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UPPER AIR TEMPERATURES

AT

MARTLESHAM HEATH,

FEBRUARY, 1917, TO JANUARY, 1918,

BY

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Lancaster Regiment.

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February, 1917, to January, 1918.

The data upon which this discussion is based were supplied to the Meteorological Office by the Controller of the Technical Department of the Air Ministry. Martlesham Heath is 5 miles E. by N. of Ipswich and stands approximately 30 metres above mean sea level with uninterrupted exposure on all sides. The data tables give the date and time of ascent, the reading of the aneroid barometer on the ground, heights in feet and temperatures in degrees Fahrenheit. The temperatures were plotted on forms similar to those in daily use in the Forecast Division of the Meteorological Office, and curves were drawn.

Table I shows how the ascents were distributed throughout the period under discussion. The period for which means have been computed is from March, 1917, to January, 1918, *i.e.*, 337 days. The total at the foot of the last column shows that ascents were made on 191 days so that there were data available for rather more than half (57 per cent.) of the number of days. With the exception of March, April and November the number of days on which there were ascents during each month is sufficiently large to afford fairly satisfactory monthly means. By a comparison of the last two columns of the table it is seen that with the exception of March and November there were about two ascents per day. Unfortunately for the purposes of this discussion ascents were not made at fixed hours of the day. Columns 2–19 give the number of ascents per month between certain hours (G.M.T.), and an examination of those columns demonstrates the unequal distributions of the times of observation. In calculating the numbers of ascents at the various hours, one which took place at the higher of any pair of consecutive hours is entered to the next pair above. Thus an ascent at 9h. is entered in the column 9h.–10h., and not in that headed 8h.–9h. The hourly totals for the period show that about one-quarter of the ascents were made between 9h. and 11h. and one-quarter between 17h. and 19h. In the computation of monthly means (Table II) all the ascents were used. The charts on

(21215—12.) Wt. 39615—519. 600. 5/19. D & S. G. 3.

TABLE I.—Number of Ascents at Various Hours.

Month.	h. 4–5	h. 5–6	h. 6–7	h. 7–8	h. 8–9	h. 9–10	h. 10–11	h. 11–12	h. 12–13	h. 13–14	h. 14–15	h. 15–16	h. 16–17	h. 17–18	h. 18–19	h. 19–20	h. 20–21	h. 21–22	Total Ascents	No. of days on which Ascents were made
March ...	0	0	0	1	1	1	2	1	1	0	2	1	1	0	0	0	0	0	11	8
April	0	0	3	1	2	4	1	1	2	1	0	1	3	0	2	0	0	0	21	12
May	0	1	9	1	0	7	2	0	0	3	1	1	1	7	10	0	0	1	44	22
June	0	3	2	2	2	4	4	0	0	2	0	0	0	8	6	3	0	1	37	19
July	0	3	5	1	1	7	5	2	0	0	0	1	0	5	16	7	0	0	53	24
August ...	0	0	0	1	1	3	2	1	1	1	7	1	4	11	20	2	0	0	55	22
September ...	0	1	4	5	1	3	6	5	1	1	4	2	3	1	3	0	0	0	40	22
October ...	0	0	0	3	0	3	10	1	0	0	2	1	0	2	0	0	0	0	22	16
November ...	0	0	0	2	1	1	3	3	2	0	1	5	0	0	0	0	0	0	18	13
December ...	0	0	0	0	3	5	6	5	1	0	6	2	0	0	0	0	1	0	29	16
January ...	0	0	0	0	2	9	3	3	1	3	18	4	0	0	0	0	0	0	43	17
Totals ...	0	8	23	17	14	47	44	22	9	11	41	19	12	34	57	12	1	2	373	191

TABLE II.—Mean Monthly Temperatures in Degrees a. Number of Cases (N). Martlesham Heath, March, 1917—January, 1918.

Heights.	March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		January.	
k	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.	a	N.
6·0	200+ —	—	200+ —	—	200+ —	—	200+ —	—	200+ 58·0	2	200+ —	—	200+ —	—	200+ 51·6	4	200+ —	—	200+ —	—	200+ —	—
5·5	—	—	50·6	4	59·0	3	—	—	61·0	2	—	—	61·8	3	53·8	6	—	—	—	—	48·7	3
5·0	59·0	2	53·9	9	61·2	13	61·2	5	64·1	15	61·9	5	64·6	14	55·6	8	55·9	7	53·5	14	53·4	20
4·5	56·9	8	56·6	16	64·5	23	65·0	17	66·7	36	65·6	35	68·0	29	57·0	17	59·3	16	55·6	24	56·2	33
4·0	59·3	8	59·0	18	67·5	33	68·6	22	69·8	41	68·6	42	71·2	33	59·3	19	62·4	16	58·0	26	58·6	37
3·5	60·8	10	61·6	20	70·2	39	71·3	28	72·3	46	71·0	48	73·5	37	62·3	22	65·0	18	60·5	27	60·9	40
3·0	63·3	10	63·6	21	72·8	43	73·4	35	75·0	52	73·2	54	75·7	41	64·8	22	67·3	18	62·8	29	62·9	43
2·5	65·5	11	65·6	21	74·5	44	76·4	37	77·5	53	75·3	55	77·6	41	67·5	22	69·4	18	65·0	29	65·2	43
2·0	67·7	11	67·6	21	77·5	44	79·2	37	80·0	53	78·1	55	79·8	41	70·5	22	71·8	18	67·2	29	68·0	44
1·5	69·9	11	70·0	21	80·2	44	82·0	37	82·4	53	81·4	55	81·9	41	73·5	22	73·8	18	69·5	29	70·9	44
1·0	73·3	11	73·0	21	82·9	44	84·9	37	85·1	53	84·7	55	84·0	41	76·5	22	76·0	18	71·9	29	73·1	44
0·5	76·0	11	76·0	21	85·3	44	87·9	37	88·0	53	88·6	55	86·9	41	79·8	22	78·2	18	74·4	29	75·4	44
Ground	78·4	11	80·2	18	87·6	44	90·8	37	90·8	53	91·8	55	89·7	41	82·6	22	80·7	17	76·3	27	77·3	43

TABLE III.—Deviations from Normal Temperatures for S.E. England.

Heights k.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.
5	—	+2	+5	+2	+3	+1	+5	−1	+3	+4	+4
4	+2	0	+5	+3	+2	+1	+5	−5	+2	0	+3
3	−1	−2	+5	+2	+2	0	+4	−4	+1	−1	0
2	−1	−3	+4	+2	+2	0	+3	−4	0	−2	0
1	0	−3	+4	+3	+1	+1	+2	−3	−1	−2	+1
0	+1	0	+4	+5	+3	+4	+4	−1	+1	−2	+1

TABLE IV.—Monthly Mean Temperatures in Degrees a.

—	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.
Yarmouth ...	275·6	277·9	284·2	288·6	289·6	289·2	287·8	281·1	280·6	275·9	275·7
Felixstowe ...	275·8	278·1	284·7	289·4	289·8	289·7	288·0	281·4	280·6	275·4	275·4
Clacton	275·8	278·2	285·0	289·2	289·7	289·6	288·1	281·4	280·6	275·6	275·9
Martlesham Heath	278·4	280·2	287·6	290·8	290·8	291·8	289·7	282·6	280·7	276·3	277·3

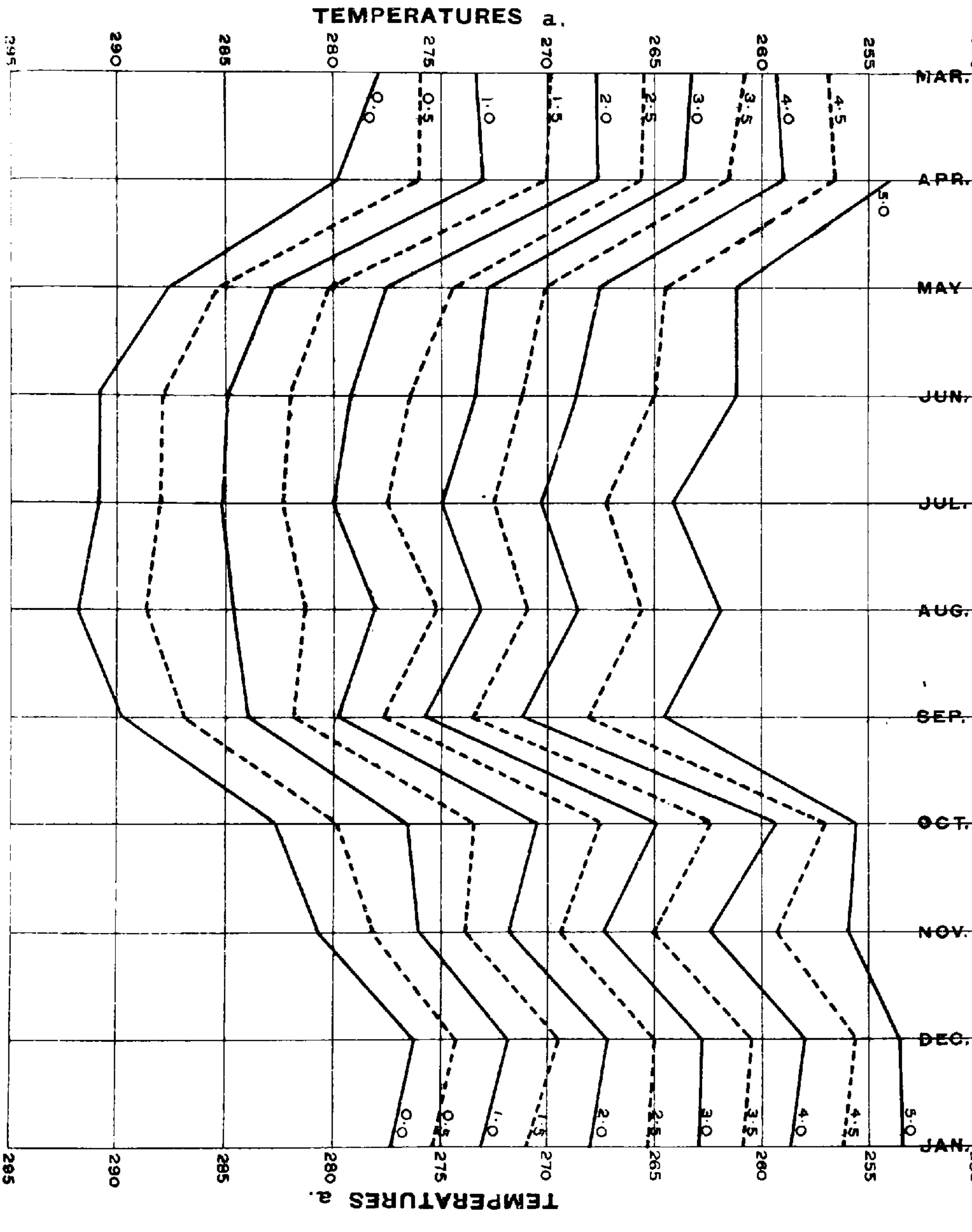
which the curves were drawn were ruled off in half kilometre height steps and temperatures " a " (273a. = 0°C.) to the nearest ½ degree were read off from a scale. Table II gives the monthly mean temperatures for every half kilometre up to 6k. together with the number of observations at each height which were used in computing these means. Reference to Table I shows that most of the ascents took place between 6h. and 20h. so that there are no observations for what are normally the coldest hours of the day. It follows therefore that the monthly means calculated for Martlesham Heath should be too high, and this is shown to be the case, at any rate at the surface, if the means given in Table II are compared with those for Yarmouth, Felixstowe and Clacton (*see* Table IV). It was not thought advisable to attempt to " correct " the temperatures for Martlesham Heath for several reasons, the chief of which are :—

(1) No information is to hand of the type and exposure of the instrument used to measure temperatures.

(2) The elimination of the errors due to the method of reading off temperatures " a " for every half kilometre from curves giving temperatures F and heights in feet would require long calculation, which, it is felt, would not produce results of sufficient importance to compensate for the time and labour involved. Assuming, therefore, that the values are too high for all heights given, the means in Table II are still of value if it can be shown that their departures from standard normals are consistent. In order to determine this, the results have been compared with the adjusted means for South-East England computed by Mr. W. H. Dines, F.R.S. (cf. Computer's Handbook, Section II, p. 55). The Martlesham Heath departures from Mr. Dines' means are tabulated in Table III and consistency of departure is particularly evident from May to November. Even the months of March, April, December and January are by no means inconsistent.

The means given in Table II are used in Fig. I to show the fluctuations in temperature from month to month at given heights. As the figure is not constructed on conventional lines it requires detailed explanation. The months, beginning with March, 1917, are shown at equal intervals reading from left to right; temperatures from 295a to 250a from the bottom to the top of the figure. The means for each half kilometre for each month were plotted and the curves drawn, the dotted lines being the half, and the full lines the whole kilometre curves. The figure is unconventional because a curve sloping *downwards* indicates an *increase* of temperature, while one sloping *upwards* a *decrease*. The value of the figure lies in the fact that it shows the temperature curves in their correct order of height and that the differences from month to month at various heights can be

MEAN MONTHLY TEMPERATURES (March, 1917—January, 1918) every 0·5 km. Martlesham Heath.



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compared with ease. Thus the surface curve is at the bottom of the figure, and, if necessary, can be compared easily with the 5k. curve which is at the top of the figure. Conformity of temperatures with height is shown by the parallelism, and nonconformity by the convergence or divergence of the curves.

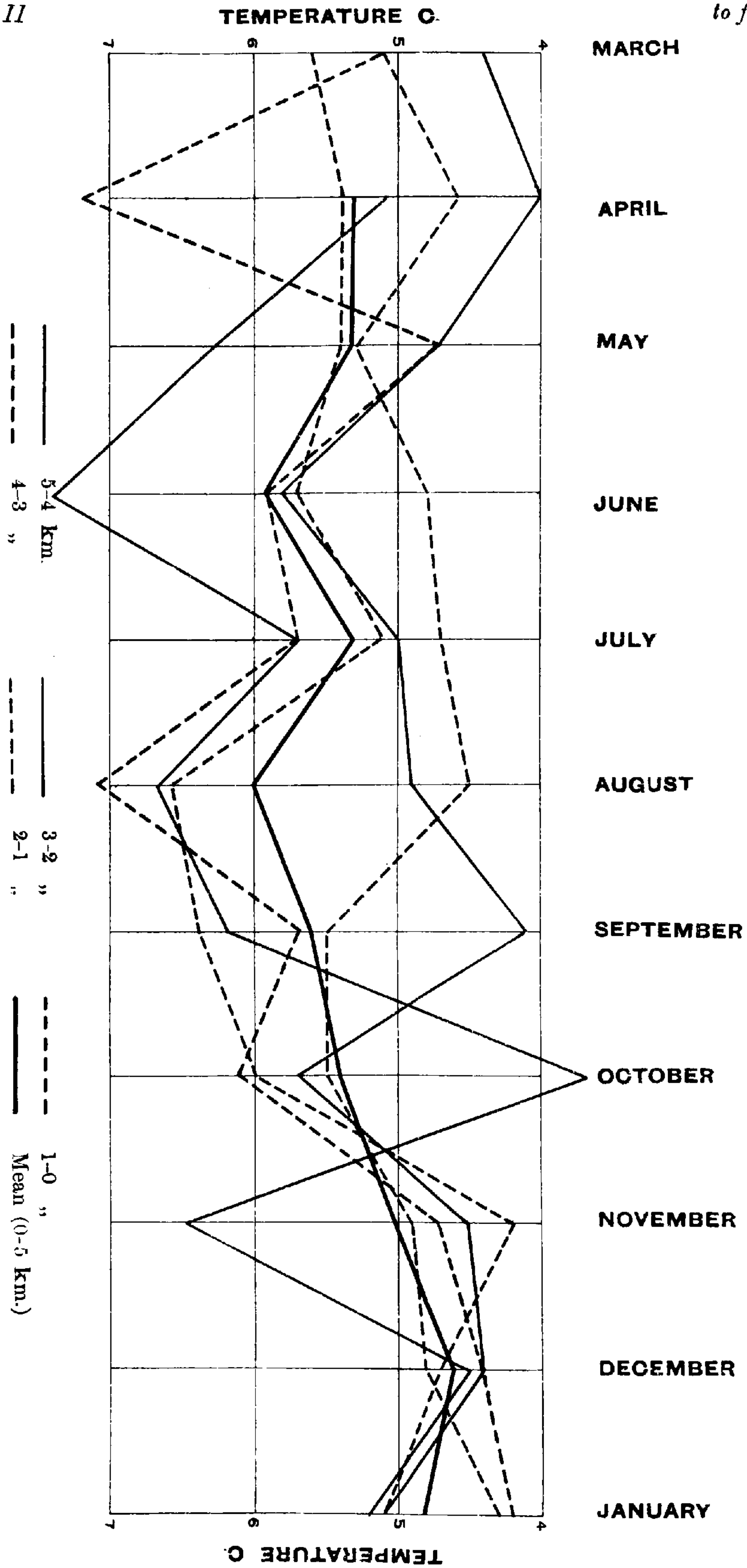
The most striking feature of the figure is that whereas August is the month of maximum temperature at the surface and 0·5k., it ceases to be so at 1·0k., and from 1·5k. to 5·0k. it is a secondary minimum. From 1·5k. to 5·0k. August is on the average 1·7a cooler than July and 2·2a cooler than September. On an examination of the August ascents it was found that the low values from 1·5k. upwards were due to the low temperatures in the last week of the month, *i.e.*, on the 25th, 27th, 30th and 31st. It was during that week that one of the deepest depressions which has visited these islands for many years crossed the country. The very deep depression of August 27th–30th was centred south of Roches Point and opposite the mouth of the Bristol Channel at 18h. on the 27th. By 7h. the next morning the centre was midway between Flamborough Head and Morecambe Bay, and at 18h. it was situated on the Greenwich meridian and opposite the mouth of the Firth of Tay. On the 29th at 7h. the centre had moved N. by E. to a point opposite Buchanness, and by the next morning was approximately midway between Skudesnaes and Faerder in South Norway. At all times, therefore, Martlesham Heath was to the right of the path of the depression. Until about mid-day on August 27th Martlesham Heath was in the right front (E. quadrant) of the depression and then in the right rear (S. quadrant). It has been shown by Hann, Grenander, Dines, Gold and others that the temperatures over a cyclonic region are lower than those over an anticyclone. Not only is this shown to be the case in the present instance, but it is also clear that the passage of a deep depression may so affect temperatures above a short height from the ground as to turn what should be a maximum for a given period into a secondary minimum. It follows, therefore, that in dealing with upper air mean temperatures for any given period, the frequency of passing depressions during that period must be taken into account. This noteworthy depression of the 27th to 30th was preceded on the 26th and 27th by a shallower cyclone which had an eastward V, and which dispersed in the North Sea. On the 30th and 31st another "low" crossed South Ireland and Central England while on the 1st September yet another depression passed across Central Ireland and Southern Scotland. Reference to the September ascents shows that the low temperatures of the last week of August were continued to 2nd September. From a study of the individual ascents it is seen that the depressions which have a marked effect on the temperatures at Martlesham Heath are those whose centres pass near that observing station. That this should be so follows at once from the fact already previously established of the existence of low temperatures over regions of low pressure. The lowest temperatures recorded at Martlesham

Heath occurred, on the whole, on the morning of August 27th, *i.e.*, when the depression was nearest from the point of view of days of observation. Unfortunately, there are no observations for August 28th. Had there been it is probable that the lowest temperatures of the week would have been recorded on that day. The point of the nearness of the centres of depressions and the consequent low temperatures has been laboured because it suggests a line of investigation which may yield results of practical value in forecasting. The suggestion is that more regular and better distributed observations of temperatures up to 5k. in any region might assist in determining the path that the centre of a depression will follow

Another marked feature of Fig. I is the abrupt change at all heights from the cold of April to the warmth of May and from the warmth of September to the cold of October. In the former months, however, the change is most abrupt from the surface to 1·5k., and this is shown by the slight divergence from April to May of the four lowest curves. From September to October the most abrupt changes are found between 0k. and 4k., for the curves diverge slightly between those heights. In this instance therefore the changes from a cold to a warm month are most marked at a less height above the ground than the changes from a warm to a cold month.

Fig. I also shows a secondary maximum occurring in November from 1·5k. to 5·0k. It is curious that 1·5k. should again be the critical height. It seems, therefore, that diurnal changes of temperature cease to be really effective above 1·5k., for above that height the gain of heat by absorption of radiant energy and by convection is small, as is also the loss of heat by radiation. Above 1·5k. there is a more intimate connection between pressure and temperature than below that level. The surface pressures for November were above the normal for the whole country. At Yarmouth and Clacton the mean pressures at mean sea level were 4·2mb. and 5·5mb. respectively in excess of the mean for the month. During October Yarmouth shows a deficit of 5·7mb. and Clacton 5·0mb. from the mean pressure of the month. October was, in fact, very similar to August in one respect; during both months there were unusually large numbers of depressions whose centres crossed the British Isles. During November, on the other hand, there was only one depression whose centre can be said to have crossed the British Isles. Here again, then, is another case in which low pressures are associated with low temperatures and conversely.

Another significant feature of Fig. I is that the curves from 1·5k. upwards show December to be but very little colder than October. Above 1·5k. the mean difference of temperature between the two months is 2·1a, below that level 5·1a. The mean pressure for December was well above normal (Yarmouth 8·1mb., Clacton 7·8mb.). The increase of pressure in December therefore was nearly sufficient to compensate, at heights greater than 1·5k., for a seasonal difference of temperature.



LAPSE LINES for every 1 km. and MEAN of 0-5 km.

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Fig. II

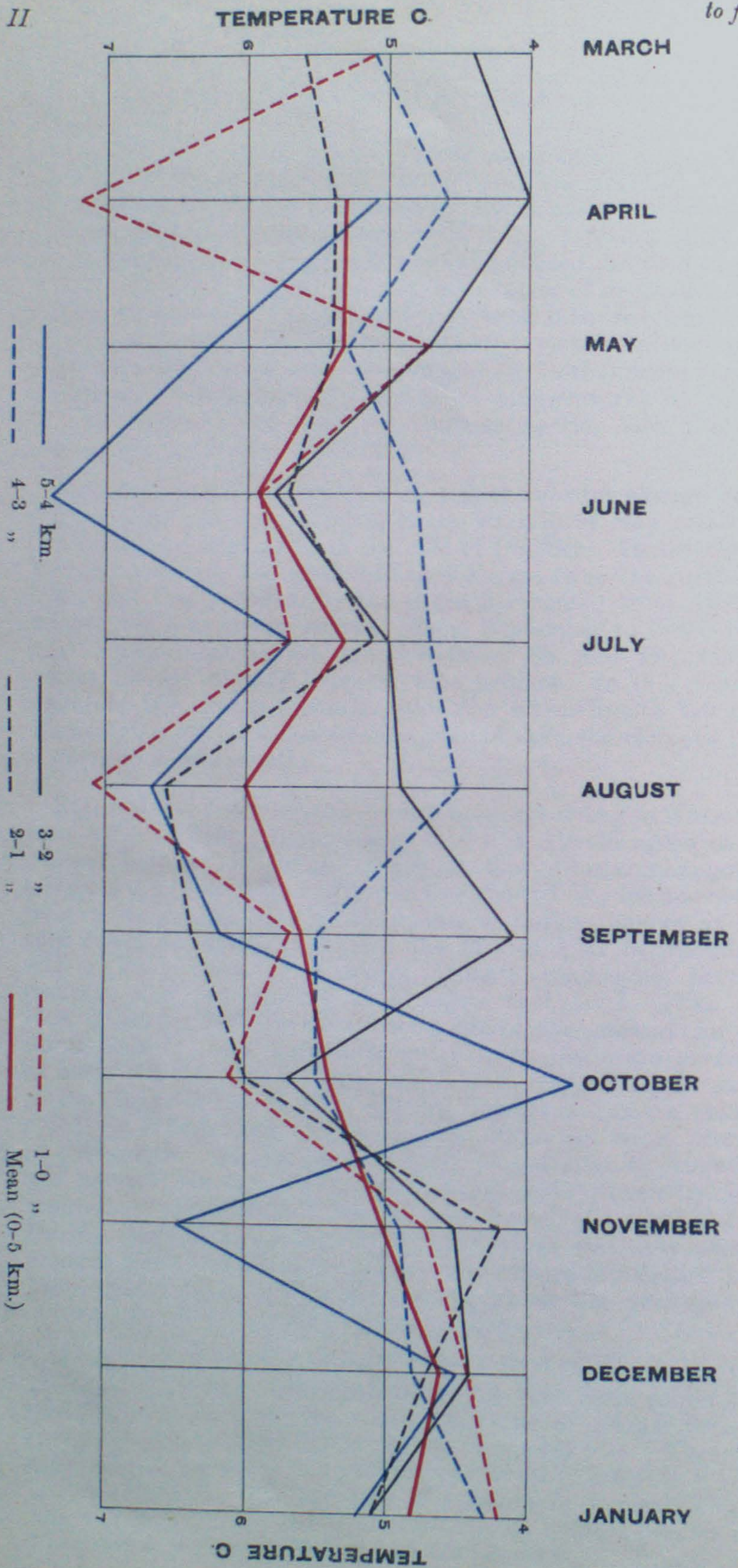

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TABLE V.—Lapse Rate in Centigrade Degrees for every Kilometre from 0k.—5k. and Mean Lapse Rate per Kilometre from 0—5k.

Heights k.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.
5—4	—	5·1	6·3	7·4	5·7	6·7	6·2	3·7	6·5	4·5	5·2
4—3	4·0	4·6	5·3	4·8	4·7	4·6	5·5	5·5	4·9	4·8	4·3
3—2	4·4	4·0	4·7	5·8	5·0	4·9	4·1	5·7	4·5	4·4	5·1
2—1	5·6	5·4	5·4	5·7	5·1	6·6	6·4	6·0	4·2	4·7	5·1
1—0	5·1	7·2	4·7	5·9	5·7	7·1	5·7	6·1	4·7	4·4	4·2
Mean 0—5	4·8*	5·3	5·3	5·9	5·3	6·0	5·6	5·4	5·0	4·6	4·8

* Mean 0—4 k.

In Table V are given the mean monthly lapse rates for every kilometre from 0k.–5k., together with the mean of 0–5k. Gold (*Geophysical Memoirs,* No. 5, p. 39) has calculated the monthly values of gradients of temperatures for England. The Martlesham Heath results do not agree at all closely with Gold's results at each kilometre interval, but there is a fairly close agreement between the means of 0-5k. The departures of the Martlesham Heath 0-5k. gradients from Gold's are as follows:—

March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Jan.
—0·8	—1·4	—0·1	+0·4	—0·4	+0·8	+0·3	+0·5	—0·4	—1·5	0·0

In April and December therefore the Martlesham Heath gradients are considerably smaller than the means for England, during March appreciably smaller, during August appreciably greater, but for the rest of the period very little either smaller or greater.

The changes in lapse rate from month to month are shown in diagrammatic form in Fig. II. The greatest variations in lapse rate occur from 5k.–4k. which in most months is considerably above the mean of 0-5k. At other heights the gradients agree fairly closely from May to July and from October to January. During August and September there is a striking decrease in the gradient between 2k. and 3k. as compared with that between 2k. and 1k.

TABLE VI.—Monthly Extremes and Absolute Range.

Heights.	March.					April.					May.					June.				
k.	Max. a	Date	Min. a	Date.	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date.	Range a
5·5	200+		200+			200+ 56·5	22	200+ 43·5	13	13·0	200+ 59·5	3	200+			200+		200+		
5·0						59·5	22, 23	47·5	13	12·0	64·5	3	58	7	6·5	66	9	58	26	8·0
4·5	64	18	45	22	19·0	62	22, 23	50	13	12·0	68	18, 21	60·5	1	N 7·5	68	9, 16	59·5	22	8·5
4·0	67	17	49	22	18·0	65·5	23, 24	46	10	19·5	71	13	63	1	8·0	74·5	15	62·5	22, 26	12·0
3·5	69	17	51	22	18·0	68	23	48·5	10	19·5	74	27	65·5	1	8·5	77	14, 15	64·5	26	12·5
3·0	74	17	56	22	18·0	71	24	52·5	10	18·5	77	26	67	1	10·0	80	15	66	26	14·0
2·5	75	17	58·5	27	16·5	72	23, 24	56	10	16·0	79	13, 21, 26	67·5	1	11·5	82·5	15	68·5	23	14·0
2·0	77	17	61	27	16·0	73	23	60	10	13·0	83·5	21, 26	69	1	14·5	84·5	16, 19	71·5	23	13·0
1·5	77·5	17	64	27	13·5	74·5	23, 30	63	10	11·5	86·5	21, 26	74	1	12·5	88	16	75·5	23	12·5
1·0	79	17	66	9	13·0	78	30	67·5	10	10·5	88·5	27	75·5	6	13·0	91	16	79·5	23	11·5
0·5	82	17	70	9, 22	12·0	82	30	71·5	10	10·5	91·5	27	76	6	x 15·5	94	16	83	3	11·0
0·0	86	17	72·5	9, 22	13·5	87·5	30	73	10	14·5	96	13	77·5	1, 7	x 18·5	97	16	84	22	13·0

N = Minimum for Period. x = Maximum for Period.

TABLE VI.—Monthly Extremes and Absolute Range—(*continued*).

Heights.	July.					August.					September.					October.				
k.	Max. a	Date.	Min. a	Date.	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date.	Range a
5·5	200+ —	—	200+ —	—	—	200+ —	—	200+ —	—	—	200+ —	—	200+ —	—	—	200+ 62·5	2	200+ 44·5	26	18·0
5·0	68	3	61	21	7·0	65	13	60	20, 25	N 5·0	68·5	10	57·5	2	10·5	65·5	22	48	26	17·5
4·5	71	27	63	10, 15	8·0	71	7	60	27	11·0	74	25	62·5	2	11·5	67·5	1, 2, 22	51·5	26	16·0
4·0	77·5	10	66·5	9, 15	11·0	71·5	7, 16	64	27	N 7·5	77	25	65	2	12·0	71	1	54	6, 26	17·0
3·5	79·5	10	68	15	11·5	74·5	22	67·5	27	N 7·5	79	25	68	2	11·0	75	1	56·5	26	18·5
3·0	79·5	13	69	16	10·5	78	22	69·5	27	N 8·5	81	25	69·5	2	11·5	77·5	1	60·5	5, 24	17·0
2·5	83	13	73	16	N 10·0	82	22	71	25	11·0	83	25	71·5	2	11·5	78·5	2	62·5	6, 24	16·0
2·0	86	13	75·5	16	N 10·5	84·5	22	74	25	N 10·5	85	25	74	14	11·0	81·5	2	65·5	6	16·0
1·5	89	27	77	10	12·0	86·5	22	77·5	25	N 9·0	86·5	6, 16, 25	76	14	10·5	84·5	2	69	6	15·5
1·0	91	14	80	10	11·0	91	22	81	25	N 10·0	89·5	6	79·5	21	N 10·0	86·5	2	73	6	13·5
0·5	95	14	82·5	1	12·5	94	22	84	30	10·0	91·5	25	83·5	29	N 8·0	88·5	2	74	27	14·5
0·0	97·5	14	84	1	13·5	95	5	86·5	30	N 8·5	94	9	83·5	8	10·5	91	1	75·5	27	15·5

X = Maximum for Period. N = Minimum for Period.

TABLE VI.—Monthly Extremes and Absolute Range—(*continued*).

Heights.	July.					August.					September.					October.				
k.	Max. a	Date	Min. a	Date.	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date	Range a	Max. a	Date.	Min. a	Date.	Range a
	200+		200+			200+		200+			200+		200+			200+		200+		
5·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	62·5	2	44·5	26	18·0
5·0	68	3	61	21	7·0	65	13	60	20, 25	N 5·0	68·5	10	57·5	2	10·5	65·5	22	48	26	17·5
4·5	71	27	63	10, 15	8·0	71	7	60	27	11·0	74	25	62·5	2	11·5	67·5	1, 2, 22	51·5	26	16·0
4·0	77·5	10	66·5	9, 15	11·0	71·5	7, 16	64	27	N 7·5	77	25	65	2	12·0	71	1	54	6, 26	17·0
3·5	79·5	10	68	15	11·5	74·5	22	67·5	27	N 7·5	79	25	68	2	11·0	75	1	56·5	26	18·5
3·0	79·5	13	69	16	10·5	78	22	69·5	27	N 8·5	81	25	69·5	2	11·5	77·5	1	60·5	5, 24	17·0
2·5	83	13	73	16	N 10·0	82	22	71	25	11·0	83	25	71·5	2	11·5	78·5	2	62·5	6, 24	16·0
2·0	86	13	75·5	16	N 10·5	84·5	22	74	25	N 10·5	85	25	74	14	11·0	81·5	2	65·5	6	16·0
1·5	89	27	77	10	12·0	86·5	22	77·5	25	N 9·0	86·5	6, 16, 25	76	14	10·5	84·5	2	69	6	15·5
1·0	91	14	80	10	11·0	91	22	81	25	N 10·0	89·5	6	79·5	21	N 10·0	86·5	2	73	6	13·5
0·5	95	14	82·5	1	12·5	94	22	84	30	10·0	91·5	25	83·5	29	N 8·0	88·5	2	74	27	14·5
0·0	97·5	14	84	1	13·5	95	5	86·5	30	N 8·5	94	9	83·5	8	10·5	91	1	75·5	27	15·5

X = Maximum for Period. N = Minimum for Period.

TABLE VI.—Monthly Extremes and Absolute Range—(*continued*).

Heights.	November.					December.					January.				
k.	Max. a	Date.	Min. a	Date.	Range a	Max. a	Date.	Min. a	Date.	Range a	Max. a	Date.	Min. a	Date.	Range a
	200 +		200 +			200 +		200 +			200 +		200 +		
5·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5·0	63·5	29	42	25	21·5	61	19	45·5	17	15·5	59·5	25	36·5	8	x 23·0
4·5	68	28	46·5	25	x 21·5	63	13, 19	47	17	16·0	62·5	25	41	8	x 21·5
4·0	72	28	52	25	20·0	66·5	13	49	17	17·5	66·5	25	45	8	x 21·5
3·5	74	28	56·5	25	17·5	68	13, 19	52·5	2, 3, 17	15·5	69·5	25	48	8	x 21·5
3·0	76	28	59	25	17·0	70·5	31	54·5	17	16·0	72·5	25	50	8	x 22·5
2·5	78·5	28	62	25	16·5	74	13	58·5	17	15·5	76·5	25	53	8	x 23·5
2·0	80	28	65	25	15·0	77	13	62	2, 17	15·0	78·5	25	57	8	x 21·5
1·5	80·5	28, 29	69	7	11·5	79	13	65·5	17, 27	13·5	80·0	25	61·5	8	x 18·5
1·0	83	29	70·5	26	12·5	80	13	68·5	17	11·5	81·5	25	64	8	x 17·5
0·5	85	29	73	8, 26	12·0	80·5	13	70·5	27	10·0	82	24	68	8	14·0
0·0	87	6	73·5	11	13·5	80·5	13	71·5	19	9·0	85	30	69	8	16·0

x = Maximum for Period. N = Minimum for Period.

TABLE VI.—Monthly Extremes and Absolute Range—(*continued*).

Heights.	November.					December.					January.				
k.	Max. a 200 +	Date.	Min. a 200 +	Date.	Range a	Max. a 200 +	Date.	Min. a 200 +	Date.	Range a	Max. a 200 +	Date.	Min. a 200 +	Date.	Range a
5·5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
5·0	63·5	29	42	25	21·5	61	19	45·5	17	15·5	59·5	25	36·5	8	x 23·0
4·5	68	28	46·5	25	x 21·5	63	13, 19	47	17	16·0	62·5	25	41	8	x 21·5
4·0	72	28	52	25	20·0	66·5	13	49	17	17·5	66·5	25	45	8	x 21·5
3·5	74	28	56·5	25	17·5	68	13, 19	52·5	2, 3, 17	15·5	69·5	25	48	8	x 21·5
3·0	76	28	59	25	17·0	70·5	31	54·5	17	16·0	72·5	25	50	8	x 22·5
2·5	78·5	28	62	25	16·5	74	13	58·5	17	15·5	76·5	25	53	8	x 23·5
2·0	80	28	65	25	15·0	77	13	62	2, 17	15·0	78·5	25	57	8	x 21·5
1·5	80·5	28, 29	69	7	11·5	79	13	65·5	17, 27	13·5	80·0	25	61·5	8	x 18·5
1·0	83	29	70·5	26	12·5	80	13	68·5	17	11·5	81·5	25	64	8	x 17·5
0·5	85	29	73	·8, 26	12·0	80·5	13	70·5	27	10·0	82	24	68	8	14·0
0·0	87	6	73·5	11	13·5	80·5	13	71·5	19	9·0	85	30	69	8	16·0

x = Maximum for Period. N = Minimum for Period.

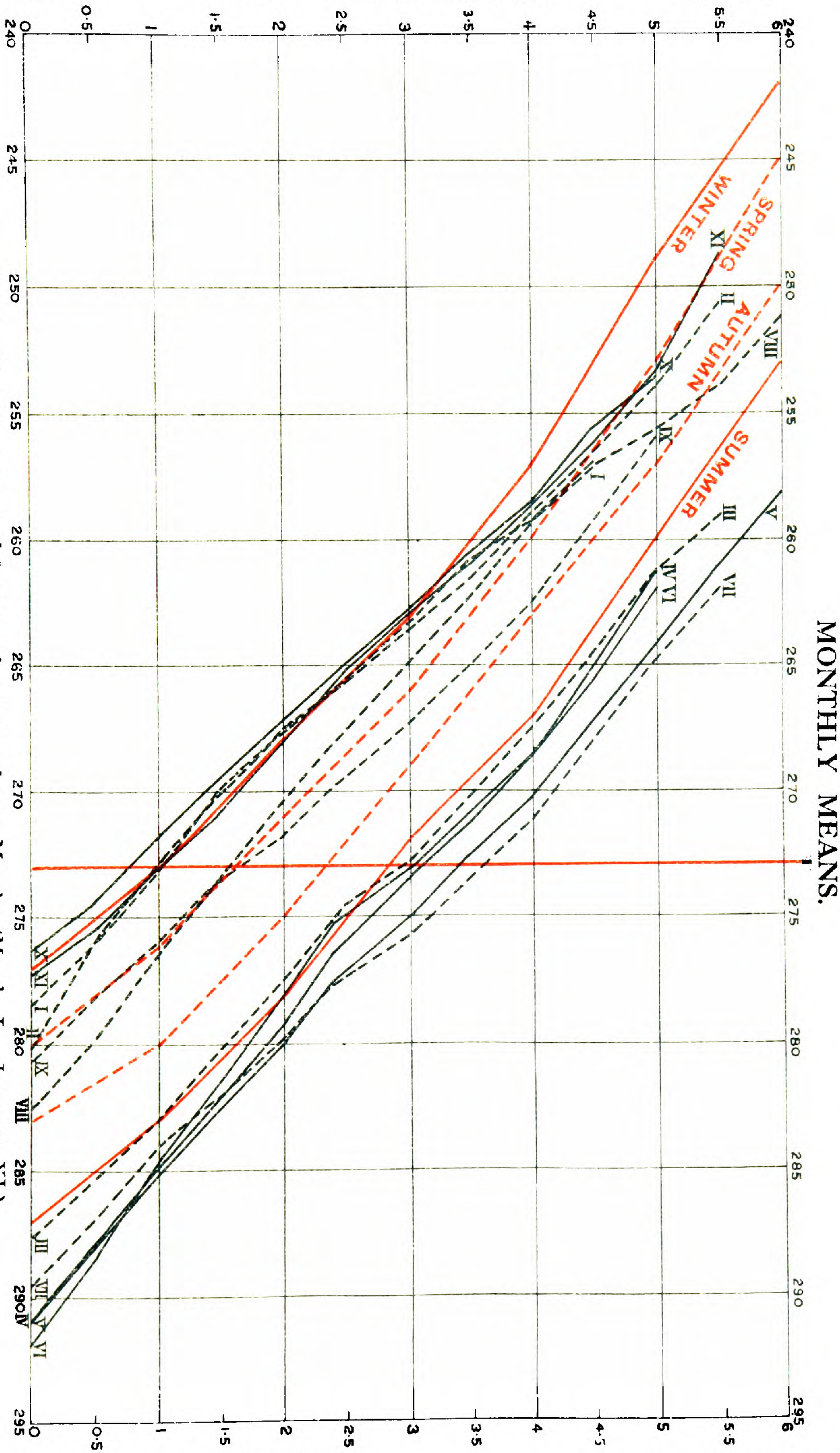
The monthly extremes and absolute ranges are given in Table VI. From 1k. upwards the greatest ranges are in January (January and November have equal absolute ranges at 4·5k.). At 0k. and 0·5k. the greatest ranges occur in May. Minimum ranges are confined almost entirely to August. The minimum at 2·5k. occurs in July and at 0·5k. in September. During July and August the ranges at 2·0k. are equal and at 1·0k. the months of August and September have equal ranges. In the period under review, therefore, the greatest extremes are found in winter and the least in late summer. During March the maximum range is found at the greatest height (4·5k.) and decreases slowly downwards to 2·0k. Then follows a rapid decrease to a minimum at 0·5k. In the lowest layer of all there is an increase of range. From 4·5k. to 0·5k. therefore there is a decrease of 37 per cent. in temperature range, the mean range is 15·8a. In April the maximum range is found at 4·0k. and 3·5k., and the minimum at 1·0k. and 1·5k. From the maximum to the minimum there is again a rapid decrease (46 per cent.) and the mean range is 14·2a. May shows a maximum at the surface with a local maximum at 2·0k.; the minimum occurs at the greatest height (5·0k.). The May decrease is 65 per cent., the mean range being 11·5a. 3·0k. and 3·5k. give the greatest ranges for June but the minimum is again at 5·0k. The decrease for this month is 43 per cent. and the mean range 11·8a. The conditions for July are very similar to those for May, for the greatest range is at the ground level and the least at the greatest height (5·0k.). 48 per cent. decrease occurs in July and the mean range is 10·7a. August, the month of least ranges for the period, has two maxima at 4·5k. and 2·5k.: the minimum is at 5·0k. The mean range is 9·0a and the decrease 55 per cent. The ranges in September are very uniform. The greatest occurs at 4·0k., the least at 0·5k. The decrease is only 33 per cent. The mean range is 10·7a. October is also a month of uniform ranges, the greatest and least being found at 3·5k. and 1·0k. A decrease of 27 per cent. is very small compared with the other months but the mean range is high (16·3a). November is very similar to March, for the maximum is found at the greatest heights (5·0k.–4·5k.) and the minimum near the ground (0·5k.). The decrease is calculated at 44 per cent. and the mean range at 16·2a. December resembles April. Its greatest range is at 4·0k., its least at the surface. A decrease of 49 per cent. and a mean range of 14·1a are obtained for December. The month of maximum ranges (January) has its greatest value at 2·5k. and its least at 0·5k. The percentage decrease is 40; the mean range is 20·1.

It has already been pointed out that August and January were the months of minimum and maximum ranges and in this connection it is interesting to note that August was a cyclonic month while January presented a strong contrast between the anticyclonic conditions of the first half and the cyclonic conditions of the second half of the month. Map 2, p. 87, Monthly Weather Report, August, 1917, shows the paths of 12 depressions, 10 of which crossed the British Isles. There was hardly a day during the whole month when the conditions were not definitely cyclonic. In striking contrast is the map of Movements of Depressions for January, 1918 (p. 3 Monthly Weather Report, January, 1918). Only two tracks are shown as crossing any part of our islands and except for a depression which developed in the northern North Sea on the evening of the 6th all the depressions for January were confined to the second half of the month.

Minimum ranges are found at the greatest heights (*i.e.*, 5·0k.) during the summer months (May-August). For the rest of the period the least ranges are found below 2·0k. and in many cases between 1·0k. and 0·0k. As a general rule the maximum ranges for the period are found between 4·0k. and 5·0k. but in May and July they occur at the ground level. The mean monthly range varies from 9·0a in August to 20·1a in January, and the percentage monthly decrease of temperature range fluctuates from 27 per cent. in October to 65 per cent. in May.

Figure III shows the individual monthly curves together with normal curves for the four seasons calculated from Mr. Dines' normals for S.E. England. The seasonal curves are shown in red. The dotted monthly curves are for the spring and autumn months, the full lines for winter and summer. With the exceptions of October and November the monthly curves are conspicuously grouped into two sets. March, April, December and January form one set which approximate very closely to the winter curve up to 3·5k. and then follow the spring curve. May, June, July, August and September form the other set. They follow the summer curve fairly closely but are all on the whole appreciably warmer. This is especially the case in July and September. September from 2·5k. upwards was the warmest month of the period. The curves for October and November might reasonably be expected to follow the autumn curve but this is not shown to be the case. From the figure October (curve VIII) is shown to be a typical spring month up to 4·5k. It only approximates to the autumn curve above that height. November (curve X) is typically spring up to 3k. and then typically autumn.

The various mean monthly heights above which temperatures are below the freezing point of water (273a) is shown by the intersections of the monthly curves and the vertical red line. The freezing point is met with nearest the ground in December when it is approximately at a height of 0·75k. The greatest height at which 273a is met with occurs in September when it is 3·6k. above the ground. The mean monthly heights above which temperatures are below 273a is shown diagrammatically in Figure IV. This figure shows more clearly the fluctuations in the height at which 273a is met than does Figure III, and it also serves as a useful summary for the whole period. The broken lines in the figure show the normal heights for S.E. England for 273a for the four seasons. One of the most striking features in Figure IV is the long period of unusual warmth from May to October. With regard to surface temperatures reference to the District Values (England S.E.) in the Monthly Weather Reports for those months



Roman Figures at top and bottom of curves refer to Months (March, I., January, XI.)
Vertical Red Line = 273a = 0°C = 32F. = Freezing Point of Water.

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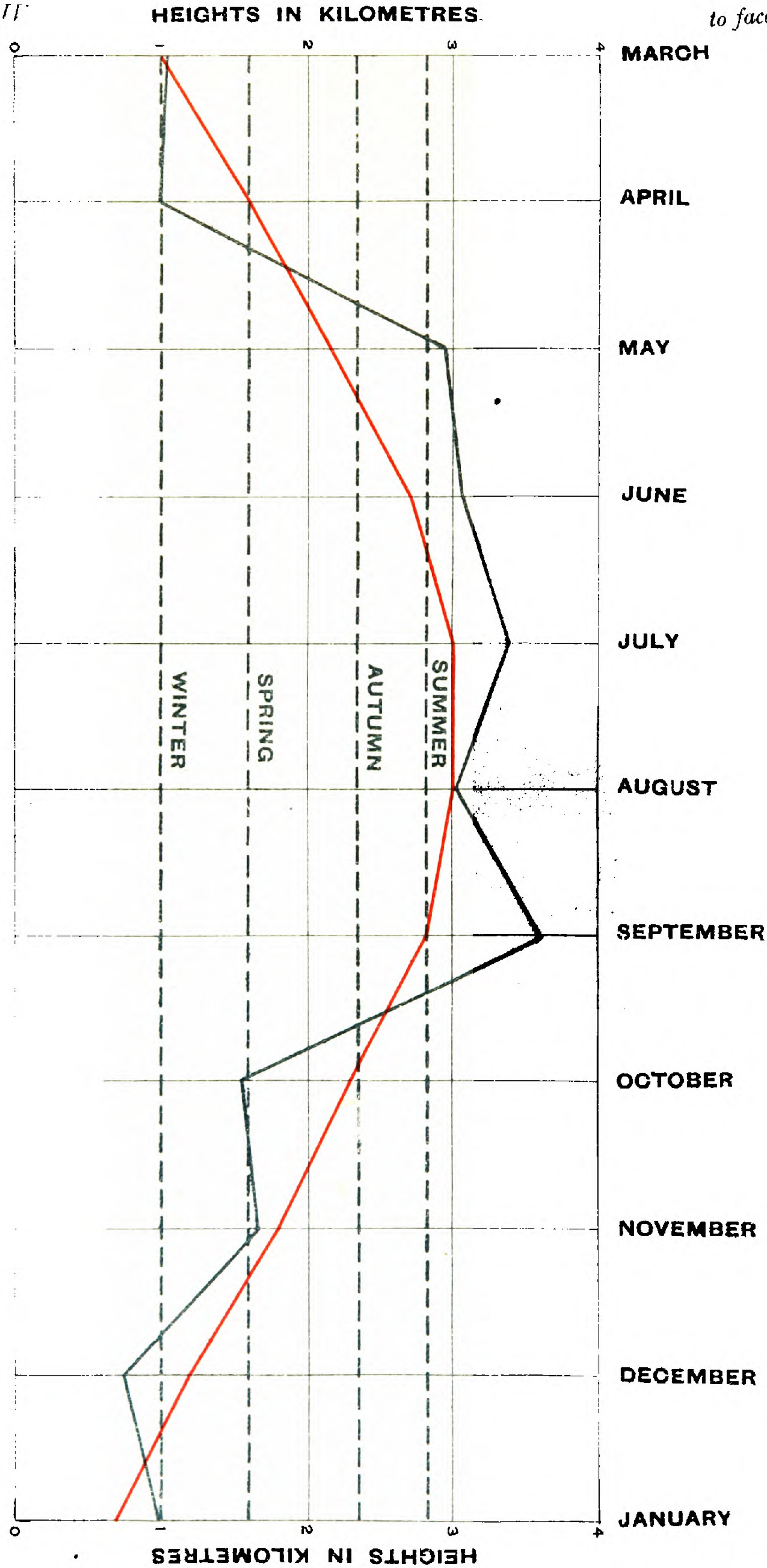
Fig. II. *to face page 45.*



MEAN MONTHLY HEIGHTS above which Temperatures are below 273a (Black Line)—Normal Height (Red Line).

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shows that May and June were distinctly above normal, July was slightly above, August slightly below and September appreciably above normal. If the black and the red lines in Figure IV be compared it is seen that only in August were conditions normal during the period May to September. All the other months are distinctly above normal in spite of the fact that at the surface May, June and possibly September are the only months that can be regarded as being above normal. Another noticeable feature of the diagram is the absence of spring and autumn conditions. From April to May there is a sudden change from winter to summer; October and November are distinctly cold for autumn but the transition from summer to winter is not nearly as sudden as that from winter to summer. With regard, therefore, to the temperatures at Martlesham Heath (0k.–5k.) from March, 1917, to January, 1918, the following conclusions can be drawn:—

(1) If conditions for warmth or cold become established they tend to continue in spite of fluctuations which are more apparent on the ground than in the free air.

(2) The transition from warmth to cold and vice-versa is sudden.

The data have been carefully examined in order to trace if possible the course of diurnal changes of temperature with height. The results have been disappointing. The great drawback is the fact that ascents were not made at fixed hours. On many of the days in the period only one ascent was made and thus these results are of little use in determining diurnal changes. The ascents for June 27th are not an uncommon example of the time distribution on a day when more than one ascent was made. On that day three ascents were made at the following times:—17h. 20m., 17h. 45m., and 18h. 30m. G.M.T. On more than one occasion two flights were made at the same time but the results are not always in close agreement, and this is seen in the two ascents for December 31st at 10h. 30m. The results in degrees absolute for successive half kilometres of height are as follows:—

5·0	4·5	4·0	3·5	3·0	2·5	2·0	1·5	1·0	0·5	0·0k
258	261·5	264	267·5	270·5	273	274·5	273	274·5	276	277a
-	256	259·5	262	266	269	271·5	272	272	274	276·5a

To attempt to calculate means for fixed hours was impracticable and therefore two other methods were utilised. In the first case, the following hours were grouped together: 7, 8, 9, 10; 12, 13, 14, 15; 17, 18, 19, 20, in order to obtain means for morning, midday and evening. The results are far from satisfactory, for the number of cases in each group varies considerably from month to month; the mean values, therefore, must often be regarded as incorrect. The results for May, for instance, show the midday temperatures from the ground to 5·0k. to be lower by 2 to 3 degrees than the morning temperatures. For isolated instances this might conceivably be true, but for mean values such a result must be regarded as erroneous. On the rejection of this method individual results for days of two or more ascents were carefully examined. As was expected, these results are by no means clear but they contain several suggestive features.

In dealing with the individual ascents pairs of curves were examined to ascertain the changes from morning to midday. A morning ascent was taken as one not occurring later than 10h. and a mid-day ascent as one between 12h. and 15h. Only 27 such pairs of curves were found for the whole period and they fall into five classes:—

(*a*) Midday, warmer throughout the ascent.
(*b*) Midday, colder throughout the ascent.
(*c*) Midday, at first warmer, coinciding with the morning curve at one particular height or for a short distance, and then again warmer.
(*d*) Midday, at first warmer, intersecting morning curve, and becoming colder.
(*e*) Midday, at first warmer and then coinciding with morning curve.

Of the 27 cases examined, 6 fell in class (*a*), 1 in (*b*), 3 in (*c*), 7 in (*d*) and 10 in (*e*). The monthly results are given below.

TABLE VII.

—	Mar.	Apl.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.
CLASS *a* ...	2	1	1	–	–	1	–	–	1	–	–
„ *b* ...	–	–	–	–	–	–	–	–	–	–	1
„ *c* ...	–	1	–	–	–	–	1	–	–	–	1
„ *d* ...	–	–	1	–	1	–	2	1	–	1	1
„ *e* ...	1	–	1	1	–	1	1	1	–	1	3

As a general rule, even when the mid-day curves show warmer conditions throughout the ascent they have a steeper gradient from the ground than have the morning curves. In many cases the rapid convergence of the mid-day curve due to its steeper gradient reduces the temperature difference between mid-day and morning to 1a or less at a height seldom exceeding 2k. and often less than 1k. After this the mid-day curve generally diverges slightly from the morning curve, at any rate for a short distance. Thus, in most cases when the mid-day curve shows warmer conditions throughout, its gradient is steeper for a short distance above the ground and then less steep than the morning curve gradient. It seems reasonable to conclude, therefore, that radiation ceases to be effective at quite a short distance above the ground, but there is a layer of the atmosphere immediately above that, in which terrestrial radiation is effective and which forms a minor radiating surface. This is due in all probability to water vapour, which is either in the form of mist or low cloud, or in which the particles are considerably larger than is usual in the air in contact with the earth. The differences in temperature at each half kilometre between mid-day and morning for each of the six cases in class *a* are given in Table VIII. As the mid-day curves show warmer conditions throughout, the

TABLE VIII.—Differences of Temperature between Midday and Morning in Class *a* (*see Table VII.*).

Date.	Heights in Kilometres.										
	0·0	0·5	1·0	1·5	2·0	2·5	3·0	3·5	4·0	4·5	5·0
	Temperatures °C.										
March 18th	1	1	1	1	1	4	3	4	3	5	
March 27th	2·5	4	1	2	2	1	0	2	2	2	
April 22nd	8	4·5	3	2	2	0	2	2	2·5	2	
May 1st	12	5·5	2	2·5	3·5	3·5	3·5	3	1	0·5	
August 16th	1	2	1	1	1	1	4	3·5	2	2	
November 11th	7·5	3·5	2	2·5	2·5	2·5	0·5	0·5	1	3	

differences are all of the same sign. It is interesting to note that in two instances, viz., March 18th and August 16th, the greatest differences occur in the top half of the 5k, whereas in all the other cases the greatest differences are in the lower half. The parallelism of the curves for a greater or smaller part of their course is clearly seen in Table VIII. On May 1st and November 11th Martlesham Heath was in a wedge of high pressure, and on the other dates it was on the border of high and low pressure systems. Although the evidence is far too scanty for the formulation of any general conclusion with regard to this particular type of diurnal change, yet the suggestion that a diurnal change of temperature will be evident at least up to 5·0k. during periods of transition from high to low pressure, or *vice-versâ,* is useful as a working hypothesis. Class *b* (mid-day colder than morning) is represented by one case only in the 27 examined. It would indeed be surprising if there were many cases of this sort, but that they can, and do, occur is worthy of note. Class *c*, which is represented by three cases, is really a modification of class *a*. The three cases occur when Martlesham Heath is on the border of a low pressure system.

Class *d* seems a fairly common type, accounting for seven of the cases. It is associated with various pressure distributions, but is most marked when the centre of a fairly deep depression is either over Norway or the Bay of Biscay.

The commonest type of all is class *e*, claiming 10 of the 27 cases. In this class the steep mid-day gradient soon causes the two curves to coincide. Above this point of coincidence the curves frequently cross one another, deviating but slightly in the intervals. The mean height at which the two curves first cross is 1·1k. The actual heights vary considerably and by no means regularly. The minimum height is 0·3k. and the maximum 2·7k. A height of 0·6k. occurred on three occasions, and of 1·4k. on two occasions. In all probability this is the normal type of change from morning to mid-day. It occurs in most types of pressure distribution, and suggests that the usual increase of temperature experienced on the ground at mid-day disappears rapidly in the free air.

The data were further examined to ascertain, if possible, the changes of temperature between "mid-day" and "evening." There were only 11 days with suitable pairs of ascents, and they were distributed as follows:—May 1st, June 26th, July 2nd and 23rd, August 9th, 10th, 13th. 16th, 25th and 31st, and September 2nd. For the mid-day temperatures any ascent taking place between 11h. and 14h. was taken; the evening ascents not earlier than 17h. 30m. Six of the 11 cases show that the evening was at first colder than mid-day up to an average height of 0·5k. Above this height the evening curves show warmer conditions up to an average height of 1·4k., and then the mid-day and evening curves coincide fairly closely. The changes, therefore, are confined to the bottom 1·5k. of the atmosphere, which bears out the suggestion brought forward in that part of the paper dealing with the monthly mean values. The remainder of the 11 cases consists of pairs of curves showing one of the following conditions:—(*a*) Evening warmer throughout, (*b*) evening colder throughout, (*c*) mid-day and evening practically coinciding throughout. With regard to diurnal changes generally, the following conclusions can be made:—

1. As a general rule, a diurnal change of temperature ceases to exist at an everage height of 1·5k.
2. Cases do occur when the diurnal change is apparent up to 5·0k., and probably higher.
3. As a general rule, morning, mid-day and evening curves approximately coincide above 1·5k.
4. Cases do occur when there is a reversal of the diurnal change, *i.e.*, from the ground, but more often from an average height of 1·5k., mid-day is colder than morning and evening warmer than mid-day.

The data were finally examined from the point of view of inversions of temperature gradient. Inversion of temperature is defined in the Meteorological Glossary (Fourth Issue, p. 164) as an increase of temperature with height. In the following remarks this definition has been widened, and is taken as any temperature gradient that does not show a decrease of temperature with height. This not only includes increases of temperature with height, but also those numerous cases of layers of air of varying thicknesses and of varying heights which are isothermal. The wider definition is justified if, as it should be, an inversion of temperature is regarded as an abnormality in the troposphere.

TABLE IX.—Number of Inversions per Month at various Heights.

Height of Base		Mar.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Total
A	Ground	1	0	7	3	0	1	3	1	2	1	5	24
B	0–1k.	0	2	7	0	3	0	2	0	1	1	1	17
C	1–2	2	2	4	0	3	0	4	0	2	7	2	26
D	2–3	2	2	4	1	2	12	10	2	6	2	10	53
E	3–4	4	1	2	2	4	6	3	1	0	1	2	26
F	4–5	1	0	4	0	0	0	1	0	0	2	5	13
G	Above 5	0	0	0	1	0	0	0	0	0	0	1	2
	Totals	10	7	28	7	12	19	23	4	11	14	26	161

In Table IX inversions have been classified according to the heights of their bases, *i.e.*, the height above the ground at which the temperature curves begin to show either an increase or no change of temperature with height. It will be seen that the greatest number of inversions commenced above 2k. and below 3k. (Class D), and 32 of the 53 cases occurred in August, September and December. Of the 161 observations, 104 fall into classes C, D, and E, and these inversions must be attributed to the lower cloud layer. The small number of inversions included in conditions:—(*a*) Evening warmer throughout, (*b*) evening colder throughout, (*c*) mid-day and evening practically coinciding throughout. With regard to diurnal changes generally, the following conclusions can be made:—

1. As a general rule, a diurnal change of temperature ceases to exist at an everage height of 1·5k.
2. Cases do occur when the diurnal change is apparent up to 5·0k., and probably higher.
3. As a general rule, morning, mid-day and evening curves approximately coincide above 1·5k.
4. Cases do occur when there is a reversal of the diurnal change, *i.e.*, from the ground, but more often from an average height of 1·5k., mid-day is colder than morning and evening warmer than mid-day.

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B	0–1k.	0	2	7	0	3	0	2	0	1	1	1	17
C	1–2	2	2	4	0	3	0	4	0	2	7	2	26
D	2–3	2	2	4	1	2	12	10	2	6	2	10	53
E	3–4	4	1	2	2	4	6	3	1	0	1	2	26
F	4–5	1	0	4	0	0	0	1	0	0	2	5	13
G	Above 5	0	0	0	1	0	0	0	0	0	0	1	2
	Totals	10	7	28	7	12	19	23	4	11	14	26	161

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TABLE X.—Mean Heights of Bases and Tops of Inversions together with Mean Depths, Extremes, and Extreme Depths.

Class (see Table IX)	Mean Height of Base	Mean Height of Top	Mean Depth	Least Height of Base	Greatest Height of Base	Least Height of Top	Greatest Height of Top	Greatest Depth
	k.	k.	k.	k.	k.	k.	k.	k.
A	0·0	0·6	0·6	0·0	0·0	0·3	1·3	1·0
B	0·51	1·16	0·65	0·2	0·85	0·65	1·95	1·25
C	1·52	2·08	0·56	1·0	1·95	1·3	2·85	0·95
D	2·5	2·9	0·4	2·0	2·9	2·3	4·1	1·35
E	3·3	3·7	0·4	3·0	3·95	3·3	4·25	0·65
F	4·3	4·6	0·3	4·0	4·7	4·3	5·0	0·35
G	5·2	5·5	0·3	5·0	5·4	5·3	5·7	0·3

It will be seen from the above Table that the mean depth of the inversion layer is greatest between the ground and 2k., and that the depth of inversion decreases with height. As a general rule, it is approximately 0·5k., but, as the last column shows, it may be as great as 1·35k. In dealing with temperatures in an inversion layer, it seems convenient to introduce the term "intensity of inversion." By this term is meant the difference between the highest and lowest recorded temperatures in an inversion layer. This intensity was generally small (1° to 3° F.), but when the inversion occurred at or near the ground it was not infrequently as great as 5° to 7° F. In no case was the intensity greater than 3° F. in any inversion the height of whose base was greater than 3·0k., and only in a few cases where the height of the base was greater than 2·0k.

The estimation of the persistence of an inversion was rendered difficult owing to the irregularity of the hours and days of observation. In most cases an inversion persists for a comparatively short time, especially in the lowest layers of the troposphere. The normal sequence of events seems to be that one which appears in a morning set of observations has disappeared by the afternoon. It may reappear in the evening. Most of the inversions occur in the morning or evening, but there are a few cases of inversions which make their first appearance in the middle of the day. It is not uncommon for an inversion layer to travel upwards. The observations for December 22nd show this clearly. At 14h. 30m. there was an inversion layer extending from 1·9k. to 2·5k., by 14h. 40m. the dimensions had become 1·9k. to 2·85k., showing an expansion of the top of the layer. Twenty minutes later (15h.) the base was at 2·2k. and the top at 2·8k., showing a rise of the base and a slight depression of the top.