M.O. 626 AIR MINISTRY

METEOROLOGICAL OFFICE

THE METEOROLOGICAL MAGAZINE

VOL. 86, No. 1,023, SEPTEMBER 1957

ESTIMATION OF THE FREQUENCY OF "RUNS OF DRY DAYS"

By E. N. LAWRENCE, B.Sc.

Summary.—The frequencies of runs of dry days (that is, sequences of days with nil, trace or 0·1 mm. of recorded rainfall) of different lengths are described with special reference to southern and eastern England and to the months May to September. The relation between the frequencies of different lengths, for a particular site, is examined, with special reference to persistence, and their approximation to various series is discussed. The series may be referred to as: geometric, logarithmic, "natural-persistence" or "Jenkinson-probability". Each of these types of series lends itself to one or more methods of approximation to the actual series. Each method uses one, two or three meteorological variables in a convenient form for charting. It is shown that the "natural-persistence" series with area values for the probabilities is the most convenient and accurate approximation.

Part I

Introduction.—In climatological work the rainfall chart is perhaps very familiar. With an extensive network of rainfall stations and long experience of drawing isopleths of rainfall, the charts provide a suitable basis for the estimation of monthly mean rainfall by interpolation. No doubt, this technique will in time be extended to many other macroclimatic variables. In this paper, the frequencies of runs of dry days of various lengths are examined. In order to extend the use of charts and also as a contribution to the study of weather persistence, the series of the actual frequencies of runs of different lengths was, for a number of stations, compared with or fitted to series of the geometric, logarithmic, "natural-persistence" and "Jenkinson-probability" types.

Data.—Data for some 70–80 stations in southern and eastern England (see Fig. 1) were examined for the period 1921–46, where possible, and for the months April to September. For "Jenkinson-probability" series, a special study was made of the 21 sites examined in the area of south-west England, with particular reference to August.

The daily (0900 to 0900) rainfall records were used to compute the frequencies of 1, 2, 3, etc. consecutive dry days. A dry day is defined as one on which the recorded rainfall was nil or trace, or in the case of millimetre recording, nil, trace or 0·1 mm. Days on which 0·01 in. or 0·2 mm. or more were reported are defined as rain-days.

In computing frequencies the following conventions were used:

(i) A run of dry days starting in one month and ending in another has been credited to the month with the greater portion of the spell.

(ii) If a run is equally divided between two months, each of these months has been credited with half a run of the full length.

(iii) For runs which end after September 30 or begin before April 1 (May 1 for south-west England), only those days which occur on or after April 1 (or May 1) or on or before September 30 are considered.

Ideally, runs should be proportionally divided between the months in which they occur, but this convention involves more computation and loses its advantage when long periods are used. The convention is not employed in this paper.

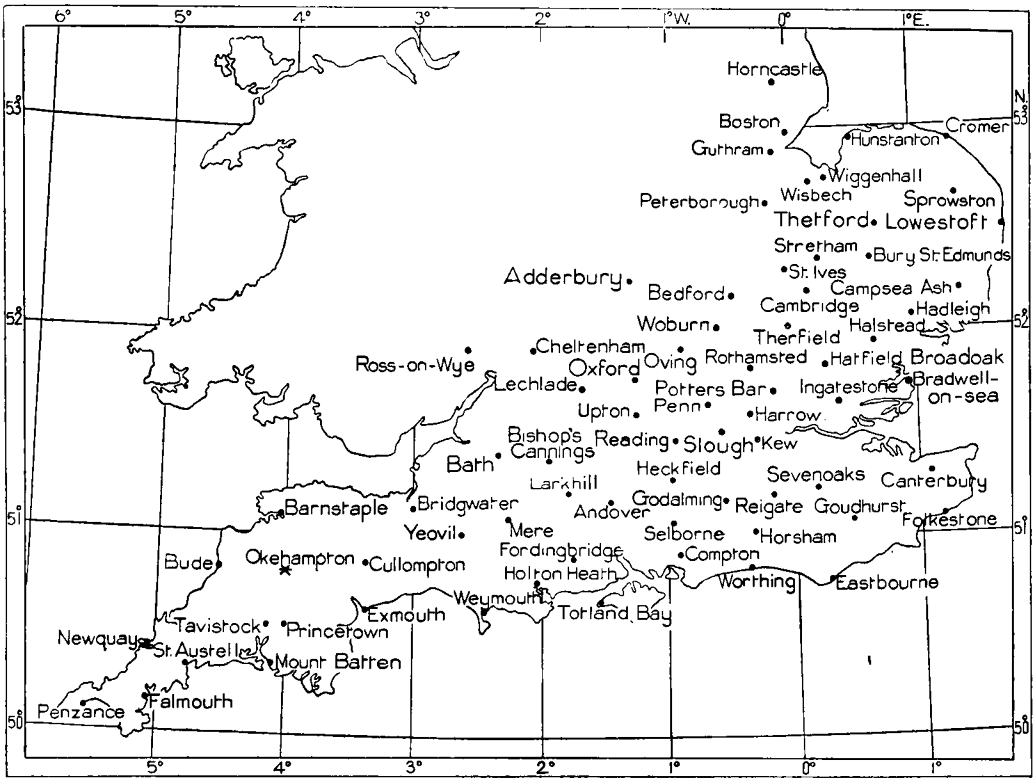


FIG. 1—STATIONS IN SOUTHERN AND EASTERN ENGLAND

Geometric series.—The representation of the frequencies of runs of different lengths by the terms of a geometric series implies that no matter how many consecutive dry days have already occurred, there is a constant probability that the next day will be dry. The validity of this approximation will be discussed later.

Given N runs of 3 or more days and P the constant probability that a run of dry days will continue for at least another day, the theoretical frequencies of runs lasting 3 or more, 4 or more, 5 or more,. . . t or more days, etc. (i.e. "cumulative frequencies") are

$$N, NP, NP^2, NP^3, \ldots\ldots NP^{t-3}, \ldots\ldots$$

If the sum of this series is S, then $S = N/(1 - P)$ and hence $P = 1 - N/S$.

For each station, P was calculated from observed values of N and S and charts of isopleths of P and N were drawn for each month. The procedure of interpolating the values of P and N from charts and calculating the frequency (NP^{t-3}) of runs lasting at least t days is illustrated in the Appendix (following Part I). The Appendix (p. 269) gives values of N and P from which charts for the summer months for southern and eastern England can be drawn.

Logarithmic series.—This series does not assume a constant value for P; it can readily be shown that it implies "positive persistence", i.e. that the longer a run lasts the more likely will it last another day. This has been discussed in an earlier paper[1].

In this representation, the number of runs in a given period lasting only 1 day, only 2 days, only 3 days . . . only t days, etc., are given by the terms

$$a, \frac{ar}{2}, \frac{ar^2}{3}, \frac{ar^3}{4}, \ldots\ldots \frac{ar^{t-1}}{t}, \ldots\ldots,$$

where a and r are constants depending on the site. If the total number of runs be T, then

$$T = a + \frac{ar}{2} + \frac{ar^2}{3} + \frac{ar^3}{4} + \frac{ar^4}{5} + \ldots\ldots$$

$$= -\frac{a}{r}\log_e(1 - r) \,. \qquad \ldots\ldots (1)$$

If the observed number of dry days be n, then

$$n = a + ar + ar^2 + ar^3 + ar^4 + \ldots\ldots$$

$$= a/(1 - r) \,. \qquad \ldots\ldots (2)$$

Therefore $r = (n - a)/n$. $\qquad \ldots\ldots (3)$

Substituting for r in equation (1)

$$T = \frac{an}{a - n}\log_e\frac{a}{n} \,. \qquad \ldots\ldots (4)$$

Using the observed values of n and T, the values of a and r were calculated for each site from equations (3) and (4). A graphical method of solution described by Williams[2] was employed, using the graph of

$$\frac{n}{T} = \frac{r}{(r - 1)\log_e(1 - r)}$$

for different values of n/T and r, and substituting the graphically obtained value for r in $a = n(1 - r)$ to obtain a.

For each station, the values of a and r were plotted and charts of the isopleths of a and r were drawn for each month. The procedure of interpolating the values of a and r from the charts and calculating the frequency F_t of runs lasting t or more days, as given by

$$F_t = -\frac{a}{r}\log_e(1 - r) - \left(a + \frac{ar}{2} + \frac{ar^2}{3} + \frac{ar^3}{4} + \ldots + \frac{ar^{t-2}}{t-1}\right),$$

is illustrated in the Appendix (p. 269) where values of a and r for the summer months in southern and eastern England are also given.

Charts of T, based on equation (1), may facilitate the calculation when t is not very large, but when t is greater than about 10, the use of T charts is inaccurate.

"Natural-persistence" series.—If N is the number of runs lasting at least 3 days, the series of terms giving the frequency of runs lasting at least 3, 4, 5 . . . . t days is

$$N,\ NP_4,\ NP_4P_5,\ NP_4P_5P_6,\ \ldots\ldots\ NP_4P_5\ \ldots\ldots\ P_t,$$

where P_t is the probability that, following $(t-1)$ dry days, the next day will be dry. For each of the 21 stations in the south-west of England for August, the values of P_4 to P_{15} were plotted. A specimen chart (P_4) is shown in Fig. 2. The interpolation of values of P_4 to P_{15} and N to obtain the frequency of runs lasting at least t days ($NP_4P_5 \ldots\ldots P_t$) is illustrated in the Appendix.

P_1 is defined as the ratio of the number of dry days n to the total number of days. For convenience, n was approximated by using the frequencies of runs lasting 1, 2, 3, ... days, after employing the conventions mentioned in the section on data. The values of the probabilities $P_1\,P_2\,P_3 \ldots\ldots P_{15}$ (see Table I) were plotted for each station in south-west England and the results are as shown in Fig. 3. It will be seen that a certain pattern emerges. There appears to be a tendency for graphs to run roughly parallel. Thus it would seem that an approximation to the P's for a station could be based on the mean values of P_D ($D = 4, 5, \ldots\ldots 15$) for the area and the local value of P_1. The corresponding series would be

$$N,\ N(\bar{P}_4 + x),\ N(\bar{P}_4 + x)(\bar{P}_5 + x),\ N(\bar{P}_4 + x)(\bar{P}_5 + x)(\bar{P}_6 + x),\ \ldots\ldots$$

where $x = P_1 - \bar{P}_1$ ignoring values of P_1 outside the range $\bar{P}_1 \pm 0{\cdot}05$.

This series involves two station constants: N and x. Series were also computed, using only one "station" constant, N with the mean (area) probability values $\bar{P}_4, \ldots\ldots \bar{P}_{15}$, and also using $\bar{N}$ with x the appropriate adjustment to the $\bar{P}$'s. An example of each of these series and of the previous series with both N and x station values is given in the Appendix.

"Jenkinson-probability" series.—For each year, the maximum length of run during August was extracted from observed data. If the longest run partly extended into July or September it was accepted or thrown out according as the greater or lesser part of it occurred during August. If the longest run was exactly shared between two months, then it was assumed that for one year it did occur within August, and that for a second year it did not occur, the maximum spell then being obtained from the remaining runs; all other years, in which the equally divided run did not arise, were then considered as having occurred twice. In this way the values of D_m (the average maximum length of run in days), σ_1 (standard deviation of the length of maximum run) and σ_1/σ_2 (where σ_2 is the value of the standard deviation for two-year maxima, not necessarily for two consecutive years) were computed. The details of the calculations are given in an earlier paper[3]. The computed values of D_m, σ_1 and σ_1/σ_2 are given in Table II. Specimen charts for south-west England in August are shown in Figs. 4–6. Table II shows that for June, which has a greater number of dry days than the remaining summer months, there is also a higher mean maximum length of dry run, a higher standard deviation of maximum length of dry run and a slightly lower value of σ_1/σ_2, the latter corresponding to a slightly higher degree of "mean persistence".

TABLE I—VALUES OF THE ADDITIONAL VARIABLES USED IN "NATURAL-PERSISTENCE" METHOD. AUGUST

	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}	P_{13}	P_{14}	P_{15}
Ross-on-Wye	0·52	0·51	0·70	0·81	0·84	0·69	0·77	0·82	0·86	0·83	0·60	0·50	1·00	1·00	1·00
Cheltenham	0·57	0·64	0·65	0·73	0·69	0·82	0·78	0·89	0·81	0·92	0·83	0·80	0·75	0·83	0·60
Bishop's Cannings	0·54	0·56	0·68	0·73	0·67	0·83	0·85	0·76	1·00	0·84	0·95	0·70	1·00	0·71	0·80
Larkhill	0·55	0·56	0·66	0·75	0·82	0·68	0·81	0·89	0·81	0·76	0·89	0·88	0·60	0·78	0·14
Bath	0·56	0·51	0·69	0·78	0·73	0·72	0·95	0·79	0·74	0·91	1·00	0·62	0·77	0·60	0·67
Bridgwater	0·59	0·60	0·67	0·71	0·79	0·81	0·84	0·90	0·63	1·00	1·00	0·75	0·67	0·50	1·00
Yeovil	0·51	0·55	0·70	0·72	0·81	0·72	0·81	0·82	0·57	0·87	0·71	0·80 ,	1·00	0·75	0·67
Holton Heath...	0·61	0·63	0·68	0·72	0·70	0·84	0·71	0·83	0·87	0·69	0·89	0·75	0·83	0·80	0·75
Weymouth	0·61	0·60	0·72	0·74	0·63	0·79	0·71	0·94	0·77	0·83	0·84	0·87	0·86	1·00	0·50
Barnstaple	0·44	0·45	0·61	0·61	0·80	0·80	0·67	0·64	0·86	0·50	1·00	0·67	1·00	...	...
Collompton	0·50	0·47	0·73	0·69	0·76	0·84	0·71	0·93	0·79	0·82	0·78	0·86	0·67	0·75	0·33
Exmouth	0·58	0·58	0·72	0·73	0·76	0·71	0·77	0·88	0·80	0·92	0·86	0·89	0·76	0·54	1·00
Plymouth (Mount Batten) ...	0·53	0·60	0·75	0·72	0·68	0·71	0·80	0·94	0·63	1·00	0·95	0·67	0·67	0·75	1·00
Princetown	0·44	0·52	0·70	0·68	0·76	0·75	0·67	0·87	0·86	0·83	1·00	0·80	0·50	1·00	0·50
Tavistock	0·47	0·46	0·61	0·77	0·60	0·80	0·75	0·83	0·90	0·89	0·81	1·00	0·85	0·82	0·44
Bude	0·48	0·50	0·73	0·64	0·74	0·82	0·73	0·56	1·00	0·87	0·92	0·83	0·80	0·50	1·00
Mere	0·49	0·56	0·73	0·67	0·84	0·66	0·64	0·76	0·84	0·87	0·86	0·83	1·00	0·80	0·50
Falmouth	0·50	0·54	0·68	0·67	0·71	0·67	0·75	0·83	0·90	0·89	0·87	0·86	0·83	0·60	0·67
Newquay	0·46	0·49	0·67	0·65	0·62	0·68	0·84	0·90	0·79	1·00	0·80	0·83	0·60	0·67	1·00
Penzance	0·51	0·54	0·64	0·71	0·62	0·91	0·74	0·93	0·78	0·90	0·95	0·56	0·80	0·25	1·00
St. Austell	0·44	0·51	0·62	0·68	0·69	0·74	0·86	0·92	0·82	0·78	0·86	0·83	0·60	1·00	0·67
Mean	0·52	0·54	0·68	0·71	0·73	0·76	0·77	0·84	0·81	0·85	0·87	0·78	0·79	0·70	0·68
Standard deviation	0·05	0·05	0·04	0·05	0·07	0·07	0·07	0·10	0·10	0·11	0·10	0·12	0·15	0·24	0·29

Assuming that we know the D_m, σ_1 and σ_1/σ_2 for a station, we may draw the curve of the probability function $y \{= -\log_e \log_e (1/p)$ where p is the probability$\}$ and length of spell D using the formula[4]

$$D = D_m + R\sigma_1$$

where R is given in Table III.

TABLE II—VALUES OF THE VARIABLES USED IN "JENKINSON-PROBABILITY" METHOD

	σ_1/σ_2			D_m			σ_1		
	June	July	August	June	July	August	June	July	August
Ross-on-Wye	0·92	1·01	0·92	10·63	8·46	7·73	7·58	4·41	4·61
Cheltenham	1·01	1·13	1·07	12·33	9·17	8·31	7·59	5·99	4·43
Bishop's Cannings ...	0·97	1·05	0·91	9·77	7·77	9·19	6·09	4·19	6·63
Larkhill...	0·99	0·99	1·04	10·79	7·63	7·69	6·53	4·68	4·40
Bath	1·02	1·08	0·93	11·35	8·08	8·35	6·61	3·83	5·43
Bridgwater	0·95	0·99	1·05	13·00	7·02	8·73	7·79	4·21	4·71
Yeovil	1·07	1·05	0·97	11·94	7·94	7·79	5·72	4·47	4·48
Holton Heath	0·99	1·00	0·88	12·83	8·21	8·92	7·36	4·55	5·88
Weymouth	0·98	1·01	0·90	13·11	8·87	8·69	7·90	4·86	5·69
Barnstaple	0·89	1·02	1·00	10·02	7·06	5·81	7·21	4·14	3·16
Cullompton	1·03	1·03	1·04	10·89	7·89	7·50	5·86	4·67	4·43
Exmouth	0·97	0·95	0·94	10·92	8·67	8·85	5·85	5·13	5·83
Plymouth	0·99	1·04	0·98	12·27	7·15	8·04	8·15	4·02	4·47
Princetown	0·92	1·12	0·96	7·31	5·78	6·61	4·76	3·17	3·49
Tavistock	0·90	0·97	0·96	8·85	6·83	6·96	6·36	4·72	4·57
Bude	0·91	0·95	1·01	9·33	7·11	7·25	5·63	4·89	5·32
Mere	0·98	1·02	0·96	11·92	7·52	7·52	7·32	4·45	4·42
Falmouth	0·92	1·01	0·97	10·27	7·83	7·27	6·71	4·80	4·27
Newquay	0·88	0·91	0·91	8·87	5·92	6·27	6·39	4·47	3·93
Penzance	0·91	0·94	1·00	9·77	6·40	7·42	6·49	4·91	3·93
St. Austell	0·91	0·95	0·91	9·60	6·52	6·61	6·77	4·83	4·19
Mean...	0·96	1·01	0·97	10·75	7·52	7·69	6·70	4·54	4·68

TABLE III—VALUES OF R FOR COMPUTING EXTREME VALUES OF D LIKELY TO BE REACHED ONCE IN t YEARS

t	...	...	1·58	5	10	25	50	100	250
y / σ_1/σ_2	−2	−1	0	1·50	2·25	3·20	3·90	4·61	5·52
0·80	−0·95	−0·72	−0·39	0·34	0·86	1·73	2·57	3·61	5·39
0·85	−1·24	−0·89	−0·44	0·48	1·05	1·95	2·76	3·72	5·22
0·90	−1·50	−1·02	−0·45	0·58	1·18	2·06	2·78	3·60	4·79
0·95	−1·76	−1·13	−0·46	0·66	1·26	2·07	2·71	3·38	4·31
1·00	−2·01	−1·23	−0·45	0·72	1·31	2·04	2·59	3·14	3·85
1·05	−2·26	−1·32	−0·44	0·75	1·34	2·00	2·47	2·91	3·45
1·10	−2·49	−1·38	−0·42	0·77	1·34	1·93	2·32	2·67	3·09
1·15	−2·73	−1·44	−0·39	0·79	1·34	1·85	2·19	2·47	2·78
1·20	−2·97	−1·50	−0·36	0·81	1·33	1·79	2·08	2·30	2·52

The mean annual frequency[4] of runs of length D or more days (F_D) is given by

$$F_D \doteq e^{-y}$$

for values of D of the order of the maximum length of run. The value of y for values of $D = 3, 4, 5, \ldots 15$ was read from the curve, and the calculated frequencies thus obtained. The interpolation of values of D_m, σ_1 and σ_1/σ_2 from charts and the calculation of the frequency series is illustrated in the Appendix.

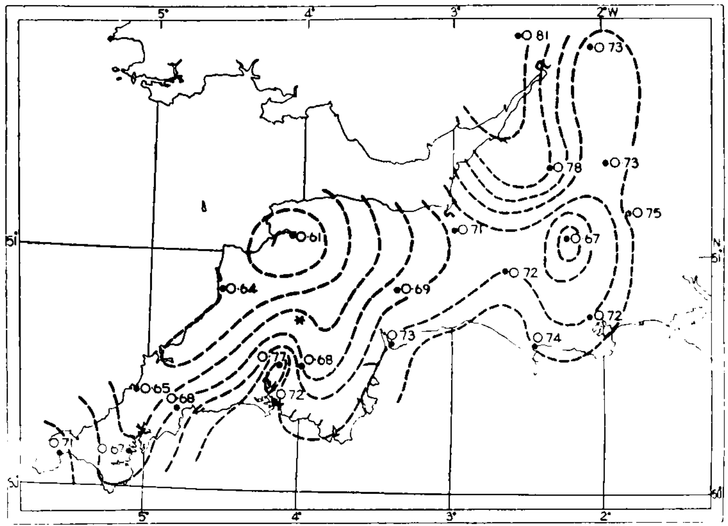


FIG. 2—VALUES OF P_4 IN AUGUST
The position of Okehampton is shown by a star.

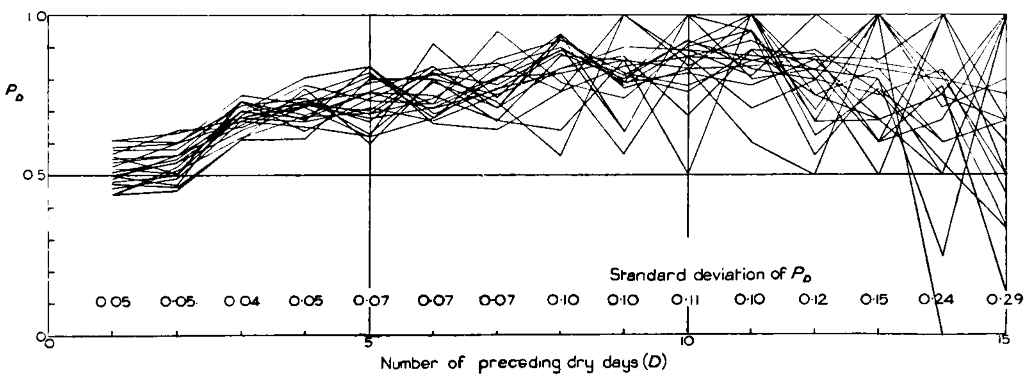


FIG. 3—VALUES OF P_D IN SOUTH-WEST ENGLAND IN AUGUST
P_1 = Proportion of dry days.

$$P_D = \frac{\text{number of spells of at least } D \text{ days}}{\text{number of spells of at least } (D-1) \text{ days.}}$$

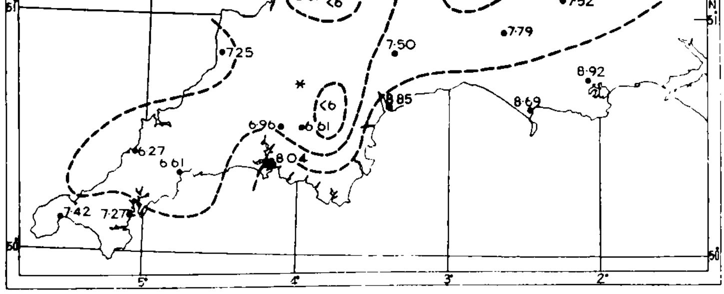


FIG. 4—MEAN LENGTH OF MAXIMUM SPELL OF DRY DAYS IN AUGUST (D_m)
The position of Okehampton is shown by a star.

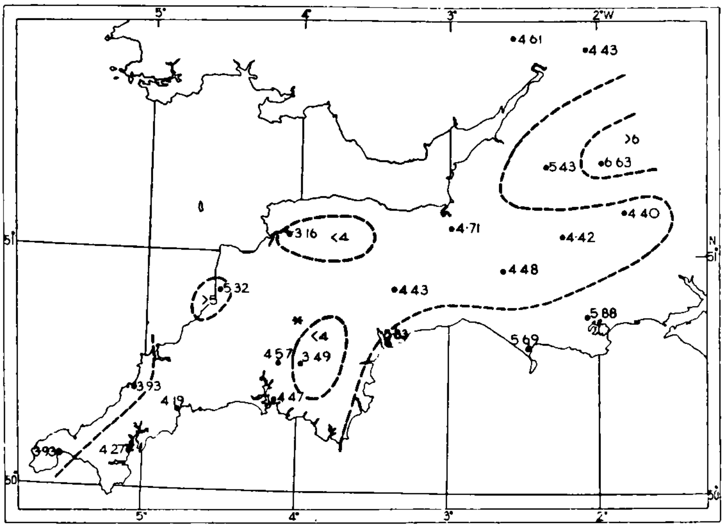


FIG. 5—STANDARD DEVIATION OF LENGTH OF MAXIMUM SPELL OF DRY DAYS IN AUGUST (σ_1)

The position of Okehampton is shown by a star.

TABLE IV—COMPARISON OF THE GEOMETRIC AND LOGARITHMIC SERIES

21 stations in south-west England, August, 1921–46

Length of run	Mean percentage error: Geometric series				Logarithmic series			
	N, P	$N, \bar{P}$	$\bar{N}, P$	$\bar{N}, \bar{P}$	a, r	$a, \bar{r}$	$\bar{a}, r$	$\bar{a}, \bar{r}$
days	*per cent.*				*per cent.*			
4	14	13	16	17	9	21	11	16
6	13	14	14	19	10	20	15	18
8	10	17	10	19	14	24	17	21
10	27	33	26	34	24	35	24	33

TABLE V—COMPARISON OF THE FOUR SERIES

21 stations in south-west England, August 1921–46

	Parameters: Variable	Constant	Cumulative series, mean error: 3–10	3–15	6–15
			percentage frequency		
Geometric	N, P	...	8	11	17
Logarithmic	a, r	...	8	11	16
"Natural-persistence" ...	$N, (\bar{P}_4 + x)$ etc.	...	9	13	24
	N	$\bar{P}_D$ $(D=4 \ldots 15)$	7	9	16
	$(\bar{P}_4 + x)$ etc.	$\bar{N}$	10	13	17
"Jenkinson-probability"	$\sigma_1/\sigma_2, D_m, \sigma_1$	...	17	19	20
	D_m, σ_1	$\sigma_1/\sigma_2 = 1$	19	20	22
	D_m	$\sigma_1/\sigma_2 = 1, \bar{\sigma}_1$	18	19	20
	σ_1	$\sigma_1/\sigma_2 = 1, \bar{D}_m$	28	28	25

Table IV confirms the superiority of the logarithmic series (when actual values of *a* and *r* are used) over the geometric series. Mean values for *N* and *a*

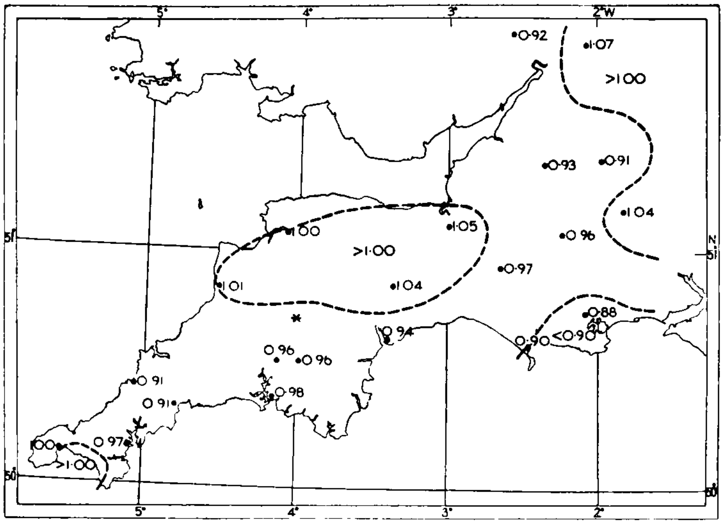


FIG. 6—RATIO OF STANDARD DEVIATIONS OF 1 YR. AND 2 YR. MAXIMUM LENGTHS OF SPELL OF DRY DAYS IN AUGUST (σ_1/σ_2)

The position of Okehampton is shown by a star.

appear to give useful approximations but, as might have been expected, mean values for P or r give errors which generally increase with length of run. However, in practice, good approximations may be obtained by reading P or r to 2 places of decimals with N or a to the nearest integer (see Appendix).

A good degree of agreement (see Table V) appears to be given by the "natural-persistence" series with area values for the probabilities, even though the latter are averaged for the whole of south-west England. When the area is more restricted an even better degree of agreement might be expected.

The approximate mean value of σ_1/σ_2 is unity, and if we assume that for a particular site $\sigma_1/\sigma_2 = 1$, we may calculate its series from the values of D_m and σ_1 (see example in Appendix, p. 269). Further approximate series may be obtained using $\sigma_1/\sigma_2 = 1$, a mean (area) value for D_m and σ_1, or alternatively using $\sigma_1/\sigma_2 = 1$, a mean (area) value $\bar{\sigma}_1$ and the local value of D_m. Examples are given in the Appendix.

It should be noted that when $\sigma_1/\sigma_2 = 1$, the y, D curve is a straight line of which the slope is $1/(0\cdot78\sigma_1)$, and the frequency series becomes a geometric series, i.e. there is zero persistence. The common ratio P of this series is given by

$$P = F_{D+1}/F_D = \exp(y_D)/\exp(y_{D+1})$$
$$= \frac{\exp[D/0\cdot78\sigma_1 + k]}{\exp[(D+1)/0\cdot78\sigma_1 + k]}, \text{ where } k \text{ is a station constant,}$$
$$= \exp(-1/0\cdot78\sigma_1) .$$

Comparison of the series.—The geometric and logarithmic series have been compared in an earlier paper[1]. A further comparison is given in Table IV. As a means of comparing the degree of agreement of the series with actual observations, the values of the mean percentage error,

$$\frac{\text{sum of observed minus calculated frequencies}}{\text{sum of observed cumulative frequencies}} \times 100,$$

were calculated for various stations for the ranges of lengths of run given in Table V.

TABLE VII—VALUES OF THE VARIABLES USED IN GEOMETRIC AND LOGARITHMIC METHODS

South-west England

	May				June				July				August				September			
	N	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*
Ross-on-Wye ...	53·0	0·74	22·7	0·86	54·0	0·81	16·1	0·91	49·0	0·78	22·3	0·86	47·0	0·79	22·0	0·86	45·0	0·77	21·3	0·86
Cheltenham ...	53·0	0·76	22·5	0·86	56·0	0·83	14·8	0·93	45·5	0·81	21·7	0·87	55·5	0·77	22·4	0·87	53·0	0·75	21·9	0·86
Bishop's Cannings ...	63·0	0·74	21·2	0·88	56·0	0·80	18·6	0·90	49·0	0·75	22·3	0·86	48·0	0·80	20·0	0·88	52·0	0·73	23·5	0·85
Larkhill ...	58·5	0·76	21·7	0·87	55·5	0·81	16·5	0·91	47·5	0·76	24·3	0·85	51·5	0·77	23·3	0·86	47·0	0·75	23·8	0·85
Bath ...	57·0	0·73	23·5	0·86	52·0	0·83	15·9	0·92	46·5	0·77	24·0	0·85	50·0	0·79	23·6	0·86	49·5	0·77	22·1	0·86
Bridgwater ...	57·5	0·79	18·8	0·90	48·0	0·86	15·3	0·93	49·5	0·74	24·5	0·84	55·0	0·78	21·8	0·88	49·0	0·78	21·5	0·87
Yeovil ...	53·0	0·73	20·5	0·87	50·0	0·84	14·1	0·92	43·0	0·78	20·3	0·86	50·0	0·76	22·5	0·86	44·0	0·74	22·3	0·84
Holton Heath ...	55·0	0·77	20·2	0·88	56·5	0·84	14·7	0·93	47·0	0·78	21·3	0·87	60·5	0·77	22·8	0·88	49·0	0·78	22·0	0·86
Weymouth ...	53·0	0·78	20·8	0·88	58·5	0·84	14·4	0·93	53·5	0·78	21·0	0·88	61·5	0·76	23·7	0·87	52·5	0·76	25·2	0·85
Barnstaple ...	59·0	0·71	23·0	0·86	48·5	0·83	17·6	0·90	42·0	0·74	23·3	0·83	41·5	0·70	28·8	0·79	38·0	0·75	24·4	0·82
Cullompton ...	55·5	0·75	21·4	0·87	47·5	0·85	14·9	0·92	46·0	0·77	20·2	0·86	48·0	0·76	24·9	0·84	43·0	0·76	21·9	0·85
Exmouth ...	54·5	0·78	19·7	0·89	57·5	0·82	17·2	0·91	52·5	0·77	19·3	0·88	56·0	0·78	21·6	0·88	49·5	0·78	19·9	0·88
Plymouth ...	57·5	0·78	21·1	0·89	49·0	0·83	17·4	0·91	42·0	0·80	20·8	0·86	57·0	0·75	20·0	0·87	50·5	0·73	21·8	0·85
Princetown ...	53·4	0·76	19·7	0·88	44·1	0·77	20·2	0·86	42·6	0·70	18·6	0·84	44·8	0·74	20·9	0·85	34·7	0·71	17·7	0·83
Tavistock ...	58·0	0·74	20·9	0·87	47·5	0·79	19·7	0·88	44·5	0·75	21·0	0·85	39·0	0·78	25·4	0·82	45·0	0·75	20·1	0·86
Bude ...	58·0	0·75	22·2	0·87	56·0	0·80	17·9	0·90	42·5	0·74	25·2	0·82	47·5	0·75	23·5	0·84	41·0	0·78	22·4	0·85
Mere ...	55·0	0·76	19·2	0·88	52·5	0·84	14·1	0·93	48·0	0·76	21·8	0·86	52·0	0·74	21·7	0·86	39·0	0·79	17·7	0·83
Falmouth ...	56·0	0·75	21·0	0·87	49·5	0·82	19·9	0·89	47·0	0·78	22·5	0·86	51·0	0·75	19·6	0·87	46·5	0·79	22·1	0·86
Newquay ...	52·0	0·73	23·6	0·85	51·0	0·79	19·9	0·89	35·5	0·73	26·1	0·80	46·0	0·72	25·1	0·82	39·0	0·77	22·0	0·84
Penzance ...	62·5	0·73	19·0	0·89	49·0	0·81	19·8	0·89	38·0	0·74	26·8	0·80	48·5	0·75	25·1	0·84	42·0	0·78	21·4	0·85
St. Austell ...	57·0	0·75	19·9	0·88	49·5	0·81	19·2	0·89	34·5	0·77	24·3	0·81	40·5	0·75	23·1	0·83	39·5	0·79	21·9	0·85
Mean ...	56·3	0·75	21·1	0·87	51·8	0·82	17·1	0·91	45·0	0·76	22·5	0·85	50·0	0·76	22·9	0·85	45·2	0·76	21·8	0·85

TABLE VIII—VALUES OF THE VARIABLES USED IN GEOMETRIC AND LOGARITHMIC METHODS

South-east England

	April				May				June				July				August				September			
	N	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*
Adderbury ...	47·0	0·77	22·7	0·86	56·5	0·77	18·3	0·89	54·5	0·83	14·5	0·93	50·0	0·77	21·5	0·87	53·5	0·80	20·0	0·89	56·5	0·75	22·2	0·87
Oxford ...	46·0	0·77	21·0	0·86	52·5	0·77	21·3	0·87	57·5	0·82	15·4	0·92	49·0	0·74	24·9	0·84	58·0	0·79	20·6	0·89	54·0	0·74	22·0	0·86
Lechlade ...	53·5	0·77	19·5	0·89	57·0	0·71	21·0	0·86	54·5	0·83	14·9	0·92	46·5	0·76	23·4	0·85	54·0	0·82	19·7	0·90	51·5	0·75	20·4	0·87
Oving House ...	50·5	0·78	18·1	0·89	53·0	0·77	21·0	0·87	55·5	0·82	16·9	0·91	53·0	0·74	23·1	0·86	52·0	0·80	21·2	0·88	48·0	0·77	25·0	0·25
Penn	49·0	0·80	18·8	0·89	58·0	0·80	16·6	0·91	53·0	0·84	15·3	0·92	53·5	0·77	22·8	0·87	54·5	0·77	23·1	0·87	57·0	0·74	23·3	0·86
Slough ...	55·5	0·77	18·4	0·89	56·5	0·79	16·3	0·91	52·0	0·83	16·1	0·92	55·5	0·75	21·0	0·87	59·5	0·76	20·4	0·89	45·0	0·81	20·9	0·87
Harrow ...	52·5	0·79	18·9	0·89	59·0	0·78	18·7	0·89	56·5	0·83	14·9	0·92	55·5	0·75	22·4	0·87	58·0	0·78	22·6	0·88	47·5	0·79	24·5	0 86
Potters Bar ...	55·5	0·76	18·9	0·89	60·5	0·77	19·8	0·89	53·5	0·83	16·7	0·91	52·0	0·77	21·6	0·87	53·5	0·80	20·6	0·89	50·0	0·77	23·6	0·86
Reading ...	52·5	0·77	19·9	0·88	61·5	0·76	20·0	0·89	58·0	0·81	16·2	0·92	57·5	0·74	23·8	0·86	58·5	0·79	21·1	0·89	50·0	0·77	23·3	0·86
Upton ...	45·0	0·80	19·6	0·88	55·0	0·77	20·1	0·88	59·0	0·81	15·0	0·92	54·0	0·76	22·5	0·87	44·0	0·82	21·5	0·87	57·0	0·75	22·4	0·87
Godalming ...	45·0	0·78	21·8	0·86	61·0	0·76	20·9	0·89	56·0	0·82	14·9	0·92	57·5	0·74	23·6	0·86	56·5	0·75	22·4	0·87	50·0	0·77	24·1	0·86
Kew	49·5	0·78	19·9	0·88	55·0	0·78	20·9	0·88	56·5	0·83	15·0	0·92	56·5	0·74	23·4	0·86	55·5	0·78	20·8	0·89	50·0	0·76	25·3	0·85
Reigate ...	50·0	0·78	19·9	0·88	60·0	0·78	18·7	0·90	55·5	0·83	15·6	0·92	58·5	0·77	22·4	0·87	54·0	0·78	22·4	0·87	52·0	0·77	23·9	0·86
Canterbury ...	60·0	0·76	21·1	0·88	57·5	0·79	20·1	0·89	60·5	0·80	18·8	0·91	60·0	0·78	21·8	0·89	57·5	0·79	20·5	0·89	50·5	0·78	23·4	0·86
Folkestone ...	51·0	0·77	21·9	0·87	52·5	0·81	19·3	0·89	60·5	0·80	17·4	0·91	56·5	0·75	21·4	0·87	57·5	0·79	20·8	0·89	52·0	0·76	24·1	0·86
Goudhurst ...	55·5	0·77	20·8	0·88	65·5	0·78	18·6	0·91	61·0	0·80	18·5	0·91	65·0	0·77	18·5	0·90	58·0	0·78	22·6	0·88	57·0	0·77	23·9	0·87
Sevenoaks ...	49·0	0·80	18·8	0·89	62·5	0·78	21·0	0·89	56·0	0·83	15·6	0·92	61·5	0·76	20·3	0·89	55·5	0·77	24·0	0·87	51·5	0·77	26·4	0·85
Andover ...	59·0	0·78	18·9	0·89	61·0	0·78	20·3	0·89	50·0	0·86	14·1	0·93	59·5	0·73	23·2	0·86	55·5	0·79	21·3	0·89	52·0	0·78	21·9	0·87
Fordingbridge	49·0	0·79	21·0	0·87	56·5	0·78	18·3	0·89	52·5	0·84	15·1	0·92	42·5	0·81	21·8	0·87	54·0	0·79	22·6	0·87	41·5	0·79	24·1	0·85
Heckfield ...	52·0	0·79	18·7	0·89	56·5	0·78	17·2	0·90	64·0	0·79	15·1	0·92	54·0	0·78	19·9	0·89	56·5	0·80	20·4	0·89	48·0	0·78	19·3	0·88
Selborne ...	46·0	0·78	19·5	0·87	53·0	0·80	19·3	0·89	56·0	0·81	15·1	0·92	50·5	0·73	24·5	0·84	56·5	0·75	21·8	0·87	50·0	0·76	21·0	0·87
Totland Bay ...	55·0	0·78	21·4	0·88	54·5	0·79	18·9	0·89	55·5	0·85	15·8	0·93	60·0	0·75	22·6	0·87	65·0	0·76	23·5	0·88	51·0	0·78	22·2	0·87
Compton ...	51·5	0·78	20·9	0·87	61·0	0·76	19·5	0·89	56·5	0·84	14·0	0·93	57·0	0·75	22·8	0·87	53·0	0·78	22·0	0·87	53·0	0·77	21·5	0·87
Eastbourne ...	48·0	0·77	24·6	0·85	59·0	0·76	20·2	0·89	61·0	0·79	18·3	0·91	48·5	0·79	23·7	0·86	56·0	0·72	25·4	0·85	46·5	0·77	24·6	0·85
Horsham ...	48·0	0·79	19·8	0·88	58·5	0·76	19·9	0·89	59·5	0·83	15·6	0·92	53·5	0·76	19·4	0·88	54·5	0·79	19·9	0·89	48·0	0·78	23·6	0·86
Worthing ...	57·0	0·78	20·6	0·89	61·0	0·80	18·5	0·91	63·0	0·82	16·1	0·92	58·0	0·78	21·1	0·89	57·0	0·80	21·6	0·89	52·0	0·79	22·1	0·87
Mean	51·3	0·78	20·2	0·88	57·9	0·78	19·4	0·89	56·8	0·82	15·8	0·92	54·8	0·76	22·2	0·87	55·7	0·78	21·6	0·88	50·8	0·77	23·0	0·86

TABLE IX—VALUES OF THE VARIABLES USED IN GEOMETRIC AND LOGARITHMIC METHODS

East England

	April				May				June				July				August				September			
	N	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*	*N*	*P*	*a*	*r*
Guthram ...	53·0	0·78	21·5	0·87	61·0	0·77	22·5	0·88	58·5	0·80	16·5	0·91	61·5	0·79	20·6	0·89	65·0	0·71	26·3	0·86	58·0	0·73	27·7	0·85
Boston	53·0	0·76	22·8	0·86	52·0	0·81	20·5	0·89	60·0	0·79	18·0	0·90	64·0	0·77	21·1	0·89	57·0	0·79	20·1	0·89	60·0	0·72	25·0	0·86
Horncastle ...	56·5	0·69	22·6	0·85	51·0	0·78	23·9	0·86	58·5	0·79	19·3	0·89	56·5	0·75	20·4	0·88	59·5	0·71	25·3	0·85	53·0	0·73	24·6	0·85
St. Ives ...	53·0	0·77	21·5	0·87	69·5	0·75	21·4	0·89	61·5	0·78	17·9	0·90	64·0	0·75	23·7	0·87	58·0	0·78	22·6	0·88	56·0	0·76	24·5	0·86
Peterborough ...	50·5	0·77	21·5	0·87	59·0	0·77	20·9	0·89	55·0	0·80	17·3	0·91	64·0	0·75	20·9	0·89	64·5	0·69	27·5	0·84	59·0	0·74	22·7	0·87
Cambridge ...	54·0	0·76	19·4	0·89	68·5	0·76	21·2	0·89	61·5	0·80	13·5	0·93	51·5	0·79	21·1	0·88	55·0	0·79	22·5	0·88	56·5	0·77	22·5	0·87
Stretham ...	62·0	0·78	20·9	0·89	70·5	0·76	20·1	0·90	60·5	0·81	15·8	0·92	56·5	0·81	20·5	0·89	61·0	0·79	24·3	0·88	59·5	0·77	21·7	0·89
Wisbech ...	55·5	0·74	24·3	0·86	61·5	0·76	21·1	0·89	60·5	0·80	18·0	0·91	55·5	0·75	23·2	0·86	62·0	0·73	24·0	0·87	56·0	0·73	26·1	0·85
Thetford ...	47·5	0·76	23·7	0·85	58·5	0·73	20·8	0·87	57·5	0·79	16·3	0·91	56·0	0·75	23·2	0·86	53·5	0·73	24·8	0·85	44·0	0·74	26·2	0·82
Hunstanton ...	62·0	0·72	23·2	0·86	53·0	0·77	22·2	0·87	59·5	0·79	18·8	0·90	58·5	0·77	23·2	0·87	61·5	0·75	21·9	0·88	57·5	0·75	23·0	0·87
Wiggenhall ...	61·0	0·74	21·8	0·87	61·0	0·77	21·6	0·89	59·5	0·80	17·4	0·91	59·5	0·76	22·2	0·87	63·5	0·74	24·1	0·87	60·5	0·73	24·2	0·86
Sprowston ...	51·5	0·74	19·8	0·87	62·0	0·75	17·2	0·90	57·5	0·79	17·5	0·90	60·5	0·76	21·5	0·88	58·0	0·75	23·7	0·86	48·5	0·71	24·3	0·83
Cromer ...	57·5	0·69	25·6	0·84	56·5	0·73	21·8	0·87	63·0	0·77	17·1	0·91	58·0	0·72	22·6	0·86	52·0	0·72	24·8	0·84	45·0	0·73	24·4	0·83
Lowestoft ...	50·5	0·74	23·5	0·85	60·0	0·79	18·0	0·91	54·5	0·81	18·0	0·90	52·5	0·79	22·7	0·87	62·5	0·74	21·9	0·87	58·0	0·73	21·9	0·87
Bury St. Edmunds	56·5	0·75	20·7	0·87	65·0	0·76	20·4	0·89	57·5	0·80	13·8	0·92	49·5	0·80	18·8	0·89	63·0	0·76	24·3	0·87	50·5	0·75	24·5	0·85
Campsea Ash ...	63·0	0·74	23·3	0·87	57·5	0·79	18·7	0·90	61·5	0·82	16·3	0·92	54·0	0·80	21·6	0·89	66·0	0·77	22·9	0·89	57·0	0·75	24·6	0·86
Hadleigh ...	49·0	0·77	21·0	0·87	61·0	0·78	18·6	0·90	55·5	0·81	18·2	0·90	57·5	0·77	21·5	0·88	65·0	0·73	23·2	0·87	48·0	0·75	26·8	0·83
Woburn ...	42·0	0·79	21·8	0·86	59·0	0·70	22·3	0·86	54·0	0·79	17·7	0·90	52·0	0·74	23·2	0·86	49·5	0·76	21·7	0·86	50·5	0·72	26·6	0·83
Bedford ...	49·5	0·80	19·5	0·89	65·0	0·74	21·8	0·88	55·0	0·82	16·7	0·91	61·0	0·76	21·6	0·88	58·0	0·76	22·6	0·87	52·5	0·77	22·6	0·87
Rothamsted ...	47·0	0·80	20·6	0·87	54·0	0·75	22·2	0·86	55·0	0·82	16·8	0·91	47·0	0·76	25·7	0·84	56·0	0·77	23·9	0·87	43·0	0·76	27·3	0·82
Therfield ...	50·0	0·77	21·6	0·87	60·0	0·73	23·1	0·86	55·5	0·81	16·6	0·91	56·5	0·74	26·3	0·85	58·0	0·74	24·6	0·86	52·0	0·75	24·0	0·86
Bradwell-on-Sea	56·0	0·80	21·8	0·89	69·5	0·79	17·7	0·92	62·0	0·82	16·5	0·92	65·5	0·79	20·2	0·90	69·0	0·79	21·0	0·90	59·0	0·78	21·5	0·89
Ingatestone ...	48·0	0·80	18·7	0·89	57·5	0·76	22·1	0·87	60·5	0·80	18·2	0·91	61·0	0·76	21·7	0·88	62·0	0·75	25·5	0·86	54·0	0·72	27·7	0·83
Halstead ...	54·0	0·78	21·1	0·88	60·0	0·78	19·7	0·89	58·0	0·83	17·9	0·91	60·0	0·79	18·3	0·90	63·0	0·78	22·1	0·89	56·0	0·76	25·5	0·86
Hatfield Broad Oak	50·0	0·77	19·7	0·87	63·5	0·78	18·4	0·90	55·5	0·83	15·6	0·92	52·5	0·78	21·9	0·87	57·0	0·78	21·0	0·89	52·5	0·73	24·7	0·85
Mean	53·3	0·76	21·7	0·87	60·6	0·76	20·7	0·89	58·3	0·80	17·0	0·91	57·4	0·77	21·9	0·88	60·0	0·75	23·5	0·87	53·9	0·74	24·6	0·85

APPENDIX

To calculate the frequencies of runs of dry days at Okehampton in August.

Geometric-series method.—Interpolating from charts based on the actual values of N and P observed at other stations, a selection of which is given in Table VII, N is 42 and P 0·74 for Okehampton. Using these values, the cumulative frequencies are calculated from N, NP, NP^2, NP^3, ... The results are shown in Table VI.

TABLE VI—OKEHAMPTON: OBSERVED AND CALCULATED DRY-RUN FREQUENCIES

	Chart parameters	No. of runs during the period 1921–46 with lengths (in days) ⩾3	⩾4	⩾5	⩾6	⩾7	⩾8	⩾9	⩾10	⩾11	⩾12	⩾13	⩾14	⩾15
Observed ...	...	41	29	21	17	11	9	7	6	6	3	2	2	1
Geometric ...	N, P	42	31·1	23·0	17·0	12·6	9·3	6·9	5·1	3·8	2·8	2·1	1·5	1·1
Logarithmic ...	a, r	42·5	28·5	19·9	14·3	10·4	7·7	5·8	4·4	3·3	2·5	1·9	1·5	1·2
"Natural persistence"	N, $P_4 \ldots P_{15}$	42	28·1	20·3	16·8	11·3	8·8	8·0	6·9	6·3	5·1	4·3	3·4	1·4
"Jenkinson probability"	σ_1/σ_2, D_m, σ_1	48·3	35·8	26·3	19·3	14·1	10·4	7·6	5·6	4·1	3·0	2·2	1·7	1·2

Logarithmic-series method.—Interpolating from charts drawn from actual values at other stations (see Table VII), a is 24 and r is 0·82 for Okehampton. Using these values the non-cumulative series is calculated from $a, \frac{ar}{2}, \frac{ar^2}{3}, \frac{ar^3}{4}, \frac{ar^4}{5}$, etc., and the cumulative series is

$$\frac{a}{r}\log_e\left(\frac{1}{1-r}\right) - a, \quad \frac{a}{r}\log_e\left(\frac{1}{1-r}\right) - a - \frac{ar}{2}, \quad \frac{a}{r}\log_e\left(\frac{1}{1-r}\right) - a - \frac{ar}{2} - \frac{ar^2}{3}, \text{ etc.}$$

The results are shown in Table VI.

"Natural-persistence" method.—Interpolating as before from values in Table I N is 42 and $P_4 \ldots P_{15}$ are 0·67, 0·72, 0·83, 0·67, 0·78, 0·91, 0·86, 0·92, 0·80, 0·84, 0·80, 0·40 respectively. The series is N, NP_4, NP_4P_5, $NP_4P_5P_6$, etc. The results are shown in Table VI.

"Jenkinson-probability" method.—Interpolating from stations in the region (Figs. 4–6) $\sigma_1/\sigma_2 = 0·99$, $D_m = 6·9$ and $\sigma_1 = 4·2$. Values of D are calculated from the formula

$$D = 6·9 + 4·2\,R,$$

where R is obtained from Table III (for $\sigma_1/\sigma_2 = 0·99$ and $y = -2, -1, 0, 1·50, 2·25, 3·20, 3·90$). The curve of y against D is plotted, and values of y corresponding to $D = 3, 4, 5, 6 \ldots 15$ are read off from this graph. The values of e^{-y} are then obtained from standard tables and, after multiplying by 26 (the number of years in the period), are shown in Table VI.

To be concluded

A TEST OF SYNOPTIC CHARTS FOR THE SOUTHERN OCEAN

By U. RADOK, Ph.D., B.Eng.

The construction of synoptic charts for the Southern Ocean presents problems without parallel in meteorological practice. In no other region must so many conclusions be drawn from so few observations. Except for the whaling grounds in summer the analysis has to rest on single-station techniques and models for the behaviour of pressure systems established from subsequent events on similar previous occasions. Yet just as the available observations define the present state only imperfectly they often leave considerable doubt about subsequent events, and it seems clear that only a limited check on a synoptic analysis for the region is provided by the time series of the data used in its construction.

A much more stringent test can be made by means of ships' observations which were either not reported or else not available to the analyst at the time. Quite a few such sets of observations must be in existence, and their systematic examination in conjunction with Southern Ocean charts for the same period would be instructive. To exemplify this, the present note deals with a short series of observations made by the writer in the course of a summer journey on board the M.V. *Tottan* from Hobart to the Antarctic continent and back, at a time when there was no other ship anywhere in the region and the only reports received were those from Macquarie Island and Campbell Island, further east, and from Heard Island, much further west.

Two different series of Southern Ocean charts for the period of the journey were available for examination. They will be distinguished by the letters A and B in the following, and differed from one another in several respects. A small number of the ship's observations were used in analysis A, whereas analysis B was made without any knowledge of them. However, while analysis A was left in its initial form the charts of set B were re-drawn later with subsequent events as a guide. A comparison of these two analyses, with the observations at a moving point, will thus show not only whether the charts are realistic, but will also have a bearing on the relative merits of careful re-analysis as against just one more isolated station.

Method of comparison.—An exhaustive comparison of synoptic analyses represents a major task much beyond the scope of this note. Instead, the comparisons here will be exclusively in terms of surface pressures, those observed by the ship on the one hand and those given by the two chart series for the location of the ship on the other. The ship's observations were made every three hours during the day, with larger gaps at night, whereas the charts were drawn once a day, at 0600 G.M.T., only. To enlarge the comparisons, use was made of continuity. Each chart series was transformed into a diagram showing isobars for the ship's latitude in a time-longitude coordinate system. Fig. 1 shows the diagrams constructed from seven charts from series A and B covering part of the return journey. This representation gives a clear idea of the motion of pressure systems provided this is largely zonal. The ship's track has been indicated and the pressures expected from the analysis can be found by interpolating between the points of intersection of the track with the isobars. Naturally the new sets of isobars involve some additional smoothing, so that exact agreement between the observed and the chart pressures is ruled out. However the pattern of changes in the two pressure series would certainly be similar if the analysis were realistic.

Such comparisons between the observed pressures and those given by the two chart series are shown in Fig. 2 for two 7-day periods. The second of these is that illustrated in Fig. 1. The ship during the first part of this period was heading north but later was forced by the seas from a 60-kt. gale to turn west. Thus the total latitude change amounted to less than 10° during this period. On the other hand during the first 7-day period the ship travelled south through some 20° of latitude; the time-longitude isobars have not been reproduced for this period because they permit of no simple interpretation, even though they still serve for their immediate purpose here. The dots in Fig. 2 give the observed pressures. Some of these have been joined to the full curve of the series-A pressures to indicate that the observation in question was used in drawing the chart for that day at 0600 G.M.T.

Discussion.—The curves in Fig. 2 largely speak for themselves, but a few comments may be made. In the first period the agreement between the observed pressures and those given by the charts of series A is very good, even

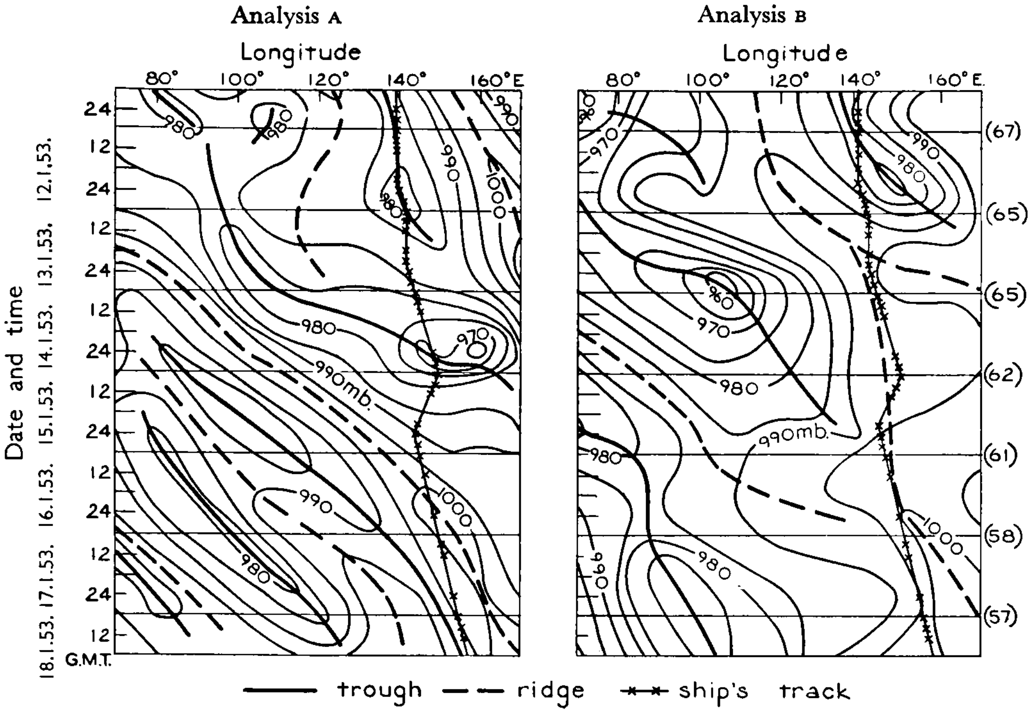


FIG. 1—DIAGRAM ON A TIME-LONGITUDE-COORDINATE SYSTEM SHOWING ISOBARS FOR THE SHIP'S LATITUDE

Figures in brackets represent the ship's latitude at 0600 G.M.T. in °S.

though only every second chart included the ship's observation. The correct placing of the pressure rise on December 29 should be noted. The charts of series B show similar features but the pressures were underestimated throughout; also the Antarctic trough was placed into too low a latitude i.e. at too early a date. At the end of the period a break occurred in the weather messages while the ship was engaged in landing operations; as might be expected both chart series seem to have got out of step with events at that stage.

More striking differences between the two analyses occurred during the second period, illustrated in Fig. 1. As series A started with four successive charts including the ship's observations it was possible to appraise correctly the essential details of the intense depression which appears to have deepened right on the ship's track. Series B also showed this depression but allowed it to fill prematurely. This emerged from the individual charts; the representation in Fig. 1 permits no distinction between a filling depression and one that moves away from the ship's latitude. On the other hand the renewed pressure fall on January 17 was contained in analysis B but not in A which by then had been placed on the same footing, with the ship's radio out of action after the rough weather of the preceding two days.

The foregoing comparisons could also have been made in terms of observed and expected weather; but the pressure discussion will suffice to illustrate the enormous value of a single additional station and the magnitude of errors that can creep into the most careful analysis for the Southern Ocean in regions without at least an occasional observation. It may be hoped that the behaviour of the Southern depressions will become much better understood in

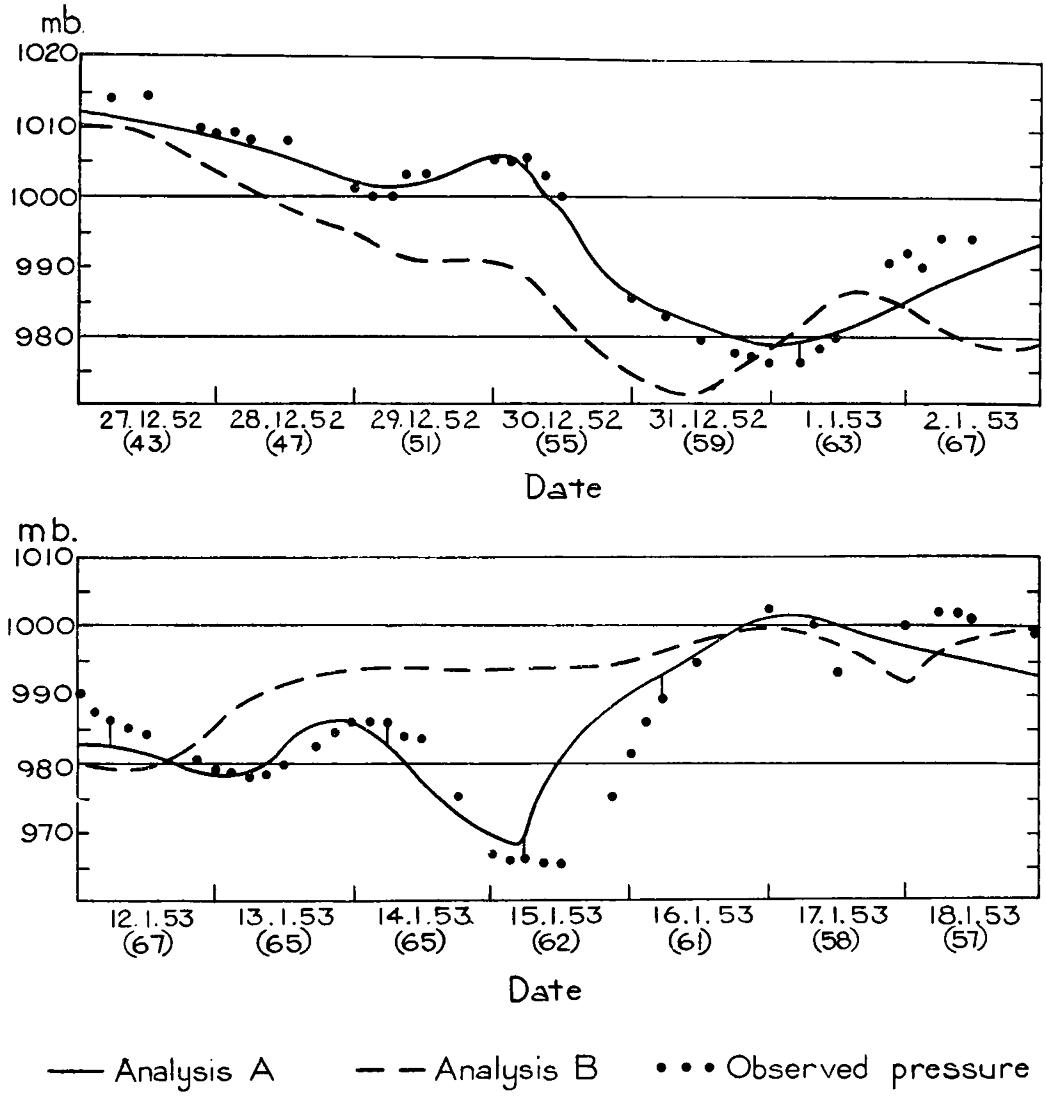


FIG. 2—OBSERVED AND CHART PRESSURES FROM ANALYSES A AND B FOR THE SHIP'S POSITION

Figures in brackets represent the ship's latitude at 0600 G.M.T. in °S.
Where the dot is joined to the full curve the chart of analysis A was drawn with knowledge of the ship's observation.

the course of the International Geophysical Year; already reports from some of the preliminary bases have given the clues to events in the Australia–New Zealand sector which would have remained puzzles with the network in existence a few months earlier. However, even greater assistance for the analysis of the Southern Ocean will result from one or other of the Antarctic stations that may be kept operating permanently after 1958.

Acknowledgement.—Thanks are due to the analysts who made available the charts used in this note.

ERRATUM

On page 196, line 16 of the *Meteorological Magazine* for July 1957 the word diameters which appears twice should be replaced by radii in both cases.

Photograph by D. W. S. Limbert

WATER SKY AND ICE BLINK

The phenomena of water sky and ice blink are depicted. They are the result of the reflection of the water and ice upon the lower cloud surface. To ice navigators they are of prime importance as they act as a road map to the areas of open water. At Halley Bay in summer the angular elevation of water sky boundary helped in estimating cloud height.

(see p. 285)

Photograph by D. W. S. Limbert

THE MIDNIGHT SUN—NOVEMBER 1956

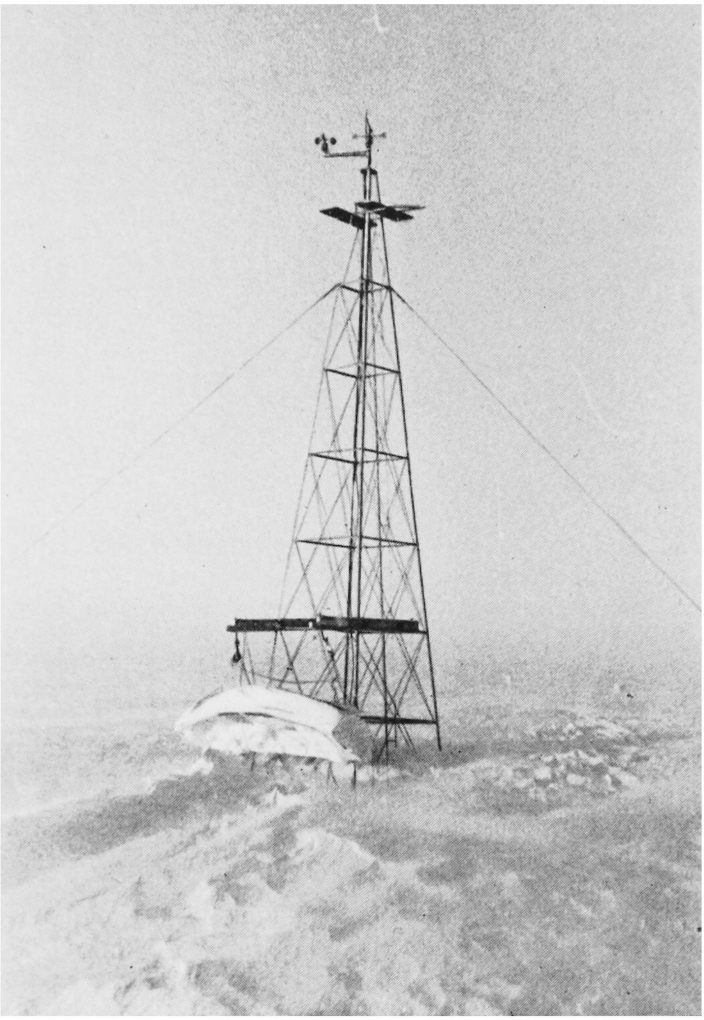
At Halley Bay the sun was above the horizon continuously for approximately 100 days. To obtain complete 360° coverage of sunshine two modified temperate latitude sunshine recorders were placed facing north and south respectively (seen either side of diffuse radiation solarimeter mounting). The actual total and diffuse radiation on a horizontal surface was continuously recorded using standard Moll-Gorczinski solarimeters. All the instruments were mounted on a roof platform at ridge level.

Owing to the rate of accumulation of snow—both actual precipitation and drift—it will be necessary to build a higher platform for the summer of 1957–58.

The cloud in the picture was high altocumulus.

The longest run of continuous sunshine was from 20th to 23rd November—a total time of 79·7 hours.

(see p. 285)



Photograph by D. W. S. Limbert

THE ANEMOMETER TOWER

The anemometer tower erected in April was put to a novel use. The boat was hung upside down on davits, so that, in an emergency, a sledge could be driven underneath and the boat could be driven down to the open water about one and a half or two miles away. This was a case of learning from a previous expedition. Two men had been drowned and one spent an uncomfortable sixteen hours on a floe, after their tractor had been driven in bad visibility into the sea. The rescuers spent twelve hours digging their boat out of the snow.

At the time of the picture there was slight drift reducing visibility to about 400 yds. With overcast sky this would have meant a complete 'white out'. That is, no undulation or surface feature could be discerned, and locomotion became a form of stumbling and falling up or down drifts.

(see p. 285)

Photograph by D. W. S. Limbert

ANTARCTIC DESOLATION

The old (unmodified) and new (modified) screens are shown just after one of the worst blizzards, during which much snow accumulated, covering the optical system of the All Sky Camera (right). The storm in question lasted for five days at the beginning of September (maximum gust 74 knots) and it was necessary for the observer to follow the line of stakes to reach the screen in use (modified screen). Even a two yard separation of stakes was at times too great. It was easy to get lost ten yards away from the hut.

(see p. 285)

NOTE ON THE MEAN CHARACTERISTICS OF THE MARITIME EQUATORIAL TROPOSPHERE OVER SINGAPORE

By L. S. CLARKSON, M.Sc.

Summary.—Characteristics significant to aviation of the equatorial atmosphere over Singapore are evaluated, and some information is given on the probable errors of the mean parameters.

The Observations.—From time to time, meteorological flights have been made at approximately 0300 G.M.T. (1030 hr. local time) over Seletar (01°25′N., 103°53′E.) on Singapore Island during the period September 1949 to October 1954. These ascents are a continuation of those made from December 1946 to July 1948 which have been comprehensively analysed by John[1]. In addition to the aircraft ascents, which rarely reached levels above 250 mb., daily radio-sonde ascents to 100 mb. over Singapore at 0300 G.M.T. have been broadcast by the Malayan Meteorological Service during the period of operation of the sonde from August 1954 to October 1955.

Analysis and Discussion.—Mean monthly and annual temperatures and heights of the standard pressure surfaces and their standard deviations evaluated from the Seletar ascents are presented at Table I. The results are consistent with those set out by John[1] for the earlier series of flights, the mean annual temperatures at corresponding pressure levels differing by less than 0·5°C., except at 900 mb. and 300 mb., where the differences are 0·8°C. and 1·1°C. respectively.

The standard deviation of the temperature observations from their annual mean values varies at the different levels between 1·5°C. and 2°C. The standard random error of the observations themselves is not known, but is likely to be comparable with random errors in radio-sonde temperatures, which have been quoted[2] as 0·5–0·8°C. Thus, the real variation of temperature at 0300 G.M.T. at any given pressure level is clearly quite small, with a probable error of about 1°C. Hence it follows that there is seldom any appreciable temperature contrast between the air masses which affect Singapore, and real departures from the mean, of significance for forecasting, occur very infrequently. Consequently, it is unlikely that further regular upper air temperature observations over the Island will provide information of any considerable value for forecasting weather developments in equatorial south-east Asia.

TABLE II—MEAN ATMOSPHERE FOR 0300 G.M.T., AT SINGAPORE

I.C.A.O. Height (Sub-scale 1013·2)	Altitude	Alticor	Pressure	Virtual Temperature	Temperature	Density†
Thousands of feet		ft.	mb.	°C.	°C.	%
0·057	Zero	...	1011	31·3	+28·0	94·4
0·363	0·315	− 48	1000	28·9	+25·7	94·2
4·77	4·95	+ 180	850	19·9	+18·1	82·5
9·88	10·34	+ 460	700	10·2	+ 9·4	70·3
13·79	14·47	+ 680	600	3·0	+ 2·4	61·8
18·28	19·24	+ 960	500	...	− 5·5	53·1
23·56	24·86	+1,300	400	...	−15·6	44·2
30·05	31·78	+1,730	300	...	−30·6	35·2
38·64	40·78	+2,140	200	...	−52·9	25·8
44·63	46·67	+2,040	150	...	−67·0	20·7
53·09	54·09	+1,390	100	...	−77·9	14·6

† Relative to that of dry air at 1013·2 mb. and 15°C.

TABLE I—SUMMARY OF RESULTS OF AIRCRAFT UPPER AIR TEMPERATURE SOUNDINGS: SELETAR

Pressure		Jan. 1951–53	Feb. 1950–54	Mar. 1950–54	Apr. 1950–52, 54	May 1950–52, 54	June 1950–52, 54	July 1950–54	Aug. 1950–52, 54	Sept. 1949, 51, 53–54	Oct. 1950–54	Nov. 1950, 51, 53	Dec. 1950, 51, 53	Year
mb. 1,000	Height in ft. ...	310 (42)	309 (41)	296 (38)	267 (27)	251 (45)	255 (54)	275 (82)	284 (39)	305 (48)	306 (46)	288 (41)	315 (34)	288
	S.D.* of height ...	40	44	32	35	41	45	40	34	39	39	37	28	44
900	Temperature in °C.	20·9 (42)	19·9 (41)	20·7 (39)	21·3 (29)	21·3 (45)	21·6 (57)	21·0 (82)	21·1 (39)	21·0 (48)	21·8 (46)	21·1 (42)	21·0 (35)	21·6
	S.D. of temperature	1·9	1·4	1·3	1·0	1·1	1·1	1·1	1·3	1·2	1·7	1·7	1·6	1·5
	Height in ft. ...	3,328 (41)	3,330 (40)	3,326 (38)	3,302 (27)	3,293 (45)	3,292 (54)	3,307 (82)	3,319 (39)	3,337 (47)	3,348 (45)	3,317 (40)	3,342 (34)	3,320
	S.D. of height ...	39	53	37	42	42	46	41	43	45	42	43	27	46
850	Temperature in °C.	18·2 (42)	17·4 (41)	17·9 (39)	18·3 (29)	18·6 (45)	18·7 (58)	18·2 (81)	18·1 (39)	18·1 (49)	18·8 (46)	18·2 (41)	18·0 (34)	18·2
	S.D. of temperature	1·9	1·4	1·2	1·2	1·3	1·2	1·0	1·1	1·2	1·8	1·9	1·7	1·5
800	Temperature in °C.	15·7 (42)	14·6 (41)	15·2 (39)	15·6 (29)	15·8 (45)	15·7 (58)	15·0 (82)	15·2 (39)	15·1 (49)	15·8 (47)	15·3 (41)	15·1 (33)	15·3
	S.D. of temperature	2·1	1·4	1·1	1·3	1·5	0·9	1·0	1·3	1·4	1·8	1·6	1·5	1·5
	Height in ft. ...	6,640 (41)	6,647 (40)	6,651 (36)	6,629 (27)	6,614 (45)	6,623 (54)	6,630 (81)	6,643 (39)	6,660 (46)	6,676 (45)	6,645 (40)	6,661 (33)	6,643
	S.D. of height ...	40	64	49	53	49	46	49	46	52	56	55	35	53
700	Temperature in °C.	10·3 (42)	8·6 (41)	9·1 (39)	9·8 (29)	9·8 (44)	9·9 (58)	9·0 (82)	8·8 (39)	9·0 (49)	9·8 (46)	9·5 (40)	9·6 (32)	9·4
	S.D. of temperature	2·3	1·5	1·4	1·2	1·4	1·0	1·1	1·4	1·4	1·8	1·8	1·7	1·6
	Height in ft. ...	10,310 (41)	10,320 (40)	10,330 (35)	10,300 (27)	10,290 (42)	10,310 (54)	10,310 (82)	10,320 (39)	10,340 (47)	10,370 (46)	10,330 (39)	10,350 (32)	10,320
	S.D. of height ...	13	77	55	61	63	55	63	55	63	81	82	56	71
600	Temperature in °C.	3·4 (42)	1·3 (41)	2·4 (38)	2·4 (29)	2·4 (44)	2·0 (58)	2·1 (79)	1·7 (38)	2·0 (49)	2·8 (46)	2·6 (41)	2·4 (31)	2·3
	S.D. of temperature	2·4	1·8	1·1	1·0	1·4	1·1	1·1	1·1	1·6	2·0	1·9	1·7	1·7
	Height in ft. ...	14,450 (41)	14,460 (40)	14,500 (35)	14,470 (27)	14,450 (44)	14,570 (54)	14,450 (79)	14,460 (39)	14,490 (47)	14,530 (45)	14,490 (38)	14,510 (32)	14,490
	S.D. of height ...	27	97	102	82	90	78	75	74	91	103	120	77	93
500	Temperature in °C.	− 3·8 (42)	− 6·5 (41)	− 5·7 (37)	− 5·4 (29)	− 5·4 (44)	− 6·0 (56)	− 6·6 (78)	− 6·8 (39)	− 6·2 (49)	− 5·3 (46)	− 5·6 (40)	− 6·0 (28)	− 5·8
	S.D. of temperature	2·6	1·8	1·0	1·4	1·3	1·2	1·4	1·2	1·8	1·7	1·4	1·4	1·7
	Height in ft. ...	19,220 (41)	19,210 (40)	19,270 (35)	19,230 (27)	19,220 (44)	19,230 (52)	19,200 (79)	19,200 (39)	19,230 (47)	19,310 (46)	19,260 (37)	19,240 (28)	19,230
	S.D. of height ...	26	102	106	102	56	83	83	99	97	137	146	111	105
400	Temperature in °C.	−13·8 (40)	−17·3 (40)	−15·9 (36)	−15·6 (29)	−15·9 (43)	−16·2 (56)	−16·7 (80)	−16·9 (38)	−16·9 (48)	−16·1 (44)	−15·7 (40)	−16·5 (27)	−16·1
	S.D. of temperature	3·9	2·2	1·0	1·2	1·3	1·4	1·6	1·2	1·8	1·7	1·4	1·4	2·0
	Height in ft. ...	24,820 (39)	24,830 (39)	24,920 (33)	24,830 (26)	24,850 (43)	24,840 (51)	24,820 (78)	24,820 (39)	24,860 (47)	24,930 (43)	24,880 (37)	24,880 (27)	24,860
	S.D. of height ...	359	126	171	170	101	87	98	114	114	163	165	142	203
300	Temperature in °C.	−28·6 (39)	−32·1 (38)	−31·6 (36)	−30·4 (26)	−30·6 (42)	−31·2 (56)	−32·4 (82)	−32·4 (39)	−32·7 (46)	−32·6 (44)	−31·2 (40)	−32·2 (27)	−31·5
	S.D. of temperature	2·1	2·3	2·3	1·1	1·6	1·3	1·2	0·9	1·6	1·4	1·4	1·3	2·0
	Height in ft. ...	31,770 (39)	31,690 (38)	31,820 (33)	31,820 (25)	31,770 (42)	31,770 (52)	31,700 (78)	31,700 (38)	31,730 (45)	31,830 (44)	31,810 (36)	31,780 (27)	31,770
	S.D. of height ...	219	148	203	201	108	88	114	134	122	174	202	170	168
200	Temperature in °C.	...	...	...	...	−54·7 (9)	−54·3 (24)	−55·6 (22)	−56·0 (17)	−56·4 (19)	−56·7 (8)	...	...	−55·6 (May–Oct.)
	S.D. of temperature	...	...	...	...	2·2	1·0	2·3	1·1	1·8	1·5	...	...	1·9
	Height in ft. ...	...	...	...	...	40,780 (3)	40,760 (24)	40,570 (22)	40,570 (17)	40,550 (19)	40,500 (8)	...	...	40,620 (May–Oct.)
	S.D. of height ...	...	...	...	...	110	100	114	92	109	187	...	...	163

Heights are heights of pressure surface above mean sea level.

* S.D.=Standard deviation.

The number of observations is shown in brackets.

TABLE III—MEAN ATMOSPHERE FOR 0300 G.M.T. AT SINGAPORE AT 2,000-FT. INTERVALS OF I.C.A.O. HEIGHT

I.C.A.O. Height*	Altitude	Alticor	Pressures	Virtual Temperature	Temperature	Density†
Thousands of feet		ft.	mb.	°C.	°C.	%
0·057	0·00	− 57	1011·0	31·3	+28·0	94·4
2	2·05	+ 50	942·1	25·5	+23·0	89·8
4	4·15	+ 150	875·1	21·5	+20·0	84·5
6	6·25	+ 250	811·9	17·5	+16·5	79·5
8	8·35	+ 350	752·6	13·5	+13·0	74·7
10	10·45	+ 450	696·9	10·0	+ 9·5	70·0
12	12·6	+ 600	644·3	6·0	+ 5·5	65·7
14	14·7	+ 700	595·1	2·5	+ 2·0	61·4
16	16·8	+ 800	549·0	...	− 1·5	57·5
18	18·9	+ 900	505·7	...	− 5·0	53·6
20	21·1	+1,100	465·3	...	− 9·0	50·1
22	23·2	+1,200	427·8	...	−12·5	46·7
24	25·3	+1,300	392·5	...	−16·5	43·5
26	27·5	+1,500	359·6	...	−21·0	40·6
28	29·6	+1,600	329·1	...	−25·5	37·8
30	31·7	+1,700	300·8	...	−30·5	35·3
32	33·8	+1,800	274·2	...	−35·5	32·8
34	35·9	+1,900	249·8	...	−41·0	30·6
36	38·0	+2,000	227·1	...	−46·0	28·4
38	40·1	+2,100	206·3	...	−51·5	26·5
40	42·1	+2,100	187·4	...	−56·0	24·6
42	44·1	+2,100	170·2	...	−61·5	22·9
44	46·0	+2,000	154·6	...	−66·0	21·2
46	47·9	+1,900	140·4	...	−69·0	19·6
48	49·7	+1,700	127·5	...	−71·5	18·0
50	51·6	+1,600	115·9	...	−74·0	16·6
52	53·4	+1,400	105·4	...	−76·5	15·3

* Sub-scale set at 1013·2 mb.

† Relative to that of dry air at 1013·2 mb. and 15°C.

Taylor[2] has estimated the standard error of heights of the 500-mb. surface, computed from radio-sonde pressure and temperature observations, as 35 ft. The standard deviation of the computed heights over Singapore from the annual mean value of the height of the 500-mb. surface is 105 ft. (Table I). From this, it is apparent that the real variation in height of the 500-mb. surface over Singapore is small, the annual mean having a probable error of about 64 ft.

At present, no upper air temperatures are being measured over Singapore. But, because of the small scatter about the mean that has been shown by past observations, it is possible to write down the characteristics of a mean maritime equatorial atmosphere, actual departures from which should seldom be of significance for aviation. This has been done in Table II by utilizing all the aircraft upper air temperature observations, and also the Malayan Meteorological Service 0300 G.M.T. daily radio-sonde observations from August 1954 to October 1955. By graphical interpolation between the data in Table II, Table III has been derived, giving at 2,000-ft. intervals of I.C.A.O. height, the mean true altitude; altimeter correction (alticor); air pressure, temperature, virtual temperature and percentage density relative to that of dry air at 1013·2 mb. and 15°C.

It is thought that the data in Table III may prove useful in computing performance curves and characteristics of aircraft destined for Malaya more realistic than those based on the assumption of the aircraft operating in upper air temperatures and densities equivalent to those in the standard I.C.A.O. atmosphere.

Particularly in the height range 34,000–46,000 ft., the large corrections which must be added to the readings of the pressure altimeter with the sub-scale set at 1013·2 mb. to obtain true altitude over Singapore are noteworthy. Since upper air winds and temperatures are forecast at heights above mean sea level, and since there is often a marked increase of wind speed with height around 40,000 ft. over Singapore, neglect of these altimeter corrections (alticors) in flight planning is liable to lead to marked discrepancies between actual and anticipated performance of jet-engined aircraft.

REFERENCES

1. JOHN, I. G.; The properties of the upper air over Singapore. *Mem. Malay met. Serv., Singapore,* No. 4, 1950.
2. TAYLOR, A. P.; Accuracy of the height of a given pressure level as determined from radio-sonde and radar data. *Met. Res. Pap., London,* No. 673, 1951.

SOME EARLY OBSERVATIONS OF THE FREE ATMOSPHERE IN HIGH LATITUDES

By F. LOEWE, Ph.D.

The earliest instrumental observation in the free atmosphere of polar regions seems to have been made on January 26, 1822, when during an expedition with *Fury* and *Hecla*, W. E. Parry and G. Fisher raised a kite with a "register thermometer" attached, to a height of 400 ft. at Winter Island (66°11'N., 83°10'W.). They found that the temperature at the greatest height was almost identical with that of −24°F. at the surface[1, 2]. In other references[3, 4] the place of the ascent is erroneously given as Igloolik (69°21'N., 81°53'W.), the location of Parry's subsequent wintering. On December 12, 1836, Back, drifting icebound in the *Terror* off Southampton Island (65°12'N., 83°40'W.) sent a kite with a recording thermometer to 1,200 ft. where the temperature was found to be 8°F. lower than at the surface. These flights were repeated a few times during the same winter[5, 6, 7]. At the suggestion of Arago, two captive balloon flights to 900 and 1,400 ft. and 32 kite ascents to 200–400 ft. were made in 1838 by Bravais, Lottin and Martins during the winter at Bossekop (70°N. 23°E.) in Alta Fjord near the European North Cape[8, 9]. They found a prevalence of temperature increases with height to about 300 ft. and slow decreases above that height. The size of the temperature inversions increased with decreasing surface temperature and cloudiness. Some temperature observations were taken during Andrée's ill-fated balloon flight from Spitsbergen over the polar sea in 1897[10]. The first comprehensive studies of the free atmosphere by captive balloons and kites in a truly polar climate were made by Wegener in Danmarkshavn (76°46'N., 18°45'W.) during Mylius Erichsen's expedition[11, 12]. At the same time Hergesell had started to make sounding-balloon flights in northern waters[13, 14, 15, 16]. During these flights the stratosphere was possibly reached on July 16, 1906, off Spitsbergen (79°N., 08°E.) at a height of 25,000 ft., and definitely on August 11, 1910 (76½°N., 09°E.) at 35,000 ft. Simultaneously sounding-balloon flights had been started in Kiruna (68°N., 20°E.) in northernmost Sweden where the stratosphere had been reached in March 1907[17]. The first successful radio-sonde flights in the Arctic were probably those launched by Molchanov and Weickmann from the airship *Graf Zeppelin* during its Arctic cruise in July 1931[18, 19, 20].

In the Antarctic the first meteorological measurements in the free atmosphere to a height of 1,000 ft. were taken by the Gauss expedition in a manned balloon on March 29, 1902 from the sea ice off Kaiser Wilhelm II Land (66°S., 89½°E.)[21]. During the midday hours a weak inversion of temperature was established. No meteorological observations seem to have been made at the occasion of the slightly earlier balloon ascent of the *Discovery* expedition on February 2, 1902 on the Ross Ice Shelf (78½°S., 164°W.). The first Antarctic sounding-balloon flights were made in 1911 by G. C. Simpson in McMurdo Sound (77°S., 166°E.); the highest reached 22,000 ft.[22] Shortly afterwards, in 1912, Barkow made a great number of balloon and kite ascents during the drift of the *Deutschland* in the Weddell Sea[23, 24, 25]. After unsuccessful attempts by Holmboe at Deception Island (63°S., 60½°W.) in 1934[26], the first radiosonde flights in the Antarctic were made by Lange and Regula during the *Schwabenland* expedition[27, 28, 29, 30]. These flights were also the first to reach the Antarctic stratosphere. It was first established by Court in *Little America III* that in high southern latitudes the stratosphere of nearly uniform temperature disappears towards the end of winter[31, 32].

REFERENCES

1. PARRY, W. E.; Second voyage for the discovery of a north-west passage from the Atlantic to the Pacific. London, 1824, p. 155.
2. London, Meteorological Council; Contributions to our knowledge of the meteorology of the Arctic regions, Part 3. London, 1882, p. 281.
3. HARVEY, G.; Meteorology. Encyclopaedia Metropolitana, General system of knowledge. Scientific treatises, Vol. V, 2nd division. London and Glasgow, 1834, p. 73.
4. London, Meteorological Office; Scientific kite work in the Arctic regions. *Met. Mag., London*, **32**, 1897, p. 34.
5. BACK, G.; Narrative of an expedition in H.M.S. *Terror*, undertaken with a view to geographical discovery on the Arctic shores in the years 1836–7. London, 1838, pp. 165, 328.
6. London, Meteorological Council; Contributions to our knowledge of the meteorology of the Arctic regions, Part 2. London, 1880, p. 94.
7. London, Meteorological Office; The scientific use of kites. *Met. Mag., London*, **30**, 1895, p. 10.
8. BRAVAIS, A., LOTTIN, V. C. and MARTINS, C. F.; Lettre de M. M. Lottin, Bravais et C. Martins à M. Arago relative aux travaux de la Commission scientifique du Nord. *C.R. Acad. Sci., Paris*, **10**, 1840, p. 283.
9. BRAVAIS, A.; De la température de l'air à diverses hauteurs au-dessus du sol dans les contrées boréales. *C.R. Acad. Sci., Paris*, **30**, 1850, p. 697.
10. [Stockholm], Swedish Society of Anthropology and Geography. The Andrée diaries. London, 1931.
11. WEGENER, A.; Vorläufiger Bericht über die Drachen–und Ballonaufstiege der Danmark–Expedition nach Nordostgrönland. *Met. Z., Braunschweig*, **26**, 1909, p. 23.
12. WEGENER, A.; Drachen–und Fesselballonaufstiege. Danmark–Ekspeditionen til Grønlands Nordøstkyst 1906–08. *Medd. Gronland, Kobenhavn*, **42**, 1909.
13. HERGESELL, H.; Die Erforschung der freien Atmosphäre über dem Polarmeer. *Beitr. Phys. frei. Atmos., Strassburg*, **2**, 1906–08, p. 96.
14. HERGESELL, H. und MIETHE, A.; Mit Zeppelin nach Spitzbergen. 1911, p. 262.
15. HERGESELL, H.; Aerologische Studien im arktischen Sommer. *Beitr. Phys. frei. Atmos., Leipzig*, **6**, 1914, p. 224.
16. HERGESELL, H.; Der erste Registrierballonaufstieg in hohen arktischen Breiten. *Beitr. Phys. frei. Atmos., Leipzig*, **20**, 1933, p. 261.
17. TEISSERENC DE BORT, L.; Sur la distribution de la température dans l'atmosphère sous le cercle polaire. Nord et à Trappes. *C.R. Acad. Sci., Paris*, **145**, 1907, p. 149.
18. WEICKMANN, [L]. und MOLTSCHANOFF, [P].; Kurzer Bericht über die meteorologisch-aerologischen Beobachtungen auf der Polarfahrt des "Graf Zeppelin". *Met. Z., Braunschweig*, **48**, 1931, p. 409.
19. WEICKMANN, L.; Die meteorologischen Aufgaben bei der Polarfahrt des "Graf Zeppelin". Juli 1931, *Petermanns Mitt, Gotha.* Ergänzungsheft Nr. 216, 1933, p. 48.

20. MOLTSCHANOW, P.; Einige ergänzende Ausführungen zu dem von Prof. Weickmann erstatteten Bericht über die meteorologisch-aerologischen Ergebnisse der Polarfahrt. *Petermanns Mitt, Gotha.* Ergänzungsheft Nr. 216, 1933, p. 60.
21. MEINARDUS, W.; Meteorologische Ergebnisse der Winterstation des "Gauss", 1902–1903. Deutsche Südpolar Expedition 1901–1903. Berlin, Band III, Meteorology I, 1, 1909, p. 193.
22. SIMPSON, G. C.; Meteorology, Vol. 1, Discussion. British Antarctic Expedition, 1910–13, Calcutta, 1919, p. 270.
23. BARKOW, E.; Vorläufiger Bericht über die meteorologischen Beobachtungen der Deutschen Antarktischen Expedition, 1911/1912. *Veröff. preuss. met. Inst., Berlin,* **4,** Nr. 11, 1913.
24. BARKOW, E.; Die Ergebnisse der meteorologischen Beobachtungen der Deutschen Antarktischen Expedition, 1911–12. *Veröff. preuss. met. Inst., Berlin,* **7,** No. 6, 1924.
25. BARKOW, E.; Die Ergebnisse der Drachen-und Ballonaufstiege der Deutschen Antarktischen Expedition, 1911 bis 1912. *Met. Z., Braunschweig,* **37,** 1920, p. 346.
26. COURT, A.; Antarctic atmospheric circulation. Compendium of meteorology. Boston Mass., 1951, p. 917.
27. REGULA, H.; Vorbericht über die Deutsche Antarktische Expedition 1938/39. Die Arbeiten der Expeditions-Wetterwarte. Teil I, *Ann. Hydrogr., Hamburg,* **67,** August-Beiheft, 1939, p. 33.
28. LANGE, H.; Vorbericht über die Deutsche Antarktische Expedition 1938/39. Die Arbeiten der Expeditions-Wetterwarte. Teil II, *Ann. Hydrogr., Hamburg,* **67,** August-Beiheft, 1939, p. 35.
29. FLOHN, H.; Grundzüge der allgemeinen atmosphärischen Zirkulation auf der Südhalbkugel *Arch. Met., Wien,* A, **2,** 1950, p. 17.
30. REGULA, H.; Die Wetterverhältnisse während der Expedition und die Ergebnisse der meteorologischen Messungen. Deutsche Antarktische Expedition 1938–39, Ausgeführt unter der Leitung von Kapitän A. Ritscher. Wissenschaftliche Ergebnisse. Band II, Lieferung 1, Hamburg, 1954, p. 16.
31. COURT, A.; Tropopause disappearance during the Antarctic winter. *Bull. Amer. met. Soc., Milton Mass.,* **23,** 1942, p. 220.
32. COURT, A.; Meteorological data for Little America III. *Mon. Weath. Rev., Washington D.C.,* Supplement No. 48, 1949.

LETTERS TO THE EDITOR

Non-circular wind distributions

It is suggested that caution is needed in accepting that normal circular frequency distributions are characteristic of homogeneous upper wind observations above the friction layer in all parts of the world, including the equatorial regions.

N. Goldie[1] implies that the strongly elliptical distribution found by Scott[2] for a set of winds at 50,000 ft. over Singapore observed in September, October and November, 1953, was due to these observations not being confined to a single régime.

However, in an analysis by months of observed winds at 50,000 ft. over Singapore, Clarkson[3] has discussed the evidence for an elliptical distribution about the monthly vector means, and has shown that the chance of the observations made in the month of November, 1953 and 1954 being a sample from a normal circular distribution is negligible. Scott[4] has confirmed that 85 observations at 50,000 ft. in March, 1951–1955 are elliptically distributed.

Table I below includes statistics for all 0300 G.M.T. winds at 50,000 ft. measured by radar over Singapore up to the end of 1956. In September, and in each of the months from November to April inclusive, σ_E is at least 50 per cent greater than σ_N. It is thought that this non-circular distribution must properly be regarded as a characteristic of the high level winds over Singapore and not ascribed to the overlapping of different wind régimes in each of the seven specified months.

F.E.A.F., Changi, January 23, 1957. L. S. CLARKSON

TABLE I—STATISTICS OF MONTHLY MEAN WINDS AT 50,000 FT. OVER SINGAPORE AT 0300 G.M.T.

	No. of obs.	V_N	V_E	$\mathbf{V}_R$		σ_N	σ_E	σ
		knots		°	kt.	knots		
January	95	−8·3	38·9	102	39·8	13·0	19·7	23·5
February	102	−9·7	34·1	106	35·5	14·2	28·8	32·1
March	116	2·9	8·7	72	9·1	10·4	22·8	24·9
April	107	3·0	18·4	81	18·6	9·9	18·1	21·0
May	108	9·0	26·1	71	27·6	11·6	14·7	18·7
June	105	9·4	34·0	75	35·2	14·7	19·5	24·4
July	107	8·6	39·5	78	40·4	13·8	18·9	23·4
August	94	13·5	50·7	75	52·4	13·0	19·2	23·1
September	90	7·9	44·2	80	44·9	12·6	24·2	27·3
October	105	5·4	35·6	81	36·0	10·9	14·7	18·3
November	122	2·2	37·5	87	37·6	8·8	19·2	21·6
December	95	−3·7	31·7	97	31·9	9·2	22·5	24·4

REFERENCES

1. GOLDIE, N.; Frequencies and correlation in upper air data. *Met. Mag., London,* **85,** 1956, p. 299.
2. SCOTT, J. R.; A note on the parametric representation of non-circular wind distributions. *Quart. J. R. met. Soc., London,* **82,** 1956, p. 87.
3. CLARKSON, L. S.; Analysis of winds at 40,000 ft. and 50,000 ft. over Singapore. *Met. Mag., London,* **85,** 1956, p. 1.
4. SCOTT, J. R.; A regression method for estimating time changes of elliptically distributed winds. *Quart. J. R. met. Soc., London,* **82,** 1956, p. 337.

Waterspout on the River Severn near Shrewsbury

A waterspout was observed on the River Severn at Montford Bridge 5 miles west-north-west of Shrewsbury by Mr. Welch of Shrewsbury and his family at 4.15 p.m. on Friday 19 April, 1957.

The waterspout appeared on the edge of the river about 50 yards from the observer, crossing to the other side, a distance of 60 to 70 yards. It was in the form of a column of water 1 to 3 feet in diameter and 1 foot tall, with spray reaching a height of 8 feet and producing a swishing sound. The phenomenon was estimated to last about 15 to 20 seconds.

The weather at the time was warm with no noticeable wind before the occurrence; afterwards the temperature dropped as a cold northerly wind blew upstream for 2 to 3 minutes producing ripples on the river surface.

At this point the river runs roughly from south to north through a valley about 200 yards from the road, with a steep partially wooded slope between.

No observation of the sky was made by Mr. Welch, but he states that the waterspout did not have any connection with cloud, the weather being quite bright at the time.

On the 1500 G.M.T. chart there was a weak ridge of high pressure over the British Isles from an anticyclone over the Continent, the gradient was very slack and a shallow heat trough had formed over the west Midlands.

This would explain the onset of the northerly wind and also the increased instability to cause a waterspout.

The Liverpool ascent for 1100 G.M.T. showed unstable air up to 6,000 to 7,000 feet. Temperature and dew-point readings at Shawbury for 1500

G.M.T. were 53° and 37°F. respectively, probably a higher temperature was experienced at Montford Bridge due to the sheltered locality.

Cloud observations at Shawbury during the afternoon were 3/8 to 4/8 fair weather cumulus base around 2,800 feet with cirrus above.

Shawbury, 29 *May*, 1957. J. J. MYATT

NOTES AND NEWS

Whirlwind at Cairngorms Nature Reserve

Mr. F. H. W. Green, The Nature Conservancy, reports that a whirlwind occurred at Invereshie Lodge, Rotheimurchus, Inverness-shire, in the Cairngorms Nature Reserve about 11 a.m. on Saturday, 2 March. A complete juniper bush, 12 to 15 ft. high was uprooted and dropped in the middle of a field with part of the root remaining and the rest of the bush broken off at ground level. The place where the bush came from has not been found. The Lodge Keeper reported that a trailer attached to a Land Rover car outside a shed in which, having heard the noise of the wind he had taken shelter, was lifted completely off the gound.

A cold front had passed south-eastwards over the area during the previous night and was stationary along the east coast of Scotland during the day. Winds were moderate south-westerly over the area.

OBITUARY

R. G. K. Lempfert, C.B.E., M.A., F.R.Met.S.

It was with great sorrow that his former colleagues learned of the death of Mr. Lempfert in the early hours of 24 June after a stroke and just over 50 hours subsequent unconsciousness. R. G. K. Lempfert was the son of Rudolf Bernard Lempfert and Olga (née von Pein) who had come independently to Manchester from Kiel and Hamburg respectively, had met at a choral society and were married in 1869. R. G. K. Lempfert was born on 7 October, 1875. It was natural, with such parents, that he should love music, find his recreation in it, and in due course (June 1916) marry a distinguished violinist, Marjorie Hayward; and that music should also be the profession of their only daughter, Marjorie.

Lempfert was tall, distinguished in appearance and courteous both in bearing and in approach: Science, Art and Courtesy found they could, indeed, live together in R. G. K. Lempfert and make, in broad truth, the perfect gentleman.

From Manchester Grammar School, famous then for the Scholars it sent to the Old Universities, Lempfert went in 1894 to Emmanuel, Cambridge, took a First Class in both parts of the Natural Science Tripos (Part I, 1896, Part II Physics, 1898) and demonstrated at the Cavendish Laboratory. In 1900 he went to Rugby School as an assistant master and thence to the Meteorological Office in 1902.

Until fifty-five years ago "one of the peculiarities of the Meteorological Office as a scientific establishment was that none of the members of the staff had had any preliminary scientific training" (Sir Napier Shaw). The appointment of Lempfert in 1902 was the first step of Sir Napier's to remedy this defect; and most abundantly has it been justified: not only by the investigations which Lempfert undertook or had a part in, but also by the influence he exerted on meteorological administration and meteorological publications throughout a quarter of a century. Among the official publications for which he was responsible were the *Observer's Handbook*, the *Codex of International Resolutions*, the *Instructions in Meteorological Telegraphy* and the English Editions of *Reports of the International Meteorological Committee.* As he was bilingual, speaking English and German with practically equal facility, he was exceptionally qualified for the task of ensuring accurate correspondence in the technical terms and in the discussions at international meetings. He was also for many years effective, though unacknowledged, editor of the *Quarterly Journal of the Royal Meteorological Society.*

Lempfert took a leading part in securing the voluntary acceptance by 'Health Resorts' of inspection (at their expense) of their meteorological stations and the transmission of their weather reports to the Press via the Office and in official code. His too was a leading part in the transfer from the Royal Meteorological Society to the Office of the oversight and publication of the monthly reports from the Society's voluntary observers. The relative homogeneity and areal completeness of our meteorological statistics are largely due to these two steps, taken over forty years ago. Lempfert's scientific investigations were made often in collaboration with others. The first was the London Fog Inquiry (with Carpenter). Then came the Life History of Surface Air Currents (with Shaw). This was the first serious scientific attempt to find out whence the wind cometh and whither it goeth, and to relate the facts to the major developments of weather. It was a monumental task to collect and co-ordinate all the observations necessary for the detailed examination of the eight selected cases of travelling and developing storms and the six cases of trajectories of air over the North Atlantic Ocean. This investigation and the two papers on Line Squalls, (Lempfert 1906, Lempfert and Corless 1910) were the natural precursors of the Norwegian introduction of the Polar Front and the consequent impetus to frontal research in the period between the two wars. The first use of the word 'front' as a technical term seems to have been made, in the 1910 paper, for the cold front of the Line Squall. Other notable papers were *British Weather Forecasts* (1913) invaluable to the meteorological historian; the *Publication of Upper Air Reports* (1928, with Sir Napier Shaw and Miss E. Austin); *Scientific Work of the Meteorological Office, Cardington* (1931) and *Presentation of Meteorological Data* (1932), with its fertile suggestions especially in respect of humidity.

His appointments in the Office were Scientific Assistant (1902), Superintendent of Instruments (1905), of Statistics (1906), of the Forecast Division (1910), Assistant Director 1919. He retired on 31 December, 1938. He was President of the Royal Meteorological Society 1930–32.

It is difficult to realize that he had been over eighteen years in retirement—half as long as the period of his active service in the Meteorological Office. He was one of the executors of Sir Napier Shaw's will and in that capacity was responsible for the establishment of the Napier Shaw Library (Meteorological) in the Cavendish Laboratory at Cambridge and for the publication of the volume of *Shaw's Selected Papers*, fortunately completed last year after many difficulties and long drawn out negotiations. When in 1915 it was decided that the needs of the Army and Royal Flying Corps in France could not be met adequately from London but required meteorologists "in the Field", Lempfert was nominated by Sir Napier Shaw to take charge of the contingent initially. After preliminary agreement the War Office changed its mind. Lempfert, loyal to the land of his birth and upbringing, had looked forward to playing a more directly active part in the war against Germany. Disappointed as he was, he went far beyond his official duty in the help and encouragement he gave to me who took his place; and never did he utter one word of bitterness at his deprivation of the opportunity which came to me instead of to him.

E. GOLD.

REVIEWS

Physical Geography and Climatology. By N. K. Horrocks. $8\frac{1}{2}$ in. $\times$ $5\frac{1}{2}$ in., pp. xv+368, *Illus.*, Longmans, Green and Co., London, 1956. Price: 20*s.*

This pleasantly bound book, with its many clear diagrams and excellent photographs, is intended for grammar-school use. The general tone and level of the book is quite satisfactory for its purpose and the arrangement is systematic. The book is in six parts. Only Parts III and V, Meteorology and Climatology respectively, are discussed here; the remaining parts, dealing with the structure of the earth's surface, earth sculpture, plants and soils and oceanography, do not fall within the scope of this review.

Part III, Meteorology, has many faults. The chapter on water vapour in the atmosphere gives quite a few wrong ideas to the reader. In particular, the author gets the required small difference between dry and saturated adiabatic lapse rates at low temperatures, not by a curved saturated adiabatic, but by a sharp *increase* in the saturated adiabatic lapse rate at temperatures below 32°F. (i.e. a negative latent heat of fusion).

The proof given for the geostrophic deflexion is the familiar one which only applies to meridional flow. In a book of this nature I think a statement of observed fact would be best for the school pupil, with a reference to some book where the correct proof is given for the more advanced student.

There are other criticisms of this part of the book. The cross-section diagram and the description of warm-front cloud are both misleading. It was surprising, too, to find the distinction between advection fog, warm air over cold surface, and arctic smoke, cold air over warm water, dismissed by calling the processes "much the same". Some simple statement on the behaviour of moist unsaturated air would have made for easier phraseology; by calling all unsaturated air "dry", the author is trapped into such phrases as "dry air with high relative humidity".

The chapter on Precipitation is quite satisfactory and the whole of Part V, Climatology, is well done. In particular I liked the pleasant and effective diagrams in Part V, which give a good deal of clearly expressed information.

H. D. HOYLE

Die Mondfinsternisse. By F. Link. 9 in. × 6 in., pp. viii + 127, *Illus*. Akademische Verlagsgesellschaft Geest and Portig K.-G., Leipzig, 1956. Price: 15*DM*.

There is much more opportunity of seeing lunar eclipses than solar eclipses but while most people will have seen some solar eclipses few have seen a lunar eclipse. Lunar eclipses give rise to no superstitions, no excitement, and even most astronomers take little note of them. However, much information can be gained by observing them and the information is mainly about the earth's atmosphere. Dr. Link has therefore performed a useful service by assembling all that is known in a concise and well-prepared monograph.

Although there are other important matters which have to be considered, such as the solar limb darkening and the nature of the lunar surface, the heart of the problem is to analyze the behaviour of a slightly divergent beam as it is refracted, scattered and absorbed through the earth's atmosphere. A large part of the book is taken up with this treatment, which is complex and cannot be handled analytically. The main difficulty is that the earth's atmosphere is a very complicated optical system owing to its spherical shape and the rapid change of density with distance from the earth's surface. The effect of this density variation is an advantageous one, namely that the atmosphere acts as a divergent lens and gives an enlarged view of itself projected onto the lunar surface.

Passing over this geometrical problem, the object of this kind of study is to account for the distribution of light at the edge of the shadow in terms of the properties of the atmosphere.

To account for the refraction the pressure-height relationship in the atmosphere must be assumed. It may perhaps not be important, but it is somewhat alarming to find that Dr. Link makes use of Humphreys's data up to 40 Km. and Lindemann and Dobson's data above this level.

This relationship also allows the molecular scattering to be computed which leaves to be determined the absorption by gaseous constituents and the absorption and scattering by dust. These can be distinguished by spectral characteristics. For example by observing the Chappuis band of ozone the distribution of this gas can be determined up to high levels.

As a method of ozone research this technique offers two interesting advantages. Firstly, it is possible from the same photographic plate to determine the distribution simultaneously at many latitudes. Secondly, owing to the very long path taken through the upper atmosphere very small amounts can be detected and hence the distribution can be determined up to far greater heights than balloon sondes can reach.

After all gaseous absorption and scattering has been taken into account there remains a residual effect which is attributed to dust. At this point the astronomer and the meteorologist will probably disagree. Dr. Link wants this to be meteoric dust and shows a correlation between the variable diameter of the earth shadow and meteoric showers which is not at all convincing. As he realises, this dust cannot be at high levels, for he needs an optical thickness of 0·005 to account for the observations and even at 30 Km. this would show up as bright night-luminous clouds. On the other hand, if the layer is any lower it is much more reasonable to look to the earth's surface as the source.

The question can be readily clarified by means of the search-light experiments projected by the Meteorological Office. These will show immediately the presence of dust below 50 or 60 Km. and will give quantitative data for comparison with meteor-shower frequencies.

The book contains a bibliography of 192 references which must be practically a complete bibliography of the subject. It is in German, but the style is concise and reasonably clear so that it should afford no difficulty to any interested reader. The diagrams and equations are of the high standard which is expected from a German publisher. Altogether, it is a pleasing and well constructed monograph which should appeal to a meteorologist of catholic tastes.

R. M. GOODY

BOOKS RECEIVED

Les buts scientifiques de l'expédition radiométéorologique polar suisse pendant l'anée géophysique internationale. By J. Lugeon. (Reprinted from La Suisse Horlogére No. 20, 1957). 9 in. × 11½ in., pp. 16, *illus.*

Gustave Swoboda 1893–1956. (Reprinted from Verhandlungen der Schweiz. Naturforschenden gesellschaft, Basel, 1956). 9 in. × 6 in., pp. 4, *illus.*

OFFICIAL PUBLICATION

PROFESSIONAL NOTES

No. 122—*The subtropical jet stream of the Eastern North Pacific Ocean in January and April* 1952. By H. D. Hoyle, B.Sc.

Daily maps of the main jet-stream cores in the eastern North Pacific Ocean in January and April 1952 are shown. The days are grouped into four types and average vertical cross-sections for each type are given. Two separate jet-stream cores are frequently present, one associated with the polar front and one, at a higher level, often 1,000 miles or more farther south.

Variation from day to day in the strength of the more southerly of the streams is discussed in relation to the upper air temperature field and the major surface synoptic features. The thermal-wind relation appears to hold reasonably well at these rather low latitudes and geostrophic advection of the temperature field seems to make an important contribution to these day-to-day variations in the intensity of the jet stream.

When there is only one jet-stream core, the upper air temperature field and the surface synoptic charts show interesting changes. This leads to a suggestion that the ageostrophic meridional circulation accompanying the subtropical high-pressure cell is important in establishing the upper air temperature field.

HONOURS

The Director-General, Sir Graham Sutton, C.B.E., D.Sc., F.R.S., has been elected an Honorary Fellow of the Society of Engineers.

Meteorological Office awards to airline pilots

At a pleasant ceremony at the House of the Guild of Air Pilots and Navigators, Park Lane, London on July 4, 1957, the Director-General presented the annual awards to airline pilots for long and meritorious service in the provision of weather reports. The recipients of brief-cases this year were Captain S. A. Calder of Britavia Ltd. and Captain R. H. Payne of British European Airways.

In introducing the Director-General the Master of the Guild, Mr. J. Lankester-Parker, spoke of the confidence of pilots and navigators in the Meteorological Office. The Director-General spoke of the great value of reports from aircraft in increasing knowledge of the upper air.

Books for the best series of reports are being awarded to the following Captains and Navigators:

Mr. G. F. Andrews, B.O.A.C.
Captain B. D. Barrow, B.O.A.C.
Captain A. J. Campbell, B.O.A.C.
Mr. H. L. Chandor, B.O.A.C.
Captain M. D. Deloford, B.O.A.C.
Captain R. A. J. Hanson, B.O.A.C.
Mr. P. E. Hobbs, B.O.A.C.
Mr. R. H. Hughes, B.O.A.C.
Mr. E. V. Jenkins, B.O.A.C.
Captain M. A. Kyle, B.O.A.C.
Mr. W. C. L. McKay, B.O.A.C.
Captain R. H. Rose, B.E.A.
Captain J. E. Sayce, B.O.A.C.
Mr. F. S. Tanner, B.O.A.C.
Mr. H. T. Thompson, B.O.A.C.
Captain F. A. Tricklebank, B.E.A.
Captain J. R. Turner, B.E.A.
Captain W. J. Wakelin, B.E.A.
Mr. J. B. Weston, B.O.A.C.

INTERNATIONAL GEOPHYSICAL YEAR

Royal Society Expedition to Antarctica

We are indebted to Mr. D. W. S. Limbert for the photographs and descriptions which are reproduced between pp. 272–3. Mr. Limbert was a member of the advance party which was established early in 1956 at Halley Bay.

LATE RAINFALL REPORTS 1957

Skye (Glenbrittle)*

Month ...	Jan.	Feb.	Mar.	Apl	May
In. ...	9·89	6·02	8·55	4·29	3·37
Per cent. of Av. ...	123	92	134	92	75

Rothesay (Ardencraig)

Month ...	Apl	May
In. ...	2·72	91
Per cent. of Av. ...	2·18	72

* In lieu of Skye (Broadford)

WEATHER OF JULY 1957

The month was marked by considerable mobility in the main centres of action and less firmly established circulation pattern over the northern hemisphere than characterizes July in many years. On balance, however, the average pressure field for July 1957 showed strong resemblance to that for July 1956. The Azores anticyclone was centred near 35° N. 40°W., highest monthly mean pressure 1025 mb. (about normal intensity) in both summers, though in 1957 the mid-Atlantic ridge to south Greenland was a trifle more intense than the same feature had been in 1956: this was the product of one or two spells of a few days high pressure associated with mobile anticyclones in 1957 which did not occur in the previous year; for the rest of the month the sequences over the North Atlantic were very similar in both years. Mean pressure in the Atlantic sector was lowest (about 1010 mb.) over Labrador and between central Scandinavia and north-east England. The polar anticyclone was displaced towards the Atlantic–European sector, pressure being highest (1018 mb.) in north-east Greenland and Novaya Zemlya.

As in July 1956 also, the Eurasian monsoon low gave about normal pressure values over India but below normal pressures over wide areas in extensions into eastern Europe and north-east Asia. Low pressure spread from the latter area right across the polar basin into northern Canada (the monthly mean being probably about 1005 mb. near 80°N. 180°, an apparent anomaly of −9 mb.).

The pattern described involved a great change from that of June 1957, which had produced remarkable heat waves over much of Europe culminating with reported afternoon temperatures of 35 to 40°C. as far north as central Europe about the turn of the month. The abrupt change to a cooler régime was accomplished between the 5th and 10th July as cold outbreaks swept across the continent from north Russia and the north-eastern Atlantic. About the end of the month there was a reversion to a more anticyclonic type of weather in central and northern Europe. The average temperatures for July as a whole were near normal or slightly above in Europe generally. Greatest anomalies reported in the northern hemisphere were +3°C. in Lapland and in North Dakota and −3°C. in east Greenland.

The month was decidedly wet over most of Europe, with over twice the normal rainfall in several widely separated regions. The usual dry régime was established in central and southern parts of the Mediterranean. Over North America the rainfall distribution was patchy, as also in India and South-East Asia, where the monsoon was on the whole giving less rain than normal. There were rainfall excesses over most of Japan.

In the British Isles the month began with the last of June's "heat-wave" dying away. During the first six days of July a weak low pressure area lay to the south-west of the country and weather was generally sunny though there were local outbreaks of thundery rain or thunderstorms every day. Severe thunderstorms occurred in southern England on the night of the 2nd–3rd as a shallow depression moved northward from the Bay of Biscay—2·46 in. of rain fell during one such storm at Plymouth in one hour, an amount almost equal to the average rainfall there for the whole of July. Another rare fall occurred at Hastings where more than 1½ in. of rain was collected in 15 min. Heavy thunderstorms and widespread floods were reported from many places on the 4th and again on the 6th when a depression from off the coast of Portugal moved northwards over the British Isles. Afternoon temperatures exceeded 80°F. locally during each of these first six days and 90°F. was reached at London Airport on the 6th. The nights also were very warm; by the 7th, the temperature at Kew had not fallen below 60°F. for ten days. On the 7th weather changed to a more usual westerly type, which persisted for most of the remainder of the month, with depressions from the Atlantic moving eastwards over the country. Weather was generally more cloudy than during the first week, although some places continued to enjoy almost unbroken sunshine, and there was frequent rain with temperatures generally below normal. A depression which deepened to the west of Ireland and moved eastwards on the 11th was the first of three such systems to give widespread rain, which was heavy and thundery in places over the country. This depression was slow moving and took three days to reach the North Sea, the second moved across the country on the 17th and 18th, and the third gave considerable rain in Scotland on the 20th. By the morning of the 21st 4.37 in. of rain had fallen at Aberdeen in 72 hr. On the 22nd warm air began to spread across the country from the south-west bringing light rain to many places and fog to windward coasts during the next three days. By the 25th this warm air had reached north-east Scotland and gave persistent and locally heavy rain over the mainland though Shetland, in the cooler air to the north, had 13·4 hr. of sunshine. A slow moving cold front brought a broad belt of rain from the west over the country late on the 25th and the next three days were cooler and showery with west to north-west winds. On the 29th a small anticyclone developed over the British Isles giving the first generally fine day for about four weeks.

In England and Wales this was the wettest July since 1940, with rainfall 140 per cent. of the average. Less than the average rainfall occurred locally in Cornwall, East Anglia and Cumberland, but more than twice the average fell in parts of Montgomery and Anglesey. Parts of northern Scotland had 250 per cent. of the average. Locally in south-east England temperature was as much as 10°F. above the average for the period, but during the remainder of the month temperature was generally below the average. Sunshine also was considerably below the average except during the first week when in Scotland it exceeded 150 per cent of the average for the period.

At the beginning of the month the hot dry spell was causing farmers great concern. Fruit was splitting, potatoes were very backward and the ground was very dry. Later thunderstorms with hail caused considerable damage, particularly to fruit and hops in Kent, but subsequent rain did much to alleviate the effects of the dry weather. The warm dry weather at the end of the month came at the right time, particularly for the corn harvest.

The general character of the weather is shown by the following provisional figures:—

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Percentage of average	No. of days difference from average	Percentage of average
	°F.	°F.	°F.	%		%
England and Wales ...	93	38	+0·5	144	+5	78
Scotland	82	31	−0·1	152	−1	73
Northern Ireland ...	77	41	−0·3	144	+5	61

RAINFALL OF JULY 1957

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
London	Camden Square ...	3·32	139	*Glam.*	Cardiff, Penylan ...	5·17	168
Kent	Dover	5·18	245	*Pemb.*	Tenby	3·66	124
,,	Edenbridge, Falconhurst	4·29	187	*Radnor*	Tyrmynydd	6·13	149
Sussex	Compton, Compton Ho.	4·45	157	*Mont.*	Lake Vyrnwy	8·00	225
,,	Worthing, Beach Ho. Pk.	3·89	191	*Mer.*	Blaenau Festiniog ...	14·53	171
Hants.	St. Catherine's L'thouse	3·89	199	,,	Aberdovey	6·51	186
,,	Southampton (East Pk.)	4·30	189	*Carn.*	Llandudno	3·23	144
,,	South Farnborough ...	3·63	178	*Angl.*	Llanerchymedd ...	5·90	206
Herts.	Harpenden, Rothamsted	2·51	109	*I. Man*	Douglas, Borough Cem.	3·01	98
Bucks.	Slough, Upton... ...	4·10	214	*Wigtown*	Newton Stewart ...	4·62	147
Oxford	Oxford, Radcliffe ...	3·35	141	*Dumf.*	Dumfries, Crichton R.I.	5·11	156
N'hants.	Wellingboro' Swanspool	2·91	127	,,	Eskdalemuir Obsy. ...	4·93	120
Essex	Southend, W. W. ...	2·24	113	*Roxb.*	Crailing...	3·15	109
Suffolk	Felixstowe	4·29	220	*Peebles*	Stobo Castle	3·91	135
,,	Lowestoft Sec. School...	2·24	99	*Berwick*	Marchmont House ...	3·79	124
,,	Bury St. Ed., Westley H.	3·27	131	*E. Loth.*	North Berwick Gas Wks.	4·35	169
Norfolk	Sandringham Ho. Gdns.	1·98	77	*Midl'n.*	Edinburgh, Blackf'd. H.	4·83	171
Wilts.	Aldbourne	3·76	149	*Lanark*	Hamilton W. W., T'nhill	3·69	129
Dorset	Creech Grange... ...	3·36	137	*Ayr*	Prestwick	3·82	156
,,	Beaminster, East St. ...	3·79	146	,,	Glen Afton, Ayr San. ...	5·28	126
Devon	Teignmouth, Den Gdns.	3·23	139	*Renfrew*	Greenock, Prospect Hill	5·97	161
,,	Ilfracombe	3·78	149	*Bute*	Rothesay, Ardencraig ...	6·56	166
,,	Princetown	7·88	147	*Argyll*	Morven, Drimnin ...	5·43	123
Cornwall	Bude	2·89	118	,,	Poltalloch	5·98	145
,,	Penzance	3·13	115	,,	Inveraray Castle ...	6·50	131
,,	St. Austell	3·09	92	,,	Islay, Eallabus... ...	5·89	173
,,	Scilly, Tresco Abbey ...	2·07	93	,,	Tiree	5·06	140
Somerset	Taunton	2·44	115	*Kinross*	Loch Leven Sluice ...	5·91	205
Glos.	Cirencester	3·53	132	*Fife*	Leuchars Airfield ...	4·97	191
Salop	Church Stretton ...	4·51	171	*Perth*	Loch Dhu	5·77	119
,,	Shrewsbury, Monkmore	3·18	151	,,	Crieff, Strathearn Hyd.	4·57	154
Worcs.	Malvern, Free Library...	3·64	160	,,	Pitlochry, Fincastle ...	4·19	156
Warwick	Birmingham, Edgbaston	3·88	152	*Angus*	Montrose Hospital ...	4·37	166
Leics.	Thornton Reservoir ...	2·75	111	*Aberd.*	Braemar	4·33	168
Lincs.	Boston, Skirbeck ...	2·66	111	,,	Dyce, Craibstone ...	8·27	273
,,	Skegness, Marine Gdns.	2·55	117	,,	New Deer School House	5·15	168
Notts.	Mansfield, Carr Bank...	3·05	116	*Moray*	Gordon Castle	4·09	128
Derby	Buxton, Terrace Slopes	5·83	148	*Nairn*	Nairn Achareidh ...	5·23	205
Ches.	Bidston Observatory ...	4·47	173	*Inverness*	Loch Ness, Garthbeg ...	5·76	182
,,	Manchester, Ringway...	4·42	159	,,	Loch Hourn, Kinl'hourn	7·85	124
Lancs.	Stonyhurst College ...	6·05	156	,,	Fort William, Teviot ...	6·11	125
,,	Squires Gate	3·71	133	,,	Skye, Glenbrittle ...	6·97	110
Yorks.	Wakefield, Clarence Pk.	3·06	121	,,	Skye, Duntulm... ...	4·24	113
,,	Hull, Pearson Park ...	3·29	141	*R. & C.*	Tain, Mayfield... ...	7·14	262
,,	Felixkirk, Mt. St. John...	4·27	156	,,	Inverbroom, Glackour...	4·53	122
,,	York Museum	3·05	121	,,	Achnashellach	5·19	107
,,	Scarborough	3·37	139	*Suth.*	Lochinver, Bank Ho. ...	3·90	129
,,	Middlesbrough... ...	3·69	144	*Caith.*	Wick Airfield	4·02	153
,,	Baldersdale, Hury Res.	4·59	157	*Shtland*	Lerwick Observatory ...	2·95	129
Norl'd.	Newcastle, Leazes Pk....	3·48	136	*Ferm.*	Crom Castle	4·03	116
,,	Bellingham, High Green	4·07	124	*Armagh*	Armagh Observatory ...	3·68	127
,,	Lilburn Tower Gdns. ...	3·25	132	*Down*	Seaforde	4·48	140
Cumb.	Geltsdale	5·22	151	*Antrim*	Aldergrove Airfield ...	4·19	150
,,	Keswick, High Hill ...	3·55	92	,,	Ballymena, Harryville...	4·53	132
,,	Ravenglass, The Grove	4·02	107	*L'derry*	Garvagh, Moneydig ...	6·62	204
Mon.	A'gavenny, Plâs Derwen	3·83	141	,,	Londonderry, Creggan	6·35	173
Glam.	Ystalyfera, Wern House	6·30	137	*Tyrone*	Omagh, Edenfel ...	3·69	109

Printed in Great Britain under the authority of Her Majesty's Stationery Office
By Geo. Gibbons Ltd., Leicester

Wt-36. K16.