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A DISCUSSION OF THE TEMPERATURES OF INLAND KENT WITH PARTICULAR REFERENCE TO NIGHT MINIMA IN THE LOWLANDS

By A. A. HARRISON

Summary. An examination was made of air minimum temperatures at 4 ft at 21 inland rural sites in Kent and east Sussex for the period March 1968–May 1969. Over the 137 nights selected for analysis, averages for stations on a valley floor but at various heights above MSL were almost identical. When the station averages were plotted against height above the valley floor (a.v.f.) adjacent to the station a linear relationship was obtained giving an increase of temperature with height (a.v.f.) of 1.5 degF/100 ft. For 28 chosen radiation nights the rate was about 2.8 degF/100 ft and for 4 extreme radiation nights it was about 3.6 degF/100 ft. Over short distances near steep slopes rates exceeding 9 degF/100 ft are known. Departures from expected temperatures occur because of the warming effects of increased turbulence over steep slopes, and there may be heat island effects, e.g. at Wye College.

For stations within 50 ft of the valley floor the frequency of frosts was twice that for stations exceeding 250 ft a.v.f. High diurnal ranges were found to be quite common.

Introduction. The purpose of this note is twofold. The original intention was to show that the low night minimum air temperatures frequently recorded at London/Gatwick Airport are not peculiar to the basin in which Gatwick lies, but that they are indicative of an extensive lake of cold air at night throughout the Low Weald of Kent bordered by the North Downs and the Ragstone Ridges in the north and the Forest Ridges in the south. (Frost and low night temperatures are particularly important in this fruit-growing area. Much of it is wholly devoted to horticulture as opposed to agriculture.)

However, during the course of the investigation a relationship between night minima and topography emerged and it is thought that this is the main outcome of the project.

The preliminary results were encouraging and it was decided to extend the survey outside the Low Weald and include all parts of rural Kent and some of east Sussex excluding only the coastal regions. The survey was confined to rural areas, as far as possible, since Chandler¹ in one of his reports on London's climate observed '... there is no simple, certainly no linear relationship between the extent of an urban area and the intensity of its heat island ... one can imagine a small settlement, probably no more than a hamlet, warmer by several degrees than its rural setting ...'.

Observers. The number and also the distribution of official stations regularly recording temperatures in this area is clearly inadequate for a close survey and it was necessary to augment the official network; suitable people in the area were therefore asked to co-operate. Advice was taken from the Regional Horticultural Advisers (of the National Agricultural Advisory Service), who know the farming community intimately, and people known to be reliable and keenly interested in such activities were approached. Another, most important, requirement was that they had to be available and willing to make observations day in and day out. Nine supplementary stations were set up.

The voluntary observers were visited fairly frequently in the early stages, not only to show continuing interest but also to make sure the instruments were in good condition and that the sites had not become overgrown. There were also a few emergency calls when 'bubbles' developed in thermometers.

Personal errors were very few in number and fairly easy to detect, taking the form of misreading by 5 or 10 degF — a mistake that even the trained observer occasionally makes.

Sites. All the stations, official and otherwise, are listed in Appendix I together with the names of the voluntary observers, and a code letter has been allocated to each station which gives its location in Figure 1. References to stations will be given by name followed by the code letter, e.g. Gatwick (C).

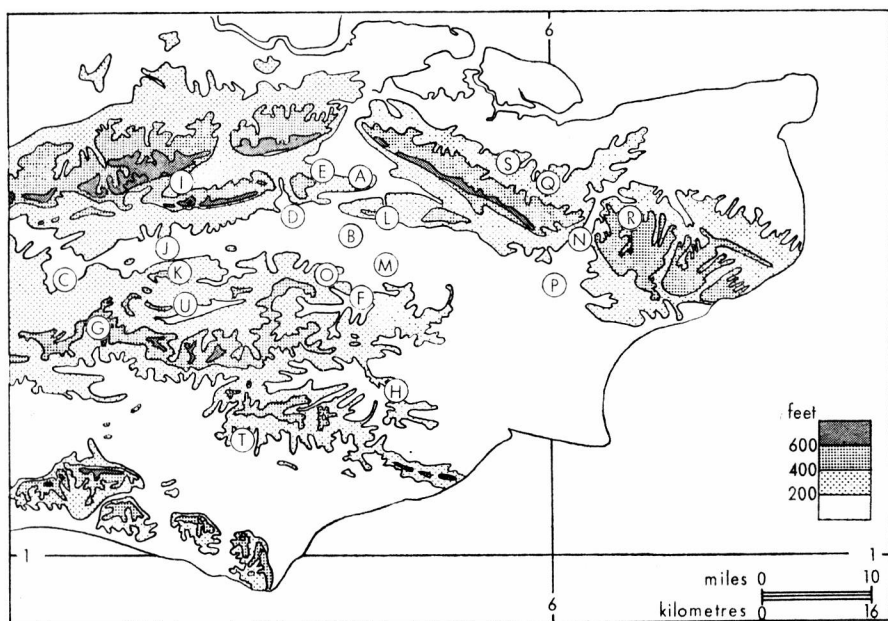


FIGURE 1—DISTRIBUTION OF 21 STATIONS

See Appendix I for identification of code letters.

Instruments and equipment. Most of the voluntary observers maintained their own weather records and had some sort of thermometer of their own but it was thought preferable that instruments be supplied by the Meteorological Office since this would help to standardize the readings and would also provide an opportunity to resite some of the thermometers.

Fahrenheit temperatures were used for the investigation because of the requirements of the horticultural community, and for convenience in relating results to previous work. Temperatures in Celsius at various official sites were converted to Fahrenheit to the nearest decimal place. The main results are given in degrees Celsius per 100 metres in the conclusions.

To avoid transporting bulky equipment it was decided to expose the thermometers in the shielded mounts which are commonly referred to as 'cocoa-tin screens' (described by Gloyne and Smith²), supported by simple stakes. This complicated matters somewhat since some thermometers were housed in 'cocoa-tins' and some (at the official stations) in thermometer screens, and a relationship had to be found between the two. Numerous papers were read on the subject but, with respect to their authors, none seemed wholly convincing. So at Collier Street (B), in the heart of the area, a small thermometer screen was installed by the side of the 'cocoa-tin' to establish this relationship. It was found that a similar pairing of 'cocoa-tin' and conventional screens existed at East Malling (A) so the semi-sum of the correction at these two stations each night was applied to the readings made at all the other unofficial stations on that night. This correction was never very great, usually being an addition to the 'cocoa-tin' temperature of between 1 and 2 degF. The average correction for all the nights considered was 1.1 degF.

All the thermometers were exposed at a height of 4 ft (1 ft = 0.3048 m) over grass, and the small screen at Collier Street (B) was also used to house a maximum thermometer.

Paper work was kept to a minimum. Each voluntary observer was provided with a set of stamped addressed post cards, the blank side of which was ruled-up and headed with the station name and the month so that all the observer had to do was to enter the temperature each morning and post the card at the end of the month. In addition, however, each station was provided with a small note-book suitably prepared so that the observers could keep records for their own use. This would have been invaluable had one of the cards been lost in the post.

A total of about 12 740 temperatures were obtained from 21 sites during a period of 15 months between the beginning of March 1968 and the end of May 1969.

Technique. The problem now arose as to which nights to select for analysis. It is felt that most papers dealing with night temperatures fall into one of two categories. Either they confine their discussion to calm clear nights with virtually uninhibited long-wave radiation or they accept all nights, disregarding whether they be cloudy, wet and windy, or still and starlit, and deal with average values, monthly or even annual. As katabatic drainage and the establishment of nocturnal temperature inversions, indeed the whole concept of valley temperature at night, depend on radiation from

the ground there must be, in an experiment of this nature, a bias towards the calm, clear radiation night; but (i) a period of only 15 months did not provide enough instances of 'radiation' nights, and (ii) there are many nights during which radiation plays an important part but its effect is reduced by other factors such as variable cloud and its counter-radiation, and also turbulence caused by wind.

To have included all nights would have masked to a very great extent the contrasts it was intended to highlight. Accordingly it was decided to steer a middle course and the nights were passed through the following sieves :

(i) *Daily Weather Reports** were examined and nights that were wet or predominantly cloudy were discarded. Furthermore the proximity of a frontal trough with its attendant complications of advection made the night unacceptable.

(ii) Wind tabulations from Gatwick (C) and anemograms from East Malling (A) were considered and only those nights with mean wind speeds of less than 10 kt ($1 \text{ kt} \approx 0.5 \text{ m/s}$) and no marked gustiness were used.

(iii) If long-wave radiation from the ground is the main cause of the fall of temperature throughout the night rather than advection of a different air mass, it seems likely that the lowest values of temperature will occur at the end of the night, or, better still, soon after dawn as the balance of incoming and outgoing radiation swings the other way; if the lowest temperature is reached early in the night some air-mass change at or above the surface has probably taken place. So thermograms from East Malling (A) were scrutinized and if the traces were irregular or showed that the minimum temperature had not been reached during the dawn period the night's observations were excluded from the experiment. It is suggested that this is a very good and speedy, though subjective, method of selecting nights on which radiation has been effective. This method of selection left 137 nights (more than 33 per cent of the total) for analysis from the 15-month period.

Analysis. Average values of minimum temperature on the selected nights were obtained for each station for :

- (i) The whole 15-month period.
- (ii) The combined springs (March, April and May) of 1968 and 1969.
- (iii) The spring of 1968.

While most months were covered only once, the important months from the fruit-growing point of view were covered twice. The results are given in Table I with the number of occasions taken shown in brackets.

It was hoped, at first, that it would suffice to draw isotherms based on these averages and that the isotherms would be sympathetic with the main height contours. They are to a certain extent, see Figure 2, but despite the scarpland topography and comparatively simple drainage of the area it was found that there were some stations which were not easy to fit, e.g. Brasted (I), Brenchley (O) and Linton (L), and there seemed a need for a less crude method of analysis.

* London, Meteorological Office. *Daily Weather Report*.

TABLE I—AVERAGE MINIMUM TEMPERATURES

	Cowden (K)	Linton (L)	Marden (M)	Wye (N)	Brenchley (O)	Kings- north (P)	Throwley (Q)	Anvil Green (R)	Doddington (S)	East Hoathly (T)	Hartfield (U)
		East Malling (A)	Collier Street (B)	Gatwick (C)	Hadlow (D)	West Malling (E)	Goudhurst (F)	Wakehurst (G)	Bodiam (H)	Brasted (I)	Marsh Green (J)
Whole period		38.5 (137)	36.5 (137)	36.8 (137)	37.4 (137)	39.5 (131)	37.8 (137)	40.6 (137)	37.9 (137)	—	36.9 (137)
Combined springs 1968/69		34.8 (68)	33.3 (68)	32.7 (68)	33.8 (68)	35.8 (62)	33.9 (68)	37.1 (68)	33.9 (68)	34.6 (68)	33.0 (68)
Spring 1968		35.5 (40)	33.9 (40)	33.5 (40)	34.4 (40)	36.6 (40)	34.4 (40)	37.5 (40)	34.8 (40)	35.9 (40)	33.5 (40)
Whole period		40.7 (118)	36.9 (135)	39.5 (136)	39.0 (137)	38.1 (137)	40.3 (137)	41.1 (137)	39.3 (128)	37.1 (137)	—
Combined springs 1968/69		36.7 (59)	33.2 (68)	35.9 (67)	35.7 (68)	34.5 (68)	36.8 (68)	37.7 (68)	35.9 (66)	32.9 (68)	—
Spring 1968		37.6 (40)	33.9 (40)	36.8 (40)	36.4 (40)	35.3 (40)	37.4 (40)	38.5 (40)	37.0 (40)	34.0 (40)	35.5 (38)

Note: (i) Observations from Brasted (I) were missed during August and September 1968 due to a defective thermometer.

(ii) Observations from Hartfield (U) were discontinued after spring of 1968.

(iii) Number of occasions taken shown in brackets.

A method which took into account the slope of ground was first considered but this approach was not pursued since most land profiles are curved and irregular and it was impossible to decide over what horizontal distance the change of height was to be taken; and also because Lawrence³ was unable '... to draw any firm conclusions concerning the relation between slope of ground and the rate of increase of temperature with height ...'.

As altitude is fundamental to the investigation the temperatures were plotted against height above mean sea level; see Figure 3.

Despite a correlation coefficient of 0.8 between height and temperature this graph reveals a scatter that is too great for the correlation to be meaningful, especially between 75 and 225 ft above MSL.

However, it was noticed that there was no great disparity between temperatures at Gatwick (C), Marsh Green (J), Marden (M) and Collier Street (B) which lie on the floor of the valley running east-west through the area. It was found that average temperatures at these stations were almost exactly the same despite the fact that their heights varied between nearly 200 ft and less than 50 ft above MSL; see Table II.

It seemed that this fact would provide a foundation from which to work. Temperatures were therefore plotted against height above the valley floor (a.v.f.), rather than above sea level to see if a more coherent pattern would result.

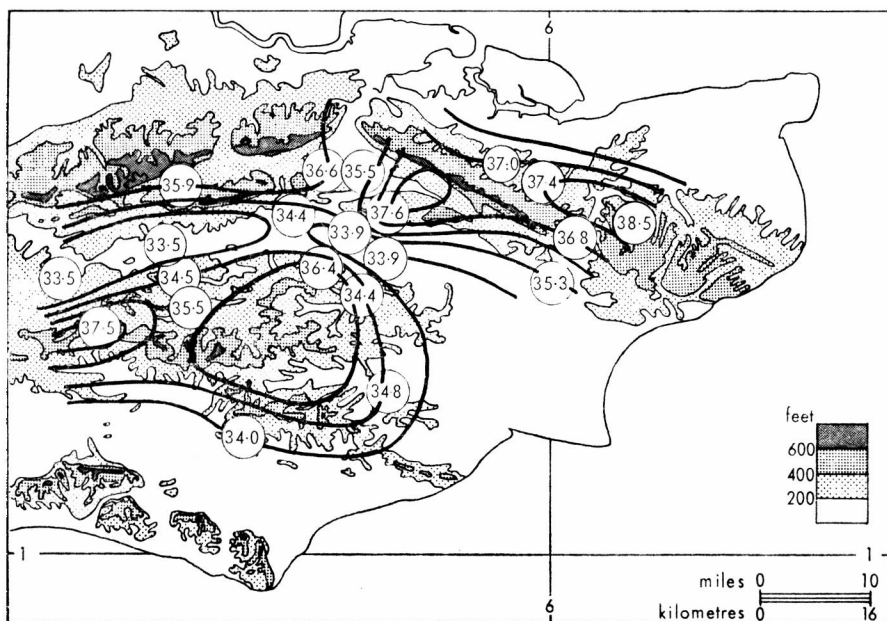


FIGURE 2—ISOPLETHS OF NIGHT MINIMUM TEMPERATURE IN SPRING OF 1968

— Isotherms at intervals of 1 degF (values at individual stations in °F).

This period was chosen because the greatest number of stations (21) was reporting and the greatest number (40) of nights of any season was used.

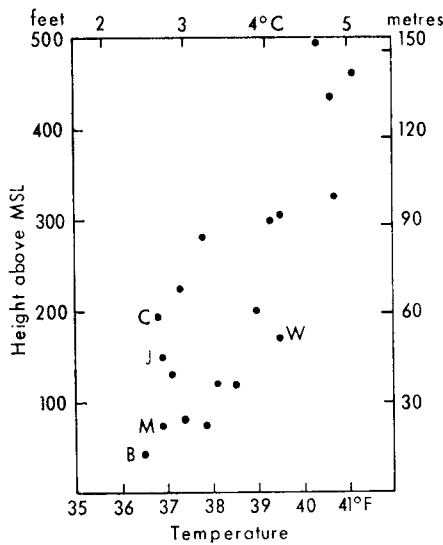


FIGURE 3—NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT ABOVE MSL
19 stations (omitting Hartfield and Brasted), 137 nights, 15-month period
C Gatwick, J Marsh Green, M Marden,
B Collier Street, W Wye (N in Figure 1)

TABLE II—AVERAGE MINIMUM TEMPERATURES AT VALLEY FLOOR STATIONS

	Gatwick (C) *194 ft	Marsh Green (J) 150 ft	Marden (M) 75 ft	Collier St (B) 45 ft
	<i>degrees Fahrenheit</i>			
Whole period				
March 1968–	36.8	36.9	36.9	36.5
May 1969 incl.				
Spring 1968	33.5	33.5	33.9	33.9
Spring 1969	31.6	32.1	32.2	32.5
Combined springs	32.7	33.0	33.2	33.3

* Heights above MSL; 100 ft = 30.48 m.

The height of each station a.v.f. was determined, e.g. the height of Linton (L) is 325 ft above MSL but the height of the valley adjacent to it is 50 ft above MSL; so its height a.v.f. is 275 ft. There are, however, some stations which do not drain (katabatically) directly into the broad valley running through the area and Goudhurst (F) in Bedgebury Forest is a noteworthy example of this. Inspection of a 2½-inch Ordnance Survey Map (1:25 000) showed that the katabatic drainage from this station was into a sizeable lake called the Great Lake. This reduced the effective height of Goudhurst from 280 ft to 110 ft. Each station was considered individually (using 2½-inch maps) and heights a.v.f. were determined. There is admittedly a subjective element in this procedure but three people were given this height determination as an exercise and it was found that they were all in reasonably close agreement. A list of the stations used showing their heights above sea level and their heights above the adjacent valley floor is given in Table III.

King⁴ has investigated two sites, S_1 and S_2 situated on the floor of the Chess Valley in the Chilterns, the notorious Rickmansworth frost hollow discussed

TABLE III—HEIGHTS OF STATIONS ABOVE MSL AND ABOVE VALLEY FLOOR

		Height above MSL	Height above valley floor
		<i>feet</i>	
East Malling	(A)	120	100
Collier Street	(B)	45	0
Gatwick	(C)	194	0
Hadlow	(D)	80	40
West Malling	(E)	304	234
Goudhurst	(F)	280	110
Wakehurst	(G)	437	260
Bodiam	(H)	73	53
Brasted	(I)	400	125
Marsh Green	(J)	150	0
Cowden	(K)	225	70
Linton	(L)	325	275
Marden	(M)	75	0
Wye	(N)	170	75
Brenchley	(O)	200	125
Kingsnorth	(P)	120	95
Throwley	(Q)	493	270
Anvil Green	(R)	460	290
Doddington	(S)	300	200
East Hoathly	(T)	130	30
Hartfield	(U)	253	85

100 ft = 30.48 m

by Hawke.⁵ King found that these two sites, only 1.2 miles apart and one 50 ft above the other, had significantly different night minima. This might appear to vitiate the line of approach used above; but between the two sites, S_1 and S_2 , there is (or was) a woodland, and cold air from the leaf canopy is likely to drain towards one site rather than the other. Oliver,⁶ looking at an abnormally cold spot (Grime's Graves in the Breckland of west Norfolk), has attributed the very low night temperatures there to cold air draining off a leaf canopy (which with its low thermal capacity would be a very effective heat exchange surface), and accumulating in the clearing in which Grime's Graves lies. Thus the woodland may well explain the differing night minima found by King at his two sites in the Chilterns.

Results. Figure 4(a) shows the average temperature of all the 137 selected nights during the whole 15-month period plotted against height a.v.f., and Figure 4(b) shows the average temperatures (using the same nights) of the valley floor stations plotted against height above MSL.

It is seen by inspection that temperature increases with height a.v.f. at the rate of about $1\frac{1}{2}$ degF per 100 ft and that there is a high degree of correlation. Using the method of least squares the regression equation is

$$T = 0.014 H + 36.6,$$

with a correlation coefficient of 0.9, where T = temperature (°F) and H = height (ft). Temperatures on the valley floor are almost identical despite differing heights above MSL; see Figure 4(b).

Similar scatter diagrams were constructed for spring 1968 and for the combined springs of 1968 and 1969; see Figures 5 and 6. The regression equation for Figure 6 (combined springs) is

$$T = 0.015 H + 32.9,$$

with a correlation coefficient of 0.96.

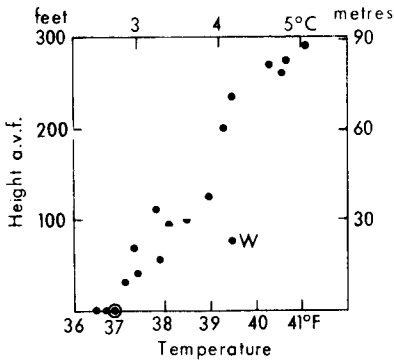


FIGURE 4(a)—NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT A.V.F., MARCH 1968–MAY 1969

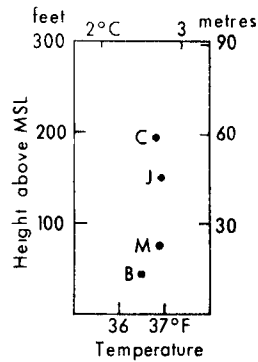


FIGURE 4(b)—VALLEY FLOOR NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT ABOVE MSL, MARCH 1968–MAY 1969

19 stations (omitting Hartfield and Brasted), 137 nights

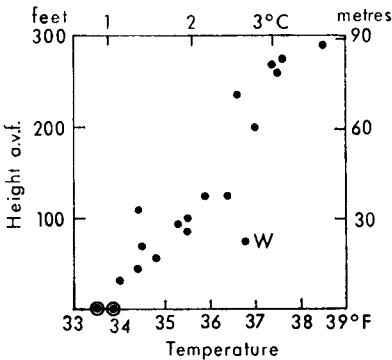


FIGURE 5(a)—NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT A.V.F., MARCH–MAY (SPRING) 1968

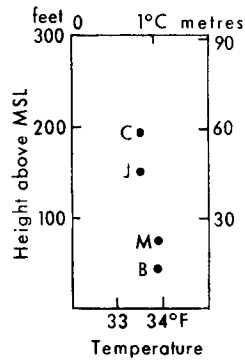


FIGURE 5(b)—VALLEY FLOOR NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT ABOVE MSL, MARCH–MAY (SPRING) 1968

21 stations

It has been well established by Geiger⁷ and others that, in general, the sides of valleys are warmer at night than both the valley floor and the plateaux on either side. These graphs (Figures 4(a), 5(a) and 6(a)) show an almost linear increase of temperature with height a.v.f., but there are no plateaux observations. During a previous investigation of the area⁸ between Linton (L) and a point near Goudhurst (F) an almost linear relationship was also found to extend from the bottom of the valley to 220 ft above MSL. But neither that investigation nor the present one have really covered the highest ground and the use of a network of stations which included stations on flat high-level ground might have indicated lower temperatures at higher levels in agreement with Geiger's findings, although 'plateaux' is scarcely an apt term to describe the hills of Kent.

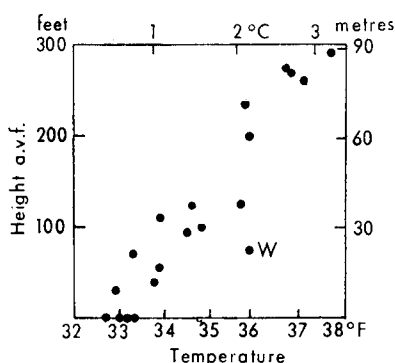


FIGURE 6(a)—NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT A.V.F., COMBINED SPRINGS 1968 AND 1969

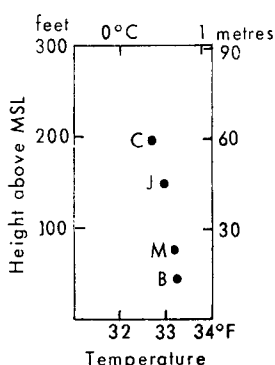


FIGURE 6(b)—VALLEY FLOOR NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT ABOVE MSL, COMBINED SPRINGS 1968 AND 1969

20 stations (omitting Hartfield)

Results for selected radiation nights. Figures 4, 5 and 6 deal with many nights on which outgoing radiation was considerably reduced and the overall range of temperature was only 4 to 5 degF between the valley floor and 290 ft above it. It was noticed when logging the data that there were a number of occasions when this range was much greater.

The 137 nights first selected for investigation were therefore reconsidered. The *Daily Weather Reports* for each occasion were examined to find nights during which the effect of radiation was predominant. (It was not found possible to work to any of the objective criteria normally used in papers on night cooling because of the paucity of cloud and wind observations and because a fairly large area was under consideration rather than one station.) Twenty-eight nights were adopted; they were mainly anticyclonic with generally light winds and little or no cloud; see Table IV.

For each station the average of the minimum temperatures on these 28 nights is plotted against height in Figure 7. Here, again, there is a good fit. The overall range of temperature is about 8 degF from the valley floor to 290 ft above it, i.e. the increase of temperature with height is about 2.8 degF per 100 ft. The regression equation is

$$T = 0.025H + 34.3$$

with a correlation coefficient of 0.9

The increase of minimum temperature with height a.v.f. is in close agreement with the average rate of 2.7 degF per 100 ft found in the mobile survey⁸ between Linton (L) and Goudhurst (F).

Extreme variation of temperature with height. Even the 28 nights already discussed covered quite a wide range and in an attempt to isolate an extreme variation of temperature with height the four nights with the greatest temperature/height response were considered; see Figure 8.

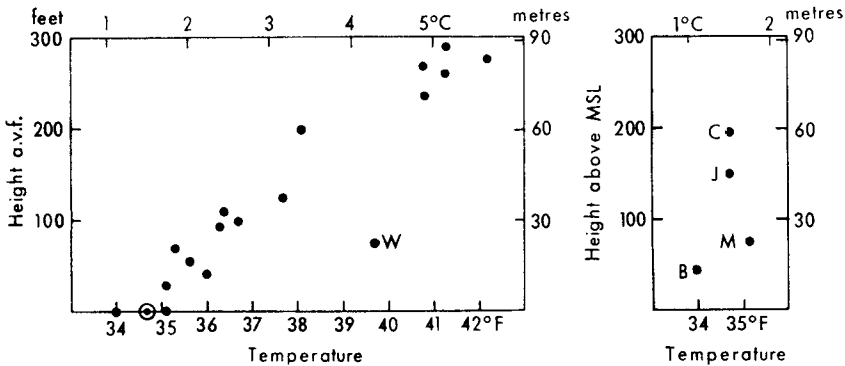


FIGURE 7(a)—NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT A.V.F. FOR NIGHTS WHEN RADIATION EFFECTS OUTWEIGHED OTHERS

FIGURE 7(b)—VALLEY FLOOR NIGHT MINIMUM TEMPERATURES PLOTTED AGAINST HEIGHT ABOVE MSL FOR NIGHTS WHEN RADIATION EFFECTS OUTWEIGHED OTHERS

28 selected radiation nights, 19 stations (omitting Hartfield and Brasted)

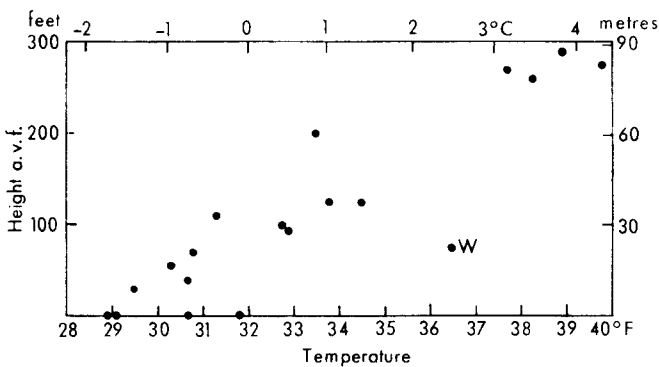


FIGURE 8—AVERAGES OF THE FOUR NIGHTS ON WHICH NIGHT MINIMUM TEMPERATURE INCREASE WITH HEIGHT WAS GREATEST
19 stations (omitting West Malling and Hartfield)

The variation over the 300-ft band was nearly 11 degF, i.e. 3.6 degF per 100 ft. It must be emphasized at this point, however, that this is an average rate over an area the size of a county. Each region must still be treated on its own merits and over short distances, especially near scarp slopes, rates exceeding 9 degF per 100 ft are not uncommon.⁸

It is interesting to note, perhaps paradoxically in this context, that in this set of figures there is a considerable variation of minima along the valley floor. In fact if Figures 4, 7 and 8 are compared it is seen that the variation of valley floor temperatures increases with the variation of temperature with height, albeit to a lesser extent. It is suggested, however, that a possible explanation of this is the spatial variation of the incidence of fog or of high water vapour content. This is far from being a dry valley, containing numerous water courses. Frequent observations across it have shown that there are

but few radiation nights on which at least patchy ground fog does not form. Even on occasions of no fog, if there are light winds and a stable stratification of the surface layers there must be a variation of water vapour content sufficient to cause unequal outgoing long-wave radiation. The stronger the outgoing radiation the more cellular the distribution of water vapour in the surface layers.

Frequency of frosts. While the depth of air frost, i.e. night minimum temperature, is important, perhaps, to a horticulturalist at least, the frequency of frosts is even more important. Figure 9 shows the percentage frequency of frosts among the 137 nights first selected for investigation. It is seen that the ratio of the number of frosts on or near the valley floor to the number of frosts at heights exceeding 250 ft above it is very nearly 2:1. It is interesting that this frequency is much the same within 50 ft of the bottom of the valley. Perhaps a constant cold pool concept is applicable here.

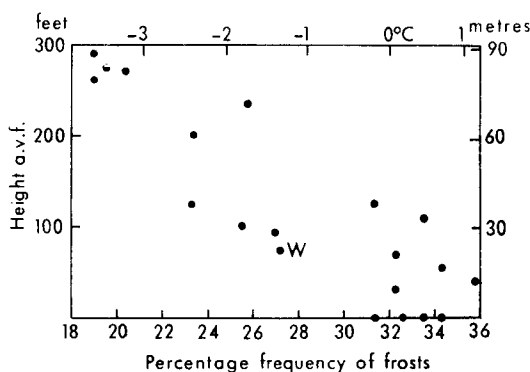


FIGURE 9—COMPARATIVE PERCENTAGE FREQUENCY OF FROSTS
20 stations (omitting Hartfield), 137 nights, 15-month period

Diurnal range of temperature. Until recent times the incidence of a diurnal range of temperature of 40 degF or more seems to have been regarded by climatologists as a rarity anywhere in the British Isles (Hawke⁵). At Greenwich there were no more than 10 examples of a diurnal range reaching or exceeding 40 degF during a period as long as 102 years. Indeed, during the early years of this century variations of a mere 35 degF or so between maximum and minimum temperatures were not infrequently considered worthy of comment in learned publications.

At Collier Street (B) during this short period of 15 months the diurnal range exceeded :

30 degF on 19 occasions,	35 degF on 5 occasions,
38 degF on 4 occasions and	40 degF once.

A range of 50.9 degF has been recorded⁵ at Rickmansworth and statistical considerations indicate a limiting value of 55 or 56 degF. Rickmansworth is, however, in a dry valley whereas the Low Weald of Kent has many rivers and streams which must have a mitigating effect, not only because of the absorption of outgoing long-wave radiation by water vapour but also because of the slight surface turbulence resulting from the temperature difference between

the water and the adjacent land. Although diurnal variations of temperature in Kent are therefore liable to be larger than might have been expected, it seems unlikely that values as high as those found at Rickmansworth would occur.

Notes on particular sites. While it is hoped that the method of analysis outlined above goes some way towards rationalizing the diversity of minimum temperatures in this area, it is obviously not the complete answer and many sites have still to be treated on their own merits.

It was mentioned earlier that the connection between slope of ground and variation of night temperature proved too difficult to handle on the broad scale but it clearly has a marked effect when certain sites are under consideration, since the katabatic winds induced by steep slopes must increase turbulence in the surface layers, effectively entrain warmer air from a level a little above the surface and consequently reduce the rate of cooling at screen level.

Linton (L) is situated on the scarp slope of the Ragstone Ridges and its night minima are high, even considering its height a.v.f., in consequence of the excellent run-off of cold air and the surface turbulence caused by the katabatic wind. Brenchley (O) is also relatively warm for the same reason.

There was one station which defied any form of analysis. This was Wye Agricultural College which makes, of course, most reliable observations. However, when the site was visited (to check, as a last resort, the night minima against the autographic records) it was discovered that not only was the college site contiguous with the township of Wye, but that the instrument enclosure was in close proximity to heated glass-houses some two acres in extent.

It is not surprising, therefore, that for its height a.v.f. it is 'too warm' by $1\frac{1}{2}$ degF on Figure 4 (137 nights) by $3\frac{1}{2}$ degF on Figure 7 (28 nights) and by $5\frac{1}{2}$ degF on Figure 8 (4 nights), i.e. relative warmth increased as the occasion tended to the perfect radiation night.

Conclusions.

(i) The low night minima frequently recorded at Gatwick are applicable to valley floor sites in Kent.

(ii) On average, during selected nights when the minimum temperature was reached during the dawn period, the increase of temperature with height a.v.f. is about 1.5 degF per 100 ft (2.7 degC per 100 metres).

(iii) On nights when the effect of radiation has been predominant this rate is about 3.5 degF per 100 ft (6.4 degC per 100 m) though on exceptional nights and over short distances the rate may be far greater, especially near scarp slopes.

(iv) For stations within 50 ft of the valley floor the frequency of frosts is twice that for stations exceeding 250 ft a.v.f.

(v) High diurnal ranges are found to be quite common.

Acknowledgements. Appreciation must be expressed to the voluntary observers for their support and perseverance; without them the project

would not have been possible. It was suggested that their enthusiasm would wane before sufficient observations had been collected but this was far from the case; only one observer dropped out and a replacement was found immediately. It is most gratifying to record that although the observers were asked to make these observations for 15 months in the first instance, most of them have elected to continue so that ultimately a far more comprehensive study can be made.

In addition, the author wishes to thank Mr G. F. Trowell for making records readily available at East Malling, Mr G. H. Parker for checking the original manuscript, Mr R. J. Ogden for helping prepare the final draft and especially Miss A. M. Davis, who gave invaluable assistance at all stages of the work.

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Appendix I

Supplementary stations

B	Collier Street	Mr A. Todd, Jarmon's Farm, Collier Street, Kent.
I	Brasted	Mr R. S. Steven, Court Lodge Farm, Westerham, Kent.
J	Marsh Green	Mr F. W. Gilbert, Magpie Cottage and Mr Bufford, Cornwallis Gardens, Marsh Green, Edenbridge, Kent.
K	Cowden	Mr L. M. Adam, Uphill Fruit Farm, Cowden, Edenbridge, Kent.
L	Linton	Mr G. C. Smith, Loddington Farm, Linton, Maidstone, Kent.
M	Marden	Mr S. Tomsett, Springfield, Marden, Kent.
O	Brenchley	Mr P. J. Gibbons, Bell Cottage, Hatmill Lane, Brenchley, Kent.
P	Kingsnorth	Mr W. J. Chantler, Court Lodge Farm, Kingsnorth, Nr Ashford, Kent.
U	Hartfield	Mr K. W. Paul, Chiswell House, Hartwell Farm, Hartfield, Kent.

Official stations

	Type
A East Malling	Agrometeorological
C London/Gatwick Airport	Synoptic
D Hadlow	Agrometeorological
E West Malling	Synoptic
F Goudhurst	Agrometeorological
G Wakehurst	Climatological
H Bodiam	Climatological
N Wye College	Agrometeorological
Q Throwley	Agrometeorological
R Anvil Green	Auxiliary
S Doddington	Auxiliary
T East Hoathly	Auxiliary

WATERSPOUTS OFF CYPRUS, 14 JANUARY 1970

By W. D. HYDE

Summary. A storm which generated a family of waterspouts is examined for distinctive features. A comparison is made with an earlier case when damaging tornadoes resulted from waterspout activity.

Introduction. Waterspouts occasionally occur in the Mediterranean in almost any season except summer. Until recently they were regarded by meteorologists as interesting but hardly dangerous phenomena. Hardy¹ described the destruction in the south of Cyprus on 22 December 1969 when waterspouts failed to decay on crossing the coastline. That occasion emphasized the need to study situations in which waterspouts are generated and maintained by self-perpetuating storms. An opportunity to do this occurred on 14 January 1970; the outcome of the storm on that day was not nearly as spectacular as on 22 December but a comparison of the two occasions contributes towards a solution of the forecasting problem.

Synoptic situation. The surface and 300-mb charts for 00 and 12 GMT on 14 January 1970 are shown in Figures 1-4. Surface lows centred in the

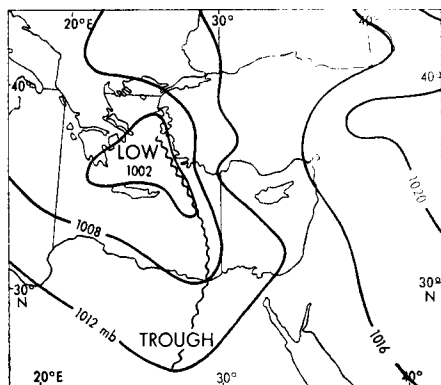


FIGURE 1—SURFACE ANALYSIS,
00 GMT ON 14 JANUARY 1970

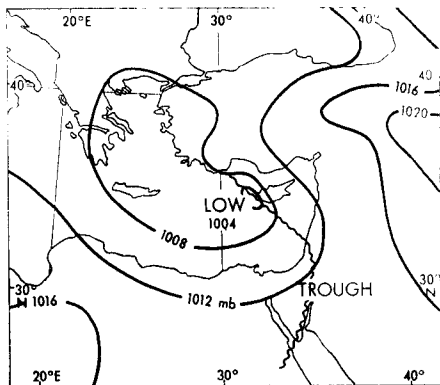


FIGURE 2—SURFACE ANALYSIS,
12 GMT ON 14 JANUARY 1970

Ionian Sea area at 12 GMT on 13 January transferred to the Aegean Sea and subsequently to the west coast of Cyprus, as the rather short upper jet stream propagated east-south-east near the north coast of Africa. By 00 GMT on the 14th (Figure 3) a defined upper vortex at 300 mb near western Crete had separated from the sharp upper trough to the north-west. Atmospheric sources (SFLOCs) were reported near the surface trough over the sea during the 13th and the possibility of a 'severe storm'² situation developing in the Cyprus area was considered. The 00 GMT sounding from Episkopi on the 14th (Figure 5) revealed an inversion at 900 mb surmounted by fairly dry mid-level air and a moderate wind shear through the troposphere. The ESSA 8 satellite picture is given at Plate V. This shows a clearly defined rear edge to cloud associated with the surface trough at about 34°N 30°E (i.e. south-west of Cyprus).

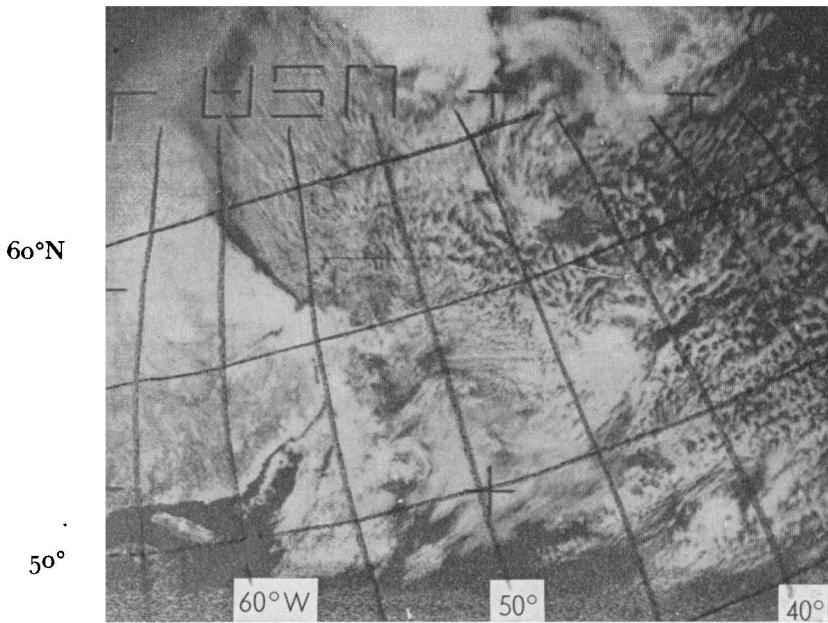


PLATE I—SATELLITE PHOTOGRAPH FROM ESSA 8 AT 1336 GMT ON 20 MARCH 1970
See page 118.

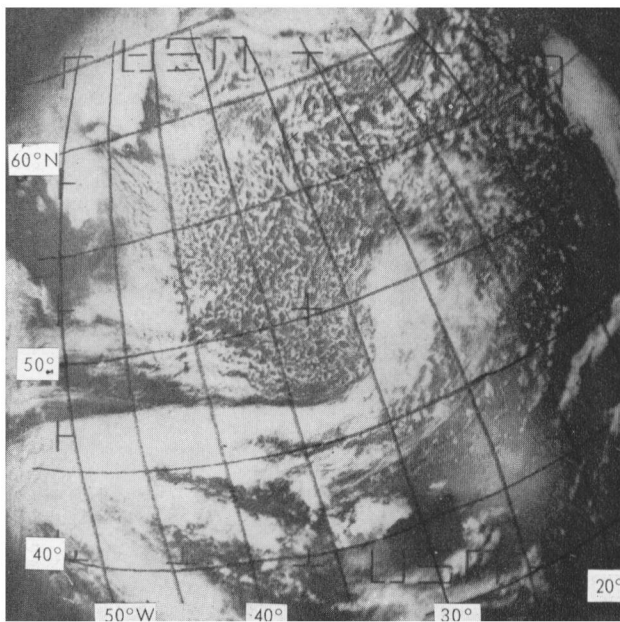


PLATE II—SATELLITE PHOTOGRAPH FROM ESSA 8 AT 1232 GMT ON 21 MARCH 1970
See page 118.

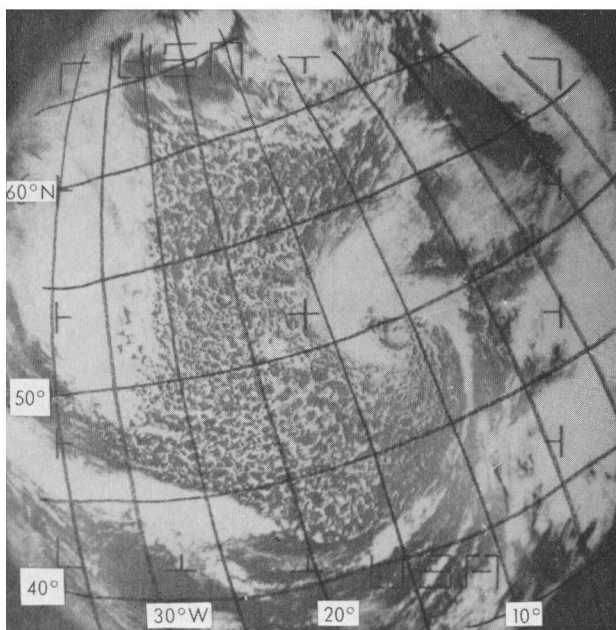


PLATE III—SATELLITE PHOTOGRAPH FROM ESSA 8 AT 1128 GMT ON 22 MARCH 1970
See page 118.

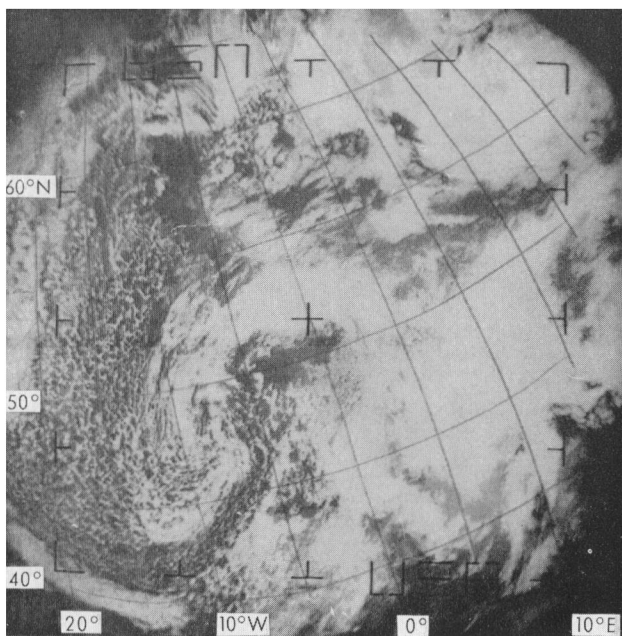


PLATE IV—SATELLITE PHOTOGRAPH FROM ESSA 8 AT 1025 GMT ON 23 MARCH 1970
See page 118.

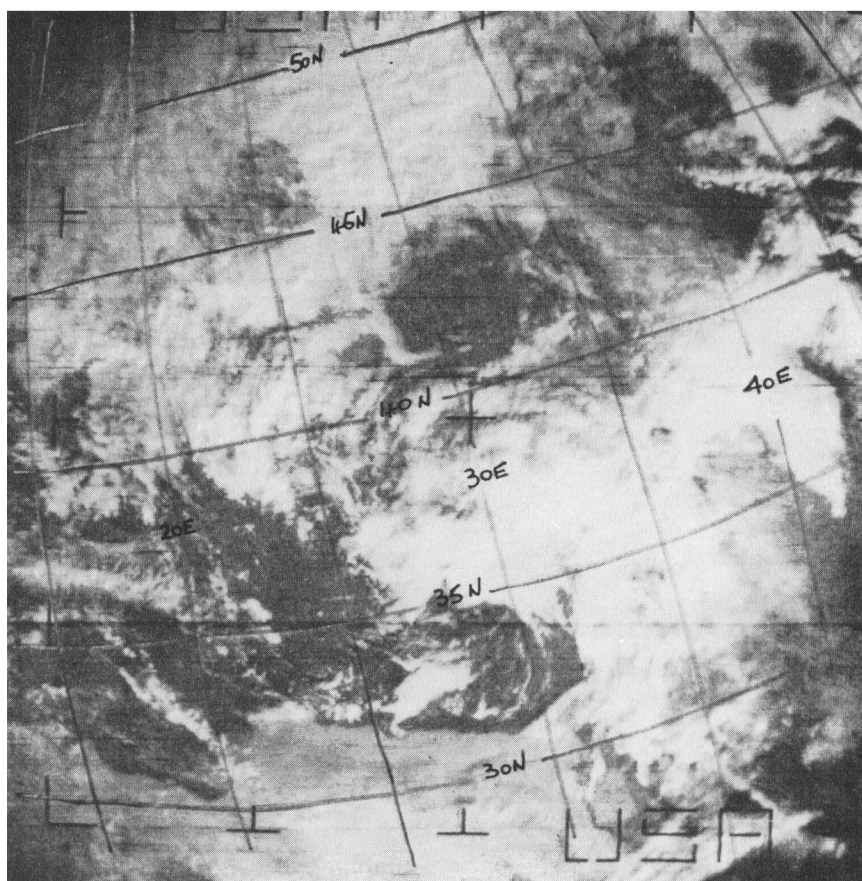
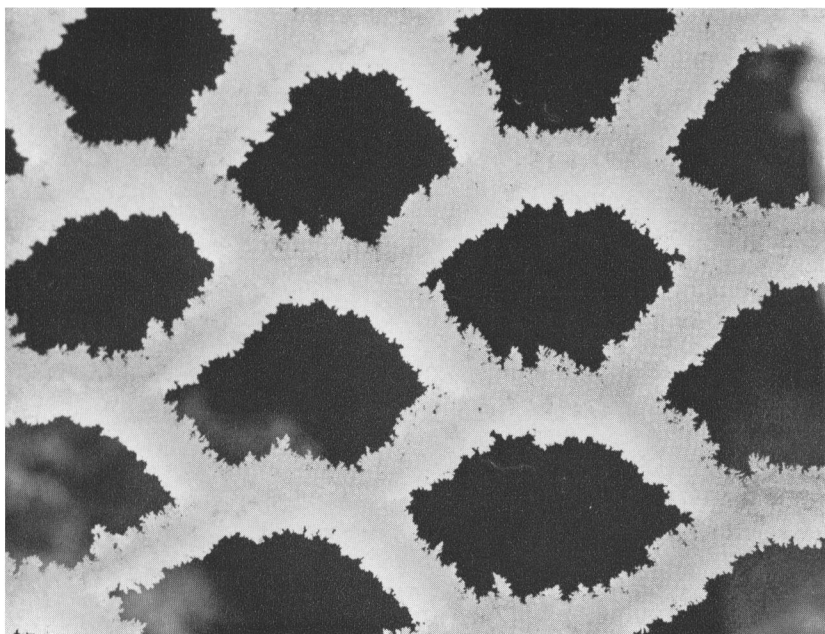


PLATE V—SATELLITE PHOTOGRAPH FROM ESSA 8 AT 0757 GMT ON 14 JANUARY 1970

A clearly defined rear edge to cloud associated with the surface trough can be seen at about $34^{\circ}\text{N } 30^{\circ}\text{E}$ (see page 112).

To face page 113



Photograph by R. K. Pilsbury

PLATE VI—RIME ON WIRE-NETTING AT BRACKNELL ON 5 JANUARY 1971

The wire-netting has a 2-inch mesh.

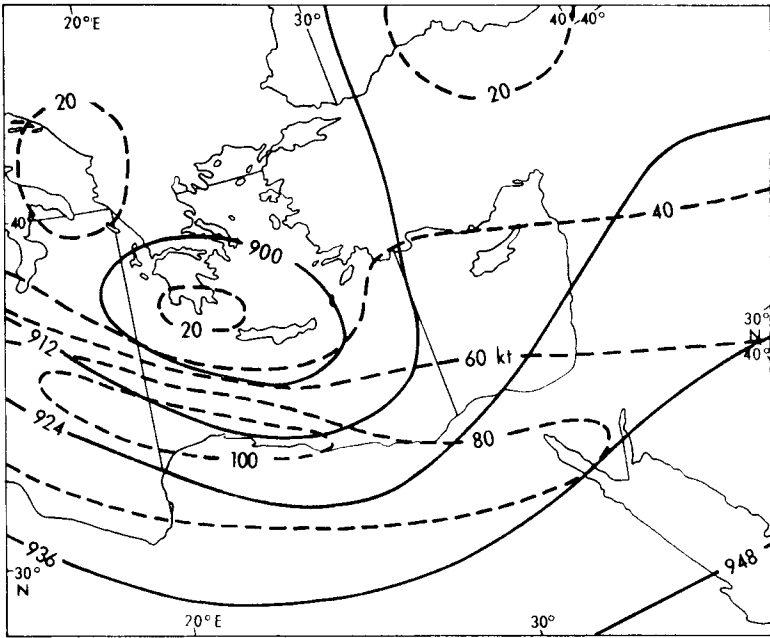


FIGURE 3—CONTOURS AND ISOTACHS AT 300 mb, 00 GMT ON 14 JANUARY 1970
—— Contours at intervals of 12 geopotential decametres
--- Isotachs at intervals of 20 kt

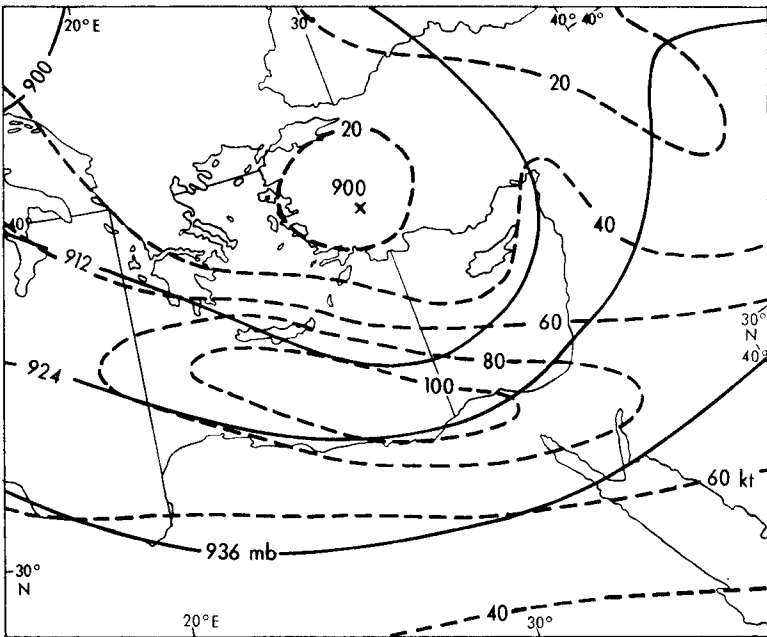


FIGURE 4—CONTOURS AND ISOTACHS AT 300 mb, 12 GMT ON 14 JANUARY 1970
—— Contours at intervals of 12 geopotential decametres
--- Isotachs at intervals of 20 kt

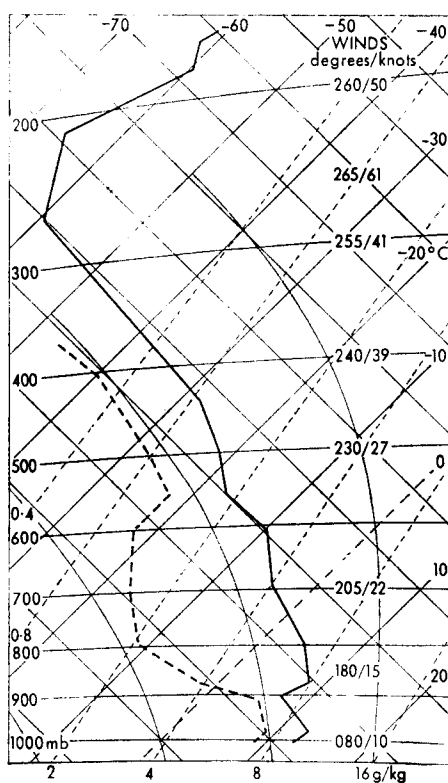


FIGURE 5—EPISKOPI UPPER AIR ASCENT, 00 GMT ON 14 JANUARY 1970

—— Temperature - - - Dew-point

Waterspout detection. Early on the morning of 14 January the crew of the routine flight to El Adem was briefed and attention drawn to the need for information over the sea. The subsequent reports for 0820 and 0830 GMT indicated a very active 'front' with severe turbulence and a wind of 210° 45 knots at 14 000 feet.* The position of the aircraft is shown in Figure 6. The aircraft traversed the trough between cumulonimbus cells; no hail was encountered and no waterspouts were seen. As soon as the report was received at Akrotiri, arrangements were made to monitor developments by radar. The intensity and growth of the radar echoes were judged to be sufficient to merit air reconnaissance. The track of the aircraft is shown in Figure 6. The pilot was directed to descend to low level at the rear edge of the radar echo. Almost immediately he started to report waterspouts at intervals of about $1\frac{1}{2}$ nautical miles. There were about 12 spouts in various stages of development and decay; at least 4 were large and well developed (about 15 yards in diameter at the base). The aircraft then climbed through the cloud, emerging at 34 000 ft. It was turbulent from 10 000 to 25 000 ft, but hail was not encountered. A waterspout was also seen from

* Wind speed, heights and distances are given in traditional British units. Conversion factors are : 1 kt \approx 0.5 m/s; 1000 ft \approx 305 m; 1 n. mile \approx 1.85 km; 10 yd \approx 9.1 m.

Episkopi at 1225 GMT. Nothing was seen from Akrotiri apart from appendages from the main belt of cloud, which may have been the remains of decaying vortices.

Cyprus weather. There were thunderstorms with abundant small hail; the evening road report from Troodos (about 5000 ft above MSL) indicated hail two inches deep. The main storm damage occurred on the west side of Famagusta, where a citrus-packing house collapsed, a laundry was severely damaged and cars were overturned. Eye witnesses described a swath of minor damage in the same area. This may well have been caused by a small tornado, though a line-squall cannot be entirely discounted. There were no reports of waterspouts off Famagusta.

Radar data. The outlines of echoes received by an airborne radar at 40 000 ft are shown in Figure 6 and these data provide the most westerly

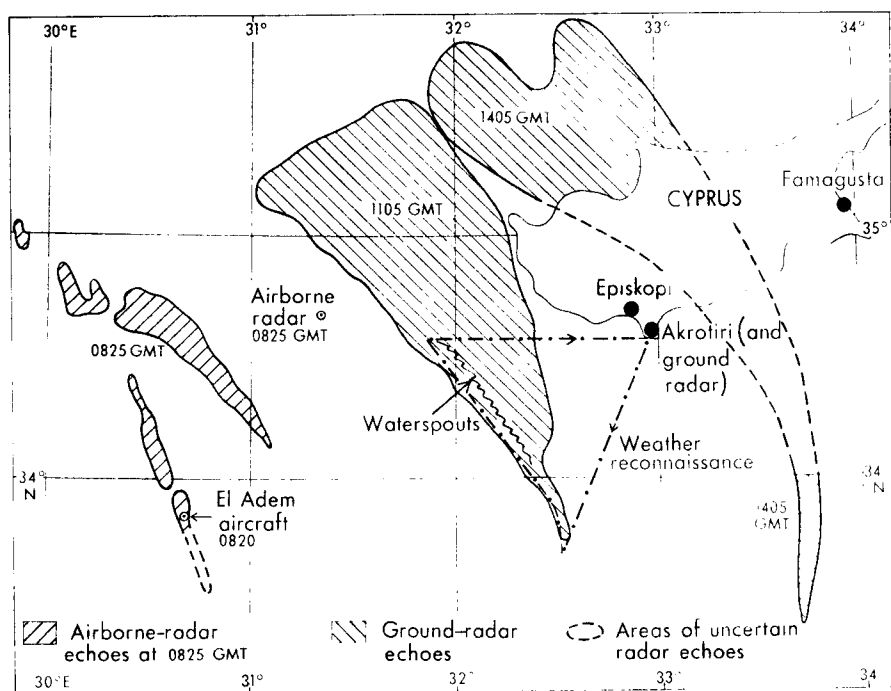


FIGURE 6—RADAR ECHOES ON 14 JANUARY 1970

delineation of the storm. A notable feature is the double line of echoes about 20 nautical miles apart (the radar operators recall a similar structure in the December storm). The El Adem aircraft crossed the rear line, which subsequently degenerated into star-shaped echoes and decayed altogether some two hours later. Meanwhile, the storm to the north was developing and moving towards Cyprus. The other two 'fixes' in Figure 6 are derived from ground-radar photography. They are not strictly comparable with the airborne-radar data but this factor is not important in the overall study. There is some uncertainty about the echo position over Cyprus but the

northern and southern extremities are quite distinct. During the air reconnaissance a careful watch was maintained on the ground-radar display for features which might help to identify waterspouts, but there were none. The intensity of the intervening precipitation and the large vertical beam width of the radar negated any chance of success.

Discussion. The movement of the radar echoes in relation to the upper winds is shown on the hodograph (Figure 7). It is clear that the storm travelled towards a direction to the right of and more slowly than the mid-level winds, thus falling into the 'Severe Right' (SR) storm category proposed by Browning.² The life of the waterspouts spawned near the rear of the storm is uncertain but the interval between the air reconnaissance and the Episkopi sighting was 1 hour 20 minutes. Comparison of data for 22 December¹ and 14 January reveals many similarities. Those occurring on the synoptic scale assist in the identification of a potential severe-storm situation, which forms a part of normal forecasting practice. On the mesoscale the forecaster is faced with assessing the severity of particular storm systems; or he may be asked to provide guidance on whether or not tornadoes are likely in Cyprus. Table I compares selected features of the December and January storms.

TABLE I—COMPARISON OF METEOROLOGICAL FEATURES ON TWO OCCASIONS OF WATERSPOUTS AT CYPRUS

Meteorological features	22 December 1969	14 January 1970
Cloud tops (by aircraft)	37 000–38 000 ft (very turbulent at 41 000 ft)	35 000–40 000 ft
Maximum number of waterspouts observed in a family at one time	7	12
Waterspout diameter at surface	50 m	15 m
Shear vectors at 12 GMT (deg/kt)		
Surface–850 mb	185/11	190/28
850–700 mb	220/28	230/27
700–500 mb	245/25	315/27
500–300 mb	230/46	325/18
Hail size	Large (1–2 cm)	Small
Inversion at 00 GMT	3 degC at 800 mb	1 degC at 900 mb
700-mb dew-point depression at 00 GMT	10 degC	13 degC

Despite the importance of initial low-level stability and the appropriate vertical distribution of moisture content, the 12-hourly sampling by radiosonde is hardly sufficient to ensure enough detail in the Cyprus area. As far as forecasting waterspouts is concerned, it may be sufficient to assume that stability and moisture content are features inherent in the synoptic situation common to both cases. Hail size may well be a relevant factor in assessing the severity of a storm system since it depends to some extent upon the intensity of convection; the difference between the two storms was very marked in this respect, though the comparison is difficult because the occurrence of large hail may be limited to a small area and go unnoticed. Probably the most important difference to emerge from the comparison concerns the shear in the 500–300-mb layer; note, on Figure 7, the increase above 500 mb on 22 December and the decrease on 14 January. A large shear value in the upper part of the storm favours high-level divergence, which in turn bears on the activity and life of the system. This feature is relatively easy to forecast and is of added significance for this reason.

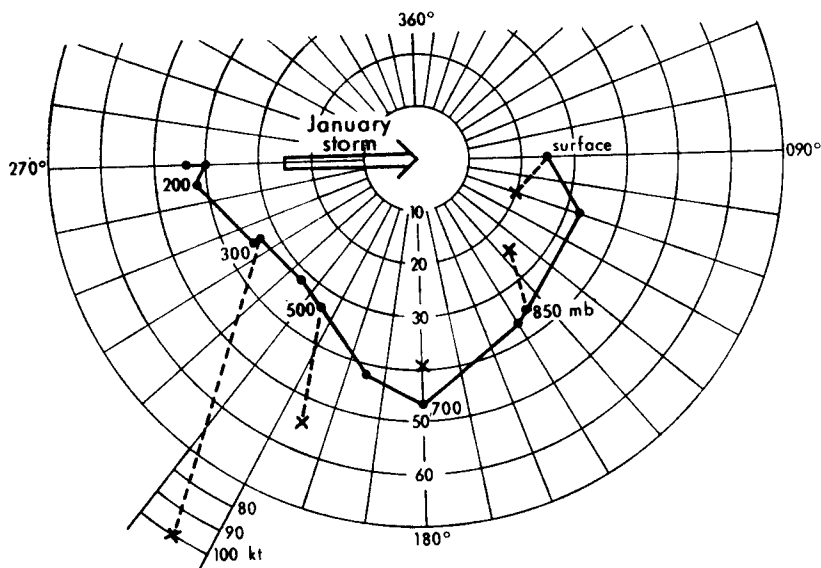


FIGURE 7—EPISKOPI WINDS AT 1119 GMT ON 14 JANUARY 1970 COMPARED WITH THOSE ON 22 DECEMBER 1969

— Winds on 14 January 1970 x Winds at 12 GMT on 22 December 1969
 - - - Vector difference between 22 December and 14 January

Conclusions. The SR storm on 14 January 1970 spawned a family of waterspouts which were hardly comparable in size with those associated with the December 1969 storm. The features which were especially important in assessing the severity of the storm system were the shear in the 500–300-mb layer and the hail size. In the Cyprus area the best chance of achieving warning of exceptionally large waterspouts, with the possibility of tornadoes, is to use radar for severe-storm diagnosis and tracking, combined with air reconnaissance and a special coastal watch; the forecaster plays an important part in co-ordinating these activities.

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551.507.362.2:551.511.32:551.576.2

DEVELOPMENT OF COLD AIR VORTICITY MAXIMUM AS SEEN BY SATELLITE

By B. K. LLOYD

Areas of cyclonic vorticity are often visible on the satellite pictures, frequently behind cold fronts. They are easily recognizable in the early stage of development as lines of cumulus curving towards a common centre. With advection of the vorticity centre considerable upward motion takes place in the atmosphere, and middle- and high-level clouds are produced ahead of the

centre and form the characteristic 'comma' shape. Some centres develop entirely within the cold air and form a separate cloud system behind a major frontal band while others form along the frontal band itself.

On Friday, 20 March 1970 a complex area of low pressure existed in the northern Atlantic with a broad upper trough at about 45°W . The afternoon picture (Plate I) of the western Atlantic revealed cold-air instability with an area of enhanced cloudiness at 52°N 44°W . This was favourably situated for cyclonic development forward of the diffluent trough (Figure 1). In the

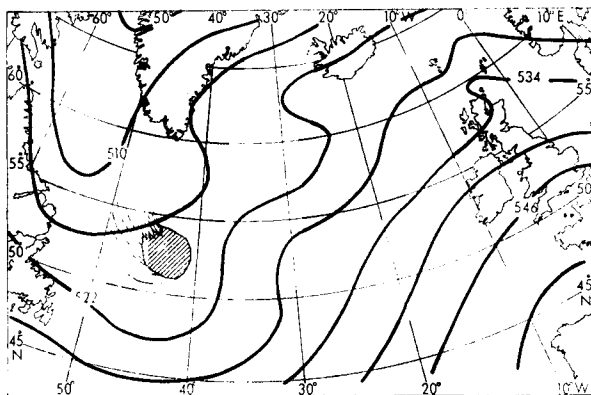


FIGURE 1—THICKNESS CHART FOR 1000–500 mb AT 12 GMT ON 20 MARCH 1970 WITH DIAGRAMMATIC REPRESENTATION OF CLOUD DEVELOPMENT SHOWN ON PLATE I

—— Thickness contours at intervals of 6 geopotential decametres

satellite picture (Plate I) the southern tip of Greenland, the ice off the coast of Labrador, and Newfoundland can be seen.

By Saturday considerable development had taken place and the midday picture (Plate II) showed the cloud mass more organized and 'comma shaped'. The cold air made visible by the convective cells was beginning to be drawn into the circulation. The upper trough had moved eastwards to 27°W and further deepening was likely (Figure 2).

The midday picture (Plate III) on Sunday showed the cold air well entrained into the 'comma' with a clear slot located to the north of the centre indicating no further development (Figure 3). The upper trough was sharpening and there were indications that it would become disrupted.

By midday on Monday the trough was cut off leaving a cold pool to the south-west of the British Isles. The morning picture (Plate IV) still showed the 'comma shape' but the cloud bands had become fragmented with cloud-free areas appearing between the bands. This cloud pattern was associated with a cold pool and a well-developed, but dissipating, surface low. The frontal band had separated from the vortex centre and can be seen lying across Wales and central and eastern England. Northern England, Scotland, Northern Ireland and south-west England were partly cloudy and the English Channel was free of cloud.

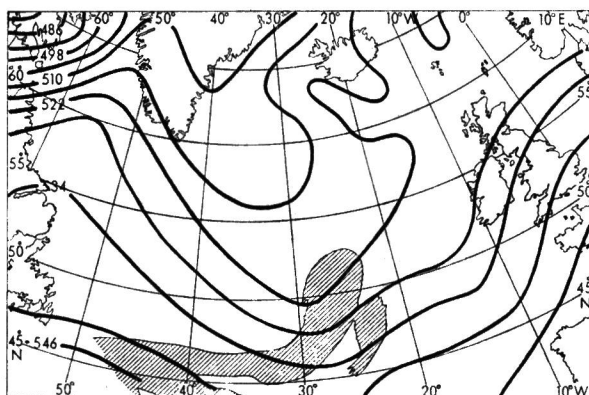


FIGURE 2—THICKNESS CHART FOR 1000–500 mb AT 12 GMT ON 21 MARCH 1970 WITH DIAGRAMMATIC REPRESENTATION OF CLOUD DEVELOPMENT SHOWN ON PLATE II

—— Thickness contours at intervals of 6 geopotential decametres

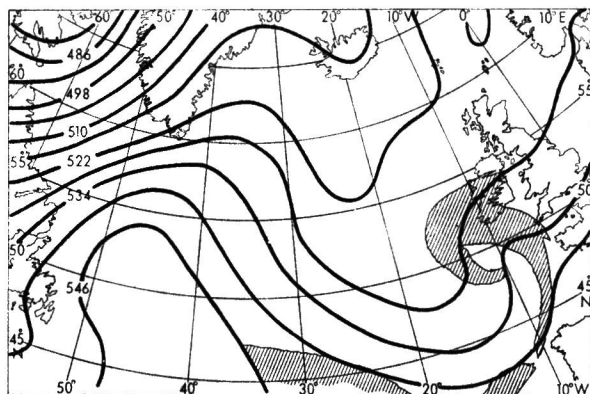


FIGURE 3—THICKNESS CHART FOR 1000–500 mb AT 12 GMT ON 22 MARCH 1970 WITH DIAGRAMMATIC REPRESENTATION OF CLOUD DEVELOPMENT SHOWN ON PLATE III

—— Thickness contours at intervals of 6 geopotential decametres

In conclusion this was an example of the vorticity developing entirely in the cold air and careful examination of the satellite pictures revealed this area of cyclonic vorticity at least 18 hours before it was evident from the surface observations.

REVIEWS

Voeikov Main Geophysical Observatory 1917-1967, M. I. Budyko, Editor. 245 mm × 170 mm, pp. iv + 362, *illus.* (translated from the Russian by Israel Program for Scientific Translations, Jerusalem). Ann Arbor-Humphreys Science Publishers Ltd, 5 Great Russell Street, London, WC1. 1970. Price: £6.30.

The purpose of this volume is to give an account of the scientific work carried out at the Voeikov Main Geophysical Observatory at Leningrad during the fifty years from 1917 to 1967 and the method chosen was the writing, by present staff members, of nearly thirty short papers reviewing the historical development of different aspects of the meteorological research, with very extensive bibliographies. There is also reference to work carried out in the period before that under review, dating back to the foundation of the Observatory in 1849, and since for much of this time the meteorological services were also centred on Leningrad the book effectively gives a survey of the development of meteorology in Russia — a somewhat one-sided survey since the emphasis is naturally on the achievements of the Leningrad group. These have ranged over much of meteorology, being perhaps specially notable in studies of climatology, the energy balance and dynamical meteorology, and many of the foremost figures of pre-war meteorology, such as Mulchanov, Multanovski, Friedmann, Sasinov, appear as contributors to the forward advance as do their equally illustrious successors. The work of the Voeikov Main Geophysical Observatory has commanded great respect in the past, does so even more today and clearly has a bright future to be described in 2017 AD.

E. KNIGHTING

Instant weather forecasting, by Alan Watts. 220 mm × 143 mm, pp. 64, *illus.*, Rupert Hart-Davis Educational Publications, 3 Upper James Street, Golden Square, London W1, 1970. Price: 90p.

This book is not intended for the professional forecaster, but is a sort of do-it-yourself handbook for those engaged in weather-sensitive activities, to help them decide, for example, whether the next few hours will be wet or dry, or windy.

It begins with some very basic ideas: the frontal depression, air masses, and a glossary. There are some brief cloud descriptions and the Beaufort scale. The remainder of the book, about three-quarters, consists of a series of double-page presentations, showing a cloud photograph on one side with an inference and forecast on the other. The user selects the picture most closely resembling the sky he can see, checks from a number of clues (for example wind direction and the relative motions of lower and upper clouds) that he has made the right selection, and then reads the likely developments, given under the headings: wind, visibility, precipitation, cloud, temperature and pressure. It is an attractive little book, substantial enough to be taken and used where it is wanted — in the open air or even at sea.

To the critical reader Mr Watts is disarming. In an introduction he says 'when the sky has a certain look about it then very often a certain sequence of weather follows. There is nothing *certain* about it however.' Nevertheless he suggests that despite the limitations of having to select from only 24 pictures there will be perhaps 75 per cent of occasions when the forecasts will be largely correct. And, of course, one's score might be expected to improve with experience. Mr Watts, who is a former professional forecaster but now a lecturer in physics, does not pretend that there is any quick and easy way to becoming a forecaster, but implies that by building on the experience in the book the layman can do as well as the shepherd of folklore. (Those of us who are professional forecasters might benefit too from lifting our eyes occasionally to study the real sky outside the window!)

There are difficulties in interpretation of some of the cloud photographs, stemming from the omission to state the time of day and direction of the camera. For example, opposite page 40 is a picture of distant cumulonimbus with associated ragged clouds. One might fairly infer that the sky above and behind the observer is as clear as the top part of the picture. Thus the scene becomes an evening sky, with activity confined to the sea in the distance. But the forecast is heavy showers within half an hour or so. On the other hand most of the photographs illustrate very well what the author has in mind, and one should remember that the book is undoubtedly for the reader prepared to persevere. There is an interesting optical illusion opposite page 24; at close quarters it seems to show clearing stratus under a blue sky, yet the description gives a totally overcast, lowering sky, with ragged cloud beneath, and when one stands back to look this is what appears. Indeed all the pictures take on a more realistic perspective when studied from a few feet away.

There are some oddities: cool but fair with good visibility is not an adequate description of returning polar maritime air, and it is puzzling to be told (page 16) that vigorous depressions form some hundreds of miles on the equatorial side of jet streams. There are other examples, important to the meteorologist, but minor in this context. There is a misprint on page 10, Sb for St.

The more this book is studied the more it grows on one. It seems to be an admirable attempt to provide the sportsman and the outside worker with a basis on which to develop a 'weather eye.'

D. J. CLARK

Look and forecast chart, by Alan Watts. 1 m × 0.7 m, wall chart in colour, Rupert Hart-Davis Educational Publications, 3 Upper James Street, Golden Square, London W1, 1970. Price: 70p.

This wall chart is derived from *Instant weather forecasting* by Alan Watts. It shows 12 coloured photographs of clouds, a weather map of a frontal depression indicating the relative position of each photograph, and a set of rules for forecasting.

The first four photographs illustrate the changing sky at the approach of a frontal depression. Next come the passage of the warm front, the warm sector and the cold front, shower clouds in polar air, evening anticyclonic conditions and, finally, three photographs of cumulus or thunder clouds.

The initial series of photographs is well chosen, but some implications of the text may easily mislead the inexperienced, for whom, presumably, the chart was designed. It states that low-pressure systems move at about 30 mph; by noting the relative position of the representative cloud picture, and using the printed scale on the weather map, the timing of the passage of the warm front may be forecast. One doesn't need to be a forecaster to see the dangers of over-simplification of the speed aspect. Again, the would-be forecaster is advised to look in the direction from which the wind is blowing for the break at the warm front. Experience suggests that the break, if it appears, is just as likely to come from his right, or even over his right shoulder because of the backing of wind ahead of the front. Incidentally, the photograph showing the approach of the break is indicated as being behind the warm front.

The photograph indicated as being appropriate to conditions just ahead of the cold front is of distant cumulonimbus clouds and includes in the caption the words 'Often hot and airless before storms'. In Watts's book the same photograph is described as being in polar air, and he is quite explicit that conditions are relatively cool and not sultry. Another cumulus picture is indicated as appropriate to the axis of the pre-frontal ridge, whereas a position on the forward side would fit in better both with the cloud and the description 'cool for the time of year'.

Forecasting can be improved, the text goes on to say, if the observer stands with his back to the wind and notes the relative motion of the upper clouds; and nobody would quarrel with that. But the direction of the wind is to be determined from 'low cloud movement, smoke, flags, or a wind vane'. It would be better to concentrate on low cloud, and in its absence to use Watts's rule of thumb of an average backing of 10° or 30° (for sea or land as appropriate) between the wind at low-cloud level (which is the wind required) and the wind at the surface.

The poster is attractive and the layout is very suitable for display in the club house or school, but it is marred by the sort of error indicated.

A more careful distillation of Watts's little book would be most useful.

D. J. CLARK

Aviation climatology, by G. Ya. Narovlyanskii. 245 mm×170 mm, pp. vi+218, *illus.* (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem), Ann Arbor-Humphreys Science Publishers Ltd, 5 Great Russell Street, London WC1, 1970. Price: £5.

This is a well-written book which presents an excellent review of methods which have been developed for producing statistical summaries of those meteorological factors which are important for the design or operation of aircraft. A good deal of the material presented relates to methods which have been standard practice for many years but the results of much recent work in the U.S.S.R. are also given. It must also be noted that proper provision of standard World Meteorological Organization climatological summaries obviates the need for some of the indices outlined.

The book has two main parts which consider two basic problems. Chapters 1 to 3 deal comprehensively with the development of climatological indices for use in connection with the provision and use of airports as well as with the operation of air routes. This part of the book is well presented and most aspects of the problem are studied. Chapters 4 and 5 make up the second part which is concerned with the problems associated with preparation of aviation climatological summaries for various regions of the world. This second part is considerably less satisfying than the first.

Chapter 1 is an introductory chapter which looks at general matters related to the processing of climatological data. Chapter 2 deals with the calculation of indices for those parameters which must be allowed for during the design or operation of airports. There is a very full study of wind, temperature, pressure and of cloud/visibility combinations as they affect take-off or landing of aircraft. Problems of airport alternates, airport usability and airport which can be concisely supplied. Chapter 3 passes on to the conditions likely to be experienced along air routes. It gives good reviews of methods for supplying statistics of winds or equivalent winds, wind gradients, jet-stream climatology, temperature in the free air and on cloudiness though the final sections, on icing and bumpiness, are sketchy.

Chapter 4 is concerned with the techniques involved in the preparation of climatological summaries for specific regions. It gives a number of useful suggestions as to the form the summaries should take though no reference is given to the standard layouts which have been recommended in WMO publications. Chapter 5 ably applies the ideas of Chapter 4 to several air routes but the summaries are far too brief to meet many of the requirements of operators. For example, the local conditions at individual airports on the North Atlantic routes are too sketchy to be of real value. The reference to conditions at London/Heathrow Airport is somewhat outdated and misleading as regards incidence of poor visibility.

The book is well produced and amply illustrated though a number of minor editing mistakes remain. It is a translation of the original Russian version and the standard of translation is generally excellent, though occasionally the phraseology used necessitates care in reading. There is no doubt that the book represents good value and should be of use to all those concerned with the supply of meteorological data for the needs of aviation.

J. BRIGGS

The climate of Africa, Part 1, Air temperature and precipitation, edited by A. N. Lebedev. 245 mm × 170 mm, pp. iv+482, *illus.* (translated from the Russian by the Israel Program for Scientific Translations, Jerusalem), Ann Arbor-Humphrey Science Publishers Ltd, 5 Great Russell Street, London WC1, 1970. Price: £8.40.

This volume largely consists of tables of monthly and annual climatological statistics for a large number of meteorological stations in some 48 African states and territories. The tables, occupying well over 90 per cent of the

pages, present information on air temperature (749 stations) and precipitation (1564 stations) only. Since the preceding text entitled *Technique of calculating and analyzing climatic parameters* covers not only temperature and precipitation, but also humidity, cloudiness, wind and aeroclimatic characteristics, and refers to tables not included in Part 1, it is assumed that Part 2 will consist almost entirely of tabular material concerning these latter elements.

A considerable part of the data presented has been collected from various existing publications. Those particularly referred to are the Meteorological Office *Tables of temperature, relative humidity and precipitation for the world* and *World weather records* published originally by the Smithsonian Institute, U.S.A., and later by the U.S. Environmental Data Service. Other data sources mentioned are periodical publications of the meteorological services of France, Belgium, Portugal and of the African countries of Morocco, Algeria, United Arab Republic and South Africa. The periods of years covered by the data vary widely but the great majority are in the range 5 to 30 years. They are given separately for each element in a table which also gives the position and altitude of each station.

Some rather surprising statements appear in the introduction. For example, 'There are no sufficiently good current surveys of the climate either of Africa as a whole, or of its individual states'; 'The only known literature on the subject is an old survey of *The climate of the African Continent* published by A. Knoch in 1911'; 'there is at present very little literature on the climate of Africa' and 'The present volume . . . contains in general form all the most up-to-date data on the distribution of meteorological elements . . .'. The authors seem to have been unaware of the existence, for example, of the *Climatic atlas of Africa*, prepared under the direction of Professor S. P. Jackson, with support from the African Regional Association of World Meteorological Organization (Regional Association I) (WMO (RA I)) and published in 1961 by the Commission for Technical Co-operation in Africa South of the Sahara, or of the fact that RA I has been considering the possible revision and improvement of this atlas. Another major work apparently overlooked is *Climate of South Africa* published in nine parts between 1954 and 1966 by the South African Weather Bureau. Even more surprising is that a book which claims to be 'the most complete of all such publications' should not contain a single map.

A good feature of the book, on the other hand, is that it does not simply present a large mass of data, but also gives a procedure for assessing its accuracy. After explaining that the widely spaced network of stations makes it impossible to use existing reduction techniques, nomograms are presented which enable the user to judge the accuracy of any given mean value, making use of standard deviations that have been computed and tabulated for selected stations and the length of the record. This seems to be a useful approach although it might be objected that monthly precipitation amounts are not normally distributed. However, Table 16 gives for a considerable number of stations the 5, 10, 20, 30, 40, 50, 60, 70, 80 and 90 percentiles of monthly precipitation, as well as the highest and lowest values for each month, thus providing a very good indication of the actual distributions.

A number of errors were noticed, the most important being some obviously

too large standard deviations of monthly mean temperature for two South African stations in Table 3.

This could be a valuable reference book for those frequently requiring, for places in Africa, monthly temperature or rainfall data not available elsewhere, but those concerned should first compare its value with the soon to be published *Climates of Africa* in the *World survey of climatology* series, edited by H. E. Landsberg (published by Elsevier).

H. C. SHELLARD

A century of weather service: a history of the birth and growth of the National Weather Service 1870-1970, by Patrick Hughes. 225 mm × 150 mm, pp. xii + 212, illus., Gordon and Breach, Science Publishers Ltd, 12 Bloomsbury Way, London WC1, 1970. Price: Hardcover £5, paperback £2.50.

This volume has been produced to celebrate the centenary of the founding of the first official weather service in the U.S.A. The writer, who serves in the Environmental Data Service of the Environmental Science Services Administration, has drawn his material from many services, and includes a great number of photographs.

The story he has to tell is one of great complexity and continuous rapid change covering as it does the period of enormous growth and development of the United States itself as well as of the science and practice of meteorology. The size and variety of the national territory and the later global interests of the U.S.A. meant that many kinds of service and many different organizations were developed, which have made a clear account difficult to write. The style is rather that of a publicity brochure than of a serious history, but quantities of dates and names are quoted. In consequence the book is neither a sober balanced account nor a popular booklet: for the latter, concentration on a few main themes would have been necessary. A tendency to journalistic 'purple' language does not encourage reliance on its accuracy of detail. Samples which the reviewer noticed include 'the frozen stratosphere' (which reminds one of the pilot's report of 'solid cloud') and the following sketch of L. F. Richardson 'working for 10 years he solved numerous complex equations to approximate atmospheric behaviour and finally arrived at a forecast'.

Nevertheless there is much of interest, particularly for the early years such as the weather maps of 1870 and 1871, almost completely blank over the then empty western half of the country, the early demand for knowledge of the climate of the newly opened West, and the scale of demand for warnings of forest fire and flood, hurricane and tornado, storms on the Great Lakes and frost and snow.

D. G. HARLEY

Introduction to meteorology, by Franklyn W. Cole. 228 mm × 158 mm, pp. xiv + 388, illus., John Wiley and Sons, Inc., Baffins Lane, Chichester, Sussex, 1970. Price: £8.40.

This is another meteorological textbook which follows a well-trodden path in the selection of topics covered. Starting with a general description of the

atmosphere and its properties, the reader is led through a discussion of physical processes, atmospheric motion and circulation, weather disturbances and finally applied meteorology. Only in 20 pages of the final section is any serious consideration given to the major problem of weather forecasting.

Where this book differs from most others is that the reader is assumed to be devoid of any prior knowledge of mathematics or physics. It is, in fact, intended for 'college and university liberal arts students who elect a course in meteorology to meet part of their science requirements'. Consequently, in the early chapters much space is devoted to a detailed and thorough verbal description of common physical ideas. To a reader with any acquaintance with the physical sciences gained at school, this part must make rather tedious reading. However, the author, who is Professor of Meteorology and Engineering at Foothill College, Los Altos Hills, California, has had extensive teaching experience in the United States. He had obviously found such painstaking detail justified for the type of student he envisages.

Later chapters in the book make much more interesting reading and Professor Cole does not hesitate to deal with more advanced ideas, even though he is unable to develop them mathematically. For example, the reviewer found the section on frontogenesis and frontolysis well in tune with modern ideas. What a pity then, that in the synoptic treatment of fronts he reverts to the stylized pictures common in textbooks 20 years ago. This particular case illustrates a general weakness. Professor Cole is very sound indeed when dealing with the academic side of meteorology, but appears to be out of touch with the day-to-day work of the synoptic meteorologist. In general though, this is a very well-produced book which will give the non-science student a sound and sympathetic appreciation of meteorology.

The main criticism however, must be of the parochial nature of the book, for rarely does it look beyond the boundaries of the continental United States. Only one reference to a non-American source was found and the whole book is directed to the student in the United States. There is little uniformity in the system of units, degrees Fahrenheit being cheek-by-jowl with degrees Celsius and certainly no mention of SI units is made. There are a number of instances too, where descriptions of observational practices and the behaviour of weather systems could be quite misleading in another context.

P. D. BORRETT

Elements of meteorology, by Albert Miller and Jack C. Thompson. 225 mm × 150 mm, pp. xiv+402, *illus.*, Charles E. Merrill Publishing Company, Columbus, Ohio, 1970. Price: £5.

In the preface the authors state that 'the text is meant for those who are curious about their physical environment but have little formal training in physics and mathematics'. Operating within such constraints they reveal great ingenuity, which obviously stems from the authors' experience as staff members of the Meteorology Department of San José State College, California.

The refusal to use anything but the simplest of mathematics does imply, however, that the standard of treatment of various topics is going to be rather

uneven. The subjects of the last three chapters on 'Structure of the Atmosphere', 'Atmospheric Measurements', and the 'Energy of the Atmosphere' are well suited to this type of treatment. As a result the authors have achieved a complete and up-to-date account. On the other hand, Chapter 4 on 'Atmospheric Motions, Causes' suffers badly from the lack of mathematics, and the standard appears rather elementary compared to the foregoing chapters. The next two chapters on 'Atmospheric Motions; Circulation Patterns' and 'Atmospheric Motions; Vortices' again lend themselves well to the descriptive approach. The idea of scales of motion is particularly well developed but it is a pity that the discussion of frontal depressions is restricted to such a simple idealized model.

Whereas the first part of the book is primarily theoretical the last few chapters deal essentially with applied meteorology. The topics are Climate, Weather Forecasting, Application to Agriculture, Aviation, Industry, etc., and finally the Modification of Weather and Climate. Generally the treatment is comprehensive and well balanced although the discussion on Weather Forecasting appears to describe the situation a few years ago, before the more recent strides in numerical forecasting. It is in this latter part of the book that the reader is made particularly aware that it has been written with the student in the United States very much in mind. Consequently, the European reader may gain the impression that forecasting is a much simpler process than it actually is on the western margin of a continent. The applications of meteorology to industry and agriculture are however readily applicable to a European environment.

Although they have used little mathematics, the authors are to be congratulated on the way in which the reader is made aware of orders of magnitude at every stage, frequently by reference to every-day events. The collections of problems at the end of each chapter are very valuable both to students and teachers. The book is handsomely bound, the diagrams clear and apposite and the printing excellent. All in all the authors have succeeded in producing an interesting, accurate and very readable text.

It is difficult to imagine the person who would not wish to supplement this volume with a more specialized textbook. However, it is to be recommended as background reading to teachers incorporating meteorology in a general science course, to Scientific Assistants in the Meteorological Office, to mariners and to pilots of both powered aircraft and gliders. The book is probably rather expensive for most people who wish to acquire an individual copy, but it would be a very worthwhile addition to the shelves of many libraries.

P. D. BORRETT

OBITUARY

It is with regret that we record the death on 5 January 1971, of Mr G. W. Hurst, B.Sc., D.I.C., Principal Scientific Officer.

HONOUR

The following award to a member of the Meteorological Office was announced in the New Year's Honours List, 1971 :

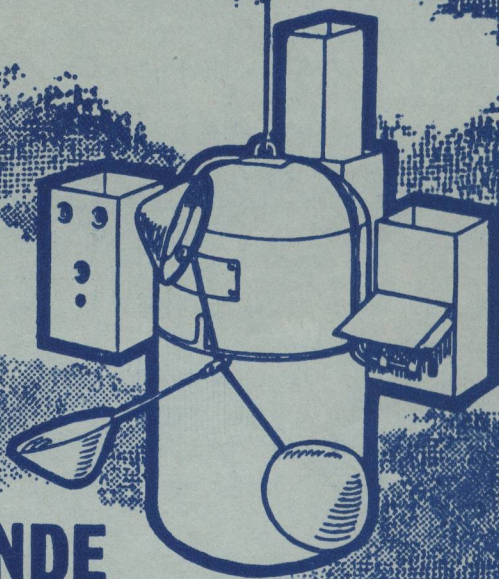
O.B.E.

A. A. Worthington, Assistant Director (Telecommunications).

CORRECTION

Meteorological Magazine, February 1971, Plate V: delete 'Mr D. N. Axford, winner of the second Memorial Award' and insert 'Mr D. P. Smith, winner of the Meteorological Observers' Award'

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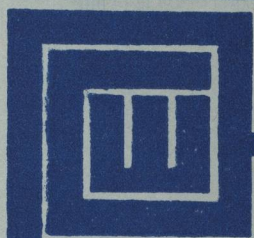


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NOTICES

It is requested that all books for review and communications for the Editor be addressed to the Director-General Meteorological Office, London Road, Bracknell, Berkshire, RG12 2SZ, and marked 'for Meteorological Magazine'.

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