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CELLULAR STRUCTURE OF CONVECTIVE STORMS

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Abstract.—Seven convective storm areas crossed south-east England on 9 July 1959; radar data on these are presented to demonstrate a higher degree of organization within the more intense storms.

Introduction.—On 9 July 1959 seven convective storm areas crossed south-east England travelling at about 40 mi hr^{-1} in a north-easterly direction. One of them (storm 1 in the plates and figures accompanying this article) became very severe and produced widespread large hail, especially in the Wokingham area of Berkshire. Detailed radar and ground observations of this particular storm have been analysed in an earlier paper[1] so as to determine the nature of the associated airflow. Throughout its existence the radars showed that this storm consisted of a number of units or cells in various stages of development. Each of them had a lifetime (1–3 hr) which was small compared with the overall life of the storm (> 8 hr) but still long compared with that of the cells associated with ordinary showers (< 1 hr). For simplicity overt consideration of this cellular nature was avoided in the above reference. The purpose of the present paper is to expose the characteristic cellular behaviour of this, and another intense storm, and to contrast their organization with the chaotic behaviour of weaker storms occurring during the same day.

General behaviour and intensity of the storms.—For an outline of the synoptic situation on this occasion the reader is referred to section 4 of the paper already mentioned.[1] According to this reference the Wokingham storm developed over Brittany just before 0800 BST:† it subsequently crossed the Channel and travelled within a cold front zone across south-east England, where it came under radar surveillance from East Hill near Dunstable (Bedfordshire). The progress of this and six other individual storm areas was recorded by an AMES type 14/10 cm PPI (plan position indicator) radar and is illustrated by the plates between pages 356 and 357 which include photographs of the full-gain display at 15-minute intervals (apart from a break after 1300 caused by a power failure).

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†All times in this article are in British Summer Time (BST=GMT+1).

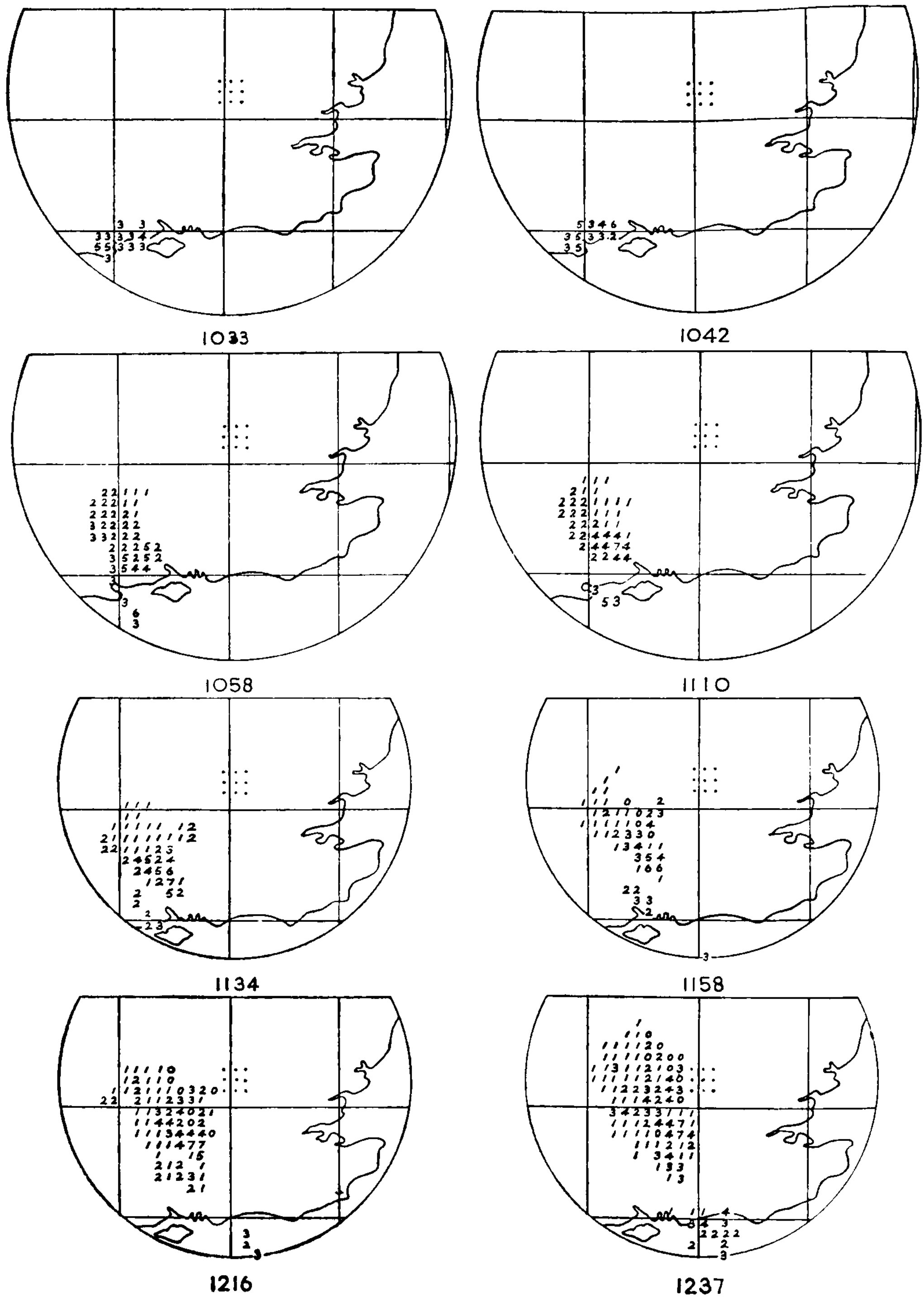


FIGURE 1 — THE HEIGHT-INTEGRATED ECHO-INTENSITY DISTRIBUTION OVER A REGION WITH THE EAST HILL RADAR STATION AS CENTRE, FROM 1033 TO 1646 BST.

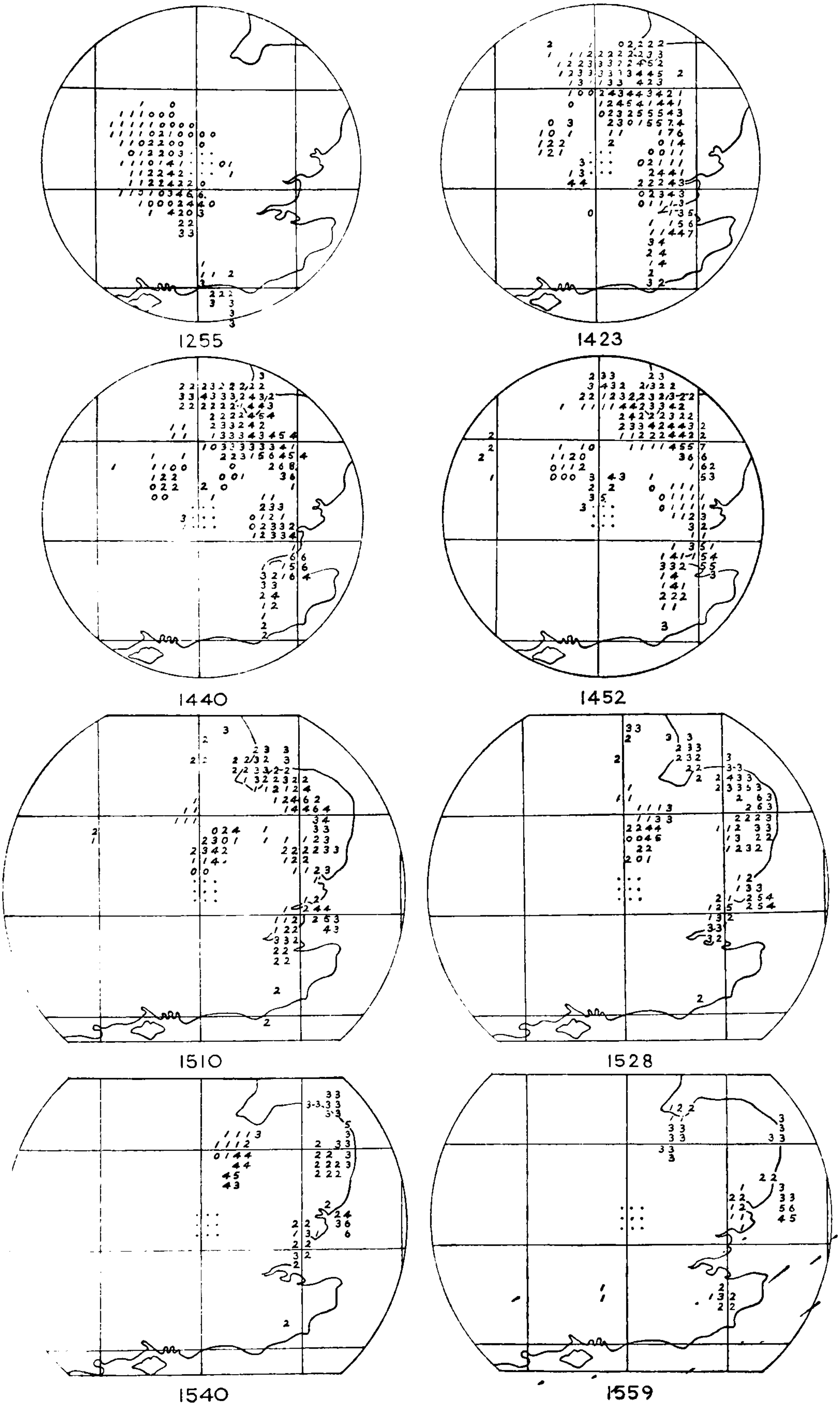
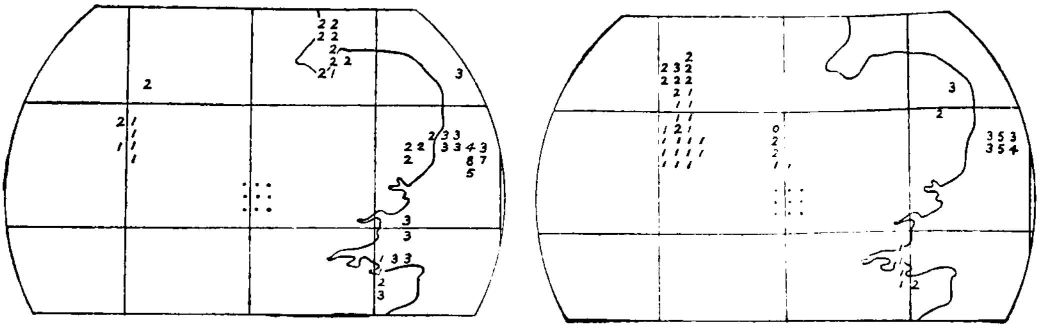


FIGURE 1 (*cont.*)



1623 1646

FIGURE 1 (*cont.*)

The grid lines are those of the National Grid and divide the area into squares of side 100 km. Each of these is subdivided into 100 squares, which contain figures representing the greatest echo intensity present over any area of at least 4 km² according to the following code:

Code figure	10 log Z_e*	Code figure	10 log Z_e*
0	≤ 25	5	46–50
1	26–30	6	51–55
2	31–35	7	56–60
3	36–40	8	61–65
4	41–45	9	≥ 66

The nine dots in the centre of each diagram indicate those squares which are at least partly obliterated by echoes from ground objects. (Times are in BST).

A record of the height-integrated intensity distribution within these storms at frequent intervals throughout the day was obtained in the form of series of photographs of the 10 cm PPI display at different gain settings. At this wavelength errors arising from attenuation are negligible and so the only correction necessary was that for the incomplete filling of the beam, which is broad in the vertical. One correction to observed intensities was applied because a part of the beam lay below the radar horizon; another was made on the assumption that strong echo occurred only from the ground up to 30,000 ft, with negligible echo outside these limits. The resulting distributions of height-integrated intensity at various times are displayed in Figure 1 in which the figure in each 10 km square represents the greatest echo intensity present over any area of at least 4 km².†

Figure 2 shows the trend with time of the maximum intensity within each of the storms. (Unfortunately the 10 cm PPI radar tended to drift off-tune and could not readily be set to a standard brightness, so that the absolute values are rather unreliable). Figure 2 illustrates some interesting features; in particular

(i) storm 1‡ was the most persistently intense as well as the largest storm,

(ii) there is no obvious relation between intensity and location over land and sea, and

(iii) storms 3, 5, 6 and 7, and storm 2 while over land had intensities which usually were too low to be associated with the occurrence of thunder:[2] by comparison storms 1 and 4 became very severe.

Figure 3 shows that, whereas storms 1 and 4 respectively produced wide-

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*Z_e is the equivalent radar reflectivity in units of $mm^6 m^{-3}$.

†These values may underestimate the maximum intensity by up to 5 decibels.

‡The Wokingham storm.

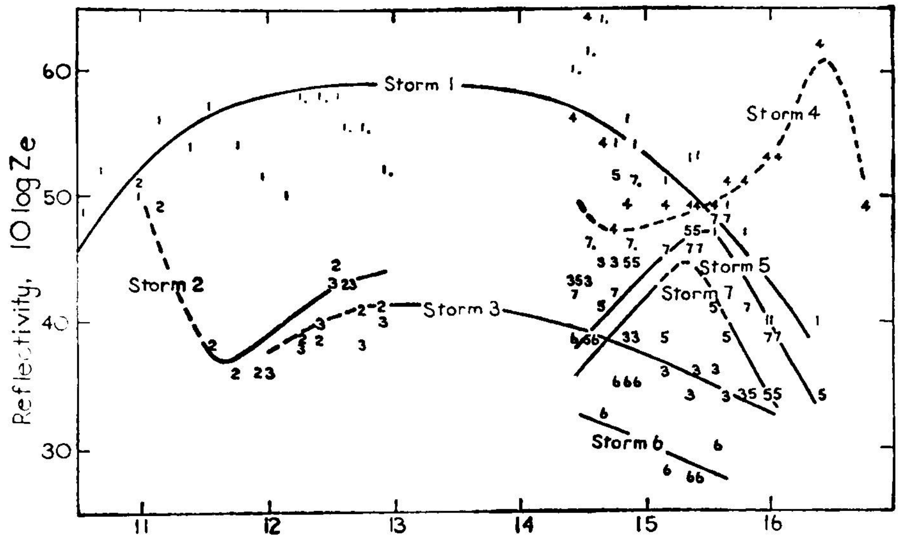

FIGURE 2 — THE TEMPORAL VARIATION OF THE MAXIMUM INTENSITY WITHIN EACH OF THE SEVEN STORMS AS DETERMINED BY THE 10 CM PPI RADAR

The individual measurements have smoothed curves drawn through them, which are dashed during periods when the storms were over the sea. Those values followed by a dot are liable to be under-estimated since they correspond to occasions when it was impossible to reduce gain sufficiently to remove the echo from the display. (Times are in BST.)

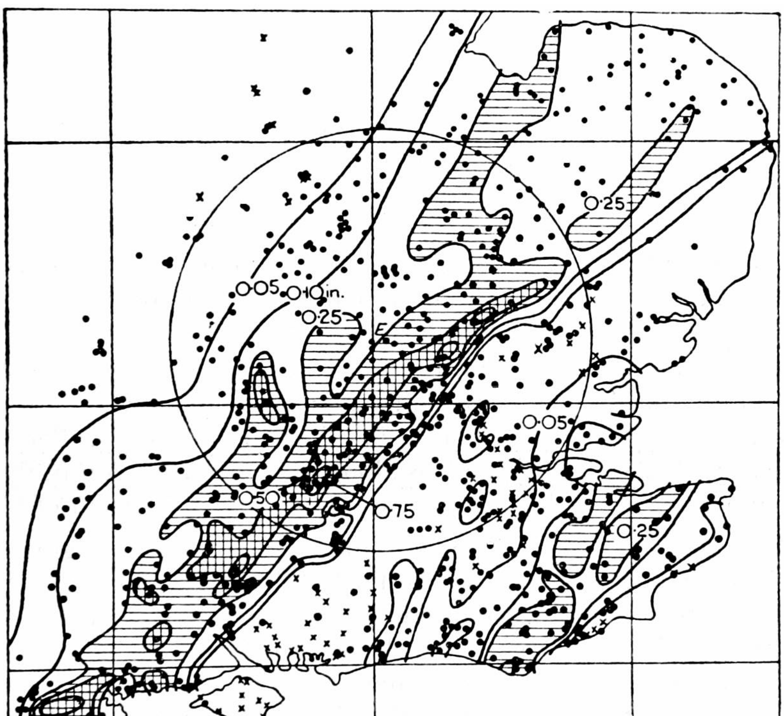

FIGURE 3 — DISTRIBUTION OF RAINFALL IN SOUTH-EAST ENGLAND ON 9 JULY 1959

The positions of 910 observations are indicated as dots or crosses according to whether or not measurable rainfall was reported. *E* denotes the location of the East Hill radar station. The circle marks a radius of 50 miles from East Hill.

spread rainfall totals exceeding 0.5 and 0.25 in., storm 3 produced few totals over 0.05 in. (Storms 2, 5, 6 and 7 probably made comparatively small contributions to these totals). Only storm 1 produced hail overland, giving a 130 × 5 mile swath roughly in association with the region of highest rainfall (see Figure 2 in Browning and Ludlam's paper[1]).

The motion of the storm cells.—Regions of radar echo corresponding to each of the seven storm areas portrayed in the plates between pages 356 and 357 are referred to as echo-masses. These varied in size from about 10 to 100 miles across and each comprised a number of distinguishable, but not necessarily completely detached, regions of higher intensity with diameters of the order of a few miles which are referred to as cells.* The velocity of travel of each echo-mass was determined not only by the translational velocity of the individual cells but also by their positions of formation and dissipation. In this respect there is found to be a notable difference between the behaviour of the two intense storms (1 and 4) and that of each of the others, as is now shown.

Storm 3 was the weakest of the seven: it developed off the Sussex coast

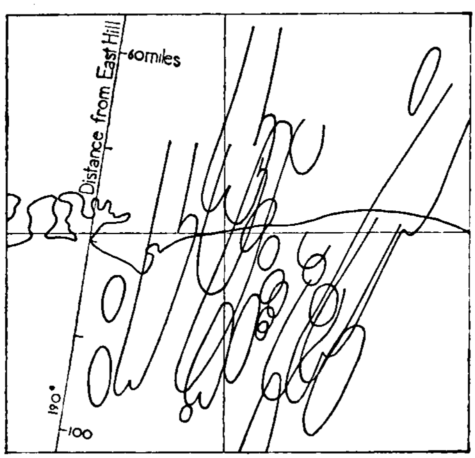

FIGURE 4 — PATHS OF CELLS COMPRISING THE GROUP CLASSIFIED AS STORM 3 DURING THE PERIOD 1150 TO 1300 BST AS THEY CROSSED THE SUSSEX SHORELINE

Note their short duration and lack of organization.

around midday as an irregular cluster of small weak cells. Figure 4 shows that these formed and dissipated in the unsystematic manner which is typical of feeble showers, the majority persisting for short periods only. The motion of the weaker cells (from about 195°) was along the wind direction in the medium levels: the more intense cells moved up to about 10° to the right of this.

The cells comprising storm 2 showed more organization (Figure 5). When the storm first came within range of the East Hill radars it was over the English Channel and consisted of a single intense cell travelling at 40 mi hr^{-1} from 209°: as it approached the south coast it weakened but further cells formed on both flanks, aligned approximately at right angles to their motion (from about 195°). The most intense cells occurred near the right-hand end of the line but none had an intensity within an order of magnitude of that of the first one.

The intense storms 1 and 4 were even more highly organized, the principal new development invariably occurring on the right flank. This is vividly demonstrated by Figure 6, which shows the path of their constituent cells. Like the preceding two diagrams, Figure 6 has been derived from the analysis

*Probably associated with single convective cells.

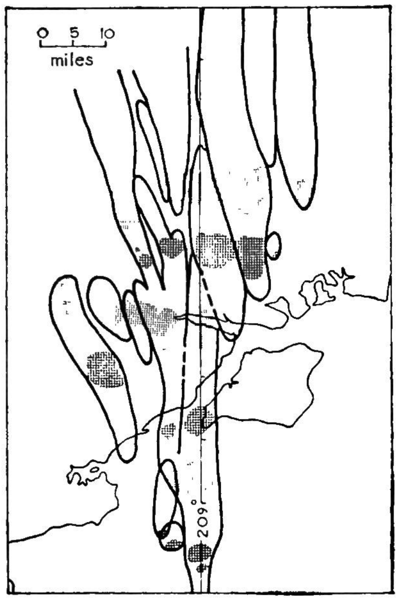

FIGURE 5 — PATHS OF CELLS COMPRISING STORM 2
Positions of the paths are indicated at times 1051, 1109, 1124, 1145, 1203 and 1218 BST (moving northwards).

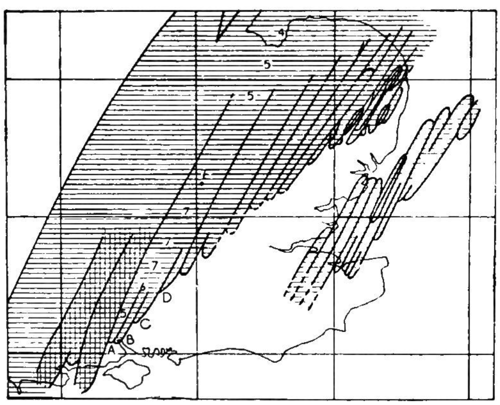

FIGURE 6 — PATHS OF CELLS COMPRISING STORMS I AND 4
The paths have been determined largely from the 10 cm PPI records. Boundaries between adjacent cells are terminated as soon as it becomes impossible to resolve them on any of the reduced-gain photographs. Numbers at intervals along the path of the largest cell indicate the trend in its maximum radar intensity according to the code in Figure 1. The two cross-hatched paths are of compact clusters of cells. Note especially the longevity of many of the cells and their systematic formation on the right flank of each echo-mass.

of photographs of the full-gain 10 cm PPI display taken at 3-minute intervals. However, in the case of Figure 6, because most of the cells could only be resolved by the radar at reduced gain, these data had to be supplemented by the frequent series of photographs of the display at different receiver gains. The gap in the 10 cm records caused by the failure of the mains electricity supply was filled in by data obtained using a 4.67 cm MPS-4 radar whose power was supplied by a petrol generator. Unfortunately this radar was operating with a poorer temporal and azimuthal resolution, so that parts of the cell paths derived therefrom (and drawn dashed in Figure 6) are less reliable.

The orientation of each path in Figure 6 lies within 5° of 210–030°. This is in good agreement with the wind direction of 214 ± 6° at all heights between 3000 and 30,000 ft recorded at Hemsby at 1200 (150 miles north-east of storm 1), but is veered a little from the wind direction at all medium levels at Crawley and Larkhill at this time. However, this need not necessarily imply a discrepancy between cell motion and the predominant direction of the large-scale geostrophic wind, as the sounding at Crawley and more particularly that at Larkhill were made fairly close to (and therefore may have been modified by) storm 1 during its intense phase. The Crawley sounding shows the wind veering with height throughout the medium levels, suggesting that the motion (from 195°) of the weaker cells comprising storms 2 and 3 was influenced more by the winds at lower levels than were the cells within storms 1 and 4.

The behaviour of cells within the intense storms.—The organization

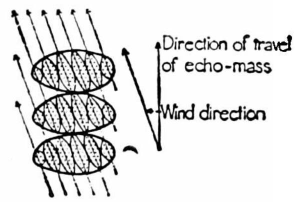

FIGURE 7 — SCHEMATIC DIAGRAM

This illustrates how the formation of new echoes at the right flank of an echo-mass and their eventual decay on the left flank causes the centroid of the echo-mass to travel to the right of the winds.

of storms 1 and 4 is illustrated schematically in Figure 7. It emphasizes the propagation of the centroid of the echo-mass to the right of the winds,* as has been observed by Newton and Katz.[3] Each constituent cell eventually became weak and diffuse so as to be indistinguishable from its forerunners on the left flank, its persistence determining the over-all size of the echo-mass.

In Figure 7 the cells are depicted as becoming elongated along the direction of the wind. Elongation along this direction occurred on this occasion because the wind direction was almost invariant with height, so that the shear vector also lay in this direction. This meant that the major component of the convective circulation occurred within a vertical section orientated parallel to the winds. Accordingly the updraught entered the cell at low levels at the downshear end and emerged at high levels at the upshear end before being accelerated downstream. This behaviour is demonstrated in Figure 6 of Browning and Ludlam's paper[1] which shows a series of radar photographs of vertical sections along the axis of a particular cell within storm 1: it portrays a succession of towers (roughly 3 mi in diameter) rising at the upshear end of the cell, each of which becomes the highest echo whilst moving in a downshear direction through the cell before subsiding and decaying at the downshear end. Although the presence of discrete towers implies an updraught which was essentially intermittent, nevertheless it must have been quite persistent, since this cell (and others like it) could be traced

*A similar process can be inferred where this deviation is evident, even though the resolution of the radar is inadequate to distinguish the freshly-formed parts of the echo, as in the case of the most intense cells in storms 2 and 3.

for over an hour, which is longer than the period required for air in a moderate convective updraught to move through the cell or for the precipitation particles formed therein to reach the ground.

Four of these cells (labelled A, B, C and D in Figure 6) became very intense soon after storm 1 came inland and they amalgamated to form a single large cell with horizontal dimensions of the order of 10 mi. This cell has been analysed in particular detail by Browning and Ludlam.[1] They show that it maintained a virtually steady structure throughout a 30-minute period, and employ certain characteristic features of this structure to evolve a three-dimensional model of the associated quasi-steady airflow, a feature of which is the reinforcement of the updraught flux by an inflow from the right flank. During the period prior to the development of new cells on its right flank this "supercell" was reaching the greatest heights and intensities of the day as well as producing the largest and most widespread hail. Although it declined somewhat after the development of new cells to its right, it persisted as a resolvable entity for more than two hours before decreasing in intensity to that of the diffuse decaying echo in which it was embedded.

In contrast with those cells forming during the more intense phases of storm 1, the cells appearing after about 1445 formed quite detached from the main body of the echo-mass, even at full-gain. Thereafter the rate of formation of new cells increased in inverse proportion to their intensity, size and persistence until the storm reached the North Sea, when regeneration ceased altogether.

Conclusions.—Although even small and comparatively weak cells often lasted for an hour, indicating the presence of a persistent (if intermittent) updraught, the larger more intense cells are most notable for their longevity. Indeed, one could still be identified more than three hours after its formation, continuing to be resolvable even after several new cells had developed to its right. This behaviour was responsible for the broad extent of storm 1, the echo-mass of which reached a width of 100 miles at one stage.

The storms which attained high radar intensities and which produced large rainfall totals were not only characterized by long-lived cells; they were also highly organized, propagating systematically to their right. This propagation generally occurred in the form of discrete cells which remained resolvable from their predecessors often for an hour or two. A notable exception occurred during the most intense phase of storm 1 when successive cells amalgamated within 30 minutes of detection to form a large and intense "supercell".

Acknowledgments.—The author is pleased to thank the Director-General of the Meteorological Office for the provision of staff and facilities at the East Hill Radar Station, from which the observations were made, and also for providing British rainfall data. The research on severe storms of which this work has been a part, is also supported by the Geophysics Research Directorate, Air Force Cambridge Research Center of the Air Research and Development Command, United States Air Force. The author is particularly indebted to Dr. F. H. Ludlam for helpful discussions during the course of the analysis.

REFERENCES

1. BROWNING, K. A. and LUDLAM, F. H.; Airflow in convective storms. *Quart J. R. met. Soc., London*, **88**, 1962, p.117.

2. LUDLAM, F. H.; The role of radar in rainstorm forecasting. *Nubila, Verona*, **3**, 1960, p.53.
3. NEWTON, C. W. and KATZ, S.; Movement of large convective rainstorms in relation to winds aloft. *Bull. Amer. met. Soc., Lancaster, Pa.*, **39**, 1958, p.129.

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FORMATION AND DISPERSAL OF FOG OVER THE FENS

By M. H. FREEMAN, O.B.E., M.Sc.

Introduction.—Forecasters in East Anglia have long been aware that the presence of the fens has an effect on the formation of fog in the area. At Waterbeach, for instance, it was asserted that fogs tend to form earlier and persist longer than in surrounding areas. The extent of the influence of the fens was not known accurately, so a detailed investigation was planned to seek further information on the formation and dispersal of fog over the fens and at the seven meteorological offices (Upwood, Wyton, Oakington, Waterbeach, Mildenhall, Marham and West Raynham) near the borders of the fens.

To this end the co-operation of about 50 voluntary observers (listed in the appendix on pp. 356–7) was obtained. Using the simple forms provided, they undertook to record, whenever practicable, the time at which visibility fell below or improved above the three limits 50, 200 and 1000 yards. Mr. W. B. Painting visited each observer to explain the project and assist in selecting suitable visibility objects and lights. Figure 1 shows a map of the region and indicates the approximate boundary of fen-land. It also shows the locations of the meteorological offices and the voluntary observing stations. The investigation related only to that part of the fens south of the Wash; no reports were obtained from the region to the north-west of Spalding.

The first phase of the investigation took place during the winter October 1959 to March 1960. A detailed analysis of the observations obtained was made by Mr. S. P. Peters, and in the light of his report it was decided to continue the investigation during the following winter 1960–61. A smaller number of strategically placed observers took part in this second phase; their locations are marked by small circles on Figure 1.

Analysis of the observations.—From the two winters 79 periods of fog were examined; a few occasions of patchy short-lived fog were ignored. For each selected period hourly charts on a scale of 1 : 253,440 were plotted and lines indicating the boundaries of visibilities less than 50, 200 or 1000 yards were drawn. The standards of reporting achieved by the voluntary observers naturally varied, but it was usually possible to arrive at a coherent analysis of each situation. As would be expected the number of reports between 2300 and 0700 hours was small, and the formation of fog was less well documented than its dispersal. About half the observing stations were at schools, most of which were unable to report during holidays and at week-ends. Week-ends were also less well covered by Meteorological Office stations since Upwood, Oakington and Waterbeach were often closed then. Another, more or less inevitable, difficulty was that voluntary observers could not maintain a continuous watch and their records merely showed the times at which the visibility had been observed to be below a certain limit. Also some occasions of fog were found to be missed so that absence of a fog report could not necessarily be taken as indicating that the visibility was greater than 1000 yards. Nevertheless sufficient reports were usually received to enable a worthwhile analysis to be made. The

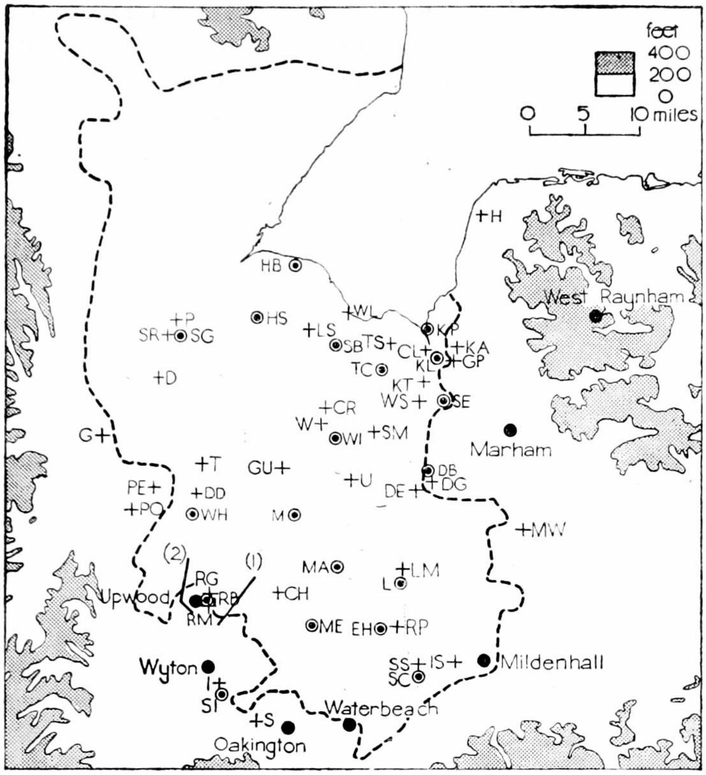


FIGURE I — OBSERVING STATIONS FOR THE FEN FOG INVESTIGATION

● Meteorological Office stations

◉ Voluntary observers for two winters

\+ Voluntary observers in 1959–60 only.

—— Routes of mobile surveys

Names and locations of voluntary observers are listed in the Appendix on p. 356–7.

area where uncertainties were greatest was to the north-west of Wisbech, where observers and reports were rather few.

In addition to the limits of the fog, various other data were recorded. For each occasion notes were made of the synoptic situation, the areas of first formation of fog, the clear areas, the areas of dense fog (less than 50 yards) and the area of final clearance. From the daily registers of the Meteorological Office stations details of temperatures, winds and cloud cover were extracted. The following broad picture of the distribution of fog over the fens emerged from an examination of all this material.

Features of fog in the fens.—Most of the fogs examined were associated with synoptic situations which resulted in weak pressure fields. On about 60 per cent of occasions there was a light wind from a southerly point, on 20 per cent of occasions the wind was from some other direction and on the remaining 20 per cent it was predominantly calm. Radiation fogs were the commonest but the sample also included fogs associated with very low cloud or precipitation.

One of the questions to which an answer was sought was whether fog was more likely to form first in one section of the fens than another. Difficulties arose because most of the volunteers did not observe during the night, when many of the fogs first formed. However, from the known habits of each observer estimates were made of whether or not he was likely to be observing at the time when fog was first reported. For each station the percentage frequency was calculated of occasions when the first appearance of fog occurred at that station. When fog first formed at several stations within a period of one hour all were credited with the first formation. For the voluntary observers the figures are necessarily imprecise, but they probably err on the side of being too low.

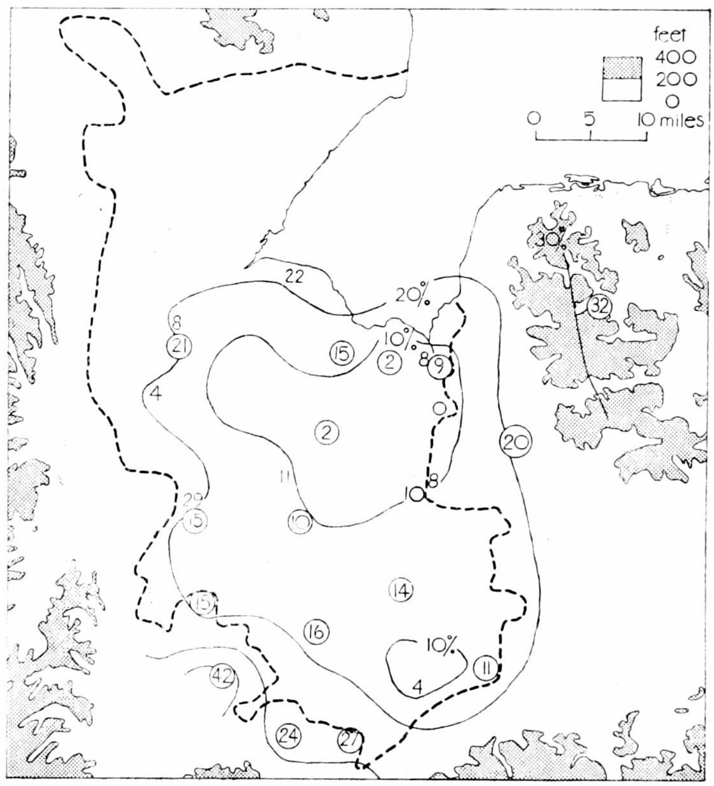


FIGURE 2 — PERCENTAGE FREQUENCY OF FIRST FORMATION OF FOG
Encircled numbers refer to two winters, other numbers to one winter only.

Figure 2 shows the percentage frequency with which fog formed first at each station. Numbers encircled relate to two winters combined, plain numbers to one winter only. Fog is most likely to form first on the borders of the fens, and the area least liable to the initial formation of fog is the interior of the fens, especially the eastern half. The high frequency (42 per cent) with which the first formation of fog was reported at Wyton is noteworthy.

Fog covered all, or almost all, the area on about two-thirds of the occasions considered, so that if fog is reported at any station it is likely that the whole area will be (or already is) affected. However, it should be remembered that short periods of patchy fog were specifically excluded from the investigation. When fog was not widespread a note was made of the clear areas. The south-west of the fens was least often clear and the eastern side the most often clear. Fog appeared to be rather less frequent also in the Holbeach–Spalding area.

The incidence of dense fog is a matter of importance in connection with road transport. The number of periods during which selected stations reported

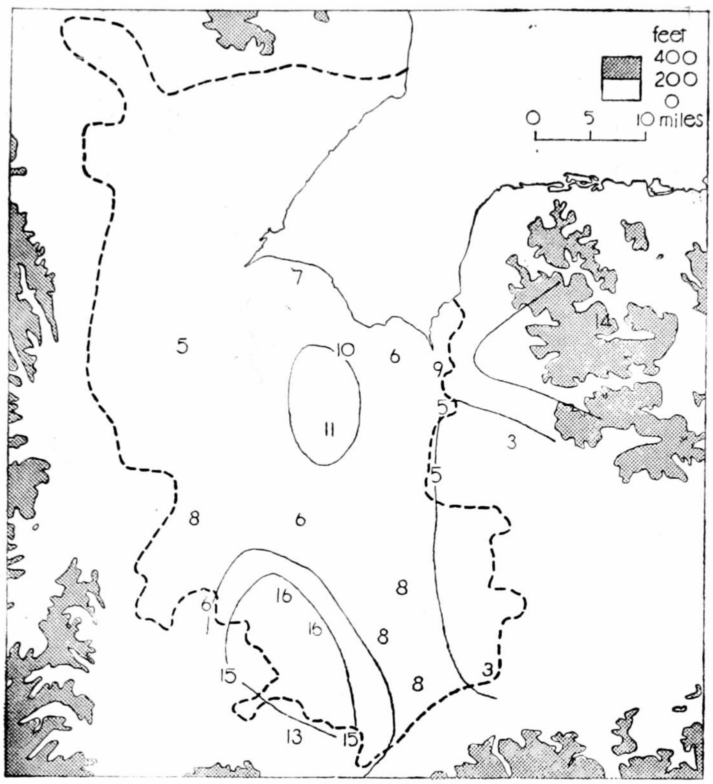


FIGURE 3 — NUMBER OF REPORTS OF DENSE FOG (< 50 YD) OUT OF 79 FOG SITUATIONS

visibilities of less than 50 yards are shown in Figure 3. The relatively high frequency over the south-west of the fens, and adjacent borders, and the low frequencies near the eastern borders are noteworthy. Since most stations were not observing all the time the individual figures are not strictly comparable. However, significant differences are shown between the four Meteorological Office stations which reported 24 hours per day, namely Wyton (15 dense fogs), Mildenhall (3), Marham (3) and West Raynham (14).

The irregularity of observing times can be partially overcome by considering the incidence of fog at 0900 hours, a time when most stations were usually reporting and fairly reliable estimates could be made for the few missing reports. In the two winters there were 73 occasions when fog existed somewhere in the fens at 0900 hours and Figure 4 shows the number of times each station had, or probably had, fog at this time. Fog was least frequent in the south-east, where it was present on a little more than one-third of occasions, and most frequent in the west, where it occurred on two-thirds of occasions.

Although reports of first formation of fog were rather few, the final dispersal of fog was well documented. A striking result was that on only five out of 79 occasions was the last report of fog at a station in the interior of the fens. Almost always the fog persisted longest at a place near the borders of the fens, and on two-thirds of occasions the last dispersal of fog was at the downwind edge. It appears that clearance of fog on the borders is often delayed by the drift of fog from the interior. When fog has dispersed at a downwind meteorological office on the borders, it is most likely that the fog has already cleared from the interior of the fens.

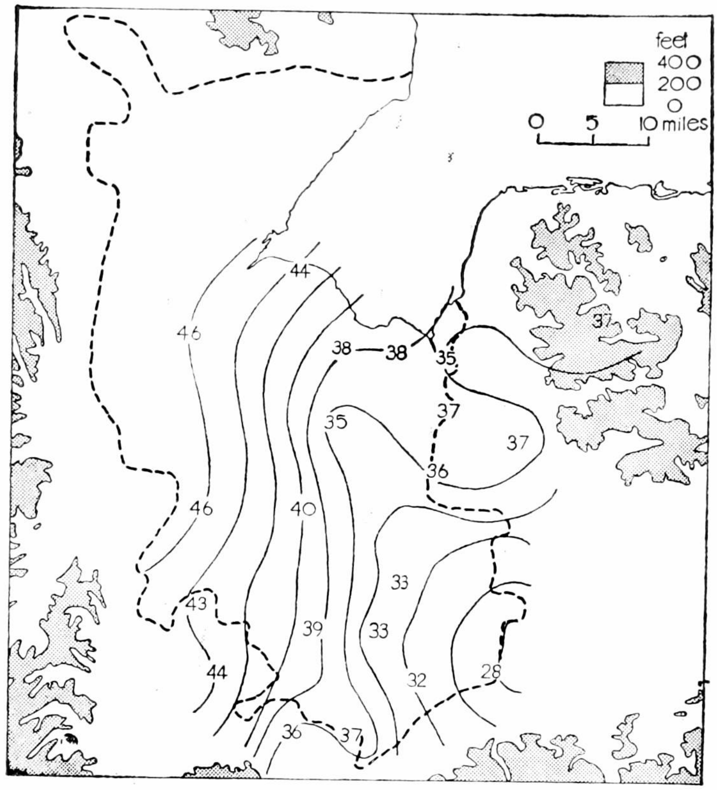


FIGURE 4 — FREQUENCY OF OCCURRENCE OF FOG AT 0900 GMT IN TWO WINTERS (OUT OF 73 OCCASIONS)

Persistence of fog with fairly strong winds was noted quite often. On nearly half the occasions at least one of the Meteorological Office stations reported fog with a surface wind of 10 knots or more, the extreme being 22 knots at West Raynham. The phenomenon was commonest at West Raynham (26 times out of 64) and Wyton (20 out of 73); these are the two highest stations (263 and 128 feet above sea level respectively).

The high frequency with which fog formed first at Wyton has already been noted. Examination of the fog-points, as defined by the temperatures at which fog actually formed, showed that Wyton had a fog-point which was as high or higher than all other Meteorological Office stations on 34 out of 73 occasions. The station which most often had the lowest fog-point was Marham (26 occasions). Differences between the greatest and least fog-points as high as 5°C were noted, and the average difference was 2.2°C. The existence of such differences over a small area highlights the difficulties of accurately forecasting fog-points. Part of Wyton's liability to high fog-points may be attributed to the fact that fog formed with a relative humidity less than 95 per cent on eight occasions, twice as often as at any other station.

Mobile surveys of temperature.—In order that a direct comparison might be made between temperatures over the fens and the surrounding higher ground four mobile surveys were made by Mr. R. Bojdys. His car was fitted with a strut thermometer, and observations were made at short intervals over two four-mile stretches of road. On each occasion conditions were suitable for the formation of radiation fog, with clear skies and light winds. The routes

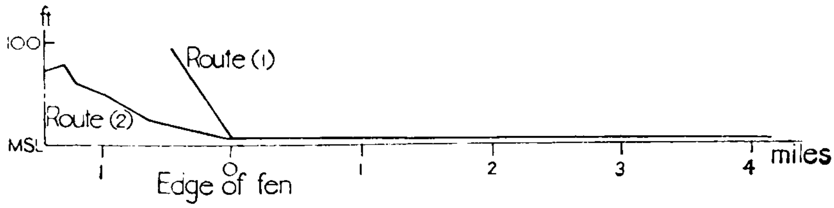


FIGURE 5 — GROUND PROFILES OF ROUTES OF MOBILE SURVEYS

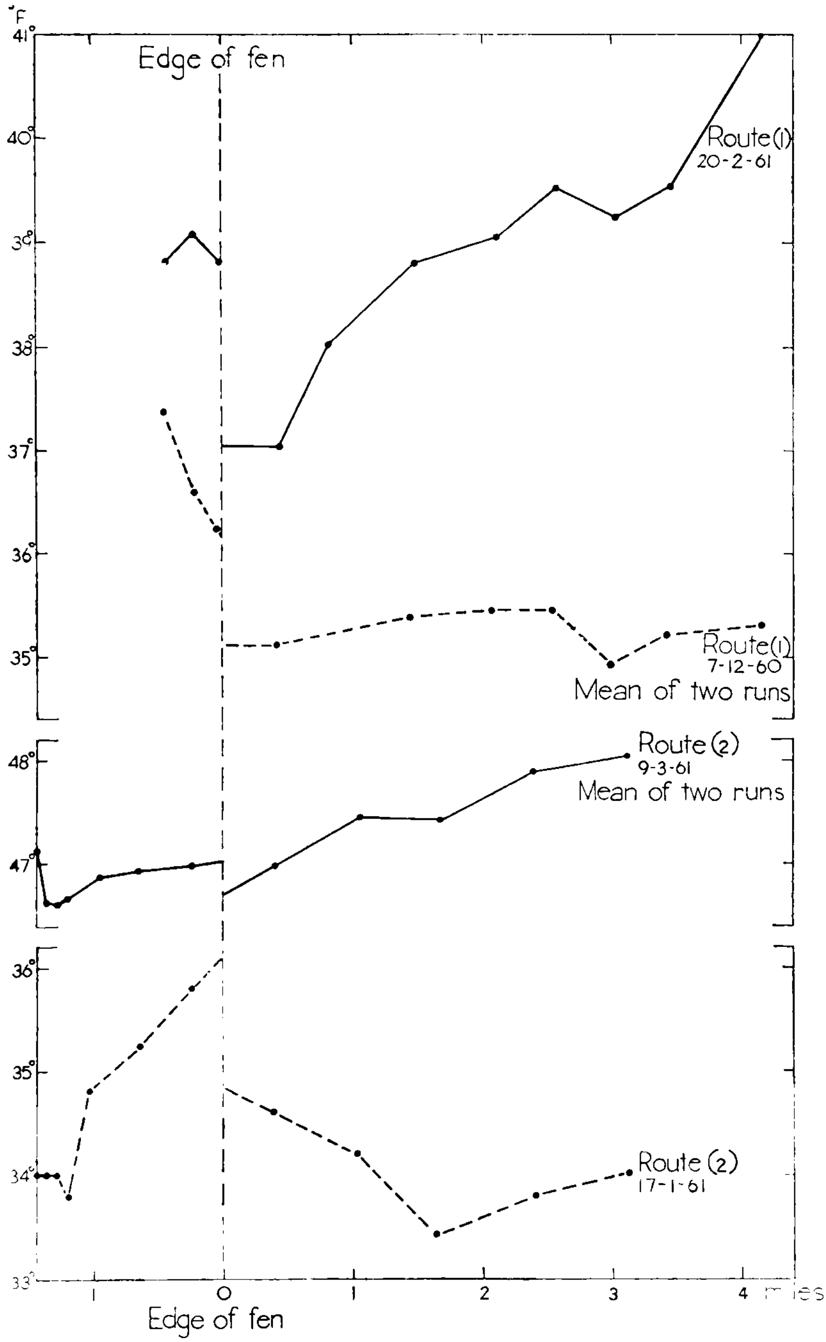


FIGURE 6 — TEMPERATURES ON RADIATION NIGHTS OVER PEAT FEN AND HIGHER CLAY GROUND

chosen, Warboys to Forty Foot Drain and Upwood to Ramsey St. Marys, were partly over flat fen-land and partly over slightly higher ground. The profiles are shown in Figure 5.

The most interesting aspect of the readings was that on crossing from the clay "hills" to the peat fen there appeared to be a drop in temperature of about 1°F. This was well marked on 7 December 1960, 17 January and 20 February 1961, but was only barely evident on 9 March 1961. Figure 6 has been drawn to accentuate this effect by depicting a discontinuity in the horizontal temperature profile at the boundary of the fen. On all occasions there appeared to be different trends on either side of the boundary. The evidence from these four radiation nights in winter indicates that the fen soil (dark peat) cools more rapidly than nearby clay soil.

Conclusion.—The main features of interest disclosed by this investigation are that fog more often first formed near the borders than in the centre of the fens and that the final clearance was almost always on the borders, and was usually on the downwind edge. The south-west of the area was least often clear of fog and most often had dense fog, the opposite being true of the east of the fens.

Appendix

List of observers in the fen-land fog investigation

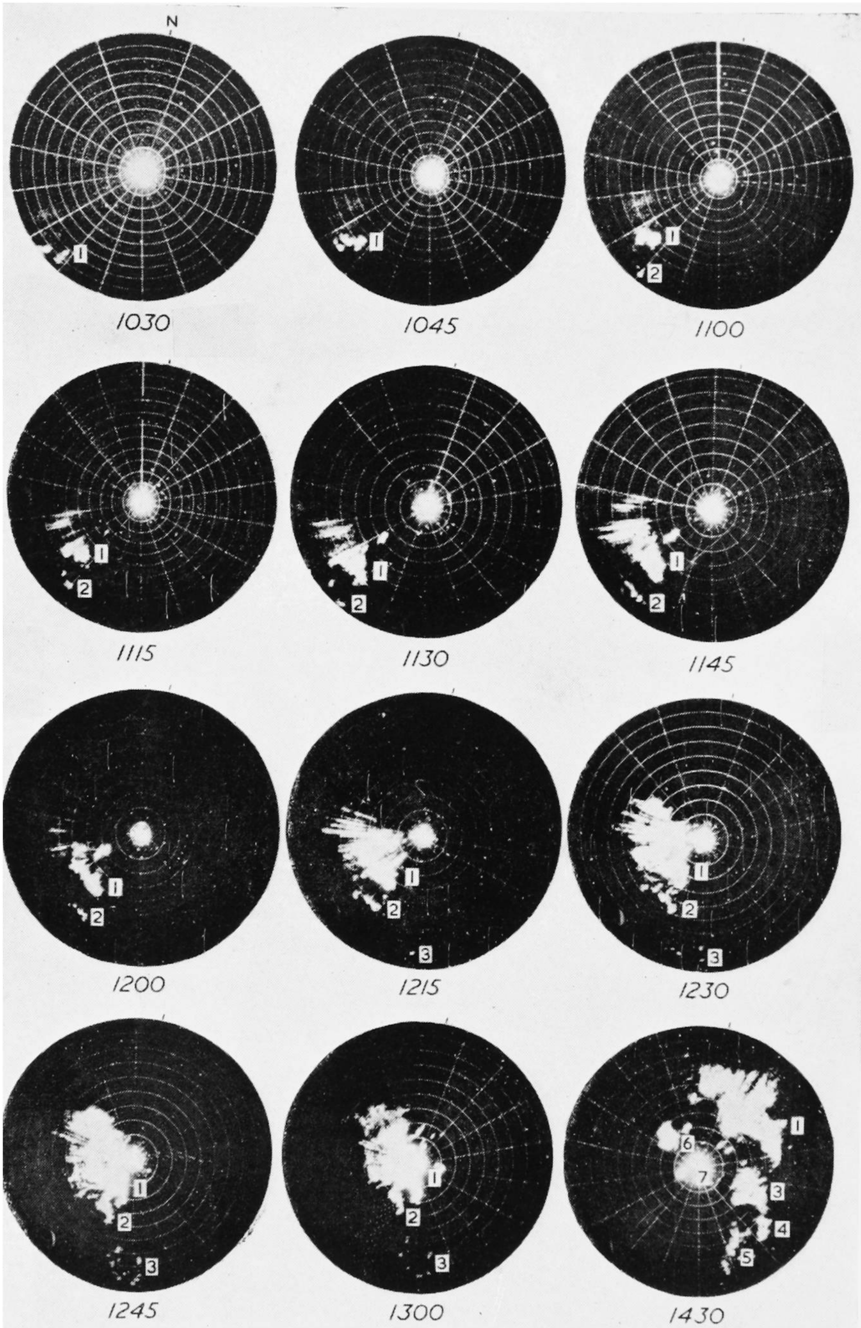
CH	Chatteris	Rev. J. C. Hawthorne
CL	Clenchwarton	Mr. S. Brown
CR	Crabmarsh	Mr. H. Crowe
D	Deeping St. Nicholas	Mr. J. A. Pick
DB	Downham Street	Mr. G. Rich
DD	Whittlesey	Mr. A. J. Foster
DE	Downham Market	Mr. J. O. Vince
DG	Downham Market	Miss E. J. Tebbutt
EH	Ely	Miss E. Langton
G	Glinton	Mr. R. Booker
GP	King's Lynn	Mr. C. Guy
GU	Guyhirn	Mr. J. H. Cox
H	Hunstanton	Mr. G. A. Timothy
HB	Holbeach	Royal Air Force
HS	Holbeach	Mr. P. A. Moxon
I	St. Ives	Mr. H. King
IS	Isleham	Mr. H. W. Woodward
KA	King's Lynn	Mr. A. Chadwick
KL	King's Lynn	Mr. W. J. R. Baxter
KP	King's Lynn	Mr. W. Marshall
L	Littleport	Mr. J. H. Martin
LM	Littleport	Mr. C. R. Browning
LS	Long Sutton	Mr. F. A. Noon
M	March	Mr. C. E. M. Fyson
MA	Manea	Mr. R. Loose
ME	Mepal	Royal Air Force
MW	Methwold	Mr. R. S. Ashwell
P	Pinchbeck	Mr. E. Bain
PE	Peterborough	Miss B. Bennett
PO	Peterborough	Mr. G. Buffham
RB	Ramsey	Mr. R. Bojdys
RC	Ramsey	Mr. A. M. Rees
RP	Ely	Mr. Jones
RM	Ramsey	Mr. F. J. Burton
S	Swavesey	Mr. J. F. Gale

(*cont. on p. 357*)

To face p. 356

Photograph by D. McFarlane

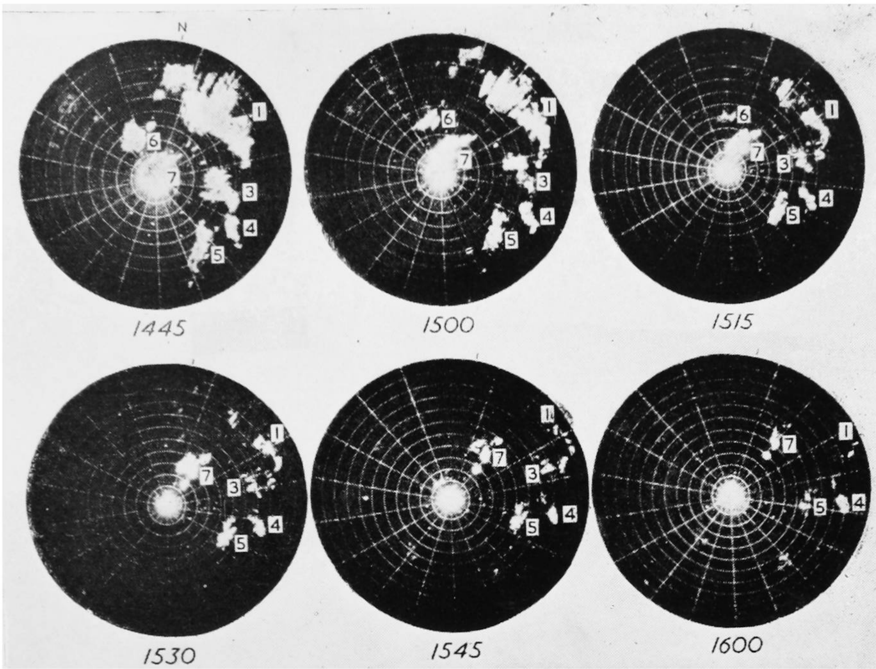
THE AUXILIARY REPORTING STATION ON THE SUMMIT OF MOUNT OLYMPUS (6403 FEET) IN THE SUMMER



PHOTOGRAPHS OF THE 10 CM PPI RADAR BASED AT EAST HILL, SHOWING THE PASSAGE OF SEVEN SEPARATE STORM AREAS ACROSS SOUTH-EAST ENGLAND ON 9 JULY 1959

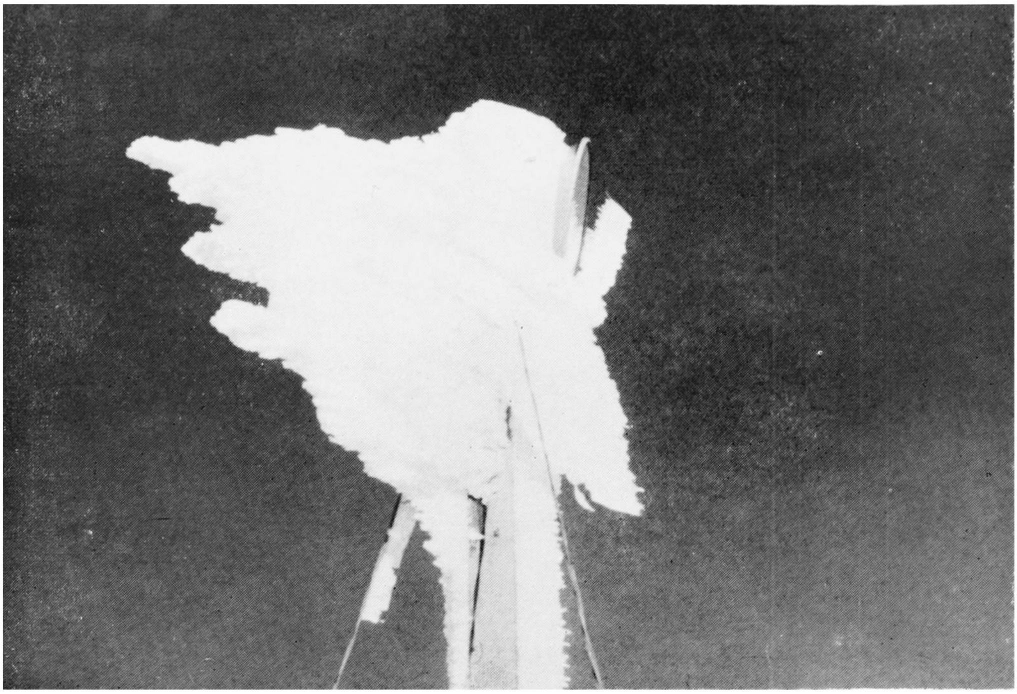
(*cont. on next art page*)

The range markers are at intervals of 10 miles and the azimuth markers are at 20° intervals from 010° (true).



(cont. from previous art page)

SUMMIT OF MT. OLYMPUS AFTER HEAVY SNOWFALL
(See also the following two photographs.)



Photograph by Cpl. R. Hacker, Royal Corps of Signals

Photograph by S/Ldr. E. R. Lacey, R.A.F.

SUMMIT OF MT. OLYMPUS AFTER HEAVY SNOWFALL

The conditions depicted in these photographs are not exceptional. The great deposits of rime become dangerous when strong winds carry off the more recent formations.

List of observers in the fen-land fog investigation (cont.)

SB	Sutton Bridge	Mrs. A. Noble
SC	Soham	Mr. G. W. J. Leach
SE	Setch	Mr. W. J. Hoff
SG	Spalding	Miss P. Wheatley
SI	St. Ives	Mr. J. R. O. Sandison
SM	Smeeth	Mr. J. Frost
SR	Spalding	Mr. Renfall
SS	Soham	Mr. G. D. Watts
T	Thorney	Mr. T. Glover
TC	Terrington St. Clement	Mr. A. C. Owers
TS	Terrington St. Clement	Mr. H. S. Kenyon
U	Upwell	Mr. J. R. Frost
W	Wisbech	Mr. D. E. C. Morgan
WH	Whittlesey	Mr. R. Shadrake
WI	Wisbech	Mr. A. F. R. Fisher
WL	Sutton Bridge	Mr. J. Thompson
WS	Wiggenhall St. Germans	Mr. J. W. P. Rees

The indicator letters are those marked on the map at Figure 1 (p.351).

551.524.3:551.576.11:551.589.5

NORTH SEA STRATUS OVER THE FENS

By M. H. FREEMAN, O.B.E., M.Sc.

Introduction.—An investigation of the effect of the fens on the formation and dispersal of fog has been reported elsewhere.[1] For this purpose the co-operation of numerous voluntary observers had been obtained and a selection of them agreed to report also the times of formation or dispersal of low cloud when there was a north-easterly wind. Most observers realized that they would have difficulty in recognizing the required conditions, so arrangements were made for the meteorological office at Mildenhall to issue warnings by telegram of occasions when there was a possibility of stratus forming. As spring and early summer is the time of year when North Sea stratus is commonest, the investigation was mounted for the periods April to July 1960 and 1961, immediately following the previous winter's fog investigation.

In order to find out how frequently North Sea stratus could be expected, a statistical analysis was carried out on observations at Mildenhall for 24 hours per day for the ten years 1949–1958. Table 1 shows the average number of hours per month when the surface wind was in the sector 340 to 070 degrees inclusive, the average number of hours when there was also $\frac{5}{8}$ or more cloud at 1000 feet or below, occasions of precipitation other than drizzle being excluded, and the percentage frequency of low stratus in north-easterly winds for each month.

The figures in Table 1 for April are interesting. North-easterly winds are commoner in April than in any other month but their chances of being associated with cloud at 1000 ft or below are less than at any other time of the year. Even in May, June and July, the peak period for North Sea stratus, the frequency of its occurrence is low, and in the years 1960 and 1961 opportunites for investigating the phenomenon were also few.

Analysis of the observations.—In 1960 stratus occurred extensively in only two periods, 16 to 21 May and 24 to 27 June. The voluntary observers had not been alerted for the formation of stratus on 16 May and its dispersal on the 17th. Stratus re-formed during the night of 17th/18th after the volunteers had ceased observing, and the low cloud then persisted for four days. Wide-

TABLE I—AVERAGE MONTHLY FREQUENCY OF NORTH-EASTERLY WINDS AND LOW CLOUD AT MILDENHALL, 1949-1958

Month	No. of hours with surface wind 340°–070°	No. of hours with $\frac{5}{8}$ or more cloud at 1000 ft or below	Percentage frequency of low cloud with north-east winds
Jan.	95	9	10%
Feb.	122	12	10%
Mar.	150	22	15%
Apr.	198	8	4%
May	191	25	13%
June	150	29	19%
July	122	21	17%
Aug.	84	9	11%
Sept.	85	6	7%
Oct.	80	5	7%
Nov.	87	12	13%
Dec.	58	8	14%
Year	1422	166	12%

spread thunderstorms on the night of 23/24 June formed cloud below 1000 feet over the fens and this persisted until early on the 25th. Very few reports relating to these periods were made, but useful information was obtained from the voluntary observers concerning the formation of stratus on the evenings of 25 and 26 June; these occasions are discussed below. In 1961 warnings of the possibility of stratus formation were issued on six occasions, but on five of them no more than a few patches of stratus occurred and the last was associated with precipitation. In the two years therefore, useful results were obtained for only two occasions.

On 25 June 1960 there was a light north-easterly air flow over England between a shallow depression near Switzerland and a belt of high pressure from Norway to O.W.S. "J"*. During the afternoon temperatures inland over East Anglia rose to 75–80°F. Nearer the coast and over the fens the maxima were in the lower 70's, while on the coast the maximum was 64–65°F. The sea temperature in the Wash was 63°F. Isotherms of maximum temperature are shown in Figure 1. By evening, reports from ships indicated that there was no cloud over the southern North Sea. No stratus formed over the eastern part of Norfolk and Suffolk or over northern Lincolnshire. Elsewhere stratus formed when the temperature had fallen to about 58°F and the dew-point to near 56°F. This happened first near the coast, where only a small drop in temperature was needed. Isochrones of stratus formation are shown in Figure 2. Times given in brackets are for offices which had closed for the weekend; these times were estimated from thermograms, which usually had a marked change of slope which could be associated with the arrival of stratus. To some extent the isochrones reflect the shape of the coastline, but they also show a bulge southwards over the fens, where lower maximum temperatures had been recorded. Slightly lighter winds may have been the reason for the eastern half of East Anglia remaining clear. At some of the meteorological offices near the fens the cloud dispersed again during the night when the surface wind speed dropped; at other places the clearance occurred with rising temperatures soon after dawn.

On 26 June 1960 there was little cloud over land during the day and the

*Ocean Weather Station "J" is at 52½°N, 20°W

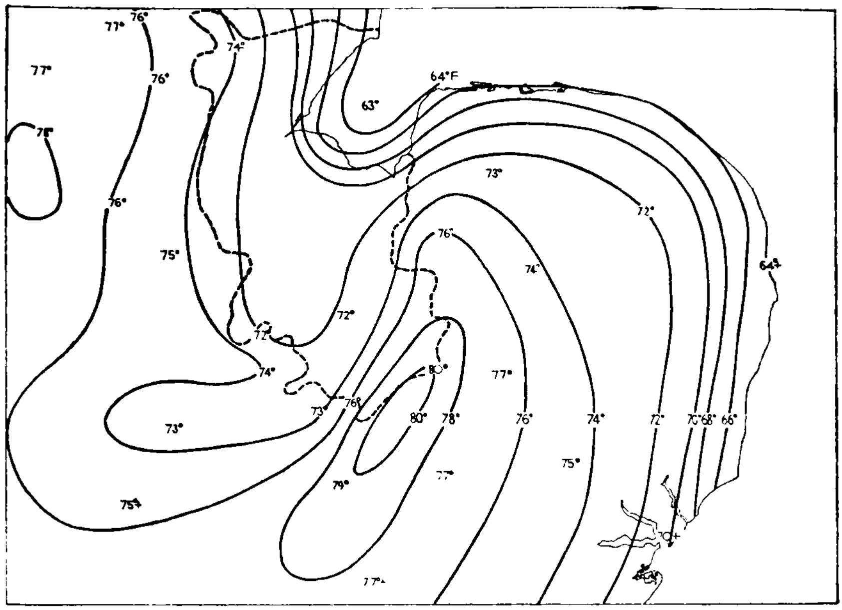


FIGURE I — MAXIMUM TEMPERATURES (°F) ON 25 JUNE 1960
The pecked line indicates the boundary of the fens

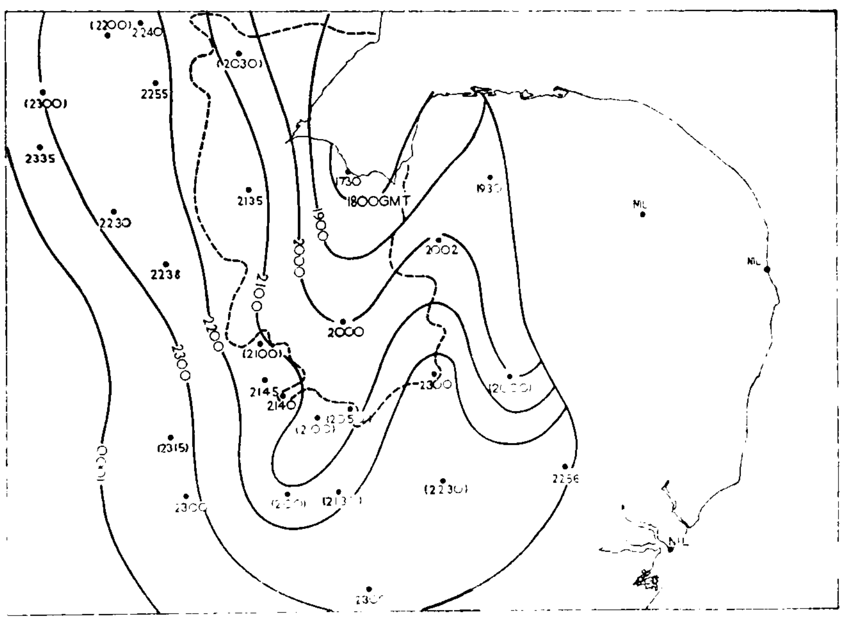


FIGURE 2 — TIMES OF FORMATION OF STRATUS ON 25 JUNE 1960

temperature rose to a maximum of 72–77°F, the distribution being very similar to that of the previous day; the lower values over the fens were again noteworthy. Little change in the isobaric pattern occurred in the 24 hours but, over the North Sea, stratus had spread southwards and by late afternoon was near the Norfolk coast. Stratus spread southwards across East Anglia fairly quickly during the evening. The earliest report was from Sutton Bridge at 1600 GMT. The lower maximum temperatures over the fens resulted in stratus spreading in more quickly in this area. Isochrones of cloud arrival are shown in Figure 3. The temperature at which cloud appeared was about

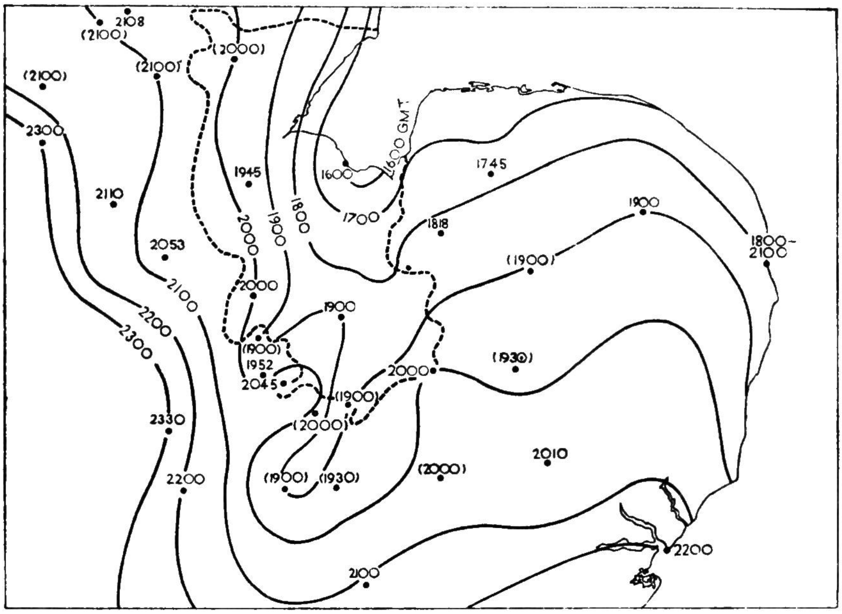


FIGURE 3 — TIMES OF FORMATION OF STRATUS ON 26 JUNE 1960

the same as on the previous evening. There was no clear-cut dispersal of the stratus next day; the cloud base gradually lifted and breaks occurred in the afternoon.

Recording thermometers had been installed at Manea, in the fens, and at Waterbeach, on the borders, and comparisons were made of the daily maximum and minimum temperatures. In the period May–July 1960, on the average Manea had a maximum 1°F higher and a minimum 2°F lower than Waterbeach. In June there were only five days when Manea had the lower maximum temperature, and the two largest differences (4° and 5°F) occurred on the 25th and 26th, two occasions when stratus formed. It is possible that the lower temperatures on these days had been caused by a sea breeze.

Conclusions.—The two occasions which were all that could be analyzed are insufficient to provide generalizations. They gave similar patterns of maximum temperature, both having relatively lower values over the fens. On one night stratus formed over land and on the other it spread in from the sea, but on both occasions cloud appeared over the fens and to the south of fenland earlier than in neighbouring areas. Analysis of the thermograms from Manea and Waterbeach suggested that the tendency for lower maximum temperatures over the fens was not a persistent feature.

REFERENCE

1. FREEMAN, M. H.; The formation and dispersal of fog over the fens. *Met. Mag., London*, **91**, 1962, p. 350.

551.552:551.576.11

THE SPREAD OF LOW STRATUS FROM THE NORTH SEA ACROSS EAST ANGLIA

By W. R. SPARKS

Introduction.—The problem of the rate at which low stratus over the North Sea spreads over East Anglia with north-east winds is of concern to many forecasters in the area. For the investigation of this problem a dense network of reporting stations was needed, so a war-time period, namely 31 July to 7 August 1944, was selected for study, and daily registers from 123 stations within 100 miles of the Wash were examined. Throughout the period pressure was high over the North Sea and low over Germany, giving a gradient wind direction between north and east. There was stratus over the North Sea the whole time and the investigation was confined to a study of when and how the stratus moved inland.

Analysis of the data.—Charts of surface wind and M.S.L. pressure were plotted for 1800 GMT each day. An attempt was made to measure the gradient wind on each chart, but it was found on all occasions that a balance was not possible between the forces due to the pressure gradient, the curvature of the isobars and the earth's rotation. The air was therefore being accelerated and it was impossible to make a reliable estimate of the 2000 ft wind from the isobars. For example, on the six days when the point at which balanced flow became impossible was east of Downham Market, the mean angle of backing of the measured 2000 ft wind from the direction of the isobars at Downham Market was 60°. The range of the angle of backing was 29°–100°. On the one occasion during the period when balanced flow was possible at, and to the east of, Downham Market the angle of backing of the measured 2000 ft wind from the direction of the isobars was 15°. Figure 1 is the isobaric chart for 1800 GMT on 4 August 1944. The inability of the air to follow the isobars round the ridge is seen in the marked backing of the surface wind from the direction of the isobars on the western side of the ridge.

Since it proved impossible to estimate the wind at stratus level from the pressure pattern, reported winds had to be used. Surface winds from all stations were plotted on large-scale charts (10 miles to the inch) and stream lines were drawn from an isogonal analysis. Figure 2 shows an example corresponding to the isobaric chart at Figure 1. The streamline analysis proved very interesting and from an examination of this one series of charts the following points emerged:

(i) On every occasion there was diffluence from the region of the Wash.

(ii) There was a tendency for surface winds to be stronger at stations bordering the fens than at other stations to the east and north.

(iii) The surface streamlines were a good approximation to the direction of advection of the stratus sheet.

(iv) To the south-west of the Wash the speed of advection of the stratus was approximately the speed of the surface wind at 1800 GMT

(v) To the south-east of the Wash the speed of stratus advection was much less consistent but the average speed was always slower than the surface wind speed at 1800 GMT.

(vi) A change of surface wind direction during the night seemed to have an effect on stratus advection but a decrease in the surface wind did not.

(vii) Lines of shear in the surface wind field were almost certainly important in the advection of stratus sheets but, even when streamline charts were drawn hourly using the very dense network of stations available for this investigation, it was difficult to place shear lines accurately and usually impossible to be sure of their exact form.

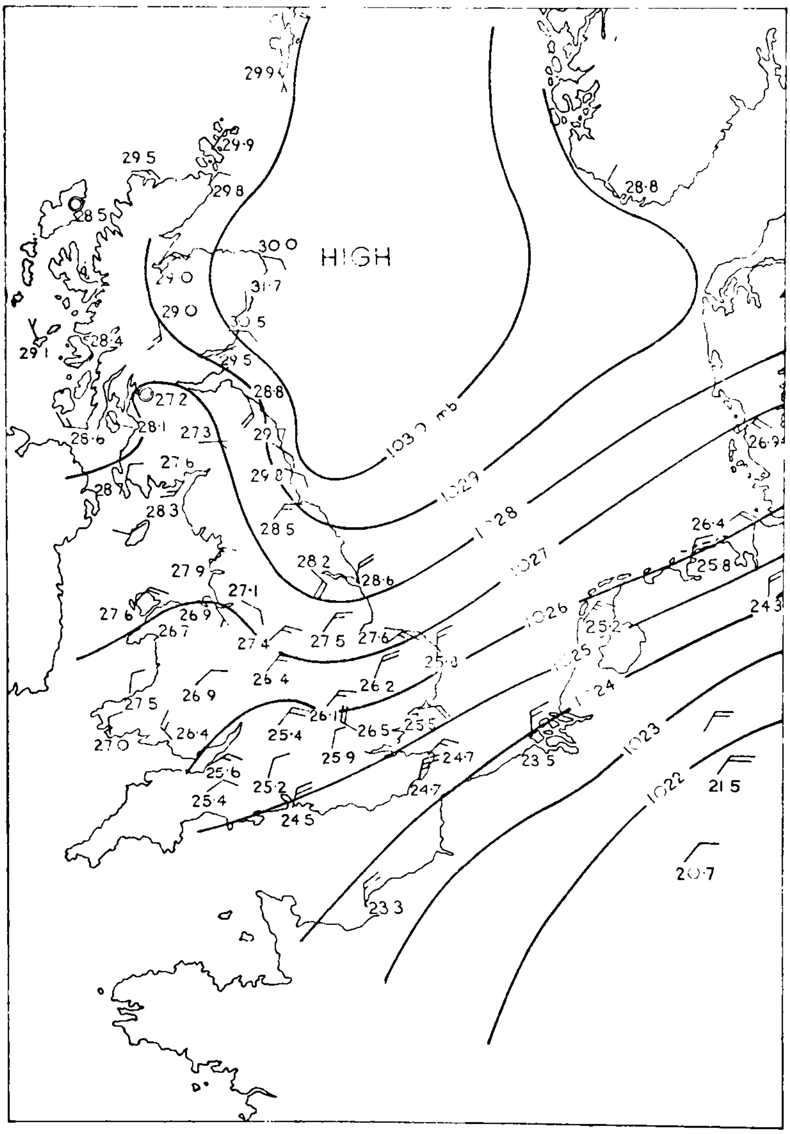


FIGURE I — SURFACE SYNOPTIC SITUATION FOR 1800 GMT, 4 AUGUST 1944
The figures beside the plots indicate pressure (millibars and tenths)

Charts of stratus advection were drawn and on most occasions it proved sufficient to plot a chart showing the time of the first report of stratus and to draw isochrones of the position of the leading edge of the stratus sheet. Figure 3 is the chart for 4–5 August 1944. It was not possible to use this method on two occasions when stratocumulus had persisted over land during the day and

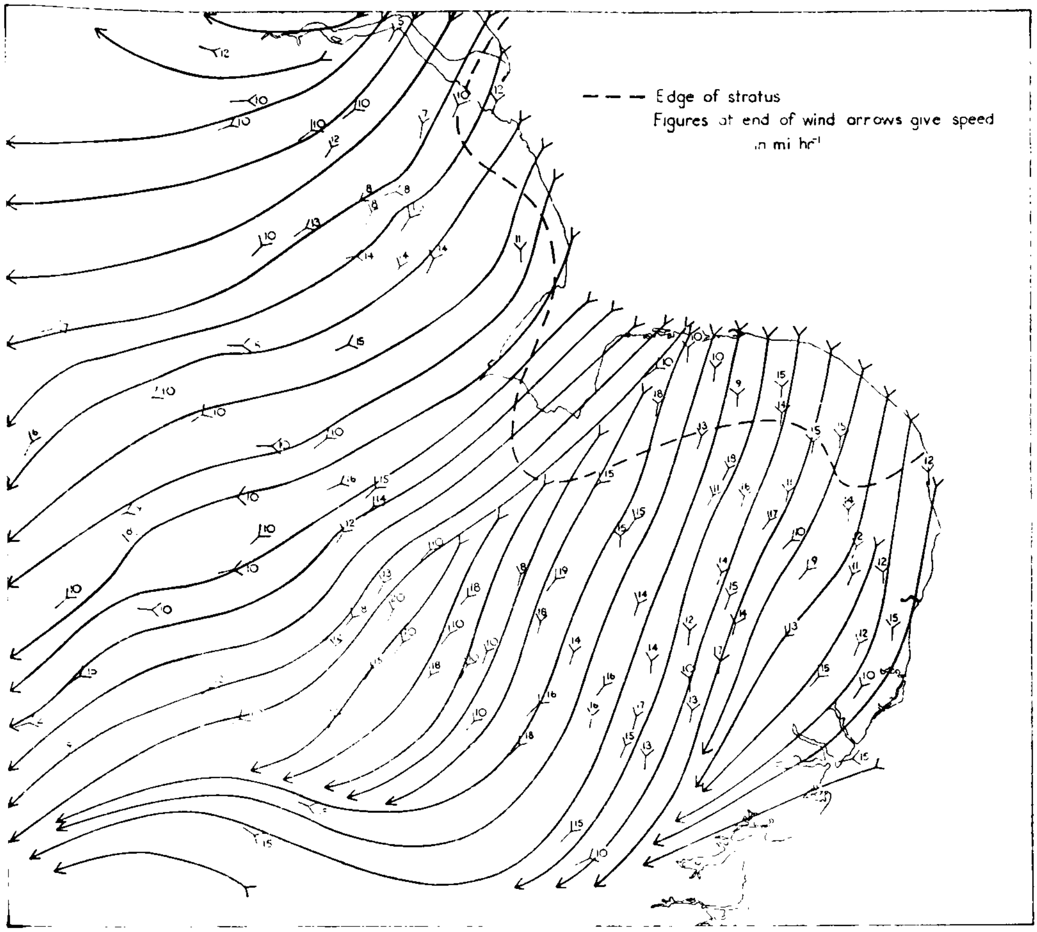


FIGURE 2 — SURFACE WINDS AND STREAMLINES AT 1800 GMT, 4 AUGUST 1944

gradually lowered to stratus during the night.

Time cross-sections showing isotherms in the layer from the surface to 900 mb were plotted for the whole period for Downham Market (radiosonde observations) and Bircham Newton (aircraft observations). These cross-sections showed that, although no fronts passed either station during the period, the air stream was far from homogeneous. Warm and cold closed centres appeared on the cross-sections, usually near the inversion base, and although they were modified by diurnal heating, this cannot account for them (for example, at Downham Market the temperature at 970 mb rose from 56°F at 1200 GMT to 66°F at 2359 GMT on 3 August 1944). Similar results were found by Findlater.[1]

A chart was plotted for 5 August 1944, showing the temperature at which the stratus cleared. The clearance temperature was almost constant over the chart (62°F in the north, gradually becoming 63°F in the south-east). On other days a chart was not plotted but a glance through about 20 selected registers was sufficient to show the clearance temperature for the day. Charts showing the temperature when stratus reached each station were also plotted. The main features shown by these charts were:

(i) Stratus affected coastal stations as soon as their temperature fell below the clearance temperature of the stratus sheet.

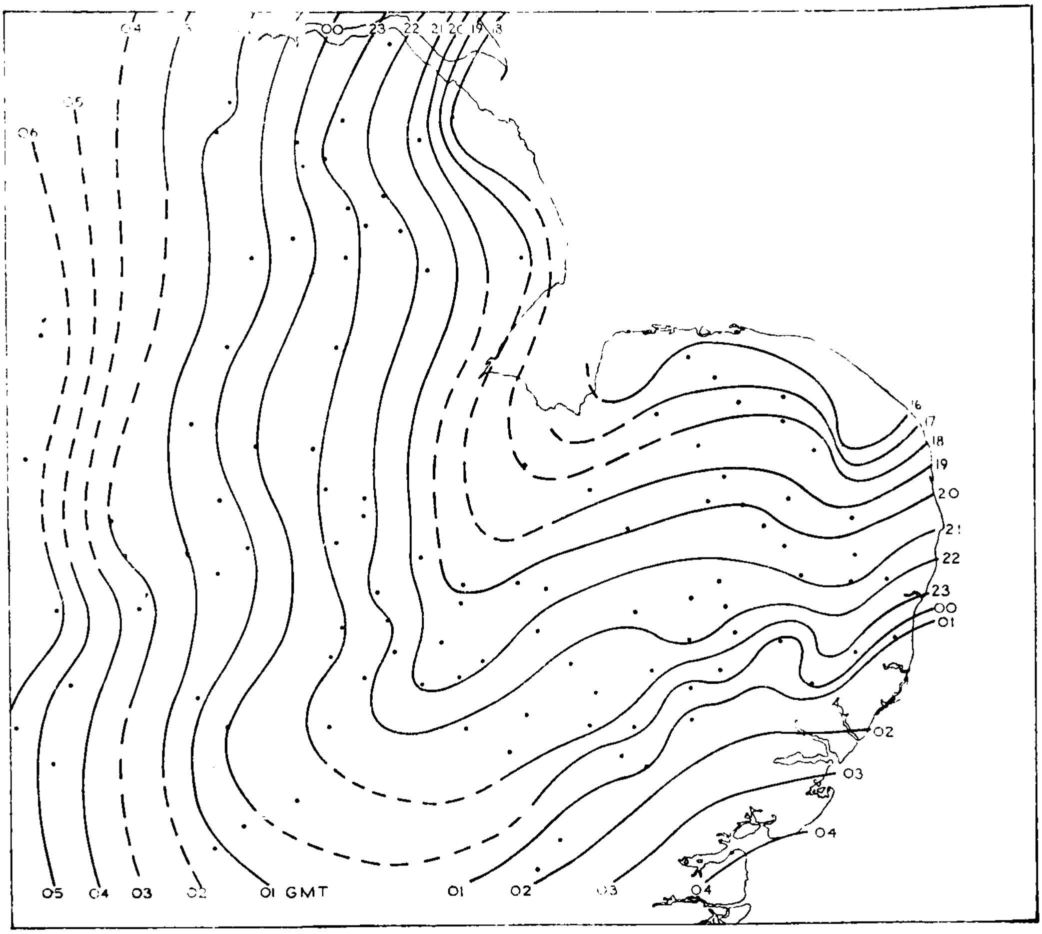


FIGURE 3 — ISOCHRONES OF STRATUS EDGE, 4–5 AUGUST 1944

The dots show the positions of stations which provided data

(ii) Stratus did not affect an inland station until its temperature was below the clearance temperature and sometimes the temperature fell considerably below the clearance temperature before the station was affected.

Conclusions.—The following simple model is suggested by this analysis of the data for one particular stratus situation. When a stratus sheet is present over the North Sea during the day it is presumably in dynamic equilibrium, with continual formation over the sea and continual evaporation of the leading edge of the sheet as it advects over land. When the temperature at coastal stations falls below the clearance temperature of the stratus sheet the leading edge is no longer evaporated and the stratus will then move inland. The leading edge of the stratus moves inland at the speed of the wind at its own level, provided the temperature at inland stations has fallen below the clearance temperature. This simple picture is complicated by the heterogeneous temperature structure of the air stream. The advection of a warm area to replace a cold area at about 950 mb causes a change in the inversion height and a change in the clearance temperature of the stratus sheet.

The spread of stratus inland was mainly due to advection, but on two occasions there was evidence of stratus forming over high ground ahead of the main sheet.

In the absence of a suitable temperature sounding through the stratus, the temperature at which stratus cleared in the morning provided the best estimate of the temperature at which it started to move inland in the evening.

When a balanced gradient wind was impossible the surface winds gave a much better approximation to the direction of stratus advection than the direction of the isobars.

The speed of the surface wind, at a time when convection and turbulence were still operative in the lowest layers (say 1800 GMT in August), gave a fair approximation to the speed of stratus advection.

REFERENCE

1. FINDLATER, J.; Thermal structure in the lower layers of anticyclones. *Quart, J.R. met. Soc., London*, **87**, 1961, p. 513.

551.510.42:551.515.8:551.521.16

A CONTRIBUTION TO THE PROBLEM OF DAY-DARKNESS OVER LONDON

By P. B. GILDERSLEEVES

Introduction.—This report describes and examines the factors contributing to the formation of a belt of extreme day-darkness which crossed the London area during the morning of 1 December 1961. Comparisons are made with the report of another occasion by Helliwell and Blackwell[1] and some suggestions are made which may assist in forecasting this phenomenon.

The synoptic situation.—Figure 1 shows the synoptic situation at 0600 GMT on 1 December. Pressure was low over Scandinavia and high to the west of the

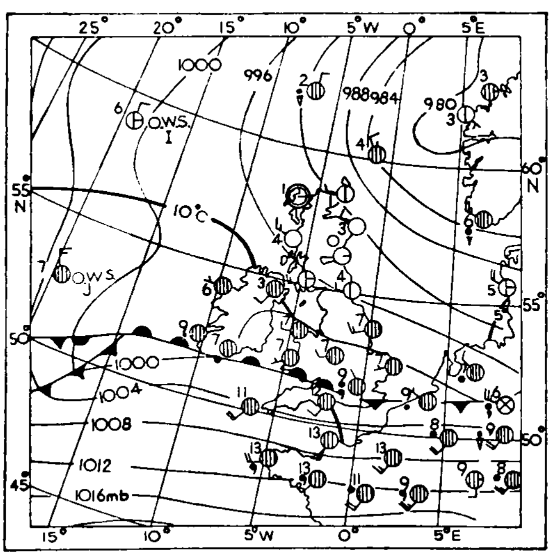


FIGURE 1 — SURFACE SYNOPTIC SITUATION AT 0600 GMT, 1 DECEMBER 1961

The isotherms are of mean sea temperature (10°C)

Iberian Peninsula. A cold front which had been moving quickly south over the United Kingdom since 1800 GMT on 30 November became quasi-stationary over southern England during the morning of the 1st.

In the London area the front remained almost stationary between Bovingdon and London Airport from 0200 to 0330 GMT, eventually passing through London Airport just after 0330 when the temperature and dew-point fell from 12° and 10°C to 8° and 7°C respectively and the wind veered from 250° to 310°. This temperature contrast across the front is comparable to that reported by Helliwell and Blackwell.[1]

Analysis.—A streamline analysis was carried out for the period 0100 to 1200 GMT on 1 December using hourly surface wind reports from 12 synoptic stations and 10 auxiliary climatological stations (Table 1) in south-east England.

TABLE I — STATIONS WHOSE WIND RECORDS WERE USED TO PRODUCE STREAMLINE CHARTS

Meteorological Office stations	Auxiliary climatological stations
Benson	Amersham (Radio Chemical Centre)
Bovingdon	Coryton
Kew	Garston (Building Research Station)
London (Gatwick) Airport	Gravesend (Thames Ferry Station)
London (Heathrow) Airport	Hampden
London Weather Centre (Kingsway)	Isle of Grain
Northolt	Rothamsted (Lawes Agricultural Trust)
Shoeburyness	Sheerness
South Farnborough	Stanstead Abbots
Stanstead	Woolwich (Thames Ferry Station)
West Malling	
White Waltham	

Surface air trajectories were computed using these streamlines. An example of the streamline analysis is shown in Figure 2.

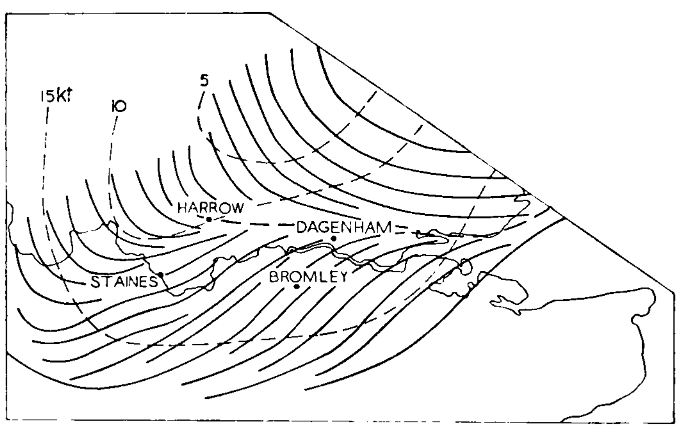


FIGURE 2 — STREAMLINES FOR THE HOUR ENDED 0300 GMT (THE FLOW IS FROM LEFT TO RIGHT), AND ISOTACHS (PECKED LINES), 1 DECEMBER 1961

Four trajectories were computed, the starting points being in the form of a square, the sides of which enclosed an area of 1600 square miles. Figure 3 shows the trajectories of the surface air starting at 0001 GMT on 1 December, from the corners of a square just to the west of London. These were found to converge on central London by 1000 GMT. This compares with an observation of smoke-pall to the south-west made by the London Weather Centre at 0900 GMT.

The positions of the end points of the four trajectories at 1000 GMT formed a quadrilateral of area 490 square miles, a reduction of 69 per cent in the original area, an indication of convergence processes operating with consequent vertical

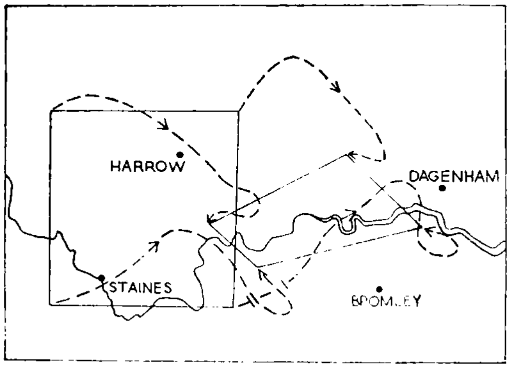


FIGURE 3 — TRAJECTORIES, 0001–1000 GMT, 1 DECEMBER 1961

motion. This quadrilateral was positioned almost symmetrically about the Thames with an orientation ENE–WSW.

Upper air analysis.—The ascents made on 1 December from Hemsby at 0001 GMT, and from Crawley at 1200 GMT, are shown in Figure 4.

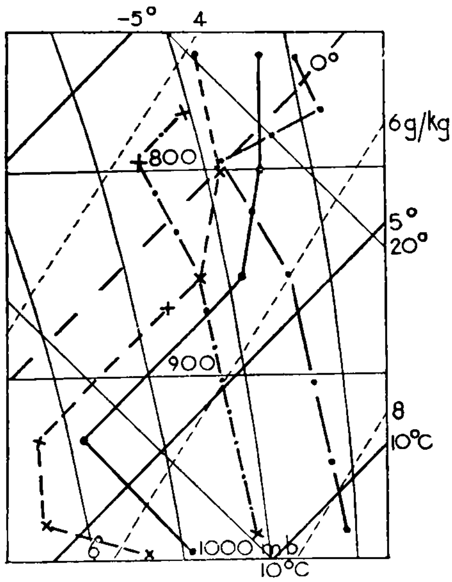


FIGURE 4 — TEPHIGRAM SHOWING ASCENTS FROM HEMSBY AT 0001 GMT AND CRAWLEY AT 1200 GMT, 1 DECEMBER 1961

Hemsby ———— Dry bulb Crawley —— · —— · Dry bulb
— — — — Wet bulb — — · — · Wet bulb

The Hemsby ascent can be seen to be somewhat complex, consisting of three distinct layers. In the lowest layer, that is below 550 m, one can see the moist cold air behind the front whilst above 1500 m the moist warm air is ahead of it. This air was very moist and from humidities reported dense cloud can be inferred to at least 5000 m. Between these two layers was a very moist transition zone characterized by a marked increase in wet-bulb potential temperature, from 6°C at 550 m to 10°C at 1500 m.

The 1200 GMT ascent for Crawley (Figure 4) shows the structure of the moist tropical air south of the front with temperatures from the surface to 850 mb following closely the saturated adiabatic line for 12°C.

Illumination in the dark belt.—The daylight illumination records and total radiation records for Kew and the London Weather Centre were examined to provide some quantitative data on illumination in the dark belt. Figure 5

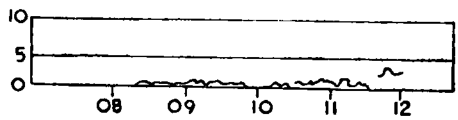


FIGURE 5 — DAYLIGHT ILLUMINATION RECORD FOR LONDON WEATHER CENTRE ON 1 DECEMBER 1961 (IN KILOLUX)

shows the daylight illumination record for the London Weather Centre on 1 December. It is immediately apparent from the record that the combined effect of the dense frontal cloud and smoke had the effect of delaying the dawn until 1140 GMT.

The illumination at London Weather Centre from 0815 when the record started, until 1010 GMT, was less than 0.1 kilolux,* and during this period the illumination fell twice to a value almost indistinguishable from zero, namely at 0900 GMT, when an observation of day-darkness was recorded in the daily register, and again at 1000 GMT. This second minimum in the illumination lasted for some 12 minutes compared with 6 minutes for the first one. A tentative explanation for this is that a secondary smoke-pall had formed and drifted northwards in the light south-easterly drift. There is no corroboration of this hypothesis by way of observations; there was, however, a marked confluence in the surface wind field just to the north-west of the Weather Centre at 1000 GMT. A rough mean value for the illumination at the Weather Centre using all the available data (3 years) has been calculated for 0900 GMT in December for those occasions on which there was more than 7/8 of cloud, with the base of the lowest layer less than 1000 feet, or less than 1500 feet if it was raining continuously. This value, 2.03 kilolux, may be used to obtain an estimate of the contribution made by the smoke alone in reducing the illumination, on the assumption that under dense cloud illumination is reduced to 2.03 kilolux; if, following Helliwell and Blackwell,[1] a value of 0.03 kilolux is taken as the intensity of illumination at the time when the smoke-pall crossed the area, then the reduction in illumination due to the smoke alone was about 2 kilolux. This compares with a value of just under 7 kilolux adduced by Helliwell and Blackwell for 1300–1400 GMT in January and quoted in their report.[1] Also in this report they offer a hypothesis to account for this reduction in illumination; the mechanism they suggest may well be operative in the present case as essential details are similar.

Conclusions.—Although it is not possible at present to assess the frequency of occurrence of the phenomena the following seem to be the most important factors contributing to day-darkness. (Hence they may be taken as examples of the type of element which forecasters should look for when deciding to issue a day-darkness warning.)

Helliwell and Blackwell stressed the importance of the first two.

(i) A very active front with a marked temperature contrast and dense cloud.

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*1 kilolux = 1000 lumens m^{-2}.

(ii) Marked convergence on the front.

(iii) A long period of stagnation with a slow-moving front, enabling smoke to be entrained in the lowest layers of cloud.

(iv) Low-level inversion or stable layer, reducing the dissipation of smoke upwards, thus enabling the lower layers of the atmosphere to become heavily polluted. (The importance of this is brought out in DSIR's report on *Investigation into Atmospheric Pollution*[2]).

(v) Confluent wind field across the front with light winds moving the polluted air into the convergent frontal zone.

REFERENCES

1. HELLIWELL, N. C. and BLACKWELL, M. J.; Day-time darkness over London on January 16, 1955. *Met. Mag., London*, **84**, 1955, p. 342.

2. London, Department of Scientific and Industrial Research; The investigation of atmospheric pollution, research and observations in the year ending 31st March, 1958. London, HMSO, 1960.

551.5:06.045:63

WORLD METEOROLOGICAL ORGANIZATION, COMMISSION FOR AGRICULTURAL METEOROLOGY

Representatives of 31 nations attended the third meeting of the Commission for Agricultural Meteorology held at the University of Toronto, Ontario, Canada from 9–27 July 1962 under the presidency of P. M. Austin Bourke of Eire. A feature of the session was the excellent series of reports submitted by the Working Groups which had been set up by the previous meeting at Warsaw. The reports on apple scab, frost protection, shelter, forest fires, the storage of fruit, and agricultural aviation were outstandingly good and will provide material for valuable additions to the series of Technical Notes published by WMO.

Further working groups were planned to deal with other important subjects, namely, wheat rust, the oriental fruit moth and codling moth, air pollution and crop yields, local climatological influences, the storage of cereals, soil moisture problems, lucerne, animal experiments, and instruction syllabi in agricultural meteorology.

Three scientific sessions were held including one sponsored jointly with the Royal Meteorological Society's Canadian Branch under the chairmanship of Dr. Andrew Thomson, O.B.E., at which a number of interesting papers were read.

Visits were also arranged to the Canadian Meteorological Service and to research stations in the neighbourhood, including one to the hydro-electric installations at Niagara Falls.

The undoubted success of the meeting was greatly helped by the extremely efficient organization for which the Canadian Meteorological Service was largely responsible.

Mr. L. P. Smith (United Kingdom) was elected President of the Commission.

REVIEW

Über die Fruchtgrössenveränderung einiger Apfelsorten und ihre Abhängigkeit von atmosphärischen Umweltbedingungen, by S. Stenz. 9 in. x 6 in. pp.60, *illus.*, Akademische Verlagsgesellschaft, Geest & Portig K.-G. Leipzig C1, 1962. Price: *D.M.*6.50.

This publication from the Institute of Agrometeorology in Leipzig describes experimental work on the variation in fruit size of certain apple varieties in relation to weather. The author has developed an instrument for providing a continuous record of the growth of an apple still on the tree and the records from such instruments are compared with standard meteorological data, including global radiation. The investigation is based on records from one site in East Germany in 1955 and four sites in 1956.

The growth records show that a diurnal variation in fruit size is superposed on the normal increase in size which occurs during the growing season. The maximum size occurs at about 0800h and then follows a decrease in size until early afternoon, which may amount to 2 per cent. of volume. By late afternoon the pre-shrinking size is regained and during the night there is a net increase. The diurnal shrinkage varies directly as radiation, sunshine and maximum air temperature, and inversely as minimum daily relative humidity. These are not unexpected results, but it appears that the most important factor is relative humidity. This suggests to the reviewer that two fundamental factors are involved, radiation and air mass.

Seasonal fruit growth is estimated from the 0400h values and the relationship with weather is much less definite than for the diurnal variation. In fact, correlation coefficients between growth over a period of a month or two and the meteorological elements are not consistent in sign when different years and locations are considered, and more extensive investigations over wide areas are necessary to clarify these results.

A section of this paper deals with variations in fruit size from a physiological point of view and is of somewhat less interest to the meteorologist. Fruit shrinkage is shown to be due to the insufficient capacity of the capillary vessels at times of high transpiration, or to insufficient water uptake by the roots. In general, soil moisture appears to exert less influence on fruit development than those weather elements which lead to a high transpiration rate, with the associated moisture stress phenomena in the tree. A study of fruit-fall, and of the June drop in particular, suggests that this is a complex problem; it is probably related to water losses, but these are to some extent affected by available nitrogen. These ideas are quite consistent with those now current in general farming, that water and nitrogen are to some extent interchangeable.

W. H. HOGG

PUBLICATION RECEIVED

The Weather: fronts (in the series "Physics-astronomy and space exploration"). 30 in. x 40 in., Wallchart (C.851) in three colours, Educational Productions Ltd., East Ardsley, Wakefield, Yorkshire, 1962. Price 10*s*.

OFFICIAL PUBLICATION

The following publication has recently been issued: *Cloud types for observers*, London, HMSO, 1962. Price: 8s. Details are given on p. 372.

AWARDS

R.A.F.V.R. awards.—We are pleased to note that the undermentioned officers in the Meteorological Section of the R.A.F.V.R. have been granted the Air Efficiency Award.

Flt.-Lt. J. M. Mulvey.
Flt.-Lt. G. M. Smith.

METEOROLOGICAL OFFICE NEWS

Retirements.— The Director-General records his appreciation of the services of:

Mr. P. Powell, Senior Experimental Officer, who retired on 3 September 1962 after 43 years' service. Mr. Powell joined the Office as a Boy Clerk in March 1919 and served at various stations in south-east England as a Clerk Grade III and Technical Assistant III and II until he was mobilized into the Royal Air Force Reserve on the outbreak of war and sent to France. He returned to the U.K. early in 1940 and was demobilized in 1941. After service at No. 1 Group and No. 2 Group Headquarters he was attached to the 21st Weather Squadron, U.S.A.F., in 1943, and for his work there was awarded a Certificate of Merit by the squadron. In 1943 he was commissioned in the Royal Air Force and served with the Bomber Wing of 2nd T.A.F. until demobilization in 1945. In the post-war reconstruction he was assimilated as an Experimental Officer and served at High Wycombe until he went to Germany in 1947, where he stayed for five years, being promoted to Senior Experimental Officer in 1949. On his return to the U.K. in 1952 he went to Mildenhall, and stayed there for the remainder of his career.

Mr. A. Lee, Experimental Officer, who retired on 2 September after 33 years' service. Mr. Lee joined the Office as a Grade III Clerk in June 1926 at Calshot. After a year he was transferred to Sealand and later to Calshot where he became an Assistant III. In 1939 he was posted to Thorney Island, where he remained until 1941 when he moved to Headquarters. During three years' service at Prestwick between 1942 and 1945 he was mobilized into the Royal Air Force in the rank of Flying Officer. On demobilization in 1946 he was assimilated as an Experimental Officer and after a year's service at London (Heathrow) was transferred to the radio-sonde station at Fazakerley where he became officer-in-charge. He was responsible for the move of the unit to Aughton and remained there until he retired.

CORRIGENDUM

In the equation halfway down p. 323 of the November 1962 *Meteorological Magazine*, $R(t)1=-\frac{1}{2}$ . . . should read $R(t)=1-\frac{1}{2}$ . . .