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OCCURRENCE OF LOW LAYER-TYPE CLOUD OVER EASTERN ENGLAND IN RELATION TO THE SYNOPTIC SITUATION

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Summary.—An investigation has been made of the occurrence of low layer-type cloud at four stations in East Anglia and the east Midlands, the data (amount, height of base) being related to the synoptic situation, season of the year, time of day, etc. The study has shown that frontal conditions and south-westerly tropical air streams, relative to their periods of influence, are accompanied by rather more low cloud than situations when the air flows from the North Sea. Significant differences were revealed between the average cloud height over individual stations.

Introduction.—*Cloud classification.*—The cloud layers reported in the hourly observations of Bircham Newton (220 ft. above M.S.L.), Mildenhall (15 ft. above M.S.L.), Cranfield (350 ft. above M.S.L.) and Felixstowe (10 ft. above M.S.L.) for the period January–December 1944 were classified as follows:—

CX	Sky obscured	Visibility normally less than 550 yd.
C1	Severe* stratus	9–10 tenths (7–8 oktas) layer base below 550 ft. or 4–8 tenths (3–6 oktas) layer base below 250 ft.
C2	Moderate* stratus	9–10 tenths (7–8 oktas) layer base 550–950 ft. or 4–8 tenths (3–6 oktas) layer base 250–550 ft.
C3	Slight* stratus	9–10 tenths (7–8 oktas) layer base 950–1,450 ft. or 4–8 tenths (3–6 oktas) layer base 550–950 ft. or trace—3 tenths (2 oktas) layer base below 950 ft.
C4	.. ..	9–10 tenths (7–8 oktas) layer base 1,450–1,950 ft. or 4–8 tenths (3–6 oktas) layer base 950–1,550 ft.
C5	.. ..	9–10 tenths (7–8 oktas) layer base 1,950–7,900 ft.

*These adjectives are used for convenience of description only.

If, at one hour, two layers existed satisfying different specifications, the class of lower number was assigned. No account was taken of cloud type, although the neglect of layers 8 tenths (6 oktas) or less in amount above 1,550 ft. effectively eliminated cumulus observations. Thus category C5 consisted mainly of stratocumulus, altostratus (below 8,000 ft.) and nimbostratus cloud.

During periods of fog, the cloud report assumed one of three forms:—

- (i) cloud type and base stated as if no fog present
- (ii) cloud amount reported as nil (Beaufort letter b)
- (iii) sky reported as obscured (Beaufort letter o).

In this investigation it was decided to exclude cases of shallow radiation fog (ii), but to include cases when the vertical thickness of the fog was such that the sky was obscured (iii); the latter effectively represent stratus “on the surface”. Instances of (i) were considered on their merits, ignoring the visibility.

In the discussion, reference will sometimes be made to the frequency of conditions worse than fixed limits. For convenience, abbreviations such as CX—1 will be used to describe conditions including or worse than cloud category C1, and so on.

Synoptic classification.—The synoptic situation at each hour was classified under one of the following headings. Conditions with geostrophic wind less than 15 kt. are indicated by an asterisk; the absence of an asterisk against a particular class means that only situations with geostrophic wind exceeding 15 kt. are included.

									Notation for diagrams, etc.
S1	Fronts								
	(a)	moving from south-west, west or north-west	...	...	...				FW
	(b)	moving from north, north-east, east, south-east or south...	...	...	...				FE
	(c)*	moving from any direction, including quasi-stationary and complex situations...	...	...	...	...	...	...	F*
S2	Tropical maritime air								
	(a)	reaching the British Isles in a direct south-westerly air stream	...						Tsw
	(b)	arriving from west or west-north-west	...	...	...	...			Tw
S3	Polar maritime air								
	(a)	returning in a south-westerly air stream	...	...	...	...			Psw
	(b)	arriving from west or west-north-west (wind direction at 2,000 ft. 250–315°)	...	...	...	...	...	...	Pw
	(c)	arriving from north-north-west or north (wind direction at 2,000 ft. 320–25°)	...	...	...	...	...	...	Pn
S4	North-easterly and easterly air streams	...	...	...	...	...
	(a)	air flowing from north-east or east (wind direction at 2,000 ft. 30–105°)	...	...	...	...	...	...	NE
	(b)*	air flowing from north-east or east	...	...	...	...	...	...	NE*
S5	South-easterly and southerly air streams								
		air flowing from south-east or south (wind direction at 2,000 ft. 110–190°)	...	...	...	...	...	...	SE
S6	Slack pressure gradients								
	(a)*	air flowing from south-east, south, south-west, west, north-west or north	...	...	...	...	...	...	*
	(b)*	conditions of light wind of no definite direction (geostrophic wind less than 6 kt.)	...	...	...	...	...	...	**

The alternatives within each heading were separate classes during the analysis, and have been grouped because this proved justifiable.

In order to determine the representativeness of the year 1944, an examination was made of the low cloud and surface wind direction summaries for Mildenhall 1944–48. In 1944, north-easterly and easterly air streams (class S4) were about 20 per cent. below average frequency in the winter, and 50 per cent. above average frequency in the summer; otherwise the year chosen appeared to be reasonably representative. The abnormalities in cloud occurrence could roughly be associated with those of wind direction. Therefore, although the subsequent discussion is based on only one year's data, it is thought that a reasonably representative picture is portrayed of average cloud conditions associated with the various synoptic classes.

Presentation of the statistics.—The overall frequencies at the individual stations of sky obscured, severe stratus, moderate and slight stratus, and of cloud categories C₄ and C₅, are shown in Table I.

TABLE I—OVERALL PERCENTAGE FREQUENCIES OF CLOUD CATEGORIES

	CX	C ₁	Cloud categories		Total
			C ₂ and C ₃	C ₄ and C ₅	
			<i>per cent.</i>		
Bircham Newton	3·3	4·3	13·5	20·9	42·0
Mildenhall	2·9	2·1	9·5	26·2	40·7
Cranfield	3·5	3·6	13·9	20·2	41·2
Felixstowe	1·3	1·3	6·3	27·2	36·1

Fig. 1 shows the over-all same cloud frequency for the separate synoptic classes. The abscissae are proportional to the periods of influence of the synoptic situations, whilst the ordinates represent the frequency of stratus within those situations. Thus, areas on the histograms correspond to actual numbers of observations.

Fig. 2 contains histograms showing the incidence of the various cloud categories at Cranfield for fronts moving from south-west, west or north-west with geostrophic wind exceeding 15 kt. (class S₁ (a)). The figures beneath the columns are the average durations in hours of the conditions when they occur. The fronts are sub-divided into

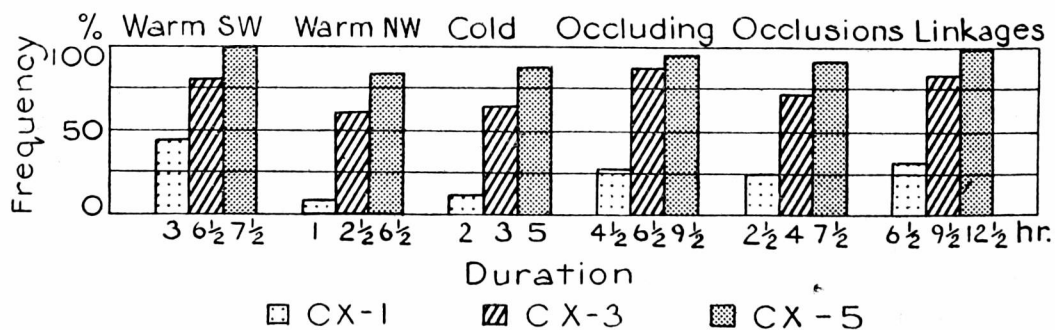
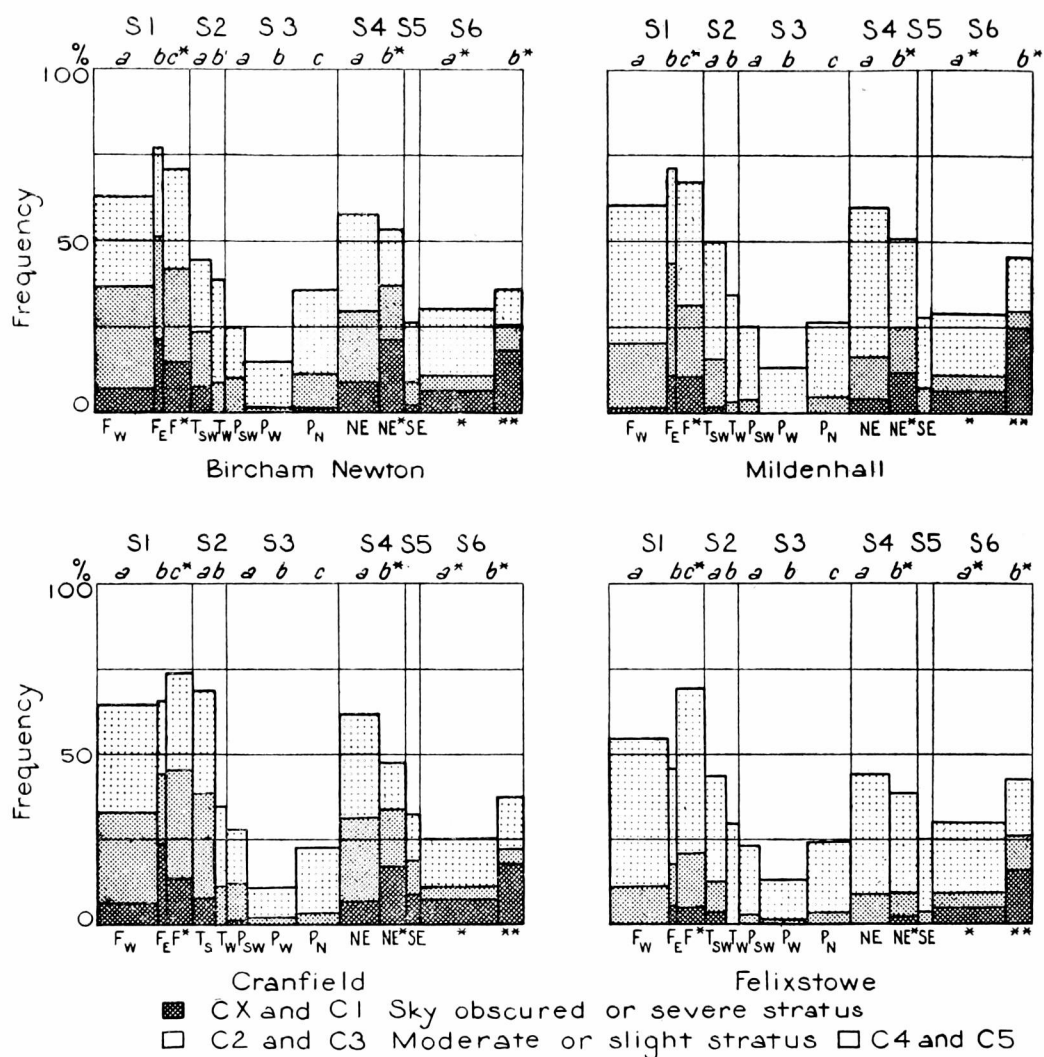
- (i) warm fronts moving from south-west or west
- (ii) warm fronts moving from north-west
- (iii) cold fronts
- (iv) occluding fronts (station within 100 miles of path of point of occlusion)
- (v) occlusions
- (vi) frontal linkages (sections of front which approached or passed the station as a cold front and returned as a warm front without intermediately passing out of range of the station concerned).

The zone limits adopted from experience were

- (i) 150 miles pre-surface front, 100 miles post-front for warm and occluding fronts
- (ii) 100 miles pre-front, 100 miles post-front for occlusions
- (iii) 50 miles pre-front (warm air) 100 miles post-front (cold air) for cold fronts and frontal linkages.

Fig. 3 shows the seasonal variation of cloud conditions in the various synoptic classes (winter, December–February; spring, March–May; etc.). The data are for Cranfield with, in addition, diagrams for Bircham Newton in north-easterly and easterly air streams; otherwise the variations at the other stations resemble those at Cranfield. The ordinates are as in Fig. 1, but the abscissae have no frequency significance; mean ordinates have been entered when the data for two seasons did not appear to differ significantly.

Fig. 4 illustrates the diurnal variation of cloud conditions in north-easterly and easterly air streams at Bircham Newton (coastal) and Cranfield (inland). The ordinates are as in Fig. 1, and the abscissae are 3-hr. periods 0100–0300 G.M.T., 0400–0600, etc. The diagrams are compounded of conditions in



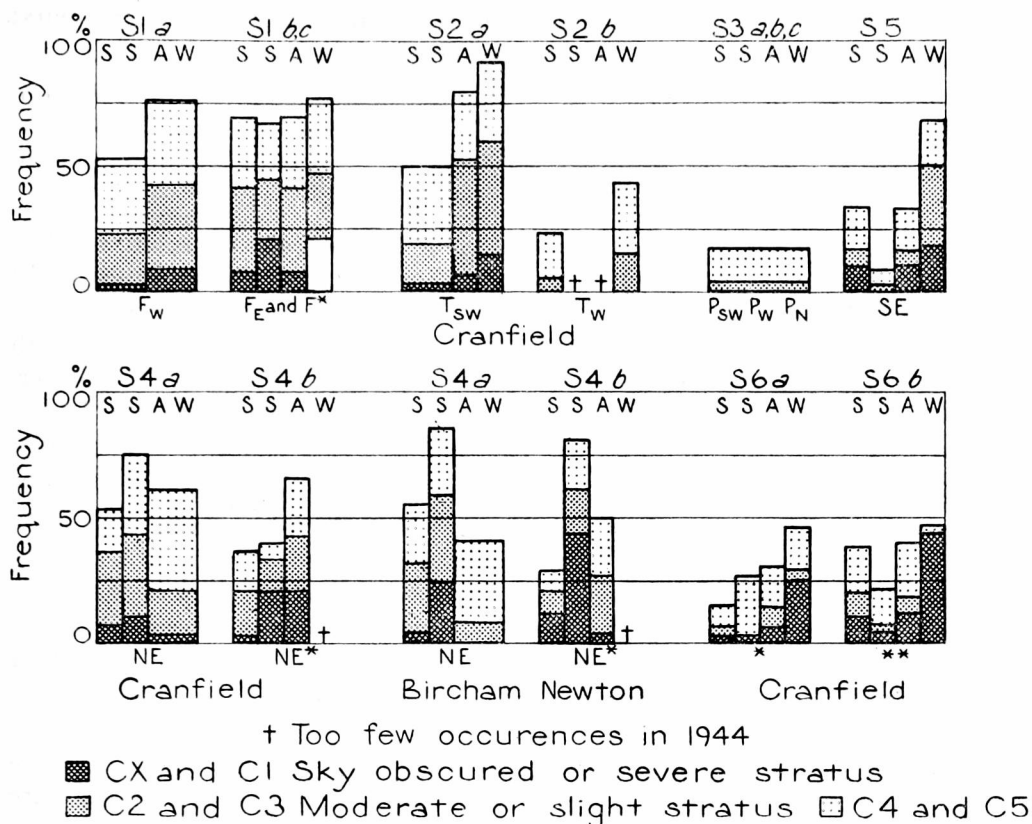


FIG. 3—SEASONAL VARIATIONS OF CLOUD SEVERITY

Where any ordinate is less than five per cent. shading as for the next above has been used.

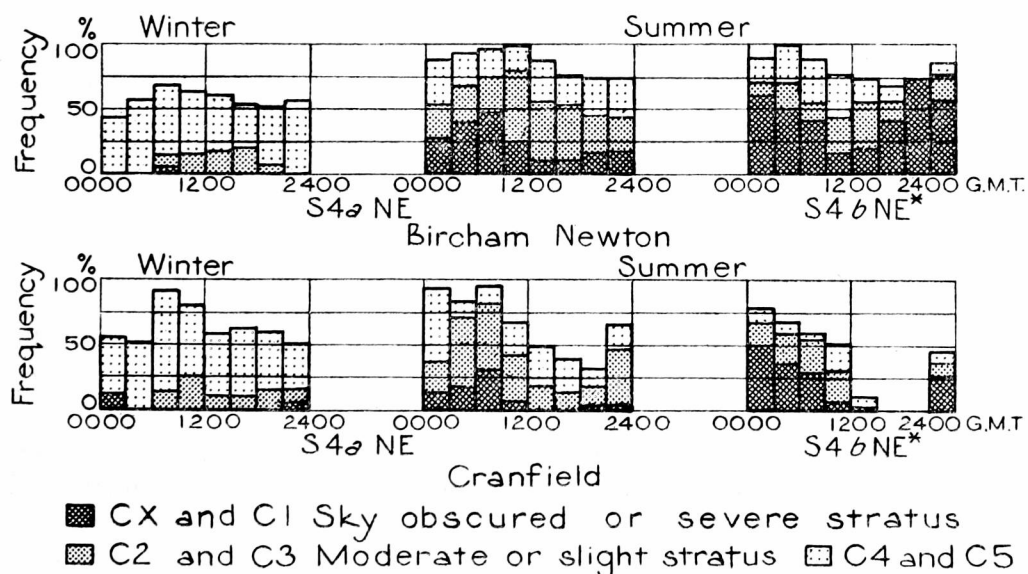


FIG. 4—DIURNAL VARIATIONS OF CLOUD SEVERITY IN NORTH-EASTERLY AND EASTERLY AIR STREAMS

Where any ordinate is less than five per cent. shading as for the next above ordinate has been used.

several periods of varying duration, usually less than a complete 24 hours; thus some irregularities in their general pattern may be expected.

The frequencies represented in Figs. 2, 3 and 4 are averages derived from limited numbers of occurrences. Although individual values may not be accurate guides to the long-period normals, the differences subsequently remarked upon are thought to be significant.

Discussion.—The main features of Table I are: (a) the relatively low frequency of sky obscured at Felixstowe, and of severe, moderate and slight stratus at Felixstowe and Mildenhall; (b) the relatively high frequency of cloud categories C₄ and C₅ at the above two stations, which combined with (a) leads to a nearly constant frequency of CX—5 conditions. However, considering the method of classification which lays emphasis on the lowest cloud layer, it is probable that the frequency of cloud actually occurring at levels 4 and 5 is approximately equal at the four stations. In 1944, winter was the most cloudy season and spring the least (Cranfield, CX—5 conditions, 49 per cent. and 31 per cent. respectively).

Sky obscured conditions were almost entirely confined to synoptic situations with geostrophic wind less than 15 kt. (those marked with an asterisk). Severe stratus occurred with roughly equal frequency (relative to the periods of influence) in north-easterly situations (NE, NE*), at fronts (F_W, F_E and F*), and in south-westerly tropical air streams (T_{SW}). However, moderate or slight stratus was rather more frequent at fronts than in north-easterly situations; whilst, especially at Cranfield, south-westerly tropical air streams were accompanied by much cloud at these levels.

At Bircham Newton and Cranfield, fronts produced the highest average frequency of CX—3 conditions, with north-easterly situations and south-westerly tropical air streams holding second and third places according to station. Mildenhall and Felixstowe, compared with the other stations, experienced a lower frequency of CX—3 conditions in each of the above synoptic situations, but a slightly higher frequency of the same conditions in situations with very light wind (**). Thus, at Mildenhall and Felixstowe, comparing the synoptic classes, situations with very light wind produced a relatively high frequency of CX—3 conditions. At all stations, CX—3 conditions were least frequent in polar maritime air from west or west-north-west (P_W).

The average cloud conditions in the main synoptic classes are considered briefly below:—

S₁ Fronts.—Features of Fig. 2 (F_W fronts only) of particular interest are the differences between warm fronts according to direction of motion (statistically significant at the 5 per cent. level), and the prolonged periods of stratus which occurred at frontal linkages.

In each type of F_W front, the frequency of CX—1 and CX—3 conditions decreased sharply from Cranfield and Bircham Newton to Mildenhall and Felixstowe. For example, the average frequencies of CX—2 and CX—4 conditions at Mildenhall were respectively closely similar to those of CX—1 and CX—3 conditions at Bircham Newton and at Cranfield. The general level of the cloud base, measured above ground, was thus 400–500 ft. higher at Mildenhall (and, correspondingly, about 800 ft. higher at Felixstowe) than at Bircham Newton and Cranfield. As these differences substantially

exceed those between the station altitudes, the data imply that the cloud base does not follow a constant height above sea level. Cranfield's altitude is probably typical of that of the east Midlands, and the rise in cloud base eastwards is presumably due to a drying of the air with increasing distance from the Atlantic. The lowering of the cloud base at Bircham Newton is possibly associated with the forced ascent and, in some cases, increased moisture content of the air after passing over the Wash.

F_W fronts produced rather worse conditions in autumn and winter than in spring and summer. However, more detailed analysis suggests that the effect was confined mainly to cold and occluding fronts and to frontal linkages. F_E and F^* fronts were accompanied by worse conditions than F_W fronts, particularly as regards occurrence of sky obscured and severe stratus. The seasonal variation shows a double maximum of CX—1 conditions due to the combination of fronts moving from north-east or east, which have a cloud maximum in summer, with fronts from other directions which have worst conditions in winter.

S2 Tropical maritime air streams.—At Cranfield, conditions in south-westerly tropical air streams (T_{SW}) were least severe in spring and summer. Moreover, in all seasons except winter, the cloud severity decreased very considerably from Cranfield to Bircham Newton, Mildenhall and Felixstowe, the frequencies of CX—3 and CX—4 conditions at Mildenhall being comparable only with those of CX—1 and CX—2 conditions at Cranfield. In winter, the eastwards decrease of cloud severity was less marked. Study of the diurnal variation showed that conditions were worst at night and in the early morning.

Tropical air reaching the British Isles from west or west-north-west (T_W) was generally accompanied by less stratus cloud (C1—3) than air arriving direct from the south-west. The seasonal variation indicates a winter maximum.

S3 Polar maritime air streams.—Polar maritime air returning in a south-west air stream was also accompanied by less low cloud (C1—3) than tropical air from the south-west; the difference was marked in autumn and winter, but, except at Cranfield, was insignificant in spring and summer.

Polar maritime air arriving from west and west-north-west was the most cloud free of the synoptic classes. The frequency of CX—3 conditions averaged only 1.9 per cent. at Cranfield and Bircham Newton, and 0.6 per cent. at Mildenhall and Felixstowe, these occurrences mainly being isolated and associated with showers. Polar air arriving direct from north-north-west or north was accompanied by rather more cloud, especially at Bircham Newton where these winds are on shore.

There was no significant seasonal variation in any of these classes.

S4 North-easterly and easterly air streams.—S4(a) Air streams with geostrophic wind exceeding 15 kt. (NE). In autumn and winter 1944, severe and moderate stratus was rare, but slight stratus or cloud at levels C4 or C5 occurred on roughly 50 per cent. of occasions. The station altitude influenced the individual frequencies of CX—3, CX—4 and CX—5 conditions; thus it appeared that, on average, the cloud base was at a constant height above sea level over East Anglia, but 300–350 ft. lower at Cranfield. The effect is presumably due to the forced ascent of air over the Midland heights. There was no definite

diurnal variation, except perhaps a tendency to a lower cloud base by day presumably associated with increased turbulence.

In summer, severe, moderate and slight stratus occurred frequently at Bircham Newton, Mildenhall and Cranfield. At Bircham Newton, presumably owing to the coastal position, conditions were particularly bad and, on a few occasions, the sky was obscured. The frequency of CX—5 conditions decreased with increasing distance from the coast (Bircham Newton 85 per cent., Cranfield 65 per cent.) due mainly to the greater tendency at inland stations for the cloud to break or disperse during the day. Curiously, Felixstowe is apparently sheltered from the main cloud effects of north-easterly and easterly air streams; severe stratus was rare, and CX—5 conditions covered only 40 per cent. of the time.

In spring 1944 the cloud conditions were intermediate between those of winter and summer, being roughly equal at Bircham Newton and Cranfield, and progressively less severe at Mildenhall and Felixstowe.

S₄(b). Air streams with geostrophic wind less than 15 kt. (NE*). In winter, sky obscured and severe stratus were frequently recorded at the inland stations between 2200 and 0900 G.M.T., and everywhere the frequency of CX—3 conditions was approximately double that in class S₄(a). In summer also, the frequencies of sky obscured and severe stratus were higher than in class S₄(a); however, at the inland stations, the frequencies of CX—3 and CX—5 conditions were less, due, as mentioned below, to the greater likelihood of cloud dispersal during the day.

S₄(a) and S₄(b). At Bircham Newton in bad situations, the stratus may be expected to vary only from severe around dawn to moderate in the afternoon or early night. However, at Cranfield, the severe stratus frequently occurring between 0100 and 0900 hr. will lift during the late morning, and especially in the weak air streams (NE*) there is a very good chance of a clearance to no classifiable cloud by early afternoon; the stratus may be expected to re-form sometime after 2100, frequently suddenly at a low level. Of course, these conclusions assume that the humidity and thermal structure of the air stream remain basically constant, and this is by no means always so.

The presence beneath stratus cloud of a layer of poor visibility has been reported by several authors, particularly Bull¹ and Lamb². In this investigation the visibility at ground level in north-easterly and easterly situations was correlated with the height of the cloud base. The frequency of visibilities less than $2\frac{1}{2}$ miles was found to increase from 20 per cent. to 50–70 per cent. as the cloud base lowered through a critical value, about 400 ft.; and for bases estimated at 100 ft. the median visibility was $1\frac{1}{4}$ miles. The layer of poor visibility is probably associated with an increase in size of hygroscopic condensation nuclei as the relative humidity approaches 100 per cent.

S₅ *South-easterly and southerly air streams*.—These situations were accompanied by very much less cloud than north-easterly and easterly air streams, and the seasonal variation was of opposite phase (Fig. 3). Especially in winter, the conditions were worst at Cranfield, possibly due to a reduction in the average surface wind and consequent increased liability to fog to the lee of the Chiltern Hills.

S₆ *Slack pressure gradients*.—These situations accounted for the majority of

occurrences of sky obscured. The worst season was winter (Fig. 3) when almost one half of the periods were accompanied by fog, occasionally persisting for the entire duration of these situations. A few periods of stratus occurred in each season, and cloud at levels C₄ or C₅ was moderately frequent. The average conditions at the four stations were more nearly equal than in the synoptic divisions previously considered.

The preceding discussion has been concerned with the incidence of the various cloud categories in the individual synoptic classes; the frequency of occurrence of the particular class has been of no consequence. In the following table the latter factor is included. Table II gives the distribution of the occurrences of the cloud categories amongst the main synoptic divisions; the figures are means over the four stations.

TABLE II—PERCENTAGES OF ANNUAL TOTALS OF CLOUD CATEGORIES ACCOMPANYING PARTICULAR SYNOPTIC DIVISIONS

Synoptic division	Percentage time of influence	Cloud categories			
		CX	C ₁	C ₂ and C ₃	C ₄ and C ₅
				<i>per cent.</i>	
S ₁ Fronts	22·6	15·4	36·4	46·5	32·7
S ₂ Tropical air	7·8	1·0	7·6	9·2	9·5
S ₃ Polar air	27·0	0·3	2·0	8·7	19·0
S ₄ North-easterly situations	15·8	14·1	28·7	21·5	19·1
S ₅ South-easterly situations	3·3	1·7	0·9	1·9	2·5
S ₆ Slack pressure gradients	23·5	67·5	24·4	12·2	17·2

Certain of the synoptic divisions were especially important as cloud producers in certain seasons; thus, in summer 1944, north-easterly situations (probably of above average occurrence, see p. 162) accounted for substantially more severe stratus than fronts. However, over the year north-easterly and easterly air streams were accompanied by only about 25 per cent. of the total occurrences of stratus (levels C₁–3), compared with approximately 40 per cent. at fronts.

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RELATIONS BETWEEN STANDARD DEVIATIONS OF DAILY, 5-DAY, 10-DAY AND 30-DAY MEAN TEMPERATURES

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Summary.—An examination of data for the months of January, April, July and October at fourteen widely spaced northern-hemisphere stations shows that the ratios σ_1/σ_{30} , σ_5/σ_{30} , σ_{10}/σ_{30} , where σ_1 , σ_5 , σ_{10} , σ_{30} are respectively the standard deviations of daily, 5-day, 10-day and monthly mean temperatures, vary little about the mean values of 2·03, 1·62 and 1·31. A brief theoretical discussion is given.

Data.—The stations for which data were examined are listed in Table I.

For stations 1 to 10 the daily mean temperatures were extracted for each day of the four months January, April, July and October for a 10-yr. period, and σ_1 , σ_5 , σ_{10} , σ_{30} , the standard deviations of mean daily, 5-day, 10-day and

TABLE I—LIST OF STATIONS AND PERIODS EXAMINED

No.	Station	Latitude	Longitude	Period for $\sigma_1, \sigma_5, \sigma_{10}$	Period for σ_{30}
1	London (Kew)	51°N.	0°	1928-37	1900-49
2	Naples	41°N.	14°E.	1919-28	1901-25
3	Alexandria	31°N.	30°E.	1931-40	1931-40
4	Odessa	46°N.	31°E.	1903-12	1896-1915
5	Leningrad	60°N.	30°E.	1901-08, 1910-11	1891-1915
6	Tomsk	56°N.	85°E.	1901-08, 1910-11	1886-1910
7	Rykovskoe	52°N.	142°E.	1894-1903	1886-1904
8	Tokyo	36°N.	139°E.	1944-53	1924-53
9	Toronto	44°N.	79°W.	1944-53	1924-53
10	New York	41°N.	74°W.	1936-45	1921-50
11	Edmonton	54°N.	113°W.	1942-51	1922-51
12	Churchill	59°N.	94°W.	1942-51	1932-54
13	Gander	49°N.	55°W.	1942-51	1942-51
14	San Francisco	35°N.	122°W.	1941-50	1921-50

30-day (monthly) temperatures were computed; for stations 11 to 14 only 5-day mean temperatures were extracted, and σ_5, σ_{30} were computed. In computing values of σ_1, σ_5 and σ_{10} only variations of temperature from the average for the time of month were considered. Variations due to the change of average temperature during the month were eliminated; for the stations examined, this change was considerable during the months of April and October.

Tabulation of results.—The computed values of $\sigma_1, \sigma_5, \sigma_{10}, \sigma_{30}$ are set out in Table II.

The relations between $\sigma_1, \sigma_5, \sigma_{10}, \sigma_{30}$.— σ_5 and σ_{30} .—Graphs of values of σ_5 against σ_{30} for all stations are shown in Fig. 1. The estimate of σ_5 from σ_{30} is

$$\sigma_5 = 1.62 \sigma_{30}$$

Using this relation, values of σ_5 were estimated from σ_{30} ; they are compared with observed values in Table III.

The mean error is 6 per cent. in January, 7 per cent. in April, 9 per cent. in July and 10 per cent. in October.

σ_1 and σ_{30} ; σ_{10} and σ_{30} .—Fig. 2 shows the graph of σ_1 against σ_{30} ; and Fig. 3 the graph of σ_{10} against σ_{30} . Estimates of σ_1 and σ_{10} in terms of σ_{30} are:

$$\sigma_1 = 2.03 \sigma_{30}, \text{ with a mean error of 9 per cent.}$$

$$\sigma_{10} = 1.31 \sigma_{30}, \text{ with a mean error of 9 per cent.}$$

Estimates of $\sigma_5, \sigma_{10}, \sigma_{30}$ in terms of σ_1 .—Using only stations 1 to 10, the following estimates were obtained:

$$\sigma_5 = 0.78 \sigma_1, \text{ with a mean error of 6 per cent.}$$

$$\sigma_{10} = 0.64 \sigma_1, \text{ with a mean error of 10 per cent.}$$

$$\sigma_{30} = 0.49 \sigma_1, \text{ with a mean error of 10 per cent.}$$

Seasonal and regional variation of the ratios among $\sigma_1, \sigma_5, \sigma_{10}, \sigma_{30}$.—Means are given in Table IV of the various ratios, for

- (i) each station with all months combined
- (ii) each month with all stations combined
- (iii) all stations and all months combined.

Theoretical approach.—The variance of the mean of n correlated variables x_1, x_2, \dots, x_n is

$$\frac{1}{n^2} \left(s_1^2 + s_2^2 + \dots + s_n^2 + 2 \sum_{i>j} r_{ij} s_i s_j \right), \quad \dots \dots (1)$$

TABLE II—COMPUTED VALUES OF STANDARD DEVIATION OF TEMPERATURE, ($^{\circ}\text{C.}$)

	London (Kew)				Naples				Alexandria			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
σ_1	3.13	2.40	2.28	2.60	2.48	2.33	1.86	2.60	1.73	1.96	0.73	1.37
σ_5	2.58	1.88	1.83	1.92	1.84	1.84	1.60	2.03	1.51	1.44	0.64	1.15
σ_{10}	2.22	1.50	1.59	1.47	1.62	1.59	1.45	1.84	1.39	1.05	0.58	0.88
σ_{30}	1.66	1.22	1.36	1.29	1.22	1.08	1.12	1.21	0.87	0.73	0.49	0.77

	Odessa				Leningrad				Tomsk			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
σ_1	5.29	2.67	2.50	3.70	6.50	3.51	3.29	3.45	8.17	4.51	3.43	4.17
σ_5	4.26	1.93	1.84	2.97	5.13	2.85	2.81	2.83	6.51	4.08	2.85	2.98
σ_{10}	3.28	1.56	1.28	2.50	4.61	2.51	2.41	2.32	4.87	3.21	2.26	2.23
σ_{30}	2.87	1.28	1.09	2.00	2.98	1.97	1.56	2.08	4.03	2.55	1.66	2.04

	Rykovskoe				Tokyo				Toronto			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
σ_1	6.63	3.45	3.12	3.22	2.21	2.65	2.46	2.01	5.54	3.65	2.52	3.64
σ_5	5.21	2.59	2.33	2.05	1.57	2.03	2.15	1.21	4.16	2.81	1.81	2.72
σ_{10}	4.45	1.81	1.98	1.51	1.34	1.55	1.94	0.98	3.77	2.07	1.46	2.18
σ_{30}	3.43	1.38	1.54	1.10	0.96	0.97	1.44	0.77	2.56	1.75	1.06	1.64

	New York				Edmonton				Churchill			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
σ_1	4.81	4.16	2.36	3.73	...	...	...	...	...	...	...	...
σ_5	3.71	3.17	1.67	2.61	9.08	4.45	1.79	3.94	5.96	5.21	2.72	3.61
σ_{10}	3.06	2.85	1.31	1.94	...	...	...	...	...	...	...	...
σ_{30}	2.49	1.57	0.95	1.70	5.35	2.78	0.86	2.14	3.98	3.00	1.50	2.51

	Gander				San Francisco			
	Jan.	Apr.	July	Oct.	Jan.	Apr.	July	Oct.
σ_5	3.92	2.39	2.24	1.86	2.26	1.50	0.99	1.49
σ_{30}	2.12	1.56	1.42	1.08	1.49	1.07	0.58	0.67

TABLE III—COMPARISON OF OBSERVED AND ESTIMATED VALUES OF σ_5 , ($^{\circ}\text{C.}$)

	January		April		July		October	
	Ob-served	Esti-mated	Ob-served	Esti-mated	Ob-served	Esti-mated	Ob-served	Esti-mated
London (Kew)	2.58	2.69	1.88	1.97	1.83	2.21	1.92	2.19
Naples	1.84	1.98	1.84	1.75	1.60	1.81	2.03	1.96
Alexandria	1.51	1.41	1.44	1.39	0.64	0.80	1.15	1.25
Odessa	4.26	4.65	1.93	2.08	1.84	1.76	2.97	3.24
Leningrad	5.13	4.83	2.85	3.19	2.81	2.53	2.83	3.37
Tomsk	6.51	6.51	4.08	4.13	2.85	2.70	2.98	3.30
Rykovskoe	5.21	5.56	2.59	2.24	2.33	2.49	2.05	1.78
Tokyo	1.57	1.56	2.03	1.57	2.15	2.33	1.21	1.25
Toronto	4.16	4.25	2.81	2.84	1.81	1.72	2.72	2.65
New York	3.71	4.03	3.17	2.54	1.67	1.54	2.61	2.75
Edmonton	9.08	8.87	4.45	4.50	1.79	1.40	3.94	3.46
Churchill	5.96	6.45	5.21	4.86	2.72	2.43	3.61	4.07
Gander	3.92	3.43	2.35	2.43	2.24	2.30	1.86	1.75
San Francisco	2.26	2.41	1.50	1.73	0.99	0.94	1.49	1.09

where s_i is the standard deviation of x_i and r_{ij} is the correlation coefficient between x_i and x_j .

For n successive daily values of a meteorological element we have the relations

$$\left. \begin{aligned} s_1 &= s_2 = s_3 = \dots = s_n \\ r_{ij} &= r_{i+m, j+m} = r_{i-j, \text{ say}} \end{aligned} \right\} \dots \dots \dots (2)$$

Thus the ratio of the variance of the mean of n daily values to that of the daily mean is

$$\frac{\sigma_n^2}{\sigma_1^2} = \frac{1}{n^2} \left(n + 2 \sum_{i>j} r_{i-j} \right) . \dots \dots \dots (3)$$

It is usually assumed for meteorological data that

$$r_k = r_1^k . \dots \dots \dots (4)$$

TABLE IV—SEASONAL AND REGIONAL VARIATION OF THE RATIOS AMONG σ_1 , σ_5 , σ_{10} , σ_{30}

		σ_5/σ_1	σ_{10}/σ_1	σ_{30}/σ_1	σ_1/σ_{30}	σ_5/σ_{30}	σ_{10}/σ_{30}	σ_5/σ_{30}
(i)	London	0.79	0.65	0.53	1.88	1.48	1.23	...
	Naples	0.79	0.70	0.50	2.00	1.58	1.40	...
	Alexandria	0.82	0.68	0.49	2.02	1.66	1.36	...
	Odessa	0.78	0.61	0.51	1.95	1.52	1.19	...
	Leningrad	0.81	0.71	0.51	1.95	1.58	1.40	...
	Tomsk	0.81	0.62	0.51	1.97	1.60	1.22	...
	Rykovskoe	0.74	0.60	0.45	2.20	1.64	1.31	...
	Tokyo	0.75	0.62	0.44	2.25	1.68	1.40	...
	Toronto	0.75	0.62	0.46	2.19	1.64	1.35	...
	New York	0.74	0.61	0.45	2.24	1.66	1.37	...
	Edmonton	...	...	...	...	1.73	...	...
	Churchill	...	...	...	...	1.60	...	...
	Gander	...	...	...	...	1.68	...	...
	San Francisco	...	...	...	...	1.61	...	...
(ii)	January	0.79	0.66	0.49	2.02	1.58	1.33	1.60
	April	0.79	0.63	0.46	2.16	1.70	1.36	1.67
	July	0.79	0.66	0.50	2.00	1.59	1.33	1.64
	October	0.74	0.58	0.48	2.09	1.61	1.22	1.59
(iii)	Stations 1 to 10							Stations 1 to 14
		0.78	0.64	0.49	2.03	1.60	1.31	1.62

NOTE.— (i) Mean ratios for each station separately with all months combined,
(ii) mean ratios for each month separately and all stations combined,
(iii) mean ratios all months combined and all stations combined.

TABLE V—THEORETICAL VALUES OF σ_n/σ_1

r_1	σ_5/σ_1	σ_{10}/σ_1	σ_{30}/σ_1
0.9	0.92	0.85	0.66
0.8	0.85	0.73	0.51
0.7	0.78	0.64	0.41
0.6	0.72	0.57	0.35
Mean values computed from data			
	0.78	0.64	0.49

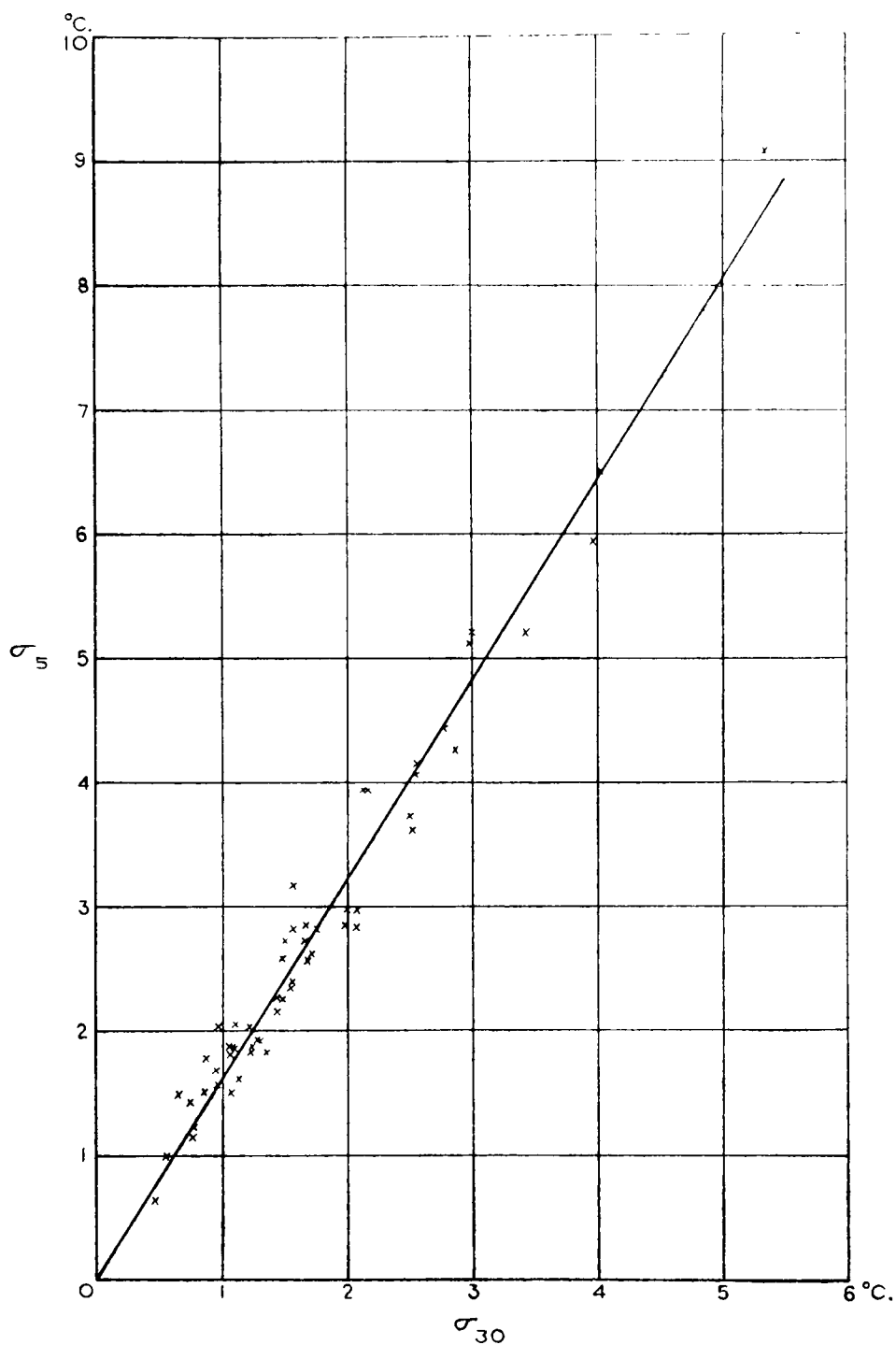


FIG. 1—RELATION BETWEEN STANDARD DEVIATIONS OF 5-DAY AND MONTHLY MEAN TEMPERATURES

This can be shown¹ to be equivalent to assuming that the series of daily values is made up of random variations combined with some degree of persistence, with an autocorrelation r_1 between successive daily values.

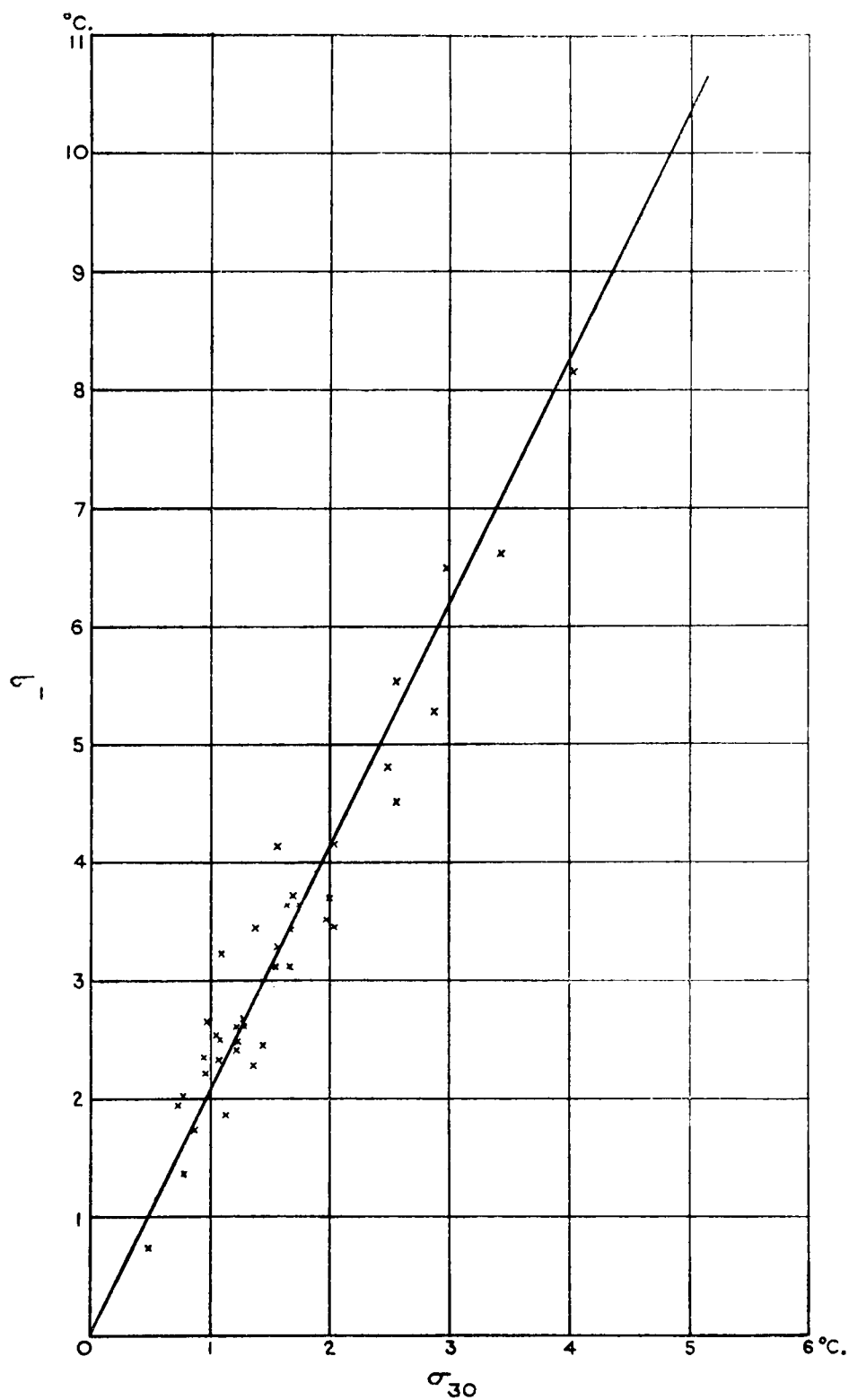


FIG. 2—RELATION BETWEEN STANDARD DEVIATIONS OF DAILY AND MONTHLY MEAN TEMPERATURES

Using the assumption (4), equation (3) can be written

$$\begin{aligned} \frac{\sigma_n^2}{\sigma_1^2} &= \frac{1}{n^2} \left(n + \sum_{i>j}^2 r_1^{i-j} \right) \\ &= \frac{1}{n^2} \left[n + 2 \left\{ (n-1)r_1 + (n-2)r_1^2 + \dots + 2r_1^{n-2} + r_1^{n-1} \right\} \right] \\ &= \frac{n(1-r_1^2) - 2r_1(1-r_1^n)}{n^2(1-r_1)^2} . \end{aligned} \qquad \dots\dots (5)$$

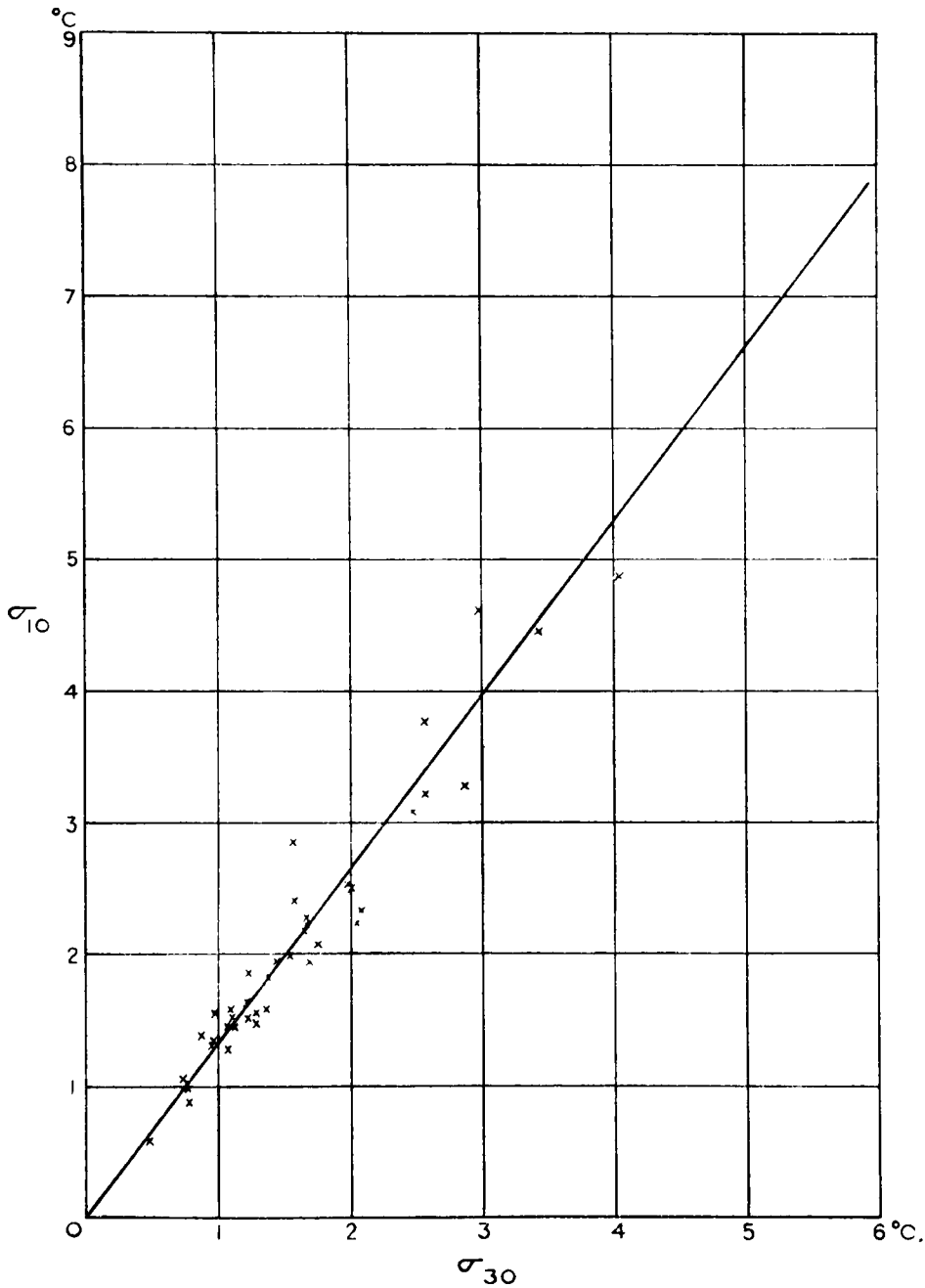


FIG. 3—RELATION BETWEEN STANDARD DEVIATIONS OF 10-DAY AND MONTHLY MEAN TEMPERATURES

Table V shows the values of σ_n/σ_1 for $n = 5, 10, 30$ and $r_1 = 0.9, 0.8, 0.7, 0.6$.

There is a reasonable correspondence between the computed ratios of σ_n/σ_1 and the theoretical ratios obtained for a value of r_1 of about 0.7.

Conclusion.—Anomalies of daily, 5-day and 10-day mean temperatures can be quite accurately referred to constant multiples of the standard deviation of monthly mean temperature, for which a large amount of data are available, for example those given by Nagao².

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METEOROLOGICAL OFFICE DISCUSSION

Mesoanalysis

The discussion on Monday, January 21, 1957, held at the Royal Society of Arts, was opened by Mr. W. D. S. McCaffery of The Central Forecasting Office, Dunstable, whose opening statement was based mainly on the paper by Fujita, T., Newstein, H. and Tepper, M.¹:—"Mesoanalysis, an important scale in the analysis of weather data".

In 1953 Swingle and Rosenberg² published a paper with the title "Mesometeorological analysis of cold front passage using radar weather data". Since then meteorological literature has been enriched by the addition of such words as mesosystem, mesostructure, mesomap. But although the words are new and new synoptic models are being evolved, there is nothing essentially new in the method of attack. The earliest workers in the field of mesoanalysis were the Norwegians during and immediately after the First World War, and papers by Bjerknes³ and by Bjerknes and Solberg⁴ can be classed as mesometeorological studies.

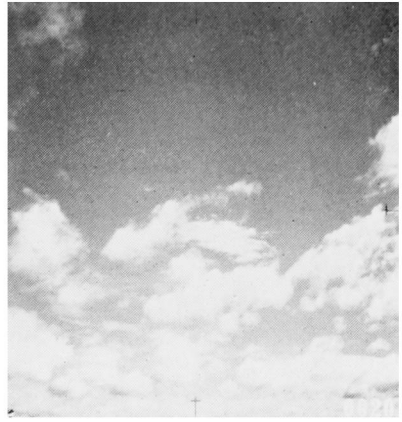
Scales of synoptic analysis.—Synoptic analysis, carried out as a normal daily routine, is primarily concerned with weather systems whose dimensions are of the order of several hundreds of miles. This may be termed macroanalysis. Synoptic studies have also been carried out over limited areas⁵, say 10 miles by 20, with a station spacing of about one mile and synoptic charts have been constructed at intervals of as little as one minute⁶. These are studies on a microscale.

Work in recent years, particularly by the Severe Local Storms Research Unit of the United States Weather Bureau has revealed that between the two extremes of phenomena on the micro and macro scales, there is an important third class of phenomena—too small to be detected with certainty by the coarse network of stations normally available for macroanalysis and too big for their motion to be investigated in the limited area used in micrometeorological investigations. Characteristic physical dimensions of these systems lie between 10 and 100 miles, so in an arbitrary way this defines the scale of mesoanalysis with macro and micro scales being used for atmospheric motions respectively greater than 100 and less than 10 miles in extent. The time interval used in meso studies is one hour, but very full use is made of autographic records and intermediate reports.



Reproduced by courtesy of Kenneth Woodley

THAMES FLOODING ABOVE TEDDINGTON
(See p. 189)



ALTOCUMULUS IN A STANDING WAVE

We are indebted to Mr. L. G. Bird of the Meteorological Office, Defford, Worcestershire for this report and the photographs reproduced above which show a patch of altocumulus which was stationary between 0914 and 0935 G.M.T. on July 24, 1956 N.E. of Defford though the wind at its level had a speed of 45 kt.

When the existence of this stationary Ac patch was realized a series of photographs was taken at fifteen-second intervals with a camera facing 030° true. The photographer was Mr. J. Dowding of the Photographic Section, Defford. The first photograph was taken at 0914 G.M.T. and the photographs reproduced are numbers 1, 20, 24, 28, 32, 36, 60 and 70 of the series.

The Ac patch is visible on all the photographs reproduced and from the vertical and horizontal register marks is seen to have remained stationary as small Cu move quickly from left to right.

The Ac patch slowly dispersed and the dispersal appeared to coincide with a temporary dispersal of the small Cu. In photographs 24, 28, 32 and 36 the



progression through the cloud of a small cloudlet can be clearly seen with fresh cloud forming upwind of it.

On July 24, 1956 a NW'ly airstream covered the Welsh hills and the Midlands of England and a warm-cold front link ran from east to west between Northern Ireland and Lincolnshire between two wave depressions, one centred on the Atlantic and one centred near Denmark. Between 0800 and 1000 G.M.T. the weather was cloudy over the Welsh mountains but to their lee the cloud was well broken with small cumulus forming between 2,000 and 3,500 ft. At Defford there was little cloud above apart from thin slowly dispersing Ac patches which were estimated to be at 13,000-15,000 ft. where the winds were 310° , 45 kt. The photographs are of one of these patches. It seems probable that the patch was formed in a stationary lee wave. Conditions were favourable for the formation of such waves as Scorer's parameter l^2 varied from 2.02 (naut. miles)² to 1.14 (naut. miles)² in the layer 1000-800 mb. and from $.84$ (naut. miles)² to $.77$ (naut. miles)² in the layer 700-400 mb.*

* SCORER, R. S.; Forecasting mountain and lee waves. *Met. Mag., London*, **82**, 1953, p. 232.



Photograph by P. Keeling

CONTRAIL SHADOW

Photograph taken at Defford on February 18, 1957
(See p. 187)

Mesoanalysis in the mid-West United States of America.—In an area of the United States comprising all or part of ten mid-West States centred on Kansas, the Severe Local Storms Research Unit has set up a special network of “co-operative” stations which together with the normal synoptic network gives an average station spacing of between 20 and 30 miles over an area which is approximately a 600 mile square. In this area station heights vary from less than 1,000 ft. to over 6,000 ft. above sea level and immediately to the west the Rockies rise to over 9,000 ft. The synoptic stations are equipped with the normal complement of meteorological instruments and in addition they and the co-operative stations are equipped with high speed barographs revolving once in twelve hours. Thirty-one of the co-operative stations also have high speed hygro-thermographs. During the period of the analyses which were used to illustrate the techniques and results of mesoanalysis, data were also available from six radar stations operating in the area and about a dozen upper wind and radio-sonde stations.

Processing the data.—Before the available data could be used in the construction of mesomaps, barograms and thermograms had to be calibrated and a method found which made the best possible use of 24-hr. rainfall totals.

Pressure.—Using hourly values of pressure reduced to sea level from the synoptic reporting stations, a 24-hr. mean pressure at sea level was calculated for each synoptic station in the area and plotted on a map. Through these values, smoothed isobars were drawn. On this map 24-hr. vector mean winds were also plotted and a rough fit with the mean isobars obtained. By interpolation a 24-hr. mean pressure at sea level (which in many cases would have been difficult to compute) was read off for every station used in the analysis. A horizontal line was drawn across each barogram such that it, in effect, represented the mean value of the barogram for the 24-hr. period. As such it was given the same value as that interpolated from the mean smoothed pressure field. This procedure provided for a calibration of the barograms so that the value of sea-level pressure could then be read directly from the recorded trace for any time.

Temperature.—From the hourly values of station-level temperature at the synoptic reporting stations, 24-hr. mean temperatures were calculated which revealed at once the influence of station elevation. By plotting the 24-hr. mean temperatures on a scatter diagram of station height against station latitude, and drawing isotherms of best fit, lapse rates at various latitudes through various heights could be found. These were found to be very similar and in the interests of simplicity one mean lapse rate of 3°F. per 1,000 ft. was used to determine “sea-level” mean temperatures. Micro variations in temperature, due to patchy cloudiness, variations in surface texture, etc., were eliminated by drawing smoothed isotherms through the plotted values of sea-level mean temperatures. A smoothed mean temperature at sea level could then be interpolated for each station and the thermograms calibrated.

Precipitation.—Most of the precipitation data were available as 24-hr. rainfall totals, but a scatter of stations reported hourly values. Using the hourly values, for any particular hour the percentage of the 24-hr. total which fell during that hour could be calculated and plotted on a chart. Sufficient values were available for a reasonable pattern of iso-percentage lines to be drawn. Using this field it was then possible to calculate for each of the other

stations the percentage of the 24-hr. total which fell during the hour in question. Having the 24-hr. total for these stations it was then possible to infer the hourly precipitation accumulation and unique isohyetal patterns could be drawn for each hour analysed.

Station time sections.—In order that all of the weather elements could be viewed in their proper interrelation and to assist in understanding events at any one station, individual station time sections were constructed which were, in effect, a composite of all the weather data on one chart. The time scale of the time section ran from right to left and in this way, for weather systems which moved mainly from west to east, the time section approximated to a space section through the station. The barograms and thermograms were entered across the top half of the section after calibration. An entry for clouds was made under the thermogram trace, symbols plotted roughly according to height indicating more than 9/10, 6/10 to 9/10 and nil to 5/10. Reports of precipitation appeared on the line below the cloud data and were presented in the form of a line spectrum which indicated the duration of light, moderate or heavy rain and also hail. On the next line below, shading represented thunderstorms in two categories; thunderstorm and heavy thunderstorm. The lowest entry on the chart showed wind speed and direction. Written vertically across the chart at the appropriate time were edited additional remarks giving extra information from special observations, climatological forms, reliable newspaper reports and the like.

Construction of the mesomaps.—For each hour of the period chosen for study, four basic maps were drawn:

- (i) Pressure (including winds and isogon pattern)
- (ii) Temperature
- (iii) Precipitation (including radar data and storm reports)
- (iv) Clouds (both lower and upper).

In the analysis of these charts there were three basic techniques which were applicable to all:

- (i) The interpretation of time gradients as space gradients.
- (ii) The adherence to the principle of continuity of pattern from hour to hour.
- (iii) The smoothing of irregularities of a purely local nature.

In constructing the pressure chart, a rough analysis indicated the speed and direction of movement of the mesosystems. When this is known, and assuming that for short intervals of time the pressure field moves without very much change, it is possible to interpret the time scale of the barogram in such a way that one hour of the trace corresponds in length to the distance that the pressure system has moved in one hour on the map scale. By retracing the portion of the barogram plus or minus half an hour each side of the map time and oriented along the track of the perturbation being followed (time increasing against the motion), the pressure variation falls, more or less, in its proper spatial position on the map and clearly indicates the pressure field between the station observations. Fujita⁷ in another paper describes a technique for dealing with cases of rapidly changing pressure patterns. In the analysis more weight was given to the gradient of pressure than to the numerical value of the pressure

itself, and values were ignored if drawing to them meant introducing pressure gradients not supported by the barograms.

From the wind field, it was possible to delineate the isogon pattern and emphasize lines of significant wind shift.

The construction of the temperature chart was accomplished in a similar manner to that of the pressure field.

On the hourly rainfall maps, were entered in their appropriate location, the severe storm reports and also radar echo reports from stations within the analysis area.

The cloud charts showed the data divided into two categories—by height (high clouds and low-medium clouds) and by amount (1/10 to 9/10 and 10/10).

When all four charts for one hour were complete, a composite coloured chart was prepared which showed all the above features superimposed. In this way the inter-relationship between the various elements was clearly brought out.

Case of June 24–25, 1953.—The macroanalysis over this period, done in the conventional manner with charts at three-hourly intervals, shows a cold front progressing steadily south-eastwards, entering a trough of low pressure, initially in warm air, and finally both trough and front moving along together. The authors comment: “The analysis appears to represent a very orderly sequence of events, i.e. the progress of a ‘classical’ cold front along which precipitation is distributed prefrontally, post-frontally, and at times even along the front.”

The mesoanalysis of this situation presented on ten-hourly composite charts, reveals instead of the simple cold front, eleven major mesofeatures which grow, move and decay in an orderly fashion, persisting from three or four hours to upwards of eight hours and being closely related to the areas of precipitation, overcast skies, radar echoes, wind and electrical storms, and tornadoes. Fig. 1 shows the pressure, temperature and precipitation fields taken from the last in the series of composite charts (0300 c.s.t., June 25, 1953). The central State in the diagram is Kansas with Oklahoma immediately to the south and Nebraska to the north. The macroanalysis for this time is similar to this mesomap from the low pressure area in Oklahoma south-westwards. North-eastwards the two analyses are very different without any one feature on the mesomap corresponding closely with the cold front of the macroanalysis. The mesosystems shown are: System XI, a pressure jump line, located entirely in the warm air, and at which a sudden wind shift accompanies the sharp rise of pressure, but without precipitation and with very little cloud; System VII, a well developed meso-high or thunderstorm high and trailing wake depression (Fujita⁷) with which there is associated a large rain area; System X, which started off as a pressure couplet—a small high and a low of comparable magnitude in close association—but which at this time resembles more closely the model of the thunderstorm high. Some precipitation and radar echo were associated with this system earlier, but at the time of the map, only an area of overcast skies is reported.

Meso-synoptic models.—After showing a series of slides illustrating the main features of the mesoanalysis of the case of June 24–25, 1953, Mr.

McCaffery used further slides to illustrate in greater detail the three synoptic models which seem to emerge. The pressure couplet is a new feature about which little is known except that when it appears, storminess seems to be associated with the low pressure part, which is often warm. The origin of the pressure jump line, as illustrated in the analyses discussed, has been explained by Tepper⁶. Newton⁸ has proposed an alternative theory for the prefrontal squall line while Fujita⁷ refers to the pressure surge line. It is not altogether clear that these three phenomena are one and the same thing and further work is obviously required.

The model of the thunderstorm high seems the most satisfactory from the forecasters' point of view, in that when it appears the chart analysis often resembles the simplified synoptic model and it often has a long enough life for a short term forecast to be successful on the basis of growth and decay over six to twelve hours. The phenomena of the thunderstorm high has been studied in

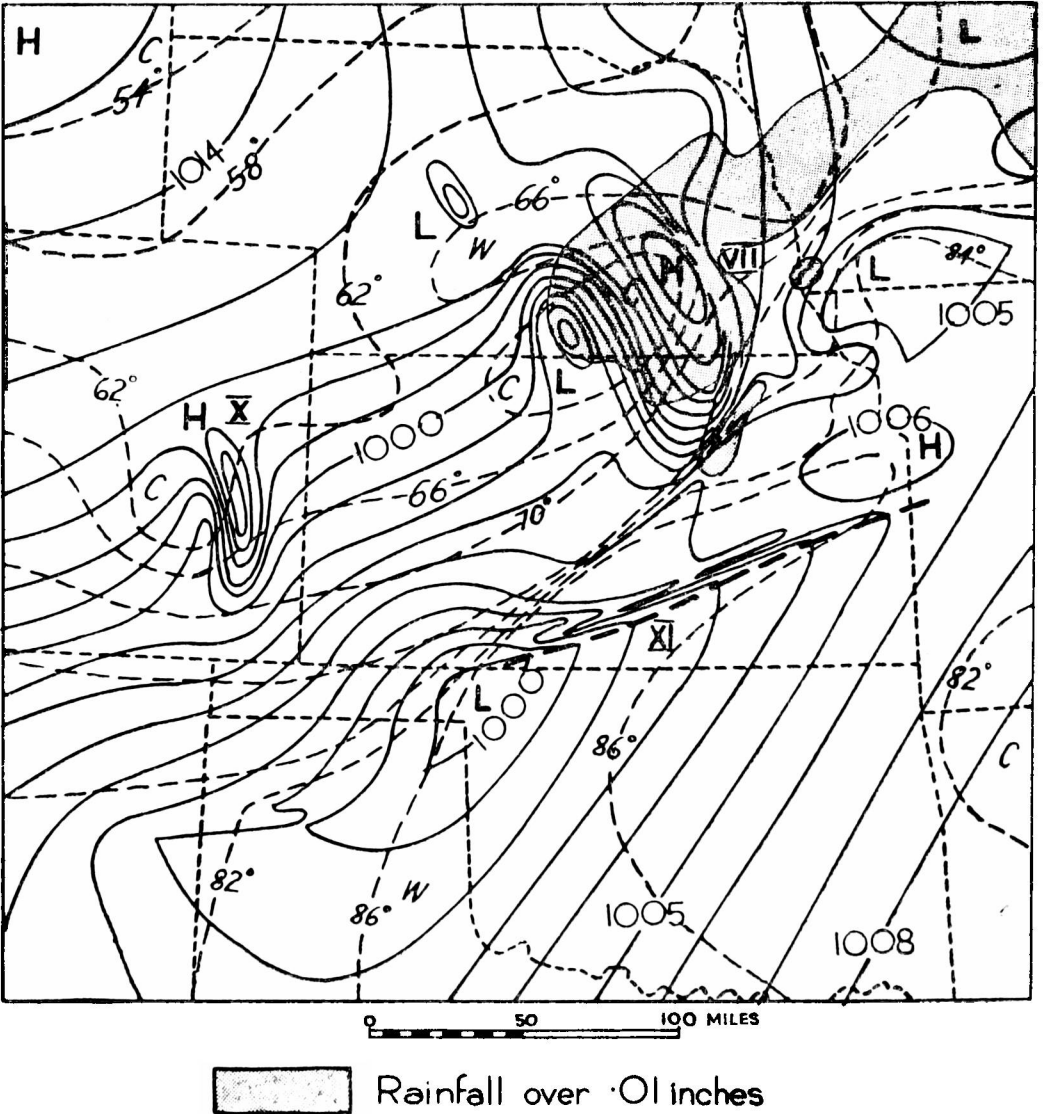


FIG. 1—MESOMAP OF THE MID-WEST UNITED STATES OF AMERICA 0300 C.S.T.,
JUNE 25, 1953

India, Japan and elsewhere, and a synoptic study over the United Kingdom by Douglas⁹ attributes the observed rise of pressure to cooling due to rain.

In concluding, Mr. McCaffery said that with the hourly observations available from the synoptic network over the United Kingdom, it was possible to do a crude form of mesoanalysis as an hourly routine. What was lacking was systematic investigation of small disturbances by which the background knowledge of the forecaster could be so increased that instead of smoothing out all irregularities, mesosystems could be confidently drawn in and some improvement in short-term local forecasting hoped for.

The Director, in opening the general discussion, asked if mesosystems were predictable or if they were minor eddies of an unpredictable variety. He did not remember anything like a pressure couplet in orthodox hydrodynamics and wished to know if there was any other evidence for them. In reply, Mr. McCaffery said that the examples studied suggested that there were mesosystems with a long enough life history to make a knowledge of them useful in short-range forecasting, but others were more ephemeral and akin to unpredictable eddies. With regard to pressure couplets it had been suggested that the initial smoothing of the average sea-level pressure data might mean that any low which then appeared on the charts would be accompanied by a corresponding high. But as the barograph trace had been calibrated without changing the shape of the barogram, and as these showed peaks and troughs above and below the main run of the trace, the pressure couplet must be accepted as a real phenomenon.

Mr. Sawyer pointed out that features similar to those described were to be observed over the United Kingdom and mentioned Potheary's¹⁰ description of a pressure jump line observed moving across southern England independently of the wind-fields. He went on to describe the formation of the thunderstorm high as due to cooling by precipitation falling into dry air. Although observed in this country it was thus more frequently seen in dry regions such as the mid-West United States of America and north-west India. Mr. Sawyer thought that if we could draw detailed mesomaps over this country some interesting phenomena, e.g. coastal and other orographic effects, would be observed. He was glad that a start had been made on this type of work.

Dr. Sutcliffe recalled that 25 years ago he had investigated irregularities in barogram traces during thundery weather in the Mediterranean. Pressure rises of 4 mb. or so in half an hour were observed often without any actual thunderstorms or indeed sometimes with no definite weather at all. The cooling of a mass of air by rain falling through it was important as only a 5°F. difference in the mean temperature of adjacent columns of air could account for the observed pressure changes. It was interesting to note that broadly similar synoptic situations—upper south-westerlies above lower southerlies—gave rise to mesoscale features in the United Kingdom, the United States of America and the Mediterranean. It was perhaps rather difficult to see how mesoanalysis could be used in forecasting and possibly its importance might lie more in increasing the background knowledge of the forecaster.

Mr. Harper stated that one of the features of weather radar is that many systems are seen on the screen which are not related to anything on the

synoptic chart and he thought that it would be useful to study radar observations against hourly observations. A case of a well defined pattern of radar echo was that of the West London Tornado¹¹ of December 1954 which could be tracked back to Hayling Island where a whirlwind had occurred an hour earlier. Without radar the connexion between these two events could not have been proved.

Mr. Craddock mentioned a spectacularly successful thunderstorm forecast which had been made at The Festival of Britain by means of radar location of thunderstorms originating near the Channel Islands. With radar location of mesosystems a special forecast service for persons interested in minor-scale phenomena might be possible.

Dr. Caton referred to his study of the possibility of producing detailed forecasts of precipitation from weather radar displays—forecasts of the type: “Rain or shower expected, commencing, ceasing” In conditions of instability a satisfactory standard of accuracy had been achieved for periods up to about two hours ahead.

Mr. C. V. Smith thought that the uncertainties in the evolution of the more readily identifiable synoptic systems (e.g. pressure centres and fronts) were always such as to obviate the use of analysis on the mesoscale, at least as far as the Central Forecasting Office was concerned. The difficulty of recognizing what would be a persistent meso feature and of forecasting its displacement suggested that information on this scale was probably useful only as background knowledge and for the interpretation of developments after the event.

Dr. Farquharson said that the atmosphere is not split into phenomena of special periods of say, six or 24 hours, but that we must expect all scales of motion and attempt to predict them.

Mr. Peters wanted further work on these lines and recalled that J. Bjerknes spent two periods in the United Kingdom teaching and doing research on frontal analysis over the British Isles. His published result¹² was one of the earlier works in mesoanalysis. Studies of the effects of coasts, mountains, river valleys and urban areas on the major features of weather were unco-ordinated and not in a form useable by forecasters. Little was known of the synoptic climatology of large cities or popular holiday resorts. With the extension of WEA (telephone weather service) fresh responsibilities were being laid on certain outstation forecasters, and Senior Meteorological Officers should examine the need for new synoptic reporting stations.

Mr. R. F. Jones drew attention to the fact that pressure variations of 8 mb. in 10 miles such as had been shown on the mesomaps were important to aircraft for altimeter settings.

Mr. Roberts was not satisfied that the present synoptic network was anything like good enough to catch small systems since inquiries from the general public often reveal phenomena not recorded on the synoptic chart.

Mr. Hanson, speaking of the experience in the use of radar in forecasting from Victory House, said that the radar information is additional to, but cannot replace synoptic reports. Referring to the analyses discussed by the opener, Mr. Hanson wondered if excessive smoothing in some cases had removed features associated with tornadoes. Mr. McCaffery, replying, said that

tornadoes were essentially micro features and the locally intense pressure gradient associated with them might escape a meso-synoptic network. Drawing to the data actually available seemed to have been done without undue smoothing.

Mr. Gold wanted the scale of mesoanalysis extended down to about 1 mile or 1 Km. as 10 miles was too big for a lower limit. He would also like to see upper air charts on the same scale. *Mr. Gold* stressed the importance of the time element, as features with a life history of an hour or less were obviously unpredictable. Mesoanalysis might be most important in a "flat" situation since then such things as evaporation and radiation would have the greatest chance of producing meso phenomena. He would like to think that meso-meteorology could lead to a WEA forecast for the London area of the type "rain at Mill Hill but not at Golders Green".

Dr. Sutcliffe, taking up *Mr. Gold's* point about the definition of the meso scale, said that perhaps we should refer to meso-synoptic-analysis, micro-synoptic-analysis and so on, distinguishing between these scales and the limits implied by such terms as, for instance, the micro-physics and macro-physics of clouds.

Mr. Clements was of the opinion that if we were ever to forecast successfully for a local area we must do this sort of analysis. The station network had much increased since 1939, but he doubted if there had been any improvement in detailed forecasts for individual places. How does the forecaster today set about forecasting local detail?

Mr. Harley doubted if many forecasters could say exactly how they arrived at the final version of any forecast. He was much in favour of mesoanalysis being done in the United Kingdom, but thought an increased station network might be necessary. He would welcome the opportunity to take part in such work.

Mr. Bradbury described detailed short-range forecasting for fly-pasts when aircraft reconnaissances were necessary to reveal phenomena which escaped the existing network of stations.

Mr. Jacobs thought that over the past twelve years, observations from hourly reporting stations, together with climatological data, reports from railway controllers and the like, and observations from over 5,000 rainfall stations provided ample data for research in the meso-synoptic field.

The Director, closing the Discussion, said that the wider use of weather radar would depend on our establishing its usefulness in normal synoptic work. He went on to relate the circumstances in which early in the Second World War, *Mr. Gold* had made a brilliantly successful local forecast, in which he predicted a complete reversal of wind direction, simply by carefully noting the local topography and applying the physics of katabatic winds.

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WORLD METEOROLOGICAL ORGANIZATION

Second Session of the Commission for Climatology, Washington, January 1957

It seems rather ironic that the Commission for Climatology of the World Meteorological Organization should have had to hold its second session in Washington, D.C., United States, from January 14 to 25, 1957 when, although the city is sheltered by the Appalachians from the bitter cold of central North America, the normal monthly temperature ranges between 20°F. and 44°F. and, on the average, 6 in. of snow falls during the month! However, in these days of financial stringency, one has to be grateful that there is a Government willing to act as host—and, anyway, the weather was not too bad although the writer found the indoor climate much too cosy! Indeed, all delegates were deeply appreciative of the invitation of the United States Government and of the excellent facilities provided in the International Conference Suite. Delegates from more than 20 Members of the World Meteorological Organization, observers from the International Civil Aviation Organization, the Food and Agriculture Organization, the United Nations Educational, Scientific, and Cultural Organization and other international organizations (including the recently formed International Society of Climatology and Biometeorology), also a number of invited experts, were given a cordial welcome by Mr. Francis O. Wilcox, Assistant Secretary of State for International Organization Affairs and by Dr. F. W. Reichelderfer, Chief of the United States Weather Bureau. The meeting was presided over by the President, Dr. C. W. Thornthwaite, Director of the Laboratory of Climatology, Drexel Institute of Technology, Centerton, New Jersey, United States of America, who gave an opening address on "The task ahead in climatology"; which was reported in the World Meteorological Organization Bulletin¹. Messages wishing the meeting success from the President and Secretary-General of the World Meteorological Organization were read by Dr. K. Langlo, Chief of the Technical Division of the World Meteorological Organization Secretariat.

Only two Working Committees were established, one under the Chairmanship of Dr. Helmut E. Landsberg, Director, Office of Climatology, United States Weather Bureau and the other under the Chairmanship of Mr. C. C. Boughner, Chief, Climatological Division, Meteorological Service, Canada. Dr. Landsberg's Committee dealt with those agenda items which related to research and applied climatology whilst Mr. Boughner's Committee dealt with agenda items relating to general climatology, requirements, regulations,

rules and practices. There was an excellent spirit of co-operation among all delegates and the work of the Committees proceeded smoothly and efficiently; it was most helpful for each Committee to have the assistance of a member of the World Meteorological Organization Secretariat, i.e. Dr. K. Langlo and Mr. O. M. Ashford.

The final resolutions and recommendations covered many aspects of climatology. The resolutions related mainly to the establishment of working-groups. In view of the difficulty of conducting the business of working-groups by means of correspondence (funds, available to finance meetings, are very limited) it was decided to keep their number to a minimum. Nevertheless as many as eight were set up. One has the formidable task of preparing a system of climatic classification "based on dynamic climatological concepts". Another is called upon to study methods of determining and mapping "derived" climatic elements e.g. heat content and flux, evaporation, moisture deficit, precipitable water. A third is expected to provide an advisory service on the application of statistical methods to specific climatological problems and is required to prepare a chapter thereon for inclusion in the projected World Meteorological Organization Guide to Climatological Practices. The other working groups will be concerned with the review of World Meteorological Organization Technical Regulations relating to climatology, the machinery for the exchange of past weather data, the provision of advice and the preparation of a publication on the processing of climatological data by means of punch-cards (it was decided that there is no need for international standardization of the punch-card layout for general climatological purposes), the review and co-ordination of contributions to the Guide to Climatological Practices, the study of current work on microclimatology and the preparation of a chapter thereon for inclusion in the Guide.

The recommendations embraced many aspects of climatology. Perhaps the most important was that covering proposed amendments to the World Meteorological Organization Technical Regulations. Others dealt with the possibility of establishing national data-control authorities (it is proposed that the views of Members of the World Meteorological Organization should be sought), the use of aircraft meteorological observations for climatological purposes (Members of the World Meteorological Organization to be invited to carry out pilot studies on models and procedures for summarization), CLIMAT broadcasts and CLIMAT publication, earth-temperature measurements. In connexion with certain agenda items it was decided to seek the views or advice of other Technical Commissions or the Regional Associations. For example, the Commission considered that the maintenance of a selection of climatological stations as "reference" stations at places where the exposure could be kept unchanged over a very long period, was of great importance for the determination of "trends" and long period fluctuations in temperature, rainfall etc. and decided to invite each Regional Association to study the requirement for such key stations in its area and to urge that early action be taken to set up sufficient stations to cover all climatic régimes of the Region. In view of the need for more extensive measurements of, and for the adoption of a standard definition for, daylight illumination, the Commission decided to seek the advice of the Commission for Instruments. It was also decided to consult the latter regarding automatic climatological stations, and the measurement of the water equivalent of snow and of earth temperature.

At the request of the Executive Committee the Commission studied in detail a report of a Working Group on Climatic Atlases which the Executive Committee had itself set up. It was decided to pass certain comments to the Working Group with the suggestion that their report be revised accordingly. With regard to the proposed World Meteorological Organization Guide to Climatological Practices, the Commission considered that it should not embrace material readily available in existing textbooks but recommended that liberal use be made of references to such publications. As some chapters of the Guide would be ready for publication before others, the Commission decided to recommend that the Guide should be issued in loose-leaf form and that individual chapters should be issued separately as completed.

So much for the actual business of the Commission. It is important to mention, however, that the meeting provided an invaluable opportunity for the exchange of ideas and experience among the various delegates. Two afternoons were devoted to scientific discussions. Papers were read by Dr. M. I. Budyko, Director, Central Geophysical Observatory, Leningrad, on the "Heat balance of the surface of the Earth", by Dr. H. E. Landsberg on "Preparing climatic data for the user", by Dr. W. C. Jacobs, Director for Climatology, Air Weather Service, United States Air Force, on "Problems associated with modern requirements for data processing", by Mr. N. Rosenan, Chief, Climatological Division, Meteorological Service, Israel, on "Special problems in arid zone climatology" and by Dr. L. J. L. Deij, Director, Climatology Division, Royal Netherlands Meteorological Institute on "Evaporation in the Netherlands". In addition, one of the invited experts, Dr. F. K. Hare, Professor of Geography, McGill University, Toronto, Canada, read a paper on "The dynamic aspects of climatology".

In addition to many individual acts of hospitality on the part of members of the United States meteorological services, there were the usual social functions including receptions by our hosts, the United States Government, our American and Russian colleagues, the Microcard Corporation, and a dinner by the Bendix-Friez instrument makers. Through the courtesy of the Chief, interesting visits were made to various Offices of the Weather Bureau, including the Meteorological Office at Washington Airport. Many of the delegates accepted Dr. Reichelderfer's kind invitation to tour the United States' National Weather Records Centre at Asheville, North Carolina. This is a most impressive organization which comes under the control of Dr. Landsberg, and the Director, Mr. Leslie Smith, and his staff spared no effort to make the visit both instructive and enjoyable. The history of this centre is a story in itself, a story which might well be entitled "Automation as applied to climatology". Suffice it to say that many of the visitors, having seen the huge array of machinery, including modern electronic computers, the enormous store of cards, now 300 million and increasing at the rate of 30 million per year, the facilities for making micro-films, the highly efficient printing section, and especially the man-power at Mr. Leslie Smith's disposal, came away feeling extremely envious and, perhaps, a little ashamed of the "Stone-Age" methods in use in their own country.

All that remains to be said is that the Second Session of the Climatological Commission was very well run and quite successful. The task of distributing and publishing documents was very efficiently dealt with by the experienced

staff of Mr. Hampton Davis, the capable Executive Secretary, in collaboration with Dr. Langlo and Mr. Ashford of the World Meteorological Organization Secretariat: the interpreting facilities were excellent.

At the end of the meeting the writer had the honour of being elected President of the Commission in succession to Dr. Thornthwaite and Mr. C. C. Boughner of Canada was elected Vice-President in succession to Dr. A. Ångström of Sweden.

R. G. VERYARD

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METEOROLOGICAL OFFICE NEWS

Retirements.—*Mr. C. S. Herbert*, Senior Experimental Officer, retired on April 30, 1957. He joined the Office in January, 1912 in the General Services Division. He was transferred to the Forecast Division in 1924 and from 1930 until 1943 he served successively at a number of aviation outstations including a tour of duty in the Middle East. Since 1943 until his retirement he served in the Instruments Division at Headquarters. He was "Mentioned in Despatches" in June 1943.

Mr. E. S. Tunstall, Senior Experimental Officer, retired on April 30, 1957. He joined the Office as a Staff Assistant in February 1920 after service in the Seaforth Highlanders (1915–17) and the Meteorological Section, Royal Engineers (1917–19) during the First World War. Apart from the period between 1928 and 1937 which was spent in the Forecast and General Services Divisions at Headquarters, Mr. Tunstall has been at aviation outstations. For the past twelve years he has been forecasting for civil aviation and since 1946 until his retirement he has been the Officer-in-Charge of the Meteorological Office at Speke Airport, Liverpool.

NOTES AND NEWS

Contrail shadow photograph

The photograph which is reproduced (see p. 177) was taken at Defford at 1030 G.M.T. on February 18, 1957. The bearing of the contrail from the Meteorological Office was 160° east of true north. The height of the contrail was estimated to be 23,000 ft.; the shadow was cast on thin but dense altostratus cloud estimated to be at 13,000 ft.

Torrential Rainfall at Royal Air Force station Tengah

A heavy fall of rain occurred in the north-west of Singapore Island at Royal Air Force station Tengah on September 16, 1956, when 118.5 mm. (4.67 in.) were recorded in a thunderstorm. On this occasion the normal shower development over the Malacca Strait during the night was intensified by a convergence zone separating the Pacific easterlies and the Indian Ocean westerlies. The zone was lying at 0730 local time (0001 G.M.T.) on September 16 just to the west of Singapore Island and extending in a north-south direction. The showers developing over the sea were carried eastwards by the general westerly flow at 10,000 and 15,000 ft.

The rain commenced at 0627 local time (2257 G.M.T.), about dawn. The rain was slight at first, but after three minutes became torrential. A solid sheet of water reduced the visibility to under 500 yd. Thunder was not heard until 40 min. after the rain had commenced, and it did not become frequent or heavy. The wind was calm at first, but later freshened to north-north-westerly about 15 kt. The large monsoon drains designed to take the normal heavy tropical rains could not cope with this torrent, and the ground was soon under water. After $1\frac{1}{2}$ hr. the rain eased slightly and the observer was able to measure the rain. In 99 min. from 0627 to 0806 (2257–0036 G.M.T.) 111.9 mm. (4.40 in.) had fallen. Heavy rain continued for a while then became slight, and finally ceased at 1050 local time (0320 G.M.T.).

This intense rainfall was fairly local, and only in a few areas were floods reported. Rainfall figures for other airfields on Singapore Island, during the same period, are given below:—

R.A.F. Seletar (north-east coast)	17.1 mm. (0.67 in.)	0843–1007 local time
Singapore Airport (north-east inland)	6.6 mm. (0.26 in.)	0745–1010 local time
R.A.F. Changi (extreme east coast)	3.0 mm. (0.12 in.)	0857–0957 local time

This is not the heaviest fall recorded at Tengah, but it is considered to be the heaviest yet measured from the early morning “rains”. Other heavy falls recorded on the Island are:—

R.A.F. Changi	... ..	4.28 in. in one hour ¹	April 20, 1953
Kallang Airport	4.73 in. in one hour (1430–1530 local time)	July 28, 1951

D. C. MASON

REFERENCE

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LETTERS TO THE EDITOR

Mean range in an autoregressive series

The note on “Mean range in an autoregressive series”, by A. F. Jenkinson¹ is based on Exercise 370 of “Exercises in theoretical statistics” by M. G. Kendall². This exercise, in turn, is based on “The distribution of extreme values in samples whose members are subject to a Markoff Chain Condition”, by Benjamin Epstein³.

But Dr. Epstein subsequently published⁴ a correction:—

“In the paper mentioned . . . I claim to have proved a number of results dealing with the distribution of extreme values in samples of size n drawn at equally spaced intervals from a stationary Markoff process. As Professor W. Feller has kindly pointed out to me in personal correspondence, this is actually not the case. However, the theorems and their proofs remain completely valid in their present form if the observations are drawn from a stochastic process satisfying condition (5) of the paper. This chain condition states that the process be such that

$$\text{Prob}(X_n \leq x \mid X_1 \leq x, X_2 \leq x, \dots, X_{n-1} \leq x) = \text{Prob}(X_n \leq x \mid X_{n-1} \leq x)$$

is satisfied for all x and all positive integers n .”

This restriction, therefore, applies also to the ingenious application that Mr. Jenkinson offered in his note. It requires, for example, that the probability that today’s temperature will not exceed some value that also was

not exceeded yesterday be completely independent of whether that value was exceeded on any of the preceding days. In other terms, it permits no correlation of lag more than one. Since few meteorological phenomena, if any, satisfy this condition, Mr. Jenkinson's result is of only academic interest.

Another approach to the distribution of the largest member of a sample from a stochastic process was taken by G. S. Watson⁵. He showed that as the sample size increases, the distribution of the largest member tends asymptotically to the distribution of the largest member in a sample from a population all of whose elements are independent. Although of theoretical interest, this result is not directly applicable to samples of size 30, used by Mr. Jenkinson. Consequently, the problem that Mr. Jenkinson posed, of the relation between mean monthly temperature range and standard deviation of daily values, has not yet been solved.

ARNOLD COURT

*California Forest & Range Experiment Station,
Forest Service, U.S. Department of Agriculture,
Berkeley, California, December 26, 1956.*

[The solution proposed by Kendall², is correct for the autoregressive series under discussion, which is a wide-sense strictly stationary Markov process⁶. For such processes, Doob (pp. 80-91, especially equation 6.1, p. 80) says: "For any integer $n \geq 1$, if $t_1 < \dots < t_n$ are parameter values, the conditional *t_n probabilities relative to $^*t_1, \dots, ^*t_{n-1}$ are the same as those relative to $^*t_{n-1}$ in the sense that for each λ

$$P \{^*t_n \leq \lambda \mid ^*t_1, \dots, ^*t_{n-1}\} = P \{^*t_n \leq \lambda \mid ^*t_{n-1}\}."$$

In my opinion therefore, for the autoregressive series of my note the distribution function of the largest member is correctly given and I believe that Mr. Court is wrong in his conclusion that this distribution function would only apply to series with no correlation of lag more than one.

A. F. JENKINSON]

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3. EPSTEIN, B.; The distribution of extreme values in samples whose members are subject to a Markoff Chain Condition. *Ann. math. Statist., Ann. Arbor*, **20**, 1949, p. 590.
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5. WATSON, G. S.; Extreme values in samples from m-dependent stationary stochastic processes: *Ann. math. Statist., Ann. Arbor*, **25**, 1954, p. 798.
6. DOOB, J. L.; Stochastic processes, New York, 1953, p. 233.

Thames flooding above Teddington, February, 1957

You may be interested in the attached photograph (facing p. 176) the best of four taken at the same time, which shows the increased flow over Teddington Weir on the afternoon of Saturday, February 16, 1957.

The normal daily flow over Teddington Weir is given by the Thames Conservancy as 2,399 million gallons per day. On this day the flow is given as about 4,300 million gallons. This was not the maximum flow recorded during this February's floods, for that occurred on the previous Saturday.

The maximum flow recorded this century at Teddington was in March, 1947, when the day's flow was 13,700 million gallons.

Harlow, March 1, 1957

KENNETH WOODLEY

BOOKS RECEIVED

Indian Journal of Meteorology and Geophysics. 8, 1956, No. 1., *India Meteorological Department*. 9½ in. × 7¼ in., pp. ii + 126. *Manager of Publications, Delhi*, 1957. Price: Rs. 3s. or 5s.

Meteorologia por correspondencia. Nos. 13 and 14. 9 in. × 5¼ in., pp. 49–56. *Sociedad Meteorológica, Instituto de Estudios Superiores, Montevideo*, 1956.

WEATHER OF APRIL 1957

Atlantic depressional activity was largely concentrated over the north-western part of the ocean near Labrador and south Greenland, a pattern which is more usual in March and May than in April. Lowest monthly mean pressure (1003 mb.) was about 57°N. 47°W., where the value was 6 mb. below normal. The usual extension of the depression track towards the Barents Sea was present but also displaced west and north of its normal position, passing west instead of east of Iceland. The British Isles were more or less immune to cyclonic influence throughout the month and returned the highest mean pressures for the month anywhere in the Atlantic sector. The value was 1024 mb. over all Ireland and northern England. The anomaly in this region was probably the largest anywhere in the hemisphere (+12 mb. over north-east Ireland).

The polar high pressure was displaced over the Canadian North-West Territories, highest monthly mean pressure being 1026 mb. near 70°N. 110°W., i.e. 7 mb. high for this place and slightly above normal intensity for the system which is usually centred over the Arctic ice near 83°N. in April. Pressure over Siberia appears to have been generally a few millibars below normal.

These patterns showed a considerable break from March.

Monthly mean temperatures in April were above normal over all the eastern Atlantic though over the southern North Sea the excess became zero. Spitsbergen had the biggest positive anomaly (+6°C.). Most of Greenland and the western Atlantic were cold, the departure reaching –4 to –5°C. over north-western Greenland. Texas and the Plains States were again cold, as in March, and suffered very excessive rainfall; apart from this region, most of the United States and Canada from the Rockies to the Atlantic seaboard were warmer than normal (maximum anomalies +3°C. near Washington and in northern Quebec).

The most prominent feature of the rainfall pattern was above-normal falls covering most of the United States, apparently arranged about depression tracks crossing the country from California and the borders of British Columbia to converge near New England. All Europe north of the Alps was decidedly dry; falls reported in most parts of the Mediterranean were several times as great. There was some storminess in the Mediterranean.

In the British Isles, weather during the month was predominantly anti-cyclonic and dry in all areas; over much of England and Wales it was one of the driest Aprils of the century.

The first three days were cloudy with occasional rain as troughs associated with a deep Atlantic depression moved slowly east across the country. An anti-cyclone from the continent spread westward over the British Isles on the 4th

giving two fine, warm days; afternoon temperatures rose into the sixties and on the 5th several places recorded 11 hours of sunshine. There was a sharp fall of temperature the following day as the anticyclone became established between Scotland and Iceland and north-easterly winds spread over the country. Cool winds from a northerly direction continued until the 13th and brought scattered showers, occasionally of snow, but there were good sunny periods. Milder weather spread in from the Atlantic on the 14th as winds backed to the south-west but pressure was generally high to the south of England and the rain associated with the weak fronts which crossed the country during the next three days was mainly slight. The 18th was dull and stormy, particularly in the north where wind reached gale force in places as a deepening depression skirted northern Scotland. Pressure rose rapidly behind the disturbance and although there were some showers in Scotland and northern England the following three days were fine and warm in most places, although on Easter Sunday a cool south-westerly air stream brought occasional rain to the north-western half of the country. Outbreaks of thundery rain associated with a small depression over northern France occurred in southern England late on Sunday night and on Easter Monday. With a ridge of high pressure extending from an anticyclone over northern Russia to the British Isles, weather was fine and warm nearly everywhere on the 23rd and 24th, temperature reaching 70°F. locally in southern districts. On the 25th a cool north-easterly air stream spread over the country as an anticyclone moved to the north of Scotland. During the last four days of the month, pressure was high to the west of Ireland and winds continued mainly from a north or north-easterly direction with dry weather and about average temperature.

Sunshine was mostly above the average for the month and, apart from the rather cold second week, so also was the temperature. With rainfall only 20 per cent of the average it was the driest April in England and Wales since 1938; it was the driest at Blackburn and Chesterfield for 70 years. In many areas there was no measurable rain from March 28th to April 11th and in places in Herefordshire the drought lasted for more than 30 days; at Ross-on-Wye there was an absolute drought throughout the month, the only other completely dry month in nearly 100 years of records being June 1925.

The dry weather and low night temperatures combined to exert a restraining influence on the growth of plants and trees. The shortage of rain caused concern to farmers and growers in all areas, as the land was so dry that spring sowing was held up, and it was feared that the prolonged drought might affect the harvest. Frosts during the month did not on the whole cause serious damage except to near ground level plants in some areas.

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

	AIR TEMPERATURE			RAINFALL		SUNSHINE
	Highest	Lowest	Difference from average daily mean	Per-centage of average	No. of days difference from average	Per-centage of average
	°F.	°F.	°F.	%		%
England and Wales ...	71	22	+1·0	19	—8	103
Scotland	65	17	+1·9	68	—3	119
Northern Ireland ...	63	29	+1·1	57	—4	126

RAINFALL OF APRIL 1957

Great Britain and Northern Ireland

County	Station	In.	Per cent. of Av.	County	Station	In.	Per cent. of Av.
<i>London</i>	Camden Square ...	·26	17	<i>Glam.</i>	Cardiff, Penylan ...	·23	9
<i>Kent</i>	Dover	·49	30	<i>Pemb.</i>	Tenby	·32	1
"	Edenbridge, Falconhurst ...	·20	11	<i>Radnor</i>	Tyrmynydd	·26	7
<i>Sussex</i>	Compton, Compton Ho. ...	·14	7	<i>Mont.</i>	Lake Vyrnwy	·46	15
"	Worthing, Beach Ho. Pk. ...	·10	6	<i>Mer.</i>	Blaenau Festiniog ...	2·04	33
<i>Hants.</i>	St. Catherine's L'thouse ...	·27	17	"	Aberdovey	·60	23
"	Southampton (East Pk.) ...	·09	5	<i>Carn.</i>	Llandudno	·16	9
"	South Farnborough ...	·37	24	<i>Angl.</i>	Llanerchymedd	·50	23
<i>Herts.</i>	Harpenden, Rothamsted ...	·29	18	<i>I. Man</i>	Douglas, Borough Cem. ...	1·05	43
<i>Bucks.</i>	Slough, Upton	·24	17	<i>Wigtown</i>	Newton Stewart	1·59	62
<i>Oxford</i>	Oxford, Radcliffe	·39	24	<i>Dumf.</i>	Dumfries, Crichton R.I. ...	1·83	78
<i>N'hants.</i>	Wellingboro' Swanspool ...	·30	20	"	Eskdalemuir Obsy. ...	2·91	86
<i>Essex</i>	Southend, W. W.	·12	9	<i>Roxb.</i>	Crailling... ..	·28	17
<i>Suffolk</i>	Felixstowe	·25	21	<i>Peebles</i>	Stobo Castle	2·03	97
"	Lowestoft Sec. School... ..	·49	33	<i>Berwick</i>	Marchmont House	·83	41
"	Bury St. Ed., Westley H. ...	·30	20	<i>E. Loth.</i>	North Berwick Gas Wks. ...	1·43	104
<i>Norfolk</i>	Sandringham Ho. Gdns. ...	·38	25	<i>Midl'n.</i>	Edinburgh, Blackf'd. H. ...	·61	41
<i>Wilts.</i>	Aldbourn	·36	18	<i>Lanark</i>	Hamilton W. W., T'nhill ...	1·80	96
<i>Dorset</i>	Creech Grange... ..	·19	9	<i>Ayr</i>	Prestwick	2·23	128
"	Beaminster, East St. ...	·16	7	"	Glen Afton, Ayr San. ...	2·36	79
<i>Devon</i>	Teignmouth, Den Gdns. ...	·07	3	<i>Renfrew</i>	Greenock, Prospect Hill ...	2·86	83
"	Ilfracombe	·31	15	<i>Bute</i>	Rothsay, Arden Craig ...	...	...
"	Princetown	·55	11	<i>Argyll</i>	Morven, Drimnin	2·81	77
<i>Cornwall</i>	Bude	·25	13	"	Poltalloch	2·02	67
"	Penzance	·75	31	"	Inveraray Castle	4·58	100
"	St. Austell	·51	18	"	Islay, Eallabus	2·14	75
"	Scilly, Tresco Abbey ...	·66	34	"	Tiree	1·78	72
<i>Somerset</i>	Taunton	·03	2	<i>Kinross</i>	Loch Leven Sluice	1·68	87
<i>Glos.</i>	Cirencester	·30	15	<i>Fife</i>	Leuchars Airfield	·46	29
<i>Salop</i>	Church Stretton	·61	23	<i>Perth</i>	Loch Dhu	3·45	73
"	Shrewsbury, Monkmore ...	·44	30	"	Crieff, Strathearn Hyd. ...	1·58	72
<i>Worcs.</i>	Malvern, Free Library... ..	·00	00	"	Pitlochry, Fincastle	·89	40
<i>Warwick</i>	Birmingham, Edgbaston ...	·19	10	<i>Angus</i>	Montrose Hospital	·80	44
<i>Leics.</i>	Thornton Reservoir	·15	9	<i>Aberd.</i>	Braemar	1·29	54
<i>Lincs.</i>	Boston, Skirbeck	·23	17	"	Dyce, Craibstone	1·41	68
"	Skegness, Marine Gdns. ...	·35	26	"	New Deer School House ...	1·48	74
<i>Notts.</i>	Mansfield, Carr Bank ...	·17	10	<i>Moray</i>	Gordon Castle	·61	35
<i>Derby</i>	Buxton, Terrace Slopes ...	·52	18	<i>Nairn</i>	Nairn Achareidh	·56	40
<i>Ches.</i>	Bidston Observatory	·34	21	<i>Inverness</i>	Loch Ness, Garthbeg	1·24	54
"	Manchester, Ringway... ..	·29	16	"	Loch Hourn, Kinl'hourn ...	4·19	67
<i>Lancs.</i>	Stonyhurst College	·75	28	"	Fort William, Teviot	3·13	70
"	Squires Gate	·31	17	"	Skye, Broadford ... ..	...	...
<i>Yorks.</i>	Wakefield, Clarence Pk. ...	·16	10	"	Skye, Duntulm... ..	2·85	88
"	Hull, Pearson Park	·33	21	<i>R. & C.</i>	Tain, Mayfield... ..	·68	37
"	Felixkirk, Mt. St. John... ..	·54	32	"	Inverbroom, Glackour... ..	2·08	56
"	York Museum	·20	13	"	Achnashellach	3·18	59
"	Scarborough	·73	47	<i>Suth.</i>	Lochinver, Bank Ho. ...	2·52	88
"	Middlesbrough... ..	·25	18	<i>Caith.</i>	Wick Airfield	1·03	52
"	Baldersdale, Hury Res. ...	·46	21	<i>Shiland</i>	Lerwick Observatory	2·29	100
<i>Norl'd.</i>	Newcastle, Leazes Pk....	·43	27	<i>Ferm.</i>	Crom Castle	2·01	79
"	Bellingham, High Green ...	·58	27	<i>Armagh</i>	Armagh Observatory	1·17	56
"	Lilburn Tower Gdns. ...	·30	15	<i>Down</i>	Seaforde	1·15	44
<i>Cumb.</i>	Geltsdale	1·30	61	<i>Antrim</i>	Aldergrove Airfield	1·14	54
"	Keswick, High Hill	1·06	35	"	Ballymena, Harryville... ..	1·60	61
"	Ravenglass, The Grove ...	1·30	52	<i>L'derry</i>	Garvagh, Moneydig	1·37	56
<i>Mon.</i>	A'gavenny, Plâs Derwen ...	·06	2	"	Londonderry, Creggan ...	1·17	46
<i>Glam.</i>	Ystalyfera, Wern House ...	·74	19	<i>Tyrone</i>	Omagh, Edenfel	1·62	62

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