfalls in the range 0·50 to 0·99 in. were extracted for the December-January season and these are given in Table 2. The value of χ^2 is again larger for the Quiet Sun Years but a significant value is not reached. Correlating the frequencies for Quiet Sun Years in Table 2 with those for the larger rainfalls in Table 1 gives a correlation coefficient of $+0 \cdot 42$ but with only 8 degrees of freedom this is not significant.

The rainfalls less than 0·5 in., which in December and January occur on 42 per cent of all days at Djakarta, give no evidence whatever of any lunar effect on the frequencies.

In so far as the summer rainfall data support a variation within the lunar cycle, it appears to be confined to the heavier rainfalls. At Djakarta situated on the east coast of Java, the bulk of a large daily precipitation total in the summer monsoon is associated with large-scale convergence of and disturbances in the westerly stream accompanied by clouds towering to great heights. Small 24-hour totals, on the other hand, can be ascribed predominantly to local orographic convergence and sea breeze convergence giving rise to rain clouds of generally much less vertical extent. The evidence from the Djakarta data, therefore, suggests that a lunar effect should be sought in rain originating from freezing clouds by the Bergeron process.

Some data available for Mangalore on the West Coast of India have also been examined to see if they give any support to the tentative indications presented above. These were from the monograph of Ramakrishnan and Narayanan (1955) which contained the daily falls during spells of heavy rain, a spell being defined such that the cumulative amount, say R_s, has a lower limit of $2\,(n+1)$ inches, n being the duration in days. The period covered by these records was 1901—1950 and daily rainfalls of greater than 2 inches were selected from the the spells in the peak SW monsoon months of June and July. These rainfalls in relation to the lunar cycle are shown in Fig. 3 and the frequencies are given in Table 3. Comparison of the "all years" and "Quiet Sun" graphs in Figs. 1 and 2 show fairly good agreement in the timing of

TABLE 1

Frequencies of daily rainfalls at Djakarta exceeding 1·5 inches in ten divisions of the lunar synodic period

(New Moon occurs between phases 10 and 1, Full Moon between 5 and 6)
Period 1864/5 to 1944/5

	Phase in lunar synodic decimals										Total	χ^2	P
	1	2	3	4	5	6	7	8	9	10			
(DEC/JAN)													
Quiet Sun	17	19	12	8	20	7	17	15	7	19	141	17·23	0·04
Active Sun	19	17	13	16	16	11	16	15	13	14	150	3·20	0·96
All years	36	36	25	24	36	18	33	30	20	33	291	14·53	0·10
(FEB/MAR)													
Quiet Sun	18	8	11	9	20	14	8	9	16	12	125	13·48	0·14
Active Sun	13	11	11	17	20	16	19	18	11	15	151	7·07	0·64
All years	31	19	22	26	40	30	27	27	27	27	276	10·16	0·34
(DEC/MAR)													
Quiet Sun	35	27	23	17	40	21	25	24	23	31	266	16·13	0·06
Active Sun	32	28	24	33	36	27	35	33	24	29	301	5·62	0·78
All years	67	55	47	50	76	48	60	57	47	60	567	14·37	0·10

"Quiet Sun"/"Active Sun" signifies years of below/above median sunspot number for the 80 years

TABLE 2

Frequencies of daily rainfall amounts at Djakarta in range 0·50 to 0·99 inch related to ten divisions of the lunar synodic period

(Months of December and January in the period 1864/5 to 1944/5)

	Phase in lunar synodic decimals										Total	χ^2	P
	1	2	3	4	5	6	7	8	9	10			
Quiet Sun	33	29	36	23	28	22	22	17	25	26	261	10·92	0·28
Active Sun	23	34	32	25	29	28	29	18	29	24	271	7·27	0·62
All years	56	63	68	48	57	50	51	35	54	50	532	13·56	0·14

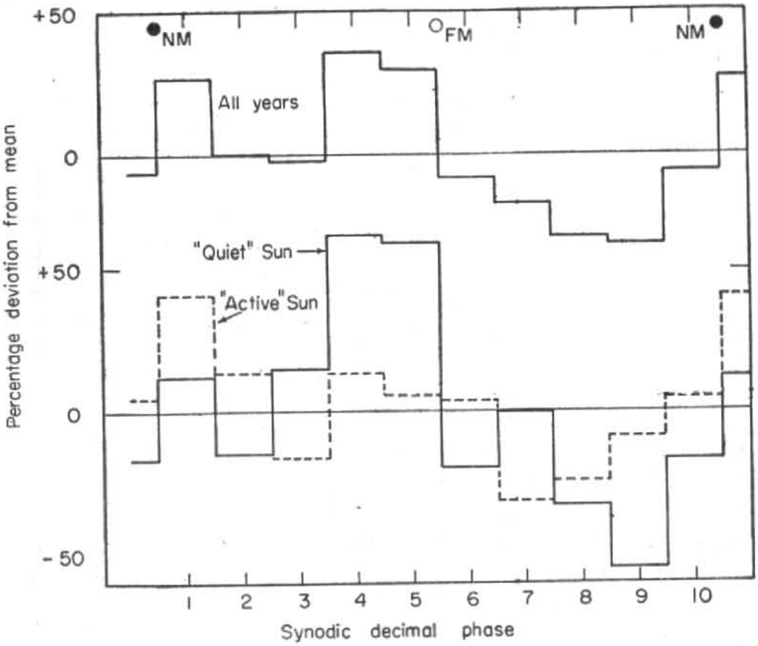

Fig. 3. Percentage deviation from mean of the precipitation on days of heavy spell rainfall exceeding 2 inches in months June and July at Mangalore, India, over the period 1901-1950

TABLE 3

Frequencies of heavy spell rain days at Mangalore (India) related to ten divisions of the lunar synodic period

(Months of June and July in the period 1901—1950)

	Phase in lunar synodic decimals										Total	χ^2
	1	2	3	4	5	6	7	8	9	10		
Quiet Sun	21	20	30	34	37	29	21	15	11	18	236	27·47
Active Sun	34	28	21	29	27	26	19	21	24	25	254	7·02
All years	55	48	51	63	64	55	40	36	35	43	490	20·00

the maxima. The values of χ^2 in Table 3 show that markedly greater departures from a uniform distribution occur with Quiet Sun than Active as was found with the Djakarta data. As effects of persistence in these spell data are greater than in the Djakarta data significance levels cannot safely be assigned to the Mangalore χ^2 values. However the Mangalore data give a useful measure of support to the evidence from the Djakarta observations for a variation of heavy rainfall in the lunar cycle.

Only tentative conclusions can be drawn from this study: the attempt to obtain reasonably firm indications out of the data for one station is seen to have been over optimistic. Furthermore, in view of the complexity of weather processes in the troposphere and the interactions and quasi-periodicities involved, it is perhaps not surprising that the correspondence between the present results and those for U.S.A. and New Zealand is not close. It is, however, considered that this work is sufficiently suggestive for a much more comprehensive study of Indian rainfall statistics to be worthwhile. This is especially the case as a useful number of stations have long records. It is hoped that this contribution may help to stimulate a full-scale study in the Indian region.

Perhaps the most interesting feature to emerge from the present work is the fact that at both Djakarta and Mangalore there appears to be more evidence of lunar effect in years of below average sunspot number than at other times. It is worth recording that when a copy of the first version of this note was communicated to Dr. Brier, he was interested enough to have the United States data divided in a similar manner between years of above and below median sunspot number. The result was to show that the lunar effect appears to be quite markedly greater in the Quiet Sun years than with Active Sun (Brier and Bradley 1964). This finding may help in the elucidation of the underlying causes.

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