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AN INVESTIGATION INTO THE VARIATION OF THE LAPSE RATE OF TEMPERATURE IN THE ATMOSPHERE NEAR THE GROUND AT ISMAILIA, EGYPT

By W. D. FLOWER, B.Sc., A.Inst.P.

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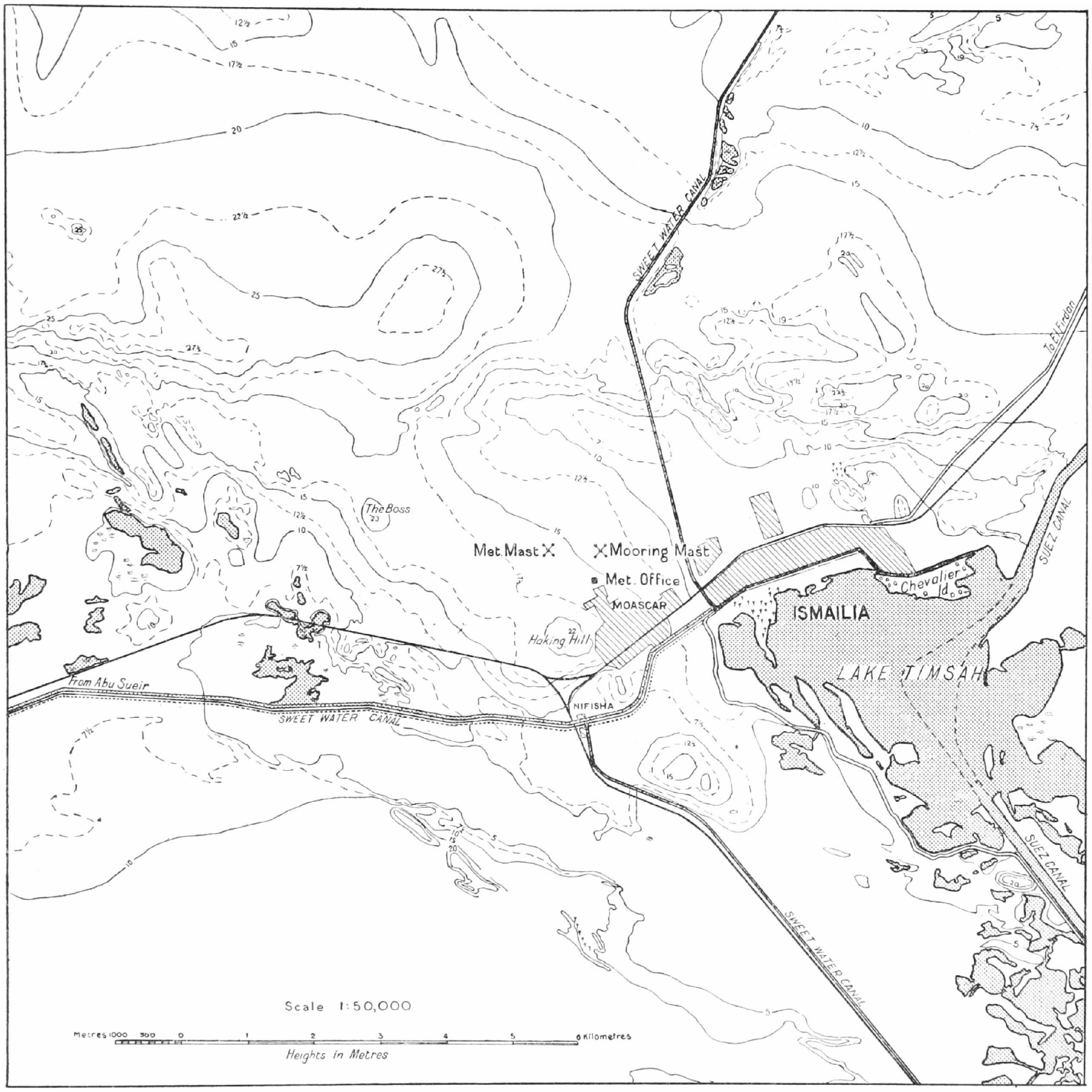

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AN INVESTIGATION INTO THE VARIATION OF THE LAPSE RATE OF TEMPERATURE IN THE ATMOSPHERE NEAR THE GROUND AT ISMAILIA, EGYPT

PART I—INTRODUCTION AND SCOPE OF WORK

§ 1—INTRODUCTION

The lapse rate of temperature in the free atmosphere generally varies between fairly narrow limits but it is well known that near the ground large lapse rates, both positive and negative, are of frequent occurrence. Over the desert areas of Egypt the dry clear air permits of intense insolation by day and a correspondingly large loss of heat by radiation at night and the diurnal variation of temperature is considerably greater than that experienced in the British Isles.

A systematic study of the magnitude and variation of the lapse rate in the atmosphere near the ground on Salisbury Plain has been made by Johnson (1),* who obtained continuous records of the difference in temperature over the intervals of height 1·2m. to 7·1m. and 1·2m. to 17·1m. The variation of temperature at four different heights on the Eiffel Tower, based on a series of hourly observations, has been discussed by Angot (2), Chapman (3) and others. The results of such research are of great importance in connexion with the question of atmospheric stability and are of practical use when applied to the navigation of an airship. Not only from its bearing on aerial navigation is the problem of importance but it is worthy of an experimental investigation for the purpose of checking and supporting theory.

Ismailia, on the shores of Lake Timsah, was to serve as an intermediate landing ground on the airship route to India and arrangements were accordingly made for recording the difference of temperature between the ground and the top of the mooring mast, the height of which was 61 metres. The apparatus erected for the determination of the difference in air temperature between different levels up to 61·0m. has been used for the purpose of the present investigation.

§ 2—SCOPE OF THE PRESENT WORK

A description is given of the installation which was erected for the purpose of supplying information relating to the variation of the lapse rate in the lowest 61 metres of the atmosphere at Ismailia, together with an account of the analysis of the autographic records obtained from the apparatus during the period October, 1931 to October, 1932 inclusive. The information available includes continuous records of the air temperature at a height of 1·1m. and also of the difference in temperature over the intervals of height 1·1m. to 16·2m., 16·2m. to 46·4m. and 46·4m. to 61·0m.

* The numbers in brackets refer to the bibliography on p. 87.

The results discussed below include the diurnal and annual variation of the lapse rates together with their variation under specified conditions of sky. The diurnal and annual variation of temperature at each of the four heights is also considered, while an estimate is made of the diurnal variation at the surface. The relation between vertical gradient of wind velocity, wind velocity and lapse rate are treated in detail so far as the observations available permit. The growth and decay of nocturnal inversions is considered in detail while an analysis of a number of individual charts and special phenomena is also included.

PART II—INSTRUMENTS

§ 3—INSTRUMENTAL EQUIPMENT

(*a*) *General.*—The equipment is similar to that employed by Johnson (1) for his investigation of the conditions on Salisbury Plain. The installation was erected in 1928 but the interpretation of the earlier records was doubtful owing to instrumental errors and these records have not been considered. Various alterations were made to the installation between 1929 and 1931, and a continuous set of reliable records was obtained from October, 1931 to October 12, 1932 inclusive.

(*b*) *Site.*—The site of the installation, as mentioned above, was the Airship Base near Ismailia, on the western shore of Lake Timsah, which connects the northern and southern sections of the Suez Canal. The position of the installation relative to the surrounding country is shown on the accompanying map (Fig. 1). The position of the tower carrying the instruments for measuring temperature (Met. Mast) is 760m. due west of the airship mooring mast and 755m. bearing 53° west of north from the Meteorological Office, where the recording instrument was housed. This office was fully equipped with standard meteorological instruments and the enclosure, where normal records of temperature and relative humidity were made, was on the south-west side of it.

The chief topographical features of the country surrounding the installation are the lake 3Km. to the south-east and a low ridge which runs roughly east and west for about 6·5Km. to the north-west of, and at a distance of between 5Km. and 8Km. from, the tower. Two spurs run out from this ridge, one towards east-south-east and the other towards south-east, and the installation is situated on the north-east slope of the latter. The highest points on this spur are The Boss (23m.) bearing west by north at a distance of 2·8Km., and Hacking Hill (22m.) bearing south by east at a distance of 1·5Km. The top of the spur is 1Km. from the tower and the mean downward slope of the ground towards the north-east is 1 in 250 for about 3·2Km. when it rises again to the second spur before finally falling away to sea level at Lake Menzaleh. To the east of the Suez Canal the land rises rapidly to a general level of over 100m. at a distance of under 25Km. from the instrument.

The exposure of the thermometer elements is excellent in all directions. Between the north-north-east and east-north-east the horizon is formed at a distance of about 2Km. by a plantation of trees (tamarisk and eucalyptus) the heights of which are from 10m. to 15m. The buildings of the Moascar garrison extend from east-north-east to south-south-east at an average distance of 1·5Km. although one group of single storied buildings lies 1Km. south-east of the tower. In the other directions (south-south-east through north to north-north-east) there is open desert.

(*c*) *Installation Tower.*—A latticed steel tower, a photograph of which is given in Fig. 2, carried the louvred screens containing the temperature measuring elements. The screens on the tower were mounted at the extreme ends of platforms at heights of 61·0m., 46·4m. and 16·2m. and projected 2·8m. from the north side of the tower. Two other screens were mounted on a small subsidiary support (Fig. 3) at a height of 1·1m. above the ground. The instruments were placed on the north side of the tower so as to face the prevailing wind and improve the exposure. The tower was painted black and white, and in order to minimise radiation effects no member was painted black on both sides. The aspiration plant and junction boxes for the electrical connexions were installed on the platforms in addition to the screens. At the extreme top of the tower a wind vane and a Robinson cup anemometer were

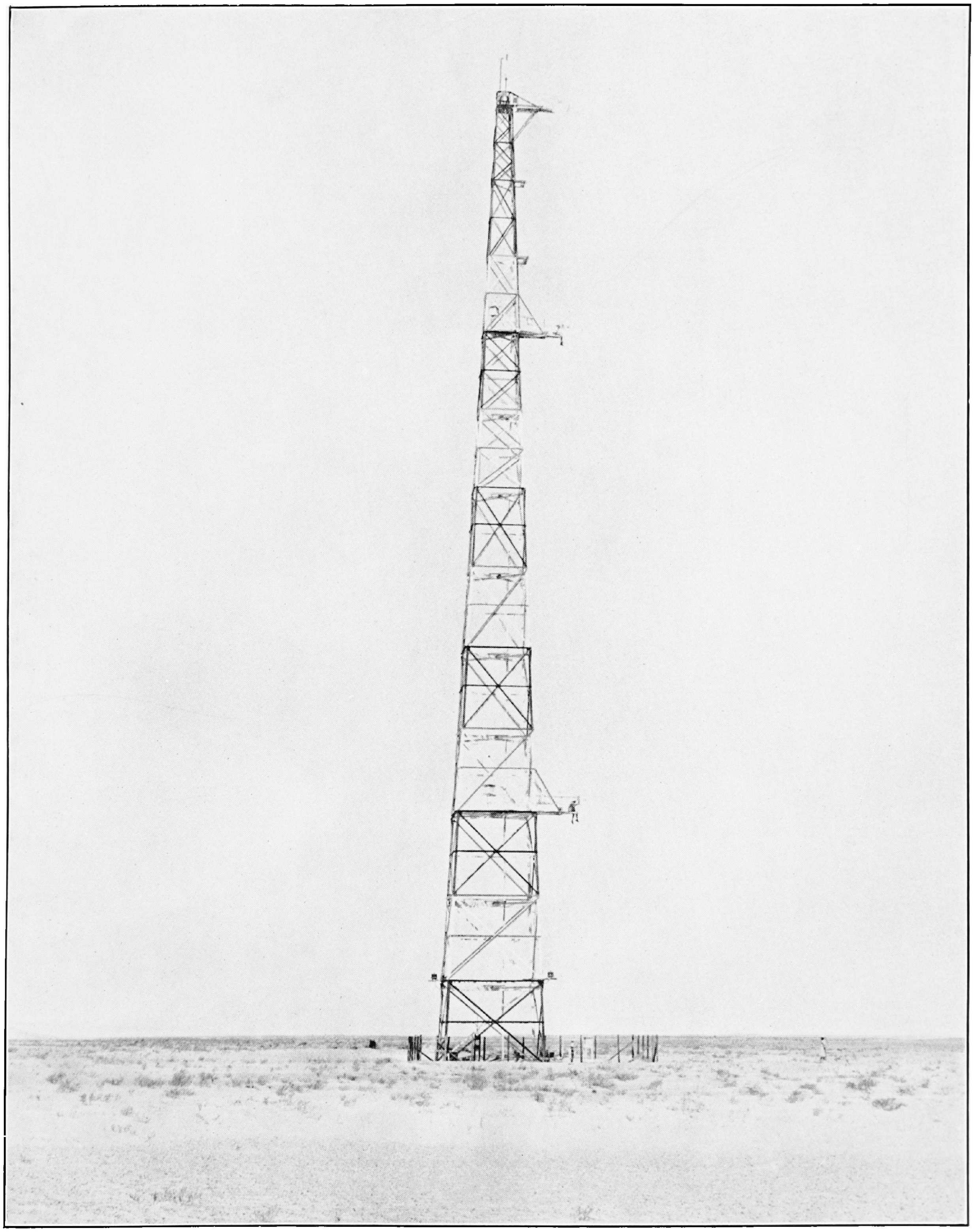

FIG. 2.—THE INSTALLATION TOWER

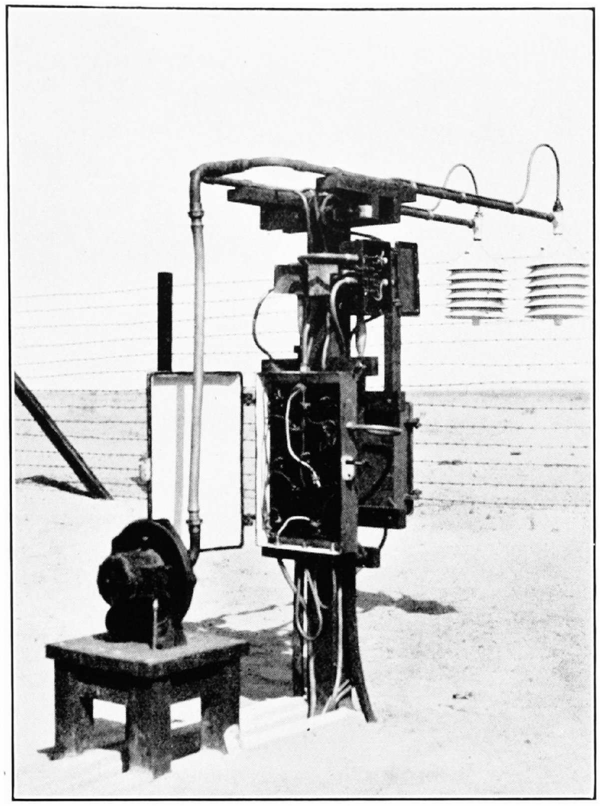

FIG. 3.—ELEMENT SUPPORT AT 1·1m

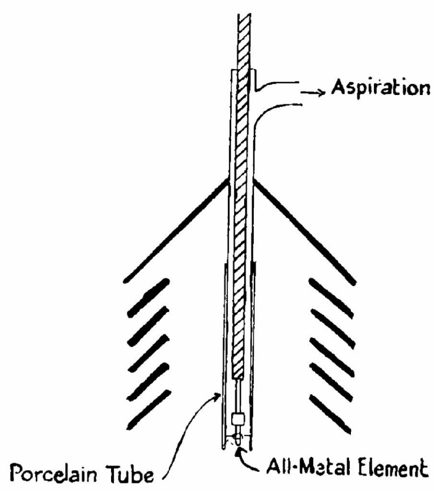

FIG. 5.—DIAGRAMMATIC CENTRAL SECTION OF ELEMENT AND LOUVRED SCREEN

mounted, the former of which projected 3·3m. above the upper platform and the latter 2·1m. above the platform and 62·6m. above the ground. The wind vane was for direct observation only but the anemometer was connected to a buzzer in the Meteorological Office. A small enclosure surrounded the base of the tower and in it a small Stevenson screen was placed in which to expose maximum and minimum thermometers in order to provide check readings for the temperatures recorded by the element at 1·1m. above the ground.

(*d*) *Temperature-Measuring Instruments.*—Platinum resistance thermometers, kept continually aspirated, were used for measuring the temperature which was registered by means of electrical connexions on a recorder in the Meteorological Office. Each resistance element consisted of a coil of platinum wire wound non-inductively on a porcelain former and enclosed in a brass sleeve. The construction of one of these elements is shown in Fig. 4, the resistance winding being contained in the " bulb " on the thin-walled stem. The thin-walled tube extending beyond the bulb was used as a guide plug in connexion with fixing the element in position in the

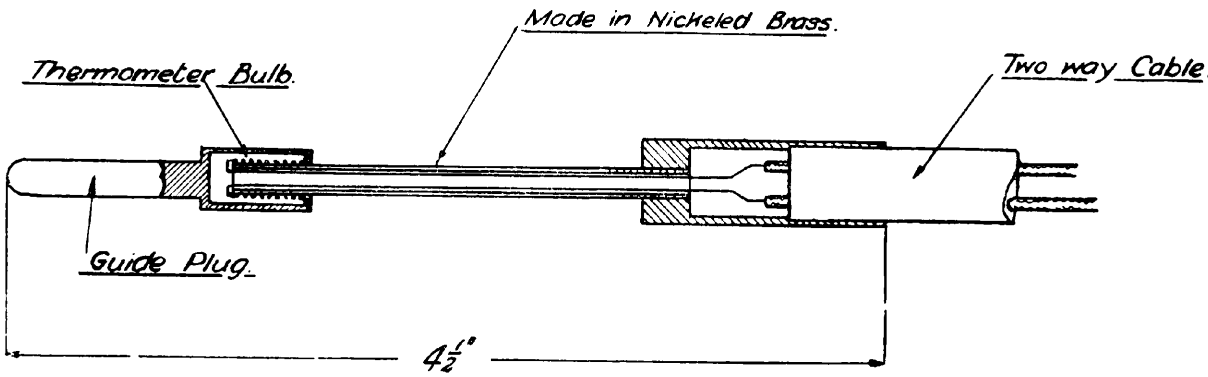

FIG. 4.—SPECIAL RESISTANCE THERMOMETER

screen. The two ends of the platinum coil were joined to gold leads and these were fixed to copper conductors in the two-core lead-covered cable which connected each element to the main leads of the recorder. The resistance of each element was approximately 109 ohms at 0°C., and increased at the rate of 0·4 ohms per 1°C.

(*e*) *Louvred Screens for the Thermometer Elements.*—In the conditions which prevail in Egypt special attention had to be given to the exposure of the elements. Each element was protected from radiation by being mounted in a porcelain tube (2·39cm. diameter) placed in a white enamelled louvred screen of special shape. The louvred screens consisted of five copper rings surmounted by a cone and supported in position from the top of the central tube. A diagrammatic central section of the final arrangement is shown in Fig. 5 and the external appearance may be seen from Fig. 3. The element was placed so that the end of its casing was about 0·65cm. from the open end of the tube and was kept central by means of a small " spider." The connecting lead to the element was carried straight out of the screen through a packing gland at the top while aspiration was effected through a branch tube.

(*f*) *Aspiration of the Thermometer Elements.*—A constant ventilation of the thermometer elements was maintained by means of small motor blowers, one of which can be seen in the foreground of Fig. 3. The motors were three phase, and commutator trouble was thereby avoided. One blower was mounted on each platform to aspirate the thermometer element exposed there but the two thermometer elements exposed at 1·1m. were served by the same blower. The suction side of each blower was connected to the appropriate louvred screen by an iron pipe approximately 2·0cm. diameter and about 2·4m. long, the connexion at the screen being effected by means of a pitcher—**T** as shown in Fig. 5. Any interruptions in the aspiration would make the records of temperature and temperature difference erroneous and as electric power is by no means infallible a device to detect power failure, and consequently the cessation of aspiration, was installed. This consisted of an open range thermograph which recorded the temperature above an electric lamp included in the power circuit. Any interruption of the power was represented by a sharp discontinuity on the thermograph trace and therefore could be easily detected.

(*g*) *Electrical Circuits.*—The electrical circuit employed for recording the air temperature at 1·1m. is shown in Fig. 6 and that for the temperature differences in Fig. 7. Both are simple Wheatstone bridge circuits. In the former the resistance of three arms " a, b and c " was fixed and the thermometer element formed the fourth arm, but in the latter only two arms were of fixed resistance and the thermometer elements at the heights over which the temperature difference was to be measured formed the other two arms of the bridge. Provision was made for both circuits to be tested for scale reading and for this to be adjusted. The leads connecting the thermometer elements were compensated by being arranged in the manner shown in the circuit diagrams (Figs. 6 and 7). In the temperature system the leads were duplicated, one pair was connected to the element and with resistance " e " formed one arm of the bridge while the other pair of leads in series with resistance " c " formed another arm. In the differential system compensation was obtained by employing a five-lead method of wiring with the connexions so arranged that whichever pair of elements was in circuit the total length of leads in each arm of the bridge was constant.

(*h*) *Recording Instrument.*—The recorder, which was of the thread type manufactured by the Cambridge Instrument Company, was placed in the Meteorological Office at a distance of 755m. from the tower. This instrument comprised the Wheatstone bridge circuits described above together with two galvanometers mounted side by side. These were swinging free so that any errors due to friction between pen and chart were eliminated. One galvanometer was used for recording the temperature of the air at 1·1m. above the ground and the other was used to give three separate records on a single chart, viz. :—

(i) The difference in temperature between the thermometer element at 1·1m. and the thermometer element at 16·2m.

(ii) The corresponding difference for the levels 16·2m. and 46·4m.

(iii) The corresponding difference for the levels 46·4m. and 61·0m.

These three records were made in different colours by the depression at regular intervals of the galvanometer pointer by means of a chopper bar. A thread impregnated with coloured ink was stretched between the pointers and the chart and the recorder mechanism arranged for the coloured thread, appropriate to the reading to be recorded, to be in position below the chopper bar. The threads were coloured green, black and red and a dot of each colour was made normally every three minutes although the chopper bar could be arranged to fall every half-minute. The resulting records thus consisted of a series of dots, one every minute in the case of the air temperature at 1·1m. above the ground and one every three minutes for each of the other readings. The normal time scale of the chart was 12·75mm. to the hour but this could be adjusted to either 25·50mm. or 153·00mm. At right angles to the time scale the chart was divided into two parts ; on one part the air temperature at 1·1m. was recorded in the three colours and on the other part the difference between the air temperature at a height of 1·1m. and 16·2m. was recorded in green, that between 16·2m. and 46·4m. in black, and that between 46·4m. and 61·0m. in red. The scale range available on the temperature side was 30°F. (—1·0°C.) to 130°F. (54·4°C.). On the differential side the zero position was at the centre of the chart rulings and the galvanometer was adjusted to record a difference in temperature of 10°F. on either side of zero. The scale value for a mean air temperature of 75°F. (24°C.) was 4·75mm. per 1°F. Increasing the resistance in series with the galvanometer by opening the range switch (see Fig. 7) enables the range to be adjusted to a difference of 20°F. on either side of zero, and in this case the scale value for a mean air temperature of 75°F. was 2·875mm. per 1°F.

§ 4—POSSIBLE CAUSES OF INACCURATE RECORDS

(*a*) *Rate of Aspiration.*—The effect on a thermometer element of a current of air flowing past it will depend on the velocity of the air stream. The air flow in the annular space between the element bulb and the porcelain tube was determined

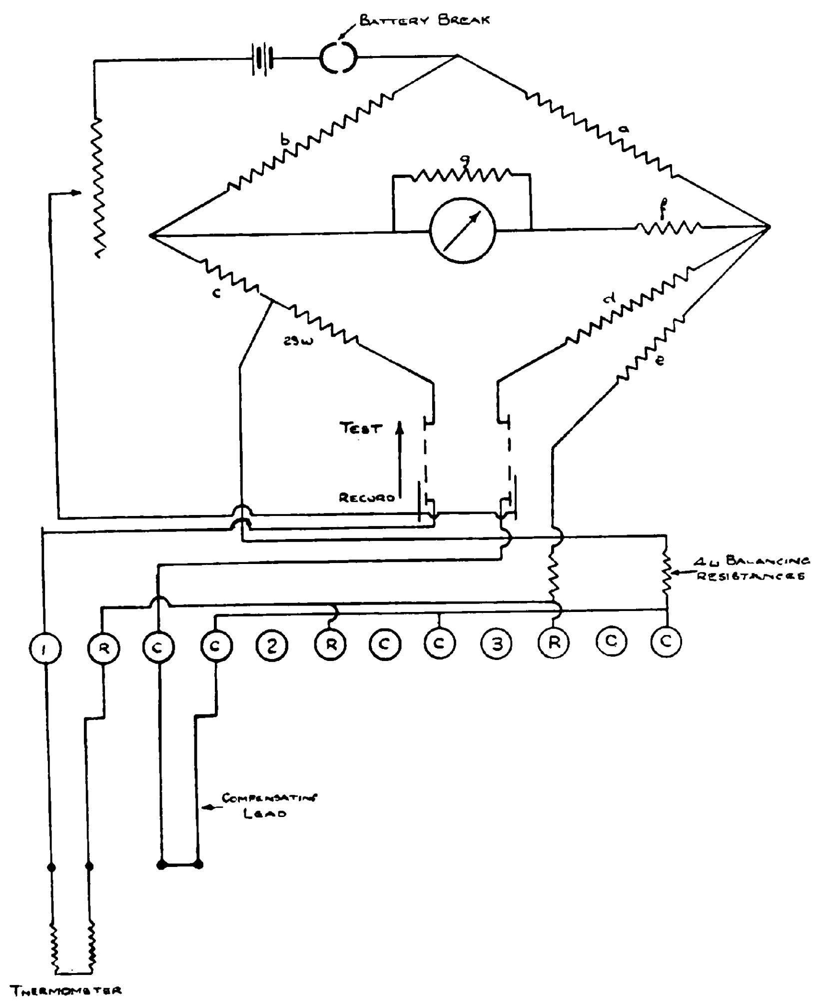

FIG. 6.—CAMBRIDGE RECORDING DISTANCE THERMOMETER, COMPENSATED TYPE

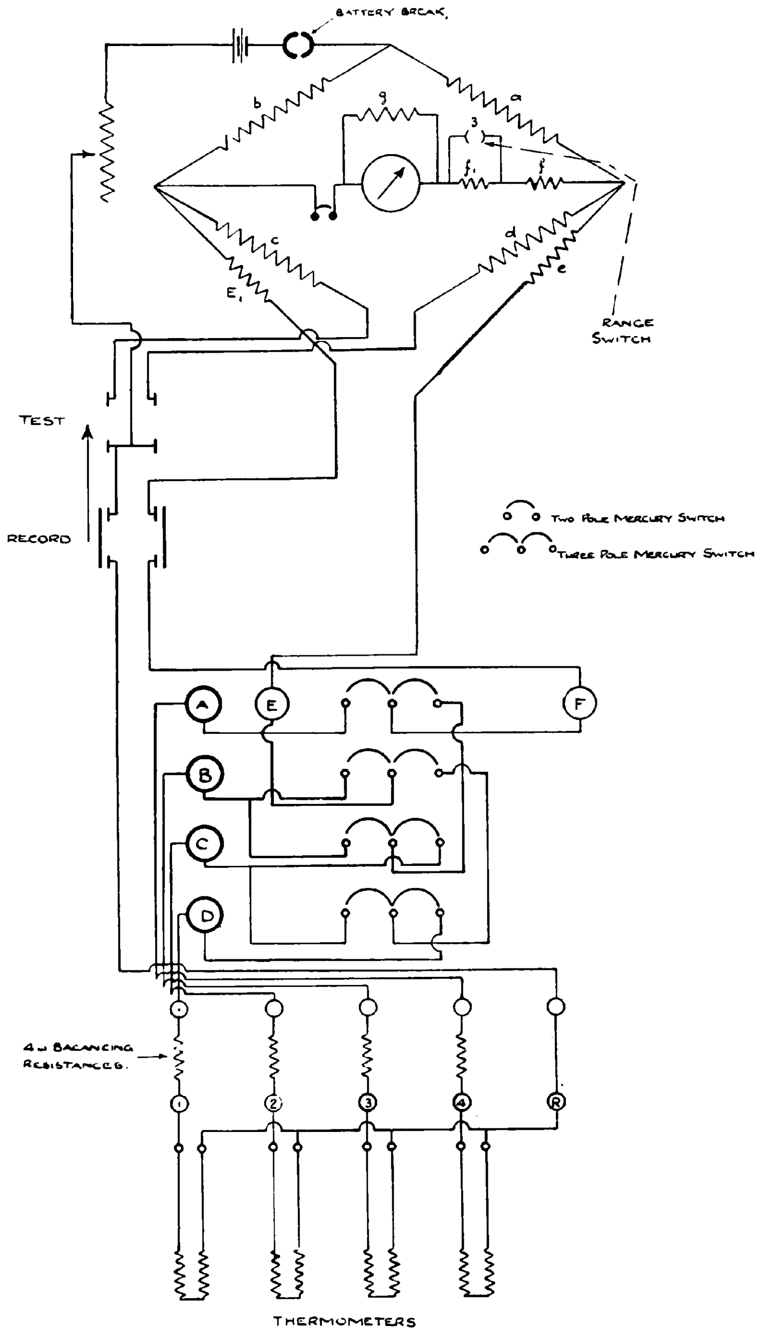

FIG. 7.—CAMBRIDGE RECORDING DISTANCE THERMOMETERS FITTED WITH SPECIAL MERCURY SWITCH GEAR, DIFFERENTIAL TYPE

experimentally and the values were found to depend upon the wind velocity. The results of determinations for different values of the wind velocity at a height of 15·2m. are given in Table 1.

TABLE I—RATE OF ASPIRATION IN METRES PER SECOND FOR A SPECIFIED WIND VELOCITY

Height of louvred screen	Wind velocity at 15·2m. in m./sec.				
	0	2	5	7	10
metres					
61·0	6·0	6·4	7·1	7·6	8·0
46·4	5·5	6·0	6·8	7·3	7·8
16·2	4·4	4·8	5·4	5·9	6·3
1·1	3·8	4·2	4·9	5·4	5·8

Pressure reduction in the air just past the bulbs of the elements was measured by Johnson (1) and found to be about 3mm. of water for an air flow of 8m./sec. This pressure reduction corresponds with an adiabatic cooling of 0·05°F. so that the error involved due to different rates of aspiration between the extreme values in the above table will be less than 0·02°F. and may be neglected.

(*b*) *Intermittent Heating of the Elements.*—The heating of the thermometer elements by the current passing through them may affect the temperatures recorded. Reference to Fig. 7 will show that the heating effect is not the same for all elements ; the elements at 1·1m. and 61·0m. will be heated for one minute in three while those at 16·2m. and 46·4m. will have a current flowing through them for two minutes in three. Further, when the temperature difference for each of the height intervals 16·2m. to 46·4m. and 46·4m. to 61·0m. is recorded the lower element will have been in circuit for two minutes but the upper element for only one minute, whereas in the case of the height interval 1·1m. to 16·2m. both elements will have been in circuit for one minute only. Johnson (1) found that for metal elements, similar to those used in the present investigation, the rise of temperature after one minute was 0·39°F. and a steady value of 0·43°F. was reached in two and one half minutes. Thus an element which was continuously in circuit would acquire a temperature not more than 0·04°F. above that of an element which was heated for only one minute. Reference to the curves obtained by Johnson for rise of temperature plotted against time of current flow in minutes shows that after being heated for two minutes the temperature of an element would have risen 0·41°F. so that the possible error due to the intermittent heating of the elements will not be greater than 0·02°F.

(*c*) *Effect of Radiation.*—The lead-covered cable fitted to each element was exposed to sunshine after it left the screen, and conduction of heat from the exposed portion of the cable down the metal casing and the electrical leads which connect with the resistance winding might have been a source of error. The cable after leaving the screen was painted white and it has been shown (1) that under these conditions the probable error is very small. It was assumed that the effect of painting black one side of some of the lattice members of the mast would be negligible owing to the extreme openness of the structure and consequent good ventilation. In order to confirm this assumption a series of readings was taken of the temperature of the air adjacent to different members of the mast when they were under the influence of direct sunshine. The results (Table II) show that the temperature of the air drawn off the black surface was approximately the same as that of the air drawn off a white surface. The temperature of the air adjacent to members of different colours was obtained by placing an Assman psychrometer at right angles to the member, with its air intake 0·25cm. away from the surface, and orientated so that the thermometers were shielded from the direct rays of the sun.

TABLE II—TEMPERATURE OF AIR DRAWN OFF IRON GIRDERS PAINTED DIFFERENT COLOURS COMPARED WITH THE AIR TEMPERATURE AT A HEIGHT OF 1·1 METRES

Painting scheme of the members	Dimensions of cross section	Colour of surface in sun	Colour of surface against which temperature was read	Height at which readings were taken	Mean wind velocity at 15·2m.	Temperature of air from surface of member minus air temperature at 1·1m.
	cm.			m.	m/sec.	°F.
White	Junction box	White	White in sun	0·9		+7·1
Black and white	12·7×12·7×1·3	Black	Black	1·5	2·7	+7·0
do.	do.	do.	White	1·5		+5·8
do.	do.	White	Black	1·5		+6·4
Black and white	10·2×7·6×0·6	White	White	1·5		+4·7
do.	do.	Black	do.	1·5		+5·1
do.	do.	do.	Black	1·5	4·5	+4·6
do.	do.	White (partially)	do.	1·5		+2·5
White	7·6×7·6×0·6	White	White in shade	1·5		+2·8
Black and white	10·2×7·6×0·6	Black	Black in sun	1·5		+2·9
do.	12·7×12·7×1·3	White (partially)	Black	1·5	6·7	+1·1
do.	do.	Part white / Part black	Black in shade	0·1		+7·0
..	sand	..	..	0·6cm.		+9·8

§ 5—CALIBRATION

It will be realised from the foregoing that it was necessary to calibrate and check the zeros of the instrument when the elements were functioning in their normal manner. Calibration was carried out by direct comparison between the recorder traces and simultaneous readings taken on Assman psychrometers. Ideal weather conditions for such comparisons would be an overcast sky with a fairly strong wind but as these conditions are seldom realised at Ismailia occasions had to be chosen when the lapse rate was steady and the change in the lapse rate was small and fairly constant. This condition is fulfilled, with a few exceptions, by a period of about one hour before, to about one half-hour after sunset. For any pair of elements to be calibrated a series of ten observations at three minute intervals was made both on the recorder and also with the Assman psychrometers, placed with the thermometer bulbs at the same level as the resistance coil in the element. The correction to the recorder trace was deduced from the mean of these readings and either the differential traces were adjusted to agree approximately with the temperature differences over each interval of height thus obtained, or the tabulated values adjusted accordingly. It was not possible to adjust the dry bulb trace to read correctly to within less than 0·2°F. and in practice the correction was frequently allowed to be larger than this. In order to have a daily check on the readings of the dry bulb trace the maximum and minimum temperatures were read each day from instruments exposed in a Stevenson screen situated 4·0m. west of the element and at a height of 1·1m. above the desert.

PART III—DISCUSSION OF RESULTS

§ 6—MEAN HOURLY VALUES OF THE LAPSE RATE

As previously mentioned the recorder gives four traces on one chart, namely the dry bulb reading at 1·1m. on one half of the chart and on the other half the difference in temperature between heights of 1·1m. and 16·2m., 16·2m. and 46·4m., and 46·4m. and 61·0m. The three differential traces will be denoted by I, II and III where trace I refers to the lowest height interval. All temperatures have been reduced to degrees centigrade, temperature differences have been converted into lapse rates in degrees centigrade per 100 metres, and east European (or zone) time (two hours

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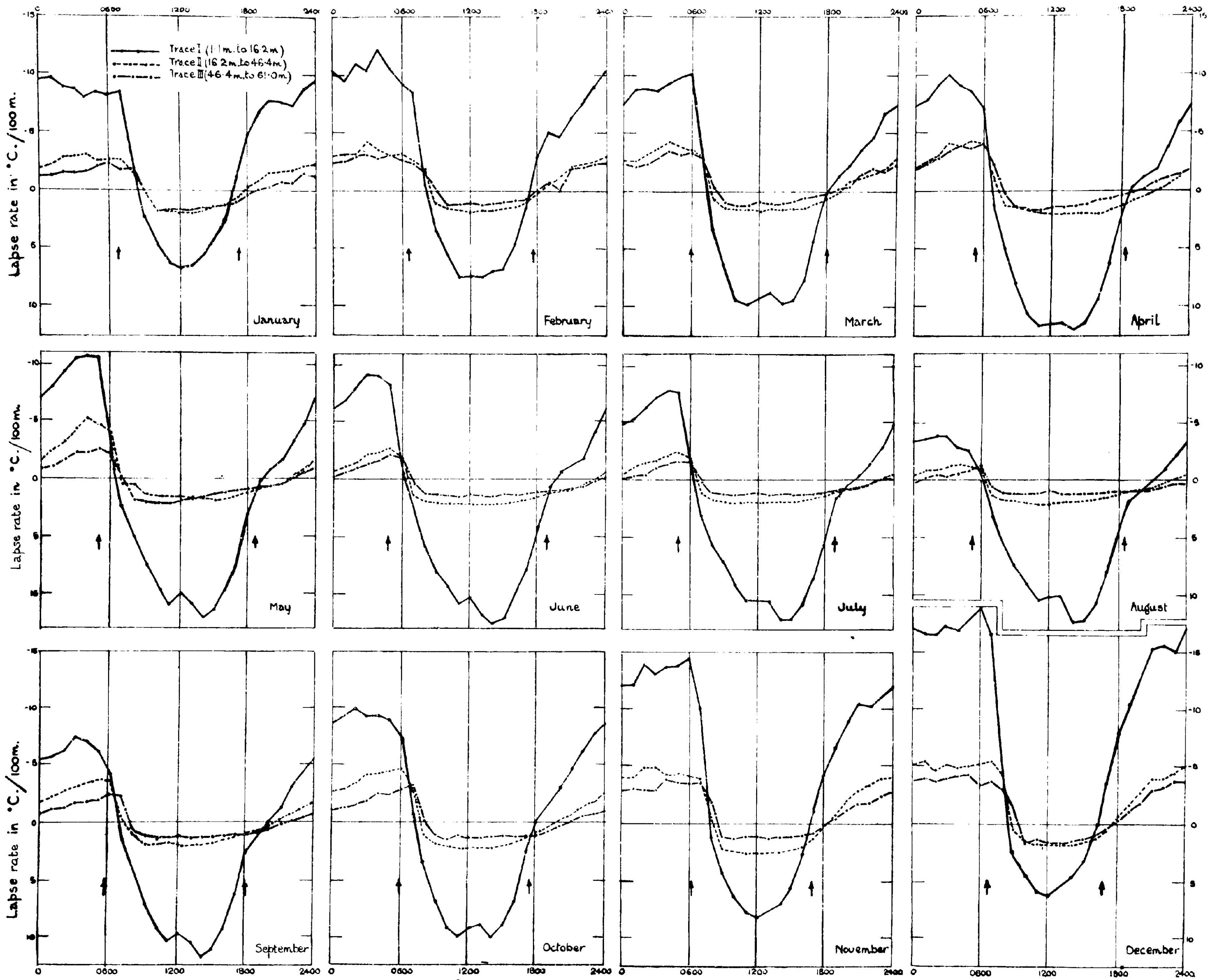
Plate V.



NOTE - Arrow heads indicate times of sunrise and sunset for middle day of month. Times are zone time.

FIG. 8. MEAN DIURNAL CURVES SHOWING LAPSE RATES OF TEMPERATURE IN THE AIR BETWEEN HEIGHTS OF 1·1m. AND 16·2m. (FULL CURVE), 16·2m. AND 46·4m. (BROKEN CURVE) AND 46·4m. AND 61·0m. (DOT-DASH CURVE).

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fast on G.M.T.) is used throughout. Local time at Ismailia is 9 minutes fast on zone time so that local noon occurs at 1151 zone time. Hourly values for the period October, 1931 to October 12, 1932 are used for the present discussion. The value assigned to each hour is the mean value over an interval of twenty minutes centred at the hour in question and normally this can be estimated directly by the aid of a suitably ruled glass scale. When the temperature differences exhibited rapid changes the practice was adopted of reading off the numerical value for each dot over the twenty minute period and obtaining the mean of these values.

The mean hourly values of the lapse rate for each month are given in Table III and are represented graphically in Fig. 8. Before considering these results there are certain points which should be borne in mind. The mean monthly curves will seldom, if ever, be reproduced by individual traces, as exceptional lapse rates on particular days will give rise to irregularities in the curves for each month. The irregularities, however, are likely to be smaller than those in England owing to the greater regularity of occurrence of various phenomena in Egypt. The effect due to the change of times of sunrise and sunset in the course of the month will also be less marked than in England.

§ 7—CURVES OF MEAN DIURNAL VARIATION OF THE LAPSE RATE

The curves of mean diurnal variation are given in Fig. 8 and the outstanding features exhibited by the curves for each month will now be discussed. The salient features of all the curves are an inversion until after sunrise, a rapid change over to adiabatic or superadiabatic conditions followed after about local noon by a decrease in the lapse rate, and the development of an inversion again in the evening.

Considering the curves for January the outstanding feature is the preponderance and magnitude of the temperature inversion especially in the case of the lowest height interval. An inversion is recorded by trace I on an average for nearly sixteen hours (1640—0830) and its value is between 7·5°C./100m., and 9·5°C./100m. for over eleven hours (1930–0700), by trace II for approximately fifteen hours (1740–0850) and by trace III for fourteen hours (1850–0850). The values of the inversion recorded by traces II and III are much smaller than in the case of trace I ; for trace II the inversion does not exceed 3·1°C./100m. while the upper limit for trace III is 2·3°C./100m. After 0700 trace I exhibits a sudden decrease in the value of the inversion followed by the rapid development of superadiabatic conditions. The change is less rapid and commences slightly later in the case of trace II, although the change occupies about the same time as in the case of trace I, but trace III records a nearly steady inversion until 0800 which is followed by a rapid change over to an approximately steady lapse. The change over to a lapse is completed at about the same time, 1000, in both cases. The most rapid development of superadiabatic conditions below 16·2m. occurs before 1000 but thereafter the lapse rate continues to increase at a continually decreasing rate until approximately local noon when it commences to decrease, very slowly during the first hour, and gives way to an inversion about one hour in advance of sunset. The lapse rate recorded by traces II and III exhibits only minor fluctuations from 1000 to 1500 but thereafter it gradually decreases and gives way to an inversion soon after sunset ; zero lapse rate is recorded by trace II roughly at the time of sunset and by trace III one hour later. The chief difference between traces II and III is that the former shows a slight increase in lapse rate between 1000 and 1300 ($<0·5$°C./100m.) while the latter is sensibly constant over the same period. The growth of the inversion becomes less rapid after sunset. Each trace crosses the other two twice in the course of twenty-four hours and in such an order as to infer that the cause of the development of either an inversion or a lapse is propagated upwards from the ground. Thus at the breakdown of the nocturnal inversion trace I crosses trace II at 0816 and trace III at 0820. The values given in Table III show that at local noon in winter the mean lapse rate between heights 1·1m. and 16·2m. is nearly seven times the dry adiabatic value (1°C./100m. equals the dry adiabatic lapse rate approximately). This lapse rate decreases rapidly with height and is barely twice the adiabatic value between 16·2m. and 46·4m. and only about 1·5 times the adiabatic value between 46·4m. and 61·0m.

The curves for the other months exhibit a similar sequence of changes to those

TABLE III—MEAN HOURLY VALUES OF THE LAPSE RATE IN DEGREES CENTIGRADE ON RECORDS FOR THE PERIOD

Height interval	Month \ Hour, Zone Time	1	2	3	4	5	6	7	8	9	10	11
Height interval 1·1m. to 16·2m. Trace I	Jan.	−9·74	−9·01	−8·90	−8·12	−8·54	−8·35	−8·60	−2·61	2·17	4·67	6·14
	Feb.	−9·52	−11·11	−10·41	−12·32	−10·67	−9·42	−8·50	−0·66	3·38	5·44	7·43
	March	−8·79	−8·98	−8·79	−9·45	−9·93	−10·18	−3·27	3·13	6·32	9·34	9·72
	April	−7·98	−9·16	−10·04	−9·16	−8·68	−7·02	1·14	4·96	7·91	10·45	11·50
	May	−8·09	−9·34	−10·51	−10·70	−10·55	−2·72	2·24	4·96	7·32	9·30	10·81
	June	−6·99	−8·24	−9·12	−9·01	−8·42	−0·44	2·87	5·81	8·02	9·38	10·77
	July	−5·33	−6·33	−7·28	−7·91	−7·69	−1·43	3·16	5·63	6·99	9·12	10·44
	Aug.	−3·57	−3·90	−3·79	−2·87	−2·57	−0·37	3·13	5·44	7·43	9·01	10·37
	Sept.	−5·63	−6·18	−7·24	−6·99	−6·14	−4·71	1·47	4·08	7·02	9·30	10·45
	Oct.	−9·27	−9·90	−9·34	−9·31	−8·87	−7·21	−0·70	3·35	6·70	9·16	10·00
	Nov.	−12·13	−13·90	−13·05	−13·71	−13·82	−14·45	−9·97	1·10	4·27	6·29	7·69
	Dec.	−16·58	−16·55	−17·25	−16·99	−17·87	−18·94	−16·58	−4·52	2·46	4·38	5·77
Height interval 16·2m. to 46·4m. Trace II	Jan.	−2·17	−2·87	−2·93	−3·07	−2·56	−2·67	−2·67	−1·53	0·28	1·53	1·75
	Feb.	−3·17	−3·26	−4·26	−3·61	−3·17	−3·24	−2·69	−1·88	0·94	1·42	1·55
	March	−2·62	−3·19	−3·68	−4·29	−3·83	−3·52	−2·78	0·61	1·29	1·40	1·45
	April	−2·52	−3·15	−4·11	−3·92	−4·29	−4·18	−0·94	1·09	1·31	1·64	1·71
	May	−2·56	−3·31	−4·44	−5·30	−4·81	−4·13	0·37	0·48	1·29	1·42	1·49
	June	−1·01	−1·16	−2·21	−2·38	−2·73	−1·82	1·49	1·90	2·08	2·12	2·17
	July	−1·01	−1·44	−1·60	−2·10	−2·38	−1·92	1·14	1·73	1·88	2·04	1·92
	Aug.	−0·79	−0·83	−1·16	−1·29	−1·22	−0·81	1·29	1·73	1·82	1·99	2·06
	Sept.	−2·21	−2·69	−3·04	−3·37	−3·67	−3·56	−0·44	0·99	1·77	1·86	1·71
	Oct.	−2·84	−3·35	−4·05	−4·14	−4·38	−4·64	−2·93	1·01	1·77	2·01	2·30
	Nov.	−3·91	−4·77	−4·77	−4·18	−4·24	−4·02	−3·85	−0·52	2·21	2·36	2·58
	Dec.	−5·32	−4·64	−5·01	−4·83	−4·94	−5·08	−5·34	−4·25	0·33	1·47	1·66
Height interval 46·4m. to 61·0m. Trace III.	Jan.	−1·25	−1·56	−1·44	−1·63	−2·09	−2·28	−1·74	−1·86	0·27	1·56	1·59
	Feb.	−2·62	−3·03	−3·19	−2·84	−3·26	−2·69	−2·39	−1·63	−0·11	1·06	1·02
	March	−2·09	−2·31	−2·88	−3·49	−3·19	−3·41	−2·84	−0·46	0·83	1·10	1·06
	April	−2·47	−2·77	−3·49	−3·95	−3·72	−4·10	−2·28	0·15	1·25	1·44	1·59
	May	−1·14	−1·71	−2·31	−2·31	−2·62	−2·20	0·00	1·82	1·97	2·09	2·09
	June	−0·53	−0·95	−1·33	−1·56	−2·16	−1·78	0·34	1·25	1·29	1·48	1·52
	July	−0·30	−0·42	−1·02	−1·33	−1·56	−1·52	0·15	1·06	1·18	1·29	1·21
	Aug.	−0·11	−0·38	−0·27	−0·57	−0·76	−1·29	0·53	1·06	1·10	1·14	1·10
	Sept.	−1·18	−1·29	−1·74	−1·78	−1·97	−2·47	−2·28	0·65	1·02	1·21	1·21
	Oct.	−1·33	−1·56	−1·82	−2·50	−2·39	−2·77	−3·19	−0·15	1·06	1·44	1·02
	Nov.	−2·96	−2·81	−2·81	−3·72	−3·49	−3·41	−3·49	−1·78	1·06	1·29	1·06
	Dec.	−3·95	−3·57	−3·91	−4·10	−4·25	−3·30	−3·57	−3·00	−1·52	1·52	1·33

described for January although the relative duration of the various features and their magnitude vary from month to month. During February and March the nocturnal inversion reaches a greater value than in January for each height interval. The value of the inversion recorded by trace I is greater in February (12·32°C./100m.) but traces II and III attain similar values, approximately 4·3°C./100m. and 3·3°C./100m. respectively, during both months. In the case of trace I the midday lapse progressively increases but for traces II and III there is no appreciable change although the values reached are less than those recorded in January. In April the nocturnal inversion is of the same magnitude as for March but now all three traces exhibit an increase in the midday lapses although the time of occurrence of the maximum value differs for each curve. The May curves exhibit characteristics which differ from those of any other month. The value of the nocturnal inversion has increased between 1·1m. and 46·4m., the increase being greater between 16·2m. and 46·4m. while a decrease is shown between 46·4m. and 61·0m. In the case of the lowest height interval the nocturnal inversion commences to break down at 0500 and at about 0600 for the two other intervals (traces II and III). The subsequent rate of change of the lapse rate is similar to that for the previous months, namely

PER 100 METRES OVER THREE HEIGHT INTERVALS FOR EACH MONTH, BASED OCTOBER, 1931 TO OCTOBER, 1932

12	13	14	15	16	17	18	19	20	21	22	23	24
6·55	6·44	5·59	4·27	2·46	−1·25	−4·93	−6·84	−7·80	−7·69	−7·43	−8·79	−9·64
7·32	7·32	6·77	6·62	4·52	1·25	−2·94	−5·18	−4·74	−6·47	−7·58	−9·16	−10·45
9·30	8·75	9·64	8·94	7·61	3·09	0·0	−1·47	−2·24	−3·68	−4·63	−6·88	−7·50
11·47	11·33	11·84	11·33	9·42	6·10	1·87	−0·40	−1·21	−1·91	−3·75	−5·84	−7·36
9·96	10·70	11·95	11·29	9·60	7·18	3·03	0·37	−0·70	−1·62	−3·31	−4·74	−7·18
10·30	11·70	12·50	12·10	10·81	7·87	4·16	0·59	−0·63	−1·29	−2·32	−4·19	−6·06
10·48	10·55	12·06	12·02	10·88	8·68	5·30	1·65	0·48	−0·33	−1·36	−2·79	−4·78
10·18	10·11	12·28	12·17	10·52	7·80	4·23	1·82	0·77	−0·07	−0·96	−2·17	−3·46
9·78	10·52	11·77	11·17	9·42	6·10	2·61	1·03	−0·11	−1·43	−3·05	−4·27	−5·41
9·27	8·94	10·04	8·98	6·92	2·65	−0·07	−1·62	−3·13	−4·67	−6·11	−7·65	−8·54
8·13	7·61	6·95	5·63	2·91	−1·10	−4·23	−6·44	−8·57	−10·48	−10·26	−11·14	−12·02
6·07	5·22	4·52	3·16	0·77	−3·53	−7·83	−10·52	−13·09	−15·40	−15·62	−15·11	−17·10
1·82	1·82	1·71	1·47	1·23	0·68	−0·29	−0·83	−1·51	−1·62	−1·68	−2·19	−1·80
1·73	1·55	1·58	1·45	1·29	0·90	0·07	−0·55	−1·16	−2·12	−2·34	−2·58	−3·00
1·58	1·34	1·51	1·42	1·38	0·87	0·52	0·02	−0·90	−1·23	−1·47	−1·97	−2·71
1·86	1·90	1·88	1·79	1·93	1·62	1·18	0·75	0·42	0·0	−0·55	−1·47	−1·90
1·49	1·62	1·71	1·82	1·68	1·49	1·16	0·83	0·64	0·29	−0·18	−0·88	−1·66
2·19	2·19	2·21	2·14	1·99	1·84	1·55	1·20	1·03	0·85	0·48	0·00	−0·64
1·97	1·95	1·90	1·90	1·77	1·62	1·36	0·96	0·85	0·66	0·31	−0·04	−0·42
2·03	1·93	1·95	1·79	1·69	1·49	1·18	0·94	0·81	0·59	0·20	−0·13	−0·41
1·93	1·92	1·92	1·71	1·45	1·18	0·92	0·66	0·33	−0·33	−0·81	−1·36	−1·80
2·30	2·17	2·25	2·03	1·80	1·34	0·90	0·37	−0·24	−0·72	−1·49	−1·79	−2·60
2·58	2·45	2·45	2·25	1·95	1·31	0·33	−0·76	−2·01	−2·87	−3·28	−3·89	−3·98
1·66	1·68	1·69	1·49	1·18	0·48	−0·70	−1·68	−2·69	−3·98	−3·96	−4·48	−5·07
1·52	1·59	1·40	1·29	1·18	0·91	0·34	−0·15	−0·30	−0·76	−0·65	−1·52	−1·18
0·91	1·06	0·95	0·83	0·72	0·57	−0·08	−0·72	−0·08	−2·01	−2·05	−2·35	−2·47
0·76	0·99	0·83	0·72	0·42	0·23	0·11	−0·30	−0·46	−1·52	−2·01	−1·78	−2·35
1·33	1·37	1·18	1·02	0·65	0·57	0·30	0·08	−0·19	−0·83	−1·18	−1·40	−1·82
1·90	1·71	1·52	1·29	1·14	0·95	0·80	0·72	0·65	0·38	−0·11	−0·61	−0·95
1·37	1·48	1·52	1·29	1·40	1·25	1·10	1·02	0·91	0·76	0·53	0·08	−0·19
1·14	1·33	1·21	1·25	1·21	1·18	1·02	0·87	0·80	0·65	0·30	−0·08	−0·08
0·87	1·18	1·21	1·18	1·10	1·02	0·99	0·95	0·91	0·80	0·53	0·30	0·34
1·02	1·29	1·18	1·18	1·10	0·95	0·95	0·76	0·53	0·11	−0·11	−0·49	−0·83
1·29	1·29	1·21	1·10	1·18	1·14	1·02	0·72	0·30	−0·04	−0·53	−0·68	−1·10
1·06	1·29	1·14	1·10	0·95	0·80	0·23	−0·49	−1·21	−1·75	−1·82	−2·43	−2·73
1·56	1·63	1·44	1·33	0·99	0·46	−0·34	−1·21	−1·78	−2·96	−3·15	−3·72	−3·68

a decrease of rate of change with height, only until 0700 when the lapse rate over the upper height interval commences to increase more rapidly than that over the middle interval. Thus trace III crosses trace II twice in the early morning, about 0650 and 0720, and by 0800 the lapse rate between 46·4m. and 61·0m. (1·8°C./100m.) is three times that between 16·2m. and 46·4m. (0·6°C./100m.). After 0800 the lapse rate over the middle interval increases more rapidly than that for the upper interval and, as there is a decrease in the value of trace III after 1100, the lapse rates are eventually equal about 1330 when the value over each interval is 1·6°C./100m. After 1330 the normal daytime condition of a progressive decrease of lapse rate with height has been established. Traces II and III recross again during the development of the inversion in the evening so that in May they cross each other four times in twenty-four hours as against twice during each of the remaining months of the year with one exception, March. The maximum lapse rate recorded by trace III occurs during this month with a value of 2·09°C./100m. or just over twice the adiabatic value.

During June, July and August the value of the nocturnal inversion progressively decreases to a minimum in August. The lapses are all of the same order, the figures for trace III being less, and those for trace II being greater, than the corresponding values during May. The curves for these months represent the culmination of the various features. The nocturnal inversion has its smallest value for the year in August and for trace I does not exceed 3·9°C./100m. while the greatest mean value of the negative lapse rate recorded by both trace II and trace III during the month is 1·29°C./100m. The lapses during the day are large and prolonged, and the maximum values, which occur in June, are 12·50°C./100m. or over twelve times the adiabatic value for trace I, 2·21°C./100m. or over twice the adiabatic value for trace II, and 1·52°C./100m. or one and a half times the adiabatic value for trace III.

From September to December the nocturnal inversion increases in magnitude and duration and the magnitude of the daytime lapse for the lowest height interval rapidly decreases. The lapses over the other two height intervals show little variation and especially is this so over the topmost interval. The daytime lapses of the December curves have so far decreased as to bear a close resemblance to those given by the January curves but the nocturnal inversion is much larger. The large values of the inversion in December, 1931, may be due to this month being exceptionally cold, and the persistence of quiet conditions throughout most of the month, as the inversion was considerably larger than would be expected from the progressive increase between August and November.

Considering the curves for the year as a whole the chief features are the growth of the midday lapse between 1·1m. and 16·2m. from 6 times the adiabatic value in December to 12·5 times the adiabatic value in June, the small variability from month to month of the midday lapse between 16·2m. and 46·4m. and between 46·4m. and 61·0m., the large values of the nocturnal inversion in December and the correspondingly small values in August. In December the inversion nearly reaches 19°C./100m. between 1·1m. and 16·2m. but in August it does not exceed 4°C./100m.

Another point which deserves attention is the fact that the curves for the two upper height intervals do not exhibit any kind of symmetry although in the case of trace I the portion of the curve before about 1100 resembles the other portion if the latter is inverted.

§ 8—MEAN MONTHLY AND YEARLY VALUES OF THE LAPSE RATE

The hourly values of the lapse rate given in Table III have been meaned by months and the results are given below, Table IV.

TABLE IV—MEAN VALUES OF THE LAPSE RATE IN °C./100M. OVER THREE HEIGHT INTERVALS*

Month	Height interval		
	1·1m.—16·2m.	16·2m.—46·4m.	46·4m.—61·0m.
January	−3·33	−0·76	−0·25
February	−2·87	−1·02	−0·48
March	−0·41	−0·78	−0·81
April	1·12	−0·33	−0·63
May	1·22	−0·40	0·18
June	2·09	0·65	0·37
July	2·59	0·54	0·35
August	3·39	0·15	0·47
September	1·81	−0·21	−0·06
October	−0·43	−0·54	−0·19
November	−4·45	−1·11	−0·91
December	−7·96	−2·10	−1·38
Year	−0·60	−0·49	−0·28

* negative values denote an inversion.

These lapse rates are the mean of the values at each hour and may be considered as the mean monthly values for the three height intervals concerned. They show that between 1·1m. and 16·2m. the average lapse rate is positive from April to September inclusive and during the other six months the average condition is an inversion. Between 16·2m. and 46·4m. an inversion is the average condition for nine months, September to May, and between 46·4m. and 61·0m. for eight months, September to April. The extreme value of the mean negative lapse rate occurs in December for each interval but in the case of the lapses the extreme value over the two intervals 1·1m. to 16·2m. and 46·4m. to 61·0m. occurs in August and over the interval 16·2m. to 46·4m. in June. The values for the year show that the mean annual lapse rate between 1·1m. and 61·0m. is negative and decreases with height. The value of the mean inversion is 0·60°C./100m. for the lowest interval and decreases to 0·28°C./100m. between 46·4m. and 61·0m.

§ 9—EXTREME VALUES OF THE LAPSE RATE

(*a*) *General.*—The tabulated values of the temperature differences over the three intervals of height have been examined and the extreme hourly values of both lapse and inversion which occur during each month have been extracted and are given in Table V. The hour at which the extreme value occurs is also given together with the state of the sky, the wind velocity at 15·2m. and 62·6m. at the time of the extreme, and the weather experienced either since 1400 the previous day in the case of the extreme inversion or since 2000 in the case of the extreme lapse. The latter information is included as the magnitude of the lapse rate during the day or night would be expected to depend to some extent upon the weather during the preceding night or day.

(*b*) *Extreme hourly lapses.*—The extreme hourly values of the lapse in the case of trace I occur, with two exceptions, with clear or almost clear skies. Similar conditions prevailed during the specified period preceding the time of occurrence of these extreme values. The exceptions are confined to the winter months and occur on days when the air temperature at 1·1m. is considerably higher than on the preceding day.

The maximum values of the lapse rate during the day between heights of 1·1m. and 16·2m. vary from 9·4°C./100m. in December to 17·3°C./100m. which value occurs in each of the months April, May and June. The former figure is over nine times the dry adiabatic value and the latter over seventeen times. Half of the extreme values occur at 1200 while of the remainder one occurs at 1300 and six at 1400, the approximate time of maximum air temperature. The maximum lapse rate during the day over the height interval 16·2m. to 46·4m. varies from 2·5°C./100m. in May to 3·6°C./100m. in November, and over the height interval 46·4m. to 61·0m. from 2·1°C./100m. in July to 4·2°C./100m. in May. The times of occurrence of these maxima vary from 1000 to 1500 and in general occur earlier for trace III; of fourteen occasions of extreme value at or before noon eight refer to the upper height interval.

(*c*) *Extreme hourly inversions.*—Turning to the extreme hourly values of the temperature inversion it will be seen that the sky at the time the extreme values occur is clear or only partially clouded on all occasions except those recorded during a fog. These exceptions are restricted to the winter months and in four of the five cases of extreme values during a fog the sky was observed to be clear above the fog. The extreme inversions in the case of trace I range from 11·4°C./100m. in August to 49·6°C./100m. in December, for trace II from 6·4°C./100m. in August to 20·8°C./100m. in February and for trace III from 4·6°C./100m. in August to 20·3°C./100m. in December. The times of occurrence vary from trace to trace and on an average occur earlier the lower the height interval. Thus the values for trace I are grouped about 0400, the latest time of occurrence being 0600; for trace II the times vary from 0300 to 0700 with four occasions at 0600 and for trace III the times are still later, 0300 to 0800, with three occasions at 0700.

(*d*) *Wind velocity at the time of minimum and maximum lapse rate.*—The extreme inversions over the lowest height interval occur with little or no wind at a height

TABLE V—EXTREME HOURLY VALUES OF THE LAPSE RATE IN °C./100m. FOR EACH MONTH

Trace I, Height interval 1·1m. to 16·2m.

Month	Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 12 hours	Wind velocity at 15·2m. m./sec.	Wind velocity at 62·6m. m./sec.
(a) Lapses							
1931							
Oct.	13·4	1000 / 1200	23 / 17	b / b	b / b	7·2 / 7·2	.. / 8·5
Nov.	12·1	1100	4	bc	bcc	9·4	9·8
Dec.	9·4	1200	27	b	b	7·0	7·6
1932							
Jan.	10·8	1200	28	b	bc	8·9	8·9
Feb.	13·2	1200	26	c	bbcc	8·5	10·5
Mar.	14·5	1200 / 1500	31 / 29	c / bc	c / ccpr$_0$	9·1 / 9·8	.. / 13·0
April	17·3	1400	30	bc	b	6·7	7·6
May	17·3	1400	8	b	b	8·8	9·6
June	17·3	1400	19	b	b	9·4	10·7
July	15·6	1400	23	b	bbcb	9·6	9·8
Aug.	15·8	1400	24	b	bbcb	7·6	8·5
Sept.	15·4	1300	17	bkz	bbccb	10·1	11·0
Oct.	14·7	1100	3	bc	b	7·2	8·1
(b) Inversions							
1931							
Oct.	34·2	0500	20	bf	b	calm	<2
Nov.	36·4	0300	30	b	b	2·5	..
Dec.	49·6	0600	11	b	b	1·0	2·9
1932							
Jan.	37·1	0500	1	b	b	0·9	<2
Feb.	41·0	0200	15	b	bcb	calm	<2
Mar.	36·9	0500	21	b	b	1·0	3·8
April	23·9	0400	18	b	b	1·1	..
May	29·2	0300	7	b	b	calm	<2
June	26·5	0400	8	b	b	0·9	<2
July	25·6	0500	23	b	b	2·7	3·1
Aug.	11·4	0200	20	b	b	0·9	..
Sept.	20·4	0500	18	b	b	0·5	<2
Oct.	19·7	0100	11	bf	b	calm	..

Trace II, Height interval 16·2m. to 46·4m.

Month	Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 12 hours	Wind velocity at 15·2m. m./sec.	Wind velocity at 62·6m. m./sec.
(a) Lapses							
1931							
Oct.	3·1	1300 / 1300, 1400	18 / 23	b / c	b / bbc	4·7 / 6·3	.. / 6·0
Nov.	3·8	1200	5	bckz$_0$	bc	7·6	7·6
Dec.	3·0	1100 / 1300	24 / 27	bc / b	bc / b	4·8 / 7·9	.. / ..
1932							
Jan.	2·8	1100	9	bc	bc. cpr$_0$	7·6	8·7
Feb.	2·6	1200 / 1400	26	bc	bbcc	8·5 / 8·3	8·1 / 8·1
Mar.	2·8	1400	29	bc	c	9·1	7·2
April	3·3	1300	21	c	bcc	7·1	8·5
May	2·5	1400 / 1500	2	b	bcb	7·6 / 7·7	8·3 / ..
June	3·1	1400	19	b	b	9·5	10·7
July	3·0	1000	6	b	b	0·5	<2
Aug.	2·7	1100 / 1200	13 / 27	b / b	b / bcb	2·7 / 4·4	2·2 / 5·9
Sept.	2·8	1000 / 1100	5 / 30	b / b	bc / bcb	0·6 / 5·1	<2 / 6·0
Oct.	2·8	1000	4	b	b	4·4	5·6
(b) Inversions							
1931							
Oct.	13·8	0600	20	b	b	0·2	calm
Nov.	15·3	0300	30	bc	bbc	2·5	..
Dec.	18·9	0700	7	b	cr$_0$-b	4·6	7·9
1932							
Jan.	15·7	0700	1	bc	bbc	0·8	..
Feb.	20·8	0300	18	b	bcb	4·0	..
Mar.	13·5	0400	20	b	bcb	1·9	..
April	18·0	0500	6	b	b	3·7	4·3
May	13·4	0400	26	b	b	0·9	5·1
June	9·4	0600	1	b	b	calm	calm
July	9·3	0600	23	b	bcbb	2·5	2·7
Aug.	6·4	0500	6	b	b	2·6	3·5
Sept.	9·4	0600	21	bc	b	3·5	5·1
Oct.	8·2	0500	12	bfe	b	calm	calm

Trace III, Height interval 46·4m. to 61·0m.

Month	Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 12 hours	Wind velocity at 15·2m. m./sec.	Wind velocity at 62·6m. m./sec.
(a) Lapses							
1931							
Oct.	3·2	2000 / 2100	5 / 5	b / b	b / b	4·9 / 3·6	.. / ..
Nov.	2·7	1300	19	bc	b	2·2	..
Dec.	3·2	0600	5	c	bcc	5·8	7·9
1932							
Jan.	4·0	1300	1	bc	bbcc	0·5	..
Feb.	2·5	1700	2	bc	bbcc	6·3	..
Mar.	2·7	1400	21	b	b	6·7	7·9
April	4·0	1000	28	bc	bc	1·8	2·2
May	4·2	0900	7	bc	bbc	calm	calm
June	2·8	1100	14	b	b	2·2	2·2
July	2·1	1000, 1200, 1300, 1400	26, 7, 23, 13	b / b	b, bcb, b, b-o-b	7·6, 3·6, 9·4, 3·1	7·6, 5·6, 7·6, 3·6
Aug.	2·5	1600	24	b	bcb	7·6	..
Sept.	2·5	0900 / 1000	5	bc	bc	0·5 / 0·9	<2
Oct.	2·3	1200	1	b	b	3·6	5·5
(b) Inversions							
1931							
Oct.	9·5	0600	29	bcf	bbcf	calm	<2
Nov.	13·1	0800	8	b	b	0·5	<2
Dec.	20·3	0300	14	b	c-b	3·8	..
1932							
Jan.	12·7	2300	1	b	bc	3·6	..
Feb.	17·1	0500	17	b	b	3·6	5·6
Mar.	15·5	0300	20	b	bcb	1·3	..
April	13·8	0800	15	cf	bbf	calm	calm
May	12·7	0500	26	b	b	0·9	5·1
June	8·3	0700	26	b	b	calm	calm
July	7·0	0600	16	b	b	calm	<2
Aug.	4·6	0600	31	b	b	3·6	4·7
Sept.	9·5	0700	19	b	b	calm	<2
Oct.	7·0	0500	11	bf	bbf	calm	calm

TABLE VI—ABSOLUTE EXTREME VALUES OF THE LAPSE RATE IN °C./100m. FOR EACH MONTH

Month	Trace I, Height interval 1·1m. to 16·2m. Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 6 hours	Wind velocity at 15·2m. (m./sec.)	Wind velocity at 26·0m. (m./sec.)
(a) Lapses							
1931							
Oct.	18·0	1153	23	bcy	b	6·7	5·6
Nov.	14·7	1226	2	bcy	bcc	5·8	7·6
Dec.	11·0	1040	27	byv	b	3·6	..
1932							
Jan.	13·1	1151	28	cr$_o$r$_o$	bccr$_o$q	8·9	9·4
Feb.	15·3	1208	26	bcyq	cbc	8·9	10·5
Mar.	18·9	1240	29	bcq/pr$_c$	cpr$_o$bc	8·9	12·1
Apr.	20·4	1328 1444	26 30	by by	cbcb bbc	8·5 6·3	8·5 7·6
May	20·6	1148	21	bcyv	bcb	8·9	7·9
June	22·8	1330	20	by	bcby	7·0	7·0
July	18·6	1202	31	bc	bc	4·5	4·6
Aug.	19·5	1423	22	by	by	7·6	7·9
Sept.	20·2	1213	17	bkzq	bcckzq	8·5	10·0
Oct.	17·5	1109	10	bcfe	cm$_o$bcfe	4·0	3·7
(b) Inversions							
1931							
Oct.	36·6	0513	20	fe/b	b	calm	<2
Nov.	39·5	0223	29	b	b	1·3	..
Dec.	62·6	0430	11	by	by	2·7	3·6
1932							
Jan.	46·0	0500	1	b	b	0·9	<2
Feb.	46·0	0150	15	b	bcb	calm	..
Mar.	39·3	0505	21	by	bcbw	0·9	3·9
Apr.	28·9	0346	15	f/b	bfe	calm	..
May	30·1	0307	7	b	b	0·3	..
June	27·4	0448	8	b	b	2·2	..
July	27·8	0416	23	b	b	1·8	2·7
Aug.	14·5	0331	20	b	b	calm	<2
Sept.	22·6	0503	18	b	b	0·5	<2
Oct.	22·4	0212	11	bfe	bfe	calm	..

Month	Trace II, Height interval 16·2m. to 46·4m. Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 6 hours	Wind velocity at 15·2m. (m./sec.)	Wind velocity at 62·6m. (m./sec.)
(a) Lapses							
1931							
Oct.	4·0	1119	21	bc	bbc	3·6	4·5
Nov.	4·6	1210	11	bcy	bcc	7·2	7·6
Dec.	3·5	1153	27	byv	byv	6·7	7·4
1932							
Jan.	3·2	1230	5	cyv	bcc	8·3	8·9
Feb.	3·0	1402	26	bcyq	cbc	8·1	8·1
Mar.	3·2	1340	31	cq	bccq	7·6	..
Apr.	4·0	1213	22	bcqy	bbcq	9·4	9·4
May	3·2	1403	2	by	bcb	8·1	8·3
June	3·9	1350	16	by	by	6·7	8·1
July	3·6	1330	17	b	b	3·1	4·5
Aug.	3·2	1217	27	bcb	bcby	3·1	5·1
Sept.	3·2	0957,1012, 1006,0950	5, 6, 8	bc, bc,cm$_o$	bc, cbc, bc,bccm$_o$	0·9, 1·3,1·8	<2
Oct.	3·6	0840	5	bcm$_o$	bcm$_o$	2·2	3·8
(b) Inversions							
1931							
Oct.	17·9	0630	20	bfe	b	calm	<2
Nov.	18·7	0246	30	bcw	bc	3·1	..
Dec.	22·3	0703	29	bz$_o$	by	calm	2·5
1932							
Jan.	17·1	0707, 0710	1	cy	bccy	0·5	<2
Feb.	22·1	0305	18	bc	bcby	4·0	..
Mar.	19·5	2021	21	bc	bybc	4·9	..
Apr.	20·3	0533	6	bw	bbc	1·8	3·9
May	14·5	0435	26	b	b	2·2	5·1
June	10·4	0603	1	byv	b	calm	<2
July	12·6	0542	5	b	b	2·2	<2
Aug.	6·9	0520	6	b	b	2·2	3·5
Sept.	10·3	0536	23	b	b	1·8	4·7
Oct.	10·8	0230 0430	3 12	b bf	b bf	calm	<2

Month	Trace III, Height interval 46·4m. to 61·0m. Lapse rate	Time of occurrence zone time	Date	Weather	Weather during last 6 hours	Wind velocity at 15·2m. (m./sec.)	Wind velocity at 62·6m. (m./sec.)
(a) Lapses							
1931							
Oct.	4·0	1200	20	b	bmm$_o$	1·8	3·8
Nov.	3·2	1515	26	bcyv	cbcyv	8·9	..
Dec.	4·5	1204	30	cyv	bccyv	0·5	<2
1932							
Jan.	5·1	1257	1	bcy	cbc	0·5	<2
Feb.	3·2	1013	11	bm$_o$	bm$_o$	0	<2
Mar.	3·2	1400	27	byv	b	2·2	2·2
Apr.	5·1	0959	28	bc	bc	1·8	<2
May	5·3	0832	7	bcy	bbc	0	<2
June	3·2	1116	14	by	by	2·2	2·2
July	2·9	0950 1202	14 7	bc bc	cbc bbc	1·8 3·6	4·7 5·6
Aug.	3·0	1123 1330	7 8	bc by	bcby bcby	4·5 5·4	6·2 6·2
Sept.	2·9	1052 1239	5 12	bc bc	bc cbc	0·9 2·7	<2 ..
Oct.	3·0	0828	5	bcm$_o$	bcm$_o$	2·2	3·8
(b) Inversions							
1931							
Oct.	15·7	0519	24	b	b	calm	<2
Nov.	17·5	0345	8	b	b	0·5	<2
Dec.	23·9	0810	27	b	b	0·9	8·5
1932							
Jan.	18·0	0025	2	bc	bcby	2·2	..
Feb.	23·6	0518	16	by	by	5·4	6·3
Mar.	25·8	2119	21	bc	bbc	5·2	..
Apr.	23·0	0432	26	cy	cy	5·4	7·6
May	17·8	0518	26	b	b	0·3	5·1
June	11·9	0640	1	byv	b	calm	<2
July	16·9	0612	4	b	bw	calm	3·7
Aug.	7·2	0417	31	b	b	3·6	5·2
Sept.	11·9	0731	26	bm$_o$/f	bfcmbcm$_o$	calm	<2
Oct.	10·1	0742 0813	10	bcfe	bccbcf	calm	<2

of 15·2m. but for the extremes over the other height intervals the velocity at this height is generally greater than it is in the case of the lowest interval, and on some occasions a rapid increase in velocity is noted between 15·2m. and 62·6m. This is especially so in May when the wind velocity increases from only 0·9m./sec. at 15·2m. to 5·1m./sec. at 62·6m. In the case of the largest hourly inversions between 46·4m. and 61·0m. the wind velocity at 62·6m. is of the same magnitude as it is for the extreme values over the middle height interval, although on five occasions it is calm. This confirms the view that in general a low wind velocity is favourable for the development of a large inversion while the higher wind velocities at 62·6m. indicate that under certain conditions a large inversion can exist between 16·1m. and 46·4m. and between 46·4m. and 61·0m. even though a moderate wind is blowing at 62·6m.

In the case of trace I the extreme hourly values of the lapses occur when the wind at 15·2m. is moderate or fresh and although this holds in the majority of cases for both traces II and III there are occasions of maxima with little or no wind. These occasions are associated with a very small increase of velocity between 15·2m. and 62·6m. In the case of the highest hourly value of a lapse for trace III (4·2°C./100m.) the wind at 62·6m. is calm and it appears that the higher the wind velocity and the greater the vertical difference of wind velocity over a height interval the smaller will be the lapse for a given temperature at the lower level.

(*e*) *Absolute extreme values of the lapse rate.*—Each differential trace consists of a sequence of dots made at intervals of three minutes and the extreme maximum lapses and inversions recorded by individual dots in each of the three traces have been ascertained. The values obtained must not be considered as the greatest instantaneous lapse rates which actually occur but merely as an indication of the maximum excursion of the individual dots which constitute the trace.

The fluctuations from dot to dot are most marked on trace I and by comparison those exhibited by trace III are extremely small. During each month there were a few occasions when the dots on traces II and III deviated considerably from the mean and although there is nothing to suggest that this effect is other than real it occupies such a short period of time on the chart (less than 15 minutes) in every case that it can be regarded as of no importance in the heat economy of the whole day. Each occasion referred to was marked by a sudden large deviation from the mean value followed by successively smaller deviations until the mean value was approximately the same as before the first large deviation. The number of dots involved on any occasion was never more than five and the extreme values recorded under these conditions, which only occurred when the lapse rate was positive, have been disregarded in the tabulation.

The absolute extreme lapse rates are given in Table VI together with the time at which they occurred. Included in the table is the weather at the time of occurrence of the extreme value and also during the past six hours together with the wind velocity at 15·2m. and at 62·6m. A comparison of the absolute extreme lapse rates with the extreme hourly values (Table V) is not strictly justified as in the former case the whole trace is considered while in the latter only those portions of the trace which are included in periods of twenty minutes centred at each hour. The absolute extreme values are on an average 15 to 30 per cent higher than the extreme hourly values although in a few cases, notably as regards the absolute extreme inversion on trace III, the percentage increase is very much greater.

The absolute extreme lapses in the case of trace I, apart from two exceptions, occur with clear or almost clear skies; for trace II there are three exceptions to this rule and for trace III one exception. Thus, as is to be anticipated, the state of the sky associated with absolute extreme lapses is similar to that for extreme hourly lapses. The wind velocity at 15·2m. associated with the extreme lapses between 1·1m. and 16·2m. varies from 3·6m./sec. to 8·9m./sec. with only three values below 5·8m./sec. but the extreme lapses between 16·2m. and 4·64m. and between 46·4m. and 61·0m. occur in most cases with a lower value of the wind velocity. The range for trace II is from 0·9m./sec. to 9·4m./sec. with values in five months below 3·7m./sec. and for trace III from calm to 8·9m./sec. with values in only two months exceeding 3·6m./sec. Extreme values recorded by trace I occur with high values of the wind velocity at 62·6m. while the extremes for traces II and III are associated with lower wind velocities. The absolute extreme lapse rates during the day over the lowest height interval vary from 11·0°C./100m. in December to 22·8°C./100m. in June. Thus in June, a lapse rate, more than twice the highest value recorded in December may be expected. The values in eight months occurred within an hour centred at noon and the earliest time of an extreme occurred in December at 1040 and the latest in August at 1423. The extreme values over the middle height interval exhibit little variation, the lowest value being 3·0°C./100m. in February and the highest 4·6°C./100m. in November while for the top height interval the values vary from 2·9°C./100m. in July and September to 5·3°C./100m. in May. The time of occurrence of the extreme values on trace II varies from 0840 to 1403 with a fairly even distribution between 1200 and 1400 and on trace III the time varies from 0828 to 1515 with a slight preference for the hour 1200 to 1300.

The highest recorded value of the inversion is, in the majority of cases, associated with a cloudless or almost clear sky and the exceptions in all cases but two, are associated with occasions of fog. The wind velocity at both 15·2m. and 62·6m. is light, less than 5m./sec. on the occasion of every absolute extreme inversion over the lowest and middle height intervals. The wind velocity associated with extreme values over the top height interval is less than 2·3m./sec. at 15·2m. in nine months and does not exceed 5·4m./sec. in any month although the vertical gradient of wind velocity between 15·2m. and 62·6m. is relatively large on one or two occasions. The velocity increases from 0·9m./sec. at 15·2m. to 8·5m./sec. at 62·6m. on the occasion of the extreme inversion in December and from 0·3m./sec. to 5·1m./sec. in May. The values of the absolute extreme inversions vary from a lapse rate of −14·5°C./100m. in August to −62·6°C./100m. in December in the case of the lowest height interval, from −6·9°C./100m. in August to −22·3°C./100m. in December in the case of the middle height interval and from −7·2°C./100m. in August to −23·9°C./100m. in December for the top height interval. The time of occurrence varies from 0150 to 0513, with the majority grouped about 0430, in the case of trace I, from 0230 to 0710, with the majority between 0500 and 0600, apart from an isolated value at 2021, in the case of trace II, and from 2119 to 0813 with the majority after 0500 in the case of trace III.

§ 10—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES

(*a*) *Hourly frequency values of various lapse rates.*—The hourly values of the lapse rate over the three height intervals, which are the basis of the mean hourly values given in Table III, have been analysed to show the frequency of occurrence of various values of the lapse rate expressed as ratios of the dry adiabatic value for each hour during each month. The result of the analysis is contained in Table VII where the frequencies are expressed as percentages of the total number of readings at the hour concerned. Inversions, which are negative lapse rates, are considered as negative ratios of the adiabatic value while a lapse of temperature has a positive ratio. In order to curtail the size of the table it has been necessary to group the figures for a number of ratios with the result that the figures given for a ratio of 0·5 include lapse rates equal to or less than the adiabatic value but greater than zero. Similarly a ratio of 2 includes lapse rates greater than 1 but equal to or less than 3 and so on.

Considering the table as a whole it is found that the figures are grouped approximately about the curves given in Fig. 8. The values for January show that in the case of trace I the midday lapse attains a value equal to eleven times the dry adiabatic value between the hours 1100 to 1300 while between 1000 and 1400 over eighty-five per cent. of the values exceed a ratio of three. At night, values of the inversions are distributed fairly evenly between minus one and minus twelve times the adiabatic value with a maximum at a ratio of minus five. Traces II and III exhibit a much smaller variation of the values of the midday lapse. The lapse recorded by trace II never exceeds three times the adiabatic value although between 1000 and 1600 over eighty per cent of the readings exceed the adiabatic

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES showing percentage frequency of stated lapse rates over the three height intervals 1·1m. to 16·2m. (Trace I), 16·2m. to 46·4m. (Trace II) and 46·4m. to 61·0m. (Trace III) for each hour during each month based on records for the period October, 1931 to October, 1932, inclusive (zone time)

January 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	9	..	..	..	..	..	..	..	..	..	10·3	31·0	48·3	37·9	31·0	3·4	..	..	..	..	..	..	..	..	..	6·7
		5	..	..	..	..	..	..	..	..	27·6	65·5	58·6	48·3	58·6	55·2	72·4	27·6	..	..	..	..	..	..	3·2	..	17·4
		2	..	..	..	..	..	..	..	10·0	58·6	20·7	10·3	3·4	3·4	13·8	20·7	55·2	20·7	3·4	3·3	..	..	..	..	..	9·3
		0·5	..	3·2	6·5	3·2	6·5	6·5	6·7	13·3	6·8	..	..	..	..	..	3·4	17·2	17·2	6·8	..	..	3·2	6·5	..	3·2	4·6
		0	..	..	..	6·5	..	..	..	10·0	..	..	..	..	..	..	..	..	..	3·4	3·3	..	3·2	..	..	..	1·1
	Inversions	−0·5	12·9	9·7	9·7	6·5	3·2	6·5	3·3	16·7	6·8	3·4	..	..	..	..	..	..	31·0	20·7	10·0	6·7	6·5	12·9	9·7	12·9	7·9
		−2	16·1	16·1	16·1	25·8	22·6	19·3	26·6	26·6	..	..	..	..	..	..	..	..	20·7	17·2	16·7	23·3	12·9	12·9	19·3	9·7	12·6
		−5	22·6	16·1	22·6	22·6	29·0	25·8	16·7	6·7	..	..	..	..	..	..	..	..	3·4	17·2	30·0	26·6	32·2	25·8	19·3	22·6	14·1
		−10	12·9	25·8	16·1	6·5	16·1	16·1	13·3	10·0	..	..	..	..	..	..	..	..	3·4	20·7	20·0	20·0	19·3	22·6	25·8	22·6	11·3
		<−13	35·5	29·0	29·0	29·0	22·6	25·8	33·3	6·7	..	..	..	..	..	..	..	..	3·4	10·3	16·7	23·3	22·6	19·3	22·6	29·0	14·9
Trace II	Lapses	2·5	..	..	..	..	..	..	..	..	6·8	20·7	27·6	48·3	37·9	37·9	6·8	..	..	..	3·3	..	..	..	..	..	7·9
		1·5	..	..	..	6·5	3·2	..	..	3·3	62·1	58·6	68·0	41·4	58·6	55·2	82·8	82·8	17·2	3·4	3·3	..	..	..	..	..	22·8
		0·5	22·6	19·3	25·8	12·9	19·3	16·1	23·3	50·0	20·7	17·2	3·4	10·3	3·4	6·8	10·3	17·2	68·0	51·7	36·7	20·0	25·8	25·8	16·1	22·6	22·7
		0	3·2	..	6·5	..	..	..	..	..	..	3·4	..	..	..	..	..	..	..	..	3·3	6·7	..	6·5	3·2	3·2	1·5
	Inversions	−1	35·5	29·0	19·3	29·0	32·2	38·7	40·0	6·7	..	..	..	..	..	..	..	..	13·8	37·9	46·7	43·4	35·5	32·2	32·2	38·7	21·3
		−4	25·8	32·2	25·8	29·0	29·0	29·0	20·0	33·3	10·3	..	..	..	..	..	..	..	..	6·8	6·7	30·0	35·5	22·6	38·7	22·6	16·6
		−8	9·7	9·7	12·9	16·1	9·7	9·7	10·0	3·3	..	..	..	..	..	..	..	..	..	..	..	..	3·2	12·9	9·7	9·7	4·9
		<−10	3·2	9·7	9·7	6·5	6·5	6·5	6·7	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	2·3
Trace III	Lapses	3·5	..	..	..	..	..	..	..	..	..	..	..	..	3·4	..	..	..	..	..	..	..	..	..	..	..	0·1
		2·5	..	..	..	..	..	..	..	6·7	3·4	10·3	6·8	10·3	6·8	10·3	..	3·4	3·4	..	..	..	..	..	..	..	2·5
		1·5	9·7	12·9	9·7	9·7	6·5	3·2	3·3	6·7	48·3	72·4	86·2	79·3	82·8	68·0	72·4	55·2	48·3	17·2	13·3	6·7	3·2	9·7	..	9·7	30·6
		0·5	19·3	16·1	19·3	19·3	16·1	16·1	20·0	33·3	20·7	17·2	6·8	10·3	6·8	20·7	27·6	41·4	37·9	51·7	33·3	30·0	35·5	25·8	29·0	32·2	24·4
		0	6·5	3·2	9·7	6·5	6·5	3·2	3·3	3·3	..	..	..	..	..	..	..	..	..	10·3	..	6·7	3·2	3·2	3·2	3·2	3·0
	Inversions	−0·5	16·1	22·6	19·3	19·3	16·1	32·2	30·0	6·7	6·8	..	..	..	..	..	..	..	10·3	10·3	43·4	40·0	25·8	19·3	9·7	16·1	14·3
		−2	35·5	22·6	19·3	25·8	22·6	16·1	23·3	13·3	10·3	..	..	..	..	..	..	..	..	6·8	6·7	16·7	19·3	38·7	45·2	19·3	14·2
		−5	9·7	16·1	19·3	9·7	29·0	19·3	13·3	20·0	10·3	..	..	..	..	..	..	..	..	3·4	3·3	..	12·9	3·2	9·7	12·9	8·0
		−10	3·2	6·5	3·2	9·7	3·2	9·7	6·7	10·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	6·5	2·6

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Feb. 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	..	..	3·6	..	..	..	..	..	..	..	..	..	..	..	..	0·1
		10	..	..	..	..	..	..	..	..	..	17·8	57·2	53·6	64·3	50·0	25·0	3·6	..	..	..	..	..	..	..	..	11·3
		5	..	..	..	..	..	..	..	3·6	64·3	64·3	39·3	35·7	28·6	42·9	67·9	78·6	21·4	..	..	..	..	..	..	..	18·6
		2	..	3·8	3·7	3·7	..	..	3·4	25·0	28·6	17·8	3·6	7·1	7·1	3·6	7·1	17·8	35·7	7·1	..	..	..	..	..	..	7·3
		0·5	3·8	3·8	7·4	3·7	3·6	3·6	13·8	28·6	..	..	..	..	..	..	..	..	21·4	17·8	3·7	..	..	..	..	7·7	5·0
		0	3·8	..	..	3·7	..	..	..	..	3·6	..	..	..	..	..	..	..	10·7	3·6	..	3·8	..	..	..	..	1·2
	Inversions	−0·5	3·8	..	3·7	7·4	7·1	7·1	..	14·3	3·6	..	..	..	..	..	..	..	..	17·8	18·5	7·7	7·7	7·4	7·7	..	4·7
		−2	7·7	7·7	7·4	7·4	17·8	21·4	17·2	14·3	..	..	..	..	..	3·6	..	..	3·6	17·8	29·6	23·1	15·4	14·8	15·4	15·4	10·0
		−5	34·6	30·8	14·8	11·1	21·4	14·3	17·2	7·1	..	..	..	..	..	..	..	..	7·1	21·4	18·5	42·3	50·0	25·9	26·9	30·8	15·7
		−10	23·1	23·1	29·6	18·5	14·3	21·4	27·6	7·1	..	..	..	..	..	..	..	..	..	10·7	22·2	15·4	23·1	37·1	23·1	15·4	13·0
		<−13	26·9	30·8	33·3	44·4	35·7	32·1	20·7	..	..	..	..	..	..	..	..	..	..	3·6	7·4	7·7	3·8	14·8	26·9	30·8	13·3
Trace II	Lapses	2·5	..	..	..	..	..	..	..	..	..	14·3	25·0	32·1	25·0	21·4	3·6	..	..	..	..	..	..	..	..	..	5·1
		1·5	..	..	..	..	..	3·6	3·4	14·3	57·2	67·9	53·6	57·2	50·0	60·7	82·2	71·4	39·3	3·6	..	..	..	..	..	..	23·5
		0·5	11·5	7·7	11·1	18·5	17·8	14·3	20·7	28·6	32·1	14·3	21·4	10·7	25·0	17·8	14·3	28·6	57·2	60·7	51·8	23·1	15·4	14·8	19·2	19·2	23·2
		0	..	..	..	3·7	3·6	7·1	3·4	..	..	..	..	..	..	..	..	..	..	..	..	7·7	..	3·7	..	..	1·2
	Inversions	−1	30·8	46·2	37·1	22·2	25·0	28·6	24·1	28·6	7·1	3·6	..	..	..	..	..	..	3·6	32·1	33·3	42·3	50·0	37·1	34·6	30·8	21·5
		−4	38·5	23·1	25·9	29·6	28·6	25·0	34·5	10·7	3·6	..	..	..	..	..	..	..	..	3·6	14·8	26·9	23·1	33·3	34·6	30·8	16·1
		−8	11·5	19·2	14·8	18·5	25·0	14·3	10·3	10·7	..	..	..	..	..	..	..	..	..	..	..	..	11·5	7·4	11·5	11·5	6·9
		<−10	7·7	3·8	11·1	7·4	..	7·1	3·4	7·1	..	..	..	..	..	..	..	..	..	..	..	..	..	3·7	..	7·7	2·5
Trace III	Lapses	2·5	..	..	..	..	..	..	..	..	..	3·6	..	..	3·6	..	..	..	3·6	..	..	..	..	..	..	..	0·5
		1·5	..	..	..	..	..	..	..	..	39·3	53·6	57·2	42·9	50·0	35·7	35·7	21·4	3·6	..	..	..	..	..	..	..	14·1
		0·5	11·5	7·7	14·8	14·8	10·7	10·7	13·8	39·3	32·1	39·3	39·3	53·6	42·9	57·2	64·3	75·0	85·8	50·0	33·3	15·4	19·2	14·8	15·4	11·5	32·2
		0	..	..	..	..	3·6	7·1	6·8	3·6	7·1	..	..	..	..	3·6	..	3·6	3·6	14·3	18·5	15·4	..	3·7	3·8	7·7	4·3
	Inversions	−0·5	23·1	19·2	14·8	22·2	21·4	17·8	20·7	3·6	3·6	3·6	3·6	3·6	3·6	3·6	..	..	3·6	25·0	18·5	30·8	19·2	22·2	19·2	15·4	13·4
		−2	26·9	42·3	25·9	29·6	32·1	39·3	31·0	32·1	7·1	..	..	..	..	..	..	..	..	10·7	22·2	19·2	42·3	29·6	23·1	26·9	18·3
		−5	34·6	19·2	33·3	18·5	21·4	14·3	17·2	17·8	3·6	..	..	..	..	..	..	..	..	..	7·4	11·5	15·4	18·5	34·6	34·6	12·6
		−10	3·8	11·5	11·1	14·8	3·6	7·1	10·3	..	7·1	..	..	..	..	..	..	..	..	..	..	7·7	3·8	11·1	3·8	3·8	4 1
		<−13	..	..	..	..	7·1	3·6	..	3·6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·6

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

March 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	..	6·5	9·7	9·7	3·2	6·5	..	..	..	..	..	..	..	..	..	1·5
		10	..	..	..	..	..	..	..	..	35·5	77·4	87·1	67·8	67·9	83·9	67·8	61·3	6·5	..	..	..	..	..	..	..	23·1
		5	..	..	..	..	..	..	..	51·8	61·3	19·3	6·5	22·6	19·3	9·7	25·8	38·7	74·2	9·7	..	..	..	..	..	..	14·1
		2	3·3	3·3	..	..	..	..	26·6	45·2	3·2	3·2	..	..	3·2	3·2	..	..	12·9	29·0	19·3	6·7	6·7	3·3	3·3	3·3	7·3
		0·5	..	..	..	10·3	3·3	10·0	6·7	..	..	..	..	..	..	..	..	..	3·2	22·6	9·7	6·7	..	..	..	..	3·0
		0	..	3·3	3·4	..	6·7	..	..	..	..	..	..	..	..	..	..	..	..	3·2	3·2	3·3	..	..	..	..	1·0
	Inversions	−0·5	6·7	3·3	10·3	10·3	6·7	13·3	16·7	..	..	..	..	..	..	..	..	..	..	22·6	35·5	23·3	13·3	6·7	6·7	6·7	7·6
		−2	6·7	20·0	10·3	17·2	16·7	10·0	13·3	3·2	..	..	..	..	..	..	..	..	..	3·2	22·6	40·0	36·7	36·7	13·3	10·0	10·8
		−5	23·3	6·7	17·2	3·4	20·0	16·7	16·7	..	..	..	..	..	..	..	..	..	3·2	6·5	6·5	13·3	30·0	30·0	33·3	26·6	10·4
		−10	40·0	30·0	34·4	24·1	13·3	10·0	10·0	..	..	..	..	..	..	..	..	..	..	..	..	3·3	10·0	23·3	33·3	46·7	11·5
		<−13	20·0	34·4	24·2	34·5	33·3	40·0	10·0	..	..	..	..	..	..	..	..	..	..	3·2	3·2	3·3	3·3	..	10·0	6·7	9·7
Trace II	Lapses	2·5	..	..	..	..	..	..	..	..	9·7	16·1	12·9	19·3	22·6	16·1	9·7	6·5	..	..	..	..	..	..	..	..	4·7
		1·5	3·3	3·3	..	3·4	..	..	10·0	29·0	51·8	58·1	71·0	67·8	41·9	61·3	74·2	74·2	54·8	9·7	6·5	3·3	3·3	3·3	3·3	3·3	26·5
		0·5	3·3	13·3	13·8	17·2	16·7	20·0	13·3	51·8	38·7	22·6	16·1	12·9	25·8	22·6	9·7	19·3	38·7	80·6	64·5	33·3	16·7	10·0	10·0	6·7	24·1
		0	..	..	..	..	..	..	..	3·2	..	..	..	..	..	..	3·2	..	3·2	..	9·7	13·3	6·7	..	..	..	1·6
	Inversions	−1	26·6	23·3	24·1	6·8	20·0	20·0	30·0	12·9	..	3·2	..	..	9·7	..	3·2	..	..	9·7	19·3	43·4	46·7	56·7	40·0	40·0	18·2
		−4	60·0	36·7	34·5	44·8	36·7	36·7	23·3	3·2	..	..	..	..	..	..	..	..	..	..	..	..	23·3	26·6	40·0	40·0	16·9
		−8	6·7	23·3	24·1	17·2	23·3	16·7	20·0	..	..	..	..	..	..	..	..	..	3·2	..	..	..	3·3	3·3	6·7	10·0	6·6
		<−10	..	..	3·4	10·3	3·3	6·7	3·3	..	..	..	..	..	..	..	..	..	..	..	..	6·7	..	..	..	..	1·4
Trace III	Lapses	2·5	..	..	..	..	..	..	..	..	3·2	6·5	9·7	..	6·5	9·7	6·5	..	..	..	..	..	..	..	..	..	1·8
		1·5	3·3	..	..	..	..	..	..	3·2	35·5	48·4	41·9	29·0	32·2	19·3	19·3	3·2	..	..	..	3·3	..	..	..	..	9·9
		0·5	6·7	6·7	6·8	6·8	6·7	6·7	6·7	48·4	51·8	41·9	41·9	61·3	61·3	61·3	71·0	80·6	80·6	71·0	41·9	16·7	6·7	6·7	6·7	6·7	33·5
		0	6·7	3·3	3·4	..	..	..	6·7	12·9	3·2	3·2	6·5	6·5	..	6·5	3·2	9·7	12·9	12·9	19·3	26·6	3·3	..	..	10·0	6·5
	Inversions	−0·5	16·7	26·6	24·1	20·7	16·9	13·3	6·7	16·1	6·5	..	..	3·2	..	3·2	..	6·5	3·2	12·9	29·0	40·0	53·3	36·7	33·3	16·7	16·1
		−2	43·4	33·3	24·1	24·1	30·0	40·0	43·4	12·9	..	..	..	..	..	..	..	..	..	..	6·5	6·7	26·6	36·7	40·0	40·0	17·0
		−5	16·7	23·3	34·5	34·5	40·0	23·3	33·3	3·2	..	..	..	..	..	..	..	..	3·2	3·2	..	6·7	6·7	13·3	20·0	20·0	11·7
		−10	6·7	6·7	3·4	10·3	6·7	16·7	3·3	3·2	..	..	..	..	..	..	..	..	..	..	3·2	..	..	6·7	..	6·7	3·1
		<−13	..	..	3·4	3·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	..	..	..	0·4

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

April 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	14·8	34·5	27·6	27·6	34·5	27·6	3·4	..	..	..	..	..	..	..	..	7·1
		10	..	..	..	..	..	..	..	28·6	64·3	66·7	65·5	68·0	68·0	62·1	68·0	93·1	34·5	..	..	..	..	..	..	..	25·8
		5	..	..	..	..	..	..	25·0	53·6	32·1	18·5	..	3·4	3·4	3·4	3·4	3·4	65·5	24·1	3·3	..	..	..	..	..	10·0
		2	..	..	..	..	..	..	25·0	10·7	3·6	..	..	..	..	..	..	..	..	34·5	16·7	3·3	3·3	3·3	3·4	..	4·3
		0·5	3·4	3·4	3·4	3·4	..	6·8	14·3	3·6	..	..	..	..	..	..	..	..	..	24·1	16·7	20·0	..	..	..	3·4	4·3
		0	3·4	..	3·4	..	..	..	7·1	3·6	..	..	..	..	..	..	..	..	..	6·8	6·7	..	..	..	..	..	1·3
	Inversions	−0·5	10·3	10·3	3·4	3·4	3·4	6·8	17·8	..	..	..	..	..	..	..	..	..	..	6·8	26·6	30·0	26·6	10·0	6·8	3·4	6·9
		−2	3·4	3·4	3·4	13·8	13·8	31·0	10·7	..	..	..	..	..	..	..	..	..	..	3·4	26·6	33·3	50·0	33·3	10·3	13·8	10·4
		−5	20·7	20·7	24·1	24·1	24·1	13·8	..	..	..	..	..	..	..	..	..	..	..	..	..	13·3	16·7	46·7	41·4	31·0	11·5
		−10	44·8	31·0	27·6	24·1	41·4	17·2	..	..	..	..	..	..	..	..	..	..	..	..	3·3	..	3·3	3·3	34·5	31·0	10·9
		<−13	13·8	31·0	34·5	31·0	17·2	24·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	3·4	17·2	7·3
Trace II	Lapses	3·5	..	..	..	..	..	..	3·6	..	..	..	..	..	3·4	3·4	..	..	..	..	..	..	..	..	..	..	0·4
		2·5	..	..	..	..	..	..	7·1	21·4	32·1	40·8	37·9	48·3	41·4	37·9	41·4	51·7	17·2	..	..	..	..	..	..	..	15·7
		1·5	6·8	..	6·8	6·8	3·4	3·4	17·8	35·7	35·7	37·1	48·3	44·8	48·3	51·7	48·3	37·9	72·4	65·5	33·3	23·3	13·3	3·3	3·4	6·8	27·3
		0·5	13·8	20·7	6·8	6·8	6·8	13·8	14·3	35·7	21·4	18·5	13·8	..	6·8	6·8	10·3	10·3	10·3	31·0	60·0	53·3	40·0	30·0	13·8	6·8	18·8
		0	..	..	..	..	..	3·4	3·6	..	..	3·7	..	3·4	..	..	..	..	..	..	..	3·3	3·3	3·3	3·4	6·8	1·4
	Inversions	−1	24·1	10·3	6·8	17·2	27·6	10·3	21·4	3·6	10·7	..	..	3·4	..	..	..	..	..	3·4	6·7	16·7	40·0	53·3	44·8	34·5	14·0
		−4	44·8	44·8	51·7	48·3	41·4	41·4	25·0	3·6	..	..	..	..	..	..	..	..	..	..	..	3·3	..	6·7	31·0	41·4	16·0
		−8	10·3	17·2	20·7	13·8	10·3	17·2	7·1	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	3·3	3·4	3·4	4·6
		<−10	..	6·8	6·8	6·8	10·3	10·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·7
Trace III	Lapses	3·5	..	..	..	..	..	..	..	..	3·7	7·4	3·4	..	3·4	3·4	..	3·4	..	..	..	..	..	..	..	..	1·0
		2·5	..	..	..	..	..	..	..	3·7	18·5	14·8	27·6	17·2	20·7	10·3	13·8	..	..	..	..	..	..	..	..	..	5·3
		1·5	..	..	..	..	..	..	11·1	40·8	33·3	33·3	41·4	55·2	44·8	44·8	34·5	24·1	10·3	7·1	6·8	3·4	3·4	..	..	..	16·4
		0·5	7·1	..	7·1	..	3·6	3·6	29·6	25·9	33·3	40·8	20·7	20·7	27·6	34·5	48·3	65·5	75·9	64·3	51·7	37·9	24·1	10·3	3·6	3·6	26·7
		0	7·1	7·1	3·6	7·1	3·6	3·6	3·7	3·7	3·7	..	3·4	6·8	3·4	..	..	3·4	10·3	14·3	13·8	17·2	6·8	13·8	7·1	3·6	6·1
	Inversions	−0·5	14·3	21·4	10·7	10·7	10·7	7·1	7·4	14·8	7·4	3·7	3·4	..	..	6·8	3·4	3·4	3·4	10·7	24·1	27·6	27·6	24·1	32·1	32·1	12·8
		−2	42·9	39·3	35·7	32·1	28·6	28·6	7·4	7·4	..	..	..	..	..	..	..	..	..	3·6	..	10·3	31·0	48·3	50·0	39·3	16·9
		−5	25·0	25·0	28·6	32·1	42·9	46·4	33·3	..	..	..	..	..	..	..	..	..	..	..	3·4	3·4	6·8	3·4	7·1	21·4	11·6
		−10	3·6	3·6	14·3	17·8	10·7	7·1	7·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2·7
		<−13	..	3·6	..	..	..	3·6	..	3·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·5

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

May 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	13·3	28·3	6·8	23·3	46·7	26·6	..	..	..	..	..	..	..	..	..	5·8
		10	..	..	..	..	..	..	..	20·0	66·7	70·0	76·7	79·3	66·7	53·3	70·0	93·4	71·0	..	..	..	..	..	..	..	27·8
		5	..	..	..	..	..	..	33·3	70·0	26·6	16·7	..	13·8	6·7	..	3·3	6·7	29·0	61·3	..	..	..	..	..	..	11·1
		2	..	..	..	..	..	..	46·7	3·3	3·3	..	..	..	3·3	..	..	..	..	38·7	29·0	3·2	..	..	..	..	5·3
		0·5	..	..	..	..	..	12·9	16·7	..	..	..	..	..	..	..	..	..	..	..	22·6	19·3	9·7	3·2	3·2	..	3·7
		0	..	..	..	..	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	12·9	3·2	3·2	..	..	3·2	1·1
	Inversions	−0·5	3·2	3·2	..	3·2	..	16·1	3·3	3·3	3·3	..	..	..	..	..	..	..	..	..	25·8	38·7	19·3	16·1	3·2	..	5·8
		−2	16·1	6·5	9·7	6·5	9·7	41·9	..	3·3	..	..	..	..	..	..	..	..	..	..	9·7	35·5	48·4	45·2	25·8	16·1	11·4
		−5	22·6	19·3	9·7	9·7	16·5	19·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	19·3	25·8	45·2	29·0	8·6
		−10	41·9	45·2	54·8	54·8	51·8	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	22·6	45·2	13·9
		<−13	16·1	25·8	25·8	25·8	29·0	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6·5	5·5
Trace II	Lapses	2·5	..	..	..	..	..	..	..	..	3·3	10·0	10·0	17·2	20·0	30·0	33·3	13·3	3·2	..	..	..	..	..	..	..	5·8
		1·5	..	..	..	..	..	..	36·7	50·0	70·0	73·4	70·0	58·6	70·0	56·7	66·7	83·3	93·6	74·2	9·7	6·5	..	..	..	..	34·1
		0·5	9·7	6·5	6·5	3·2	3·2	16·1	43·4	50·0	26·6	16·7	20·0	24·1	10·0	13·3	..	3·3	3·2	25·8	90·4	90·4	80·6	48·4	25·8	16·1	26·4
		0	3·2	..	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	6·5	6·5	..	..	0·8
	Inversions	−1	35·5	29·0	12·9	9·7	16·1	9·7	13·3	..	..	..	..	..	..	..	..	..	..	..	..	3·2	9·7	41·9	48·4	45·2	11·4
		−4	38·7	48·4	54·8	54·8	45·2	48·4	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	3·2	25·8	38·7	15·2
		−8	12·9	16·1	19·3	25·8	22·6	25·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	5·1
		<−10	..	..	6·5	6·5	12·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·1
Trace III	Lapses	4·5	..	..	..	..	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1
		3·5	..	..	..	..	..	..	3·3	6·7	6·7	10·0	6·7	3·4	3·3	6·7	..	..	..	..	..	..	..	..	..	..	2·0
		2·5	..	..	..	..	..	..	6·7	30·0	36·7	43·4	53·3	48·3	36·7	20·0	26·6	10·0	..	..	..	..	..	..	..	..	13·0
		1·5	..	..	..	..	3·2	3·2	36·7	40·0	40·0	36·7	30·0	34·5	36·7	46·7	33·3	46·7	41·9	32·2	25·8	19·3	16·1	9·7	6·5	6·5	22·7
		0·5	22·6	12·9	3·2	6·5	9·7	9·7	23·3	23·3	13·3	10·0	10·0	13·8	23·3	26·6	36·7	40·0	58·1	61·3	67·8	74·2	54·8	35·5	19·3	25·8	28·4
		0	3·2	3·2	6·5	3·2	3·2	3·2	..	..	..	..	..	..	..	..	..	3·3	..	6·5	6·5	3·2	16·1	6·5	6·5	..	3·0
	Inversions	−0·5	22·6	25·8	12·9	16·1	12·9	12·9	6·7	..	..	..	..	..	..	..	3·3	..	..	..	..	3·2	12·9	25·8	29·0	12·9	8·2
		−2	45·2	38·7	41·9	41·9	35·5	35·5	13·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	22·6	38·7	51·8	15·2
		−5	6·5	19·3	35·5	32·2	32·2	35·5	10·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	7·3
		<−7	..	..	..	..	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

June 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	6·8	17·2	10·3	43·4	43·4	46·7	13·3	..	..	..	..	..	..	..	..	7·5
		10	..	..	..	..	..	..	..	26·6	66·7	72·4	82·8	75·9	50·0	56·7	53·3	86·7	66·7	..	..	..	..	..	..	..	26·6
		5	..	..	..	..	..	3·3	48·3	66·7	33·3	20·7	..	13·8	6·7	..	..	..	33·3	76·7	..	..	..	..	..	..	12·6
		2	..	..	..	..	..	13·3	34·5	6·7	..	..	..	..	..	..	..	..	..	20·0	46·7	10·3	..	..	..	..	5·5
		0·5	..	..	..	..	..	36·7	17·2	..	..	..	..	..	..	..	..	..	..	3·3	23·3	27·6	20·7	3·3	..	..	5·5
		0	..	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	..	..	..	..	0·3
	Inversions	−0·5	3·4	10·3	20·7	10·0	6·8	20·0	..	..	..	..	..	..	..	..	..	..	..	..	10·0	20·7	31·0	30·0	6·8	3·4	7·2
		−2	27·6	17·2	..	20·0	27·6	10·0	..	..	..	..	..	..	..	..	..	..	..	..	20·0	31·0	41·4	36·7	41·4	27·6	12·5
		−5	20·7	17·2	24·1	10·0	10·3	10·0	..	..	..	..	..	..	..	..	..	..	..	..	..	6·8	6·8	23·3	27·6	34·5	8·0
		−10	37·9	31·0	24·1	23·3	31·0	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6·7	24·1	31·0	8·9
		<−13	10·3	24·1	31·0	36·7	24·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	5·4
Trace II	Lapses	3·5	..	..	..	..	..	..	..	..	3·3	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	0·3
		2·5	..	..	..	..	..	..	13·8	50·0	56·7	58·6	62·1	72·4	63·4	66·7	70·0	50·0	30·0	3·3	..	..	..	..	..	..	24·9
		1·5	..	..	..	..	..	33·3	72·4	50·0	40·0	41·4	37·9	27·6	36·7	30·0	30·0	50·0	70·0	93·4	73·4	48·3	34·5	20·0	6·8	10·3	33·6
		0·5	20·7	27·6	13·8	10·0	10·3	16·7	10·3	..	..	..	..	..	..	..	..	..	..	3·3	26·6	51·7	55·2	60·0	51·7	20·7	15·8
		0	..	3·4	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	3·3	3·4	..	0·7
	Inversions	−1	55·2	41·4	41·4	36·7	34·5	13·3	3·4	..	..	..	..	..	..	..	..	..	..	..	..	..	6·8	13·3	34·5	58·6	14·1
		−4	24·1	27·6	44·8	43·4	37·9	16·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	3·4	10·3	8·8
		−8	..	..	..	6·7	17·2	20·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·8
Trace III	Lapses	2·5	..	..	..	..	..	..	..	3·3	..	3·4	6·8	..	3·3	13·3	..	3·3	..	..	..	..	..	..	..	..	1·4
		1·5	..	..	..	..	..	..	17·2	33·3	46·7	55·2	48·3	34·5	43·4	40·0	30·0	43·4	23·3	16·7	6·7	3·4	..	..	..	..	18·4
		0·5	27·6	13·8	6·8	6·7	6·8	20·0	44·8	53·3	50·0	41·4	44·8	62·1	53·3	46·7	70·0	53·3	73·4	80·0	86·7	82·8	75·9	66·7	48·3	41·4	48·2
		0	10·3	3·4	3·4	3·3	3·4	..	6·8	6·7	..	..	..	3·4	..	..	..	..	3·3	3·3	6·7	10·3	10·3	..	6·8	10·3	3·8
	Inversions	−0·5	27·6	34·5	31·0	26·6	10·3	23·3	3·4	3·3	..	..	..	..	..	..	..	..	..	..	..	3·4	6·8	26·6	17·2	20·7	9·8
		−2	31·0	37·9	48·3	40·0	48·3	26·6	24·1	..	3·3	..	..	..	..	..	..	..	..	..	..	..	6·8	6·7	27·6	24·1	13·5
		−5	3·4	6·8	10·3	24·1	31·0	23·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	4·3
		−8	..	3·4	..	..	..	6·7	3·4	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·6

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

July 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	3·2	9·7	9·7	16·1	35·5	35·5	6·5	..	..	..	..	..	..	..	..	4·8
		10	..	..	..	..	..	..	..	9·7	64·5	93·6	87·1	87·1	83·9	61·3	61·3	93·6	96·8	6·5	..	..	..	..	..	..	31·1
		5	..	..	..	..	..	..	54·8	90·4	35·5	3·2	3·2	3·2	..	3·2	3·2	..	3·2	90·4	9·7	..	..	..	..	..	12·4
		2	3·3	..	3·3	3·2	3·2	12·9	45·2	..	..	..	..	..	..	..	..	..	..	3·2	67·8	25·8	9·7	..	..	..	7·4
		0·5	..	6·7	..	3·2	6·5	22·6	..	..	..	..	..	..	..	..	..	..	..	..	16·1	51·8	19·3	16·1	3·2	..	6·1
		0	..	..	..	..	..	9·7	..	..	..	..	..	..	..	..	..	..	..	..	3·2	..	16·1	..	3·2	3·2	1·5
	Inversions	−0·5	6·7	3·3	6·7	6·5	..	25·8	..	..	..	..	..	..	..	..	..	..	..	..	3·2	12·9	35·5	38·7	22·6	6·5	7·0
		−2	23·3	20·0	16·7	6·5	12·9	12·9	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	19·3	35·5	32·2	25·8	9·0
		−5	36·7	26·6	26·6	29·0	25·8	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	29·0	41·9	9·7
		−10	26·6	33·3	30·0	35·5	32·2	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	19·3	7·9
		<−13	3·3	10·0	16·7	16·1	19·3	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	3·1
Trace II	Lapses	3·5	..	..	..	..	..	..	..	..	..	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·3
		2·5	..	..	..	..	..	..	6·5	22·6	45·2	45·2	54·8	45·2	54·8	51·8	48·4	25·8	19·3	3·2	..	..	..	..	..	..	17·6
		1·5	3·3	3·3	3·3	6·5	6·5	12·9	77·4	74·2	54·8	48·4	45·2	54·8	45·2	48·4	48·4	74·2	80·6	87·1	35·5	25·8	19·3	6·5	3·2	6·5	36·3
		0·5	23·3	20·0	13·3	9·7	9·7	25·8	9·7	3·2	..	..	..	..	..	..	3·2	..	..	9·7	64·5	74·2	77·4	74·2	61·3	45·2	21·7
		0	3·3	..	..	..	..	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	..	..	0·4
	Inversions	−1	53·3	43·4	43·4	35·5	38·7	19·3	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	12·9	29·0	38·7	13·4
		−4	16·7	33·3	40·0	45·2	35·5	29·0	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	6·5	9·7	9·3
		−8	..	..	..	3·3	9·7	9·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·9
Trace III	Lapses	2·5	..	..	..	..	..	..	..	..	..	6·5	3·2	3·2	3·2	3·2	..	..	..	3·2	..	..	..	..	..	..	0·9
		1·5	..	6·7	..	..	..	..	38·7	58·1	64·5	64·5	51·8	58·1	74·2	74·2	74·2	71·0	67·8	41·9	22·6	12·9	6·5	3·2	3·2	..	33·1
		0·5	46·7	30·0	26·6	19·3	19·3	25·8	35·5	41·9	35·5	29·0	45·2	38·7	22·6	22·6	25·8	29·0	32·2	54·8	77·4	87·1	87·1	67·8	51·8	41·9	41·4
		0	13·3	6·7	..	3·2	12·9	..	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	12·9	6·5	16·1	3·1
	Inversions	−0·5	26·6	23·3	33·3	25·8	19·3	25·8	12·9	..	..	..	..	..	..	..	..	..	..	..	..	..	6·5	6·5	22·6	29·0	9·7
		−2	3·3	33·3	30·0	38·7	25·8	25·8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	12·9	12·9	8·0
		−5	10·0	..	10·0	12·9	22·6	22·6	9·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	..	3·8

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Aug. 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	..	6·5	9·7	16·1	32·2	29·0	..	..	..	..	..	..	..	..	..	3·9
		10	..	..	..	..	..	..	..	6·5	61·3	90·4	90·4	80·6	71·0	67·8	71·0	100·0	90·4	..	..	..	..	..	..	..	30·4
		5	..	..	..	..	..	..	54·8	93·6	38·7	6·5	3·2	9·7	12·9	..	..	..	9·7	96·8	3·2	..	..	..	..	..	13·7
		2	..	3·2	3·2	3·2	3·2	22·6	41·9	..	..	3·2	..	..	..	..	..	..	..	3·2	83·9	41·9	3·2	..	..	..	8·9
		0·5	..	6·5	3·2	9·7	19·3	22·6	3·2	..	..	..	..	..	..	..	..	..	..	..	12·9	41·9	35·5	12·9	..	..	7·0
		0	..	3·2	..	3·2	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6·5	16·1	..	6·5	..	1·7
	Inversions	−0·5	12·9	6·5	6·5	9·7	9·7	16·1	..	..	..	..	..	..	..	..	..	..	..	..	..	9·7	29·0	48·4	25·8	12·9	7·8
		−2	45·2	35·5	29·0	32·2	16·1	35·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	16·1	35·5	41·9	38·7	13·6
		−5	32·2	22·6	48·4	32·2	38·7	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	22·6	38·7	10·1
		−10	9·7	22·6	9·7	9·7	6·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·2	9·7	3·0
Trace II	Lapses	2·5	..	..	..	..	..	..	..	16·1	32·2	45·2	54·8	54·8	38·7	53·3	23·3	10·0	3·3	..	..	..	..	..	..	..	13·8
		1·5	..	..	3·3	6·7	10·0	16·7	80·0	83·9	67·8	54·8	45·2	45·2	61·3	46·7	76·7	90·0	93·4	70·0	23·3	10·0	..	..	..	..	36·9
		0·5	6·7	16·7	13·3	13·3	13·3	26·6	16·7	..	..	..	..	..	..	..	..	..	3·3	30·0	76·7	90·0	93·4	70·0	53·3	36·7	23·3
		0	13·3	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	6·7	1·2
	Inversions	−1	73·4	66·7	56·7	53·3	46·7	26·6	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	6·7	30·0	43·4	53·3	19·2
		−4	6·7	16·7	23·3	26·6	26·6	30·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	5·5
		−8	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1
Trace III	Lapses	2·5	..	..	..	..	..	3·3	3·3	..	3·2	3·2	6·5	3·2	6·5	3·3	6·7	3·3	3·3	..	..	..	..	..	..	..	1·9
		1·5	6·7	3·3	..	..	..	..	16·7	51·8	61·3	58·1	48·4	35·5	51·8	63·4	53·3	50·0	43·4	50·0	40·0	43·4	33·3	16·7	3·3	6·7	30·7
		0·5	30·0	40·0	33·3	30·0	26·6	26·6	63·4	48·4	35·5	38·7	41·9	58·1	41·9	33·3	40·0	46·7	53·3	50·0	60·0	56·7	60·0	66·7	66·7	66·7	46·4
		0	13·3	6·7	10·0	3·3	13·3	..	3·3	..	..	..	3·2	..	..	..	..	..	..	..	..	..	3·3	3·3	13·3	6·7	3·3
	Inversions	−0·5	36·7	33·3	40·0	36·7	20·0	16·7	6·7	..	..	..	..	3·2	..	..	..	..	..	..	..	..	3·3	13·3	10·0	20·0	10·0
		−2	13·3	16·7	16·7	30·0	40·0	53·3	6·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6·7	..	7·6

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Sept. 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	6·7	10·0	13·3	13·3	30·0	..	..	..	..	..	..	..	..	..	..	3·1
		10	..	..	..	..	..	..	..	..	53·3	86·7	86·7	76·7	80·0	70·0	100·0	96·7	30·0	..	..	..	..	..	..	..	28·3
		5	..	..	..	..	..	..	3·3	76·7	43·4	6·7	3·3	10·0	6·7	..	..	3·3	70·0	33·3	..	..	..	..	..	..	10·7
		2	..	..	..	..	..	..	66·7	20·0	3·3	..	..	..	..	..	..	..	..	56·7	48·3	27·6	..	..	..	..	9·3
		0·5	..	..	..	3·3	3·3	..	23·3	3·3	..	..	..	..	..	..	..	..	..	10·0	34·5	20·7	27·6	6·8	..	3·4	5·7
		0	3·4	..	3·4	3·3	..	6·7	3·3	..	..	..	..	..	..	..	..	..	..	..	10·3	3·4	..	3·4	..	..	1·5
	Inversions	−0·5	3·4	6·7	3·4	3·3	3·3	13·3	3·3	..	..	..	..	..	..	..	..	..	..	..	6·8	20·7	27·6	20·7	10·3	3·4	5·3
		−2	24·1	24·1	17·2	13·3	23·3	20·0	..	..	..	..	..	..	..	..	..	..	..	..	..	27·6	24·1	31·0	48·3	17·2	11·3
		−5	34·5	27·6	27·6	30·0	30·0	33·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	20·7	24·1	17·2	37·9	11·8
		−10	27·6	31·0	34·5	33·3	33·3	20·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	13·8	24·1	34·5	10·5
		<−13	6·8	10·3	13·8	13·3	6·7	6·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	2·5
Trace II	Lapses	2·5	..	..	..	..	..	..	..	13·3	16·7	43·4	10·0	33·3	36·7	50·0	10·0	3·3	..	..	..	..	..	..	..	..	9·0
		1·5	..	..	..	..	..	..	26·6	76·7	83·3	56·7	90·0	66·7	63·4	50·0	90·0	90·0	83·3	33·3	3·4	..	..	..	..	..	33·9
		0·5	3·4	..	6·8	3·3	3·3	3·3	16·7	10·0	..	..	..	..	..	..	..	3·3	13·3	66·7	96·5	68·0	51·7	34·5	20·7	6·8	17·0
		0	..	3·4	..	..	3·3	6·7	..	..	..	..	..	..	..	..	..	..	..	..	..	6·8	3·4	3·4	..	6·8	1·4
	Inversions	−1	51·7	37·9	41·4	43·4	23·3	23·3	36·7	..	..	..	..	..	..	..	..	3·3	3·3	..	..	24·1	31·0	37·9	44·8	48·3	18·9
		−4	44·8	48·3	37·9	33·3	43·4	43·4	20·0	..	..	..	..	..	..	..	..	..	..	..	..	..	13·8	24·1	34·5	37·9	15·9
		−8	..	10·3	13·8	20·0	26·6	23·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·9
Trace III	Lapses	2·5	..	..	..	..	..	..	..	..	3·3	3·3	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	0·4
		1·5	..	..	3·4	..	..	..	6·7	43·4	40·0	60·0	76·7	53·3	70·0	53·3	60·0	53·3	53·3	43·4	34·5	34·5	24·1	10·3	6·8	3·4	30·4
		0·5	20·7	20·7	13·8	10·3	20·7	3·4	26·6	40·0	56·7	36·7	23·3	46·7	30·0	43·4	40·0	43·4	43·4	56·7	58·6	34·5	31·0	34·5	34·5	20·7	32·9
		0	10·3	10·3	..	6·8	..	3·4	..	10·0	..	..	..	..	..	..	..	..	..	..	3·4	17·2	6·8	6·8	3·4	6·8	3·6
	Inversions	−0·5	24·1	13·8	17·2	17·2	13·8	20·7	6·7	..	..	..	..	..	..	..	..	3·3	..	..	3·4	13·8	17·2	31·0	17·2	27·6	9·5
		−2	31·0	44·8	48·3	48·3	34·5	41·4	23·3	3·3	..	..	..	..	..	..	..	..	3·3	..	..	..	20·7	17·2	37·9	37·9	16·3
		−5	13·8	10·3	17·2	17·2	31·0	31·0	23·3	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·4	6·3
		−10	..	..	..	..	..	..	10·0	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·4
		<−13	..	..	..	..	..	..	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Oct. 1931, 1932		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	>13	..	..	..	..	..	..	..	..	..	2·8	8·1	8·3	2·6	2·6	..	..	..	..	..	..	..	..	..	..	1·0
		10	..	..	..	..	..	..	..	2·9	47·2	86·2	86·5	83·4	79·0	92·1	94·8	46·2	..	..	..	..	..	..	..	..	25·8
		5	..	..	..	..	..	..	..	54·3	52·8	10·9	5·4	8·3	18·4	5·3	5·3	53·8	47·4	..	..	..	..	..	..	..	10·9
		2	..	..	..	..	..	..	35·1	37·1	..	..	..	..	..	..	..	..	39·5	21·1	5·3	..	..	..	2·6	..	5·9
		0·5	2·6	2·6	..	..	5·3	10·5	13·5	5·7	..	..	..	..	..	..	..	..	10·5	23·7	13·1	7·9	7·9	5·1	2·6	5·3	4·8
		0	..	..	..	..	2·6	..	2·7	..	..	..	..	..	..	..	..	..	..	2·6	10·5	5·2	2·6	..	..	..	1·1
	Inversions	—0·5	..	..	5·3	2·6	5·3	15·8	16·2	..	..	..	..	..	..	..	..	..	2·6	23·7	7·9	18·4	2·6	5·1	..	..	4·4
		—2	13·1	13·1	10·5	10·5	7·9	7·9	10·8	..	..	..	..	..	..	..	..	..	..	28·9	42·1	23·7	28·9	20·5	12·8	2·6	9·7
		—5	18·4	13·1	15·8	28·9	21·1	18·4	18·9	..	..	..	..	..	..	..	..	..	..	..	21·1	34·2	28·9	30·8	28·2	28·9	12·8
		—10	39·5	44·7	42·1	28·9	28·9	23·7	2·7	..	..	..	..	..	..	..	..	..	..	..	..	10·5	26·3	30·8	41·0	44·7	15·2
		<—13	26·3	26·3	26·3	28·9	28·9	23·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2·6	7·7	12·8	18·4	8·4
Trace II	Lapses	3·5	..	..	..	..	..	..	..	..	..	..	8·3	..	5·6	5·6	..	..	..	..	..	..	..	..	..	..	0·8
		2·5	..	..	..	..	..	..	..	26·5	48·6	54·3	72·2	77·8	58·3	63·9	52·8	43·2	5·6	..	..	..	..	..	..	..	21·0
		1·5	..	..	..	..	..	..	..	41·2	31·4	42·9	16·7	19·4	36·1	30·6	41·7	46·0	69·5	41·7	16·7	11·1	8·3	2·7	8·1	..	19·3
		0·5	2·7	2·7	2·7	2·7	..	..	20·0	17·6	17·1	2·9	2·8	2·8	..	..	5·6	10·8	22·2	44·5	52·8	33·3	22·2	18·9	10·8	10·8	12·7
		0	..	..	..	..	..	..	2·9	2·9	..	..	..	..	..	..	..	..	2·8	..	..	..	2·8	2·7	2·7	..	0·7
	Inversions	—1	37·8	35·1	27·0	10·8	21·6	13·5	22·8	2·9	2·9	..	..	..	..	..	..	..	..	13·9	30·6	50·0	47·3	37·8	29·7	27·0	17·1
		—4	43·2	46·0	37·8	64·9	45·9	56·8	34·3	8·8	..	..	..	..	..	..	..	..	..	..	..	5·6	19·3	35·1	46·0	51·4	20·6
		—8	16·2	16·2	27·0	16·2	29·7	21·6	17·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2·7	2·7	10·8	6·7
		<—10	..	..	5·4	5·4	2·7	8·1	2·9	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·0
Trace III	Lapses	3·5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2·6	2·6	..	..	..	0·2
		2·5	..	..	..	..	..	..	..	5·7	13·9	36·1	10·8	17·5	10·5	2·6	..	..	..	7·9	7·9	5·3	2·6	2·6	5·1	..	5·4
		1·5	5·3	5·3	5·3	2·6	..	2·6	2·7	25·7	50·0	27·8	40·5	41·7	57·9	60·3	52·7	53·8	65·8	42·1	23·7	10·5	13·2	7·7	2·6	7·9	25·3
		0·5	7·9	13·2	7·9	2·6	7·9	2·6	2·7	28·6	16·7	30·5	37·8	38·9	31·6	36·9	47·4	46·2	34·2	47·4	55·3	42·1	26·3	25·6	20·5	15·8	26·1
		0	2·6	2·6	2·6	2·6	..	2·6	2·7	2·9	8·3	2·8	..	..	..	..	..	..	..	2·6	2·6	15·8	5·3	7·7	5·1	2·6	3·0
	Inversions	—0·5	31·6	15·8	23·7	13·2	13·2	15·8	13·5	8·6	5·6	2·8	10·8	2·8	..	..	..	..	..	..	10·5	15·8	28·9	23·1	30·8	28·9	12·3
		—2	42·1	47·4	34·2	50·0	50·0	42·1	35·1	14·3	2·8	..	..	..	..	..	..	..	..	..	..	7·9	21·0	30·8	28·2	34·2	18·3
		—5	10·5	15·8	26·3	26·3	28·9	31·6	40·5	11·4	2·8	..	..	..	..	..	..	..	..	..	..	..	..	2·6	7·7	10·5	9·0
		—8·5	..	..	..	2·6	..	2·6	2·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·3

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Nov. 1931		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	10	..	..	..	..	..	..	..	..	10·0	40·0	56·7	76·7	73·4	63·4	20·0	..	..	..	..	..	..	..	..	..	14·2
		5	..	..	..	..	..	..	..	6·7	63·4	60·0	43·4	23·3	26·6	36·7	70·0	56·7	..	..	..	..	..	..	..	..	16·1
		2	..	..	..	..	..	..	..	46·7	26·6	..	..	..	..	..	10·0	33·3	3·3	..	..	..	..	..	..	..	5·0
		0·5	..	6·7	..	..	..	..	6·7	30·0	..	..	..	..	..	..	..	..	13·3	3·3	3·3	..	..	3·3	..	3·3	2·9
		0	..	..	..	..	..	..	..	3·3	..	..	..	..	..	..	..	3·3	3·3	..	..	..	..	..	..	..	0·4
	Inversions	−0·5	3·3	..	3·3	3·3	3·3	3·3	3·3	3·3	..	..	..	..	..	..	..	6·7	43·4	6·7	3·3	..	..	3·3	10·0	3·3	4·2
		−2	6·7	3·3	3·3	6·7	3·3	3·3	3·3	10·0	..	..	..	..	..	..	..	..	23·3	43·4	13·3	13·3	6·7	10·0	3·3	6·7	6·7
		−5	16·7	10·0	10·0	10·0	13·3	6·7	23·3	..	..	..	..	..	..	..	..	..	10·0	26·6	46·7	30·0	26·6	23·3	20·0	10·0	11·8
		−10	30·0	30·0	43·3	36·7	26·7	30·0	36·7	..	..	..	..	..	..	..	..	..	3·3	16·7	23·3	36·7	36·7	26·6	26·6	30·0	18·1
		<−13	43·4	50·0	40·0	43·3	53·4	56·7	26·7	..	..	..	..	..	..	..	..	..	..	3·3	10·0	20·0	30·0	33·3	40·0	46·7	20·7
Trace II	Lapses	3·5	..	..	..	..	..	..	..	3·3	10·0	16·7	36·7	33·3	20·0	30·0	13·3	..	..	..	..	..	..	..	..	..	6·8
		2·5	..	..	..	..	..	..	..	30·0	56·7	60·0	43·4	40·0	56·7	43·4	56·7	60·0	3·3	..	..	..	..	..	..	..	18·8
		1·5	3·3	..	6·7	10·0	3·3	..	10·0	20·0	30·0	23·3	16·7	26·6	20·6	23·3	26·6	23·3	76·7	33·3	13·3	3·3	..	6·7	6·7	..	16·0
		0·5	10·0	10·0	..	..	6·7	10·0	..	6·7	3·3	..	3·3	..	3·3	..	3·3	16·7	6·7	43·4	26·6	23·3	10·0	6·7	..	13·3	8·6
		0	..	..	..	..	..	..	..	6·7	..	..	..	..	..	..	..	..	3·3	6·7	6·7	..	3·3	..	..	..	1·1
	Inversions	−1	16·7	6·7	16·7	10·0	10·0	10·0	10·0	6·7	..	..	..	..	..	..	..	..	10·0	10·0	36·7	36·7	30·0	23·3	23·3	6·7	11·0
		−4	50·0	53·3	40·0	56·7	43·4	53·3	60·0	20·0	..	..	..	..	..	..	..	..	..	6·7	13·3	26·6	50·0	36·7	36·7	50·0	24·9
		−8	13·3	20·0	30·0	23·3	36·7	26·6	13·3	6·7	..	..	..	..	..	..	..	..	..	..	3·3	10·0	6·7	26·6	33·3	30·0	11·6
		<−10	6·7	10·0	6·7	..	..	..	6·7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1·3
Trace III	Lapses	2·5	..	..	..	..	..	..	..	..	3·3	3·3	..	3·3	13·3	..	3·3	..	..	..	..	..	..	..	..	..	1·1
		1·5	..	..	..	..	..	..	..	6·7	56·7	70·0	56·7	56·7	56·7	63·4	40·0	36·7	23·3	3·3	..	..	..	..	..	..	19·6
		0·5	6·7	..	3·3	6·7	..	3·3	6·7	16·7	26·6	26·6	36·7	33·3	30·0	33·3	56·7	63·4	73·4	56·7	30·0	13·3	6·7	13·3	10·0	6·7	23·3
		0	..	3·3	3·3	3·3	6·7	..	..	6·7	6·7	..	3·3	3·3	..	3·3	..	..	3·3	23·3	10·0	3·3	6·7	3·3	6·7	6·7	4·3
	Inversions	−0·5	13·3	13·3	13·3	3·3	10·0	13·3	10·0	16·7	6·7	..	3·3	3·3	..	..	..	..	..	16·7	36·7	40·0	13·3	13·3	20·0	10·0	10·7
		−2	40·0	46·7	43·4	36·7	40·0	46·7	40·0	30·0	..	..	..	..	..	..	..	..	..	..	23·3	33·3	63·4	50·0	30·0	43·4	23·6
		−5	36·7	30·0	33·3	36·7	33·3	20·0	36·7	20·0	..	..	..	..	..	..	..	..	..	..	..	10·0	10·0	20·0	30·0	23·3	14·2
		−10	3·3	6·7	3·3	13·3	10·0	16·7	6·7	3·3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3·3	10·0	3·2

TABLE VII—FREQUENCY OF OCCURRENCE OF LAPSE RATES OF VARIOUS MAGNITUDES (*continued*)

Dec. 1931		Multiple of dry adiabatic lapse rate	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Day
Trace I	Lapses	8·5	..	..	..	..	..	..	..	..	..	3·3	26·6	30·0	16·7	13·3	..	..	..	..	..	..	..	..	..	..	3·7
		5	..	..	..	..	..	..	..	..	30·0	83·3	66·7	66·7	70·0	70·0	63·4	..	..	..	..	..	..	..	..	..	18·8
		2	..	..	..	..	..	..	..	3·2	56·7	13·3	6·7	3·3	10·0	10·0	26·6	43·4	..	..	..	..	..	..	..	..	7·2
		0·5	..	..	..	..	..	..	..	9·7	10·0	..	..	..	3·3	3·3	3·3	26·6	6·5	3·2	3·2	..	..	..	..	..	2·9
		0	..	..	..	..	..	..	..	3·2	3·3	..	..	..	..	..	..	3·3	6·5	..	..	..	..	..	..	..	0·7
	Inversions	−0·5	..	..	..	3·2	..	..	..	12·9	..	..	..	..	..	3·3	6·7	10·0	3·2	6·5	..	..	..	..	..	..	1·9
		−2	..	..	6·5	..	9·7	9·7	16·1	16·1	..	..	..	..	..	..	..	16·7	32·2	12·9	3·2	..	3·2	3·2	3·2	..	5·5
		−5	16·1	16·1	12·9	12·9	16·1	9·7	9·7	35·5	..	..	..	..	..	..	..	..	41·9	29·0	35·5	29·0	19·3	19·3	12·9	19·3	14·0
		−10	22·6	19·3	19·3	29·0	12·9	19·3	12·9	12·9	..	..	..	..	..	..	..	..	6·5	35·5	29·0	29·0	22·6	22·6	32·2	19·3	14·4
		<−13	61·3	64·5	61·3	54·8	61·3	61·3	61·3	6·5	..	..	..	..	..	..	..	..	3·2	12·9	29·0	41·9	54·8	54·8	51·8	61·3	30·9
Trace II	Lapses	3·5	..	..	..	..	..	..	..	..	..	..	3·3	..	3·3	..	..	..	..	..	..	..	..	..	..	..	0·3
		2·5	..	..	..	..	..	..	..	..	10·0	23·3	20·0	33·3	30·0	33·3	13·3	..	..	..	..	..	..	..	..	..	6·8
		1·5	..	..	..	..	..	..	..	9·7	30·0	50·0	60·0	50·0	53·3	60·0	76·7	63·4	19·3	6·5	..	..	..	..	..	..	20·0
		0·5	3·2	3·2	6·5	3·2	12·9	9·7	12·9	9·7	23·3	26·6	16·7	16·7	13·3	6·7	10·0	33·3	61·3	32·2	9·7	3·2	3·2	..	3·2	3·2	13·5
		0	..	..	..	3·2	3·2	..	..	..	3·3	..	..	..	..	..	..	3·3	..	6·5	3·2	..	..	..	..	..	0·9
	Inversions	−1	9·7	32·2	9·7	19·3	9·7	16·1	16·1	22·6	23·3	..	..	..	..	..	..	..	19·3	41·9	54·8	48·4	16·1	25·8	22·6	16·1	16·8
		−4	41·9	22·6	45·2	41·9	35·5	38·7	38·7	16·1	10·0	..	..	..	..	..	..	..	..	9·7	29·0	38·7	64·5	54·8	48·4	38·7	23·9
		−8	35·5	32·2	29·0	22·6	29·0	22·6	16·1	32·2	..	..	..	..	..	..	..	..	..	3·2	3·2	9·7	12·9	12·9	19·3	35·5	13·2
		<−10	9·7	9·7	9·7	9·7	9·7	12·9	16·1	9·7	..	..	..	..	..	..	..	..	..	..	..	..	3·2	6·5	6·5	6·5	4·6
Trace III	Lapses	3·5	..	..	..	..	..	3·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0·1
		2·5	..	..	..	..	..	..	..	..	3·3	10·0	3·3	6·7	20·0	6·7	3·3	..	..	..	..	..	..	..	..	..	2·2
		1·5	..	..	..	..	..	..	3·2	6·5	36·7	73·4	70·0	83·3	73·4	73·4	73·4	46·7	19·3	6·5	..	..	..	..	..	..	23·6
		0·5	9·7	16·1	12·9	9·7	12·9	9·7	9·7	12·9	10·0	13·3	26·6	6·7	6·7	20·0	20·0	50·0	64·5	48·4	29·0	32·2	12·9	3·2	3·2	9·7	18·8
		0	..	6·5	3·2	3·2	..	..	..	..	6·7	..	..	..	..	..	3·3	3·3	3·2	6·5	6·5	..	3·2	6·5	6·5	..	2·4
	Inversions	−0·5	6·5	6·5	6·5	6·5	16·1	12·9	16·1	12·9	10·0	3·3	..	3·3	..	..	..	..	3·2	19·3	25·8	22·6	32·2	25·8	12·9	19·3	10·9
		−2	25·8	12·9	29·0	16·1	19·3	22·6	32·2	35·5	13·3	..	..	..	..	..	..	..	6·5	12·9	19·3	25·8	19·3	22·6	22·6	19·3	14·0
		−5	41·9	48·4	38·7	51·8	32·2	41·9	22·6	22·6	10·0	..	..	..	..	..	..	..	3·2	6·5	12·9	12·9	25·8	29·0	38·7	32·2	19·6
		−10	16·1	6·5	6·5	12·9	16·1	6·5	12·9	6·5	6·7	..	..	..	..	..	..	..	..	..	6·5	6·5	..	12·9	16·3	19·3	6·3
		<−13	..	3·2	3·2	..	3·2	3·2	3·2	3·2	3·3	..	..	..	..	..	..	..	..	..	..	..	6·5	..	..	..	1·2

value. The inversions show a grouping of the values around the lowest negative ratios and not more than about twenty per cent exceed a ratio of minus five at any hour. As regards the lapses recorded by trace III, over eighty per cent of the values are between one and two times the adiabatic value from 1100 to 1300 and no value exceeds a ratio of four. The values for the nocturnal inversions are distributed in a manner similar to those for trace II; the majority of inversions are less than minus six times the adiabatic ratio and not more than ten per cent exceed this ratio. A lapse occurs for each trace at some time during the night but with few exceptions the magnitude does not exceed the adiabatic value. The frequency of these nocturnal lapses is small but increases the further the height interval concerned is from the ground. Less than seven per cent of the values at any hour of the night are lapses in the case of trace I but fifteen to twenty-five per cent of the total readings for traces II and III are equal to or less than the adiabatic value. Further, the possible magnitude of the lapse increases with height above the ground and for trace III may be equal to twice the adiabatic value at any time of the night. The figures for February exhibit similar characteristics to those for January. For trace I a number of readings reach thirteen times the adiabatic value during the day, but traces II and III record a greater percentage of readings equal to or less than the adiabatic value than during January, together with the occasional occurrence of a very small inversion during the day. The nocturnal inversions show a tendency towards an increase in the number of those of great magnitude.

The March records continue the process observed for all traces in February. In April there is a decrease in the percentage of daytime lapses less than the adiabatic value for both traces II and III and for the first time a few values occur between three and four times the adiabatic value while the number of large lapses over the lowest height interval continues to increase. Occasional inversions are recorded by traces II and III in the daylight hours during this month while nocturnal inversions are of the same order as those for March.

In May the figures for trace I show a continuance of the increase in frequency of the higher adiabatic ratios during the day while the majority of the inversions are grouped about a ratio of minus ten. For trace II the daily lapses are grouped about one and two times the adiabatic value while the nocturnal inversions are distributed in much the same way as in April. The increase in frequency of higher ratios of the daily lapse is most marked for trace III and from 1000 to 1200 over half the readings exceed twice the adiabatic value while a ratio greater than four is recorded at 0900. Higher values of the nocturnal inversion decrease in frequency and an inversion exceeds a ratio of minus seven during only one hour.

The month of June marks the culmination of the increase in frequency of daily lapses greater than thirteen times the adiabatic value over the lowest height interval, and of the higher ratios (2 to 4) for trace II, but for trace III there is a large decrease in the frequency of high ratios. The values given for trace III show that between 0900 and 1200 from forty to sixty per cent of the lapses are equal to or less than the adiabatic value as against ten to fifteen per cent during May while no value exceeds a ratio of three. Occasions of high values of the nocturnal inversion continue to decrease.

The figures obtained for the months July to December show that the frequency of the larger adiabatic ratios for the midday lapse recorded by trace I continues to decrease progressively and the December figures are similar to those for January. The percentage of large values of the nocturnal inversion continues to decrease during July and August and in the latter month the largest inversion does not exceed a ratio of minus thirteen. In subsequent months these values increase to a maximum in December when over half the inversions recorded from 2100 to 0700 exceed a ratio of minus thirteen. Daytime lapses for traces II and III are within the same range as those for June except during November and December when the majority of observations for trace III are between one and two times the adiabatic value. The larger values of the inversions for both traces exhibit a decreasing frequency up to August in which month only one observation exceeds a ratio of minus six for trace II and not one exceeds a ratio of minus three for trace III. From September onwards the larger values of the inversion over the middle and upper height intervals increase to a maximum in December, as in the case of the lowest interval, and in this month a number of lapse rates exceed a ratio of minus ten for both trace II and trace III.

Considering the figures for the year it is seen that only over the lowest height interval does an inversion persist on an average throughout each night of a month. This occurs in November and December. During each of the other months small lapses, in most cases less than three times the adiabatic value, may occur at any hour of the night. Over the other two height intervals a lapse may occur during the night in any month, but the magnitude of such lapses is seldom greater than the adiabatic value with the exception of values for trace II during July and August, and for trace III during January, March, July, August, September and October, when some values may reach a ratio of two. The few small inversions recorded during the day by both traces II and III occur during the months when depressions develop over the desert west of Egypt and travel north-east into the eastern Mediterranean basin. The centres of these depressions pass nearer to Egypt in March and April and it is significant that these small inversions during the daylight hours are most frequent during these months.

(*b*) *Monthly frequency of various lapse rates.*—In addition to the hourly frequency of various values of the lapse rate, figures have been obtained to show the frequency of occurrence of such values during each month, and for the year, for each height interval. The result is contained in Table VIII where the frequencies are expressed as percentages of the total number of hourly readings.

The frequency figures for the lowest height interval exhibit two maxima in each month except January. One of these maximum frequencies occurs for inversions which lie between 0·1 and 4·0°C./100m. during the months January to November, but in December inversions between 4·1 and 7·9°C./100m. exhibit a frequency maximum. The actual frequencies vary from fifteen to twenty-five per cent. and do not exhibit any seasonal variation—the lowest value occurs in November and the highest in January. During the months March to October inclusive the other maximum occurs for lapses which lie between 8·0 and 11·9°C./100m., during February and November for lapses between 4·1 and 7·9°C./100m., and in December for lapses less than 4·0°C./100m. The frequency values in this case vary from sixteen to twenty-one per cent and are in general larger during the summer months. During February fifty-five per cent of the readings are evenly distributed between a lapse of 7·9°C./100m. and an inversion of 4·0°C./100m. while in January, as already mentioned, the figures are grouped around a maximum frequency for small inversions between 0·1 and 4·0°C./100m. The summer months are characterised by an increase in frequency of large lapses; in June twelve per cent of the hourly values are for lapse rates between 12·0 and 19·8°C./100m. but the lower value was not even reached during either January or December. The frequency of inversions between 0·1 and 7·9°C./100m. is fairly constant at about thirty per cent throughout the year but larger values of the inversion exhibit a marked annual variation with maximum frequency in winter. In June inversions greater than 19·8°C./100m. account for only one per cent of all hourly readings, but in December the corresponding figure is nineteen per cent.

The lapse rates for the middle and upper height intervals extend over a much smaller range than those for the lowest interval. In the latter case the range is nearly 70°C./100m. and individual lapse rates vary from 20°C./100m., to −50°C./100m., but the values for traces II and III are all between 5°C./100m. and −25°C./100m. The readings over the middle height interval exhibit a maximum frequency for lapses between 1·1 and 2·0°C./100m. for each month March to September, and from October to February for lapse rates between 0 and 1·0°C./100m. In midsummer the former group of lapse rates accounts for about thirty-five per cent of the hourly values but in winter the frequency of occurrence decreases to under twenty per cent. The increase in frequency of inversions in winter is very marked: inversions less than 4·1°C./100m. account for about twenty per cent of the total readings in summer but in winter for over thirty per cent. For inversions greater than 4·0°C./100m. the June value is only five per cent but in December the value has increased to nearly thirty per cent.

TABLE VIII—MONTHLY FREQUENCY OF OCCURRENCE OF VARIOUS LAPSE RATES, SHOWING PERCENTAGE FREQUENCY OF SPECIFIED LAPSE RATES OVER THREE HEIGHT INTERVALS

Month	Lapses (°C./100m.)					Inversions (°C./100m.)												
	19·8 to 16·0	15·9 to 12·0	11·9 to 8·0	7·9 to 4·1	4·0 to 0	−0·1 to −4·0	−4·1 to −7·9	−8·0 to −11·9	−12·0 to −15·9	−16·0 to −19·8	−19·9 to −23·8	−23·9 to −27·7	−27·8 to −31·7	−31·8 to −35·6	−35·7 to −39·5	−39·6 to −43·5	−43·6 to −47·3	−47·4 to −51·3
	(a) Height interval 1·1m. to 16·2m. (Trace I)																	
Jan.	..	..	3·5	15·7	18·9	25·1	12·4	7·6	5·6	4·7	4·0	1·7	0·4	0·4	..	..	..	..
Feb.	..	0·6	7·6	18·3	18·0	18·7	13·8	7·2	7·3	2·3	1·7	1·5	1·5	0·9	0·3	0·3	..	..
Mar.	..	4·0	16·7	16·6	13·6	21·0	10·1	7·7	4·4	2·6	1·9	0·3	0·5	0·3	0·1	..	..	..
Apr.	0·3	12·2	14·8	12·5	12·5	20·3	12·2	7·1	4·3	2·4	1·2	0·1	..	..	..	..	..	..
May	0·5	8·3	17·9	13·4	13·9	20·0	8·9	9·3	5·2	1·6	0·5	0·1	0·1	..	..	..	..	..
June	0·1	12·0	18·8	13·7	13·7	22·6	7·3	5·2	7·1	1·4	0·6	0·4	..	..	..	..	..	..
July	..	9·4	21·0	15·8	17·1	19·0	8·8	5·0	4·3	0·5	0·4	0·3	..	..	..	..	..	..
Aug.	..	8·7	20·3	16·0	20·6	24·3	8·5	1·6	..	..	..	..	..	..	..	..	..	..
Sept.	..	7·5	20·3	12·7	18·7	20·1	11·3	5·8	3·2	0·4	0·1	..	..	..	..	..	..	..
Oct.	..	2·8	18·0	14·6	13·9	17·3	13·7	10·0	4·9	2·3	0·3	0·1	..	0·1	..	..	..	..
Nov.	..	0·1	8·3	17·2	12·9	14·6	11·5	11·5	9·6	6·7	4·2	2·1	0·7	0·3	0·3	..	..	..
Dec.	..	..	1·2	14·9	16·4	9·5	14·8	9·9	6·7	7·7	7·2	4·2	3·8	1·4	0·7	1·0	0·3	0·3
Year	0·1	5·5	14·0	15·1	15·7	19·5	11·0	7·3	5·2	2·7	1·9	0·9	0·6	0·3	0·1	0·1	0·0	0·0

Month	Lapses (°C./100m.)					Inversions (°C./100m.)								
	5·0 to 4·1	4·0 to 3·1	3·0 to 2·1	2·0 to 1·1	1·0 to 0	−0·1 to −1·0	−1·1 to −2·0	−2·1 to −3·0	−3·1 to −4·0	−4·1 to −7·9	−8·0 to −11·9	−12·0 to −15·9	−16·0 to −19·8	−19·9 to −23·8
	(b) Height interval 16·2m. to 46·4m. (Trace II)													
Jan.	..	..	7·6	22·1	24·3	15·5	6·1	7·1	4·4	9·2	3·1	0·6	..	..
Feb.	..	..	5·2	24·0	24·5	12·0	9·1	5·3	4·1	10·2	4·7	0·5	0·2	0·2
Mar.	..	..	4·8	27·0	25·9	10·4	7·5	6·9	3·6	10·0	3·7	0·3	..	..
Apr.	..	0·4	15·5	27·2	20·4	9·2	4·9	6·8	4·0	8·2	2·3	0·7	0·3	..
May	..	..	5·7	33·7	27·3	6·5	5·0	4·5	4·2	10·1	2·5	0·4	..	..
June	..	0·3	25·0	33·8	16·4	8·8	5·2	4·1	1·6	4·5	0·4	..	..	..
July	..	0·3	17·7	36·4	22·3	7·2	6·1	3·9	2·4	3·5	0·3	..	..	..
Aug.	..	..	14·0	37·0	24·2	12·8	6·2	3·2	1·7	0·8	..	..	..	..
Sept.	..	..	9·1	34·3	18·3	10·0	8·6	6·5	3·8	8·3	1·1	..	..	..
Oct.	..	0·1	19·6	19·1	13·3	10·0	7·2	9·7	6·2	9·9	2·9	0·1	..	..
Nov.	..	6·8	18·8	16·0	9·7	5·7	5·3	6·5	6·9	20·3	3·7	0·3	..	..
Dec.	..	0·3	6·7	19·6	14·4	9·2	7·7	7·9	6·0	18·1	7·7	1·8	0·7	..
Year	..	0·7	12·5	27·5	20·1	9·8	6·6	6·1	4·1	9·4	2·7	0·4	0·1	0·0
	(c) Height interval 46·4m. to 61·0m. (Trace III)													
Jan.	..	0·1	2·5	29·9	27·5	14·6	9·3	5·3	2·8	6·4	1·5	0·1	..	..
Feb.	..	..	0·5	14·4	36·8	13·1	10·1	8·1	5·0	9·0	2·4	0·5	0·1	..
Mar.	..	..	1·5	10·1	40·6	15·9	10·1	6·6	6·4	6·3	1·8	0·8	..	..
Apr.	..	1·0	5·3	16·5	33·0	12·8	8·4	8·4	4·6	7·8	1·8	0·4	..	..
May	0·1	1·9	12·7	22·5	31·5	8·3	10·5	4·9	3·1	4·2	..	0·1	..	..
June	..	..	1·4	18·5	52·1	9·7	6·6	6·8	1·6	3·1	0·1	..	..	..
July	..	..	0·9	33·2	44·6	9·6	4·3	3·6	1·6	2·2	..	..	..	..
Aug.	..	..	1·9	30·9	49·7	9·9	4·5	1·8	1·1	0·1	..	..	..	..
Sept.	..	..	0·4	30·8	36·6	9·3	9·7	6·4	2·7	3·5	0·3	0·1	0·1	..
Oct.	..	0·2	5·2	25·2	29·2	12·4	9·0	9·5	3·2	5·9	0·2	..	..	..
Nov.	..	..	1·1	19·6	27·6	10·7	10·3	13·3	5·1	10·3	1·7	0·3	..	..
Dec.	..	0·1	2·2	23·1	21·2	11·0	8·2	6·8	5·4	16·6	3·4	1·5	0·5	..
Year	0·0	0·3	3·0	22·9	35·9	11·5	8·4	6·8	3·5	6·3	1·1	0·3	0·1	..

In the case of the upper height interval each month exhibits a maximum frequency for lapse rates between 0 and 1·0°C./100m.: in June fifty-two per cent of the hourly values fall within this range but in December the frequency decreases to only twenty-one per cent. Inversions less than 4·1°C./100m. account for over thirty per cent of the total number of readings in winter and for about twenty per cent. in summer, and thus exhibit a seasonal variation similar to that for the two lower height intervals. Inversions greater than 4·0°C./100m. account for twenty-two per cent of the observations in December but for only 0·1 per cent in August.

The average frequency for the year is shown on the last line of each table and these values are plotted in Fig. 9. The maximum frequency for the lowest height interval occurs at a lapse rate of —2·0°C./100m. although there is a flattening of the curve between 2·0 and 10·0°C./100m., which is the region of the secondary maxima referred to above when discussing the distribution of lapse rates during each month. If the curve for the lowest height interval is compared with that given by Johnson for the height interval 1·2m. to 17·1m. it is seen that at Ismailia the lapses are spread over a much wider range. About sixteen per cent of all the readings fall around a lapse rate of 2·0°C./100m., another sixteen per cent about 6·0°C./100m. and a further thirteen per cent about 10·0°C./100m., while the corresponding figures for Salisbury Plain are thirty-four per cent, eleven per cent and five per cent.

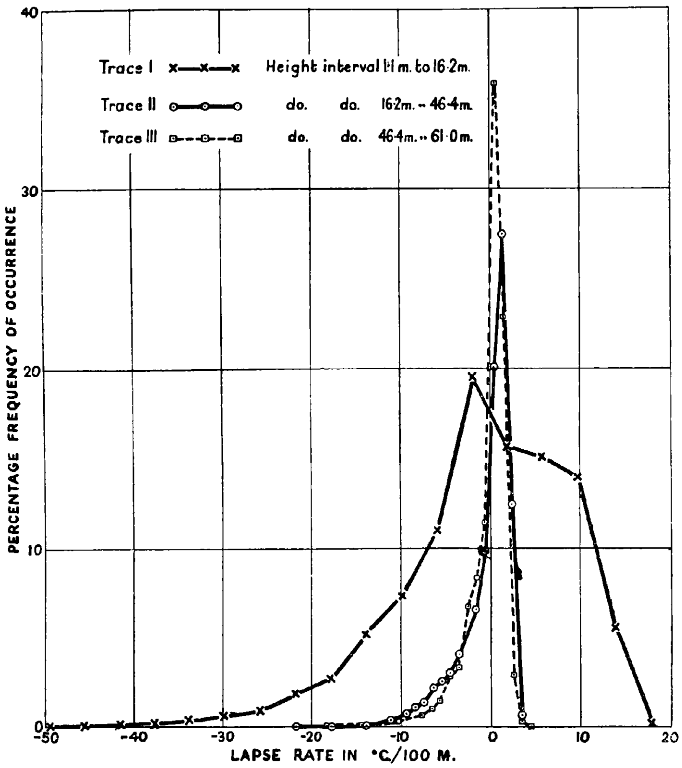


FIG. 9.—FREQUENCY OF OCCURRENCE OF VARIOUS LAPSE RATES

The frequency curve for trace II gives a sharp maximum for lapse rates around 1·5°C./100m. Further, sixty per cent of all the readings are within a range of 3·0°C./100m. centred at this point. The curve representing the readings over the upper height interval is similar to that for the middle interval but the position of the maximum is nearer zero lapse rate and the curve is much steeper. The maximum frequency occurs for lapse rates between 0 and 1·0°C./100m. and fifty-nine per cent of all the hourly values are accounted for by lapse rates between 0 and 2·0°C./100m., while inversions smaller than 4·1°C./100m. represent thirty per cent.

§ 11—EFFECT OF CLOUDS ON THE MAGNITUDE OF LAPSE RATES

In a previous section mean values of lapse rates over certain intervals of height have been considered without reference to the prevailing meteorological conditions. It is now proposed to consider the variation which occurs in these lapse rates according to whether the sky is cloudless or not. Unfortunately an overcast sky for any lengthy period is an extremely rare occurrence at Ismailia and on no occasion during the functioning of the installation was the sky overcast for the whole of the day and night. For the purpose of the present investigation, therefore, days when the sky was more than half covered with clouds at 0500, cloudy (sky 8 tenths to 10 tenths covered) at 0800, more than half clouded at 1400, and more than half clouded since 1400 the previous afternoon have been taken as representing the opposite extreme from a cloudless sky. Even with this classification the number of days to be included in the "cloudy" group is very small and any stricter conditions would mean that no days could be classed as "cloudy." The criterion for a cloudless day has been a continuous trace on the sunshine record during the daylight hours from 1400 the previous day and no reports of clouds during the night. December has been taken as representative of the winter months when clouds are liable to develop and to persist during the day. August has been taken as representative of the summer months but in this case there were no occasions of the cloud amount exceeding 6 tenths after about 1000, and as the sky was invariably clear after 1600 it is possible to consider only the lapse rates on cloudless days during summer. The hourly values for the three traces, I, II and III for cloudless and cloudy days and nights during December and for cloudless days in August are given in Table IX, together with the mean hourly wind velocity for each group as recorded by the Dines pressure tube anemometer, the head of which is at a height of 15·2 metres. The data given in Table IX are shown graphically in Fig. 10.

The curves for cloudless days in December show that traces I, II and III have maximum values of the lapse rate at 6·3, 1·7 and 1·6°C./100m. respectively compared with 6·06, 1·69 and 1·63°C./100m. already given as the mean values for all states of sky. The corresponding values for cloudy days are 6·4, 1·7 and 1·6°C./100m. which differ by not more than 0·1°C./100m. in any case from the figures for cloudless days so that the fact of the sky being cloudy has little or no effect on the magnitude of the maximum lapses, although it must be noted that on cloudy days the wind velocity is greater, especially before noon. The nocturnal inversions on clear nights reach values of 30·2, 8·7 and 7·4°C./100m. respectively for the three traces, I, II and III compared with the monthly mean values of 18·94, 5·34 and 4·25°C./100m., but on cloudy nights the extreme values are only 9·9, 4·1 and 4·6°C./100m. On cloudless nights the inversions are therefore considerably larger than on cloudy or partially cloudy nights and the increase is greater near the ground.

TABLE IX—MEAN HOURLY VALUES OF THE LAPSE RATE IN °C./100m.

	Zone time	1	2	3	4	5	6	7	8	9	10	11
December, 1931		Cloudless Days										
	1·1m. to 16·2m.	−22·5	−22·2	−22·2	−22·9	−27·1	−30·2	−29·2	− 9·4	2·3	3·8	6·3
	16·2m. to 46·4m.	− 6·3	− 5·8	− 7·8	− 8·7	− 7·7	− 7·8	− 7·2	− 8·0	− 1·1	1·2	1·5
	46·4m. to 61·0m.	− 4·7	− 5·0	− 4·0	− 5·2	− 6·8	− 4·4	− 5·0	− 4·9	− 4·3	1·3	1·2
		Cloudy Days										
	1·1m. to 16·2m.	− 9·9	− 7·0	− 4·8	− 4·6	− 3·2	− 3·2	− 2·2	− 0·4	1·9	4·7	6·4
	16·2m. to 46·4m.	− 4·1	− 4·0	− 3·2	− 0·8	− 0·2	− 0·6	− 0·3	0·8	1·4	1·6	1·7
	46·4m. to 61·0m.	− 0·9	− 1·4	− 2·1	− 1·0	− 0·8	− 1·0	− 0·2	0·5	0·9	1·1	1·5
August, 1932		Cloudless Days										
	1·1m. to 16·2m.	− 4·8	− 6·3	− 6·7	− 6·0	− 5·3	− 2·0	2·6	5·0	7·1	8·2	9·9
	16·2m. to 46·4m.	− 0·6	− 0·9	− 1·5	− 2·1	− 3·0	− 2·2	1·3	1·7	1·8	2·0	1·9
	46·4m. to 61·0m.	− 2·0	0·0	− 0·4	− 1·2	− 1·4	− 2·2	0·4	1·0	1·0	0·9	0·8
		Mean Hourly Values of Wind Velocity										
December	Cloudless days..	1·9	1·5	1·8	1·5	1·6	1·6	1·7	1·5	1·5	2·5	3·4
December	Cloudy days ..	5·3	5·5	5·2	4·7	4·6	4·6	5·1	4·8	4·6	5·4	5·7
August	Cloudless days..	1·4	1·7	1·9	2·3	2·4	1·9	2·2	2·1	2·1	2·3	2·9

The wind velocity when the sky is cloudless is at all hours lower than when it is cloudy. During daylight hours the velocity on cloudy days is about fifty per cent greater than on cloudless days but at night the increase is much greater. This is due to the diurnal variation of velocity being more marked on cloudless days than on those when cloudy conditions prevailed. Further, the velocity on a cloudy night is on an average about three times the value recorded on a clear night.

Reference to Fig. 10 shows that the change over from an inversion to a lapse, and vice versa, is very rapid with clear skies but more gradual in cloudy weather.

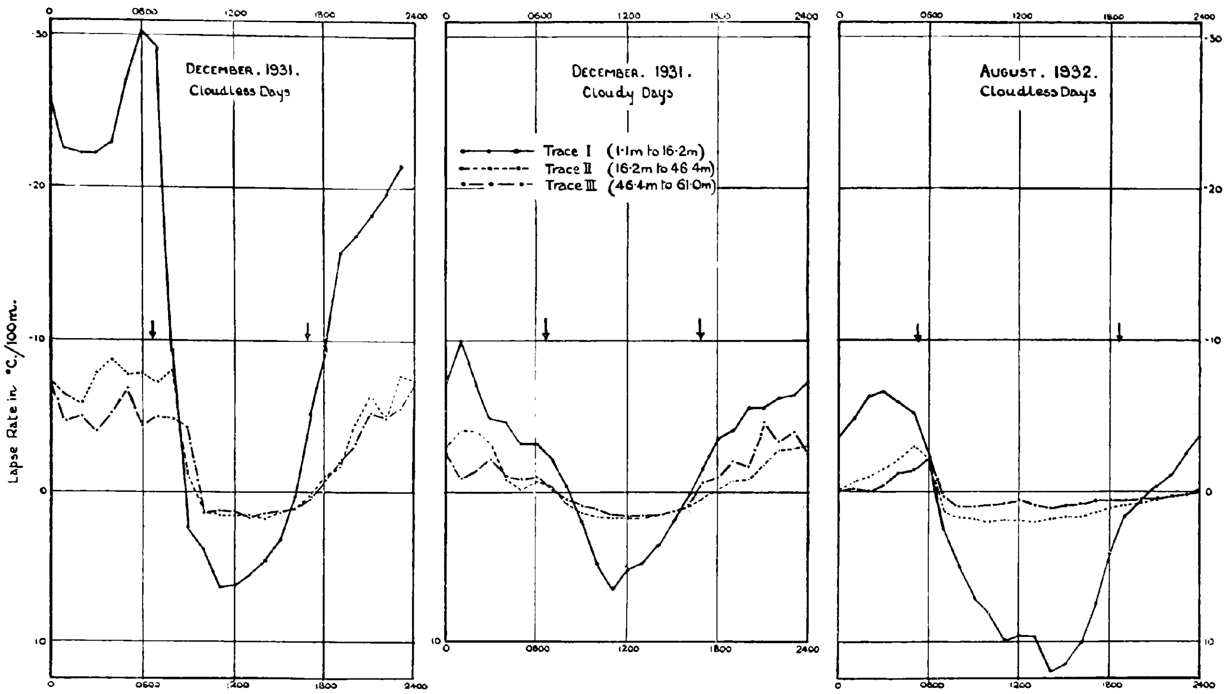
The rate at which the inversion decreases and a lapse develops after sunrise is greater than the rate of decrease of lapse and growth of inversion about sunset. In December the change over occurs earlier in the morning for each of the three traces under cloudy conditions and the order of change over is reversed. On cloudy mornings a lapse is first recorded by trace III followed in turn by traces II and I but when it is clear a lapse occurs first near the ground and develops upwards.

On cloudless days in August the lapse rate recorded over each height interval during the day is slightly less than under average conditions but the nocturnal inversion is more intense. The extreme lapses on cloudless days recorded respectively by traces I, II and III are 12·0, 2·0 and 1·1°C./100m. as against average values of 12·28, 2·06 and 1·21°C./100m., while the extreme inversions are 6·7, 3·0 and 2·2°C./100m. compared respectively with average values of 3·90, 1·29 and 1·29°C./100m. The wind velocity exhibits a well marked diurnal variation in the same way as do the figures for cloudless days in December except that the maximum velocity does not occur until 1800, or three hours later than in winter. The increase in wind velocity after 1200 and the decrease in lapse rate after 1300 are to be noted although it is doubtful whether the two features are directly related.

OVER THREE HEIGHT INTERVALS FOR CLEAR AND CLOUDY DAYS

12	13	14	15	16	17	18	19	20	21	22	23	24	Number of days
Cloudless Days													
6·2	5·5	4·6	3·2	0·3	− 5·2	− 9·5	−15·7	−16·8	−18·2	−19·6	−21·5	−26·0	
1·5	1·5	1·7	1·4	1·1	0·3	− 1·0	− 1·6	− 4·5	− 6·5	− 4·9	− 7·7	− 7·4	7
1·3	1·6	1·4	1·3	1·1	0·4	0·8	− 1·9	− 3·2	− 5·2	− 5·0	− 5·5	− 7·4	
Cloudy Days													
5·1	4·8	3·6	1·9	0·4	− 1·5	− 3·5	− 4·0	− 5·6	− 5·6	− 6·2	− 6·3	− 7·2	
1·7	1·7	1·5	1·3	1·0	0·4	− 0·1	− 0·7	− 0·8	− 1·7	− 2·7	− 2·8	− 3·0	4
1·6	1·6	1·5	1·3	0·9	− 0·6	− 0·9	− 2·0	− 1·6	− 4·6	− 3·3	− 4·0	− 2·5	
Cloudless Days													
9·6	9·7	12·0	11·5	10·1	7·5	4·1	1·6	0·6	− 0·3	− 1·0	− 2·5	− 3·6	
1·9	2·0	1·8	1·7	1·7	1·4	1·1	0·9	0·8	0·6	0·4	0·2	− 0·1	9
0·6	0·9	1·1	0·9	0·8	0·6	0·6	0·6	0·5	0·5	0·4	0·2	0·0	
at 15·2m. in metres per second													
4·0	4·0	4·1	4·9	4·7	4·7	4·1	3·1	2·6	2·4	2·3	2·1	1·8	7
5·1	5·7	6·3	5·9	5·6	5·4	5·4	5·1	4·3	4·5	4·5	4·2	3·8	4
3·1	4·8	5·6	6·3	6·9	7·6	8·1	7·7	6·0	5·0	3·7	2·4	1·6	9

A comparison of the lapse rates on cloudless days and nights in summer and in winter shows that in the case of trace I the lapse rate is considerably smaller during the winter. The daytime lapses in December are never greater than two-thirds the August value while the nocturnal inversion in December attains a value five times that recorded in August. As regards the other two traces the nocturnal inversions are much greater in winter while the daytime lapses are still slightly larger in summer in the case of trace II although they are smaller in the case of trace III. A very marked feature of the two series of lapse rates is, however, the much longer duration of a positive lapse rate in summer. Inversions account for only about one-third of the hourly readings in August compared with two-thirds of the number in December.



NOTE - Arrow heads indicate times of sunrise and sunset for middle day of month. Times are zone times.

FIG. 10.—CURVES SHEWING MEAN LAPSE RATE OF TEMPERATURE BETWEEN HEIGHTS OF 1·1m. AND 16·2m., 16·2m. AND 46·4m., AND 46·4m. AND 61·0m. ON CLOUDLESS AND CLOUDY DAYS AND NIGHTS IN DECEMBER, 1931, AND ON CLOUDLESS DAYS AND NIGHTS IN AUGUST, 1932

§ 12—ANALYSIS OF THE LAPSE RATES OCCURRING DURING THE NIGHT AND EARLY MORNING IN SUMMER

During the summer one outstanding phenomenon of the weather experienced in the Nile Delta and the adjacent desert is the frequent occurrence of a considerable amount of low cloud in the early morning. The observations of cloud amount in the early morning at Ismailia show that on an average the sky is more than 7 tenths covered with low clouds at some time between 0400 and 0800 on eight days in June and on seventeen days in both July and August. Since the climate of Egypt is not affected by the passage of cyclonic depressions during these months, the development of low cloud was considered a matter of sufficient interest to warrant an analysis of the lapse rates associated with those occasions, when either the sky is clear throughout the night and until 0800 at the earliest, or cloud developed and amounted to 8 tenths–10 tenths at some time between 0400 and 0800. The values of the lapse rate at each hour from 1800 to 0900 were abstracted for the days fulfilling the conditions as regards clear or cloudy mornings during June, July and August and the mean monthly values at each hour for each state of sky were computed and these figures, together with the mean value of the vapour pressure, the temperature at 1·1m., and the wind velocity at 15·2m. and 62·6m. are given in Table X.

On occasions when the sky is cloudless throughout the night it is seen that during June the lapse rate during the evening is, on an average, less than the mean value for the month over each height interval (cf. Table III). The difference is most marked about sunrise and at 0500 the difference in lapse rate over the lowest interval, 1·1m. to 16·2m., is 3·0°C./100m. In July the lapse rate over the upper height interval, 46·4m. to 61·0m., differs little from the monthly mean before 2300, but the lapse rates over the other two height intervals exhibit similar characteristics to the corresponding figures for June. During August the difference in the lapse rate on cloudless nights and under average conditions is far less marked than in either of the earlier months and it is only over the lowest height interval, 1·1m. to 16·2m., that any consistent difference is to be observed.

TABLE X—MEAN VALUES OF THE LAPSE RATE BETWEEN 1·1m. AND 61·0m. TOGETHER WITH THE MEAN VAPOUR PRESSURE, MEAN WIND VELOCITY AT 15·2m. AND 62·6m. AND MEAN TEMPERATURE AT 1·1m. ON OCCASIONS WHEN THE SKY WAS EITHER CLOUDLESS THROUGHOUT THE NIGHT OR 8–10 TENTHS COVERED WITH CLOUDS BETWEEN 0400 AND 0800

Zone time	JUNE							JULY							AUGUST						
	Mean lapse rate in °C./100m.			Mean vapour pressure	Mean wind velocity		Mean temperature at 1·1m.	Mean lapse rate in °C./100m.			Mean vapour pressure	Mean wind velocity		Mean temperature at 1·1m.	Mean lapse rate in °C./100m.			Mean vapour pressure	Mean wind velocity		Mean temperature at 1·1m.
	1·1m. to 16·2m.	16·2m. to 46·4m.	46·4m. to 61·0m.		15·2m.	62·6m.		1·1m. to 16·2m.	16·2m. to 46·4m.	46·4m. to 61·0m.		15·2m.	62·6m.		1·1m. to 16·2m.	16·2m. to 46·4m.	46·4m. to 61·0m.		15·2m.	62·6m.	
				mb.	m./sec.	m./sec.	°C.				mb.	m./sec.	m./sec.	°C.				mb.	m./sec.	m./sec.	°C.
	Cloudless throughout the period 1800–0900																				
1800	3·3	1·7	0·8	11·5	7·6	..	30·7	4·8	1·3	0·8	15·9	8·1	..	32·9	4·0	0·7	0·8	15·0	7·6	..	31·8
1900	0·4	0·7	0·8	12·7	7·2	..	28·4	0·7	0·9	1·1	17·1	6·7	..	30·5	1·8	0·7	1·1	21·0	7·6	..	29·5
2000	−1·1	1·1	0·4	15·2	5·8	..	26·4	0·0	0·7	0·8	19·4	5·4	..	28·7	0·7	0·7	0·8	23·2	6·7	..	27·5
2100	−1·5	0·7	0·4	17·4	4·9	..	25·0	−0·4	0·6	0·8	21·3	4·0	..	27·4	0·0	0·6	0·8	24·1	5·4	..	26·8
2200	−2·6	0·2	0·0	18·1	3·1	..	23·9	−1·8	0·2	0·0	22·8	3·1	..	26·3	−1·5	0·7	0·8	24·0	3·6	..	26·0
2300	−5·1	0·0	−0·4	18·0	1·8	..	22·8	−3·3	−0·4	−0·8	22·9	2·2	..	25·3	−2·2	0·2	0·4	24·4	2·2	..	25·1
2400	−7·7	−0·9	−0·8	17·9	1·3	..	21·9	−5·9	−1·1	−0·4	22·6	1·3	..	24·3	−3·7	0·2	0·4	24·2	1·3	..	24·4
0100	−8·8	−1·5	−1·1	17·3	1·3	..	21·1	−7·4	−1·3	−1·5	22·5	1·3	..	23·6	−4·8	−0·7	−0·4	23·9	1·3	..	23·6
0200	−10·3	−1·8	−1·5	17·3	1·8	..	20·3	−8·8	−2·0	−0·8	21·4	1·3	..	22·8	−6·3	−1·1	0·0	23·3	1·8	..	22·8
0300	−11·4	−2·9	−1·9	17·2	1·3	..	19·6	−10·7	−2·4	−1·9	21·2	0·9	..	22·2	−6·6	−1·8	0·0	22·8	1·8	..	22·3
0400	−11·4	−3·5	−2·3	17·0	1·3	2·4	19·1	−12·1	−3·3	−3·0	20·4	1·8	2·9	21·4	−6·3	−2·2	−1·5	22·3	2·2	3·3	21·7
0500	−11·4	−3·9	−2·7	16·9	1·3	2·7	18·5	−12·5	−3·9	−2·7	20·2	1·8	2·9	20·9	−5·1	−3·3	−1·1	22·0	2·7	3·7	21·3
0600	−1·1	−2·9	−2·7	18·1	1·3	2·9	19·9	−3·7	−4·2	−3·0	20·3	1·8	2·7	21·9	−1·5	−2·4	−2·3	22·4	1·8	3·4	21·8
0700	3·3	1·5	−0·4	18·7	1·8	2·2	22·4	2·2	0·9	−1·1	20·8	1·8	2·5	24·1	2·2	1·1	0·4	23·2	2·2	2·8	23·4
0800	5·9	2·0	0·8	17·7	2·2	2·5	25·0	5·5	1·5	1·5	19·8	2·2	2·8	26·4	4·8	1·8	1·1	23·5	1·8	2·5	25·4
0900	7·7	1·8	1·1	14·4	2·2	3·2	27·4	7·0	1·7	1·1	18·8	2·2	2·8	28·7	7·0	1·7	1·1	22·1	1·8	2·8	27·0
	Cloud amount 8–10 tenths at some time between 0400 and 0800																				
1800	5·1	1·7	1·5	15·6	7·6	..	27·1	5·1	1·7	0·4	16·8	7·6	..	31·6	4·0	1·3	1·1	21·4	8·1	..	30·7
1900	1·5	1·3	0·8	17·7	7·6	..	24·9	1·8	0·9	0·8	18·7	7·2	..	29·8	1·8	0·9	1·1	24·7	7·6	..	28·8
2000	0·0	1·1	1·1	19·6	5·8	..	23·9	0·4	0·9	0·8	20·2	5·8	..	28·2	0·4	0·9	0·8	25·7	6·7	..	27·6
2100	−0·7	0·9	1·1	20·3	4·5	..	23·0	0·0	0·7	0·8	21·7	4·5	..	26·9	−0·7	0·6	0·8	25·9	4·9	..	26·5
2200	−1·5	0·9	0·8	20·4	3·1	..	22·3	−1·1	0·6	0·4	23·0	2·2	..	25·9	−1·8	−0·2	0·8	25·9	3·1	..	25·5
2300	−2·9	0·7	0·8	20·5	2·2	..	21·6	−2·6	0·4	0·4	23·1	1·3	..	24·9	−2·2	−0·4	0·0	25·5	2·2	..	24·7
2400	−4·0	0·0	0·4	20·1	1·8	..	20·9	−5·1	0·2	0·4	22·8	1·3	..	23·9	−4·0	−0·4	0·4	25·2	1·8	..	23·9
0100	−3·0	−0·6	0·4	19·7	1·8	..	20·4	−5·5	−0·2	0·4	23·2	1·8	..	23·3	−4·0	−0·9	0·4	24·9	2·2	..	23·3
0200	−2·9	−0·2	−0·8	18·9	2·2	..	20·2	−3·7	−0·6	0·0	23·0	2·2	..	22·7	−2·6	−0·9	0·0	24·4	2·7	..	23·0
0300	−2·6	−0·7	−0·4	19·2	1·8	..	19·9	−4·8	−0·7	−0·8	22·5	2·2	..	22·1	−2·2	−1·1	−0·4	24·4	3·1	..	22·7
0400	−1·8	−0·7	−1·1	19·5	1·8	3·0	19·8	−3·3	−1·1	−0·8	22·5	2·2	3·8	22·0	−0·7	−0·6	0·0	24·7	2·7	3·9	22·7
0500	−1·5	−0·7	−1·1	18·7	2·2	3·9	19·5	−2·6	−0·4	−0·8	23·0	1·8	3·7	21·9	−0·7	−0·2	−0·8	24·7	2·7	4·2	22·6
0600	1·1	1·5	0·0	19·9	2·7	3·8	20·6	−2·9	0·7	0·4	22·3	2·2	3·9	22·7	0·7	0·2	−1·1	24·1	2·7	4·2	22·6
0700	3·3	1·7	1·1	19·8	2·2	3·1	22·1	3·7	1·5	1·1	22·9	2·2	3·0	23·5	3·7	1·3	0·4	24·9	3·1	3·9	24·0
0800	6·6	2·0	1·1	19·0	2·7	3·4	23·8	5·5	2·0	0·8	23·4	1·8	2·7	25·0	5·1	1·7	0·8	24·6	2·7	3·5	25·6
0900	8·8	2·2	1·1	17·7	2·7	3·5	25·1	7·0	2·0	1·1	22·1	1·8	2·8	26·6	7·0	1·7	1·1	23·9	2·7	3·4	27·0

In June when cloud develops in the early morning the lapse rate over each height interval is greater than under average conditions and the difference is most marked between 0400 and 0500 ; the lapse rate over the lowest interval at 0400 and 0500 is over 6·0°C./100m. greater than the monthly mean values. In July there is no appreciable difference in lapse rate over any height interval until after about 2300, while in August the lapse rates differ but little from the mean values throughout the night.

When the lapse rate curves for the two sets of occasions are considered with respect to one another (Fig. 11) dissimilarity between the characteristics of each set of curves is very evident. The lapse rate on cloudless nights decreases, that is the intensity of the inversion increases, throughout the night, whereas on those occasions when cloud develops in the early morning the lapse rate ceases to decrease about 2300 for the interval 1·1m. to 16·2m., about 0400 for the intervals 16·2m. to 46·4m. and 46·4m. to 61·0m., although in the case of the upper interval in August the lapse rate exhibits little variation between cloudless nights and those occasions when cloud develops in the early morning.

The vapour pressure is lower on those occasions when the sky remains cloudless throughout the night and the difference is most marked in June and August. The lower value of the vapour pressure during cloudless nights accounts for the greater value of the inversion on such occasions as the effect of an increase in the water vapour content of the air is to decrease the net loss of heat from the ground by long wave radiation. The air, by virtue of its higher water vapour content on occasions when cloud develops, is thus a better radiator of long wave radiation on cloudy nights than on those nights when low cloud does not develop. Temperature at 1·1m. falls throughout the night and does not commence to rise until after sunrise whatever the state of the sky, although on cloudy mornings the decrease between midnight and sunrise is very small. It thus seems probable that the development of early morning cloud is a radiation phenomenon associated with the greater radiative power of moist air. If a layer of air of low vapour pressure exists above the stratum of moist air the latter will cool owing to the loss of heat by radiation, but the dry air above will decrease in temperature very slowly since dry air is a much less efficient radiator. When the upper limit of the stratum of moist air has been cooled below its dew point cloud will form and effectively stop the escape of radiation from the surface. This will account for the smaller decrease in temperature on cloudy mornings as compared with that on those which are cloudless. The mean wind velocity at 15·2m. is roughly the same during nights that remain cloudless as during those on which cloud develops, although from 0100 onwards the wind velocity is slightly higher on cloudy mornings. This is also the case as regards the velocity at 62·6m. The ratio of the rate of change of temperature of the layer of air between 1·1m. and 46·4m. ($\partial T/\partial t$) to the rate of change of lapse rate with height ($\partial^2 T/\partial z^2$) is in general much greater on occasions when cloud develops than when the sky

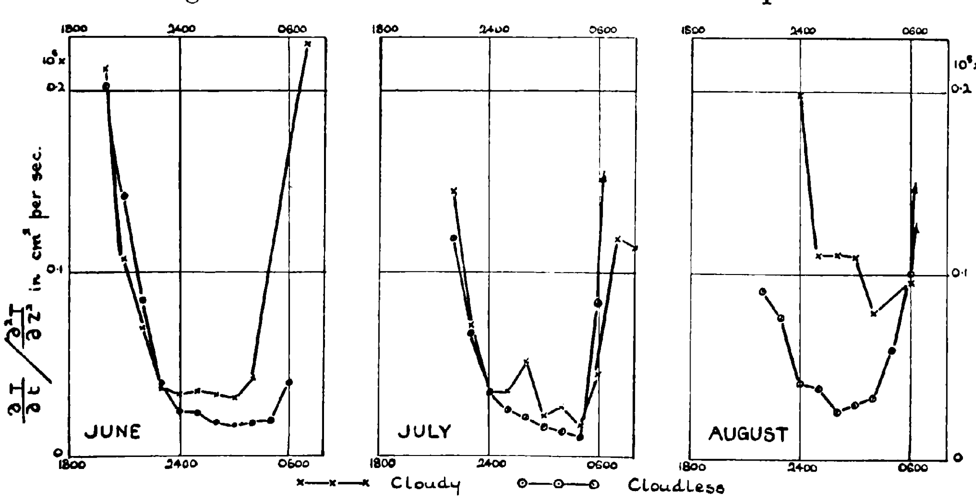


FIG. 12.—THE RATIO OF THE RATE OF CHANGE IN TEMPERATURE WITH TIME ($\partial T/\partial t$) TO THE RATE OF CHANGE OF LAPSE RATE WITH HEIGHT ($\partial^2 T/\partial z^2$) ON CLOUDLESS AND CLOUDY NIGHTS IN SUMMER

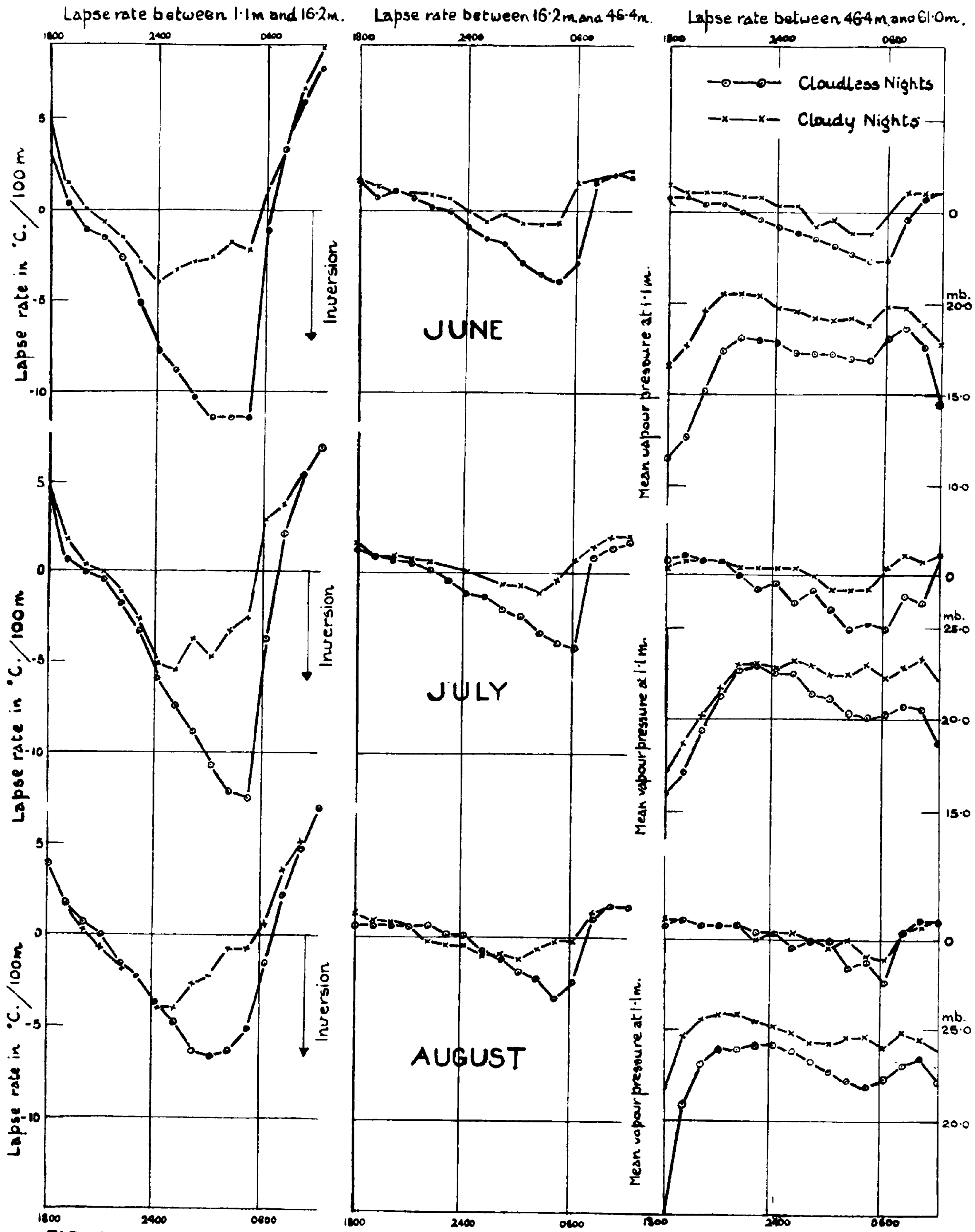


FIG. 11 – MEAN VALUES OF THE LAPSE RATE AND VAPOUR PRESSURE ON CLOUDLESS AND CLOUDY NIGHTS IN SUMMER AT ISMAILIA

remains cloudless. This ratio has been shown by Brunt (4) to represent the coefficient of eddy diffusivity to a first approximation so that, neglecting negative values of the ratio, the above implies that on cloudless nights in summer the coefficient of eddy diffusivity in the layers of air nearest the ground is less than on those occasions when cloud develops towards the end of the night (Fig. 12). This result, coupled with the slightly higher value of the wind velocity, suggests that as soon as the air has been cooled to or just below its dew point there is sufficient turbulence present to promote condensation. Once cloud has formed further development will take place owing to the turbulent mixing between successive layers of air. The cloud formed in this way would be stratiform and on all occasions the type reported has been either stratus or stratocumulus. The readings for individual days suggest the possibility of using the temperature and relative humidity at 1800, as recorded at a height of 1·1m., together with the wind velocity at 15·2m. as a means of forecasting the development of low cloud the following morning, but the readings available for only one year are not sufficient to test this idea.

§ 13—LAPSE RATE ASSOCIATED WITH THE DEVELOPMENT AND DISPERSAL OF RADIATION FOG

Fog is not frequent at Ismailia but during the autumn and, to a less extent, in the spring radiation fog may occur during the latter part of the night. During the period that the installation for recording temperature differences near the surface at Ismailia was functioning satisfactorily, a sufficient number of fogs occurred to warrant an analysis of the temperature variations associated with the development, persistence and dispersal of fog.

In the period October, 1931 to October, 1932 (to 12th inclusive) nineteen radiation fogs occurred at Ismailia, and ten of these developed during the month of October. In six cases the fog developed between 0500 and 0600, in two between 0400 and 0500 and in the other two instances between midnight and 0300 and except in three cases when the fogs were of less than two hours duration they all dispersed between 0800 and 0900. Mean values of the lapse rate between 1·1m. and 16·2m., 16·2m. and 46·4m. and 46·4m. and 61·0m. have been computed for each hour during the night for the October fogs, while the mean temperature at each of the heights

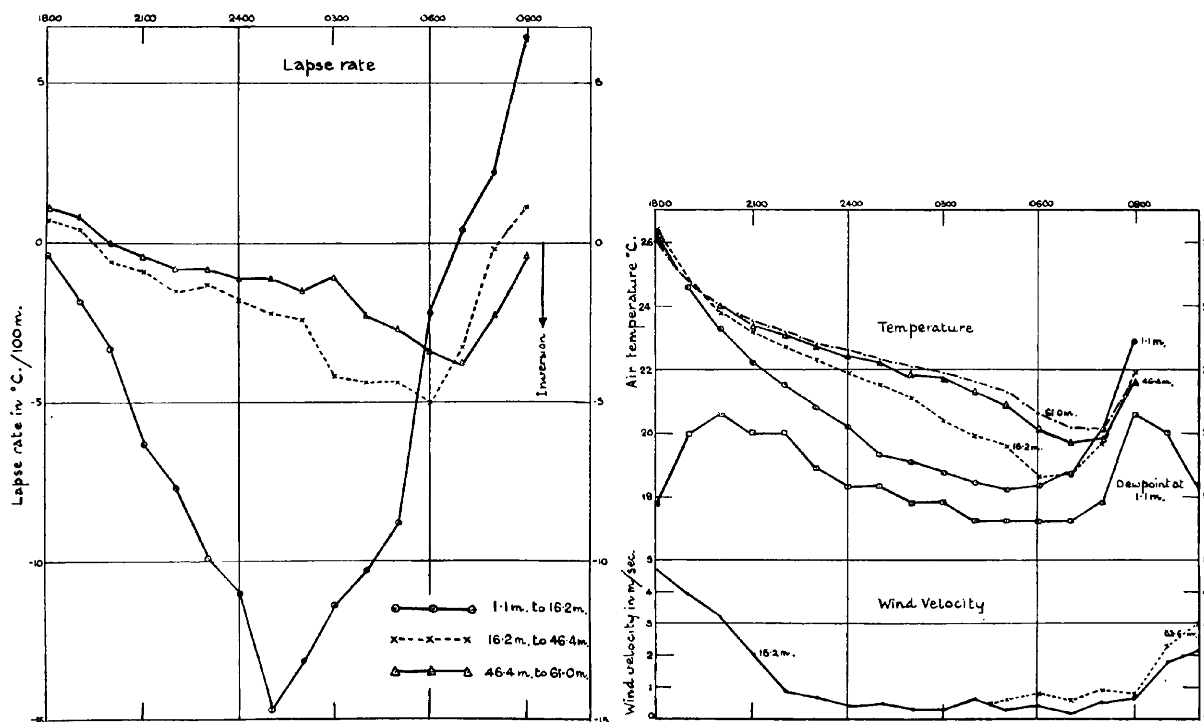


FIG. 13.—BEHAVIOUR OF THE LAPSE RATE, TEMPERATURE, DEW POINT AND WIND VELOCITY ON OCCASIONS WHEN FOG DEVELOPED AT ISMAILIA IN OCTOBER

1·1m., 16·2m., 46·4m. and 61·0m., the dew point at 1·1m. and the wind velocity at 15·2m. have also been determined. The variation of each element with time is shown in Fig. 13, and it will be seen that the lapse rate over the lowest interval of height, trace I (cf. Table III) decreases much more rapidly during the evening than under average conditions with the result that by 0100 an inversion of 14·7°C./100m. has developed as against an average value of 9·3°C./100m. After 0100 the lapse rate increases by about 1·5°C./100m./hr. until 0500 but between 0500 and 0600 a very rapid increase amounting to 6·6°C./100m. occurs. This latter change coincides with the time that the majority of the fogs developed, while the fact that the lapse rate commenced to increase about 0100 may be associated with the formation of some fogs between midnight and 0500. The lapse rate over the middle interval of height, trace II, decreases at a slower rate than under average conditions until 0200, but between 0200 and 0300 the lapse rate decreases suddenly and then remains very steady until about 0600 when the inversion breaks down rapidly. Over the upper interval of height, trace III, the lapse rate differs little from that for average conditions until 0500 when a sudden decrease occurs from −2·7 °C./100m. to −3·4°C./100m. at 0600, but after 0700 the inversion decreases rapidly in intensity and has disappeared by 1000.

Considering the change of temperature at the four heights 1·1m., 16·2m., 46·4m., 61·0m. together with the dew point at 1·1m. it is observed that the temperature at 1·1m. decreases rapidly until 0100 and more gradually between 0100 and 0500, while the subsequent change is a very slight increase between 0500 and 0700 followed by a very rapid increase. These temperature changes can be easily visualised by a consideration of the isopleth diagram for the period (Fig. 14). This shows that the more rapid cooling of the air near the ground results in the development of a pool of cold air close to the ground at about the time that fogs form and the dissipation of the fogs follow the heating up of the cold air after sunrise. The dew point rises to a maximum at 2000 and then decreases, the rate of decrease becoming less with time until 0400; between 0400 and 0700 the dew point remains constant but subsequently increases rapidly to a temporary maximum about 0900. This curve shows that when fog develops the dew point after an initial increase in the early evening decreases before the formation of fog, exhibits little change during the formation and persistence of fog but increases rapidly about 0900 when the fog is dissipating.

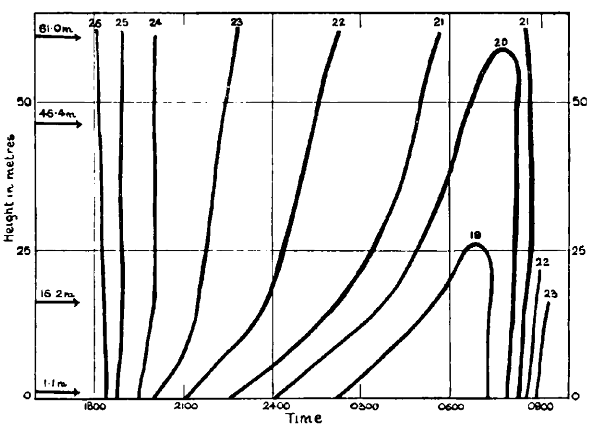
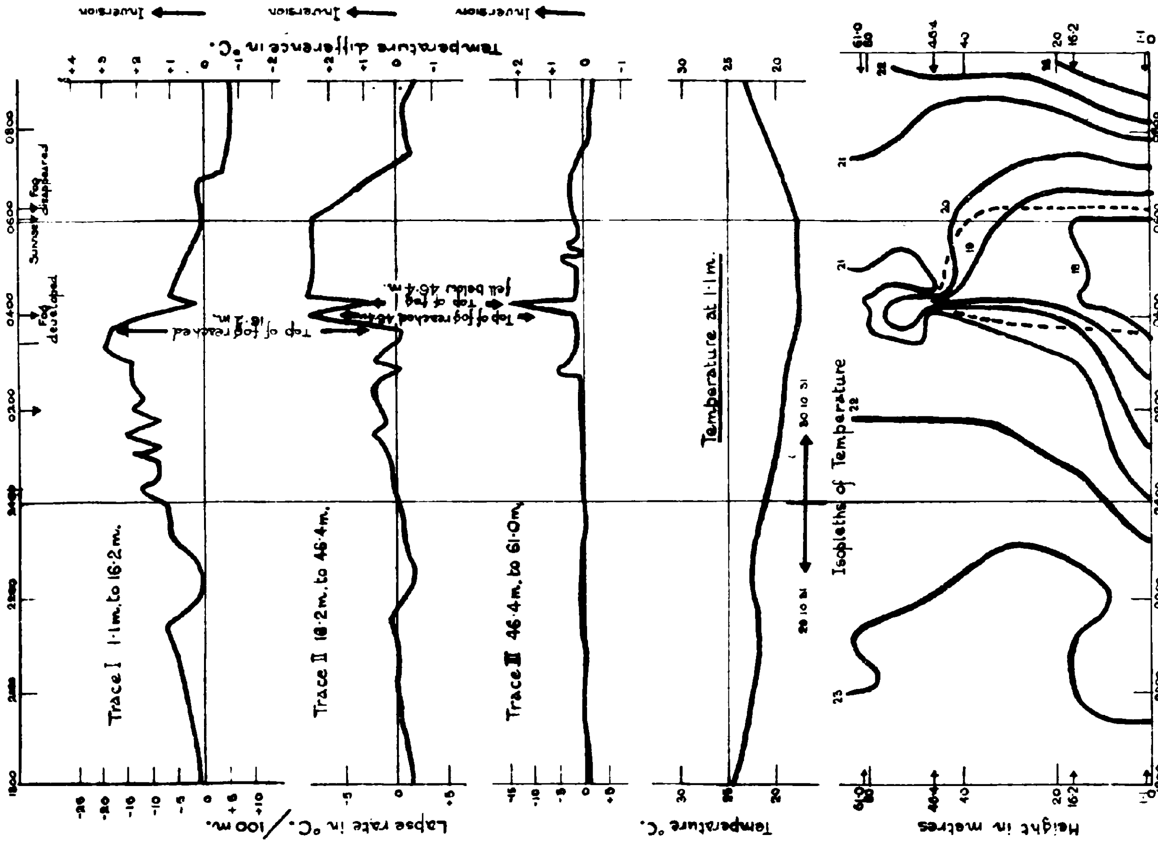


FIG. 14.—ISOPLETHS OF TEMPERATURE IN °C. OF THE AIR BELOW 61·0m. ON OCCASIONS WHEN FOG DEVELOPED AT ISMAILIA IN OCTOBER

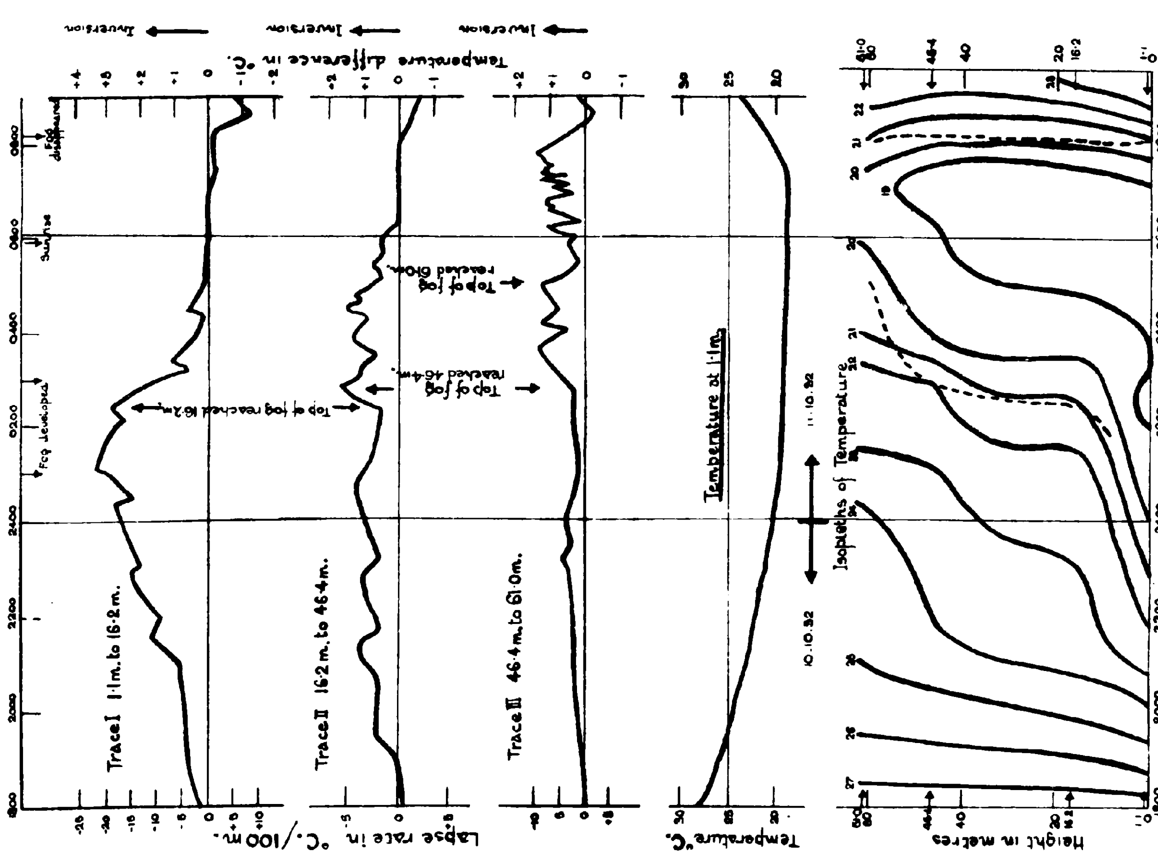
It is interesting to note that the maximum value of the vapour pressure on days when fog develops is recorded about 0700 as against about midnight for cloudless or cloudy mornings. Wind velocity decreases to a very low value at both 15·2m. and 62·6m. preceding and during the development of fog. On an average the wind velocity at 15·2m. is less than 0·5m./sec. from midnight to 0900, and at 62·6m., where observations are not available before 0430, does not exceed 1m./sec. until after 0900. The vertical difference of wind velocity within a fog is therefore seen to be extremely small and on an average is less than 0·5m./sec./50m.

In order to consider the changes in greater detail individual occasions will now be analysed. On the morning of October 11, 1932 the sky was initially cloudless but fog developed before 0300 and dispersed between 0800 and 0900. The variation of the lapse rate and of the dew point is given in Fig. 15, and from these graphs it will be seen that trace I gradually decreased at about 2·0°C./100m./hr. from zero lapse rate at 1715 until about 0220. Between 0220 and 0320 trace I recorded a rapidly increasing lapse rate but thereafter the increase was more gradual. Trace II recorded zero lapse rate about 1840 and then decreased at about half the rate of trace I until 2100 but exhibited little change between 2100 and 0100. It increased



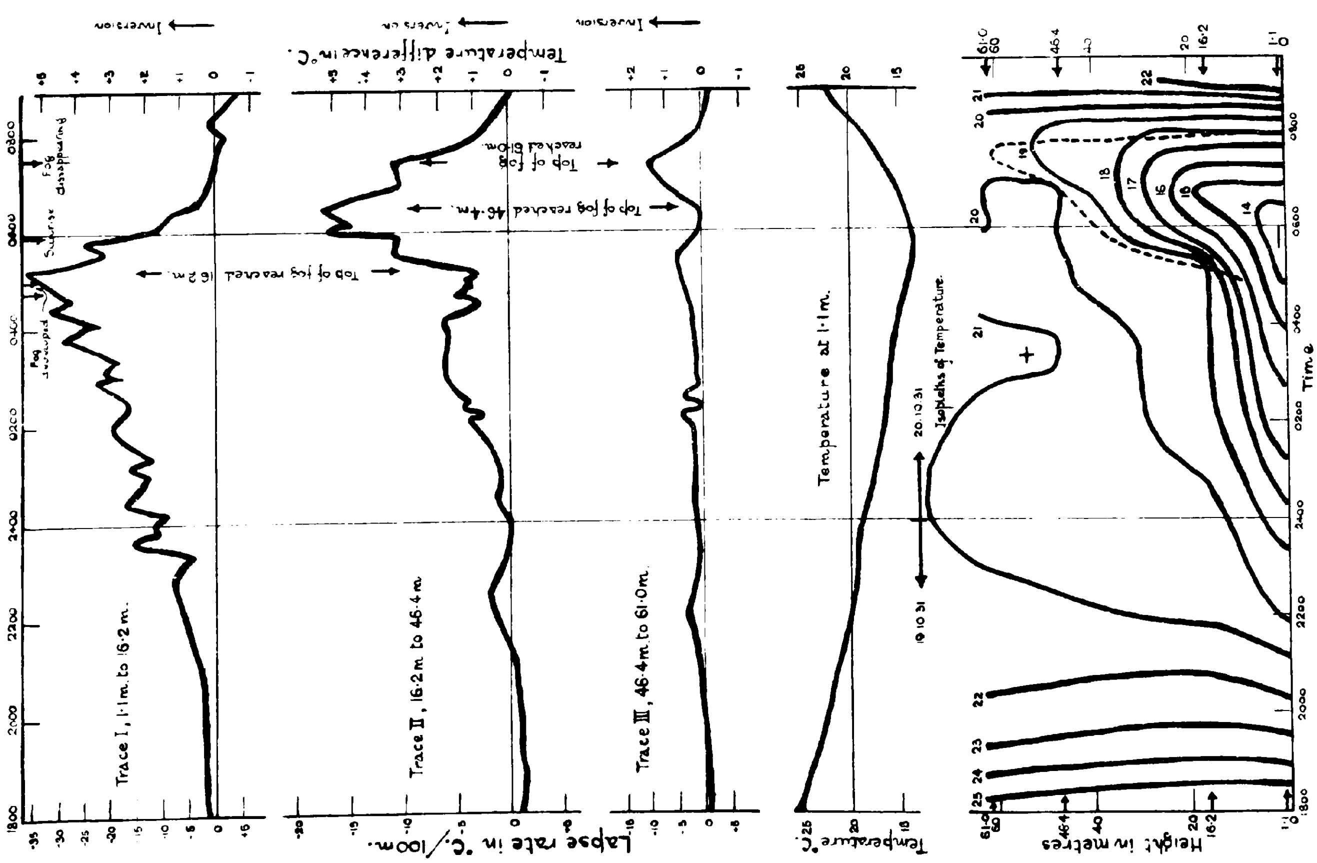
The dotted line across the isopleths indicates the height of the fog approximately

FIG. 16 - LAPSE RATES AND TEMPERATURE CHANGES ASSOCIATED WITH THE DEVELOPMENT OF FOG ON OCTOBER 30th, 1931



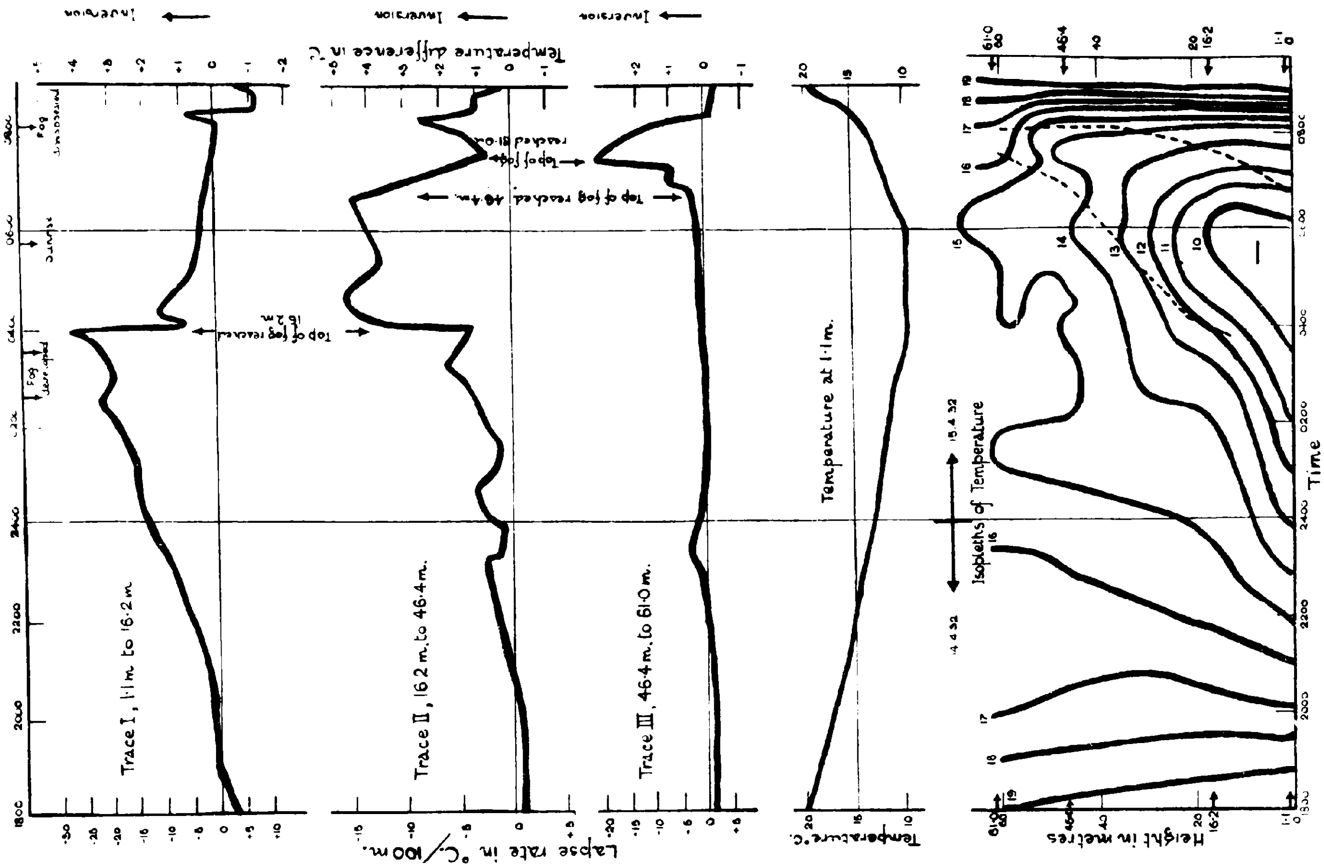
The dotted line across the isopleths indicates the depth of the fog approximately

FIG. 15 - LAPSE RATES AND TEMPERATURE CHANGES ASSOCIATED WITH THE DEVELOPMENT OF FOG ON OCTOBER 11, 1932



The dotted line across the isopleths indicates the depth of the fog approximately.

FIG. 17 - LAPSE RATES AND TEMPERATURE CHANGES ASSOCIATED WITH THE DEVELOPMENT OF FOG ON OCTOBER 20, 1931



The dotted line across the isopleths indicates the height of the fog approximately.

FIG. 18 · LAPSE RATES AND TEMPERATURE CHANGES ASSOCIATED WITH THE DEVELOPMENT OF FOG ON APRIL 15, 1932 slightly between 0100 and 0200 before a rapid decrease of lapse rate at 0225. Trace III showed a very gradual decrease in lapse rate before 0250 but then decreased by about 7°C./100m. during the next hour, it then varied irregularly until 0500 when a rapid increase occurred and after 0600 the trace fluctuated between 1·5C./100m. and 9·5°C./100m. until the fog commenced to disperse about 0750. Thereafter trace III registered a rapidly increasing lapse rate until 0830 when average forenoon conditions had developed but this was followed by a temporary decrease about 0900. The traces, together with the isopleths of temperature (Fig. 15), indicate that about the time of fog formation the rate of decrease in temperature at a height of 1·1m. became very small but that at 16·2m., 46·4m. and 61·0m. temperature temporarily decreased more rapidly. After the fog had formed and grown deeper than 61·0m. the temperature decrease at each height became very small and it was not until about one hour after sunrise, when the fog commenced to disperse, that there was any marked change. A very rapid increase then occurred. During the period of fog formation the wind was calm at 15·2m. and at 62·6m. The increased rate of fall of temperature at each height occurred when the top of the fog reached the level of the element at that height, and the resultant cooling was due to the escape of radiation from the surface of the drops composing the fog. The decrease in temperature at 16·2m. caused the inversion between 16·2m. and 46·4m. to be intensified, and a similar change occurred between 46·4m. and 61·0m. when the fog reached 46·4m. Thus the time that the upper limit of the fog passed each element was marked by a fall in temperature at the height concerned. Within the fog temperature continued to decrease very slowly, more especially at the upper levels, until just before the fog began to disperse when it commenced to rise. After sunrise the temperature at 61·0m. exhibited rapid fluctuations and the explanation of these changes is probably that the depth of the fog was at no time much greater than 61·0m. and after sunrise the loss of heat from the top of the fog was diminished. The fog, acting as a black body, absorbed the incoming radiation and the heating effect being restricted to a shallow stratum near the top of the fog caused an intensification of the inversion in the upper layers. The water drops which formed the fog were evaporated and temperature decreased, especially at the upper levels, but before the total dissipation of the fog, temperature at the surface commenced to rise owing to radiation reaching the surface through the dissolving fog. After the fog had disappeared the lapse rate up to 46·4m. increased more rapidly than under average conditions, especially below 16·2m., but about 40 minutes after the fog disappeared the lapse rate decreased over the whole stratum below 61·0m. Average conditions, characteristic of October were restored at all levels by about 1030 and the layers nearest the ground were the first to attain normality.

The irregular variations in temperature at 46·4m. and 61·0m. between 0330 and 0500, when the fog was above the former but below the latter height, were probably associated with fluctuations in the temperature at the surface of the inversion. This phenomenon has already been alluded to by Brunt (5) while an example has been quoted by Durst (6) who offers the explanation that with a suitable vertical distribution of water vapour the upper layers of the fog are cooled below the temperature of the lower layers and instability arises within the fog which sets up convectional cells.

Radiation fogs also occurred on October 30 and 20, 1931 and April 15, 1932. The charts showing the changes in lapse rate up to 61·0m. and in the temperature at 1·1m., together with the isopleths of temperature throughout the air layers concerned on these occasions are given in Figs. 16, 17 and 18.

On the morning of October 30, 1931 (Fig. 16) a shallow fog developed between 0300 and 0400 and the top reached 16·2m. at 0342 and 46·4m. at 0400. The top of the fog, however, did not rise much higher but fell below this height about 0415 and after sunrise the fog dispersed rapidly and the changes in lapse rate were similar, although less marked, to those described for October 11, 1932.

On the morning of October 20, 1931 (Fig. 17) fog developed after an intense inversion had formed below 46·4m. and it is of especial interest to note that fog formation appears to have continued for a short time after sunrise. The top of the fog reached 16·2m. at 0512, 46·4m. at 0630 and 61·0m. about 0718, although dispersal of the fog must have commenced at about the same time as the upper limit of the fog reached 61·0m. After 0700 the fog decreased rapidly in intensity and visibility had improved to between 1Km. and 2Km. by 0800.

In the third example (Fig. 18) the upper limit of the fog was well marked when it passed the element at 16·2m., as indicated by the sharp change in the lapse rate recorded by traces I and II about 0400, but the subsequent growth was very slow and the traces suggest that the fog did not reach 46·4m. until about 0640. The element at 61·0m. must have been above the fog throughout but after about 0700 the fog commenced to thin out in the lowest layers and lift. The element at 61·0m. was then in fog which had been raised above the surface and the lapse rate recorded by trace III behaved in exactly the same way as though fog persisted right down to the ground. The low cloud and fog dissolved rapidly after 0750 and the sky was clear by 0810.

The lapse of temperature at selected times on three of the occasions already discussed is shown graphically in Fig. 19. The changes which take place in the

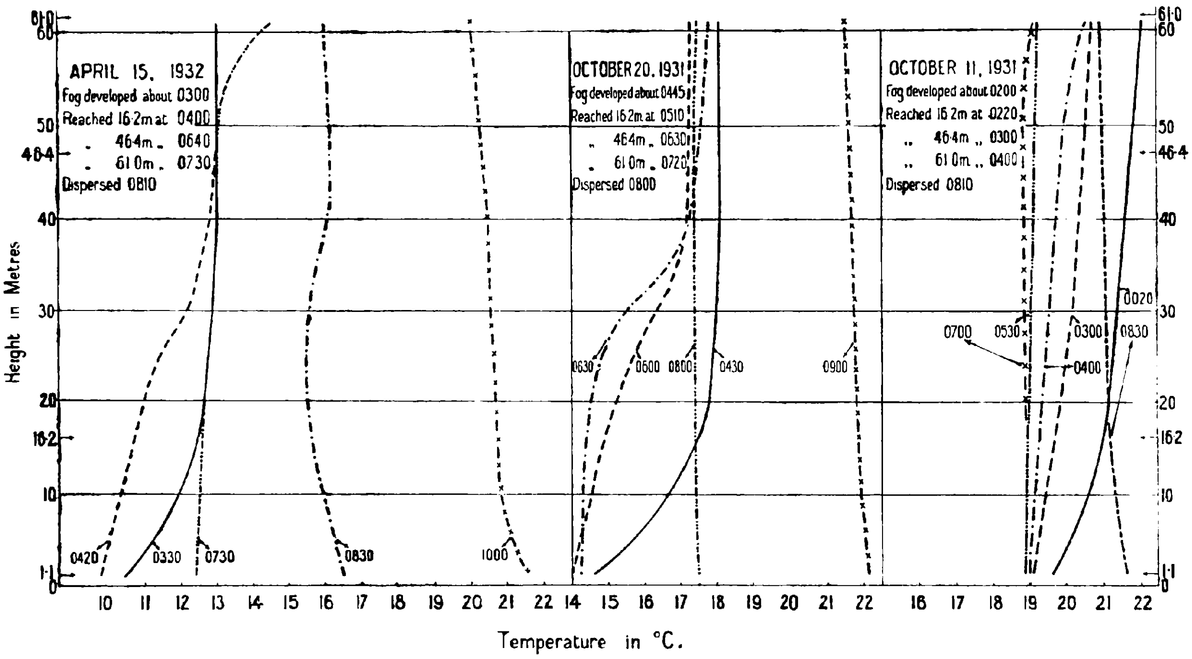


FIG. 19.—LAPSE RATES ASSOCIATED WITH THE DEVELOPMENT AND DISPERSAL OF FOG

vertical distribution of temperature when fog develops, during its persistence and after its dispersal can be easily noted. These curves are comparable with those given by Heywood (7) for Leafield, although the diagrams for Leafield all refer to conditions after sunrise. On all occasions that fog developed the inversion, recorded by trace I immediately before condensation occurred, was not less than 20°C./100m. (0·1°C./50cm.) so that nearer the ground it must have been considerably greater. Kuhnert (8) concluded that radiation fog occurred when the inversion near the ground reached a limiting value of the order of 0·5°C./50cm. and the present results lend support to this value. Especially is this the case when it is noted that on October 20, 1931 (Fig. 17) the inversion recorded by trace I just prior to fog formation was approximately 0·2°C./50cm. The differential traces indicate also that strong oscillations of the inversion occur in the upmost layers of radiation fog while there is some evidence (see Fig. 16) that the upward growth exhibits oscillations with height and is not a continuous process.

The preceding discussion of the lapse rates associated with fogs at Ismailia indicates that fog develops at the latter part of a clear and almost calm night provided the vapour content is sufficiently high. The process of formation is that the ground cools the surface layers of air until saturation is reached and the air movement being sufficient to mix these layers a shallow fog is formed. The fog increases in depth owing to radiation taking place from its upper surface which results in the air layers immediately above being cooled below their dew point. Soon after sunrise the incoming radiation stops further development and the fog commences to dissolve. As soon as the incoming radiation reaches the ground through the fog surface temperature increases and the lapse rate in the lowest layers becomes adiabatic or super-adiabatic. This results in the disappearance of the fog within a very short time.

§ 14—NOCTURNAL INVERSIONS

The behavour of the temperature in the air layers near the ground and the variation of lapse rate at the time of cross-over from lapse to inversion and *vice versa* is of importance where the question of vertical transfer of heat by radiation and turbulence is concerned. These changes in the temperature and lapse rate are associated with the development and decay of the nocturnal inversion and in what follows these phenomena are considered at length.

The curves of diurnal variation of lapse rate have been discussed in a previous section and from these curves the times of zero lapse rate between 1·1m. and heights of 16·2m., 46·4m. and 61·0m. respectively and between 1·1m. and 16·2m., 16·2m. and 46·4m. and 46·4m. and 61·0m. have been determined and are given in Table XI. These figures show that, on an average, conditions become isothermal between 1·1m. and 16·2m. when the lapse rate is increasing in the morning, 88 minutes after sunrise and, when the lapse rate is decreasing in the evening, 33 minutes after sunset. In the morning it takes, on an average, 11·5 minutes for the temperature at 1·1m. to increase from that at 16·2m. to that at 46·4m. and 8 minutes to increase from that at 46·4m. to that at 61·0m. but in the evening it takes, on an average, 42 minutes for the temperature at 1·1m. to decrease from that at 16·2m. to that at 46·4m. and 11 minutes to decrease from that at 46·4m. to that at 61·0m. The time at which zero lapse rate occurs over the individual height intervals shows that in the morning it takes, on an average, 24 minutes for the temperature to increase from that at 16·2m. to that at 46·4m. and 21 minutes to increase from that at 46·4m. to that at 61·0m. while in the evening the average time taken for the temperature at 16·2m. to decrease to that at 46·4m. is 94 minutes and for the temperature at 46·4m. to decrease to that at 61·0m. is 12 minutes.

If, however, the times for the individual months are examined it is observed that for an increasing lapse rate isothermal conditions between 1·1m. and 16·2m. never develop before sunrise and further, zero lapse rate develops first near the ground and the time of occurrence of zero lapse rate becomes progressively later the higher the upper limit of the height interval concerned. Thus in August zero lapse rate occurs between 1·1m. and 16·2m. 49 minutes after sunrise, between 1·1m. and 46·4m. 9 minutes later and between 1·1m. and 61·0m. after a further 5 minutes while in December the respective times are 120, 9 and 9 minutes. When the lapse rate is decreasing in the evening isothermal conditions develop in the layers near the ground before sunset during winter but after sunset during summer. Thus zero lapse rate extends to above 61·0m. before sunset from December to January, to between 16·2m. and 46·4m. in November and to just 16·2m. at sunset in March while during the remaining months the time after sunet at which zero lapse rate is recorded over the lowest height interval varies from 29 minutes in April to 144 minutes in August. Considering the mean lapse rate between 1·1m. and the two heights 46·4m. and 61·0m. it is seen that isothermal conditions occur progressively later the greater the height. A quite different result is obtained when the individual layers, 16·2m. to 46·4m. and 46·4m. to 61·0m. are examined, for over neither layer does zero lapse rate occur before sunset in any month. The reason for this is that in the late afternoon rapid cooling takes place in the air layers very close to the ground and the rate at which the lapse rate decreases over the lowest height interval is much more rapid than over either of the other two, with the result that a large negative lapse rate over the lowest interval is more than sufficient to counterbalance a small positive lapse rate over either of the other two height intervals. The time after sunset at which zero lapse rate occurs between 16·2m. and 46·4m.

varies from about 30 minutes in winter to over 4 hours in summer, while for the layer 46·4m. to 61·0m. it varies from 14 minutes in February to over 6 hours in August. Further during February, March, April, June and July zero lapse rate develops over the upper height interval earlier than over the middle interval.

§ 15—DECAY OF NOCTURNAL INVERSIONS

(*a*) *Annual and Monthly Mean Values.*—The transfer of heat by radiation and turbulence in the lower atmosphere has been investigated by Taylor (9), Brunt (10) and others. Brunt has shown that from theoretical considerations the joint effects of radiation and turbulence may be represented by the single equation

$$\frac{\partial T}{\partial t} = (K_E + K_R) \frac{\partial^2 T}{\partial z^2} .$$

where T and z have their usual significance, t is time and K_R and K_E are respectively the coefficients of radiative diffusivity and eddy diffusivity assumed to be independent of height above the surface. The application of this result to the upward transfer of surface temperature shows that the height to which a surface change of temperature is transmitted in t seconds is given by

$$z = 4\ (K_E + K_R)\ t$$

where z is in centimetres.

The decay of the inversion in the surface layers after sunrise is associated with the heating of the ground, and the figures given in Table XI may be used in connexion with the above equation to obtain a rough indication of the value of (K_E+K_R) although this may not be theoretically justifiable. Consider the case of the inversion being destroyed and let t_1, t_2 and t_3 be the respective times at which zero lapse rate is recorded in each of the layers 1·1m. to 16·2m., 16·2m. to 46·4m. and 46·4m. to 61·0m. whence the value of (K_R+K_E) will be given by

$$\frac{(46{\cdot}4)^2-(16{\cdot}2)^2}{4(t_2-t_1)} \times 10^4 \text{ for the layer 16·2m. to 46·4m.}$$

and $$\frac{(61{\cdot}0)^2-(46{\cdot}4)^2}{4(t_3-t_2)} \times 10^4 \text{ for the layer 46·4m. to 61·0m.}$$

Taking the mean times for the year the values are $3{\cdot}3 \times 10^3$cm.^{2}/sec. and $3{\cdot}2 \times 10^3$cm.^{2}/sec. respectively which are of the order to be expected when conditions are initially very stable with little or no turbulence (11). The values for individual months vary from $2{\cdot}1 \times 10^3$cm.^{2}/sec. in April to $4{\cdot}6 \times 10^3$cm.2/sec. in March, August and December for the lower layer, and from $2{\cdot}1 \times 10^3$cm.^{2}/sec. in September to $65{\cdot}3 \times 10^3$cm.^{2}/sec. in January for the upper layer. The high value obtained for the layer 46·4m. to 61·0m. in January indicates a greater degree of turbulence in this layer than during the other months; it is associated with one of the larger values of the wind velocity at 15·2m. and a greater frequency of occurrence of cloudy skies during the period that the inversion was being destroyed.

(*b*) *Effect of state of Sky.*—The times at which zero lapse rate occurred over the different height intervals on cloudless and cloudy days in December and on cloudless days in August were abstracted in order to compare the effect of state of sky on the decay of inversions (Table XI). These figures show that the rate of decay of the nocturnal inversion on cloudless mornings is slightly slower than under average conditions but considerably slower than when the sky is cloudy. On clear mornings in December the time that elapses between sunrise and the occurrence of zero lapse rate between 1·1m. and 16·2m. is 11 minutes longer than under average conditions and 36 minutes longer than under cloudy conditions. The figures for the height interval 16·2m. to 46·4m. are respectively 38 minutes and 138 minutes and for the height interval 46·4m. to 61·0m. 17 minutes and 149 minutes.

On clear mornings the nocturnal inversion is of greater intensity than under either average or cloudy conditions so that the air near the ground is extremely stable. This is confirmed by the lower wind velocity during the decay of the inversion on cloudless days. On cloudy mornings the wind velocity is higher than under average conditions so that the air is more turbulent on these occasions. Further,

TABLE XI—MEAN TIME AT WHICH ZERO LAPSE RATE OCCURRED BETWEEN 1·1m. AND EACH OF THE THREE HEIGHTS 16·2m., 46·4m. AND 61·0m. AND BETWEEN 16·2m. AND 46·4m., AND 46·4m. AND 61·0m.

Month	Sun-rise	Height interval in metres					State of Sky				Mean value of specified elements at stated times			
		1·1 to 16·2	1·1 to 46·4	1·1 to 61·0	16·2 to 46·4	46·4 to 61·0	c-o	bc	b	fog	Time	Wind velocity at 15·2m.	Vapour pressure at 1·1m.	Temp. at 1·1m.
Lapse rate increasing														
												m./sec.	mb.	°C.
January	0647	0834	0842	0844	0852	0853	19	7	5	0	0830	3·9	11·2	12·5
February	0632	0812	0827	0843	0841	0905	9	7	13	0	0830	4·0	9·9	12·7
March	0600	0733	0741	0747	0750	0820	12	8	11	0	0800	3·2	10·9	15·3
April	0524	0650	0704	0717	0727	0756	8	6	15	1	0730	2·5	12·2	15·8
May	0458	0634	0647	0649	0654	0700	4	5	22	0	0645	1·6	15·1	17·8
June	0450	0609	0622	0627	0632	0650	0	11	18	1	0630	1·7	19·0	21·1
July	0501	0620	0629	0633	0638	0654	5	10	16	0	0630	2·2	21·9	23·0
August	0518	0607	0616	0621	0624	0642	7	14	10	0	0630	2·8	23·9	23·0
September	0536	0645	0657	0715	0718	0749	1	14	15	0	0715	1·2	23·0	22·8
October	0551	0712	0734	0740	0744	0807	3	7	23	7	0730	1·3	20·0	20·4
November	0613	0754	0800	0810	0821	0838	6	11	13	0	0815	1·7	14·3	16·0
December	0639	0839	0848	0857	0856	0930	13	8	10	0	0900	2·7	10·0	13·9
Year		88·3	11·5	8·0	4·0	20·6	Time of zero lapse rate in minutes after sunrise							
Cloudless days and nights														
December	0638	0849	0900	0921	0933	0946					0900	1·6	7·6	12·0
August	0516	0625	0634	0637	0638	0651					0645	2·2	23·0	23·0
Cloudy days and nights														
December	0637	0812	0742	0738	0714	0716					0745	4·8	12·4	13·6
Lapse rate decreasing														
	Sunset													
January	1714	1640	1701	1712	1742	1846	6	15	10	0	1730	4·3	8·8	12·8
February	1739	1720	1732	1733	1808	1753	1	12	16	0	1745	5·2	8·1	16·8
March	1800	1800	1825	1826	1902	1821	1	10	20	0	1830	6·2	10·4	17·5
April	1818	1847	1944	1945	2100	1924	2	5	23	0	2000	4·7	12·0	18·6
May	1838	1920	2022	2038	2136	2152	1	6	24	0	2030	5·3	15·3	20·9
June	1853	1930	2116	2136	2321	2300	0	0	30	0	2130	3·8	18·4	22·9
July	1852	2036	2138	2151	2254	2242	0	0	31	0	2200	3·1	23·0	29·1
August	1831	2055	2139	2159	2238	0045	0	0	31	0	2230	3·1	25·2	25·4
September	1756	1954	2013	2022	2032	2130	0	1	29	0	2030	4·2	23·0	25·1
October	1723	1758	1839	1857	1937	2053	0	0	40	0	1930	4·2	20·5	23·5
November	1656	1645	1717	1724	1825	1827	1	5	24	0	1800	4·6	13·4	18·7
December	1654	1611	1634	1643	1725	1734	4	8	19	0	1700	4·5	9·0	17·5
Year		33·5	42·0	11·4	93·8	12·3	Time of zero lapse rate in minutes after sunset							
Cloudless days and nights														
December	1654	1603	1622	1628	1717	1724					1630	4·9	9·8	17·5
August	1834	2041	2152	2206	2338	2352					2200	3·7	24·0	25·9
Cloudy days and nights														
December	1653	1613	1649	1645	1754	1640					1630	5·4	14·1	18·3

NOTE.—All times are zone time.

the times of occurrence of zero lapse rate indicate that the decay of the inversion above 16·2m. cannot be accounted for by the upward transfer of heat, as zero lapse rate occurs earlier over the middle and top height intervals than over the lowest interval. Thus zero lapse rate is recorded between 16·2m. and 46·4m. 58 minutes earlier than between 1·1m. and 16·2m. and only 2 minutes before it occurs between 46·4m. and 61·0m.

For the decay of the nocturnal inversion on occasions when the sky is clear the value of the coefficient (K_R+K_E) is of the order $1{\cdot}8\times10^3$cm.^{2}/sec. in December and $6{\cdot}0\times10^3$cm.^{2}/sec. in August for the layer 16·2m. to 46·4m. and $5{\cdot}0\times10^3$cm.^{2}/sec. in both months for the layer 46·4m. to 61·0m. The low value for the lower layer in December indicates that conditions in that month are more stable than in August although between 46·4m. and 61·0m. the air must be about equally stable during the two months. The higher wind velocity which occurs during the decay of the inversion on cloudless days in August, together with the smaller intensity of the nocturnal inversion during this month (Table III), is thus reflected in the higher value of (K_R+K_E) necessary to account for the observed conditions.

(*c*) *Individual Days.*—In order to study the effect of different conditions, of wind velocity, state of sky and the variation of vapour pressure and temperature, on the decay of the nocturnal inversion, figures for individual days were considered, and these (Table XII) show that there is close agreement with theory only when the

TABLE XII—DETAILS RELATING TO THE DECAY OF THE NOCTURNAL INVERSION AT ISMAILIA ON SELECTED DAYS DURING THE PERIOD OCTOBER, 1931 TO OCTOBER, 1932

Date	Sunrise	Time of occurrence of zero lapse rate — Height interval in metres			Weather during decay	Values of specified elements at stated time				Minimum mean hourly lapse rate since midnight — Height interval in metres						(K_R+K_E) — Height interval in metres	
		1·1 to 16·2	16·2 to 46·4	46·4 to 61·0		Time	Mean hourly wind velocity at 15·2m.	Vapour pressure	Temperature	1·1 to 16·2 °C./100 m.	1·1 to 16·2 Time	16·2 to 46·4 °C./100m.	16·2 to 46·4 Time	46·4 to 61·0 °C./100m.	46·4 to 61·0 Time	16·2 to 46·4	46·4 to 61·0
							m./sec.	mb.	°c.							cm.^{2}/sec.	cm.^{2}/sec.
8.1.32	0648	0855	0830	0838	o	0845	5·8	7·5	15·0	6·6	0100	1·8	0100	1·9	0600	..	..
19.1.32	0647	0810	0840	0904	b	0835	0·2	9·8	10·0	17·8	0700	5·5	0800	3·2	0500	$2{\cdot}6\times10^3$	$2{\cdot}7\times10^3$
22.1.32	0647	0826	0742	0727	b	0800	8·9	7·4	8·3	4·2	0300	0·9	0700	0·6	0700	..	..
23.1.32	0646	0816	0747	0736	bv	0750	6·5	7·3	7·2	4·4	{0600 0700}	0·7	0400	0·6	0700	..	..
10.6.32	0449	0612	0550	0605	b	0600	2·7	18·8	21·1	6·6	0400	3·4	0300	4·7	0400	..	..
18.6.32	0450	0618	0702	0710	b	0640	calm	17·2	23·3	23·4	0300	6·7	0600	4·9	0500	$1{\cdot}8\times10^3$	$8{\cdot}2\times10^3$
22.6.32	0450	0539	0328	0420	c	0430	calm	19·9	19·4	6·1	0200	1·5	0300	0·9	0300	..	..
16.8.32	0519	0348	0338	0342	cm_0v	0340	4·5	24·4	21·7	3·7	0300	1·1	0300	0-9	0200	..	..
19.8.32	0520	0608	0640	0655	b	0630	calm	22·7	22·8	3·9	0500	4·2	0500	1·9	0600	$2{\cdot}5\times10^3$	$4{\cdot}4\times10^3$
20.8.32	0521	0640	0630	0635	b	0630	1·8	20·9	22·2	11·4	0200	2·1	0500	1·9	0600	..	..
23.8.32	0523	0500	0427	0650	cbc	0530	2·9	25·8	23·3	2·4	0100	3·6	0300	2·3	0400	..	..
11.12.31	0636	0820	0915	0922	bcv	0850	0·9	8·4	14·4	49·7	0600	8·1	0200	13·8	0900	$1{\cdot}4\times10^3$	$9{\cdot}3\times10^3$
13.12.31	0637	0813	0744	0800	c	0800	4·9	12·9	18·3	9·0	0400	3·7	0400	4·7	0400	..	..
22.12.31	0643	0822	0904	0910	bv	0845	0·7	11·0	11·7	30·5	0500	12·6	0700	4·7	0300	$1{\cdot}9\times10^3$	$10{\cdot}9\times10^3$
23.12.31	0643	0810	0805	0842	cm	0820	1·1	11·7	13·3	18·4	0100	6·2	0500	5·9	0300	..	..

NOTE.- All times are zone time.

air near the ground is very stable and the sky is either cloudless or only partially clouded (less than 7 tenths). The existence of appreciable movement of the air near the ground has the same effect as the presence of cloud (see August 20, 1932, Table XII) since both cause isothermal conditions to be produced between 16·2m. and 46·4m., and in most cases between 46·4m. and 61·0m., earlier than can be accounted for by the upward transfer of heat from the ground. On January 8, 1932, for example, when zero lapse rate was recorded over the two upper layers before the inversion had been destroyed between 1·1m. and 16·2m. the sky was completely covered with low cloud and the wind velocity at 15·2m. was 5·8m./sec. Similar changes in the lapse rate also occurred on a number of days with a cloudless sky and a wind velocity greater than 1·7m./sec.

The approximate value of (K_R+K_E) has been evaluated for those occasions when the expression for the decay of an inversion can be applied. These values vary from $1{\cdot}4\times10^3$cm.^{2}/sec. to $2{\cdot}6\times10^3$cm.^{2}/sec. for the height interval 16·2m. to 46·4m., and from $2{\cdot}7\times10^3$cm.^{2}/sec. to $10{\cdot}9\times10^3$cm.^{2}/sec. for the height interval 46·4m. to 61·0m. The lowest of these values is considerably larger than the figure $0{\cdot}65\times10^3$cm.^{2}/sec. which has been found to correspond closely with conditions initially very stable and marked by the absence of turbulence (11). The present values for (K_R+K_E) therefore indicate that the upward transfer of heat during the decay of the nocturnal inversion is due to both radiation and turbulence and even under the most stable conditions which occur at Ismailia the value of K_E is still of the order $0{\cdot}75\times10^3$cm.^{2}/sec.

An attempt has been made to explain the occasions when the decay of the inversion does not appear to be propagated from the ground upwards by a consideration of the true form of the equation representing the joint effects of radiation and turbulence, namely.

$$\frac{\partial T}{\partial t} = \frac{\partial K_R}{\partial z}\left(\frac{\partial T}{\partial z}\right) + K_E\,\frac{\partial^2 T}{\partial z^2}$$

but even this expression does not give a positive value for K_E in all cases.

Ali (12) has considered the decay of the nocturnal inversion in the surface layers of the atmosphere above Agra, in India, on individual days in March and obtains values of (K_R+K_E) varying from $0{\cdot}7\times10^3$cm.^{2}/sec. to $2{\cdot}1\times10^3$cm.^{2}/sec. These values were associated with either cloudless skies or the presence of only high cloud. The lowest figure was computed from readings made when the sky was cloudless and visibility poor while the highest figure was the result of observations made when the sky was almost covered with high cloud (cirrostratus).

§ 16—GROWTH OF NOCTURNAL INVERSIONS

(*a*) *Annual and Monthly Mean Values.*—During the formation of nocturnal inversions the time that elapses on the average between the occurrence of zero lapse rate between 1·1m. and 16·2m. and between 16·2m. and 46·4m. is 1hr. 34min. (Table XI) which is nearly four times as long as it takes for a similar situation to develop when the nocturnal inversion is being destroyed. The average time that elapses between the occurrence of zero lapse rate over the middle height interval and over the top height interval is only 12 minutes in the evening as against 21 minutes in the morning. The mean annual values of (K_R+K_E) computed from these figures are therefore $0{\cdot}84\times10^3$cm.^{2}/sec. for the layer 16·2m. to 46·4m. and $5{\cdot}3\times10^3$cm.^{2}/sec. for the layer 46·4m. to 61·0m.

The times of occurrence of zero lapse rate in the different layers in individual months show that throughout the year zero lapse rate occurs later over the height interval 16·2m. to 46·4m. than over the layer nearer the ground. A further point of interest is that even before sunset an inversion has developed up to at least 16·2m. during the five months November to March. The time between sunset and the occurrence of zero lapse rate between 1·1m. and 16·2m. exhibits a marked annual variation ; it varies from 43 minutes before sunset in December to 144 minutes after sunset in August. These times show that the mean net flow of heat in the lowest layers of the atmosphere over Ismailia is outward from the surface for a considerable period before sunset during nearly half of the year. The value of $(K_R + K_E)$ necessary to satisfy the approximate expression for the transfer of heat in the atmosphere is found to vary from $2{\cdot}8 \times 10^3$cm.^{2}/sec. in January to $0{\cdot}29 \times 10^3$cm.^{2}/sec. in June for the middle height interval.

During five months, February to April, June and July, zero lapse rate develops over the height interval 46·4m. to 61·0m. earlier than over the middle height interval which indicates that the temperature at 61·0m. decreases less rapidly than is required by theory. The cause may be that considerable eddying persists in this layer, possibly owing to a steep vertical gradient of wind velocity, when conditions below 16·2m. are very stable. There does not appear to be any obvious relation connecting the mean time that elapses from the occurrence of zero lapse rate over the middle interval to the occurrence of zero lapse rate over the upper layer, and either the wind velocity at 15·2m., the vapour pressure as recorded at 1·1m. or the state of the sky. It is interesting to note, however, that taking the annual variation of temperature into consideration zero lapse rate occurs, with one exception, earlier in the upper layer than in the middle layer when temperature is increasing from February to July, and later when temperature is decreasing. The value of $(K_R + K_E)$ computed for those occasions when zero lapse rate occurred later in the upper layer than in the middle layer varies from $0{\cdot}5 \times 10^3$cm.^{2}/sec. in August to $32{\cdot}7 \times 10^3$cm.^{2}/sec. in November.

(*b*) *Effect of state of Sky*.—The effect of the state of sky on the rate of growth of inversions can be considered from a knowledge of the time at which zero lapse rate occurs on cloudy and on cloudless days. In Table XI the times of occurrence of zero lapse rate over each height interval are given for cloudless days in December and August and for cloudy days in December. The inversion develops much quicker up to a height of 46·4m. in December when the night is cloudless than when it is cloudy, but on cloudy nights isothermal conditions occur between 46·4m. and 61·0m. 74 minutes earlier than over the middle interval. This indicates that on cloudy nights in December the temperature at 61·0m. decreases much more slowly than would be the case if the process was in agreement with theory. Further, in December zero lapse rate between 1·1m. and 16·2m. occurs 51 minutes before sunset when the sky is clear as against 40 minutes when the sky is cloudy but in August under clear skies zero lapse rate does not occur until 2hr. 7min. after sunset. In December zero lapse rate between 46·4m. and 61·0m. also occurs before sunset when the sky is cloudy. The computed value of $(K_R + K_E)$ on cloudless evenings is thus $1{\cdot}1 \times 10^3$cm.^{2}/sec. for the middle layer and $9{\cdot}4 \times 10^3$cm.^{2}/sec. for the upper layer but only $0{\cdot}8 \times 10^3$cm.^{2}/sec. for the middle layer on cloudy evenings.

Under clear skies in August the inversion develops much more slowly than in December and the time of occurrence of zero lapse rate over each height interval is later the higher the interval. The computed value of $(K_R + K_E)$ is $0{\cdot}4 \times 10^3$cm.^{2}/sec. for the height interval 16·2m. to 46·4m. and $4{\cdot}7 \times 10^3$cm.^{2}/sec. for the interval 46·4m. to 61·0m. The extremely low value of $(K_R + K_E)$ for the lower interval, which is only just over one-third of the December value, suggests that $(K_R + K_E)$ decreases with decreasing wind velocity and increasing vapour pressure.

(*c*) *Individual Days*.—The effects of varying conditions of wind velocity, state of sky, vapour pressure and temperature on the development of nocturnal inversions may be considered by studying the figures extracted for individual days. In Table XIII figures are given for a number of selected days throughout the year. These show that the growth of an inversion can be explained on theoretical grounds for all conditions of the air layers below 46·4m. but this is not the case for the air layer between 46·4m. and 61·0m. The time of occurrence of zero lapse rate over the upper height interval compared with the time of occurrence over the middle height interval appears to bear no relationship to either the wind velocity at 16·2m., the vapour pressure at 1·1m. or the temperature at 1·1m.: thus with similar wind velocities on the three days February 16, 1932, December 9, 1931 and August 15, 1932, zero lapse rate between 46·4m. and 61·0m. occurred on the first day 49 minutes earlier than between 16·2m. and 46·4m. when vapour pressure was negligible and air temperature 24·4°C., on the second day 54 minutes later than over the interval above when vapour pressure was 10·0mb. and air temperature 18°C., and on the third day 22 minutes earlier than over the interval above when vapour pressure was 20·0mb. and air temperature 25°C.

The value of $(K_R + K_E)$ computed from figures given in Table XIII varies from $0{\cdot}27 \times 10^3$cm.^{2}/sec. to $2{\cdot}32 \times 10^3$cm.^{2}/sec. for the layer 16·2m. to 46·4m., while for those occasions when the time of zero lapse rate was later at 61·0m. than at 46·4m. the value over the upper layer varies from $0{\cdot}21 \times 10^3$cm.^{2}/sec. to $4{\cdot}67 \times 10^3$cm.^{2}/sec. These values show that on a number of occasions the value of $(K_R + K_E)$ is considerably less than $0{\cdot}5 \times 10^3$cm.^{2}/sec. even though the mean wind velocity may exceed 3m./sec.

TABLE XIII—DETAILS RELATING TO THE DEVELOPMENT OF THE NOCTURNAL INVERSION AT ISMAILIA ON SELECTED DAYS DURING THE PERIOD OCTOBER, 1931 TO OCTOBER, 1932

Date	Sunset	Time of occurrence of zero lapse rate			Weather during development	Values of specified elements at stated times				$(K_R + K_E)$	
		1·1m. to 16·2m.	16·2m. to 46·4m.	46·4m. to 61·om.		Mean hourly wind velocity at 15·2m.		Vapour pressure	Temperature	16·2m.—46·4m.	46·4m.—61.om.
						time	m./sec.	mb.	°C.	cm.²/sec. × 10³	cm.²/sec. × 10³
3.1.32	1703	1647	2020	1835	c	1830	3·1	11·5	16·3	0·37	..
15.1.32	1713	1619	1654	1800	b	1700	4·0	8·0	18·7	2·25	0·99
9.2.32	1734	1729	1924	2000	b	1900	calm	7·3	11·1	0·69	1·81
16.2.32	1740	1700	1734	1645	b	1610 1945	5·8 7·2	(o) 18·4	24·4 19·9	2·32	..
9.6.32	1851	1917	2400	0100	b	2400	2·7	22·4	24·0	0·28	1·09
25·6·32	1856	1855	2100	2041	b	2000	3·6	12·5	25·4	0·63	..
22.7.32	1850	1855	2118	2106	b	2000	4·9	13·2	28·5	0·55	..
23.7.32	1850	1916	2021	2035	b	2000	4·0	15·7	27·8	1·21	4·67
15.8.32	1832	1934	2122	2100	b	2030	5·4	20·0	25·3	0·73	..
19.8.32	1828	1730	2220	2130	b	1800 2130	8·5 3·6	10·0 19·7	31·1 25·6	0·27	..
31.8.32	1815	2036	2130	0020	b	2100 2230	4·0 3·1	23·7 24·4	26·1 25·0	1·46	0·31
9.12.31	1651	1518	1616	1710	c	1600 1730	5·4 4·5	10·0 7·9	17·8 13·9	1·36	1·21
24.12.31	1657	1700	1904	0015	c	2300	1·8	8·7	8·3	0·64	0·21
26.12.31	1658	1705	1840	1815	c	1800 1630	3·3 calm	7·3 4·1	13·6 17·2	0·83	..
29.12.31	1700	1600	1812	2040	b	2000	1·8	5·1	9·5	0·60	0·44

NOTE.—All times are zone time.

§ 17—RELATION BETWEEN THE WIND VELOCITY, TEMPERATURE AND VAPOUR PRESSURE AT THE TIME OF ZERO LAPSE RATE AND THE TIME OF OCCURRENCE OF ZERO LAPSE RATE

(*a*) *General.*—The extent of the diurnal variation of the lapse rate is an outstanding feature of the distribution of temperature in the layers of the atmosphere nearest the ground and it has been shown that at Ismailia on nearly every night an inversion develops between a height of 1·1m. and 16·2m. above the desert. It appeared possible that should any relation exist between the time of occurrence of zero lapse rate and the air temperature, the aqueous vapour pressure and the wind velocity at the time of change over from a positive to a negative lapse rate and *vice versa*, the conditions which prevail at Ismailia would be favourable for its determination. The observations used were restricted to occasions when the sky was clear for at least two hours preceding the time of zero lapse rate.

(*b*) *Conditions associated with decreasing Lapse Rate.*—The time of occurrence of zero lapse rate in the late afternoon or evening when the lapse rate is decreasing exhibits a much greater variation with respect to the time of sunset than is the case when the lapse rate increases in the early morning about sunrise (the time here being referred to sunrise as the zero hour), as will readily be seen by reference to Table XI, and in consequence the conditions associated with the occurrence of zero lapse rate in the evening are considered in the first instance. The time of occurrence (t) of zero lapse rate between 1·1m. and 16·2m. on the occasions when the sky was cloudless was first determined, and subsequently the air temperature (T) at 1·1m., the vapour pressure (e) at 1·1m. together with the wind velocity (v) at 15·2m. for the hour terminating at the time of zero lapse rate were obtained from autographic records. Since the decreasing lapse rate is a result of the cooling of the ground by radiation from the surface, it is reasonable to suppose that the relation being investigated will involve a factor depending upon the depth of the layer of air which will completely absorb the W radiation. The term W radiation is restricted to the wave lengths within which water vapour amounting to 0·3mm. of precipitable water radiates like a black body, and since this depth is proportional to the ratio of the temperature of the air to the vapour pressure the variables to be considered can be reduced to three.

Figures were abstracted for the six months December to February and June to August and the values of T/e were plotted against t for specified values of the wind velocity v. The separate monthly curves for a given value of v appeared to be all part of one and the same curve which implied that the question of annual variation could be neglected. The abstracted figures were therefore grouped together and the mean values of T/e and t for specified ranges of v computed. The

TABLE XIV—MEAN VALUES OF THE TIME OF OCCURRENCE OF ZERO LAPSE RATE THE MEAN VALUES OF THE RATIO T/e FOR

Wind velocity for hour ended at zero lapse rate	Time of occurrence of zero																	
	Time before sunset																	
	80–61		60–41		40–21		20–0		1–20		21–40		41–60		61–80		81–100	
	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e
m./sec. $\leqslant 2$	−80	62·8	−58	58·5	−24	59·0	− 4	40·1	..	..	..	..	..	..	..	..	..	..
2·1 to 4·0	..	..	−54	63·2	−29	43·8	− 9	34·5	..	..	..	..	..	..	..	..	..	..
4·1 to 6·0	−73	67·1	−50	41·7	−33	51·3	−17	36·0	4	31·7	32	28·9	51	27·2	76	14·7	92	14·7
6·1 to 8·0	−68	47·8	−48	42·1	−34	58·5	−10	28·3	9	23·2	30	24·9	53	17·8	68	14·9	90	13·7
8·1 to 10·0	..	..	..	..	−30	41·8	− 8	25·7	18	25·7	29	16·5	56	18·5	..	..	..	..
10·1 to 12·0	..	..	..	..	..	..	..	..	9	37·2	..	..	..	..	..	..	..	..

results are given in Table XIV and the curves of T/e plotted against t for specified values of v are shown in Fig. 20. The curves connecting T/e and t are rectangular

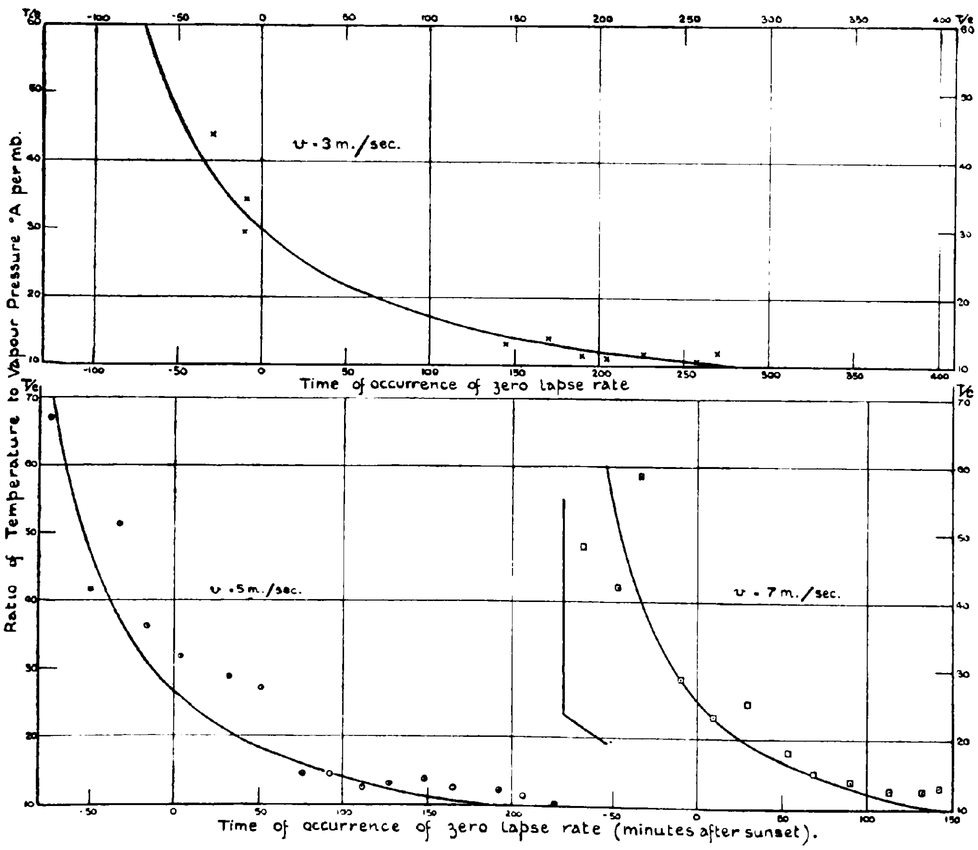


FIG. 20.—RELATION BETWEEN TEMPERATURE AND VAPOUR PRESSURE AT THE TIME OF ZERO LAPSE RATE FOR LAPSE RATE DECREASING AND TIME OF OCCURRENCE OF ZERO LAPSE RATE, REFERRED TO THE TIME OF SUNSET, FOR DIFFERENT VALUES OF THE WIND VELOCITY

hyperbolæ and the form of the equation for a given value of the wind velocity is

$$\frac{T}{e}(t + A) = B$$

where A and B are constants depending on the value of v. The values of A and B

BETWEEN 1·1m. AND 16·2m. IN THE EVENING IN MINUTES TOGETHER WITH DIFFERENT VALUES OF THE WIND VELOCITY

lapse rate in minutes																		
Time after sunset																		Number of observations
101—120		121—140		141—160		161—180		181—200		201—220		221—240		241—260		261—280		
t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e	
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6
..	..	..	..	145	13·0	170	14·1	190	11·4	205	10·8	226	11·7	258	10·7	271	11·9	14
111	12·8	127	13·3	148	14·0	165	12·7	192	12·4	206	11·5	225	10·4	..	..	..	..	57
113	12·5	132	12·3	142	12·8	161	12·4	..	..	..	..	..	..	..	..	..	..	50
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	8
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1

obtained by plotting t against e/T and determining the equation of the best straight line are given below in Table XV.

TABLE XV

Wind velocity at 15·2m.	A	B
m./sec.	minutes	°A./mb.
2	173	6397
3	117	3837
5	105	3300
7	109	2994
9	67	1839

The values of both A and B decrease as the wind velocity increases with the exception of the value of A corresponding to a wind velocity of 5m./sec. The relation between A and v deduced from the computed values of A is a straight line represented by the equation

$$A = 170 - 11v$$

The expression connecting B and v is found to be

$$B = 6350 - 4750 \log_{10}v$$

and substituting in the first equation above for A and B in terms of v the full relation between T, e, t and v is

$$\frac{T}{e}(t - 11v + 170) = 6350 - 4750 \log_{10}v$$

Thus for given values of v and T the time of occurrence in the evening of zero lapse rate is later the greater the vapour pressure. The physical reason for this result is that the greater the vapour pressure the less is the net loss of heat from the ground by long wave radiation, and the later the time of occurrence of complete balance between incoming and outgoing radiation. Similarly in the morning the greater the vapour pressure the earlier the balance between incoming and outgoing radiation.

Actual vapour pressures on the occasions used for the present analysis varied from 1·2mb. to 28·8mb. and if it is assumed that the equation can be applied to dry air the earliest possible time that zero lapse rate can occur in the evening with a clear sky is found to be 170 minutes before sunset. This would be associated with zero wind velocity and for higher wind velocities the time would approach sunset and zero lapse rate would occur just at sunset if the wind velocity was 15·5m./sec.

(*c*) *Conditions associated with increasing Lapse Rate.*—The decay of the nocturnal inversion on occasions when the sky was clear was next investigated and the values of temperature, vapour pressure, wind velocity and time of occurrence of zero lapse rate after sunrise analysed in the same manner as for the case when the inversion developed in the evening. The time range in this case is small and the results of the analysis are given in Table XVI. The figures exhibit a general variation in the value of T/e between summer and winter and during each period there is

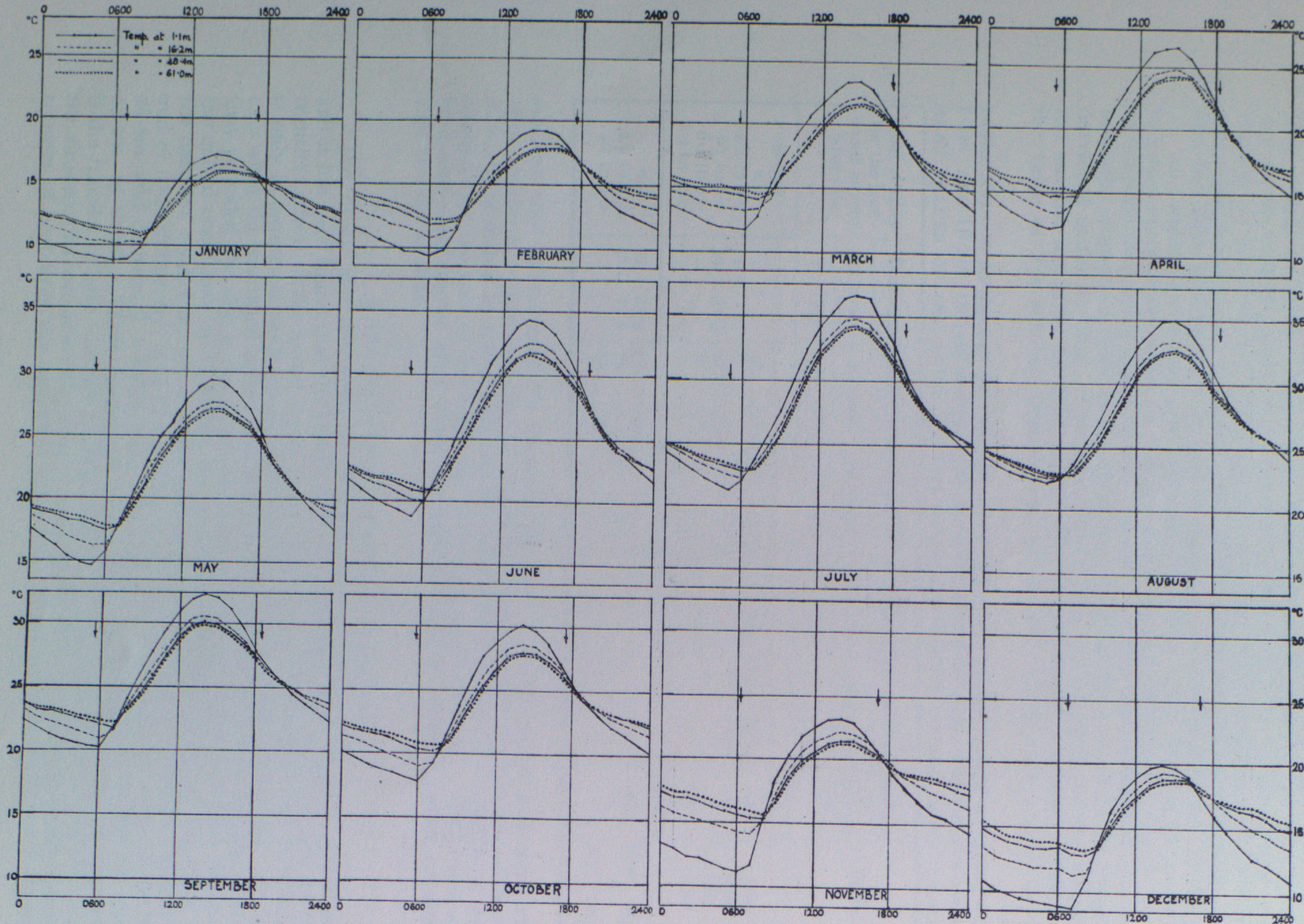
TABLE XVI—MEAN VALUES OF THE TIME OF OCCURRENCE OF ZERO LAPSE RATE BETWEEN 1·1m. AND 16·2m. IN THE MORNING IN MINUTES AFTER SUNRISE TOGETHER WITH THE MEAN VALUES OF THE RATIO T/e FOR DIFFERENT VALUES OF THE WIND VELOCITY

Wind velocity for the hour ended at zero lapse rate	Time of occurrence of zero lapse rate in minutes after sunrise										Number of observations	Period
	41 to 60		61 to 80		81 to 100		101 to 120		121 to 140			
	t	T/e	t	T/e	t	T/e	t	T/e	t	T/e		
m./sec.												
⩽2	..	..	76	27·0	90	23·8	112	34·5	129	37·0	27	June and July, 1932
2·1 to 4·0	..	..	..	..	88	20·4	..	..	129	32·3	5	
4·1 to 6·0	59	31·3	68	25·6	..	..	..	..	..	..	2	
6·1 to 8·0	..	..	70	37·0	91	38·5	109	29·4	..	..	5	
8·1 to 10·0	..	..	..	..	93	40·0	..	..	..	..	1	
⩽2	53	13·9	68	15·9	..	..	..	..	..	..	23	Nov., 1931 to Feb., 1932
2·1 to 4·0	46	15·1	73	15·4	89	14·7	..	..	..	..	9	
4·1 to 6·0	..	..	69	14·5	..	..	..	..	..	..	1	

evidence that as the ratio T/e increases the time of occurrence of zero lapse rate after sunrise also increases, and if a sufficient range of observations was available it would probably be found that the relation between t and T/e is similar to that obtained for the case of the lapse rate decreasing in the evening. Thus there will be a time after sunrise after which the lapse rate will be always positive provided that the sky is clear.

§ 18—NOCTURNAL INVERSIONS—CONCLUSION

The decay and development of nocturnal inversions have been considered and it has been found that the theoretical expression obtained by Brunt (10) for the transfer of heat in the lowest layers of the atmosphere by radiation and turbulence is only in agreement with actual conditions on certain specified occasions. In the case when the nocturnal inversion is being destroyed after sunrise it has been found that provided the sky is clear and the wind velocity at 15·2m. less than 1m./sec. the actual conditions up to 61·0m. are in agreement with theory and the value of the diffusion coefficient, which is the sum of the coefficients of radiative diffusivity and of eddy diffusivity, is of the order 2×10^3cm.^{2}/sec. for the air layer 16·2m. to 46·4m. and between 2×10^3cm.^{2}/sec. and about 1×10^4cm.^{2}/sec. for the air layer 46·4m. to 61·0m. These figures are considerably larger than would be expected if the transfer of heat was due to radiation acting alone and it seems probable that the air some distance above the ground is heated by other means than by the upward transfer of heat from the surface of the earth. Chapman (13) arrives at a similar



NOTE: Arrowheads indicate times of sunrise and sunset for middle day of month. Times are Zone Times.

FIG 21. CURVES OF MEAN HOURLY VALUES OF AIR TEMPERATURE AT EACH OF THE HEIGHTS 1·1m, 16·2m, 46·4m AND 61·0m.

(2808).

conclusion from his discussion of the Eiffel Tower records of air temperature and this is substantiated by Johnson (1) in his discussion of the records of lapse rate over Salisbury Plain. An upper air temperature ascent above Agra quoted by Ali (12) also suggests that the temperature of the air at small heights above the surface may be raised by other means than by the upward transfer of heat from the ground.

In considering the case of the development of the nocturnal inversion it is found that actual conditions can be accounted for on theoretical grounds on all occasions for the air layers below 46·4m. but not for the air layers between 46·4m. and 61·0m. For the air layers between 16·2m. and 46·4m. the value of the diffusion coefficient varies from about $0{\cdot}3 \times 10^3$cm.^{2}/sec. to over $2{\cdot}0 \times 10^3$cm.^{2}/sec. and the lower the value the more stable are the air layers during the process of development of the inversion.

A relation connecting the time of occurrence of zero lapse rate in the evening with reference to the time of sunset, wind velocity, temperature and vapour pressure has been deduced from the data available for cloudless evenings. This relation indicates that there is a maximum period before sunset beyond which an inversion would not occur in the layers nearest the ground and this can be easily explained on physical grounds.

§ 19—MEAN DIURNAL VARIATION OF TEMPERATURE AT FOUR HEIGHTS

(*a*) *Mean Hourly Values of the Temperature.*—The results so far presented have been of the same form as the readings given on the chart by the recording instrument. The only difference is that the traces show the difference in temperature between two positions vertically above one another whereas the values presented in the tables have been the actual readings merely converted into lapse rates over the interval of height involved. In what follows the readings given by the traces have been used to construct tables showing the actual diurnal variation of temperature at the different heights. The actual temperature at a height of 1·1m. has been taken to be that recorded on the charts for the aspirated element at this height, and by adding to this value the differences in temperature given by the differential traces I, II and III in turn, the actual temperature at each of the heights 16·2m., 46·4m. and 61·0m. has been obtained. In analysing the traces representing the temperature at a height of 1·1m. the same procedure has been adopted for obtaining the hourly values as in the case of the differential traces. The mean hourly values have been taken as the mean position of the trace during a twenty minutes period centred on the hour. The mean hourly values of the temperature at a height of 1·1m. obtained in this way are given in Table XVII(a), and the values at each of the heights 16·2m., 46·4m. and 61·0m., obtained in the manner mentioned above, are given in Tables XVII(b), XVII(c) and XVII(d). These values are also shown graphically in Fig. 21.

It will be seen that certain features are characteristic of all these curves. For instance the actual temperature at which the four curves cross is considerably higher in the evening than in the morning ; the time interval between the occurrence of zero lapse rate between 1·1m. and 16·2m., and between 46·4m. and 61·0m. is much shorter in the morning than in the evening. The increase in temperature during the morning is much more rapid than the decrease in the evening, especially during the winter months, while during the night the rate of decrease in temperature is fairly constant at all heights, and is slightly greater at a height of 1·1m. than at 61·0m. Further, the temperature at a height of 1·1m. does not commence to rise before sunrise, except perhaps in February, and the time that temperature ceases to fall is later the greater the height above the ground. This is well brought out by the traces for July as in this month the temperature at 1·1m. commences to rise about 0500, at 16·2m. about 0600, at 46·6m. between 0600 and 0700 and at 61·0m. about 0700.

Another very noticeable feature of the mean hourly values is the rapid decrease in the diurnal range of temperature with increasing height above the ground. In December the range at 1·1m., 16·2m., 46·4m. and 61·0m. is respectively 11·1, 8·0,

TABLE XVII—MEAN HOURLY VALUES OF THE AIR TEMPERATURE IN DEGREES
MONTH BASED ON RECORDS FOR THE

Month \ Hour	1	2	3	4	5	6	7	8	9	10	11	12
						(a) Height 1·1 metres						
January ..	9·9	9·7	9·3	9·2	9·0	8·8	8·9	9·8	11·6	13·6	15·1	16·3
February ..	11·2	10·6	10·2	9·7	9·7	9·4	9·8	11·4	13·9	15·6	17·1	18·0
March ..	13·1	12·7	12·2	11·9	11·8	11·7	12·8	15·3	17·5	19·2	20·6	21·7
April ..	14·1	13·4	12·8	12·4	12·1	12·3	14·6	17·1	19·5	21·6	23·2	24·8
May ..	16·9	16·3	15·4	14·9	14·7	15·9	18·3	20·7	22·9	24·9	26·1	27·9
June ..	20·9	20·2	19·7	19·3	18·8	20·1	22·3	24·5	26·7	28·8	30·8	32·3
July ..	23·5	22·8	22·1	21·6	21·2	22·0	23·8	25·6	27·6	30·0	32·3	34·2
August ..	23·5	23·0	22·6	22·3	22·1	22·4	23·6	25·4	27·0	29·1	31·1	32·8
September ..	21·8	21·3	20·9	20·6	20·3	20·2	21·8	24·2	26·1	27·9	29·6	31·0
October ..	19·7	19·2	18·8	18·5	18·1	17·9	19·2	21·5	23·9	25·9	27·7	28·8
November ..	13·9	13·3	13·2	12·8	12·4	12·2	12·7	15·3	18·1	20·3	21·8	22·6
December ..	10·2	9·9	9·5	9·3	9·1	8·9	8·8	10·8	13·8	16·2	17·9	19·0
						(b) Height 16·2 metres						
January ..	11·4	11·1	10·7	10·4	10·3	10·1	10·2	10·2	11·3	12·8	14·2	15·3
February ..	12·6	12·3	11·8	11·6	11·3	10·8	11·1	11·6	13·4	14·8	15·9	16·9
March ..	14·5	14·0	13·6	13·4	13·3	13·2	13·3	14·2	16·6	17·8	19·1	20·3
April ..	15·3	14·8	14·3	13·8	13·4	13·4	14·4	16·3	18·3	20·0	21·5	23·1
May ..	18·2	17·7	17·0	16·6	16·3	16·3	18·0	20·0	21·8	23·5	25·0	26·3
June ..	21·9	21·4	21·1	20·6	20·1	20·1	21·8	23·6	25·4	27·4	29·2	30·7
July ..	24·3	23·7	23·2	22·8	22·4	22·2	23·3	24·8	26·5	28·6	30·8	32·6
August ..	24·1	23·6	23·2	22·7	22·5	22·5	23·2	24·6	25·9	27·7	29·5	31·2
September ..	22·7	22·3	22·0	21·6	21·3	20·9	21·6	23·6	25·1	26·5	28·0	29·5
October ..	21·1	20·7	20·2	19·8	19·4	19·0	19·3	21·0	22·9	24·5	26·1	27·4
November ..	15·7	15·4	15·2	14·9	14·6	14·3	14·2	15·2	17·4	19·3	20·6	21·4
December ..	12·7	12·4	12·1	11·8	11·8	11·8	11·3	11·5	13·5	15·5	17·0	18·1
						(c) Height 46·4 metres						
January ..	12·1	12·0	11·6	11·3	11·1	10·9	10·9	10·7	11·2	12·4	13·6	14·8
February ..	13·6	13·3	13·1	12·7	12·2	11·8	11·9	12·1	13·1	14·3	15·5	16·4
March ..	15·2	14·9	14·7	14·7	14·5	14·3	14·1	14·6	16·2	17·3	18·7	19·8
April ..	16·1	15·7	15·6	15·0	14·7	14·7	14·7	16·0	17·9	19·5	21·0	22·5
May ..	18·9	18·7	18·3	18·2	17·8	17·5	17·9	19·6	21·4	23·1	24·6	25·9
June ..	22·2	21·8	21·7	21·3	20·9	20·7	21·4	23·1	24·8	26·8	28·5	30·1
July ..	24·6	24·1	23·7	23·4	23·1	22·8	22·9	24·3	25·9	28·0	30·2	32·0
August ..	24·3	23·8	23·5	23·1	22·8	22·7	22·8	24·1	25·3	27·1	28·9	30·6
September ..	23·3	23·2	22·9	22·6	22·4	22·0	21·7	23·3	24·5	25·9	27·5	28·9
October ..	21·9	21·7	21·5	21·1	20·7	20·4	20·2	20·7	22·3	23·9	25·4	26·7
November ..	16·9	16·9	16·6	16·2	15·8	15·6	15·4	15·3	16·7	18·6	19·8	20·6
December ..	14·3	13·8	13·6	13·3	13·3	13·4	12·9	12·8	13·3	15·1	16·5	17·5
						(d) Height 61·0 metres						
January ..	12·2	12·2	11·8	11·6	11·4	11·3	11·2	10·9	11·2	12·2	13·4	14·6
February ..	14·0	13·8	13·5	13·2	12·7	12·2	12·2	12·3	13·1	14·2	15·3	16·3
March ..	15·5	15·3	15·1	15·2	14·9	14·8	14·5	14·7	16·1	17·2	18·5	19·7
April ..	16·4	16·1	16·1	15·6	15·3	15·3	15·0	16·0	17·7	19·3	20·8	22·4
May ..	19·1	18·9	18·7	18·5	18·2	17·8	17·9	19·3	21·1	22·7	24·3	25·6
June ..	22·3	21·9	21·9	21·6	21·3	20·9	20·8	22·9	24·7	26·6	28·3	29·8
July ..	24·7	24·2	23·9	23·6	23·3	23·0	22·9	24·1	25·8	27·8	30·0	31·8
August ..	24·3	23·9	23·6	23·2	22·9	22·8	22·7	23·9	25·2	27·0	28·8	30·5
September ..	23·5	23·3	23·2	22·9	22·7	22·4	22·1	23·2	24·3	25·7	27·4	28·7
October ..	22·1	21·9	21·7	21·5	21·1	20·8	20·7	20·7	22·2	23·6	25·3	26·5
November ..	17·3	17·3	17·0	16·7	16·3	16·1	15·9	15·6	16·6	18·5	19·7	20·4
December ..	14·9	14·3	14·2	13·9	13·9	13·8	13·4	13·2	13·6	14·8	16·3	17·3

CENTIGRADE AT HEIGHTS OF 1·1m., 16·2m., 46·4m. AND 61·0m. FOR EACH PERIOD OCTOBER, 1931 TO OCTOBER, 1932

13	14	15	16	17	18	19	20	21	22	23	24	Zone time
					(*a*) Height 1·1 metres							
16·8	17·1	17·0	16·5	15·6	14·2	13·4	12·5	11·9	11·5	10·8	10·4	January
18·8	19·2	19·2	18·9	17·9	16·2	14·9	13·9	13·0	12·5	12·0	11·5	February
22·6	23·3	23·4	22·8	21·2	19·7	17·9	16·6	15·6	14·8	14·1	13·5	March
26·0	26·4	26·5	25·6	24·1	22·1	19·9	18·5	17·3	16·3	15·6	14·9	April
28·8	29·4	29·3	28·5	27·2	25·2	23·1	21·6	20·4	19·4	18·5	17·6	May
33·7	34·3	34·1	33·2	31·7	29·8	27·6	25·7	24·4	23·4	22·4	21·6	June
35·3	36·4	36·6	35·9	34·4	32·6	30·1	28·4	27·1	26·1	25·1	24·2	July
33·9	34·9	35·0	34·3	32·7	30·9	28·9	27·6	26·7	25·8	25·0	24·2	August
32·0	32·4	32·1	31·2	29·7	27·9	26·6	25·6	24·7	23·8	23·1	22·4	September
29·7	30·1	29·7	28·7	27·1	25·4	24·2	23·1	22·2	21·5	20·8	20·2	October
23·1	23·2	22·9	21·9	20·5	18·9	17·8	16·8	15·9	15·5	14·9	14·3	November
19·7	19·9	19·7	19·0	17·5	16·0	14·7	13·6	12·7	12·1	11·5	10·8	December
					(*b*) Height 16·2 metres							
15·8	16·3	16·3	16·1	15·7	14·9	14·5	13·6	13·1	12·6	12·1	11·8	January
17·7	18·2	18·2	18·2	17·7	16·6	15·7	14·8	14·0	13·6	13·3	13·1	February
21·3	21·9	22·1	21·7	20·7	19·7	18·1	16·9	16·1	15·5	15·1	14·6	March
24·3	24·6	24·7	24·2	23·2	21·8	20·0	18·7	17·6	16·9	16·4	16·1	April
27·2	27·6	27·6	26·9	26·1	24·7	23·1	21·7	20·6	19·9	19·2	18·7	May
31·9	32·4	32·3	31·6	30·4	29·2	27·5	25·8	24·6	23·8	23·1	22·5	June
33·7	34·6	34·7	34·3	33·1	31·6	29·8	28·3	27·2	26·3	25·6	24·9	July
32·3	33·1	33·2	32·7	31·6	29·7	28·6	27·5	26·7	25·9	25·3	24·7	August
30·4	30·6	30·4	29·7	28·7	27·5	26·4	25·6	24·9	24·3	23·8	23·3	September
28·3	28·6	28·4	27·7	26·7	25·4	24·4	23·6	22·9	22·4	22·0	21·4	October
21·9	22·2	22·0	21·5	20·7	19·6	18·7	18·1	17·5	17·1	16·6	16·2	November
18·9	19·3	19·2	18·9	18·1	17·2	16·3	15·6	15·0	14·5	13·8	13·4	December
					(*c*) Height 46·4 metres							
15·3	15·8	15·8	15·7	15·5	15·1	14·7	14·0	13·6	13·0	12·8	12·4	January
17·2	17·7	17·8	17·8	17·5	16·6	15·8	15·1	14·6	14·3	14·1	14·0	February
20·9	21·5	21·6	21·3	20·5	19·6	18·1	17·2	16·5	15·9	15·7	15·5	March
23·7	24·1	24·2	24·1	22·7	21·5	19·8	18·6	17·6	17·1	16·9	16·6	April
26·7	27·1	27·1	26·4	25·7	24·4	22·8	21·5	20·5	20·0	19·5	19·2	May
31·2	31·7	31·6	30·9	29·9	28·7	27·1	25·5	24·3	23·6	23·1	22·7	June
33·1	34·0	34·2	33·7	32·6	31·2	29·5	28·1	26·9	26·2	25·6	25·0	July
31·8	32·4	32·6	32·1	31·1	29·4	28·3	27·3	26·5	25·9	25·3	24·8	August
29·8	30·1	29·9	29·3	28·4	27·2	26·2	25·5	25·0	24·4	24·2	23·8	September
27·7	27·9	27·8	27·1	26·3	25·2	24·3	23·7	23·2	22·9	22·6	22·2	October
21·2	21·4	21·4	20·9	20·3	19·5	18·9	18·7	18·4	18·1	17·7	17·4	November
18·4	18·8	18·8	18·8	17·9	17·4	16·8	16·4	16·2	15·7	15·1	14·9	December
					(*d*) Height 61·0 metres							
15·0	15·6	15·7	15·6	15·4	15·0	14·7	14·1	13·7	13·2	13·0	12·6	January
17·0	17·6	17·7	17·7	17·4	16·6	15·9	15·1	14·9	14·6	14·4	14·3	February
20·7	21·3	21·5	21·2	20·4	19·5	18·2	17·2	16·7	16·2	16·0	15·8	March
23·5	23·9	24·0	24·0	22·6	21·4	19·8	18·6	17·7	17·2	17·1	16·9	April
26·4	26·9	26·9	26·3	25·5	24·3	22·7	21·4	20·4	20·0	19·6	19·4	May
31·0	31·5	31·2	30·7	29·7	28·6	27·0	25·4	24·2	23·6	23·1	22·7	June
32·9	33·8	34·0	33·6	32·4	31·0	29·4	28·0	26·8	26·1	25·6	25·0	July
31·6	32·3	32·4	31·9	30·9	29·2	28·2	27·2	26·4	25·8	25·3	24·7	August
29·7	29·9	29·7	29·1	28·2	27·1	26·1	25·4	25·0	24·4	24·2	23·8	September
27·5	27·7	27·6	27·0	26·1	25·0	24·2	23·6	23·2	22·9	22·7	22·4	October
21·1	21·3	21·2	20·7	20·2	19·4	19·0	18·8	18·7	18·3	18·1	17·8	November
18·2	18·5	18·6	18·6	17·8	17·4	17·0	16·7	16·7	16·2	15·7	15·5	December

6·0 and 5·4°C. and in August 12·9, 10·7, 9·9 and 9·7°C. Thus in winter the range decreases with height more rapidly than in summer; in December the range at 16·2m. is only three-quarters the value at 1·1m. but in August the range at 16·2m. is nearly ninety per cent of the value at 1·1m.

(*b*) *Harmonic Analysis of the Mean Diurnal Variation of Temperature.*—In the discussion of any theory of the transfer of heat in the vertical, and possibly of any question which takes account of turbulent motion in the lowest layers of the atmosphere, a knowledge of the time of occurrence of maximum temperature at different heights would be of great assistance. The diurnal inequalities of temperature at each of the four heights considered have therefore been resolved by harmonic analysis into Fourier series of the form :—

$$T = \Sigma_r P_r \sin (rnt + A_r)$$

where t is the time in hours reckoned from midnight and $n = \pi/12.\text{hr}^{-1}$.

The first two harmonics of the Fourier series expressing air temperature at heights of 1·1m., 16·2m., 46·4m. and 61·0m. are given in Table XVIII. For the present discussion, and as records for only one year are available, it is considered that no useful purpose would be served by the inclusion of succeeding harmonics in the table. As is to be expected a consideration of the amplitudes and phase angles shows that the former have a minimum value in winter and a maximum value in summer, while the phases are fairly consistent throughout the year.

The time of maximum at each height can be determined only with difficulty and doubtful accuracy from a consideration of the monthly mean values as it has to be obtained from smooth curves drawn through mean values taken over a period of twenty minutes centred at each hour. No account is therefore taken of the period of forty minutes centred at each half hour, and any values are likely to be in error by at least five minutes. In order to overcome this difficulty to some extent the time of maximum of the diurnal wave has been determined from the phase angle of the diurnal harmonic for each month. The times of occurrence of

TABLE XVIII—MEAN DIURNAL VARIATION OF AIR TEMPERATURE IN °C. AT ISMAILIA
FOURIER COEFFICIENTS $\Sigma P \sin (nt + A)$.

Height	1·1 metres					16·2 metres				
Month	Mean temp.	P_1	A_1	P_2	A_2	Mean temp.	P_1	A_1	P_2	A_2
January ..	12·4	3·922	225°11′	1·073	65°53′	12·9	2·968	211°54′	0·799	65°59′
February ..	13·9	4·656	226°29′	1·212	82°19′	14·4	3·366	214°46′	1·002	62°29′
March ..	16·9	5·612	230°25′	1·182	83°28′	16·9	4·224	223°37′	1·043	65°33′
April ..	18·8	6·838	230°18′	1·372	92°18′	18·6	5·273	224°37′	1·235	76°45′
May ..	21·8	6·930	233°04′	1·144	99°51′	21·7	5·389	228°13′	1·051	86°56′
June ..	26·1	7·310	231°01′	1·195	87°09′	25·8	5·788	226°08′	1·207	80°09′
July ..	28·3	7·168	226°08′	1·360	75°10′	27·9	5·849	221°14′	1·353	67°36′
August ..	27·7	6·084	226°33′	1·603	74°09′	27·2	5·023	220°47′	1·218	70°38′
September ..	25·7	5·651	230°40′	1·324	93°02′	25·4	4·195	226°29′	1·189	86°31′
October ..	23·4	5·608	230°08′	1·491	94°48′	23·4	4·261	220°51′	1·465	82°33′
November ..	17·3	5·148	232°08′	1·579	100°43′	17·9	3·218	216°42′	1·165	88°10′
December ..	13·8	2·914	229°48′	0·930	90°18′	15·0	2·059	215°53′	0·585	74°58′
	Cloudy days and nights									
December ..	15·7	3·959	233°12′	1·057	57°03′	16·0	3·363	219°50′	0·937	59°53′
	Cloudless days and nights									
December ..	11·9	6·403	228°18′	1·973	61°13′	13·7	4·062	219°01′	1·324	41°56′
August ..	27·8	6·553	225°08′	1·408	50°16′	27·4	5·284	219°37′	1·296	41°33′

the maximum of the diurnal wave, Table XIX, show that in nine months the time of occurrence of the maximum is later the greater the height above the surface. In March and May however the time of maximum is earlier at 61·0m. than at

TABLE XIX—TIME OF OCCURRENCE OF THE MAXIMUM OF THE DIURNAL COMPONENT OF TEMPERATURE AT EACH OF THE FOUR HEIGHTS 1·1m., 16·2m., 46·4m. AND 61·0m.

Month	Time of Maximum (Zone time)							
	1·1m.		16·2m.		46·4m.		61·0m.	
	h.	m.	h.	m.	h.	m.	h.	m.
January	14	59	15	52	16	36	16	45
February	14	54	15	41	16	06	16	21
March	14	32	15	06	15	32	15	27
April	14	39	15	02	15	06	15	11
May	14	28	14	47	14	57	14	49
June	14	36	14	55	15	00	15	01
July	14	55	15	15	15	21	15	33
August	14	54	15	17	15	26	15	27
September	14	37	14	54	15	12	15	17
October	14	39	15	17	15	17	15	24
November	14	31	15	41	15	51	16	06
December	14	41	15	41	16	17	16	41
Mean	14	42	15	17	15	34	15	40
Cloudy days and nights								
December	14	27	15	21	15	57	16	19
Cloudless days and nights								
December	14	47	15	24	16	03	16	23
August	14	59	15	22	15	25	15	25

AT FOUR HEIGHTS ABOVE THE DESERT
ZONE TIME

46·4 metres					61·0 metres					
Mean temp.	P_1	A_1	P_2	A_2	Mean temp.	P_1	A_1	P_2	A_2	Month
13·2	2·365	201°04′	0·678	46°18′	13·2	2·207	198°46′	0·558	43°49′	January
14·7	2·622	208°24′	0·917	59°10′	14·8	2·341	204°52′	0·910	57°03′	February
17·2	3·168	216°58′	1·389	62°14′	17·3	2·964	218°11′	1·158	51°18′	March
18·7	4·408	223°22′	1·368	64°35′	18·8	4·110	222°20′	1·379	60°30′	April
21·8	4·517	225°40′	1·182	68°58′	21·7	4·221	227°52′	1·253	62°47′	May
25·6	5·082	224°54′	1·305	69°34′	25·5	4·981	224°49′	1·345	65°50′	June
27·7	5·302	219°44′	1·480	60°14′	27·7	5·139	219°27′	1·502	57°45′	July
26·9	4·601	218°31′	1·301	64°40′	26·9	4·479	218°21′	1·326	62°18′	August
25·5	3·602	222°07′	1·227	74°46′	25·5	3·410	220°40′	1·315	72°08′	September
23·6	3·353	220°42′	1·299	72°01′	23·7	2·998	219°01′	1·300	71°32′	October
18·3	2·593	212°12′	1·055	80°41′	18·4	2·273	208°25′	0·985	82°22′	November
15·6	1·505	205°38′	0·464	67°13′	15·9	1·185	199°50′	0·419	64°06′	December
Cloudy days and nights.										
16·1	2·829	210°49′	0·887	50°02′	16·2	2·603	203°19′	0·915	56°08′	December
Cloudless days and nights.										
14·8	2·487	209°08′	0·984	27°53′	15·2	1·943	204°19′	0·921	27°07′	December
27·2	4·817	218°40′	1·405	31°18′	27·2	4·690	218°40′	1·414	27°53′	August

46·4m. by 5 and 8 minutes respectively while in October the maximum occurs simultaneously at 16·2m. and 46·4m. These time intervals are so small and the records cover only one year so that they cannot be taken as evidence that heat is transferred to the air layers between about 45m. and 60m. by any means other than by propagation of heat upwards from the surface of the earth. It will be observed also that the earliest mean time of occurrence of the maximum occurs in May at all heights, the respective times being 1428 or 2 hours 37 minutes after local noon, 1447, 1457 and 1449. The interval that elapses between the time of occurrence of the maximum at 1·1m. and 16·2m. varies from 17 minutes in September to 70 minutes in November, between 16·2m. and 46·4m. from zero in October to 44 minutes later in January, and between 46·4m. and 61·0m. from 8 minutes earlier at the upper level in May to 15 minutes later in November. The variation of the time of occurrence of maximum temperature throughout the year increases with increasing height above the ground. The variation at 1·1m. follows fairly closely the equation of time (Fig. 22) although the secondary minimum in May and the secondary maximum in July both differ from the value of the latter equation by about ten minutes. The variations at the other heights also exhibit maxima and minima corresponding to the equation of time with a tendency for them to be earlier, especially in the case of the autumn minimum, the greater the height above the surface. It seems possible that the variation at the surface is equal to the equation of time.

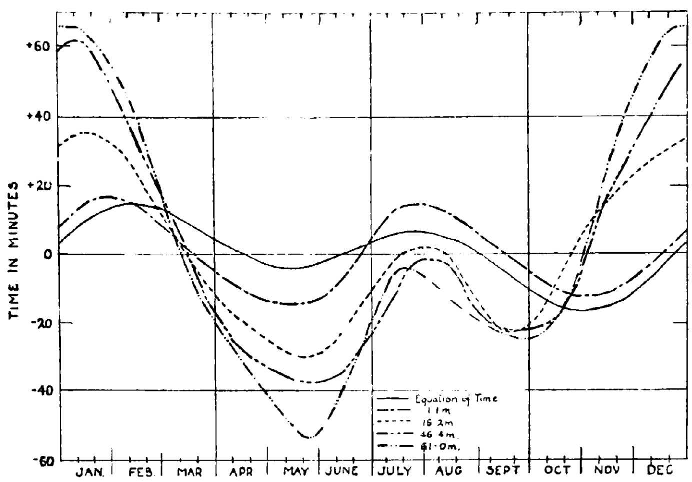


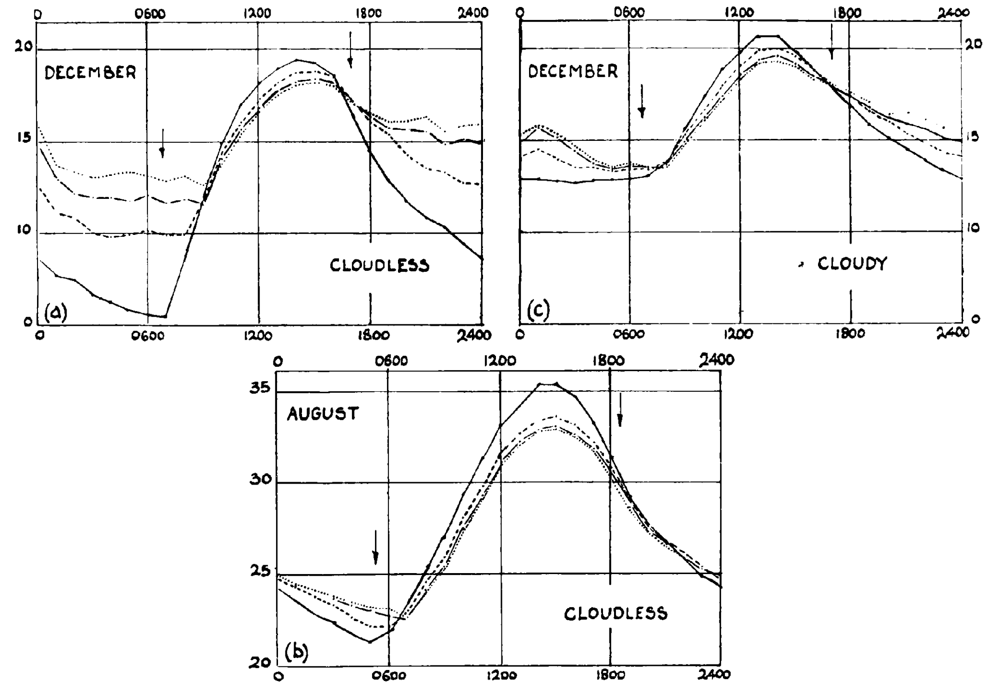
Fig. 22.—Annual variation of the time of maximum temperature at four heights above the desert at Ismailia together with the equation of time

(*c*) *Mean Values of the Temperature on Clear and Cloudy Days*.—The values given in Table XVII represent means for all types of weather but it is a matter of some interest to consider the effect of clouds on the diurnal variation of temperature and for this purpose mean values of temperature on clear days and on cloudy days have been determined. The months December and August have been taken as representative of winter and summer conditions respectively as was done when

TABLE XX—MEAN HOURLY VALUES OF AIR TEMPERATURE IN DEGREES CENTIGRADE
DAYS IN DECEMBER, 1931 AND FOR

	Zone time / Height	1	2	3	4	5	6	7	8	9	10	11	12
December	metres	Cloudless days											
	1·1	7·7	7·5	6·7	6·3	5·8	5·6	5·5	8·5	12·0	14·9	17·0	18·2
	16·2	11·1	10·8	10·0	9·8	9·9	10·1	9·9	9·9	11·7	14·4	16·0	17·3
	46·4	13·0	12·6	12·4	12·4	12·2	12·5	12·1	12·3	12·0	14·0	15·6	16·8
	61·0	13·7	13·3	13·0	13·2	13·3	13·1	12·8	13·1	12·6	13·8	15·4	16·6
		Cloudy days											
	1·1	12·9	12·8	12·7	12·8	12·8	12·9	13·1	13·8	15·6	17·4	18·9	19·8
	16·2	14·5	13·9	13·5	13·5	13·3	13·4	13·4	13·8	15·3	16·7	18·0	19·1
	46·4	15·7	15·1	14·4	13·7	13·4	13·6	13·5	13·6	14·9	16·2	17·4	18·6
	61·0	15·8	15·3	14·7	13·9	13·5	13·7	13·5	13·5	14·8	16·1	17·2	18·3
August		Cloudless days											
	1·1	23·6	22·8	22·3	21·7	21·3	21·8	23·4	25·4	27·0	29·3	31·3	33·1
	16·2	24·3	23·8	23·3	22·6	22·1	22·1	23·0	24·6	25·9	28·1	29·8	31·7
	46·4	24·4	24·1	23·7	23·3	23·0	22·7	22·6	24·1	25·4	27·5	29·3	31·1
	61·0	24·5	24·1	23·8	23·5	23·2	23·1	22·6	24·0	25·3	27·3	29·1	31·0

considering the effect of clouds on the lapse rate. The mean values of temperature under the different conditions are given in Table XX and shown graphically in Fig. 23. These figures and diagrams form a counterpart to those given in Table VIII. The number of observations upon which these curves are based and the mean wind velocities are the same as those already given in that table. Although the number of observations was relatively small the curves are reasonably smooth, and it is considered that they can be regarded as fairly accurate representations of the average temperature variations which occur under the specified conditions.



NOTE- Arrow heads indicate times of sunrise and sunset for middle day of month.
Times are zone time. Local noon is 1151 zone time.

FIG. 23.—CURVES OF MEAN HOURLY VALUES OF TEMPERATURE AT FOUR HEIGHTS ON CLOUDLESS AND CLOUDY DAYS AND NIGHTS IN DECEMBER, 1931, AND ON CLOUDLESS DAYS AND NIGHTS IN AUGUST, 1932

AT HEIGHTS OF 1·1m., 16·2m., 46·4m. AND 61·0m., FOR CLOUDLESS AND CLOUDY CLOUDLESS DAYS IN AUGUST, 1932

13	14	15	16	17	18	19	20	21	22	23	24	No. of observations
					Cloudless days							
19·0	19·4	19·3	18·6	16·4	14·6	12·9	11·7	10·8	10·3	9·4	8·7	7
18·2	18·7	18·8	18·5	17·2	16·0	15·3	14·2	13·5	13·3	12·7	12·6	
17·7	18·2	18·4	18·2	17·2	16·3	15·7	15·6	15·5	14·8	15·1	14·8	
17·5	18·0	18·2	18·0	17·1	16·5	16·0	16·1	16·3	15·5	15·8	15·9	
					Cloudy days							
20·6	20·6	19·8	18·8	17·8	16·9	15·9	15·1	14·5	13·8	13·3	12·9	4
19·9	20·0	19·6	18·8	18·0	17·4	16·6	16·0	15·3	14·8	14·3	14·1	
19·4	19·6	19·2	18·5	17·9	17·4	16·8	16·2	15·9	15·6	15·1	14·9	
19·2	19·3	19·0	18·3	18·0	17·6	17·1	16·4	16·5	16·1	15·7	15·3	
					Cloudless days							
34·2	35·3	35·3	34·7	33·3	31·4	29·2	27·8	26·8	25·9	25·0	24·3	9
32·7	33·4	33·6	33·2	32·2	30·8	29·1	27·7	26·8	26·1	25·4	24·8	
32·2	32·9	33·1	32·6	31·8	30·4	28·7	27·4	26·6	25·9	25·3	24·9	
32·0	32·8	32·9	32·5	31·7	30·3	28·6	27·4	26·5	25·9	25·3	24·9	

It is seen that during clear weather in December (Fig. 23a) temperature changes very close to the surface are more rapid than under the average conditions represented in Fig. 20. The rapid increase in temperature in the early morning and the rapid decrease in the early evening is very marked at all heights but it is especially so at a height of 1·1m. The curves corresponding to the temperature at 46·4m. and 61·0m. show that after the rapid decrease about sunset temperature becomes sensibly steady for roughly five hours, 1900—2400, followed by a sharp fall during the next two hours 2400—0200, but after 0200 the temperature shows little change until the sudden increase occurs after sunrise. At 16·2m. temperature falls during the whole of the evening, and continues to decrease until 0300 in the morning, but thereafter is fairly steady, as in the case of the temperature at 46·4m. and 61·0m., until after sunrise. The temperature at 1·1m. continues to fall throughout the night, so that after 0300 the cooling of the air layers in contact with the surface of the earth merely increases the magnitude of the inversion below 16·2m. and has no effect on the temperature at, or above, this height.

During clear weather in August (Fig. 23b) the temperature at all heights is varying rapidly throughout most of the twenty-four hours. The decrease in temperature after sunset is fairly steady at all heights, although the rate of decrease is greater the nearer the layer concerned is to the ground, and persists right up to the time that the sudden increase commences soon after sunrise. The traces exhibit one great difference from those for December in that the temperature does not remain sensibly constant at any time during the night at any of the four heights considered.

The effect of clouds, as shown by the figures for December (Fig. 23c), is to reduce the diurnal range of temperature at each height. The diurnal range is reduced to about one-half of the clear sky value at a height of 1·1m., and to about two-thirds the clear sky value at 16·2m., but there is only a slight reduction in range at 46·4m. and 61·0m. The curves in Figs. 21a and 21c show that the average cloudy day in December is warmer at 1300 by 1·6°C. at 1·1m. and 1·7°C. at the other heights than a clear day while on the average cloudy night the minimum temperature is higher than on a clear night by 7·2°C. at 1·1m., 3·3°C. at 16·2m., 1·4°C. at 46·4m. and 0·9°C. at 61·0m.

The curves for cloudless days should be compared with that derived theoretically by Brunt (13) for the diurnal variation of temperature. The time of occurrence of the maximum at 1·1m. in December is about 2·2 hours after local noon and in August about 2·5 hours after local noon which values are in very good agreement with the value of 2·25 hours given by the theoretical curve.

In the same paper Brunt has shown that the depression of the minimum temperature below the temperature at sunset, due to the effect of nocturnal radiation, is given to a close approximation by the equation

$$T - T'_M = \frac{2}{\sqrt{\pi}} \frac{R_N}{\rho_1 c_1 \kappa_1} \sqrt{t} = \frac{2}{\sqrt{\pi}} \sigma T_M^4 \frac{(1 - l - m\sqrt{e'})}{\rho_1 c_1 \kappa_1} \sqrt{t}$$

where T = the temperature at sunset in degrees Absolute,
T'_M = the minimum temperature,
T_M = the mean temperature between sunset and sunrise,
R_N = the net loss of heat by radiation from the ground to the atmosphere in gramme calories per minute,
ρ_1 = density of the ground,
c_1 = specific heat of the ground,
κ_1 = specific conductivity of heat for the surface layers of the ground,
t = time in hours between sunset and sunrise,
e' = mean vapour pressure in millibars during the night,
σ = Stefan's constant,
l and m = constants depending on the latitude.

In order to test the application of this equation to the case of clear nights during December and August at Ismailia the values of l and m have been obtained by interpolation from the figures given by Brunt (loc. cit., p. 401) for various zones over the surface of the earth whence $l = 0{\cdot}57$ and $m = 0{\cdot}07$. For sand, ρ_1 and c_1

can be taken as 2·63 and 0·19 respectively, while from Suring's (14) observations of the vertical distribution of temperature in sand the value of κ_1 may be assumed to be equal to 10×10^{-3} in c.g.s. units. For December e' and T_M may be taken as 7·5mb. and 283°A. respectively and in August as 23mb. and 298°A. respectively, whence for December

$$T - T'_M = \frac{2 \times 0{\cdot}541(0{\cdot}43 - 0{\cdot}07 \times \sqrt{7{\cdot}5})}{\sqrt{\pi} \times 2{\cdot}63 \times 0{\cdot}19 \times 10^{-1}} \sqrt{13{\cdot}7} = 10{\cdot}8°\text{C.},$$

and for August

$$T - T'_M = \frac{2 \times 0{\cdot}645(0{\cdot}43 - 0{\cdot}07 \times \sqrt{23})}{\sqrt{\pi} \times 2{\cdot}63 \times 0{\cdot}19 \times 10^{-1}} \sqrt{10{\cdot}8} = 4{\cdot}8°\text{C.}$$

These figures compare with 11°C. and 9°C. given by the curves in Figs 21a and 21b, so that while the value computed from theoretical considerations is in excellent agreement for December the value computed for August is only about half the actual value. The reason for this difference is not obvious, but it may be connected in some way with the marked diurnal variation of vapour pressure at 1·1m. which might lead to the value of e' used being too high, although even when the value of e' is taken as that at 1800 the previous evening the decrease in temperature works out as only 6·7°C. Another fact which makes the result for August all the more surprising is that in general there will be some wind movement during the night the effect of which would be to diminish the fall of surface temperature by the downward transfer of heat through the inversion to the ground.

(*d*) *Harmonic Analysis of the Diurnal Variation of Temperature on Clear and Cloudy Days.*—The readings for cloudless and for cloudy days have been resolvde by harmonic analysis into Fourier series in the same way as was done with the mean hourly values for each month. The values of the coefficients for the diurnal and semi-diurnal waves are given at the foot of Table XVIII, while the times of occurrence of maximum temperature at each height are given at the foot of Table XIX.

On cloudy days in December the amplitudes are larger at all heights than those for average conditions while the phase angles, especially those for the semi-diurnal wave, are less at all heights. The phase angles for the semi-diurnal wave do not appear to bear any relation to one another, for, whereas those for the diurnal wave decrease with height, the largest value in the case of the semi-diurnal wave is that for 16·2m. and the smallest that for 46·4m. No satisfactory conclusion can be drawn from these facts owing to the small number of cloudy days under consideration. The amplitudes on cloudless days in December are considerably larger than those for either average or cloudy conditions. At 1·1m. the amplitude of both the diurnal and semi-diurnal waves is more than double the value for average conditions, while at 61·0m. the ratio is only slightly less. The phase angles are smaller than those for either average or cloudy conditions but decrease with height in all cases.

The time of maximum in each case differs from that under average conditions. The time of occurrence of the maximum with one exception is earlier than the average both when the sky is cloudless and when it is cloudy although the maxima are earliest on cloudy days. The mean time of occurrence of the maximum of the diurnal wave on the four cloudy days in December is 14 minutes earlier than the monthly mean value at 1·1m., 20 minutes earlier at 16·2m. and 46·4m., and 22 minutes earlier at 61·0m. On the seven cloudless days in December the mean time of occurrence of the maximum is 6 minutes later than the monthly mean value at 1·1m., 17 minutes earlier at 16·2m., 14 minutes earlier at 46·4m. and 18 minutes earlier at 61·0m. This implies that on the remaining twenty days in December which could not be classified as either clear or cloudy the maximum must occur later than under average conditions. On clear days in August the time of maximum is 5 minutes later at both 1·1m. and 16·2m., and earlier by 1 minute and 2 minutes respectively at 46·4m. and 61·0m. than under average conditions. The reason for the earlier occurrence of the maximum on cloudless days in August is not connected in any way with a difference in mid-time between sunrise and sunset as this time was the same for cloudless days as for the whole month, but the explanation may be connected with the time of arrival of the cool breeze in the afternoon since the approximate mean time of arrival of the cooler air was 1435 for cloudless days and 1430 for the whole month.

(*e*) *Diurnal Variation of the Temperature at the Surface on Clear Days.*—A knowledge of the temperature of the air immediately in contact with the surface would be extremely useful in the discussion of many meteorological problems, yet the difficulties involved in the direct determination of such temperatures are too obvious to require enumeration, and any reading of surface temperature would be liable to a large margin of error. It seems possible that readings of air temperature at small heights above the surface might be used to give the temperature in a plane at a level with the surface by extrapolation and the readings for clear days already discussed will be employed for this purpose. The equation for heat transfer in the lowest layers of the atmosphere has been shown to be

$$\frac{\partial T}{\partial t} = (K_R + K_E)\frac{\partial^2 T}{\partial z^2}$$

to a close approximation. Experimental evidence indicates that even at a height of 15m. this equation does not take into account all the effects operative in heat transfer, and it has been shown also that K_R varies with height, but if it is assumed that this equation holds below about 15m. then it can be used for the purpose of determining the surface temperature from readings of temperature at 1·1m. and 16·2m.

On the assumption that below 16·2m. the amplitude of each harmonic of temperature decreases with increasing height above the surface according to the exponential law, and that the waves are propagated upwards with uniform speed, the air temperature at height z will be given by

$$T_z = \Sigma_r T_r e^{-b_r z} \sin(rnt - b_r z)$$

where $b_r^2 = nr/2(K_R + K_E)$. Thus the phase angles at the "surface" and at equal intervals of height above the surface will be in arithmetical progression while the amplitudes will be in geometrical progression. That is, the phase angle, B, and amplitude, Q, at the surface will be given respectively by $B_{1\cdot1}(B_{16\cdot2}/B_{1\cdot1})^{-\frac{11}{151}}$ and $Q_{1\cdot1} - \frac{11}{151}(Q_{1\cdot1} - Q_{16\cdot2})$ where the suffixes refer to heights in metres. Values of B and Q for the diurnal and semi-diurnal wave of the surface temperature on cloudless days and nights in August and December obtained by extrapolation from those at heights of 1·1m. and 16·2m. are given in Table XXI. The maximum of the diurnal wave at the surface occurs at the same time as at a height of 1·1m. in each case but this is probably due to the difference in time being too small to be indicated by the present means of calculation.

TABLE XXI—MEAN DIURNAL VARIATION OF "SURFACE" TEMPERATURE ON CLOUDLESS DAYS AND NIGHTS AT ISMAILIA

Fourier Coefficients $\Sigma Q \sin(nt+B)$

Month	Q_1	B_1	Q_2	B_2
	°C.		°C.	
December	6·575	228° 18′	2·020	61° 23′
August	6·645	225° 08′	1·416	50° 22′

(*f*) *Annual Variation of Temperature.*—The monthly mean temperatures at each height, obtained from a consideration of the mean values for each hour, are included in Table XVIII, and these values have been used to evaluate by harmonic analysis the date of occurrence of the maximum temperature at each height. The maxima all occur in July and the dates have been adjusted to those for a leap year since the majority of the observations were made in 1932. The respective dates, Table XXII, show that at a height of 1·1m. the maximum temperature occurs on July 10 and the lag between the temperature at 1·1m. and 16·2m. is nineteen days, but between the temperature at 16·2m. and 46·4m. and between 46·4m. and 61·0m. the lag is only one day in each case.

TABLE XXII—DATE OF MAXIMUM AIR TEMPERATURE

Height	1·1m.	16·2m.	46·4m.	61·0m.
Date	July 10	July 29	July 30	July 31

These figures afford a certain amount of evidence that in the air layers above 16·2m. changes of temperature cannot be regarded as due only to radiation transmitted from the ground upwards.

§ 20—LAPSE RATE, VERTICAL GRADIENT OF WIND VELOCITY, AND WIND VELOCITY

(*a*) *Frequency of Occurrence of Different Lapse Rates at Various Wind Speeds.*—The hourly values of the temperature difference between 16·2m. and 1·1m. were used, in conjunction with the hourly values of wind velocity at a height of 15·2m., to compile a table showing the frequency of occurrence of different lapse rates at various wind speeds during the winter months, November to February inclusive. The range of lapse rates, which includes all the available readings, varies from 12°C./100m. to −51°C./100m. where 12°C./100m. includes all lapse rates from 10·6°C./100m. to 13·5°C./100m., 9°C./100m. all values from 7·6°C./100m. to 10·5°C./100m. and so on down to −51°C./100m. which includes all readings from −49·6°C./100m. to −52·5°C./100m. The results have been subdivided among strong, moderate, light and almost calm winds, classified as follows:

Strong winds—mean velocity for the hour at 15·2m. $>$9m./sec.
Moderate winds—mean velocity for the hour at 15·2m. $>$6·5, $\leqslant$9m./sec.
Light winds—mean velocity for the hour at 15·2m. $>$2, $\leqslant$6·5m./sec.
Almost calm winds—mean velocity for the hour at 15·2m. $\leqslant$2m./sec.

The resulting frequency table is given in Table XXIII.

When the wind is almost calm the largest lapse rate recorded does not exceed 10·5°C./100m. but larger lapse rates are recorded for the stronger winds, and the value of the positive lapse rate with a maximum frequency of occurrence increases with increasing wind velocity up to 6·5m./sec. but changes little for winds over 6·5m./sec. For almost calm winds the lapse rate with the maximum frequency of occurrence is 3°C./100m. but for light winds it is 6°C./100m. and remains roughly this value for the stronger winds. In the case of inversions the expected result is obtained that the lower the wind velocity the larger the possible inversion. The largest inversion recorded when the wind is almost calm is equal to −51°C./100m. but does not exceed −9°C./100m. and −6°C./100m. respectively for moderate and strong winds.

The frequency curves are given in Fig. 24, and it will be seen that the one for almost calm winds rises rapidly from a lapse rate of 9°C./100m. to a maximum at 3°C./100m., the curve then decreases to a minimum at −6°C./100m., rises to a secondary maximum at −12°C./100m. and finally decreases gradually as the lapse rate becomes increasingly negative. The curve for light winds is similar although in this case a secondary maximum occurs at 6°C./100m., a minimum at 3°C./100m. and the principal maximum at −3°C./100m., and the curve then falls rapidly from this value to one of −15°C./100m.

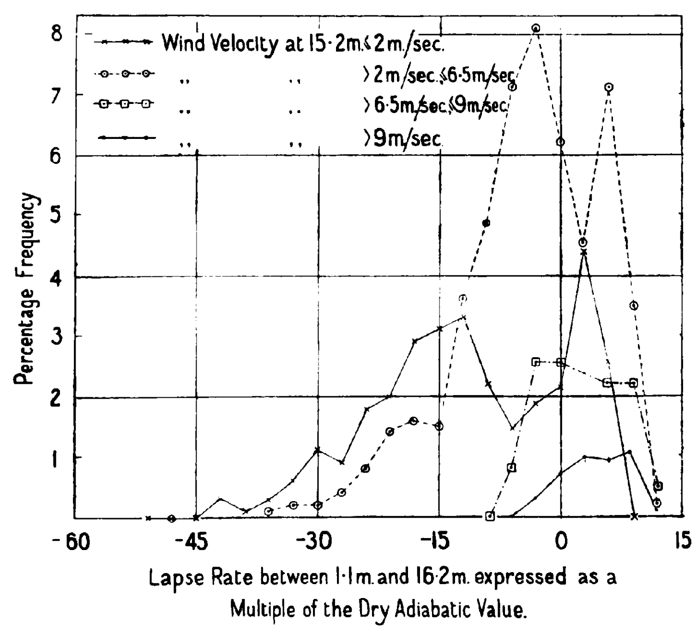


FIG. 24.—FREQUENCY OF OCCURRENCE OF DIFFERENT LAPSE RATES FOR VARIOUS WIND STRENGTHS, NOVEMBER, 1931 TO FEBRUARY, 1932

TABLE XXIII—FREQUENCY OF OCCURRENCE OF DIFFERENT LAPSE RATES FOR

Lapse rate between 1·1m. and 16·2m. in °C./100m.		Lapses 12	9	6	3	0	Inversions −3	−6
Number of hourly readings	>9m./sec.	4	30	26	28	21	8	1
	>6·5 but ≤9m./sec.	13	62	63	65	71	72	22
	>2 but ≤6·5m./sec.	6	100	202	127	176	231	201
	≤2m./sec.	..	1	71	126	60	53	42
Percentage of number of hourly readings	>9m./sec.	0·1	1·1	0·9	1·0	0·7	0·3	0·1
	>6·5 but ≤9m./sec.	0·5	2·2	2·2	2·3	2·5	2·5	0·8
	>2 but ≤6·5m./sec.	0·2	3·5	7·1	4·5	6·2	8·1	7·1
	≤2m./sec.	..	0·1	2·5	4·4	2·1	1·9	1·5

but subsequently the decrease is gradual. The curves for moderate or strong winds have characteristics of their own. They each rise rapidly as the lapse rate decreases, remain fairly steady for a range of values and finally fall rapidly. For moderate winds the curve is fairly steady for lapse rates between 9°C./100m. and −3°C./100m., and for strong winds between 9°C./100m. and 3°C./100m. An important point exhibited by these curves is that inversions equivalent to a lapse rate between −3°C./100m. and −12°C./100m. over the height interval 1·1m. to 16·2m. can exist with a wind velocity greater than 6·5m./sec. at 15·2m.

(*b*) *Lapse Rate and Vertical Gradient of Wind Velocity*.—It has been shown by Heywood (15) and Richardson (16) that there is a close relation between the lapse rate and the vertical gradient of wind velocity, and an attempt is here made to determine a relation between the lapse rate over the height interval 16·2m. to 61·0m. and the difference in wind velocity between 15·2m. and 62·6m. The observations of the wind velocity at 62·6m. were made at specified hours only and the method of observation was that described in the Meteorological Observer's Handbook (17) for obtaining wind velocity with the electric cup anemometer. This velocity used in conjunction with the wind velocity recorded by the anemometer at 15·2m. over the same period gives the difference in wind velocity at the time of observation between 62·6m. and 15·2m., and this value added to the mean hourly wind velocity at 15·2m. has been taken as an approximation to the mean hourly wind speed at 62·6m. Although this artifice may be open to may objections it is considered to be the only means available of obtaining an estimate of the mean hourly wind at the upper level. The lapse rate over the height interval concerned is easily obtained by combining the values of the temperature differences recorded by traces II and III.

The hourly lapse rates, being the mean values over a twenty minute interval centred at exact hours, were grouped around integral values of the lapse rate expressed in °C./100m. All differences of wind velocity occurring with specified lapse rates

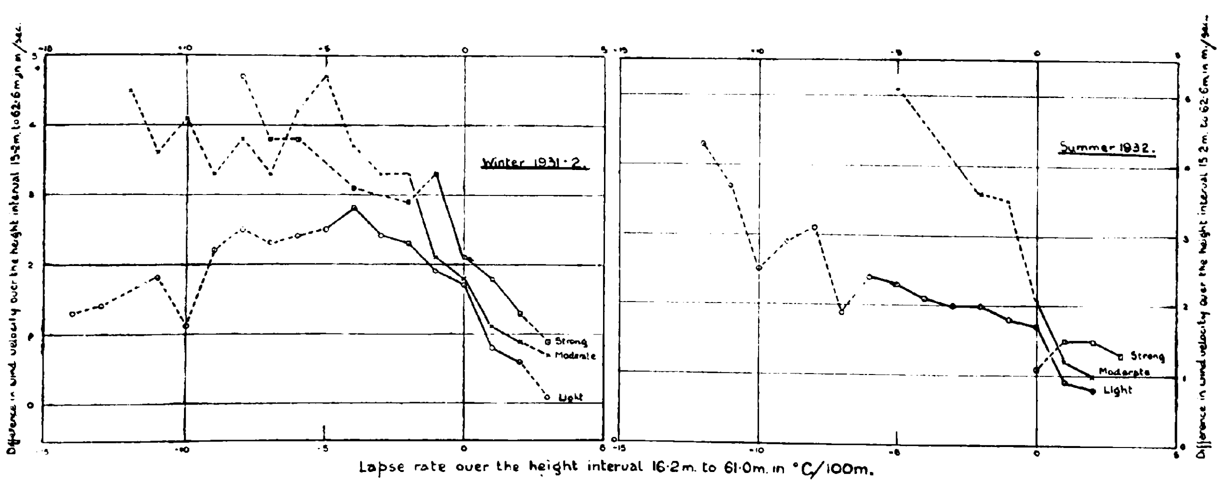


FIG. 25.—DIFFERENCE IN WIND VELOCITY BETWEEN 62·6m. AND 15·2m. FOR SPECIFIED LAPSE RATES FOR DIFFERENT WIND STRENGTHS

VARIOUS WIND STRENGTHS—NOVEMBER, 1931 TO FEBRUARY, 1932 INCLUSIVE

Inversions														
−9	−12	−15	−18	−21	−24	−27	−30	−33	−36	−39	−42	−45	−48	−51
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
140	103	42	46	41	24	10	6	5	2	..	..	..	1	..
63	95	89	82	57	51	26	31	17	8	3	9	1	1	1
..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
0·1	..	..	..	..	..	..	..	..	..	..	..	..	..	..
4·9	3·6	1·5	1·6	1·4	0·8	0·4	0·2	0·2	0·1	..	..	..	0·1	..
2·2	3·3	3·1	2·9	2·0	1·8	0·9	1·1	0·6	0·3	0·1	0·3	0·1	0·1	0·1

during the winter, November to February inclusive, and during the summer, May to August inclusive, were grouped together according as the mean wind velocity at the upper level was light, moderate or strong (classified as in para. (*a*) above). Mean values of the velocity differences were then computed. No information is available for velocities of less than 2·5m./sec. at 62·6m. as the type of cup anemometer employed cannot be used at such low speeds. The results are given in Table XXIV and are shown graphically in Fig. 25. Where the mean value represents less than ten observations the number of cases is entered in brackets below the value concerned.

TABLE XXIV—MEAN DIFFERENCE OF WIND VELOCITY BETWEEN 62·6m. AND 15·2m. IN m./sec. FOR SPECIFIED LAPSE RATES

Wind at 62·6m.	Lapse rate in °C./100m.																
	3	2	1	0	−1	−2	−3	−4	−5	−6	−7	−8	−9	−10	−11	−12	−13	−14
								(*a*) Winter									
Light	0·1 (2)	0·6	0·8	1·7	1·9	2·3	2·4	2·8	2·5 (9)	2·4	2·3 (9)	2·5 (7)	2·2 (3)	1·1 (1)	1·8 (2)	..	1·4 (1)	1·3 (2)
Moderate	0·7 (4)	0·9	1·1	1·8	2·1	3·3 (5)	3·3 (2)	3·7 (1)	4·7 (5)	4·2 (4)	3·3 (4)	3·8 (2)	3·3 (1)	4·1 (1)	3·6 (1)	4·5 (3)	.. ..	.. ..
Strong	0·9 (1)	1·3	1·8	2·1	3·3 (2)	2·9 (2)	..	3·1 (1)	..	3·8 (1)	3·8 (1)	4·7 (1)	..	..	..	..	..	..
								(*b*) Summer									
Light	..	0·8	0·9	1·7	1·8	2·0	2·0	2·1	2·3	2·4 (2)	1·9 (3)	3·1 (4)	2·9 (2)	2·5 (1)	3·7 (2)	4·3 (1)	..	..
Moderate	..	1·0	1·2	2·1 (4)	3·5 (4)	3·6 (1)	..	..	5·1 (1)	..	..	..	..	..	..	..	..	..
Strong	1·3 (1)	1·5	1·5 (7)	1·1 (1)	..	..	..	..	..	..	..	..	..	..	..	..	..	..

NOTE.—Number of observations entered in brackets when values are means of less than 10 observations

The curves show that the smallest differences of wind velocity are associated with large lapse rates and as the lapse rate decreases the difference of wind velocity increases until an inversion equal to a lapse rate of −4°C./100m. has developed. Observations for larger inversions are few but from the figures available it appears that further decreases in the lapse rate are not associated with any marked change in the difference of wind velocity, although in winter in the case of light winds the value of the velocity difference is observed to decrease for very large inversions. This indicates that when the lapse rate between 16·2m. and 61·0m. is −3°C./100m. turbulence has been reduced to a minimum and any further decrease in the lapse rate fails to produce any appreciable increase in the stratification of the air. The development of a very large inversion is not therefore associated with a corresponding increase in velocity gradient but instead appears to be accompanied by a slight decrease. A similar result was obtained by Heywood who found that at Leafield turbulence between 13m. and 87m. was reduced to a minimum when the lapse rate had decreased to approximately −1°C./100m. These results suggest that a larger negative lapse rate is required to damp out eddies in the air stream near the ground at Ismailia than is necessary at Leafield.

(*c*) *Relation between Lapse Rate, Vertical Gradient of Wind Velocity and Wind Velocity.*—In order to investigate the relation between lapse rate, vertical gradient of wind velocity and wind velocity the vertical difference of wind velocity was plotted against the wind velocity at the upper level for specified values of the lapse rate. The data used were the hourly mean values of lapse rate between 16·2m. and 61·0m. together with the hourly values of the difference of wind velocity between 15·2m. and 62·6m. and the wind velocity at 62·6m., obtained as described in para. (*b*) above, for both the winter and summer months. The hourly values of the difference of wind velocity which occurred with intervals of velocity of 0·8m./sec. and specified intervals of the lapse rate, expressed in °C./100m., were grouped together and mean values of the velocity differences computed. These values are given in Table XXV and the curves for selected lapse rates are plotted in Fig. 26. These

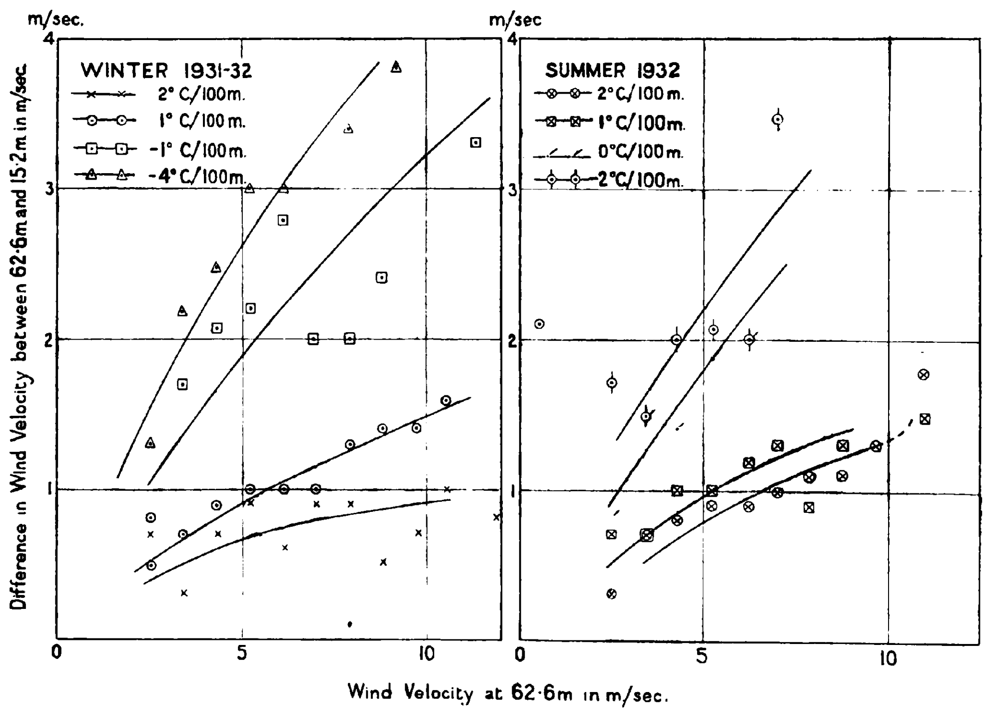


FIG. 26.—MEAN DIFFERENCE IN WIND VELOCITY BETWEEN 62·6m. AND 15·2m. for FIXED VALUES OF THE LAPSE RATE AND OF THE WIND VELOCITY AT 62·6m.

show that for a given lapse rate the vertical difference of wind velocity at first increases approximately linearly with the wind velocity at the upper level, but for higher values of the wind velocity the increase in the difference, and therefore the gradient, of wind velocity becomes less. The vertical difference of wind velocity also increases with decreasing lapse rate for a given wind velocity until the lapse rate has decreased to −4°C./100m. when a limiting value of the vertical difference of wind velocity appears to be reached. Further intensification of the inversion leaves the vertical difference of wind velocity unaltered; a result already deduced when discussing Table XXIV in para. (*b*) above.

TABLE XXV—MEAN DIFFERENCE OF WIND VELOCITY BETWEEN 62·6m. AND 15·2m., IN METRES PER SECOND, OCCURRING WITHIN SPECIFIED INTERVALS OF VELOCITY AND SPECIFIED LAPSE RATES BASED ON HOURLY READINGS IN 1931 AND 1932

The number of observations is entered in brackets

Velocity at 62·6m.	Winter months (November to February)									Summer months (May to August)							
	Lapse rate in °C./100m.																
m./sec.	3	2	1	0	−1	−2	−4	−8	−12·5	2	1	0	−1	−2	−4	−8	−11·5
2·1— 2·9	..	0·7 (8)	0·5 (22)	1·7 (4)	0·8 (3)	1·7 (4)	1·3 (4)	1·3 (7)	..	0·3 (43)	0·7 (27)	0·8 (3)	1·8 (5)	1·7 (4)	1·8 (5)	2·1 (3)	..
3·0— 3·8	..	0·3 (12)	0·7 (15)	1·7 (4)	1·7 (2)	1·4 (4)	2·2 (8)	2·1 (7)	1·6 (2)	0·7 (65)	0·7 (55)	1·5 (9)	1·5 (16)	1·5 (8)	1·7 (16)	2·5 (1)	..
3·9— 4·7	1·4 (1)	0·7 (16)	0·9 (20)	1·6 (7)	2·1 (8)	2·3 (8)	2·5 (12)	2·4 (7)	1·3 (2)	0·8 (98)	1·0 (66)	1·4 (10)	2·0 (11)	1·9 (9)	1·8 (19)	3·2 (4)	..
4·8— 5·6	..	0·9 (18)	1·0 (15)	1·2 (4)	2·2 (4)	2·9 (6)	3·0 (13)	2·7 (5)	2·0 (1)	0·9 (96)	1·0 (44)	1·9 (10)	2·1 (15)	2·4 (10)	2·4 (9)	2·7 (2)	4·3 (1)
5·7— 6·5	..	0·6 (24)	1·0 (28)	2·1 (11)	2·8 (3)	3·0 (3)	3·0 (2)	3·8 (5)	..	0·9 (73)	1·2 (17)	2·0 (9)	2·0 (2)	2·7 (2)	3·5 (5)	2·1 (2)	3·1 (1)
6·6— 7·4	0·1 (2)	0·9 (29)	1·0 (21)	1·5 (10)	2·0 (7)	3·6 (1)	5·2 (3)	3·5 (8)	3·6 (1)	1·0 (53)	1·3 (19)	2·6 (3)	3·5 (4)	3·6 (1)	5·1 (1)	..	..
7·5— 8·3	1·3 (2)	0·9 (17)	1·3 (14)	1·9 (13)	2·0 (3)	3·0 (2)	3·4 (4)	4·0 (4)	2·7 (1)	1·1 (22)	0·9 (12)	..	..	..	..	..	..
8·4— 9·2	..	0·5 (16)	1·4 (10)	1·9 (12)	2·4 (2)	3·6 (2)	4·5 (1)	..	5·4 (2)	1·1 (29)	1·3 (10)	..	..	..	..	..	..
9·3—10·1	0·9 (1)	0·7 (16)	1·4 (8)	1·9 (10)	..	..	3·1 (1)	4·3 (2)	..	1·3 (8)	0·8 (3)	..	..	..	..	..	..
10·2—10·9	..	1·0 (9)	1·6 (4)	2·9 (1)	..	2·5 (1)	..	3·8 (1)	..	1·7 (3)	1·3 (3)	1·1 (1)	..	..	..	..	..
11·0—11·8	..	0·2 (2)	1·3 (3)	2·7 (1)	3·3 (2)	3·3 (1)	..	..	..	2·3 (3)	..	..	..	..	..	..	..
11·9—12·7	..	1·0 (6)	2·9 (5)	2·0 (1)	..	..	..	..	..	0·9 (1)	..	.	..	..	..	..	..
12·8—17·2	..	1·6 (11)	1·8 (4)	2·6 (3)	..	..	..	..	..	..	4·0 (1)	..	..	..	..	..	..

The variation of wind with height in the surface layers of the atmosphere has been discussed by Geiger (18) who obtained an expression, relating wind velocity and height, of the form

$$\log \frac{v_1}{v_2} = a \log \frac{z_1}{z_2}$$

where v_1 and v_2 denote the wind velocity at the heights z_1 and z_2 above the surface respectively. According to Geiger the value of a was not constant but exhibited an apparent increase with length of the period of observation. Sutton (19) has commented on this remark and his calculations of a, from the hourly values of the wind velocity at 13m. and 93m. at Leafield given by Heywood (15), exhibit a marked diurnal and seasonal variation. The assumption that these variations are associated with variations in the lapse rate over the layer of air concerned seems to be confirmed by results obtained by Ali (20) from a consideration of the wind structure and lapse rate over India. Theoretical considerations suggest that a is closely related to μ, the coefficient of eddy viscosity of the atmosphere, which is supposed to be a function of the lapse rate of temperature and the vertical gradient of wind velocity (21), and it is interesting to note that Ali obtains an empirical expression which is a linear equation connecting a and μ. This immediately suggests the possibility of relating a to the lapse rate of temperature and the vertical gradient of wind velocity, and the results given in Table XXV have been used to determine an expression connecting these three factors. Values of $\log_{10}v_{62 \cdot 6}$ were plotted against $\log_{10}v_{15 \cdot 2}$ for specified lapse rates and the resulting graphs were found to be approximate straight lines which can be represented by the family

$$\log_{10} v_{62\cdot 6} = r \log_{10} v_{15\cdot 2} + s$$

where r and s depend on the lapse rate. The values of r and s, Table XXVI, obtained from the graphs show that s approaches a limiting value of about 0·40m./sec. for lapse rates less than −4°C./100m. in winter and of about 0·45m./sec. for lapse rates greater than 7 or 8°C./100m. in summer. For lapse rates greater than about 3°C./100m. the value of s also appears to approach a limiting value while in the region 1°C./100m. to −1°C./100m. the change is approximately linear. The physical interpretation of this result is that for given values of the lapse rate of temperature and of the wind velocity at the lower level there is a corresponding finite value of the wind velocity at the higher level. Thus in the case where the wind velocity at 15·2m. is zero the velocity at 62·6m. will be equal to s and this only approaches zero for large super adiabatic values of the lapse rate. The value of r seems to approach unity for lapse rates greater than 2°C./100m. but between 1°C./100m. and −4°C./100m. it decreases uniformly in value. For large values of the inversion there is very little data available but it seems possible that in this case also r approaches a limiting value of the order 0·55.

TABLE XXVI—THE VALUES OF r AND s IN THE EXPRESSION
$\mathrm{LOG}_{10} v_{62\cdot 6} = r\, \mathrm{LOG}_{10} v_{15\cdot 2} + s$
FOR DIFFERENT VALUES OF THE LAPSE RATE

Lapse rate °C./100m.	Winter		Summer	
	r	s	r	s
		m./sec.		m./sec.
2	0·946	0·084	0·968	0·101
1	0·941	0·121	0·930	0·145
0	0·880	0·225	0·886	0·240
−1	0·820	0·300	0·848	0·310
−2	0·810	0·365	0·820	0·355
−4	0·730	0·435	0·748	0·393
−8	(0·700)	(0·470)	(0·478)	(0·557)

(*d*) *Lapse Rate and Gustiness in the Wind.*—One of the factors which determines the gustiness of the wind at any height will be the lapse rate below that height, and in order to consider the relation between the gustiness of the wind and the lapse rate of temperature the frequencies of specified lapse rates for certain intervals of the gustiness factor have been abstracted for the month of January, 1932 (Table XXVII). The charts of the anemometer at 15·2m. were used to obtain the gustiness factor which has been defined as the ratio of the mean width of the velocity trace to the mean velocity. Owing to the open exposure of the anemometer at Ismailia the gustiness factors are all small and only a few exceed 0·2. The figures in Table

TABLE XXVII—FREQUENCY OF OCCURRENCE OF DIFFERENT LAPSE RATES
FOR VARIOUS GUSTINESS FACTORS, JANUARY, 1932

Lapse rate between 1·1m. and 16·2m. in °C./100m.	Lapses						Inversions													
	11	9	7	5	3	1	−1	−3	−5	−7	−9	−11	−13	−15	−17	−19	−21	−23	−25	−26
Number of hourly readings — Gustiness factor <0·05	..	..	..	5	13	15	17	20	16	18	24	18	19	17	18	15	18	6	13	8
0·05—0·10	..	1	7	23	25	28	44	27	28	15	6	4	2	1	1	..	1	..	..	..
0·11—0·15	2	11	22	24	27	15	32	25	9	1	..	..	..	..	..	..	1	..	..	..
0·16—0·20	2	8	14	12	3	7	9	3	..	..	..	2	..	..	..	..	..	..	..	..
>0·20	..	1	2	2	..	1	3	4	1	..	..	..	..	..	..	..	..	..	..	..

XXVII show that small values of the gustiness factor at 15·2m., <0·05, are associated with lapse rates less than 6°C./100m., and as the gustiness factor increases up to 0·20 the upper limit of the lapse rate also increases, although the range of lapse rate over which such a gustiness factor is recorded decreases. At the lowest range of gustiness factor the range of lapse rate is 5°C./100m. to −26°C./100m., for gustiness factors from 0·05 to 0·10 the range is only 9°C./100m. to −17°C./100m. and for factors from 0·11 to 0·15 the range is 11°C./100m. to −7°C./100m. There are isolated values outside these ranges on the inversion side but they are of little importance in the present instance since an examination of the anemometer traces indicates that they are associated with occasions of internal frictional eddies.

The above analysis also provided data for a consideration of the relation between gustiness, lapse rate and mean wind velocity, and it was found that the gustiness factor increased with increasing wind velocity at the same rate for lapse rates varying from −7°C./100m. to 10°C./100m. The curve of mean lapse rate as a function of the gustiness factor and the mean wind velocity is given in Fig. 27 together with the points on individual curves. For smaller values of the lapse rate, except for the lowest gustiness factor, observations are insufficient to determine the curves, but the readings suggest that for large inversions the wind velocity at which a certain value of the gustiness factor occurs will be considerably less than under super-adiabatic conditions.

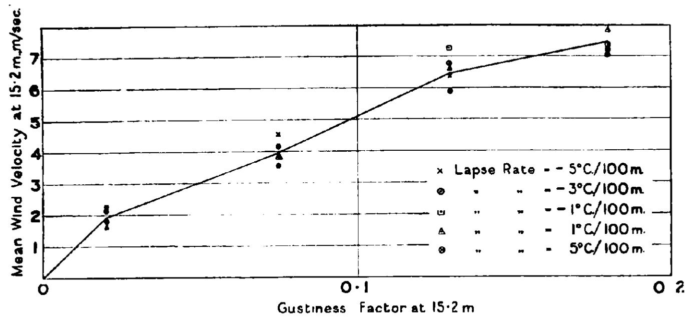


FIG. 27.—MEAN WIND VELOCITY AT 15·2m. FOR LAPSE RATES BETWEEN −6°C./100m. AND 11°C./100m. FOR FIXED FACTORS OF WIND GUSTINESS

(*e*) *Criterion of turbulence*.—The relation between gustiness, vertical gradient of wind velocity and lapse rate has been treated theoretically by Richardson (22) who derives a criterion from which to determine whether turbulence will increase or decrease. He considers the conditions which lead to the development or decay of eddies in the atmosphere when the temperature distribution in the vertical is known, and obtains as a criterion for the increase or decrease of eddying the inequality

$$\left(\frac{\partial v}{\partial z}\right)^2 > \text{ or } < \frac{g}{c_p} \cdot \frac{\partial \Phi}{\partial z}$$

where v is velocity, z is height, c_p is the specific heat of dry air at constant pressure and Φ is entropy. But the relation between entropy and temperature is given by the expression

$$\partial \Phi = c_p . \frac{\partial T}{T} - R . \frac{\partial p}{p} = c_p . \frac{\partial T}{T} + g . \frac{\partial z}{T} \qquad \text{since } \partial p = -g\rho\partial z, \quad p = \rho R T$$

where p is pressure, ρ is the density of the air, T is the absolute temperature and R is the gas constant. The inequality may therefore be written in the form

$$\left(\frac{\partial v}{\partial z}\right)^2 > \text{ or } < \frac{g}{T} \left\{\frac{\partial T}{\partial z} + \frac{g}{c_p}\right\}$$

Now since c_p is in dynamical units, g/c_p is the dry adiabatic lapse rate so that $\left(\frac{\partial T}{\partial z} + \frac{g}{c_p}\right)$ is the difference between the lapse rate and the dry adiabatic Γ and may be written $\left(\frac{\partial T}{\partial z} + \Gamma\right)$. The records obtained at Ismailia have been used to test this criterion but in so doing it has been necessary to replace infinitesimals by finite differences, and also to make certain assumptions as regards the vertical gradient of wind velocity. Autographic records of wind direction and velocity were obtained only for a height of 15·2m., so that in considering the inequality given above it has been necessary to assume that, after the development of an inversion and the damping out of external frictional eddies, the wind velocity at 15·2m. is equal to the vertical gradient of wind velocity between the surface and this height. The result will be therefore to use a value of $\partial v/\partial z$ which may occasionally be too high. A further assumption has to be made that the lapse rate between 1·1m. and 16·2m. is equal to that between the surface and 16·2m. so that a value of $\partial T/\partial z$ will be used which may be, and in large inversions undoubtedly always is, too small. The effect on the test of the above expression is that cases when the optimum value for decrease in eddying is just reached will be represented by the values of the two sides of the expression merely approaching one another and not reaching the stage of equality. It has been found that this has no material bearing on the applicability of the criterion.

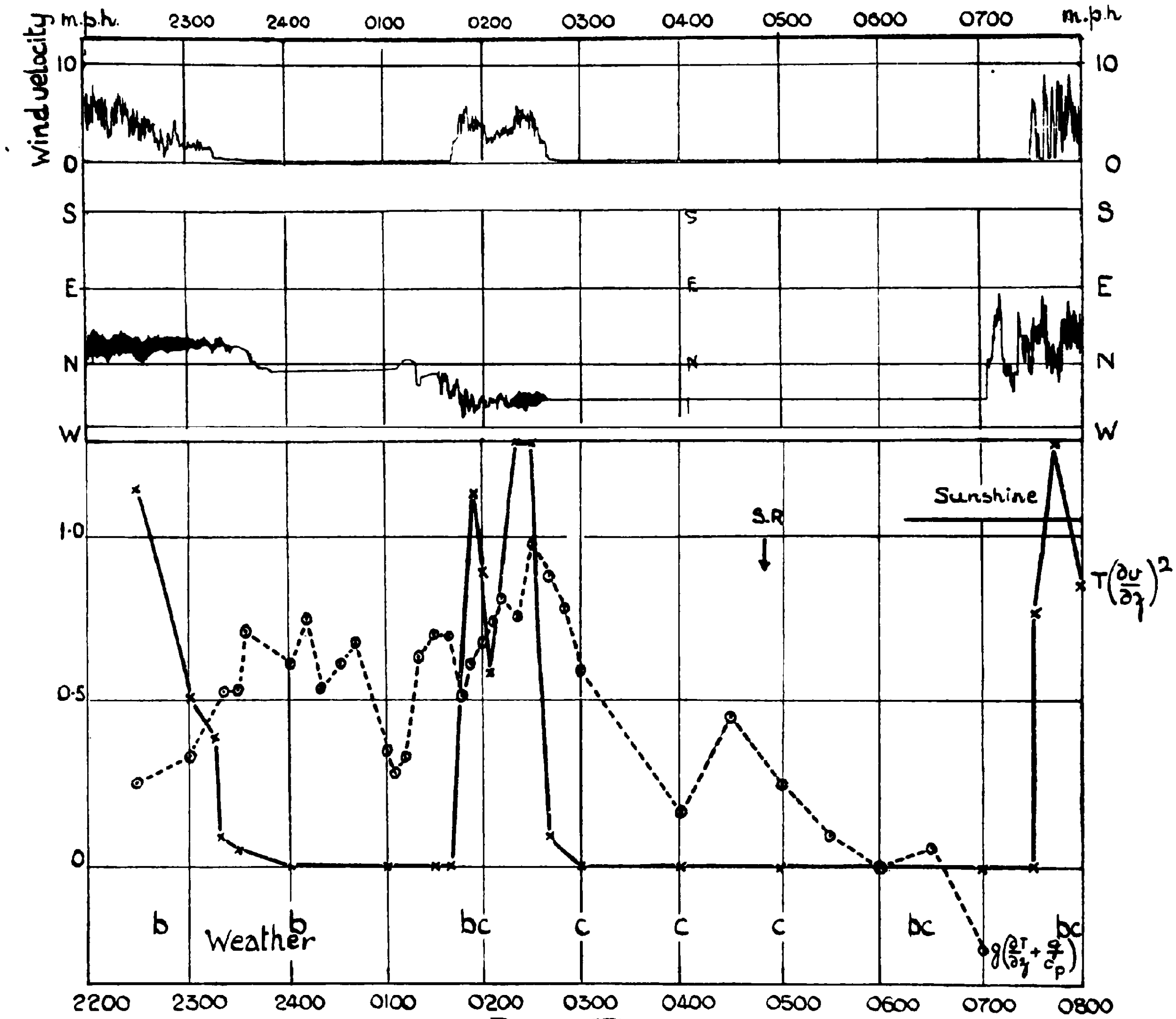


Fig. 28.—Example of internal frictional eddies on June 22, 1932

The values of the two terms $T(\partial v/\partial z)^2$ and $g(\partial T/\partial z+\Gamma)$ were evaluated and from the curves plotted it was found that whenever the values approached closely to one another, or the value of the velocity gradient term became less than that involving lapse rate, eddying decreased but set in again immediately the velocity gradient term became the larger. Some typical curves are given in Figs. 28 to 32.

One of the simplest cases is shown in Fig. 28. By 2200 the nocturnal inversion has so far developed that the lapse rate between 1·1m. and 16·2m. is $-5{\cdot}7$°C./100m., and the wind record at 15·2m. indicates that convectional eddies have died down but that frictional eddies exist. As the inversion increases in intensity these eddies tend to become damped out and by 2310, when $T(\partial v/\partial z)^2$ equals $g(\partial T/\partial z+\Gamma)$, the fluctuations in both the direction and velocity traces are very small and as the lapse rate and the vertical gradient of wind velocity further decrease even these small fluctuations become damped out until at 2400 it is calm up to 16·2m. About 0140 there is a sudden increase in the velocity gradient and eddying sets in and continues, with a slight damping of the oscillations at 0205, until about 0240 when the wind again becomes calm and no further oscillations occur until over two hours after sunrise when convectional eddies have developed. Considering the curves for $T(\partial v/\partial z)^2$ and $g(\partial T/\partial z+\Gamma)$ it will be observed that from 2310 to 0145 the condition is such that according to Richardson (22) eddying will decrease. This condition is also satisfied between 0203 and 0209 and between 0232 and 0636 and here again, to judge from the anemograph traces, eddying is either being damped out or the wind has become calm. The occurrence of eddies between 0140 and 0240 can be considered as due to the production of internal frictional eddies, the existence of which was recognised by Durst (23) when considering the anemograms for Cardington. The curves indicate that at 2310, 0140, 0203, 0209 and 0232 the energy supplied to the production of eddies was just sufficient to replace the energy converted from kinetic into potential by the stirring of the stable atmosphere. It is of interest to note that the production of internal frictional eddies coincided with the development of low cloud and that the production of these eddies ceased as soon as the sky became totally or almost totally covered with cloud (stratocumulus).

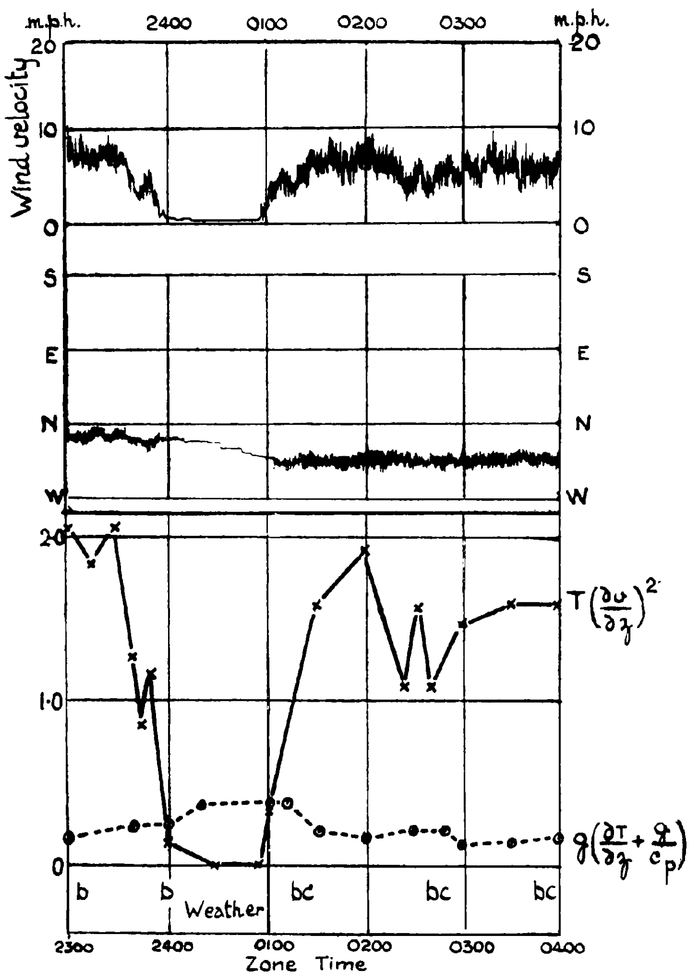


FIG. 29.—EXAMPLE OF INTERNAL FRICTIONAL EDDIES ON JUNE 20, 1932

In the next example, Fig. 29, the external frictional eddies have been damped out by 2400 but about 0100 there is a rapid increase in the vertical gradient of wind velocity, internal frictional eddies are produced and there is an increase in the lapse rate. The onset of internal frictional eddies in this case also coincides with the development of low cloud, but the amount of cloud is less than in the previous case, the sky at no time being more than half-covered, and the internal eddying persists until it is replaced by convectional eddies about 0730.

The example in Fig. 30 has been selected as being a case in between the two already described. A period of damped eddies occurs from 2200 to 2300 followed by the production of internal frictional eddies between 2300 and 0320; during this period low cloud is in course of formation and these eddies are damped out when the sky becomes obscured by low cloud. Eddying recommences earlier on this occasion, about 0520, and this is probably due to the wind not being calm with the result that as the lapse rate increases after sunrise a point is reached, while there is still an inversion, when the condition for increase of eddying is satisfied.

Figs. 31 and 32 are representative of two occasions when the wind was light throughout the night and only decreased to calm for a short period in the early morning of the first example. In both cases there are periods of damped eddies, and therefore of streamline flow, followed by periods of violent eddying and in the majority of cases the times when eddies are being damped out coincide with those when the value of $g(\partial T/\partial z+\Gamma)$ is greater than $T(\partial v/\partial z)^2$.

Durst (23) has endeavoured to show that the onset of internal frictional eddies is associated with the breakdown of a steep vertical gradient of wind velocity and

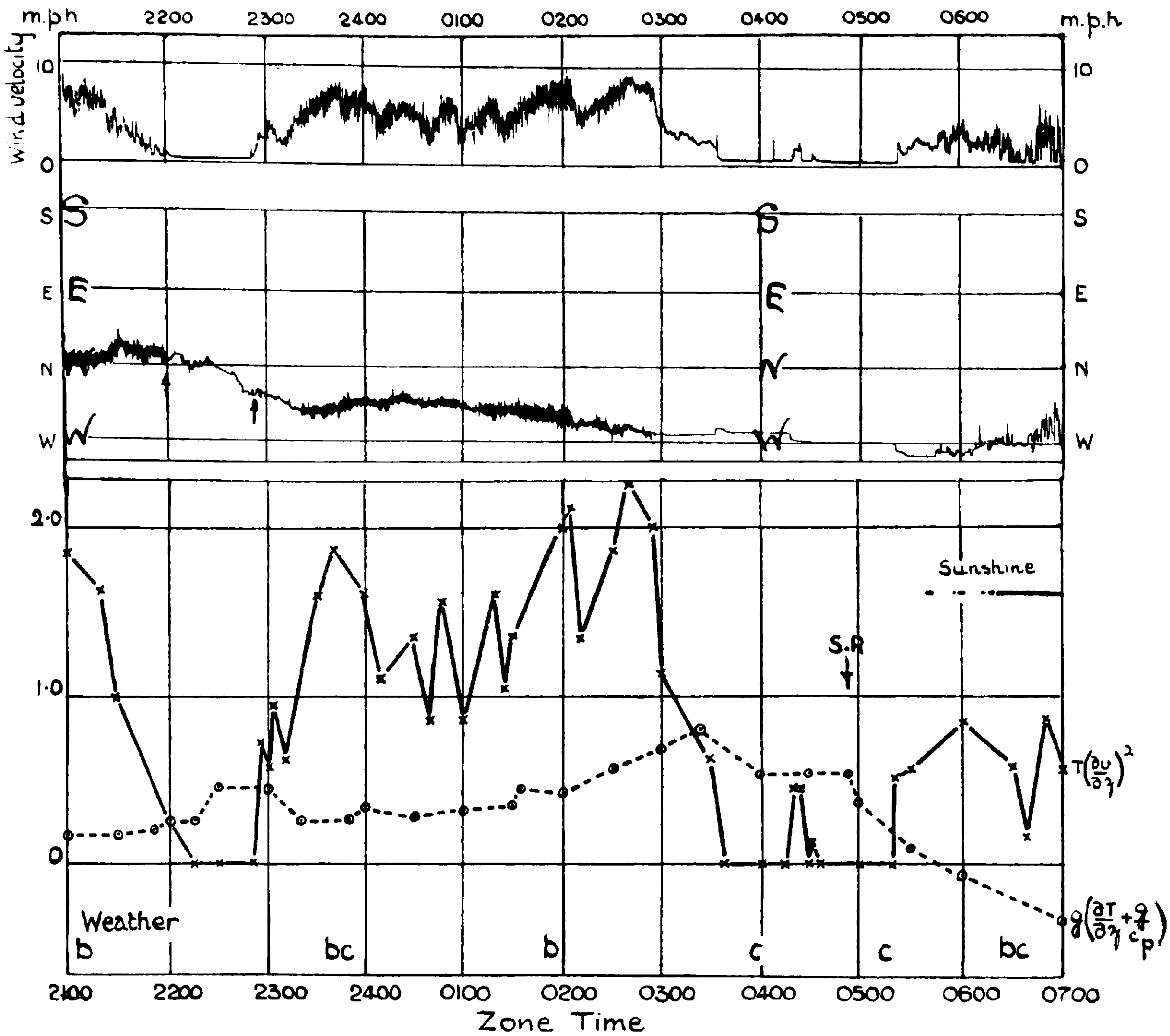


FIG. 30.—EXAMPLE OF INTERNAL FRICTIONAL EDDIES ON JUNE 30–JULY 1, 1932

that this eddying makes the lapse rate approach the adiabatic value. A consideration of the diagrams (Figs. 28 to 32) does not completely support this contention. It will be observed that on occasions eddying commences after a period of calm (Figs. 28 to 30), and therefore of zero vertical gradient of wind velocity, so that the vertical gradient of wind velocity in such cases must have increased with the onset of eddying unless a rapid increase of velocity gradient occurs just before the eddying starts. As far as temperature is concerned it appears that eddying may be associated with minor and only temporary increases in the lapse rate, and that the larger changes occur when there is either a change in wind direction (Figs. 31 and 32) or about sunrise.

It may be stated briefly in conclusion that once the noctural inversion has damped out the convectional eddies the existence of either streamline flow or turbulent motion will be determined by Richardson's criterion. When eddying sets in about the time of sunrise the relation does not appear to include all the factors operating and eddying will persist to eventually merge into the convectional eddies of the daylight hours. The result of the test of the criterion for the increase or decrease of eddying in the atmosphere is therefore most satisfactory and shows, further, that when there is a large inversion near the ground the air actually in contact with the surface is almost at rest. On certain occasions the energy required to move the air will be so great that this stagnation of the air will not be restricted to the layer of air immediately in contact with the ground but may extend up to at least 16·2m.

It is interesting to note that the Richardson criterion has been deduced by other writers in a slightly different form with a numerical factor on the right hand side.

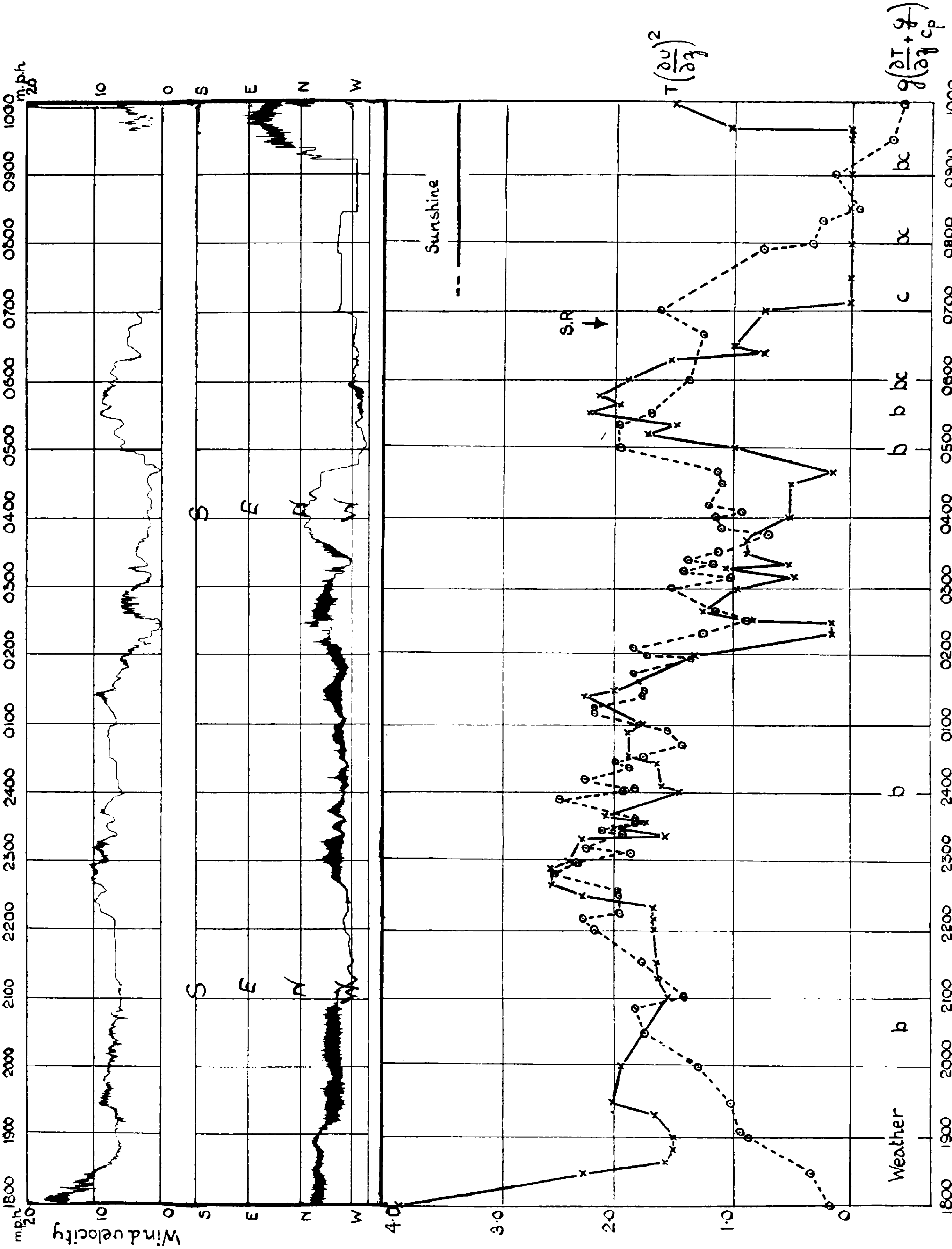


FIG. 31.—EXAMPLE OF INTERNAL FRICTIONAL EDDIES ON JANUARY 5-6, 1932

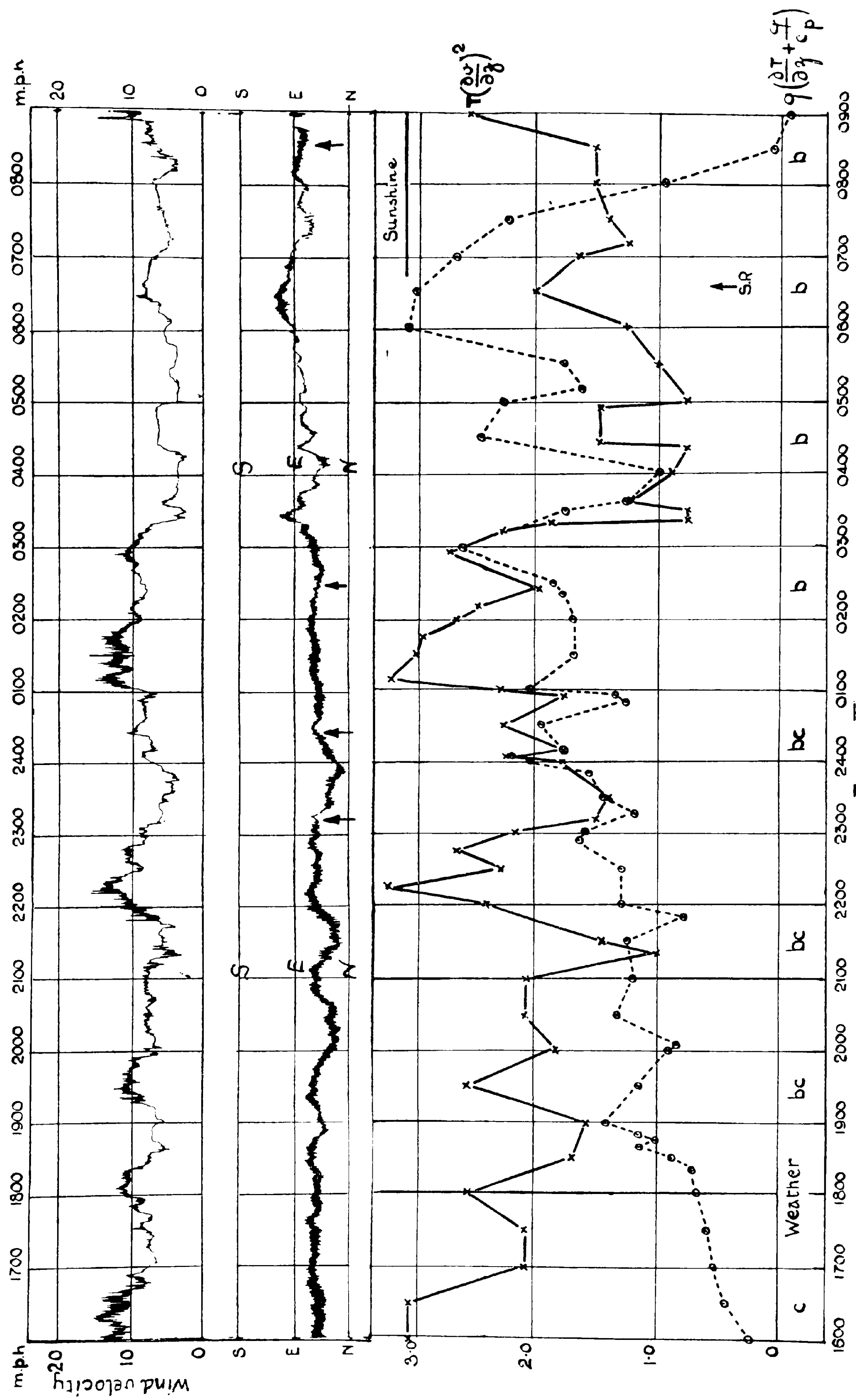


FIG. 32. EXAMPLE OF INTERNAL FRICTIONAL EDDIES ON DECEMBER 9–10, 1931

Prandtl (24), from a consideration of the effect of a stratification of density in tending to prevent turbulence, arrives at a criterion with a numerical factor of 0·5 while Taylor (25) and Goldstein (26), from considerations of the stability of superposed streams of fluids of different densities, obtain a factor of 0·25. The present comparison of the criterion with the observational data for Ismalia appears to confirm Richardson's form of the criterion with factor unity.

§ 21—DISCUSSION OF SOME CHARACTERISTIC CHARTS AND THE ASSOCIATED ANEMOGRAPH RECORDS

(*a*) *General Remarks*.—The purpose of this discussion is to draw attention to characteristic or noteworthy features of the records under various meteorological conditions. The anemograph records, with which the temperature difference traces are compared, are those from the Dines pressure tube anemometer situated at a distance of 755 metres and bearing 127° east of north from the temperature recording installation. The anemometer head is at a height of 15·2m. above the ground. In order that the records of temperature difference can be discussed in terms of lapse rate, conversion scales for each trace have been included on each chart. When considering the differential traces due account must be taken of the zero corrections which it is necessary to apply to the readings.

(*b*) *Chart of June* 25–26, 1932 (Fig. 33).—The traces recorded on this chart are good examples of those obtained during summer under a cloudless sky and a marked diurnal variation of wind velocity. The velocity gradually increased from calm at 0900 to 9m./sec. by 1530 and after 1730 again decreased to calm by 2230. Wind direction was northerly—the direction recorded in this region with very little variation throughout the summer months. The structure of the traces represented in this example is characteristic of the majority. of records. The differential traces are noteworthy for their unsteadiness during both day and night, while the period of rapid fluctuation in the case of the air temperature at 1·1m. is confined to a period of about four hours centred at local noon. Thus the trace consists of a narrow band, the width of which varies with the lapse rate and wind velocity. The rapid fluctuations in air temperature denoted by the unsteadiness of the traces have a maximum value near the ground and the trace for the upper height interval (trace III) exhibits a considerably smaller variation than that for trace I. During the day trace I consists of a band some 1·5°F. (0·8°C.) wide, trace II a band some 0·8°F. (0·4°C.) wide and trace III a band less than 0·5°F. (0·3°C.) wide. At night the fluctuations from dot to dot are smaller and are replaced by irregular variations occurring over a short period. In the case of trace I the time interval involved is of the order of half an hour, for trace II about one hour and for trace III from two to three hours. Between the unsteady trace recorded by day and that recorded at night the trace is very steady (1830–2030) and the rate of change of the lapse rate recorded by both traces II and III is fairly constant.

The mean lapse rate between 1·1m. and 16·2m. (trace I) increased from 8·5°C./100m. at 1000 to a maximum value of 14·1°C./100m. at 1430 and then slowly decreased to 11·2°C./100m. at 1600. After 1600 the lapse rate rapidly decreased and was reduced to zero by 1900. The development of the inversion was slow between 1900 (−1·8°C./100m.) and 2200 (−5·7°C./100m.) and this was associated with a decrease of wind velocity from 5m./sec. to 2·5m./sec., but after the wind had become calm the growth of the inversion was rapid and its maximum value (−22·1°C./100m.) was recorded at 0300. Traces II and III exhibited similar changes in the value of the lapse rate although the magnitude of these variations was much smaller. The mean lapse rate during the period 1000 to 1700 recorded by trace II varied from 1·8°C./100m. to 2·2°C./100m. and by trace III from 0·8°C./100m. to 1·3°C./100m. while both traces became zero about 2100. The maximum values of the inversion were respectively equivalent to a lapse rate of −10·5°C./100m. and −8·7°C./100m. and occurred at 0530 and 0700, indicating that, although the lapse rate near the ground (1·1m. to 16·2m.) increased after 0300, it continued to decrease between 16·2m. and 46·4m. until 0530 and between 46·4m. and 61·0m. until 0700.

The rapidity with which the inversion is destroyed in the early morning is noteworthy although the present example is not an outstanding case. The time of

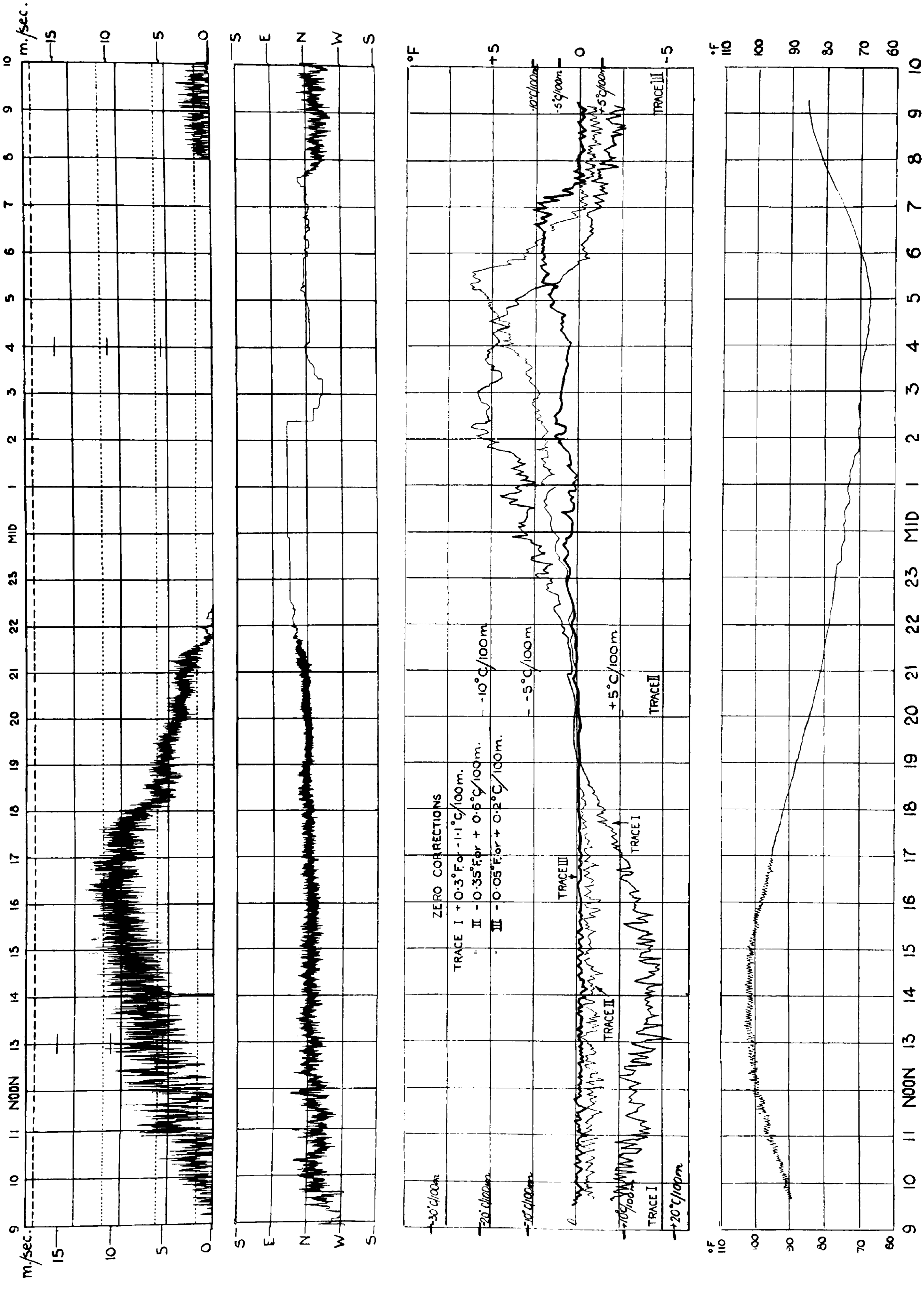


FIG. 33.—TEMPERATURE RECORDER CHART AND ANEMOGRAM FOR JUNE 25–26, 1932

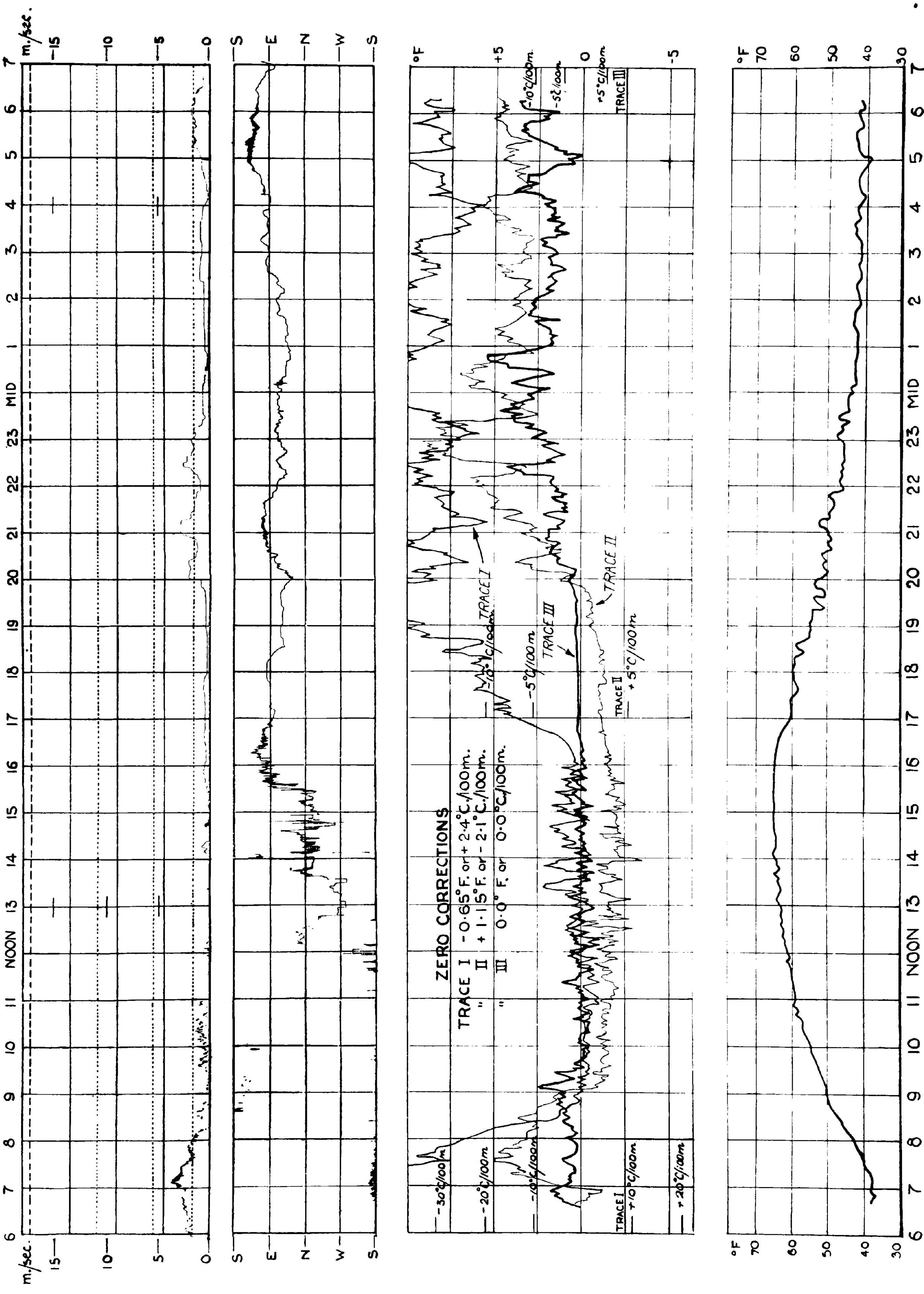


FIG. 34.—TEMPERATURE RECORDER CHART AND ANEMOGRAM FOR DECEMBER 31, 1931–JANUARY 1 1932

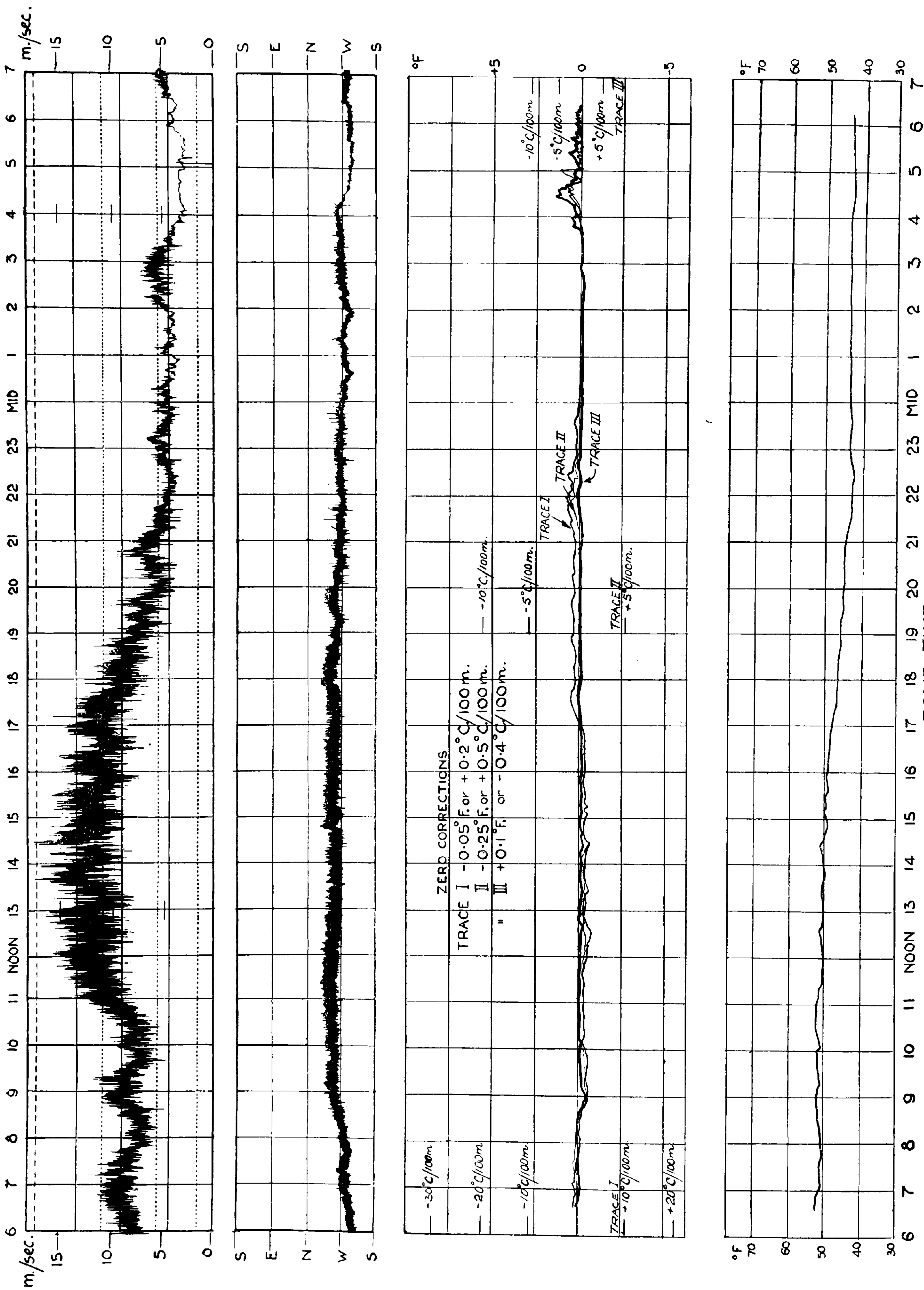


FIG. 35.—TEMPERATURE RECORDER CHART AND ANEMOGRAM FOR FEBRUARY 7–8, 1932

minimum temperature of the air at 1·1m. and the commencement of the rapid increase in lapse rate between 1·1m. and 16·2m. coincided with the time of sunrise (0451), and the inversion up to 16·2m. was annihilated in approximately one hour. Isothermal conditions did not occur until one hour later (0650) between 16·2m. and 46·4m. or until two hours later (0730) between 46·4m. and 61·0m.

(*c*) *Chart of December* 31, 1931—*January* 1, 1932 (Fig. 34).—This record is a typical example of the type of trace obtained with a clear sky and little wind during winter. The traces are noteworthy because they indicate that under such conditions a large negative lapse rate exists throughout most of the period. The wind was variable, mainly from some point between NE. and SE., and did not exceed 1·8m./sec. except for three short periods between 2000 and 2300. A study of the differential traces shows that for the height interval 1·1m. to 16·2m. (trace I) an inversion was recorded for seventeen hours, during fourteen of which the inversion was greater than 20°C./100m. Trace II recorded an inversion for fifteen hours with the inversion greater than 10°C./100m. for six hours, and trace III for eighteen hours with the inversion greater than 5°C./100m. for four hours. The rapid increase in the lapse rate between 1·1m. and 16·2m. after sunrise, and the sharp decrease about sunset, is very marked. The changes are less marked between 16·2m. and 46·4m. and even less so between 46·4m. and 61·0m., and in the latter case the fact that the decrease in lapse rate occurs as late as 0900 is to be noted. This is an outstanding characteristic under conditions of clear sky and light wind and indicates the heating of the air at 61·0m. by some means other than by the transfer of heat from below.

(*d*) *Chart of February* 7–8, 1932 (Fig. 35).—This chart has been selected as example of the types of trace obtained on the rare occasions that the sky is either cloudy or overcast throughout the period and the wind is moderate to strong. The conspicuous feature of all the traces is the small diurnal variation. The increase in the value of the inversion from 2100 to 2300 and from 0400 to 0500 was associated with a partial (bc) clearance of the sky. The wind was westerly over the whole period and the velocity fairly steady at 8m./sec. from 0600 to 1000, 12m./sec. from 1100 to 1700 and decreased to about 4·5m./sec. after 2200. What rainfall there was during the period occurred before 1200.

Under these conditions the temperature difference recorded during the day by trace I was equal to approximately 2°C./100m., that recorded by trace II, 1·5°C./100m. and that recorded by trace III, slightly less than 1·5°C./100m. The lapse rate decreased during the night, but remained positive except when the amount of cloud decreased. The effect of the decrease in cloud amount was most marked in the case of trace I which recorded small inversions, less than a lapse rate of −1·5°C./100m., from 1800 to 2300 and from 0500 to 0600 and also isothermal conditions at 0400. Trace II recorded an inversion at only one hour, 2200, and isothermal conditions from 0500 to 0600, while for trace III the lapse rate was negative at 2200 and also from 0400 to 0600.

(*e*) *Chart of June* 18–19, 1932 (Fig. 36).—This chart has been selected primarily as an example of the lapse rate associated with an outstanding example of the " seabreeze " effect. The occurrence of a moderate to fresh breeze in the late afternoon and early evening at Ismailia is a regular feature of the summer months and the effect has been considered to be analogous to a sea breeze.

The sea breeze arrived at 1600 but before this the wind was easterly and exhibited rapid fluctuations of both velocity and direction. The range of velocity in the easterly current was from zero in some of the lulls to 8·5m./sec. for a few gusts. During this period the differential traces and the air temperature trace also exhibited large and rapid fluctuations, especially traces I and II, although the mean lapse rate was below the mean value for the month. The arrival of the sea breeze was marked by the backing of the wind to NNE. and a sudden increase in velocity to about 11m./sec. while the air temperature at 1·1m. decreased by 4°C. A sharp increase occurred in the lapse rate up to 61·0m. and this was especially noticeable between 1·1m. and 16·2m. where the increase was from 11·6°C./100m. to 18·9°C./100m. Such an increase is to be expected when cool air arrives over warmer land. The wind velocity fell rapidly between 1900 and 2200 but increased to 3·5m./sec. between 2300 and 0630 and to 5·5m./sec. after 0630.

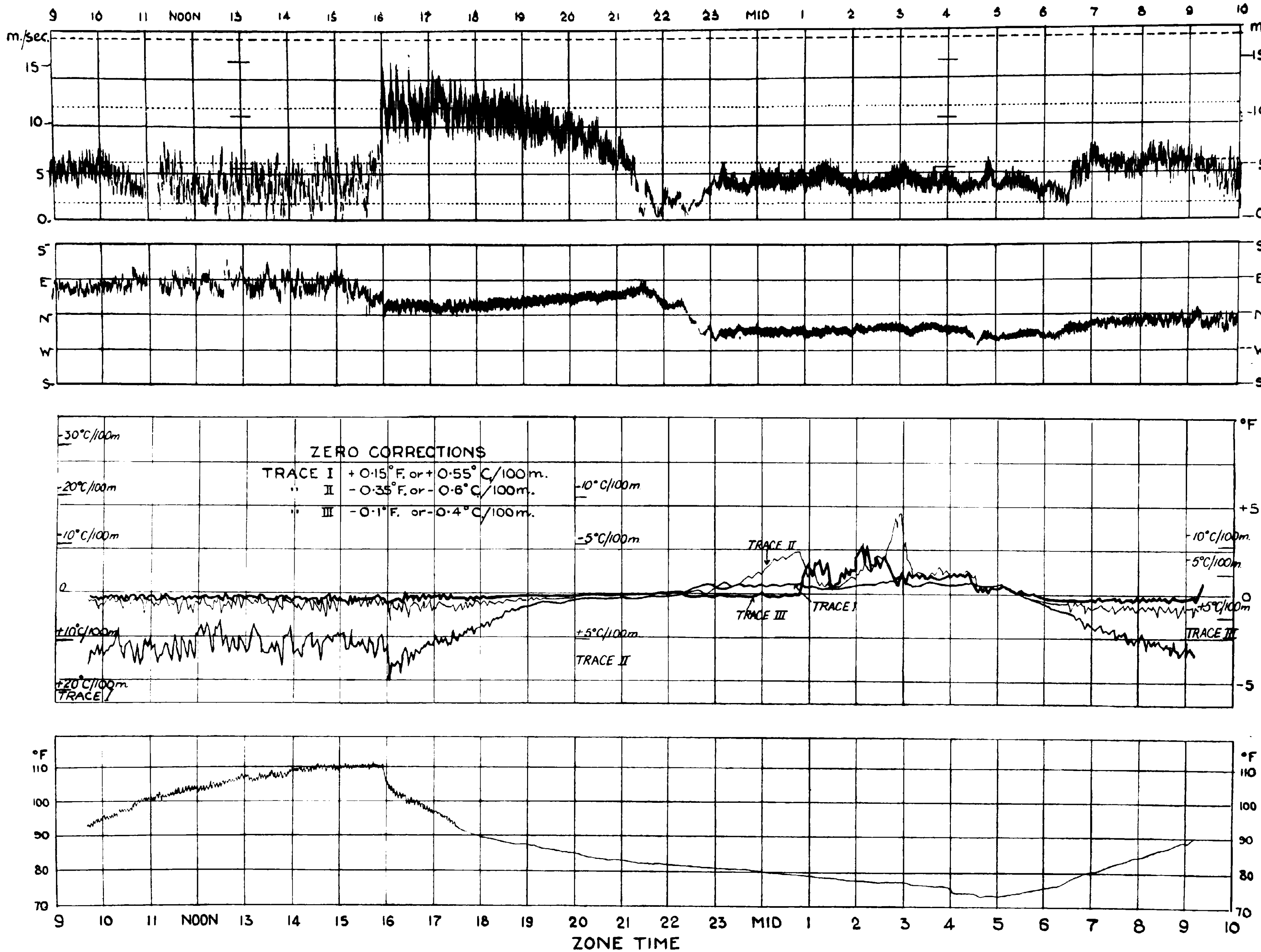


FIG. 36.—Temperature recorder chart and anemogram for June 18–19, 1932

After 1600 the lapse rate decreased and between 1830 and 2230 all the differential traces were very steady; trace I, the record for the lowest height interval, indicated a rapid decrease in lapse rate between 1600 and 1900 and recorded a lapse rate of only 2·2°C./100m. at the latter hour. The rate of decrease in lapse rate was much smaller after 1900 with the result that isothermal conditions did not develop between 1·1m. and 16·2m. until 2100, between 16·2m. and 46·4m. until 2300 and not before 0030 for the upper height interval. During the night the inversion recorded by trace I at no time exceeded a value of —3.3°C./100m., but larger values occurred between 16·2m. and 61·0m. Trace II recorded a lapse rate of —5·2°C./100m. at 0300 and trace III one of —7·2°C./100m. at 0200. Considering the individual traces over this period it will be observed that the lapse rate recorded by trace I was fairly constant from 2240 to 0500 but that trace II recorded a continually increasing inversion from 2300 until 0050, a rapid decrease between 0500 and 0130 followed by a more rapid increase until 0300. At 0300 the inversion decreased by about 6·4°C./100m. in fifteen minutes but was sensibly constant from 0315 to 0430. Trace III exhibits a sudden decrease in the lapse rate, that is an increase in the inversion, at 0050 followed by a period of fairly rapid fluctuations until 0300 when the inversion over this height interval remained constant until 0430. Between 0430 and 0500 the lapse rate commenced to decrease over each height interval.

No observations of wind velocity at 62·6m. are available between 1400 and 0400 but after the latter hour the vertical difference of wind velocity between 15·2m. and 62·6m. increased from 1m./sec. to 2m./sec. at 0600 and became negligible from 0700 to 0900, so that it is probable that the larger values of the inversion recorded by both traces II and III were associated with occasions of small vertical differences of wind velocity between the heights concerned.

(*f*) *Chart of August* 17–18, 1932 (Fig. 37).—In late summer the surface wind at Ismailia does not exhibit so marked a diurnal variation as earlier in the season. A characteristic velocity trace exhibits two minima, one in the early morning between 3 to 4 hours after sunrise and the other about midnight, and two maxima, the principal of which occurs in the late afternoon. The changes in lapse rate associated with such a wind regime are well represented in the selected example. The chief features are the great variability of the differential traces before 1600, the steadiness of the traces from 1700 onwards and the small inversion recorded during the night. The great variability of the differential traces was associated with a period of light and variable winds, and when the wind increased about 1600 and the direction became steady at north the differential and temperature traces became extremely steady. The wind decreased after 1900 to calm by 2340 by which time a small inversion had developed to above 46·4m.; after 2340 the lapse rate over the lowest layers decreased rapidly to —5·3°C./100m. by 0020 but any further decrease was retarded by the onset of a westerly wind of about 3m./sec. after 0100. This westerly current became very stable up to at least 15m. by 0200 and the differential traces became more positive. The re-development of eddying at 0330 was accompanied by an increase in the lapse rate below 16·2m. but there was little change above this height.

(*g*) *Warm Fronts of February* 22 *and* 25, 1932.—Well defined warm fronts passed over Ismailia during the mornings of February 22 and 25, 1932. In each case the warm front was associated with a depression which developed over the interior of Tripoli and moved towards Cyprus. The behaviour of the temperature trace for 1·1m. and of traces I, II, and III are shown in Figs. 38 and 39 together with the associated pressure, wind and relative humidity traces made at the Meteorological Office. On February 22 the warm front passed the temperature recording installation at 0850 and the Meteorological Office at 0855 (Fig. 38). The passage of the front was marked by a sudden increase in temperature and decrease in relative humidity at 1·1m. while the wind at 15·2m. veered and increased sharply. The temperature difference traces indicate that the warm air affected first the element at 61·0m. since trace III records a rapid decrease in the temperature difference at 0840 and by 0846 an inversion existed over the upper height interval. The warm air next affected the element at 46·4m. and as soon as the upper height interval was completely in warm air the temperature difference became negative. Similar changes

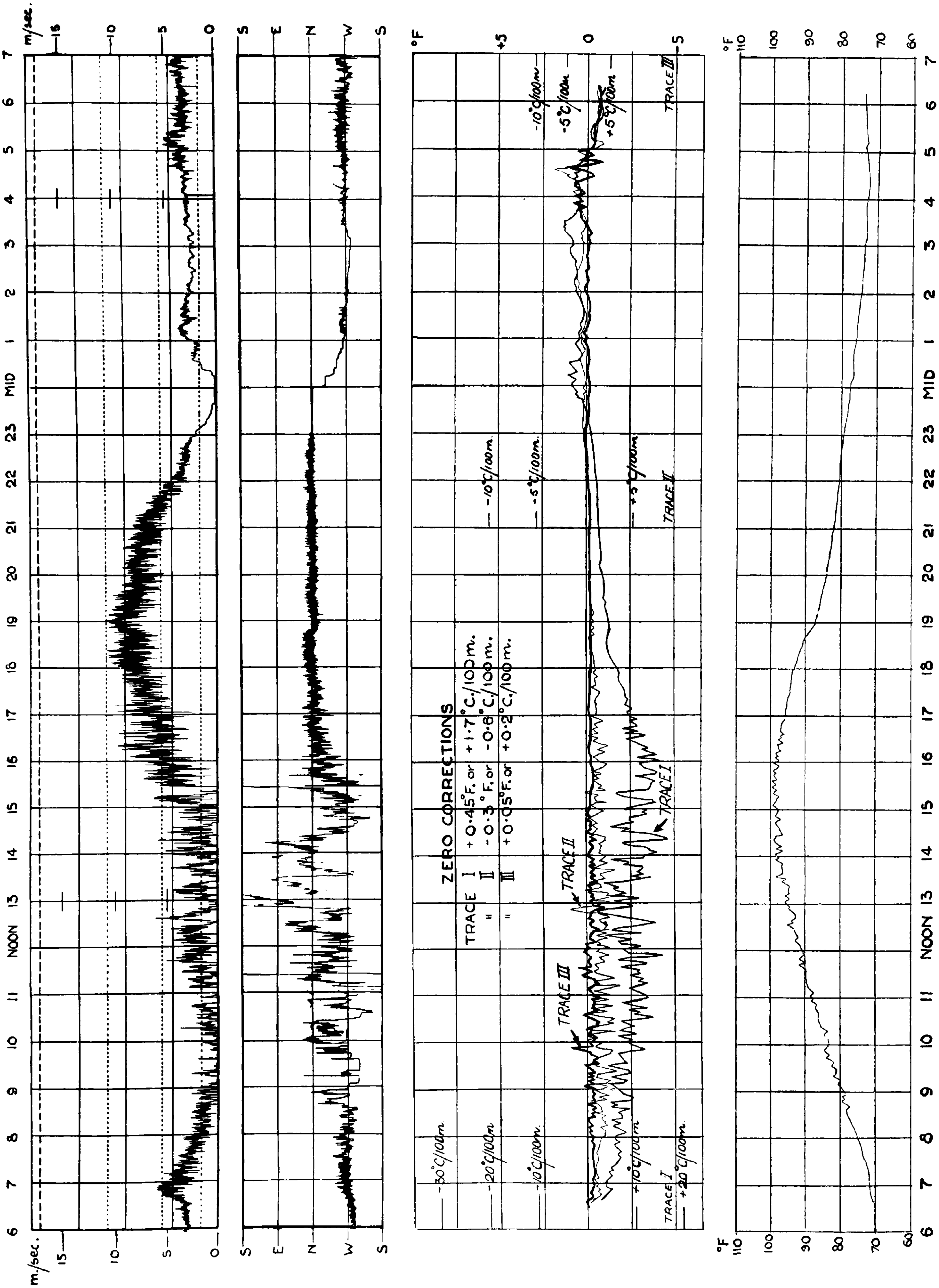


FIG. 37.—TEMPERATURE RECORDER CHART AND ANEMOGRAM FOR AUGUST 17–18, 1932

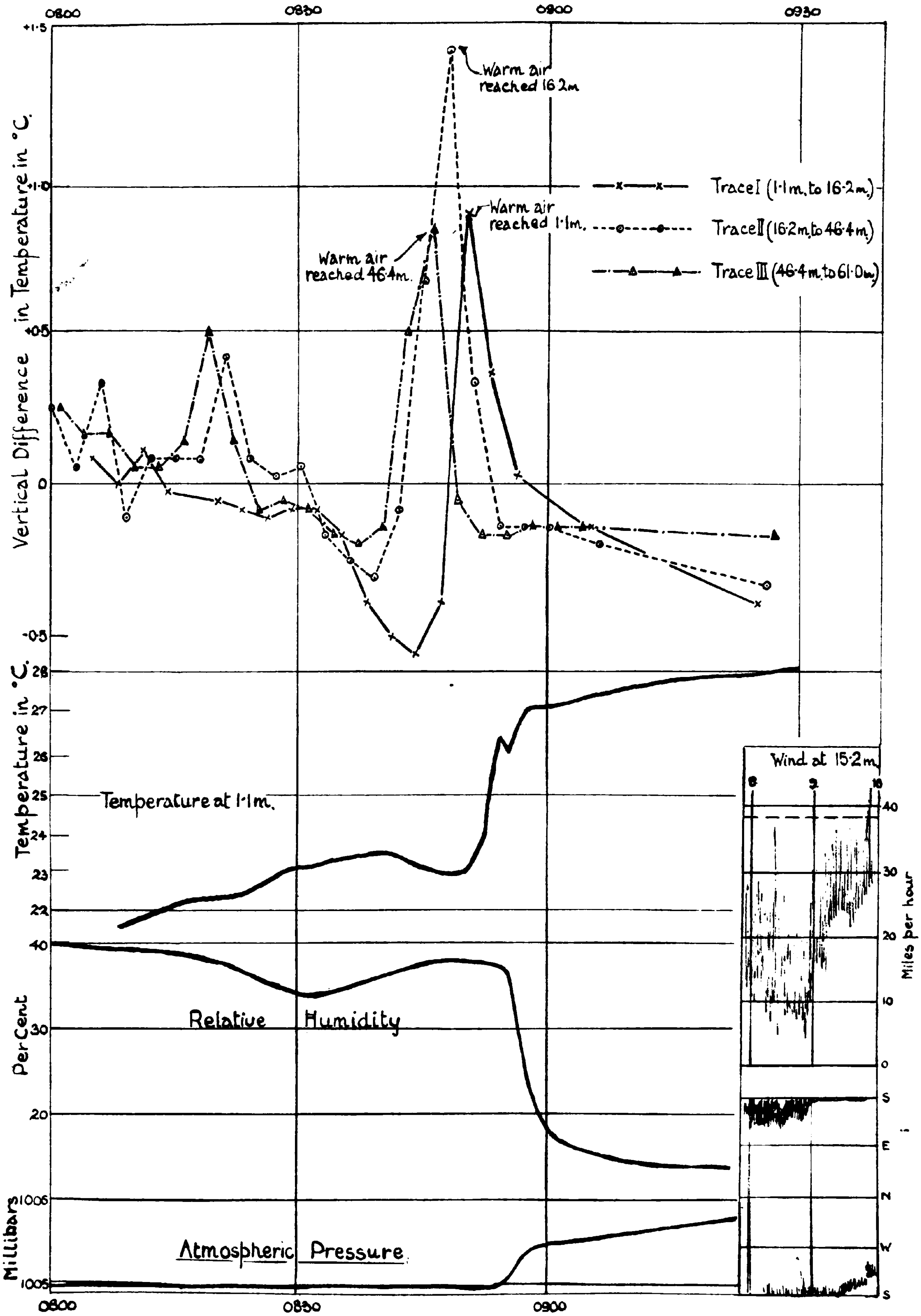


FIG. 38 - BEHAVIOUR OF THE TRACES OF VERTICAL DIFFERENCE IN TEMPERATURE AT THE PASSAGE OF A WARM FRONT, FEBRUARY 22, 1932.

(E600)

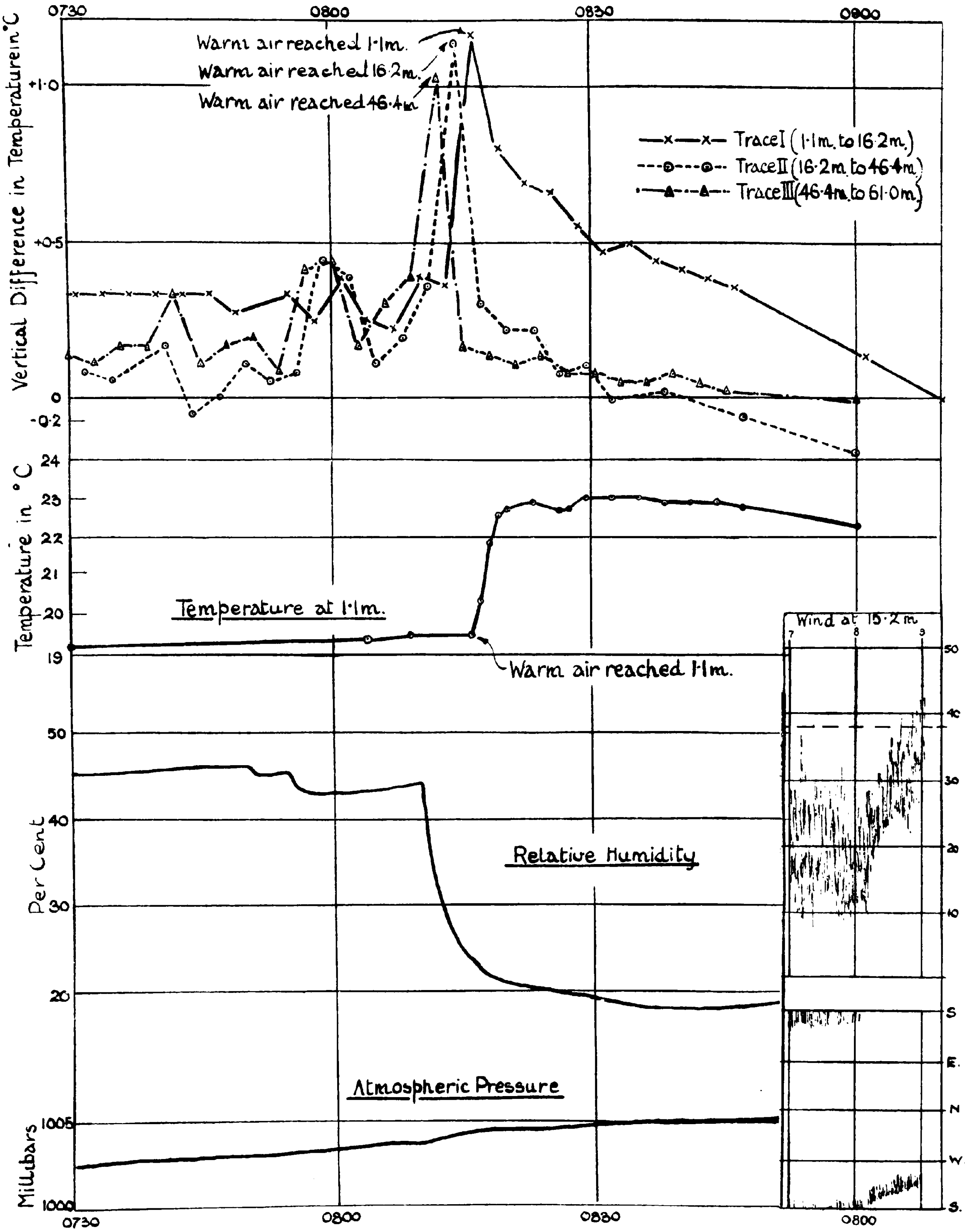


FIG. 39 - BEHAVIOUR OF THE TRACES OF VERTICAL DIFFERENCE IN TEMPERATURE AT THE PASSAGE OF A WARM FRONT, FEBRUARY 25, 1932.

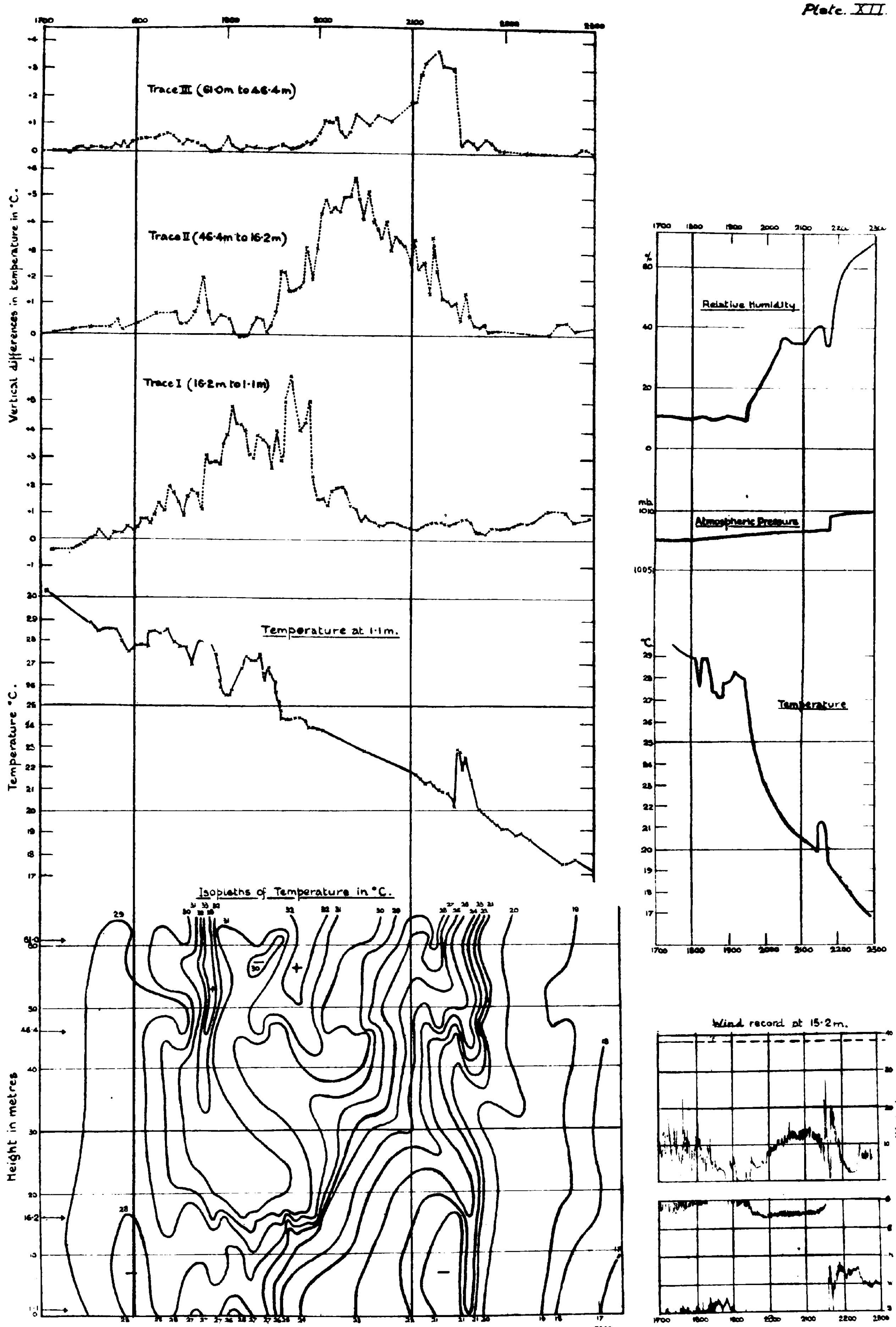


FIG. 40 - CHANGES IN METEOROLOGICAL ELEMENTS AT ISMAILIA ASSOCIATED WITH THE PASSAGE OF A COLD FRONT DURING THE EVENING OF MARCH 21, 1932.

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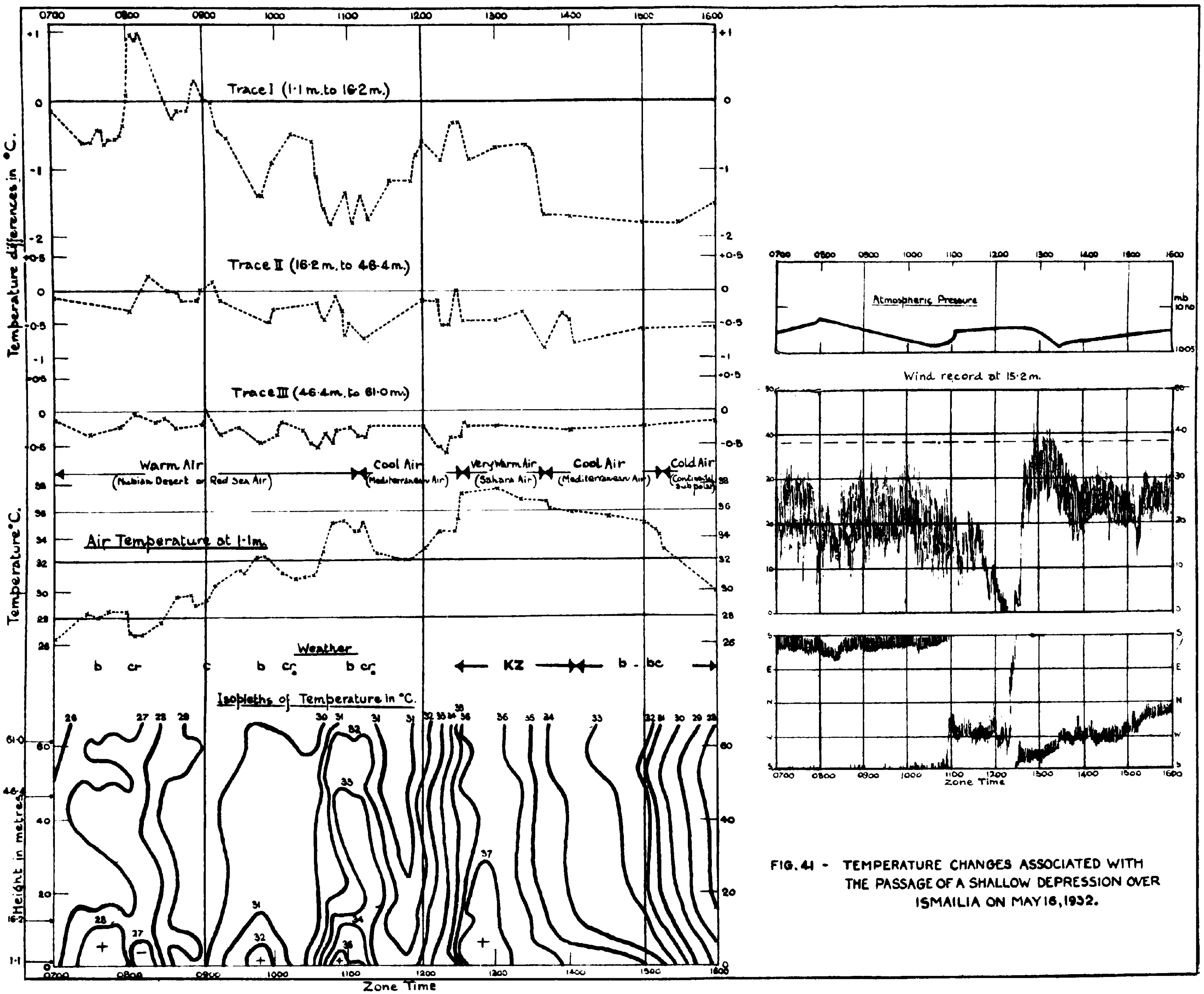

FIG. 41 - TEMPERATURE CHANGES ASSOCIATED WITH THE PASSAGE OF A SHALLOW DEPRESSION OVER ISMAILIA ON MAY 16, 1932.

were recorded by traces II and I in turn and it is seen that the warm air reached a height of 46·4m. at 0846, of 16·2m. at 0848 and of 1·1m. at 0850 so that the warm air was overrunning the cold air. If it is assumed that the velocity of the front in the direction of the wind in the warm air was about two-thirds the surface wind velocity, in this case about 20 m.p.h., the slope of the surface of separation between the warm and cold air towards the north-east between a height of 1·1m. and 46·4m. would have been 1 in 800.

The changes in temperature associated with the warm front on February 25 (Fig. 39) were similar to those described above. The front passed the Meteorological Office about six minutes before it reached the installation at 0816. The warm air first reached the element at 61·0m. at 0809, that at 46·4m. at 0812, that at 16·2m. at 0815 and the one at 1·1m. at 0816. Taking the velocity of the front towards the north-east as 16 m.p.h. the slope of the surface of separation in this direction between 1·1m. and 46·4m. would have been 1 in 670.

Rain did not occur at or before the passage of either front.

(*h*) *Cold Front during the Late Evening of March* 21, 1932.—The temperature changes that occurred at the passage of a cold front, associated with a depression south-east of Crete, during the late evening of March 21 differed considerably from those described elsewhere as associated with the passage of a cold front during the daytime (27). The temperature changes recorded by the three traces I, II and III are reproduced in Fig. 40 together with the record of temperature at a height of 1·1m. while copies of the autographic records of wind velocity and direction, relative humidity and atmospheric pressure at the Meteorological Office are also included. To enable a true conception of the meaning of the variations in the temperature difference traces to be obtained isopleths of temperature for the air layers below 61·0m. have been drawn and these are given below the temperature difference traces in Fig. 40. The temperature difference traces considered in conjunction with the record of temperature at 1·1m. show that the air temperature decreased gradually at all heights until about 1800 when an inversion had developed up to at least 61·0m. Between 1800 and 1840 temperature increased at each of the heights 16·2m., 46·4m. and 61·0m. while the temperature at 1·1m. exhibited fluctuations of about 1°C. although a general decrease was maintained at this height. The temperature increase was most marked above 16·2m. and the temperatures recorded at 46·4m. and 61·0m. indicate that these changes were associated with the descent of warm air from above the inversion. This descending air did not fall much lower than 15m. although there are indications that it affected the instruments at 1·1m. three times between 1800 and 1930. After 1930 temperature at 1·1m. returned to the condition of gradual decrease associated with nocturnal cooling although in this case it was probably due to the arrival of cooler air (see hygrogram). The cessation of the warm descending current was probably due to the arrival of cold air in the form of a wedge as the decrease of temperature recorded at 1·1m. was gradually propagated upwards until it had reached 30m. at about 2020. The upward progress of this cooling then ceased owing to a re-intensification of the downward movement of the warm air. The setting in of this second downward current of warm air is to be noted at 60·1m. about 1850 and its downward travel was slow as it did not reach 15m. until 2135. Meanwhile cold air had definitely arrived at the surface by 2120 and was over 15m. deep by 2130. This cold air was momentarily replaced by warm air about 2140 but by 2145 the thermometer elements at 1·1m. and 16·2m. were in the main cold air mass and cold air was just reaching the elements at 46·4m. and 61·0m. The frontal region of the cold air mass thus resembled the breaking of a wave upon a submerged sandbank and thus affords evidence in support of the views expressed by Durst (28) as to the form of cold fronts in general.

It is interesting to consider the wind record at 15·2m. in relation to the isopleths for it will be seen that with the development of the nocturnal inversion wind velocity decreased and wind direction backed slowly from SSE. at 1700 to SSW. at 1830. About 1930 the wind increased from almost calm to 12 m.p.h. from SE. by E. and this south-easterly wind was due to the replacement of the nocturnally cooled warm air by warm air from above the inversion. The warm air persisted at 15·2m. until about 2130 when the arrival of cold air caused a sudden veer to W. accompanied by a squall and gust to 27 m.p.h. About 2140 when warm air broke through the cold air the wind backed momentarily to S. and decreased to calm but on the arrival of the main cold air mass the direction veered to NW. with a further squall which reached 20 m.p.h. at 2150. The descent of the warm air to the surface about 2140 is clearly shown on the record of relative humidity.

(*i*) *Cold Front of May* 16, 1932.—On the morning of May 16, 1932 a low pressure system covered Lower Egypt and included a small depression centred just west of Ismailia and another centred west of Cairo. The whole system was moving north-east and the centres must have passed very close to Ismailia. The temperature difference traces as well as the record of temperature at 1·1m. are reproduced in Fig.41 together with the autographic records of wind and pressure at the Meteorological Office. There was some altrostratus cloud present throughout the morning and small amounts of rain fell about 0800, 1005 and 1110 while a thick dust storm occurred between 1230 and about 1400. A secondary cold front associated with the first depression reached the Meteorological Office at 1050 and the installation at 1110, but about 1230 this cool air was replaced by very warm air and at the same time the wind veered from W. to SW. and increased from almost calm to force 7. About 1330 cool air began to replace the very warm air and the main cold air mass arrived at 1515. The features to be noticed in the form of the temperature difference traces are the low values of the lapse rate below 16·2m. in the warm air and the much higher values in the cold air. On trace I the change in lapse rate at the transition from warm air to cold air at 1330 is well marked. Above 16·2m. this feature of a steeper lapse rate in the cold air is considerably less marked indicating that the change in the lower layers is primarily due to the effect of cold air being superposed on the warm ground. The cold air over Ismailia between 1100 and 1230 existed in the form of an overhanging tongue and may have been connected above 61·0m. with the further supply of cold air which arrived at 1330. The change in wind direction at 1230 indicates that a small whirl was associated with the change from cold to warm air. The rain at 0800 appears to have been associated with the arrival of a shallow pool of cool air although the decrease in temperature might have been due to evaporation, while the small amount of precipitation at 1005 was probably associated with instability in the air mass, and that at 1110 with the displacement of warm air by colder air. The rise in temperature at 1·1m. about 1030 was due to insolation as the sky was almost cloudless between 1030 and 1115.

§ 22—ACKNOWLEDGMENTS

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