



GEOPHYSICAL MEMOIRS, No. 5.

THE INTERNATIONAL KITE AND BALLOON ASCENTS.

A dissertation which obtained the first prize awarded in 1912 by the German Meteorological Society in the competition announced at the Society's 25th Annual Congress at Hamburg in 1908.

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PREFATORY NOTE.

THE following memoir was completed and sent to the German Meteorological Society at the end of 1911, in accordance with the conditions of the competition which the Society had organised. It is based, therefore, on data which had been published before that time, now nearly two years ago.

The memoir was prepared (partly from the results collected for a report to the British Association in 1909) outside the hours of my official duties at the Meteorological Office, and it was completed at a time when the work of collecting and publishing climatological statistics for a large number of stations in England and Ireland was being transferred from the Royal Meteorological Society to the Meteorological Office. Under these circumstances it would have been impossible for me to deal alone with the selection, the summarising according to time and space, and the discussion of the results of more than 12,000 observations, and I take this opportunity of putting upon record my grateful acknowledgment of the assistance of my wife.

E. GOLD.

August 1913.

THE INTERNATIONAL KITE AND BALLOON ASCENTS.

THE past fifteen years have been most fruitful in the application of self-recording instruments to the investigation of the free atmosphere; but the work has been mainly confined to obtaining, collecting, and publishing the results of the observations. The results obtained from manned balloons were arranged and discussed very fully and systematically twelve years ago by Von Bezold, Assmann, Berson, and Süring;* but no such comprehensive discussion of the much more numerous results obtained with kites and registering balloons has been given.† At the same time, very much valuable knowledge has been acquired, and the meteorologist of to-day is, in consequence, much better equipped in many respects for attacking the problems to which his predecessors could bring only the ingenuity of speculation and of theory, although his work may be more difficult and less entertaining than theirs.

By the use of kites, a fairly complete knowledge has been obtained of the variation in the meteorological elements up to a height of 2 km. Registering balloons have furnished information regarding the distribution of temperature up to a height of 15–20 km., and it is practically upon the data from these that the following discussion is based. It includes, as supplementary to these, observations made with kites, with pilot balloons, and with manned balloons.

The material was derived in the first instance from the publications of the International Commission for Scientific Aeronautics from January 1904 to November 1909. For Vienna the values published between December 1909 and August 1911 were obtained from the monthly publication of the *Zentral Anstalt für Meteorologie*. For Berlin the values for December 1909 and for 1910 were taken from the *Ergebnisse der Arbeiten der K. Preuss. Aeronautischen Observatoriums*. For Munich the values for December 1909 and for 1910 were obtained from the *Münchener Registrierballonfahrten*, 1909 and 1910. For England the values published in the *Weekly Weather Report* of the Meteorological Office up to November 1911 have been used. For the registering balloons the ascents used are those in which the balloon reached 8 km., but in one or two cases ascents which reached only 7 km. have been included, on the ground that the stratosphere is sometimes reached at heights less than this.

It is important in discussions of data which have been published only *in extenso* to give as fully as possible the actual summaries obtained, without smoothing or correction, and the plan has been followed of giving in all cases the summarised results of

* *Wissenschaftliche Luftfahrten*, 1899.

† Reference may be made to the following papers:—Dines, W. H., *The Free Atmosphere in the Region of the British Isles*, M.O. 202, and *Phil. Trans.*, A, vol. cxi; Köppen, W., *Dreijahre Gleichzeitiger Meteorologischer Drachenaufstiege bei Hamburg, Berlin und St. Petersburg*, 1908; Wagner, A., *Die Temperaturverhältnisse in der freien Atmosphäre*, *Beitr. Physik Atmosph.*, 1909; Gold and Harwood, *Report on the Investigation of the Upper Atmosphere*, *British Association*, Winnipeg, 1909.

the observations, in addition to smoothed and corrected values. By this method the results are made available for incorporation in, and comparison with, subsequent discussions, when additional data have been obtained, without the labour of recalculation *de novo*; and peculiarities, which may be obliterated by smoothing, are shown as the observations themselves have revealed them.

The first part of the paper deals with the observations of temperature. Some general conclusions relating to humidity are added in view of the close connexion between water-vapour and the thermal and thermodynamical processes of the atmosphere.

The results of the discussion of the observations of wind obtained by kites and registering balloons form the second part of the paper.

The discussion of temperature is subdivided into five sections: I. (a) the average temperature conditions in the atmosphere; I. (b) the annual variation of temperature at different heights; I. (c) the diurnal variation of temperature; I. (d) the stratosphere, or isothermal or advective region; I. (e) temperatures under cyclonic and anticyclonic conditions, and the dependence of temperature upon pressure.

The second part is divided into two sections: II. (a) the connexion between the direction of flight of balloons reaching the stratosphere and the direction of the "gradient" wind; II. (b) results for the variation of wind direction and velocity with altitude.

It is a matter of fundamental importance to consider how closely the temperatures recorded by the instruments sent up with registering balloons approximate to the true temperature of the air at the level shown by the barograph. The possible sources of error are (1) lag, and (2) radiation, from the earth and atmosphere below the instrument, and from the sun. It is clear that solar radiation may produce considerable effects if the ventilation of the thermo-element is not great. Dines* found that the difference of temperature between balloons sent up at sunset and at 8 a.m. was practically negligible in winter, but amounted to as much as 5° C. at 10 km. in the summer months; but he was unable to say definitely whether the difference was a real difference of temperature or arose from the effects of radiation on the instrument.

At the extreme heights reached by free balloons the effect of solar radiation may be much greater. The temperature of an unventilated thermometer may be raised as much as 50° C. above that of the air.†

This effect has been largely eliminated by the use of rubber balloons and instruments enclosed in highly polished ventilation tubes. The lag of the instrument has been diminished by the use of Bourdon tube barometers, the bi-metallic thermometers of Teisserenc de Bort and Dines, and the tube thermometer of Hergesell. The ventilation produced by the ascent of the balloon is now generally accepted by observers as sufficient. Experiments have been made in which the barometer, by completing an electric circuit at a given low pressure, set into motion a ventilating fan, producing a current of 3–4 m/s. No discontinuity in the temperature trace was produced, showing that the effect of radiation was negligible under the conditions of the ascent.‡ It is also found that instruments of different types sent up together give results which are

* *Phil. Trans.*, A, vol. ccxi. p. 260. He suggests that the effect is due to the instrument being in the wake of air which has been heated by contact with the balloon (1913).

† Assmann, *Preuss. Akad. Wiss. Berlin, Sitz. Ber.*, vol. xxiv. pp. 495–504; and *International Ascents*, Pavlovsk, Nov. 8, 1906.

‡ *Ergeb. der Arbeit. am Aer. Obs. Lindenberg*, 1907, p. xiii.

in good agreement. Thus in comparisons of the bi-metallic thermometer of Teisserenc de Bort with the tube thermometer of Hergesell the *maximum* difference between the temperatures indicated was $7^{\circ}\cdot3$ C., and the mean difference was about 2° C.

Comparisons of the Hergesell-Bosch with the Assmann instrument gave a *maximum* difference of temperature of $4^{\circ}\cdot1$ C., and a mean difference of $1^{\circ}\cdot7$ C.

The maximum difference between the temperatures indicated by two Dines' instruments sent up from Manchester was only 4° C., and the mean only 1° C.

The following is a brief theoretical consideration of the question. If $2A$ is the radiating area of the thermo-element, and S the area which is exposed to the air-current, then the equation

$$\frac{dT}{dt} = \frac{2IA}{MC} - \frac{f\rho vS}{MC}(T - \theta)$$

expresses the variation of the temperature, T , of the element owing to radiation and convection.

MC is the heat capacity of the thermometer.

I is the rate per unit area at which heat absorbed exceeds heat radiated.

ρ is density of the air.

θ is temperature of the air.

f is a constant.

v is the upward velocity.

In order to deal with an extreme case, we will consider the protecting cylinder. For this, $2A = \frac{1}{2}S$. Since the instrument is bright it is fair to assume that it does not absorb at more than one-tenth of the rate for a full radiator. Thus if we take a temperature of 200° A. ($= -73^{\circ}$ C.) and an intensity of solar radiation equal to 2 gm.

cal. per cm^2 over an area $\frac{2A}{\pi}$ we find

$$\frac{dT}{dt} = \frac{2A}{MC} [0\cdot018 - 0\cdot2(T - \theta)],$$

using de Quervain's* value for f , and putting $v = 5$ m/s, $\rho = 1\cdot2 \times 10^{-3}$.

Thus for this ventilation† ($= 6$) the convection far exceeds the effect of solar radiation for a very small difference between T and θ . Even for a ventilation equal to unity, the convection is considerably the more important factor for an excess of T of 1° C.

We may conclude, therefore, that for ventilation greater than unity, the temperature of the case, and *a fortiori* of the instrument, is very approximately that of the air, and that for a ventilation equal to 0.5 the error ought not to exceed 2° C. Cases where the published ventilation was less than 0.5 have been excluded, and in general a ventilation of 1 has been taken as necessary for a decrease of the temperature gradient to be taken as indicative of the stratosphere.

After the work of Hergesell and Kleinschmidt‡ on the temperature coefficients of the barometers, and in accordance with the suggestions of Hergesell, the barometers have been tested at various temperatures down to -50° C., and it has been found that the majority of the heights above 13–14 km. given in the earlier ascents are too low by at least 0.5 km. At 20 km. the correction is often

* *Beiträge zur Physik der Freien Atmosphäre*, vol. i. p. 192.

† The ventilation is taken to be proportional to vp .

‡ *Beiträge zur Physik der Freien Atmosphäre*, 1905, vol. i. pp. 108–208.

2 km. and even more. When the temperature correction is applied it is usually noted in publication.

It is probable, therefore, that temperatures from the earlier ascents would be lower than from those for which a temperature correction has been applied to the barometer, and that the height at which the stratosphere was reached would be affected by errors due to neglect of this correction.

I. (a).—MEAN TEMPERATURES AND GRADIENTS OF TEMPERATURE.

Temperature is the most important meteorological element of which observations can be made in the free atmosphere. Observations of pressure furnish practically the only means of estimating heights, and they cannot therefore be used to determine directly the distribution of pressure. The latter can only be determined indirectly by calculation from the observations of temperature and the pressure at the surface. Thus, while dynamical meteorology must necessarily be based on a knowledge of the pressure and density distributions, it rests ultimately on the distribution of temperature, and in a lesser degree on that of humidity, in the free atmosphere. The calculations are obviously laborious even when sufficient observations are obtained; the difficulty and expense of obtaining the observations make the task appear almost hopeless. Thus only recently by Bjerknes* has a really serious attempt been made to calculate from observational data the actual synchronous distribution of pressure in the upper atmosphere at 5–10 km. altitude. Our knowledge is confined practically to mean values.

In order to avoid as far as possible negative quantities, and to facilitate calculation and comparison, temperatures have been usually expressed in degrees C. above the absolute zero —273° C. on the ordinary scale. Atmospheric temperatures in temperate latitudes lie almost invariably between 200° and 300° on this scale, and the initial 2 may be generally omitted without risk of confusion. The letter A. is used in connection with this scale; thus (2)73° A. is 0° C. Further, the vertical gradient of temperature is expressed in degrees C. per kilometre, and is reckoned positive when temperature diminishes with increasing height. Heights are measured from Mean Sea Level.

The most complete contribution made to the discussion of upper air observations is that of Von Bezold, Assmann, Berson, and Süring,† who dealt with the observations obtained from manned balloons. The following table gives the values they found for the gradient of temperature for each kilometre up to 9 km. :—

Height in kilometres.	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9
Gradient	5·0	5·0	5·4	5·3	6·4	6·9	6·6	7·2	9·0
Number of cases	59	57	42	38	23	13	5	5	2
Probable error in gradient . . . . .	...	...	...	...	0·1	0·3	0·5	0·6	...

In the surface layer the gradient is affected by inversions, i.e. exceptional cases where the temperature increases with the height. Such cases occur most frequently in winter, and as the number of winter ascents in the series was considerably less than that for other seasons, the actual mean annual gradient in the lower layer is less than

* *Dynamic Meteorology and Hydrography*, 1910.

† *Wissenschaftliche Luftfahrten*, Braunschweig, 1899, 3 vols.

that deduced from these results. The values of the gradient for the first two layers when cases of inversion are excluded are 6·4 and 5·4 respectively.

The following values have been deduced from the later manned balloon observations, 1901–1907 :—

Height in kilometres.	0-1	1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Gradient	4·3	5·1	5·1	5·8	6·2	6·9	7·5	6·2	3·7	8·3
Number of cases	50	50	44	40	34	22	10	3	1	1
Probable error in gradient . . . . .	...	...	0·2	0·2	0·2	0·2	0·4	0·6	...	...

The feature to which Berson drew particular attention was the comparative constancy of the gradient up to a height of 4 km. and the very considerable increase in its value in the next layer. The more recent observations do not show the peculiarity so markedly and indicate a lower level for the discontinuity. Berson attributed the change to the fact that the upper limit of the lower clouds is nearly at 4 km. altitude, and near this height inversions are more frequent than in the layers above and below it. From actual observations in the clouds themselves he deduced that the gradient there agreed remarkably well with the theoretical gradient for saturated air rising adiabatically, which we may call g_s . Just beneath the upper limit of the cloud an increase in the gradient was usually observed, and just above the upper limit the gradient vanished and the air immediately above the cloud was generally found to be warmer than that beneath its upper surface. It may be noted that the value of g_s between 5 and 7 km. is approximately 7° C. per km., agreeing closely with the value found for this layer. The mean values for the gradient for each 500 m. up to 3000 m., deduced from the monthly mean temperatures found from the kite and kite-balloon ascents made at Berlin and Lindenberg, 1903–1910,* are as follows :—

Height	0-0·5	0·5-1·0	1·0-1·5	1·5-2·0	2·0-2·5	2·5-3·0
Gradient	3·9	4·5	4·7	4·7	4·6	5·6

These values differ considerably from the corresponding values for the manned balloon ascents. This may be due to the fact that the kite ascents are distributed throughout the year, and are made under a greater variety of weather conditions.

The rapid increase above 2·5 km. is a remarkable feature undoubtedly connected with condensation phenomena.

Gold † showed that the gradient up to 2 km. depended very considerably on the wind direction as well as on the time of the year. He found that inversions were most frequent in winter and with easterly winds; that they occur very rarely indeed with N.W. winds, and then in summer, a season when they are not found with winds from other directions.

Field ‡ made kite ascents in India and over the Arabian Sea during the S.W. monsoon, and found a very rapid decrease of temperature up to 300–400 m. At greater heights up to 3000 m. the gradient was very close to that for saturated air rising adiabatically, i.e. about 5° C. per km.

Hann § deduced from mountain observations that the mean temperature gradient up

* *Ergebnisse Aeronautischen Observatoriums*, Berlin and Lindenberg.

† *Barometric Gradient and Wind Force*, M.O. No. 190.

‡ *Indian Met. Memoirs*, vol. xx, part 7.

§ *Lehrbuch der Meteorologie*, p. 104.

to 3 km. is $5^{\circ}\cdot 7$ to $5^{\circ}\cdot 8$ per km. The earlier balloon ascents give for the mean value $5^{\circ}\cdot 1$, the later $4^{\circ}\cdot 8$, while the kite ascents give $4^{\circ}\cdot 7$. It is therefore to be expected that the mean temperature of the air in contact with a mountain 3000 m. high will be 2° to 3° C. below that at the same height in the free atmosphere. The elevated parts of the earth's surface exercise a cooling influence on the upper air, i.e. the mountains are not cool because the upper air has been cooled by adiabatic convection, but they are cool because of radiation to space. It follows from this that convection does actually raise the temperature of the atmosphere up to 3 km. altitude above what it otherwise would be, a fact pointed out from theoretical considerations by Gold.* The argument is briefly as follows:—

The radiation of heat from the lower layers of the atmosphere exceeds the absorption by them of radiation from external sources. Therefore, since their temperature remains practically constant, the deficiency of heat must be supplied by convection from the earth's surface carrying warmed air or water-vapour. Both diffusion and conduction are processes much too slow in their action to account for the balance, which is sufficient to cool the whole of the lower half of the atmosphere from the earth's surface up to 5 km. at the rate of 1° C. in twenty-four hours in the absence of solar radiation, and an average of about half that amount if 10 per cent. of the incident solar radiation is *absorbed* (as distinct from diffused) in that region.

The results of direct comparison of simultaneous observations are in agreement. Berson† found from a comparison of the temperature observed in balloons with that observed on the Brocken (1140 m.) that the mountain was $0^{\circ}\cdot 9$ C. colder than the free atmosphere.

Shaw and Dines‡ found from twenty-eight kite ascents made in July and August 1902 that the temperature on Ben Nevis (1343 m.) was in all cases lower than that in the free atmosphere at the same height over the sea to the west of the mountain, the mean difference being $2^{\circ}\cdot 6$ C. Additional evidence in support of their result was furnished by the fact that the height at which the kite reached the clouds was invariably greater than the height at which the clouds were observed over the neighbouring hills. They suggested that the difference might be due to the westerly stream of air rising to cross the mountains and producing an approximately adiabatic gradient of temperature.

Schmauss§ has discussed the simultaneous values observed on Zugspitze (2965 m.) and recorded at the same height in balloon ascents from Munich, 90 km. distant. He found the mean difference of $1^{\circ}\cdot 6$ C. between the synchronous temperatures, and $1^{\circ}\cdot 1$ C. between the temperature recorded in the free atmosphere and the mean temperature of the day at Zugspitze. In both cases the free atmosphere had the higher temperature. Schmauss deduced also from a comparison of the temperatures on Zugspitze and Sonnblick that the latter was $0^{\circ}\cdot 6$ C. colder than the former at the same height, and consequently a mountain in the middle of a mountainous district is colder than one on the edge of such a district. This may be taken as further evidence that the atmosphere is cooled by the mountain.

In dealing with the registering balloon results the mean temperatures at each kilometre for each month of the year have been found for twelve stations—Berlin, Munich, Strassburg, Vienna, England, Hamburg, Paris, Uccle, Pavlovsk, Koutchino, Italy, Zurich—and the full tables are included later in the section “Annual Variation of Temperature.” From these means the mean yearly temperature at each height has

* *Proc. Roy. Soc.*, vol. lxxxii., 1909, pp. 47, 67.

† *Wissenschaftliche Luftfahrten*.

‡ *Phil. Trans.*, A, vol. ccii.

§ *Registrierballonfahrten*, München, 1908.

been calculated for individual stations, and the mean monthly temperature at each height for groups of stations. Up to 8 km. it is immaterial whether gradients or temperatures are used, inasmuch as the number of ascents is the same at all heights; above this, both temperatures and gradients have been used.* It seemed possible that the higher ascents might occur mainly under exceptional conditions for the gradient, viz. anticyclonic, and that if these gradients were applied to the general means, too low values for heights above 9 km. would be obtained. In any case it is desirable to form the means of the *actual temperatures recorded*.

In one or two cases values have not been published for the surface or for intermediate heights, and this accounts for the fact that the number of ascents is not exactly the same at all heights. The exceptions are, however, trifling.

The values for (I.) Berlin, Munich, Strassburg, and Vienna, and (II.) England, Hamburg, Paris, and Uccle have been grouped to form general means. We shall for brevity call them Central Europe and N.W. Europe respectively, without suggesting that these places are fully representative of the two regions.

The following table gives the mean temperatures and gradients of temperature for the two groups, and from earlier series for comparison :—

TABLE I.—ANNUAL MEAN TEMPERATURES AT DIFFERENT HEIGHTS.

(T = Temperature in Degrees A. ($200^{\circ} +$), N = Number of cases.)

Height above M.S.L.	Berlin, Munich, Strassburg, and Vienna.			England, Hamburg, Paris, and Uccle.			Hann,** 1904, 156 Ascents.	Teisserenc de Bort,† 1904, 581 Ascents.	Manned Balloons.		Mean ‡ Gradients, 1904-1907.
	T.	N.	Gradients.	T.	N.	Gradients.	T.	T.	I.	II.	
km.											
Surface	80°3	354	...	81°2	350	...	...	80°1	83°4	81°6	...
1	77°9	354	...	77°8	359	...	79°0	78°3	78°4	77°3	...
2	73°2	354	4°7	73°4	359	4°4	74°7	73°7	73°4	72°2	4°3
3	68°0	354	5°2	68°3	359	5°1	69°7	69°0	68°0	67°1	5°2
4	62°1	354	5°9	62°6	359	5°7	64°0	63°6	62°7	61°3	5°8
5	55°7	354	6°4	56°0	359	6°6	57°7	57°6	56°3	55°1	6°3
6	49°0	354	6°7	49°3	359	6°7	50°9	51°1	49°4	48°2	6°8
7	41°6	354	7°4	42°4	359	6°9	43°9	44°1	42°8	40°7	7°2
8	34°3	353	7°3	35°3	356	7°1	36°8	36°8	35°6	34°5	7°4
9	27°7	340	6°5	28°8	350	6°5	29°8	29°5	26°6	30°8	6°8
10	22°4	321	5°4	22°8	337	5°6	24°0	23°7	...	22°5	5°0
11	19°0	293	3°5	19°5	322	3°7	...	...	...	...	3°3
12	17°9	253	1°3	18°4	287	0°9	...	...	...	...	0°7
13	18°8	212	-0°9	18°9	256	-0°3	...	...	...	...	-0°8
14	18°8	167	-0°1	18°7	216	0°2	...	...	...	...	0°0
15	18°7	124	0°0	19°2	149	-0°1	...	...	...	...	-0°1
16	19°5	37	0°4	19°7	74	...	...	...	...	...	...

ANNUAL MEAN TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.											
km.	T.	N.		T.	N.						
9	27°8	340	...	28°8	350	...	...	...	...	...	...
10	22°4	321	...	23°2	337	...	...	...	...	...	...
11	18°9	293	...	19°5	322	...	...	...	...	...	...
12	17°6	253	...	18°6	287	...	...	...	...	...	...
13	18°5	212	...	18°9	256	...	...	...	...	...	...
14	18°6	167	...	18°7	216	...	...	...	...	...	...
15	18°6	124	...	18°8	149	...	...	...	...	...	...
16	18°2	37	...	...	...	...	...	...	...	...	...

** Sitzungsbericht. der k. Akad. der Wiss. Wien, cxiii. 2a, May 1904.

† Comptes Rendus, 1904, p. 42.

‡ Gold and Harwood, B. A. Report, 1909.

* Except for Zurich.

These general means are practically identical up to 3 km. At greater heights the values for group II. become slightly higher by as much as 1° C. at 8 and 9 km., but above this height the difference again diminishes.

This indicates a diminution in the average temperature gradient from 3 to 8 km. in group II., which is no doubt due to the greater condensation of water-vapour in the region represented by this group of stations. The gradient increases again at higher levels, indicating that convection extends to greater heights over this region.

The values of the temperature for these groups are slightly lower than those found by Hann for 156 ascents, and by Teisserenc de Bort for 581 ascents. They agree very closely with the values obtained in the ascents of manned balloons carried out in Germany. The values found by Hann and Teisserenc de Bort agree very closely with the results found for Paris in the present discussion.

The following tables, II. and III., give the values for the separate places, and the number of observations used. It is interesting to compare the values in the tables

TABLE II.—MEAN ANNUAL TEMPERATURES (1904–1909).
Temperature in Degrees A. (200° +).

Height.	Berlin.*	Munich.*	Strassburg	Vienna.†	England.‡	Hamburg.	Paris.	Uccle.	Pavlovsk.	Koutchino.	Milan and Pavia.	Zurich.
km.												
Surface	80°·1	79°·9	81°·3	81°·0	82°·2	79°·9	80°·7	79°·6	74°·9	77°·0	84°·6	82°·0
1	76°·8	79°·0	78°·2	77°·6	77°·9	75°·4	78°·5	77°·1	71°·0	74°·4	80°·7	78°·8
2	71°·7	74°·4	73°·8	73°·0	73°·3	70°·4	74°·5	73°·0	66°·7	70°·2	75°·1	75°·9
3	66°·9	68°·8	68°·4	67°·6	67°·9	64°·8	69°·8	67°·8	61°·3	66°·2	69°·2	69°·9
4	61°·0	62°·7	62°·4	61°·9	61°·9	59°·1	64°·3	62°·0	55°·7	60°·3	62°·9	63°·9
5	54°·8	56°·6	56°·1	55°·6	55°·4	52°·6	58°·1	55°·3	49°·8	54°·2	56°·2	57°·2
6	47°·9	49°·9	49°·3	48°·8	48°·5	46°·2	51°·4	48°·5	43°·3	47°·7	49°·4	49°·9
7	40°·8	42°·9	42°·1	41°·2	41°·3	39°·7	44°·3	41°·5	37°·1	40°·8	41°·2	42°·3
8	33°·1	35°·7	34°·8	33°·6	34°·5	33°·5	36°·9	34°·4	29°·8	32°·9	33°·9	34°·5
9	26°·8	29°·1	27°·8	26°·9	28°·5	27°·7	30°·0	27°·7	24°·4	25°·7	27°·3	27°·9
10	21°·9	23°·8	22°·3	21°·8	23°·4	22°·5	24°·3	21°·7	21°·3	19°·8	22°·7	23°·1
11	19°·2	20°·0	18°·1	18°·4	20°·1	19°·2	20°·2	17°·5	20°·0	16°·8	18°·5	17°·1
12	18°·3	17°·2	16°·8	18°·3	19°·5	18°·4	19°·5	16°·4	20°·7	18°·7	16°·1	16°·2
13	19°·3	18°·2	17°·6	19°·6	19°·5	20°·2	19°·3	15°·3	23°·4	21°·6	16°·4	16°·7
14	18°·7	17°·3	17°·9	19°·6	19°·3	19°·4	19°·1	16°·4	23°·5	21°·0	17°·7	15°·9
15	17°·9	19°·8	18°·2	20°·1	20°·0	20°·2	18°·9	16°·4	23°·1	21°·2	17°·1	16°·2
16	17°·6	19°·9	20°·1	20°·4	20°·2	20°·8	16°·3	...	25°·0	...	18°·9	...
VALUES ABOVE 8 KM. OBTAINED BY USING MEAN GRADIENTS.												
km.												
9	26°·8	29°·3	28°·5	26°·9	28°·5	27°·6	29°·9	27°·7	24°·3	25°·7	27°·1	...
10	22°·0	23°·9	22°·9	21°·2	23°·4	22°·7	24°·2	21°·7	21°·1	19°·8	22°·0	...
11	18°·7	20°·3	18°·5	17°·8	19°·9	19°·3	20°·0	18°·4	20°·1	17°·6	17°·4	...
12	18°·3	18°·0	17°·1	17°·3	19°·1	18°·8	19°·2	16°·5	20°·2	18°·0	14°·7	...
13	19°·6	20°·1	17°·9	18°·1	19°·2	20°·3	19°·0	15°·8	22°·4	20°·2	14°·6	...
14	19°·9	20°·2	18°·0	18°·3	19°·1	20°·0	19°·0	15°·6	23°·0	19°·6	15°·6	...
15	19°·6	19°·7	18°·3	19°·6	19°·5	20°·5	19°·2	15°·1	23°·8	20°·1	16°·1	...
16	19°·5	21°·7	19°·6	19°·9	19°·5	20°·4	17°·5	...	...	...	...	...

* To December 1910.

† To May 1911.

‡ To November 1911.

with values shown in Table IV., which included observations from January 1904 to September 1907, except for the stations asterisked, for which observations up to December 1908 are included.

The differences in the mean values for different places are very slight, and show that over Europe, with the exception of Pavlovsk, there is little variation in the mean temperature in the free atmosphere above 3 km. The earlier series gives values slightly lower for heights up to 10 km., which may be due to the greater percentage of ascents for which no temperature correction was applied to the barometer.

In England, Paris, and Italy the temperatures are slightly in excess of those for other places up to 8 km., but above 10 km. Pavlovsk becomes the place of highest temperature.

TABLE III.—TOTAL NUMBER OF OBSERVATIONS (1904–1909).
Used in the preparation of Table II.

Height. km.	Berlin.	Munich.	Strassburg.	Vienna.	Total.	England.	Hamburg.	Paris.	Uccle.	Total.	Pavlovsk.	Koutchino.	Milan and Pavia.	Zurich.
Surface	96	83	99	76	354	153	46	112	39	350	52	32	70	30
1	96	83	99	76	354	162	46	112	39	359	52	32	70	30
2	96	83	99	76	354	162	46	112	39	359	52	32	70	30
3	96	83	99	76	354	162	46	112	39	359	52	32	70	30
4	96	83	99	76	354	162	46	112	39	359	52	32	70	30
5	96	83	99	76	354	162	46	112	39	359	52	32	70	30
6	96	83	99	76	354	162	46	112	39	359	52	32	70	30
7	96	83	99	76	354	162	46	112	39	359	52	32	70	30
8	96	83	98	76	353	162	46	111	37	356	51	32	70	30
9	94	81	94	71	340	162	43	108	37	350	50	32	66	27
10	87	80	88	66	321	161	33	106	37	337	47	31	59	24
11	78	73	86	56	293	157	30	98	37	322	38	28	42	22
12	74	59	73	47	253	145	20	86	36	287	31	25	42	15
13	59	45	69	39	212	138	18	68	32	256	24	22	31	10
14	47	30	58	32	167	126	16	47	27	216	19	19	26	5
15	33	18	42	31	124	80	14	31	24	149	13	15	17	4
16	11	5	6	15	37	61	7	6	...	74	3	...	13	...

TABLE IV.—MEAN TEMPERATURES.
From Observations January 1904–September 1907.
Temperature in Degrees A. ($200^{\circ} +$).

	Berlin.	Munich.	Strassburg.	Vienna.	England.	Paris.	Uccle.	Pavlovsk.	Koutchino.	Zurich.	Mean.
Height.	120 m.	516 m.	140 m.	190 m.	150 165 30 } m.	100 170 } m.	100 m.	30 m.	140 m.	480 m.	
Surface	79°4	79°2	81°0	80°4	83°4	81°3	80°2	75°3	78°0	82°7	80°0
1	77°1	78°6	77°8	76°8	78°3	78°4	77°2	71°9	75°3	79°0	77°1
2	72°2	74°1	73°9	72°7	74°4	73°7	73°2	66°9	71°8	75°3	72°8
3	67°6	68°6	68°5	67°5	69°0	69°0	67°8	61°5	67°4	69°2	67°6
4	62°0	62°4	62°6	61°5	62°8	63°6	61°8	56°3	61°3	63°2	61°8
5	55°8	56°3	56°2	55°2	56°6	57°4	55°1	50°5	54°9	56°5	55°5
6	49°0	49°5	49°6	47°9	50°2	50°8	48°5	43°9	48°3	49°2	48°7
7	42°1	42°7	42°4	40°4	43°3	43°7	41°3	36°5	40°6	41°6	41°5
8	34°7	35°4	35°0	32°4	37°2	36°2	33°9	29°4	32°6	33°8	34°1
9	28°0	29°0	28°1	25°7	30°8	29°2	26°8	23°3	25°1	26°9	27°3
10	22°7	23°9	22°8	21°4	25°4	23°8	20°9	20°9	19°0	22°4	22°3
11	19°7	19°8	18°2	18°0	21°2	19°9	17°5	21°0	17°3	16°9	19°0
12	17°5	17°4	17°1	19°1	21°2	20°2	16°3	20°5	18°1	16°0	18°3
13	18°5	17°5	17°4	21°1	20°1	19°4	14°9	23°4	20°7	17°6	19°1
14	18°9	17°8	17°7	20°5	18°5	20°4	16°3	22°2	20°5	18°0	19°1
15	17°1	19°3	17°8	20°8	19°3	19°8	16°2	22°5	20°4	18°5	19°2

The rapid decrease of the gradient of temperature above 9 km. will be considered more fully in connection with the stratosphere. For the present it may be sufficient to point out that both the actual fact and the differences for the two groups are fully in accordance with what would be expected from an atmosphere in which the tendency to a thermal state corresponding to radiation equilibrium was continuously opposed by the tendency to convective equilibrium caused by surface warming and the consequent dynamical disturbance.

The values for Pavlovsk indicate that there the convection is less intense than for the other places. For Italy the reverse is the case.

The temperatures obtained by using gradients differ little from those obtained from the actual observations. In general they tend to be slightly lower, which indicates a tendency for the higher ascents to coincide with the times of higher temperature in the region above 8 km. The maximum value of the gradient occurs in the region 6–8 km. for group I., Central Europe, and from 7–8 km. for group II., N.W. Europe, indicating that at that height the effect of radiation on the gradient is very small. In the lower layers atmospheric radiation tends to diminish the gradient, since there is in those layers an excess of radiation over absorption, an excess which diminishes from the surface upwards. Thus a layer at a height h is cooled more than a layer at a height $h + x$, thereby diminishing the temperature difference.

In the upper layers radiation approaches rapidly to absorption and tends to produce an approximately isothermal condition, and the result is again a diminution of the gradient of temperature.

If the values for Pavlovsk are taken to be representative of the conditions for lat. 60° , and those for Strassburg for lat. 50° , the mean difference of pressure between the two parallels at a height of 10 km. will be nearly 7 mm. if any difference in humidity is neglected. If allowance is made for the diminished density of the air at this height, it follows that such a difference of pressure would correspond to a steady W. wind of about 24 m/s. (metres per second). Above 10 km. the temperature over Pavlovsk is higher than in lower latitudes, so that the difference of pressure would diminish with further increase in height. It would indeed diminish more rapidly than the density, so that the wind also would diminish in intensity above a height of 10 km., and the mean wind velocity would have a maximum value at about this height. It may be noted that the effect of the diminished proportion of water-vapour present in higher latitudes would be to accentuate the difference of pressure in the upper air. The increase must, however, be small and could not exceed 2 mm., even if the air over Pavlovsk were perfectly dry; the actual value is probably only a fraction of a millimetre.

The higher values found for Paris and in England indicate that there is a slight horizontal gradient of temperature from W. to E., and this will produce in the upper air a corresponding gradient of pressure, also from W. to E., or from ocean to continent. There will therefore be a tendency for the isobars to run from N. of W. to S. of E., with a corresponding direction for the wind.

I. (b).—ANNUAL VARIATION OF TEMPERATURE.

A question of some interest is the magnitude of the yearly variation of temperature at different heights. Berson concluded from the results of the manned balloon ascents that the absolute range showed practically no diminution up to 5 km., and that above that height, although there was a tendency to decrease, the ascents were not numerous enough to warrant definite conclusions. He gives the following values for the range, taken as the difference between the extreme temperatures observed:—

Height in kilometres.	Surface.	1	2	3	4	5	6	7	8
	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$
Range	(31.6)	29.7	30.4	31.8	32.2	31.0	27.3	25.0	17.8
Number of cases	...	56	50	40	32	20	11	5	4

Table V. shows the annual range of temperature at different heights taken from the monthly means and the number of months for which the observations were available. The values found in earlier investigations have been added for comparison. The range decreases rapidly from the surface to 2-3 km., and afterwards increases. This is mainly

TABLE V.—ANNUAL RANGE OF TEMPERATURE (R) IN DEGREES C. AND NUMBER OF MONTHS (M).

Height. km.	Berlin.		Munich.		Strassburg.		Vienna.		Mean for Group A.		England.		Hamburg.		Paris.		Uccle.		Mean for Group B.		Berlin Manné Balloons.		Teisserenc de Bort.*		Pavlovsk.		Koutchino.		Italy.	
	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	R.	M.	A.	B.	R.	M.	R.	M.	R.	M.
Surface	21.7	12	23.4	12	19.4	12	23.1	12	21.1	12	13.7	12	19.8	12	15.3	12	20.6	12	15.2	12	21	12	13.7	13.4	29.2	12	31.5	12	22.1	12
1	15.8	"	21.2	"	19.6	"	19.1	"	16.9	"	14.2	"	17.7	"	17.2	"	17.9	"	14.9	"	16	"	14.7	14.6	24.1	"	21.5	"	18.4	"
2	13.3	"	17.0	"	18.7	"	16.0	"	14.5	"	15.2	"	22.4	"	18.4	"	20.6	"	15.3	"	14	"	13.5	14.3	23.3	"	17.5	"	17.7	"
3	15.4	"	16.9	"	18.9	"	13.1	"	15.2	"	15.3	"	24.1	"	19.2	"	22.5	"	16.1	"	15	"	13.0	12.5	23.6	"	17.0	"	18.8	"
4	16.2	"	18.3	"	20.3	"	13.5	"	16.3	"	16.2	"	24.3	"	20.6	"	24.5	"	17.6	"	17	"	13.6	12.6	23.0	"	17.0	"	19.3	"
5	18.1	"	19.1	"	21.8	"	14.1	"	17.6	"	17.8	"	25.3	"	22.9	"	27.5	"	18.8	"	...	"	13.7	13.3	19.6	"	17.0	"	21.5	"
6	19.4	"	20.4	"	23.2	"	15.1	"	18.8	"	18.5	"	23.3	"	24.5	"	28.9	"	19.4	"	...	"	14.4	12.5	19.4	"	17.0	"	22.1	"
7	19.9	"	21.6	"	22.9	"	16.5	"	19.4	"	18.9	"	20.9	"	25.0	"	29.8	"	19.0	"	...	"	14.1	11.8	18.6	"	19.5	"	23.4	"
8	19.5	"	22.2	"	20.9	"	16.9	"	18.4	"	17.1	"	18.0	"	23.0	"	25.8	"	17.6	"	...	"	13.7	11.6	17.0	"	21.5	"	23.7	"
9	15.3	"	20.3	"	16.4	"	17.0	"	15.0	"	12.9	"	18.2	"	18.7	"	22.0	"	14.1	"	...	"	12.3	9.2	15.1	"	23.0	"	19.7	"
10	11.7	"	15.2	"	14.6	"	13.8	"	13.5	"	7.8	"	12.8	"	15.8	"	17.3	"	7.5	"	...	"	10.1	9.1	13.6	"	27.5	"	18.4	"
11	14.6	"	11.8	"	16.3	"	14.1	"	12.9	"	10.2	"	13.3	"	14.6	"	11.5	"	9.9	"	...	"	...	9.9	14.0	"	25.5	"	21.6	"
12	16.0	"	11.1	"	18.1	"	14.5	"	12.8	"	11.4	"	15.0	"	15.4	"	12.0	"	9.9	"	...	"	...	9.3	13.5	"	21.5	"	18.5	"
13	12.9	"	14.2	"	16.8	"	11.8	"	13.3	"	13.2	"	17.0	"	19.8	"	18.8	"	10.8	"	...	"	...	...	10.8	"	18.5	"	21.2	"
14	15.3	"	14.5	"	16.2	"	14.4	"	11.8	"	15.0	"	20.0	"	17.7	"	15.5	"	11.3	"	...	"	...	...	10.5	"	19.0	"	17.7	"
15	16.0	"	11.0	"	15.2	"	11.8	"	11.0	"	13.8	"	16.0	"	17.2	"	15.5	"	11.1	"	...	"	...	...	11.0	"	22.5	"	15.6	"

VALUES ABOVE 8 KM. OBTAINED BY USING MEAN GRADIENTS.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.	
km.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.		°A.	
9	15.3	12	18.7	12	16.4	12	14.5	12	14.8	12	12.9	12	15.5	12	17.8	12	22.0	12	13.9	12	...	12	...	12	...	12	...	12	...	12	...
10	14.0	"	15.4	"	14.6	"	12.7	"	13.6	"	7.8	"	10.3	"	14.9	"	17.3	"	11.4	"	...	"	...	"	...	"	...	"	...	"	...
11	16.5	"	11.1	"	17.8	"	15.2	"	13.0	"	9.7	"	14.1	"	14.7	"	11.5	"	7.0	"	...	"	...	"	...	"	...	"	...	"	...
12	17.9	"	9.3	"	18.6	"	19.2	"	11.6	"	10.6	"	13.1	"	15.4	"	12.1	"	9.7	"	...	"	...	"	...	"	...	"	...	"	...
13	14.1	"	12.2	"	11.8	"	18.5	"	9.8	"	10.7	"	11.7	"	18.2	"	10.4	"	10.6	"	...	"	...	"	...	"	...	"	...	"	...
14	13.6	"	15.2	"	9.6	"	18.0	"	8.8	"	12.1	"	13.8	"	18.6	"	15.7	"	11.6	"	...	"	...	"	...	"	...	"	...	"	...
15	14.1	"	15.0	"	8.3	"	10.8	"	8.0	"	12.2	"	16.8	"	18.1	"	15.7	"	11.4	"	...	"	...	"	...	"	...	"	...	"	...

* *Comptes Rendus*, 1904, p. 42.

due to the fact that the condensation begins at a lower level in winter than in summer, so that the effect of the liberation of heat is to increase the temperature in winter. The same effect is of course present also to a greater degree in summer, but it occurs at higher levels and the result is the further increase in the range above 4 km.

The effect may also be partly due to condensation of water-vapour in clouds for which convection does not extend to great heights. It is clear that if the clouds are the result of a general rising current which extends to great heights, the effect of condensation on the temperature is cumulative, and the excess of temperature above that corresponding with dry air rising or falling with the same surface temperature would exceed, at great heights, the value for lower levels.

The range in England shows no actual decrease in the lower layers, but it is practically stationary from 2 to 3 km. The range in Central Europe is greater at the surface than for N.W. Europe, but it is *less from 2 to 6 km.*, afterwards increasing again.

The smaller value from 2 to 6 km. is probably accounted for by the difference between the effects of condensation of water-vapour in the two regions in the summer months. The results indicate that this effect reaches its maximum at a *greater height* for Central Europe than for N.W. Europe.

The range for Central Europe diminishes from 8 km. to the greatest height, while for N.W. Europe a second minimum is reached at 11 km., or *at the point where the stratosphere is reached*. It is difficult to judge whether this is accidental or not, in view of the opposite result for Central Europe. As the minimum is found at nearly all the individual stations, it may, however, be a real phenomenon connected with *the variation in the level of cirrus clouds, in the same way as the minimum at 2-3 km. is connected with the variation for the lower clouds*.

At Pavlovsk the range decreases from 3 to 10 km., while at Koutchino it is constant from 3 to 6 km. and increases to a maximum at 10 km. In Italy the maximum is found at 8 km.

The values for the range are considerably greater than those found by Teisserenc de Bort for Paris, both from 581 ascents and from 141 ascents which reached 14 km. The values up to 4 km. agree well with those obtained from the manned balloon ascents.

Table VI. shows the mean monthly temperatures at heights of 122, 500, 1000, 1500, 2000, 2500, and 3000 m. at Berlin and Lindenberg for the periods I. 1903-1907 (5 years), II. 1908-1910 (3 years), III. 1903-1910 (8 years). The Fourier coefficients are given in Table VII., and the number of observations used in Table VIII. The afternoon ascents in the second period were not included, as the number of such ascents in the earlier period was much smaller. The values refer therefore approximately to 8 a.m.

The exclusion of the afternoon values may account partly for the fact that the values in period I. exceed in general those for period II.

The surface values for the period January 1903-March 1905 were taken at 40 m. They have been reduced to 122 m. by taking the mean gradient from 40-500 m. observed in each of the twenty-seven months.

The results have been analysed, and the values of the coefficients in the sine series are given in the table. Time is measured from January 1. The value of the amplitude of the whole year term diminishes up to 2.5 km., where it is about three-quarters of the value at 0.5 km., but it increases slightly at 3 km. As will be seen later, this increase goes on more rapidly above 3 km. The phase angle simultaneously diminishes, showing a retardation of the dates of maximum and minimum temperatures of about twelve days between 0.5 and 3 km. The values for both periods agree very closely in this respect.

The date of minimum temperature in the whole year variation is about January 23 at 0.5 km., and February 4 at 3 km. The difference is similar to that between a

continental and an oceanic climate. The effect of the second and third terms of the sine series is to make the maximum earlier and the minimum later.

If we wish to take account of this we may do so by putting

$$nt = \frac{5\pi}{2} - \alpha_1 + \epsilon \text{ for the maximum,}$$

and

$$nt = \frac{3\pi}{2} - \alpha_1 + \epsilon' \text{ for the minimum.}$$

These lead to the equation

$$\epsilon, \epsilon' = \frac{-2P_2 \cos(\alpha_2 - 2\alpha_1) \pm 3P_3 \sin(\alpha_3 - 3\alpha_1)}{\pm P_1 - 4P_2 \sin(\alpha_2 - 2\alpha_1) \mp 9P_3 \cos(\alpha_3 - 3\alpha_1)},$$

the upper sign being taken for ϵ and the lower for ϵ' in all cases.

TABLE VI.—MEAN MONTHLY TEMPERATURES IN DEGREES A. (200°+),
BERLIN AND LINDENBERG.

Height.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
I. 1903-1907.													
m. Surface (122)	71°8	73°4	76°2	80°1	87°2	89°6	91°0	90°2	86°4	81°4	76°4	72°7	81°38
500	71°5	72°1	73°5	77°4	83°6	85°8	87°3	86°8	84°3	80°5	75°9	72°2	79°32
1000	70°4	70°1	72°1	74°6	80°4	82°5	84°2	83°6	81°6	78°8	74°5	71°0	76°97
1500	69°1	68°2	69°9	72°3	77°3	79°4	81°2	80°5	79°2	76°9	72°6	69°5	74°80
2000	67°3	66°6	67°8	70°0	74°6	76°7	78°4	78°0	77°0	74°4	70°7	68°0	72°44
2500	65°2	64°6	66°0	68°0	71°9	74°0	76°4	75°5	75°0	72°3	69°2	66°2	70°38
3000	61°6	62°4	63°9	65°6	69°2	72°2	73°9	72°9	72°2	70°4	66°7	63°8	67°90
II. 1908-1910.													
m. Surface	71°4	72°2	73°8	78°0	83°7	88°7	88°1	87°3	83°6	80°8	76°3	72°4	79°70
500	71°5	71°3	73°7	76°7	81°9	86°6	86°0	86°1	83°5	81°5	75°6	73°3	79°05
1000	70°4	69°4	71°4	73°9	79°1	84°1	83°2	83°3	80°7	79°9	73°7	72°2	76°76
1500	68°5	67°1	68°8	71°1	76°2	80°8	80°2	80°4	78°1	78°1	71°5	70°4	74°40
2000	66°3	64°8	66°2	68°6	73°1	77°8	77°3	77°7	75°9	76°0	69°2	68°2	71°74
2500	63°8	62°0	63°6	66°1	70°6	74°9	74°6	75°4	73°4	73°9	66°3	65°9	69°20
3000	60°9	59°3	60°8	63°2	67°6	71°6	71°9	72°9	70°8	71°4	63°5	63°1	66°42
DIFFERENCES BETWEEN THE VALUES FOR THE TWO PERIODS (I.-II.).													
m. Surface	0°4	1°2	2°4	2°1	3°5	0°9	2°9	2°9	2°8	0°6	0°1	0°3	1°68
500	0°0	0°8	-0°2	0°7	1°7	-0°8	1°3	0°7	0°8	-1°0	0°3	-1°1	0°27
1000	0°0	0°7	0°7	0°7	1°3	-1°6	1°0	0°3	0°9	-1°1	0°8	-1°2	0°21
1500	0°6	1°1	1°1	1°1	1°1	-1°4	1°0	0°1	1°1	-1°2	1°1	-0°9	0°40
2000	1°0	1°8	1°6	1°4	1°5	-1°1	1°1	0°3	1°1	-1°6	1°5	-0°2	0°70
2500	1°4	2°6	2°4	1°9	1°3	-0°9	1°8	0°1	1°6	-1°6	2°9	0°3	1°18
3000	0°7	3°1	3°1	2°4	1°6	0°6	2°0	0°0	1°4	-1°0	3°2	0°7	1°48

Hann* gives the following values for the amplitude of the yearly variation on mountain peaks and well-exposed places:—

Place.	Altstätten.	Trogen.	Gäbris.	Rigikulm.	Säntis.	Sonnblick.
Height . .	460 m.	880 m.	1250 m.	1790 m.	2500 m.	3100 m.
Range . .	19°4 C.	17°1 C.	15°5 C.	14°4 C.	14°1 C.	14°5 C.

* *Lehrbuch*, p. 105.

These values show the same general decrease up to 2.5 km. as those found for the free atmosphere at Berlin, but they are in all cases 2°–3° C. greater than for the free atmosphere.

This is due partly to the fact that the surface of the mountain is a better radiator than the free atmosphere, and is consequently cooled more during the winter and the

TABLE VI. (*cont.*)—MEAN MONTHLY TEMPERATURE IN DEGREES A. (200° +),
BERLIN AND LINDENBERG.

. III. 1903–1910.

Height.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
m.													
Surface (122)	71.7	73.0	75.3	79.3	85.9	89.3	89.7	88.9	85.2	81.2	76.4	72.6	80.71
500	71.5	71.8	73.6	77.1	83.0	86.1	86.8	86.5	83.9	80.9	75.8	72.6	79.13
1000	70.4	69.8	71.8	74.3	79.9	83.1	83.8	83.5	81.3	79.2	74.2	71.4	76.89
1500	68.9	67.8	69.6	71.9	77.0	79.9	80.8	80.5	78.8	77.4	72.2	69.8	74.55
2000	66.9	66.2	67.2	69.5	74.0	77.1	78.0	77.9	76.6	75.0	70.1	68.1	72.22
2500	64.7	63.4	64.8	67.1	71.4	74.4	75.6	75.5	74.4	72.9	68.1	66.1	69.86
3000	61.3	60.9	62.2	64.4	68.4	71.9	72.9	72.9	71.5	70.9	65.1	63.4	67.15

GRADIENTS OF TEMPERATURE °C PER KM.													
m.													
0–0.5	0.5	0.5	4.4	5.7	7.5	8.2	7.5	6.2	3.3	0.8	1.5	0.0	3.94
0.5–1.0	2.2	4.0	3.6	5.6	6.2	6.0	6.0	6.0	5.2	3.4	3.2	2.4	4.48
1.0–1.5	3.0	4.0	4.4	4.8	5.8	6.4	6.0	6.0	5.0	3.6	4.0	3.2	4.68
1.5–2.0	4.0	3.2	4.8	4.8	6.0	5.6	5.6	5.2	4.4	4.8	4.2	3.4	4.66
2.0–2.5	4.4	5.6	4.8	4.8	5.2	5.4	4.8	4.8	4.4	4.2	4.0	4.0	4.72
2.5–3.0	6.8	5.0	5.2	6.4	6.0	5.0	5.4	5.2	5.8	4.0	6.0	5.4	5.42

TABLE VII.—SEASONAL VARIATION OF TEMPERATURE, BERLIN AND LINDENBERG.

Values of the Constants in the Series for Temperature.

$$T = T_0 + P_1 \sin (nt + a_1) + P_2 \sin (2nt + a_2) + P_3 \sin (3nt + a_3).$$

1903–1910.

1903–1907.

Height.	P ₁ .	P ₂ .	P ₃ .	a ₁ .	a ₂ .	a ₃ .	P ₁ .	P ₂ .	P ₃ .	a ₁ .	a ₂ .	a ₃ .
	°C.	°C.	°C.				°C.	°C.	°C.			
0.5	8.17	0.27	0.57	246° 37'	126° 8'	355° 15'	8.22	0.05	0.46	249°	42°	352°
1.0	7.33	0.36	0.57	242° 55'	122° 15'	346° 50'	7.28	0.15	0.47	244°	117°	349°
1.5	6.67	0.33	0.60	239° 40'	132° 40'	351° 0'	6.53	0.24	0.35	243°	195°	384°
2.0	6.25	0.27	0.59	237° 0'	107° 45'	353° 10'	6.10	0.18	0.46	239°	90°	363°
2.5	6.20	0.28	0.45	234° 37'	155° 0'	363° 0'	5.88	0.03	0.28	236°	115°	338°
3.0	6.33	0.19	0.53	234° 16'	157° 0'	333° 20'	5.94	0.17	0.53	237°	204°	285°

night-time. Moreover, the free atmosphere is absorbing radiation from the warmer atmosphere and earth beneath it, while for the mountain this is not the case. On the other hand, if the free atmosphere is warmed by convection from below during the summer or day-time (and this will be the case as a rule; the warming will rarely be solely due to absorption of solar radiation by the air itself), the mountain will also be warmed either directly, or by air sinking to take the place of the warm air rising from the plains. Both causes therefore tend to make the range of temperature for the

mountain greater than for the free atmosphere, although the cooling by radiation is the principal factor.

The three components have been given in Table VII. to show the comparative regularity of the third both in amplitude and phase. The result appears interesting and worth investigation, because there is a similar period in the velocity of the centres of anticyclones. The following expression for the annual variation of this velocity in m/s (metres per second) in America has been deduced from results given by Herrmann* :—

$$V = 11.4 + 1.30 \sin (nt + 68^\circ) + 0.12 \sin (2nt + 138^\circ) \\ + 0.31 \sin (3nt + 18^\circ) + 0.09 \sin (4nt + 78^\circ).$$

Here the third component has an amplitude more than double that of the second, and treble that of the fourth, and its phase agrees very nearly with the corresponding term in the variation of temperature. This implies that at the time of year when anticyclones are moving rapidly in America the mean temperature over Berlin is above the normal value.

The velocity of anticyclones in Europe has not been dealt with since 1887 when Brounow† gave results based on ten years' observations. These results give

$$V = 7.7 + 0.32 \sin (nt + 85^\circ) + 0.31 \sin (2nt + 146^\circ) \\ + 0.76 \sin (3nt + 216^\circ) + 0.56 \sin (4nt + 178^\circ).$$

The number of observations was considerably less than that used by Herrmann, but the third component is still greater than the second and fourth. The phase is nearly opposite to that for America. This implies that in rapidly moving anticyclones the mean temperature up to 3 km. is below the normal. The result may be compared with Hanzlik's deduction that a rapidly moving anticyclone remains cold.

TABLE VIII.—NUMBER OF OBSERVATIONS (see Table VI.), BERLIN AND LINDENBERG.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1903-1907.												
m.												
Surface	155	141	155	150	155	150	155	155	150	155	150	155
500	155	139	154	150	155	150	155	155	150	155	150	154
1000	146	133	150	146	154	150	151	152	148	152	147	150
1500	115	98	110	122	132	128	134	132	129	134	124	120
2000	79	73	76	89	97	100	91	111	109	112	94	83
2500	49	48	48	57	67	71	66	85	85	84	77	60
3000	24	29	29	30	39	55	50	55	65	60	55	36
1908-1910.												
m.												
Surface	92	84	93	88	90	89	93	92	87	93	90	91
500	92	83	92	88	90	89	92	92	87	93	90	91
1000	88	81	87	85	86	85	90	92	84	91	88	89
1500	72	61	82	77	74	82	75	85	78	87	78	82
2000	46	52	68	63	56	67	63	73	68	79	64	68
2500	34	38	50	49	40	48	51	52	55	66	45	57
3000	25	29	42	31	29	26	35	33	33	50	30	44

Tables IX., X., and XI. show (1) the mean monthly temperatures at each kilometre from the surface up to 15 km.; (2) the mean monthly gradients of temperature; (3) the seasonal values of the gradients and of the temperature for the four periods (I.)

* *Monthly Weather Review*, April 1907.

† *Repertorium für Meteorologie*, 1887.

February, March, April; (II.) May, June, July; (III.) August, September, October; (IV.) November, December, January. The values are given for the twelve stations separately, and for the two groups: (A.) Berlin, Strassburg, Munich, Vienna; (B.) Paris, Hamburg, Uccle, England.

Dealing first with the separate stations, it is to be noted that the values, being the means of the results for ascents on slightly varying dates, refer to the 5th of each month nearly.

(1) *Berlin*.—The maximum temperature occurs in August up to 3 km., above which it changes to June, but this is probably an accidental feature. Above 10 km. it occurs in September. The minimum temperature occurs in January up to 2 km., in March from 3–9 km., and in January from 10–13 km. The maximum seasonal value of the gradient is that from 6–7 km. in period IV., but the value from 8–9 km. in period II. is nearly equally great.

(2) *Munich*.—The maximum temperature occurs in June up to 3 km., in October from 4–10 km., except at 6 km., and in September above 10 km. The minimum occurs in March from 3–9 km., when it changes to January and December. The month of maximum temperature varies considerably, which is probably accidental. Period I. is the coldest up to 10 km., and III. the warmest up to 12 km. Above 10 km. period IV. becomes the coldest, and above 12 km. period I. the warmest. The gradient from 3–7 km. is considerably less in periods II. and III. than in I. and IV. The maximum seasonal value occurs in period II. from 9–10 km.

(3) *Strassburg*.—The maximum temperature occurs in August up to 9 km., changes to September at 10, 11, and 12 km., and to July at greater heights. The minimum temperature changes from January at the surface to February at 1 km., to March from 2–8 km., to January at 9 and 10 km., to February at 11 and 12 km., and to December at 13–15 km. Period I. is the coldest up to 9 km., and III. the warmest up to 12 km. Above 9 km. period IV. becomes the coldest, and above 12 km. period II. the warmest. Up to 8 km. the rise of temperature from I. to II. is greater than the fall from III. to IV., but at higher levels this is reversed. Thus while temperature rises more rapidly than it falls in the lower layers it falls more rapidly than it rises in the upper layers. The gradient from 3–7 km. is considerably less in periods II. and III. than in periods I. and IV. The maximum seasonal value of the gradient occurs in period II. from 7–9 km., but the values between 6 and 8 km. in period IV. are nearly equally great.

(4) *Vienna*.—The maximum temperature, as at Munich, occurs in June up to 4 km., in August from 5–7 km., in October at 8 and 9 km., and in September above 9 km. The minimum is in January up to 3 km., in March from 4–8 km., and in April above 8 km. Period IV. is the coldest up to 9 km., except at 2 km., and period III. the warmest up to 13 km., except at 2 km. Above 9 km. period I. becomes the coldest, and at 14 km. period II. the warmest. The seasonal values of the gradient are greater in I. and IV. than in II. and III. from 3 to 6 km. The maximum seasonal value occurs in period I. from 7–8 km.

(5) *England*.—The maximum temperature occurs in October up to 9–10 km., in November and July above this level. The minimum temperatures occur in April from 1–3 km., in December from 4–8 km., and in April and February for higher levels. Period I. is the coldest up to 14 km., except at 7 km., and period III. the warmest up to 11 km., above which period II. becomes the warmest. The gradient

TABLE IX.—MEAN MONTHLY TEMPERATURES, BERLIN (120 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	n 68° 6	72° 7 6	72° 3 4	78° 8 6	84° 4 9	87° 6 7	88° 6 7	x 89° 7 16	84° 9 7	82° 8 12	74° 8 9	76° 1 7	80° 1
1	n 67° 8 6	70° 5 6	70° 5 4	75° 0 6	80° 4 9	82° 9 7	83° 3 7	x 83° 6 16	80° 1 7	79° 7 12	74° 0 9	73° 9 7	76° 8
2	n 64° 2 6	68° 0 6	64° 5 4	69° 0 6	73° 8 9	78° 1 7	76° 3 7	x 77° 5 16	74° 0 7	75° 3 12	69° 3 9	70° 6 7	71° 7
3	59° 7 6	64° 0 6	n 58° 0 4	64° 0 6	69° 4 9	x 73° 4 7	71° 3 7	x 73° 4 16	69° 1 7	70° 9 12	64° 8 9	65° 3 7	66° 9
4	53° 3 6	57° 7 6	n 51° 8 4	58° 0 6	63° 4 9	x 68° 0 7	65° 6 7	67° 7 16	63° 3 7	65° 1 12	58° 9 9	58° 7 7	61° 0
5	48° 7 6	51° 3 6	n 44° 3 4	51° 0 6	57° 6 9	x 62° 4 7	60° 3 7	61° 7 16	57° 6 7	58° 3 12	52° 0 9	52° 0 7	54° 8
6	41° 8 6	44° 3 6	n 37° 0 4	43° 8 6	50° 9 9	x 56° 4 7	53° 6 7	55° 3 16	51° 6 7	51° 2 12	44° 3 9	44° 1 7	47° 9
7	34° 3 6	36° 7 6	n 29° 5 4	36° 0 6	43° 7 9	x 49° 4 7	45° 9 7	48° 3 16	44° 7 7	44° 5 12	35° 8 9	35° 9 7	40° 8
8	26° 5 6	28° 8 6	n 22° 8 4	29° 3 6	36° 7 9	x 42° 3 7	37° 9 7	40° 2 16	37° 4 7	38° 2 12	28° 6 9	27° 9 7	33° 1
9	19° 3 6	23° 0 6	n 19° 0 4	24° 3 6	29° 4 9	x 34° 3 7	29° 6 7	32° 1 15	31° 9 7	32° 2 12	24° 4 9	22° 5 6	26° 8
10	n 15° 2 5	20° 3 3	17° 8 4	20° 2 5	22° 9 9	x 26° 9 7	21° 0 7	24° 5 15	28° 1 7	26° 5 12	21° 1 8	17° 8 5	21° 9
11	n 12° 0 3	15° 0 2	21° 0 2	19° 5 4	18° 1 9	21° 2 6	18° 9 7	20° 4 14	x 26° 6 7	22° 1 11	18° 3 8	17° 0 5	19° 2
12	n 11° 7 3	12° 5 2	21° 0 2	16° 7 3	17° 2 9	17° 0 6	21° 7 7	21° 5 11	x 27° 7 7	19° 4 11	16° 4 8	16° 4 5	18° 3
13	n 14° 0 1	...	25° 0 1	14° 7 3	18° 9 8	17° 4 5	22° 5 4	21° 9 9	x 26° 9 7	19° 1 11	15° 9 7	16° 3 3	19° 3
14	14° 0 1	...	...	n 10° 5 2	21° 5 6	18° 5 4	23° 7 3	22° 9 7	x 25° 8 6	18° 8 9	15° 0 6	16° 7 3	18° 7
15	13° 0 1	...	...	n 8° 0 2	21° 6 5	15° 5 2	23° 3 3	22° 0 5	x 24° 0 2	22° 3 6	14° 2 5	16° 0 2	17° 9
16	...	...	...	16° 0 1	19° 0 1	17° 0 1	27° 0 1	21° 0 3	...	13° 0 2	n 12° 0 1	16° 0 1	17° 6

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	19° 3	23° 0	n 19° 0	24° 3	29° 4	x 34° 3	29° 6	32° 1	31° 9	32° 2	24° 4	21° 1	26° 7
10	n 14° 1	18° 7	17° 8	19° 5	22° 9	26° 9	21° 0	24° 5	x 28° 1	26° 5	20° 4	18° 5	21° 6
11	n 10° 1	13° 7	16° 3	17° 5	18° 1	19° 7	18° 9	20° 7	x 26° 6	22° 0	17° 6	17° 7	18° 2
12	n 9° 8	11° 2	16° 3	16° 8	17° 2	15° 5	21° 7	21° 4	x 27° 7	24° 7	15° 7	17° 1	17° 9
13	n 12° 8	...	16° 3	14° 8	19° 5	14° 9	24° 5	22° 5	x 26° 9	24° 4	15° 7	17° 8	19° 1
14	12° 8	...	...	n 10° 8	20° 8	16° 9	24° 2	23° 9	x 26° 4	24° 2	16° 2	18° 2	19° 4
15	11° 8	...	...	n 8° 3	21° 0	17° 4	23° 8	23° 7	x 25° 9	23° 9	17° 6	17° 2	19° 1
16	...	...	...	6° 3	20° 0	18° 4	24° 4	24° 3	...	22° 4	18° 6	16° 2	18° 8

MEAN MONTHLY TEMPERATURES, MUNICH (516 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	n 66° 9 7	68° 4 5	74° 0 4	79° 8 4	84° 0 8	x 90° 3 6	88° 0 4	89° 2 18	85° 6 5	83° 5 8	76° 5 6	73° 1 8	79° 9
1	69° 6 7	n 66° 8 5	71° 8 4	77° 8 4	82° 5 8	x 88° 0 6	85° 3 4	86° 1 18	83° 0 5	84° 4 8	78° 8 6	74° 3 8	79° 0
2	67° 7 7	n 66° 2 5	66° 5 4	71° 8 4	77° 1 8	x 83° 2 6	79° 8 4	81° 5 18	76° 6 5	80° 5 8	73° 8 6	68° 5 8	74° 4
3	63° 4 7	62° 2 5	n 60° 0 4	64° 8 4	72° 1 8	x 76° 9 6	72° 8 4	75° 6 18	70° 8 5	75° 9 8	67° 5 6	63° 3 8	68° 8
4	58° 3 7	56° 6 5	n 52° 3 4	58° 0 4	65° 8 8	70° 3 6	67° 5 4	70° 1 18	65° 0 5	x 70° 6 8	60° 8 6	57° 3 8	62° 7
5	52° 1 7	50° 2 5	n 46° 0 4	52° 0 4	59° 1 8	64° 0 6	62° 8 4	64° 7 18	59° 8 5	x 65° 1 8	53° 5 6	50° 1 8	56° 6
6	45° 1 7	43° 8 5	n 38° 5 4	44° 5 4	52° 8 8	57° 5 6	55° 5 4	x 58° 9 18	54° 8 5	58° 8 8	46° 0 6	42° 8 8	49° 9
7	37° 6 7	36° 8 5	n 30° 8 4	36° 3 4	45° 6 8	50° 7 6	49° 3 4	52° 0 18	48° 2 5	x 52° 4 8	39° 7 6	35° 0 8	42° 9
8	29° 4 7	29° 2 5	n 23° 3 4	28° 3 4	39° 1 8	43° 0 6	41° 3 4	44° 7 18	41° 0 5	x 45° 5 8	34° 5 6	28° 5 8	35° 7
9	21° 3 7	23° 8 5	n 17° 7 3	24° 6 4	32° 1 8	35° 0 6	33° 8 4	37° 2 18	33° 6 5	x 38° 0 7	29° 8 6	22° 3 8	29° 1
10	n 15° 4 7	20° 2 5	18° 3 3	22° 0 4	25° 6 7	26° 8 6	25° 0 4	28° 5 18	27° 6 5	x 30° 6 7	26° 0 6	19° 5 8	23° 8
11	n 13° 4 5	18° 0 5	19° 0 2	17° 4 3	20° 7 7	21° 2 5	20° 0 4	22° 7 18	x 25° 2 5	23° 3 7	21° 3 6	17° 2 6	20° 0
12	16° 4 5	8° 0 1	20° 0 2	17° 7 3	17° 7 7	16° 8 4	17° 3 3	19° 9 15	x 24° 3 3	17° 6 7	17° 5 4	n 13° 2 5	17° 2
13	16° 6 5	18° 0 1	20° 0 1	16° 0 1	19° 2 5	19° 0 4	21° 0 2	20° 8 10	x 25° 0 2	13° 8 6	18° 0 3	n 10° 8 4	18° 2
14	13° 5 2	20° 0 1	...	18° 0 1	20° 0 4	22° 0 2	21° 0 1	21° 1 8	x 27° 0 1	n 11° 8 5	21° 0 2	n 12° 5 2	17° 3
15	...	17° 0 1	...	19° 0 1	22° 0 3	23° 0 1	21° 0 1	21° 3 4	x 25° 0 1	n 14° 0 3	20° 0 2	16° 0 1	19° 8
16	...	...	...	18° 0 1	22° 5 2	...	...	...	x 23° 0 1	16° 0 1	...	...	19° 9

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	21° 3	23° 8	n 19° 5	24° 6	32° 1	35° 0	33° 8	37° 2	33° 6	x 38° 2	29° 8	22° 3	29° 3
10	n 15° 4	20° 2	20° 1	22° 0	25° 3	26° 8	25° 0	28° 5	27° 6	x 30° 8	26° 0	19° 5	23° 9
11	n 14° 1	18° 0	21° 9	19° 4	20° 4	20° 3	20° 0	22° 7	x 25° 2	23° 5	21° 3	17° 2	20° 3
12	17° 1	15° 5	x 22° 9	19° 7	17° 4	16° 0	16° 3	19° 2	22° 3	17° 8	18° 2	n 13° 6	18° 0
13	17° 3	x 25° 4	23° 3	22° 6	19° 2	18° 2	21° 5	20° 3	22° 6	21° 6	16° 1	n 13° 2	20° 1
14	17° 0	x 27° 8	...	24° 6	21° 9	18° 6	20° 5	20° 8	21° 7	20° 5	16° 0	n 12° 6	20° 2
15	...	24° 8	...	x 25° 6	22° 3	16° 9	20° 5	20° 7	19° 7	21° 3	15° 0	n 10° 6	19° 7
16	...	...	...	24° 6	22° 4	...	...	...	17° 7	22° 1	...	...	21° 7

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, STRASSBURG (140 m.).
Temperature (T) in Degrees A. ($200^{\circ}+$), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	n 71°0 10	71°2 5	75°0 5	80°0 8	82°4 7	89°1 9	87°9 9	x 90°4 13	87°0 10	86°2 10	78°0 7	77°8 6	81°3
1	70°4 10	n 69°2 5	70°4 5	75°9 8	76°7 7	85°1 9	83°4 9	x 88°8 13	81°7 10	83°1 10	77°3 7	76°2 6	78°2
2	67°8 10	69°4 5	n 63°8 5	68°4 8	73°1 7	78°7 9	77°7 9	x 82°5 13	77°1 10	80°0 10	75°6 7	71°7 6	73°8
3	63°7 10	65°0 5	n 57°8 5	63°3 8	68°4 7	73°3 9	73°0 9	x 76°7 13	70°2 10	74°0 10	69°6 7	65°8 6	68°4
4	57°7 10	58°8 5	n 51°2 5	58°1 8	63°1 7	67°1 9	67°1 9	x 71°5 13	65°0 10	67°6 10	63°3 7	59°5 6	62°6
5	50°4 10	51°6 5	n 44°0 5	51°4 8	56°6 7	61°4 9	60°3 9	x 65°8 13	59°5 10	61°4 10	57°0 7	53°3 6	56°1
6	43°2 10	43°6 5	n 36°6 5	44°5 8	50°0 7	54°8 9	53°7 9	x 59°8 13	53°8 10	54°7 10	50°9 7	46°5 6	49°3
7	35°6 10	35°8 5	n 29°6 5	37°3 8	43°4 7	47°9 9	46°2 9	x 52°5 13	47°0 10	47°4 10	43°1 7	39°0 6	42°1
8	27°6 10	27°8 5	n 24°0 5	30°1 8	36°0 7	40°2 9	39°0 8	x 44°9 13	39°9 10	40°2 10	35°1 7	32°3 6	34°8
9	n 20°2 9	21°8 5	20°6 5	24°9 8	28°1 7	31°8 9	31°6 8	x 36°6 13	34°0 10	31°8 9	27°3 6	24°8 5	27°8
10	n 14°8 9	16°3 4	19°0 4	20°8 6	22°1 7	24°0 9	25°9 8	29°2 12	x 29°4 10	25°6 9	21°0 6	19°3 4	22°3
11	12°8 9	n 10°3 3	19°3 4	19°4 5	15°0 6	19°0 9	22°1 8	22°4 12	x 26°6 10	20°2 9	16°5 6	13°3 4	18°1
12	13°0 6	n 7°0 3	19°0 2	19°2 5	16°4 5	17°0 8	23°7 7	19°4 10	x 25°1 8	16°7 9	14°3 6	10°3 4	16°8
13	15°2 6	12°0 2	20°5 2	23°0 4	18°6 5	20°0 7	x 24°3 7	18°9 10	23°3 7	15°0 9	12°5 6	n 7°5 4	17°6
14	17°4 5	13°5 2	19°5 2	22°3 3	21°5 2	18°7 6	x 24°7 3	18°0 10	22°6 7	13°8 8	14°5 6	n 8°5 4	17°9
15	18°0 1	15°0 1	21°0 2	26°0 1	22°0 1	16°6 5	x 25°0 3	17°8 8	21°7 6	11°3 4	14°0 6	n 9°8 4	18°2
16	...	...	...	...	...	16°0 1	24°5 2	20°0 1	24°0 1	16°0 1	...	...	20°1

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	n 20°2	21°8	20°6	24°9	28°1	31°8	31°6	x 36°6	34°0	32°6	27°8	25°7	28°0
10	n 14°8	15°8	19°6	20°4	22°1	24°0	25°9	29°0	x 29°4	26°4	21°5	18°7	22°3
11	12°8	n 8°8	19°9	17°6	16°1	19°0	22°1	22°2	x 26°6	21°0	17°0	12°7	18°0
12	12°9	n 5°5	20°4	17°4	17°3	17°6	22°7	19°0	x 24°1	17°5	14°8	9°7	16°6
13	15°1	11°0	21°9	20°4	19°5	20°2	23°3	18°5	x 22°8	15°8	13°0	n 6°9	17°4
14	14°9	12°5	20°9	19°4	21°0	20°0	23°0	17°6	x 22°1	14°4	15°0	n 7°9	17°4
15	14°9	13°5	22°4	17°4	x 24°0	19°8	23°3	18°3	21°8	14°2	14°5	n 9°2	17°8
16	...	...	...	...	...	19°8	22°8	19°3	21°8	14°2	...	...	19°6

MEAN MONTHLY TEMPERATURES, VIENNA (190 m.).

Temperature (T) in Degrees A. ($200^{\circ}+$), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	n 69°3 7	72°9 7	75°1 7	77°0 6	83°1 7	90°5 4	88°5 4	x 92°4 8	87°3 4	84°4 8	77°0 5	74°4 9	81°0
1	n 68°4 7	71°7 7	72°7 7	72°3 6	77°7 7	x 87°5 4	83°5 4	86°8 8	80°3 4	81°8 8	74°8 5	73°2 9	77°6
2	n 66°3 7	68°4 7	68°1 7	69°0 6	72°9 7	x 82°3 4	76°5 4	79°6 8	73°3 4	77°6 8	71°2 5	70°3 9	73°0
3	n 61°9 7	64°0 7	62°1 7	65°2 6	68°1 7	x 75°0 4	70°0 4	74°0 8	68°0 4	73°3 8	64°8 5	64°3 9	67°6
4	56°7 7	58°3 7	n 56°3 7	59°3 6	62°4 7	x 69°8 4	64°8 4	69°1 8	63°0 4	68°1 8	57°6 5	57°7 9	61°9
5	50°0 7	52°6 7	n 49°3 7	52°3 6	56°4 7	63°0 4	58°8 4	x 63°4 8	57°8 4	62°3 8	50°4 5	50°4 9	55°6
6	42°9 7	46°7 7	n 42°0 7	44°8 6	49°1 7	56°0 4	52°5 4	x 57°1 8	51°3 4	57°0 8	43°2 5	43°0 9	48°8
7	34°6 7	39°0 7	n 34°4 7	37°2 6	40°7 7	47°8 4	44°5 4	x 50°9 8	44°3 4	50°5 8	35°8 5	34°8 9	41°2
8	26°7 7	31°4 7	n 26°1 7	27°7 6	33°0 7	40°5 4	37°8 4	42°4 8	37°0 4	x 43°0 8	30°0 5	27°3 9	33°6
9	20°4 7	25°8 5	22°5 6	n 18°4 5	25°9 7	32°0 4	30°8 4	34°6 7	31°5 4	x 35°4 8	25°0 5	20°7 9	26°9
10	14°8 6	19°8 4	19°3 6	n 14°2 5	22°6 5	24°0 4	22°8 4	26°7 7	x 28°0 4	x 28°0 8	24°5 4	17°2 9	21°8
11	15°0 5	16°8 4	17°3 4	n 11°7 3	19°0 4	15°7 3	21°5 4	21°1 7	x 25°8 4	21°4 7	21°0 4	15°0 7	18°4
12	18°3 3	19°5 4	18°0 2	n 11°5 2	16°5 4	9°5 2	25°3 3	22°0 7	x 26°0 3	17°1 7	21°3 4	14°2 6	18°3
13	20°5 2	21°0 3	20°5 2	17°0 1	16°0 2	19°0 2	25°0 3	22°9 7	x 26°3 3	13°0 6	19°5 4	n 14°5 4	19°6
14	18°0 1	19°7 3	...	16°0 1	18°0 1	19°0 2	25°7 3	23°6 7	x 27°0 2	n 12°6 5	22°0 3	14°5 4	19°6
15	19°0 1	18°3 3	...	...	18°0 1	19°0 2	25°7 3	24°4 7	x 26°0 2	n 14°2 5	22°0 3	14°8 4	20°1
16	...	n 14°0 1	...	...	19°0 1	18°0 2	x 27°0 1	24°6 5	x 27°0 1	19°0 1	20°0 1	15°0 2	20°4

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	20°4	24°4	22°6	n 19°5	25°9	32°0	30°8	34°0	31°5	x 35°4	25°0	20°7	26°9
10	15°6	17°4	19°4	n 15°3	20°3	24°0	22°8	26°1	x 28°0	x 28°0	20°5	17°2	21°2
11	15°6	14°4	19°2	n 10°6	15°3	15°7	21°5	20°5	x 25°8	21°6	17°0	16°1	17°8
12	16°2	17°1	21°7	n 7°6	12°8	9°2	24°8	21°4	x 26°8	17°3	17°3	15°6	17°3
13	18°7	17°1	24°2	n 8°6	10°8	18°7	24°5	22°3	x 27°1	14°1	15°5	16°1	18°1
14	16°7	15°8	...	n 7°6	20°8	18°7	25°2	23°0	x 25°6	14°5	17°8	16°1	18°3
15	17°7	n 14°4	...	...	20°8	18°7	x 25°2	23°8	24°6	16°1	17°8	16°4	19°6
16	...	14°4	...	...	21°8	17°7	25°2	24°2	24°6	18°1	14°8	17°9	19°9

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, BERLIN, MUNICH, STRASSBURG, AND VIENNA.
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	n 69°0 30	71°5 23	74°3 20	79°1 24	83°6 31	89°3 26	88°3 24	x 90°1 55	86°2 26	84°2 38	76°4 27	75°1 30	80°3
1	n 69°2 30	69°8 23	71°5 20	75°1 24	79°5 31	85°5 26	83°7 24	x 86°1 55	81°3 26	82°0 38	76°1 27	74°2 30	77°9
2	66°7 30	68°0 23	n 66°0 20	69°3 24	74°3 31	80°1 26	77°4 24	x 80°5 55	75°6 26	78°1 38	72°3 27	70°2 30	73°2
3	62°4 30	63°8 23	n 59°8 20	64°2 24	69°6 31	74°4 26	72°0 24	x 75°0 55	69°7 26	73°3 38	66°6 27	64°6 30	68°0
4	56°7 30	57°9 23	n 53°3 20	58°4 24	63°7 31	68°5 26	66°3 24	x 69°6 55	64°2 26	67°6 38	60°2 27	58°2 30	62°1
5	50°4 30	51°5 23	n 46°3 20	51°6 24	57°5 31	62°5 26	60°0 24	x 63°9 55	58°8 26	61°4 38	53°3 27	51°3 30	55°7
6	43°3 30	44°8 23	n 39°0 20	44°4 24	50°8 31	56°0 26	53°8 24	x 57°8 55	53°0 26	54°9 38	46°2 27	43°9 30	49°0
7	35°6 30	37°2 23	n 31°5 20	36°8 24	43°5 31	48°9 26	46°3 24	x 50°9 55	46°2 26	48°2 38	38°6 27	35°9 30	41°6
8	27°6 30	29°5 23	n 24°7 20	29°0 24	36°3 31	41°5 26	38°8 23	x 43°1 55	39°0 26	41°3 38	31°9 27	28°8 30	34°3
9	n 20°3 29	23°6 21	20°4 18	23°3 23	29°0 31	33°2 26	31°2 23	x 35°3 53	33°0 26	33°9 36	26°5 26	22°3 28	27°7
10	n 15°0 27	19°1 16	18°7 17	19°3 20	23°3 28	25°4 26	23°7 23	27°3 52	x 28°5 26	27°4 36	22°9 24	18°3 26	22°4
11	n 13°3 22	15°6 14	18°8 12	17°5 15	18°2 26	19°6 23	20°7 23	21°8 51	x 26°2 26	21°7 34	19°0 24	15°7 22	19°0
12	14°7 17	n 13°2 10	19°5 8	17°1 13	17°1 25	16°2 20	22°3 20	20°6 43	x 26°0 21	17°8 34	16°9 22	13°7 20	17°9
13	16°4 14	17°5 6	21°2 6	18°8 9	18°6 20	18°9 18	23°7 16	20°9 36	x 25°3 19	15°8 32	15°9 20	n 12°0 15	18°8
14	16°2 9	17°7 6	19°5 2	17°4 7	20°8 13	19°1 14	24°3 10	21°1 32	x 24°6 16	14°9 27	16°8 17	n 12°8 13	18°8
15	16°7 3	17°4 5	21°0 2	15°3 4	21°4 10	17°5 10	x 24°3 10	21°2 24	23°2 11	16°2 18	16°3 16	n 13°3 11	18°7
16	...	...	...	17°0 2	20°8 4	17°3 4	x 25°8 4	22°9 9	24°7 3	15°4 5	16°0 2	15°3 3	19°5

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	n 20°3	23°5	21°1	23°4	29°0	33°2	31°2	x 35°1	33°0	34°3	26°7	22°3	27°8
10	n 14°9	18°3	19°6	19°3	22°7	25°4	23°7	27°1	x 28°5	27°8	22°1	19°5	22°4
11	n 13°2	14°4	19°7	16°4	17°6	19°1	20°7	21°6	x 26°2	22°1	18°3	17°2	18°9
12	14°3	n 13°7	20°7	15°8	16°3	15°8	19°6	20°0	x 25°3	18°2	16°5	15°4	17°6
13	15°9	17°2	22°1	16°9	17°9	18°2	21°2	20°6	x 24°6	17°7	15°3	n 14°8	18°5
14	15°5	17°5	21°1	15°5	20°1	18°6	21°1	20°9	x 23°9	17°1	16°6	n 15°1	18°6
15	15°5	16°3	22°6	14°0	20°6	18°5	21°1	21°3	x 23°3	17°5	16°7	n 15°3	18°6
16	...	16°3	...	12°5	20°6	18°2	21°1	21°8	x 22°6	17°5	15°7	16°0	18°2

MEAN MONTHLY TEMPERATURES, ENGLAND (150 m., 165 m., and 30 m.).

Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	76°4 12	n 75°0 8	78°3 10	79°4 10	84°9 14	86°8 18	87°3 7	x 88°7 18	85°8 27	88°1 7	80°1 8	75°7 14	82°2
1	73°9 13	75°0 8	71°5 11	n 71°4 11	81°2 14	82°7 18	81°7 7	83°8 20	81°8 27	x 85°6 10	75°1 9	70°8 14	77°9
2	70°3 13	70°5 8	67°8 11	n 66°1 11	76°1 14	77°6 18	77°1 7	78°9 20	77°1 27	x 81°3 10	70°7 9	66°4 14	73°3
3	65°1 13	65°4 8	62°2 11	n 60°2 11	70°6 14	72°3 18	71°3 7	74°4 20	71°8 27	x 75°5 10	65°2 9	60°7 14	67°9
4	59°0 13	59°4 8	55°8 11	53°8 11	65°1 13	66°6 18	65°6 7	69°5 20	65°8 27	x 69°8 10	59°3 9	n 53°6 14	61°9
5	52°5 13	52°6 8	49°6 11	46°8 11	58°2 13	60°1 18	59°7 7	63°4 20	59°7 27	x 63°7 10	52°6 9	n 45°9 14	55°4
6	46°5 13	45°8 8	42°7 11	39°7 11	51°8 13	53°2 18	52°6 7	56°6 20	53°1 27	x 56°9 10	44°2 9	n 38°4 14	48°5
7	40°0 13	38°8 8	36°2 11	33°1 11	43°4 14	45°5 18	45°9 7	49°5 20	46°0 27	x 49°8 10	36°7 9	n 30°9 14	41°3
8	33°5 13	31°5 8	29°7 11	27°6 11	35°5 14	37°4 18	38°4 7	42°4 20	38°3 27	x 42°5 10	31°9 9	n 25°4 14	34°5
9	27°0 13	25°3 8	24°9 11	n 22°5 11	28°2 14	29°1 18	31°7 7	35°0 20	31°4 27	x 35°4 10	29°3 9	22°7 14	28°5
10	21°1 13	n 19°8 8	20°5 11	21°0 11	20°9 14	21°8 18	x 27°6 7	27°5 20	25°4 27	x 27°6 10	26°5 8	20°8 14	23°4
11	17°3 12	n 15°5 8	17°7 10	20°8 11	18°4 14	17°1 18	x 25°7 7	21°5 20	21°6 26	21°2 9	24°9 8	19°3 14	20°1
12	15°3 9	n 14°6 7	19°3 8	23°1 9	18°1 14	17°2 17	x 26°0 7	19°9 19	21°2 26	17°0 9	24°0 8	18°4 12	19°5
13	14°7 9	n 13°0 4	21°9 7	22°6 9	18°4 14	19°4 17	x 26°2 6	21°3 19	20°9 26	13°4 9	23°5 8	19°0 10	19°5
14	14°9 9	12°8 4	23°5 6	20°6 9	18°6 12	20°3 15	x 26°7 6	22°1 16	21°4 25	n 11°7 9	20°4 7	18°8 8	19°3
15	16°4 5	17°0 3	25°8 4	...	20°1 7	22°3 11	x 25°0 5	23°7 13	21°1 16	n 11°2 6	20°4 5	16°8 5	20°0
16	18°0 2	17°0 3	22°3 3	...	22°7 3	22°3 11	x 25°0 5	24°1 9	22°1 16	n 10°5 2	20°3 3	18°3 4	20°2

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	27°0	25°3	24°9	n 22°5	28°2	29°1	31°7	35°0	31°4	x 35°4	29°3	22°7	28°5
10	21°1	n 19°8	20°5	21°0	20°9	21°8	x 27°6	27°5	25°4	x 27°6	26°8	20°8	23°4
11	17°3	n 15°5	18°3	20°8	18°4	17°1	22°7	21°5	21°4	21°2	x 25°2	19°3	19°9
12	15°1	n 13°7	19°5	21°1	18°1	17°0	23°0	20°1	21°0	17°0	x 24°3	18°7	19°1
13	14°5	n 13°1	22°0	20°6	18°4	19°2	23°3	21°5	20°7	13°4	x 23°8	19°5	19°2
14	14°7	12°9	22°9	18°6	18°9	19°7	x 23°8	22°1	21°1	n 11°7	22°8	19°8	19°1
15	15°0	16°5	22°9	...	20°2	20°9	x 23°2	21°8	21°6	n 11°0	22°2	18°9	19°5
16	15°5	16°5	22°4	...	20°5	20°9	x 23°2	22°3	22°6	n 11°0	21°2	18°0	19°5

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, HAMBURG (17 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	73°3 4	72°0 3	n 70°0 2	78°7 3	80°0 2	85°7 6	88°2 6	x 89°8 5	84°8 4	84°6 5	75°5 4	76°0 2	79°9
1	70°8 4	69°0 3	n 65°5 2	71°0 3	73°0 2	80°7 6	81°7 6	82°4 5	77°8 4	x 83°2 5	76°8 4	72°5 2	75°4
2	64°3 4	66°0 3	n 59°0 2	64°0 3	66°5 2	77°5 6	74°7 6	76°6 5	72°3 4	x 81°4 5	74°0 4	68°5 2	70°4
3	58°0 4	59°0 3	n 52°5 2	58°3 3	62°0 2	72°5 6	69°3 6	70°8 5	67°3 4	x 76°6 5	69°3 4	61°5 2	64°8
4	53°6 4	53°3 3	n 45°5 2	52°0 3	58°5 2	67°0 6	63°2 6	65°6 5	60°8 4	x 69°8 5	63°3 4	56°5 2	59°1
5	47°0 4	47°3 3	n 38°5 2	44°3 3	53°5 2	60°2 6	57°3 6	60°0 5	54°0 4	x 63°8 5	56°3 4	49°5 2	52°6
6	39°5 4	41°0 3	n 33°5 2	38°0 3	48°0 2	53°8 6	51°2 6	53°4 5	46°8 4	x 56°8 5	49°3 4	42°5 2	46°2
7	31°8 4	37°0 3	n 28°5 2	33°0 3	40°0 2	47°0 6	44°7 6	46°0 5	39°8 4	x 49°4 5	43°8 4	35°5 2	39°7
8	n 24°8 4	32°0 3	25°0 2	28°7 3	30°0 2	40°2 6	37°7 6	40°2 5	31°8 4	x 42°8 5	38°0 4	30°5 2	33°5
9	n 19°8 4	26°7 3	22°5 2	24°0 3	22°0 2	32°7 6	30°8 6	33°8 5	27°8 4	x 38°0 4	28°0 2	26°0 2	27°7
10	n 17°5 2	18°0 2	24°0 1	n 17°5 2	n 17°5 2	23°8 4	22°8 5	28°5 4	25°5 4	x 30°3 4	21°0 2	23°0 1	22°5
11	18°5 2	n 11°5 2	22°0 1	17°5 2	17°0 2	18°0 4	18°3 3	x 24°8 4	26°3 4	22°8 4	14°5 2	...	19°2
12	21°0 1	n 8°0 1	x 23°0 1	20°0 1	17°5 2	15°7 3	20°0 3	22°5 2	19°5 2	19°5 2	12°5 2	...	18°4
13	19°0 1	16°0 1	23°0 1	...	18°5 2	20°3 3	19°0 1	23°8 4	x 31°0 1	17°5 2	n 14°0 2	...	20°2
14	16°0 1	15°0 1	21°0 1	...	20°0 2	22°3 3	21°0 1	23°0 3	x 30°0 1	15°5 2	n 10°0 1	...	19°4
15	16°0 1	n 13°0 1	23°0 1	...	19°0 1	22°0 3	22°0 1	24°0 3	x 29°0 1	13°5 2	...	...	20°2
16	...	...	...	...	20°0 1	20°5 2	22°0 1	...	29°0 1	12°5 2	...	...	20°8

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.													
9	n 19°8	26°7	22°5	24°0	22°0	32°7	30°8	33°8	27°8	x 35°3	29°5	26°0	27°6
10	18°8	18°7	22°5	18°5	n 17°5	24°4	23°4	x 27°8	25°5	27°6	22°5	25°0	22°7
11	19°8	n 12°2	20°5	18°5	17°0	18°6	18°7	24°1	x 26°3	20°1	16°0	...	19°3
12	18°8	n 13°2	21°5	20°5	17°5	16°3	20°4	21°8	x 26°3	16°6	14°0	...	18°8
13	16°8	21°2	21°5	...	18°5	20°9	24°4	23°1	x 26°3	n 14°6	15°5	...	20°3
14	13°5	20°2	19°5	...	20°0	22°9	x 26°4	24°1	25°3	n 12°6	15°5	...	20°0
15	13°5	18°2	21°5	...	21°0	22°6	x 27°4	25°1	24°3	n 10°6	...	...	20°5
16	...	...	...	...	...	...	27°4	...	24°3	9°6	...	...	20°4

MEAN MONTHLY TEMPERATURES, UCCLE (100 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	n 68°0 4	69°5 2	72°7 3	76°3 3	83°4 5	87°5 2	86°0 4	x 88°6 5	83°5 2	86°8 5	79°5 2	73°0 2	79°6
1	70°5 4	69°0 2	n 68°7 3	73°0 3	78°8 5	84°0 2	80°5 4	85°2 5	77°5 2	x 86°6 5	77°0 2	74°0 2	77°1
2	67°8 4	68°0 2	n 62°0 3	66°0 3	76°0 5	78°0 2	75°8 4	x 82°6 5	74°0 2	82°0 5	75°5 2	68°5 2	73°0
3	63°8 4	66°0 2	n 55°3 3	61°8 3	70°2 5	71°0 2	70°0 4	x 77°8 5	69°0 2	75°8 5	70°0 2	62°5 2	67°8
4	57°8 4	62°0 2	n 47°7 3	55°0 3	65°8 5	68°0 2	65°3 4	x 72°2 5	63°5 2	68°8 5	64°0 2	53°5 2	62°0
5	50°3 4	55°5 2	n 39°7 3	48°3 3	58°6 5	61°0 2	58°8 4	x 67°2 5	58°5 2	62°0 5	58°0 2	45°5 2	55°3
6	43°5 4	50°5 2	n 31°3 3	42°3 3	51°6 5	54°0 2	52°3 4	x 60°2 5	53°5 2	55°8 5	51°0 2	36°5 2	48°5
7	35°5 4	44°0 2	n 24°0 3	35°3 3	44°0 5	47°0 2	44°8 4	x 53°8 5	46°5 2	49°4 5	43°5 2	30°5 2	41°5
8	27°3 4	36°5 2	n 19°7 3	30°0 3	35°8 5	39°5 2	35°8 4	x 45°5 4	39°5 2	41°5 4	35°5 2	26°0 2	34°4
9	20°0 4	30°5 2	n 17°3 3	25°0 3	27°0 5	30°5 2	28°3 4	x 39°3 4	33°0 2	34°0 4	27°0 2	20°5 2	27°7
10	n 14°5 4	22°5 2	17°3 3	21°7 3	21°0 5	22°0 2	21°8 4	x 31°8 4	25°0 2	27°3 4	19°0 2	17°0 2	21°7
11	14°0 4	15°5 2	17°3 3	20°3 3	17°6 5	n 13°5 2	20°8 4	x 25°0 4	17°5 2	20°3 4	14°5 2	14°0 2	17°5
12	12°5 4	18°5 2	17°0 3	21°3 3	15°4 5	n 10°5 2	x 22°5 4	18°5 4	19°0 1	15°8 4	14°0 2	11°5 2	16°4
13	13°8 4	17°0 2	16°0 2	20°3 3	17°3 4	12°5 2	x 22°8 4	16°5 4	12°0 1	18°3 3	12°5 2	n 4°0 1	15°3
14	13°0 3	14°0 2	17°5 2	16°0 3	21°0 3	15°5 2	x 23°5 4	16°8 4	13°0 1	22°5 2	n 8°0 1	...	16°4
15	11°0 1	11°0 2	17°0 2	22°0 3	21°7 3	16°0 1	x 23°5 4	18°5 4	14°0 1	18°0 2	n 8°0 1	...	16°4

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.													
9	20°0	30°5	n 17°3	25°0	27°0	30°5	28°3	x 39°3	33°0	34°0	27°0	20°5	27°7
10	n 14°5	22°5	17°3	21°7	21°0	22°0	21°8	x 31°8	25°0	27°3	19°0	17°0	21°7
11	14°0	15°5	17°3	20°3	17°6	n 13°5	20°8	x 25°0	17°5	20°3	14°5	14°0	17°5
12	12°5	18°5	17°0	21°3	15°4	n 10°5	x 22°6	18°5	20°5	15°8	14°0	11°5	16°5
13	13°5	17°0	16°0	20°3	15°1	n 12°5	x 22°9	16°5	13°5	15°8	n 12°5	14°5	15°8
14	12°7	14°0	17°5	16°0	16°1	15°5	x 23°7	17°0	14°5	16°8	n 8°0	...	15°6
15	10°7	11°0	17°0	17°7	16°8	15°5	x 23°7	18°0	15°5	12°3	n 8°0	...	15°1

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, PARIS (171 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	75°4 11	73°8 8	n 73°3 4	80°2 12	81°4 9	84°8 5	86°9 10	x 88°6 16	84°7 10	83°5 10	77°5 8	78°7 9	80°7
1	73°6 11	71°9 8	n 70°5 4	76°6 12	79°4 9	81°2 5	84°4 10	x 87°7 16	80°7 10	83°0 10	76°6 8	76°7 9	78°5
2	70°1 11	71°6 8	n 64°5 4	71°2 12	74°4 9	76°0 5	79°7 10	x 82°9 16	76°0 10	79°2 10	74°6 8	73°3 9	74°5
3	65°0 11	66°8 8	n 59°0 4	67°4 12	69°8 9	71°2 5	75°2 10	x 78°2 16	70°4 10	75°3 10	70°0 8	69°2 9	69°8
4	59°5 11	61°3 8	n 52°3 4	61°6 12	64°9 9	65°6 5	69°8 10	x 72°9 16	65°8 10	70°2 10	64°5 8	62°8 9	64°3
5	52°3 11	55°0 8	n 44°5 4	55°5 12	58°6 9	60°2 5	64°3 10	x 67°4 16	60°6 10	63°6 10	58°1 8	56°6 9	58°1
6	45°5 11	48°6 8	n 36°8 4	48°7 12	52°0 9	53°0 5	57°9 10	x 61°3 16	53°9 10	56°7 10	51°6 8	50°4 9	51°4
7	37°2 11	42°4 8	n 29°3 4	41°8 12	44°7 9	44°4 5	50°9 10	x 54°3 16	46°4 10	50°1 10	45°5 8	44°1 9	44°3
8	29°1 11	34°1 8	n 24°0 4	34°1 12	36°6 9	38°6 5	42°9 10	x 47°0 16	39°1 9	42°4 10	37°8 8	37°2 9	36°9
9	22°0 11	27°5 8	n 21°3 4	26°3 12	27°1 8	33°6 5	35°1 10	x 40°0 14	32°3 9	34°8 10	29°3 8	30°1 9	30°0
10	n 15°8 11	22°6 8	n 20°3 4	19°5 12	20°5 8	29°8 5	27°4 10	x 31°6 14	29°3 8	28°8 9	22°9 8	23°0 9	24°3
11	n 14°6 10	16°6 7	n 21°4 3	15°6 12	17°5 6	x 29°2 5	23°3 10	23°1 14	24°1 7	21°9 8	18°3 7	17°2 9	20°2
12	n 15°0 6	n 15°0 7	n 23°0 3	16°1 12	18°3 6	x 30°4 5	26°2 9	18°8 13	20°7 7	15°5 6	18°6 5	16°7 7	19°5
13	15°3 4	16°2 6	n 20°5 2	16°7 7	18°4 5	x 32°5 2	27°7 7	19°4 13	16°8 5	n 12°7 6	16°8 5	18°5 6	19°3
14	17°0 2	17°0 3	16°0 1	19°0 4	19°5 4	x 29°0 1	28°7 3	20°3 9	18°0 5	n 11°3 6	17°8 4	15°6 5	19°1
15	...	17°5 2	15°0 1	20°0 2	16°5 2	x 29°0 1	28°0 3	20°8 5	18°5 2	n 11°8 5	18°8 4	12°5 4	18°9
16	...	...	...	17°0 1	19°0 1	...	23°0 1	...	...	14°0 1	6°0 1	19°0 1	16°3

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	22°0	27°5	n 21°3	26°3	27°8	33°6	35°1	x 39°1	32°3	34°8	29°3	30°1	29°9
10	n 15°8	22°6	20°3	19°5	21°2	29°8	27°4	x 30°7	29°4	27°2	22°9	23°0	24°2
11	n 14°5	16°6	19°6	15°6	18°2	x 29°2	23°3	22°7	24°1	20°7	18°6	17°2	20°0
12	16°3	n 15°0	21°2	16°1	19°0	x 30°4	25°8	18°4	20°7	n 15°0	17°8	15°2	19°2
13	16°3	14°4	19°7	17°1	21°0	x 30°4	26°5	19°0	20°9	n 12°2	16°0	14°7	19°0
14	14°8	14°1	19°7	18°1	23°0	x 29°4	26°5	19°7	22°1	n 10°8	16°2	13°1	19°0
15	...	14°1	18°7	17°6	22°5	x 29°4	25°8	19°7	23°1	11°6	17°2	n 11°3	19°2
16	...	...	...	16°6	22°5	...	25°8	...	...	n 11°6	15°2	13°3	17°5

MEAN MONTHLY TEMPERATURES, ENGLAND, HAMBURG, PARIS, AND UCCLE.
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	74°5 31	n 73°6 21	75°5 19	79°3 28	83°3 30	86°3 31	87°1 27	x 88°8 44	85°3 43	85°5 27	78°3 22	76°5 27	81°2
1	73°0 32	72°4 21	n 70°3 20	73°7 29	79°7 30	82°1 31	82°5 27	x 85°2 46	81°0 43	84°5 30	76°1 23	73°1 27	77°8
2	69°2 32	70°0 21	n 65°4 20	68°0 29	75°0 30	77°3 31	77°3 27	80°4 46	76°3 43	x 80°7 30	73°0 23	69°0 27	73°4
3	64°0 32	65°0 21	n 59°6 20	63°1 29	69°7 30	72°1 31	72°1 27	x 75°7 46	70°9 43	x 75°7 30	68°0 23	63°7 27	68°3
4	58°3 32	59°5 21	n 52°9 20	56°9 29	64°7 29	66°6 31	66°6 27	x 70°5 46	65°2 43	69°8 30	62°2 23	56°9 27	62°5
5	51°5 32	53°0 21	n 46°0 20	50°3 29	58°1 29	60°2 31	60°7 27	x 64°8 46	59°3 43	63°4 30	55°6 23	49°7 27	56°0
6	44°9 32	46°6 21	n 38°9 20	43°5 29	51°6 29	53°3 31	54°2 27	x 58°3 46	52°7 43	56°6 30	48°3 23	42°6 27	49°3
7	38°3 32	40°4 21	n 32°2 20	36°9 29	43°7 30	46°0 31	47°3 27	x 51°2 46	45°5 43	49°8 30	41°6 23	35°6 27	42°4
8	30°1 32	33°0 21	n 26°6 20	30°7 29	35°5 30	38°3 31	39°5 27	x 44°0 45	37°9 42	42°4 29	35°3 23	29°7 27	35°3
9	23°5 32	26°8 21	n 22°8 20	24°5 29	27°0 29	30°6 31	32°3 27	x 36°9 43	31°3 42	35°4 28	29°0 21	25°3 27	28°8
10	n 18°0 30	21°0 20	n 20°2 19	20°0 28	20°6 29	23°4 29	25°7 26	29°2 42	25°9 41	x 29°4 26	19°5 20	20°3 26	22°8
11	16°0 28	n 15°5 19	18°6 17	18°3 28	18°0 27	19°1 29	x 23°0 24	22°7 42	22°3 39	21°5 25	20°3 19	18°5 25	19°5
12	15°0 20	n 14°8 17	19°8 15	15°4 25	17°6 27	19°0 27	x 24°7 23	19°7 40	21°1 36	16°6 21	19°9 17	17°2 21	18°4
13	n 14°8 18	15°3 13	20°8 12	20°1 19	18°2 25	20°0 24	x 25°6 18	20°4 40	20°3 33	14°4 20	19°1 17	17°9 17	18°9
14	14°9 15	n 14°5 10	21°3 10	19°3 16	19°2 21	20°6 21	x 25°8 14	21°0 32	20°9 32	12°0 19	17°8 13	17°5 13	18°7
15	15°6 7	15°1 8	21°9 8	21°2 5	19°8 13	22°3 16	x 25°0 13	22°3 25	21°7 20	12°6 15	18°5 10	n 14°9 9	19°2
16	18°0 2	17°0 3	22°3 3	17°0 1	21°4 5	22°0 13	x 24°3 7	24°1 9	22°5 17	12°0 5	16°8 4	18°4 5	19°7

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	23°5	26°8	n 22°8	24°5	27°5	30°6	32°3	x 36°7	31°3	35°0	29°3	25°2	28°8
10	n 17°9	21°0	20°0	20°2	21°1	23°7	25°8	x 29°3	26°0	27°2	24°2	21°4	23°2
11	n 15°8	16°2	18°5	18°5	18°5	19°4	x 22°8	x 22°8	22°1	20°5	20°8	18°2	19°5
12	n 14°7	15°2	19°5	19°0	18°1	19°1	x 24°4	20°0	21°0	15°9	19°8	17°0	18°6
13	n 14°5	15°1	19°6	19°0	18°7	21°4	x 25°1	20°7	20°6	14°6	19°8	17°1	18°9
14	n 14°1	14°2	20°2	17°3	19°7	22°3	x 25°7	21°4	21°1	13°2	19°0	16°7	18°7
15	n 14°0	14°6	20°2	18°1	20°6	23°1	x 25°4	21°5	21°6	12°3	19°1	15°4	18°8

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, PAVLOVSK (30 m.).
Temperature (T) in Degrees A. ($200^{\circ}+$), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	65°8 4	65°0 2	67°3 3	73°3 4	76°7 7	83°0 4	x 90°0 5	88°3 7	82°8 4	78°8 4	67°3 4	n 60°8 4	74°9
1	67°0 4	62°5 2	65°0 3	68°3 4	71°9 7	75°0 4	80°6 5	x 83°6 7	76°8 4	76°5 4	65°0 4	n 59°5 4	71°0
2	64°5 4	62°0 2	61°3 3	64°8 4	66°4 7	70°0 4	74°4 5	x 77°1 7	71°5 4	72°0 4	62°3 4	n 53°8 4	66°7
3	58°3 4	57°5 2	56°0 3	59°0 4	60°4 7	64°8 4	68°6 5	x 71°4 7	67°5 4	67°3 4	56°8 4	n 47°8 4	61°3
4	52°5 4	52°0 2	51°0 3	53°5 4	54°7 7	59°5 4	63°6 5	x 65°0 7	61°8 4	61°3 4	51°5 4	n 42°0 4	55°7
5	47°0 4	45°0 2	45°7 3	46°8 4	48°9 7	53°3 4	57°2 5	x 58°1 7	56°5 4	55°0 4	45°8 4	n 38°5 4	49°8
6	40°0 4	39°0 2	38°3 3	40°5 4	42°3 7	46°8 4	50°0 5	x 51°7 7	50°0 4	49°0 4	40°0 4	n 32°3 4	43°3
7	32°5 4	31°5 2	30°3 3	34°5 4	35°6 7	40°0 4	42°8 5	x 44°9 7	43°0 4	41°8 4	35°3 4	n 26°3 4	37°1
8	25°8 4	23°5 2	24°0 3	28°5 4	29°4 7	32°5 4	36°2 5	x 37°3 7	36°0 4	34°0 4	30°5 4	n 20°3 3	29°8
9	21°0 4	17°5 2	n 17°0 3	22°0 4	25°5 6	27°8 4	30°0 5	x 32°1 7	29°8 4	27°0 4	25°3 4	17°3 3	24°4
10	17°7 4	n 15°0 2	16°0 3	18°3 3	24°3 6	24°7 3	26°2 5	x 28°6 7	24°3 3	22°8 4	20°3 4	17°7 3	21°3
11	14°3 3	19°0 1	17°0 2	n 11°0 2	22°4 5	x 25°0 3	23°8 5	24°3 6	22°5 2	21°5 4	23°0 3	16°5 2	20°0
12	n 12°0 1	18°0 1	18°5 2	17°0 1	22°3 4	x 25°5 2	24°6 5	21°8 6	25°0 2	25°0 3	22°7 3	16°0 1	20°7
13	n 17°0 1	19°0 1	18°5 2	...	26°0 3	27°0 2	x 27°8 4	21°2 5	27°0 1	27°0 1	23°0 3	...	23°4
14	...	20°0 1	n 17°5 2	...	25°7 3	x 28°0 2	26°7 3	20°8 4	27°0 1	...	22°0 3	...	23°5
15	...	...	n 16°5 2	...	23°0 1	x 27°5 2	27°0 2	22°0 4	27°0 1	...	19°0 1	...	23°1
16	...	...	...	...	...	...	28°0 2	22°0 1	...	...	...	...	25°0

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	21°0	17°5	n 17°0	22°0	25°2	27°8	30°0	x 32°1	29°8	27°0	25°3	17°3	24°3
10	17°7	n 15°0	16°0	16°3	24°0	23°5	26°2	x 28°6	24°8	22°8	20°3	17°7	21°1
11	15°7	16°0	19°0	n 12°8	22°4	23°8	23°8	x 24°4	20°8	22°8	22°3	17°2	20°1
12	14°7	15°0	19°5	n 13°8	22°7	x 25°3	24°6	21°9	23°3	22°8	22°0	17°2	20°2
13	19°7	n 16°0	19°5	...	22°7	26°8	x 26°9	23°7	23°3	22°8	22°3	...	22°4
14	...	n 17°0	18°5	...	22°4	x 27°8	26°9	26°5	23°3	...	21°3	...	23°0
15	...	...	n 17°5	...	23°4	27°3	27°4	x 27°7	23°3	...	20°3	...	23°8

MEAN MONTHLY TEMPERATURES, KOUTCHINO (140 m.).
Temperature (T) in Degrees A. ($200^{\circ}+$), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
Surface	68°0 1	n 60°0 2	61°5 2	73°3 3	89°7 3	90°5 4	89°5 2	x 91°5 6	86°0 2	79°7 3	70°5 2	63°5 2	77°0
1	69°0 1	n 62°5 2	71°5 2	68°3 3	82°3 3	x 84°0 4	x 84°0 2	x 83°8 6	81°5 2	75°3 3	66°5 2	63°5 2	74°4
2	64°0 1	n 61°5 2	69°0 2	62°3 3	73°7 3	78°0 4	x 79°0 2	77°3 6	75°0 2	70°7 3	68°5 2	63°0 2	70°2
3	61°0 1	n 56°5 2	62°0 2	60°3 3	67°8 3	72°3 4	x 73°5 2	71°2 6	71°5 2	66°7 3	64°5 2	60°0 2	65°6
4	56°0 1	n 51°5 2	56°0 2	55°7 3	60°3 3	67°0 4	x 68°5 2	65°3 6	67°0 2	62°3 3	59°5 2	54°0 2	60°3
5	51°0 1	n 47°5 2	49°0 2	49°3 3	54°0 3	60°3 4	x 63°5 2	59°3 6	60°5 2	57°0 3	52°5 2	n 46°5 2	54°2
6	43°0 1	n 41°5 2	42°0 2	42°7 3	47°0 3	54°0 4	x 58°5 2	51°7 6	54°0 2	50°3 3	46°5 2	n 41°5 2	47°7
7	35°0 1	35°0 2	n 33°0 2	39°0 3	39°0 3	46°8 4	x 52°5 2	44°8 6	46°5 2	43°3 3	39°5 2	35°5 2	40°8
8	25°0 1	27°5 2	n 25°0 2	28°7 3	30°3 3	39°3 4	x 46°5 2	37°7 6	39°5 2	35°0 3	32°0 2	28°5 2	32°9
9	17°0 1	21°0 2	n 16°5 2	22°3 3	25°0 3	31°3 4	x 39°5 2	31°2 6	32°0 2	27°7 3	23°5 2	21°0 2	25°7
10	10°0 1	16°5 2	n 8°0 2	18°0 3	20°0 3	23°0 4	x 35°5 2	27°4 5	24°5 2	22°7 3	17°5 2	14°5 2	19°8
11	n 8°0 1	14°5 2	10°0 2	19°7 3	21°0 2	17°7 3	x 33°5 2	23°6 5	19°5 2	20°5 2	15°0 2	13°0 2	16°8
12	n 10°0 1	15°5 2	16°0 2	25°0 2	19°5 2	16°3 3	x 31°5 2	22°8 4	19°0 2	21°0 2	14°0 2	12°0 1	18°7
13	...	18°0 1	19°0 2	27°0 2	22°5 2	20°0 3	x 31°5 2	24°5 4	23°0 1	22°0 2	17°0 2	n 13°0 1	21°6
14	...	16°0 1	20°5 2	...	17°0 1	22°7 3	x 32°0 2	24°8 4	24°0 1	22°5 2	17°0 2	n 13°0 1	21°0
15	...	...	19°0 1	...	17°0 1	22°3 3	x 32°5 2	22°7 3	25°0 1	23°0 2	19°0 1	n 10°0 1	21°2

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	17°0	21°0	n 16°5	22°3	25°0	31°3	x 39°5	31°2	32°0	27°7	23°5	21°0	25°7
10	10°0	16°5	n 8°0	18°0	20°0	23°0	x 35°5	26°8	24°5	22°7	17°5	14°5	19°8
11	n 8°0	14°5	10°0	19°7	17°5	17°7	x 33°5	23°0	19°5	19°2	15°0	13°0	17°6
12	n 10°0	15°5	16°0	20°7	16°0	16°3	x 31°5	21°7	19°0	19°7	14°0	16°0	18°0
13	...	n 14°5	19°0	22°7	19°0	20°0	x 31°5	23°4	17°0	20°7	17°0	17°0	20°2
14	...	n 12°5	20°5	...	21°0	17°3	x 32°0	23°1	16°0	20°2	17°0	17°0	19°7
15	...	...	18°5	...	21°0	16°9	x 32°5	24°1	17°0	20°7	17°0	n 14°0	20°2

x and n mark respectively the maximum and minimum values in each row.

TABLE IX.—*contd.*—MEAN MONTHLY TEMPERATURES, MILAN AND PAVIA (80 m.).
Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	n 72°3 8	75°0 3	75°0 3	83°7 7	87°0 2	93°8 6	91°5 2	93°3 12	x 94°4 12	90°7 9	80°8 5	78°0 1	84°6
1	n 71°9 8	75°0 3	72°7 3	78°3 7	81°0 2	88°0 6	85°0 2	x 90°3 12	88°3 12	85°0 9	77°6 5	75°0 1	80°7
2	69°5 8	68°7 3	n 65°9 3	71°6 7	73°0 2	81°8 6	77°5 2	x 83°6 12	81°0 12	80°8 9	74°0 5	74°0 1	75°1
3	64°1 8	64°3 3	n 58°6 3	65°9 7	66°0 2	76°5 6	69°5 2	x 77°4 12	74°4 12	75°1 9	68°4 5	70°0 1	69°2
4	58°8 8	58°3 3	n 52°0 3	60°5 7	58°0 2	70°8 6	62°5 2	x 71°3 12	68°3 12	69°0 9	62°4 5	63°0 1	62°9
5	51°9 8	51°7 3	n 44°3 3	53°7 7	51°0 2	65°0 6	56°5 2	x 65°8 12	63°2 12	63°1 9	55°2 5	53°0 1	56°2
6	44°5 8	46°7 3	n 37°0 3	47°4 7	45°5 2	57°5 6	49°5 2	x 59°1 12	56°7 12	56°1 9	48°4 5	44°0 1	49°4
7	36°2 8	40°0 3	n 28°7 3	42°2 7	38°5 2	50°5 6	41°5 2	x 52°1 12	50°6 12	48°0 9	40°6 5	36°0 1	41°2
8	32°2 8	32°3 3	n 20°7 3	32°3 7	30°5 2	42°7 6	33°5 2	x 44°4 12	43°1 12	41°3 9	32°8 5	27°0 1	34°4
9	19°4 7	26°3 3	n 17°0 2	27°7 6	25°0 2	34°7 6	28°0 2	x 36°7 12	x 36°7 11	33°1 9	25°4 5	18°0 1	27°3
10	n 13°8 5	22°0 2	14°0 1	23°5 6	22°0 2	26°0 6	24°5 2	27°9 11	x 32°2 11	25°9 8	17°8 5	...	22°7
11	n 6°7 3	15°0 2	14°0 1	23°0 4	25°0 2	19°7 6	21°0 2	19°3 9	x 28°3 10	18°8 8	12°4 5	...	18°5
12	n 7°3 3	9°0 1	...	20°5 4	24°0 2	15°0 4	17°0 2	14°4 6	x 25°8 9	13°6 7	14°3 4	...	16°1
13	10°0 3	n 4°0 1	...	21°2 4	25°0 1	...	16°5 2	18°5 5	x 25°2 6	12°0 5	15°3 4	...	16°4
14	13°5 2	n 8°0 1	...	23°0 3	25°0 1	...	18°0 2	17°0 4	x 25°7 6	14°5 4	14°7 3	...	17°7
15	12°0 2	n 11°0 1	...	17°5 2	25°0 1	...	20°0 1	16°5 2	x 26°6 5	14°0 2	n 11°0 1	...	17°1
16	11°5 2	...	...	19°0 1	25°0 1	...	19°0 1	17°0 2	27°3 4	18°0 1	14°0 1	...	18°9

TEMPERATURES OBTAINED FROM MEAN GRADIENTS ABOVE 8 KM.

9	23°6	26°3	n 17°2	26°7	25°0	34°7	28°0	36°7	x 36°9	33°1	25°4	18°0	27°6
10	15°4	17°9	n 15°2	22°5	22°0	26°0	24°5	28°6	x 32°4	25°3	17°8	...	22°5
11	n 7°7	10°9	15°2	19°5	25°0	19°7	21°0	19°7	x 28°1	18°2	12°4	...	17°9
12	8°3	n 4°9	...	17°0	24°0	14°9	17°0	15°7	x 25°3	12°6	12°9	...	15°3
13	11°0	n 0°1	...	17°7	23°0	...	16°5	18°3	x 25°1	12°4	13°9	...	15°3
14	12°5	n 3°9	...	16°7	23°0	...	18°0	19°1	x 25°6	14°2	13°6	...	16°3
15	11°0	n 6°9	...	16°7	23°0	...	19°0	19°8	x 25°6	15°2	13°6	...	16°8

MEAN MONTHLY TEMPERATURES, ZURICH.

Temperature (T) in Degrees A. (200° +), and Number of Cases (N).

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T. N.	T.
km.													
Surface	...	75°0 1	72°0 1	79°0 4	82°0 2	85°0 3	90°0 1	91°3 8	87°5 2	84°3 3	81°3 4	75°0 1	82°0
1	...	71°0 1	68°0 1	78°0 4	74°5 2	81°3 3	86°0 1	88°9 8	86°5 2	81°0 3	79°0 4	73°0 1	78°8
2	...	73°0 1	72°0 1	72°5 4	73°0 2	75°0 3	81°0 1	84°5 8	81°0 2	77°8 3	76°8 4	68°0 1	75°9
3	...	68°0 1	63°0 1	66°0 4	68°0 2	71°3 3	74°0 1	77°8 8	74°0 2	72°3 3	70°5 4	64°0 1	69°9
4	...	63°0 1	55°0 1	59°8 4	63°0 2	66°3 3	69°0 1	71°3 8	66°0 2	67°3 3	63°3 4	59°0 1	63°9
5	...	57°0 1	45°0 1	52°5 4	56°5 2	59°3 3	61°0 1	66°0 8	61°0 2	60°3 3	56°3 4	54°0 1	57°2
6	...	49°0 1	36°0 1	44°5 4	50°0 2	52°3 3	56°0 1	59°9 8	53°5 2	51°7 3	48°8 4	47°0 1	49°9
7	...	41°0 1	27°0 1	37°0 4	41°5 2	45°0 3	49°0 1	52°4 8	46°0 2	44°3 3	41°3 4	41°0 1	42°3
8	...	32°0 1	18°0 1	30°0 4	34°0 2	36°3 3	41°0 1	44°9 8	38°0 2	37°3 3	33°8 4	34°0 1	34°5
9	...	23°0 1	15°0 1	23°7 3	26°0 2	28°3 3	32°0 1	37°0 8	31°5 2	36°0 1	27°8 4	27°0 1	27°9
10	...	16°0 1	...	18°7 3	...	23°0 3	23°0 1	28°4 8	28°0 2	28°0 1	21°0 4	22°0 1	23°1
11	...	13°0 1	...	12°3 3	...	22°5 2	17°0 1	20°1 8	25°0 2	...	14°0 4	13°0 1	17°1
12	10°0 2	...	19°0 1	21°0 1	15°8 6	22°0 2	...	9°7 3	...	16°2
13	5°0 1	...	19°0 1	...	15°5 6	28°0 1	...	16°0 1	...	16°7
14	16°8 4	...	...	15°0 1	...	15°9
15	18°3 3	...	...	14°0 1	...	16°2

x and n mark respectively the maximum and minimum values in each row.

TABLE X.

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), BERLIN.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	0.2	2.5	2.0	4.3	4.5	5.3	6.0	6.9	5.5	3.5	0.9	2.5	3.8
1-2	3.6	n 2.5	6.0	6.0	6.6	4.8	x 7.0	6.1	6.1	4.4	4.7	3.3	5.1
2-3	4.5	n 4.0	x 6.5	5.0	4.4	4.7	5.0	4.1	4.9	4.4	4.5	5.3	4.8
3-4	6.4	6.3	6.2	6.0	6.0	n 5.4	5.7	5.7	5.8	5.8	5.9	x 6.6	6.0
4-5	n 4.6	6.4	x 7.5	7.0	5.8	5.6	5.3	6.0	5.7	6.8	6.9	6.7	6.2
5-6	6.9	7.0	7.3	7.2	6.7	n 6.0	6.7	6.4	n 6.0	7.1	7.7	x 7.9	6.9
6-7	7.5	7.6	7.5	7.8	7.2	7.0	7.7	7.0	6.9	n 6.7	x 8.5	8.2	7.5
7-8	7.8	7.9	6.7	6.7	7.0	7.1	8.0	x 8.1	7.3	n 6.3	7.2	8.0	7.3
8-9	7.2	5.8	n 3.8	5.0	7.3	8.0	x 8.3	8.1	5.5	6.0	4.2	6.8	6.3
9-10	5.2	4.3	n 1.2	4.8	6.5	7.4	x 8.6	7.6	3.8	5.7	4.0	2.6	5.1
10-11	4.0	5.0	1.5	2.0	4.8	x 7.2	2.1	3.8	1.5	4.5	2.8	n 0.8	3.3
11-12	0.3	2.5	0.0	0.7	0.9	x 4.2	n 2.8	-0.7	-1.1	2.7	1.9	0.6	0.8
12-13	n 3.0	...	0.0	x 2.0	-2.3	0.6	-2.8	-1.1	0.8	0.3	0.0	-0.7	-0.6
13-14	0.0	...	...	x 4.0	-1.3	n 2.0	0.3	-1.4	0.5	0.2	-0.5	-0.4	-0.1
14-15	1.0	...	...	x 2.5	-0.2	-0.5	0.4	0.2	0.5	0.3	n 1.4	1.0	0.4
15-16	...	...	...	2.0	1.0	-1.0	-1.0	-0.6	...	1.5	-1.0	1.0	0.2

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), MUNICH.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	-5.4	3.2	4.4	4.0	3.0	4.6	5.4	6.2	5.2	-1.8	-4.6	-1.2	1.9
1-2	1.9	n 0.6	5.3	x 6.0	5.4	4.8	5.5	4.6	6.4	3.9	5.0	5.8	4.6
2-3	4.3	n 4.0	6.5	x 7.0	5.0	6.3	x 7.0	5.9	5.8	4.6	6.3	5.2	5.7
3-4	n 5.1	5.6	x 7.7	6.8	6.3	6.6	5.3	5.5	5.8	5.3	6.8	6.0	6.1
4-5	6.2	6.4	6.3	6.0	6.7	6.3	n 4.7	5.4	5.2	5.5	x 7.3	7.2	6.1
5-6	7.0	6.4	x 7.5	x 7.5	6.3	6.5	7.3	5.8	n 5.0	6.3	x 7.5	7.3	6.7
6-7	7.5	7.0	7.7	x 8.2	7.2	6.8	n 6.2	6.9	6.6	6.4	6.3	7.8	7.1
7-8	x 8.2	7.6	7.5	8.0	6.5	7.7	8.0	7.3	7.2	6.9	n 5.2	6.5	7.2
8-9	x 8.1	5.4	3.8	n 3.7	7.0	8.0	7.5	7.5	7.4	7.3	4.7	6.2	6.4
9-10	5.9	3.6	n 0.6	2.6	6.8	8.2	x 8.8	8.7	6.0	7.4	3.8	2.8	5.3
10-11	1.3	2.2	n 1.8	2.6	4.9	6.5	5.0	5.8	2.4	x 7.3	4.7	2.3	3.6
11-12	n 3.0	2.5	-1.0	-0.3	3.0	4.3	3.7	3.5	2.9	x 5.7	3.1	3.6	2.3
12-13	-0.2	n 9.9	-0.4	-2.9	-1.8	-2.2	-5.2	-1.1	-0.3	-3.8	x 2.1	0.4	-2.1
13-14	0.3	-2.4	...	-2.0	n 2.7	-0.4	1.0	-0.5	0.9	x 1.1	0.1	0.6	-0.4
14-15	...	x 3.0	...	n 1.0	-0.4	1.7	0.0	0.1	2.0	-0.8	1.0	2.0	0.8
15-16	...	...	...	1.0	-0.1	...	...	...	2.0	-0.8	...	...	0.5

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), STRASSBURG.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	0.7	2.3	5.4	4.8	6.6	4.7	5.2	1.9	6.2	3.6	0.8	1.9	3.6
1-2	2.6	n 0.2	6.6	x 7.5	3.6	6.4	5.7	6.3	4.6	3.1	1.7	4.5	4.4
2-3	n 4.1	4.4	6.0	5.1	4.7	5.4	4.7	5.8	x 6.9	6.0	6.0	5.9	5.4
3-4	6.0	6.2	x 6.6	n 5.2	5.3	6.2	5.9	n 5.2	n 5.2	6.4	6.3	6.3	5.9
4-5	x 7.3	7.2	7.2	6.7	6.5	5.7	6.8	5.7	n 5.5	6.2	6.3	6.2	6.4
5-6	7.2	x 8.0	7.4	6.9	6.6	6.6	6.6	6.0	n 5.7	6.7	6.1	6.8	6.7
6-7	7.6	x 7.8	7.0	7.2	n 6.6	6.9	7.5	7.3	6.8	7.3	x 7.8	7.5	7.3
7-8	x 8.0	x 8.0	n 5.6	7.2	7.4	7.7	7.2	7.6	7.1	7.2	x 8.0	6.7	7.3
8-9	7.4	6.0	n 3.4	5.2	7.9	x 8.4	7.4	8.3	5.9	7.6	7.3	6.6	6.8
9-10	5.4	6.0	n 1.0	4.5	6.0	x 7.8	5.7	7.6	4.6	6.2	6.3	7.0	5.7
10-11	2.0	x 7.0	n 0.3	2.8	6.0	5.0	3.8	6.8	2.8	5.4	4.5	6.0	4.3
11-12	-0.5	3.3	-0.5	0.2	n 1.2	1.4	-0.6	3.2	2.5	x 3.5	2.2	3.0	1.4
12-13	-2.2	n 5.5	-1.5	-3.0	-2.2	-2.6	-0.6	0.5	1.3	1.7	1.8	x 2.8	-0.8
13-14	0.2	-1.5	1.0	1.0	-1.5	0.2	0.3	0.9	0.7	x 1.4	n 2.0	-1.0	0.0
14-15	0.0	-1.0	-1.5	x 2.0	n 3.0	0.2	-0.3	-0.7	0.3	0.2	0.5	-1.3	-0.4
15-16	...	...	...	...	...	0.0	0.5	-1.0	0.0	0.0	...	...	-0.1

x and n mark respectively the maximum and minimum values in each row.

TABLE X.—*continued.*

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), VIENNA.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	1.1	1.5	3.0	5.8	6.7	3.7	6.2	6.9	8.6	3.2	2.7	1.5	4.2
1-2	n 2.1	3.3	4.6	3.3	4.8	5.2	7.0	x 7.2	7.0	4.2	3.6	2.9	4.6
2-3	4.4	4.4	6.0	n 3.8	4.8	x 7.3	6.5	5.6	5.3	4.3	6.4	6.0	5.4
3-4	5.2	5.7	5.8	5.9	5.7	5.2	5.2	n 4.9	5.0	5.2	x 7.2	6.6	5.6
4-5	6.7	5.7	7.0	7.0	6.0	6.8	6.0	5.7	n 5.2	5.8	7.2	x 7.3	6.4
5-6	7.1	5.9	7.3	x 7.5	7.3	7.0	6.3	6.3	6.5	n 5.3	7.2	7.4	6.8
6-7	x 8.3	7.7	7.6	7.6	8.2	8.2	8.0	n 6.2	7.0	6.5	7.4	8.2	7.6
7-8	7.9	7.6	8.3	x 9.5	7.7	7.3	6.7	8.5	7.3	7.5	n 5.8	7.5	7.6
8-9	6.3	7.0	n 3.5	8.2	7.1	x 8.5	7.0	8.4	5.5	7.6	5.0	6.6	6.6
9-10	4.8	7.0	n 3.2	4.2	5.6	x 8.0	x 8.0	7.9	3.5	7.4	4.5	3.5	5.6
10-11	n 0.0	3.0	0.2	4.7	5.0	x 8.3	1.3	5.6	2.2	6.4	3.5	1.1	3.4
11-12	-0.6	-2.7	-2.5	3.0	2.5	x 6.5	n-3.3	-0.9	-1.0	4.3	-0.3	0.5	0.5
12-13	-2.5	0.0	-2.5	-1.0	2.0	n-9.5	0.3	-0.9	-0.3	x 3.2	1.8	-0.5	-0.8
13-14	x 2.0	1.3	...	1.0	n-10.0	0.0	-0.7	-0.7	1.5	-0.4	-2.3	0.0	-0.8
14-15	-1.0	x 1.4	...	...	0.0	0.0	0.0	-0.8	1.0	n-1.6	0.0	-0.3	-0.1
15-16	...	0.0	...	...	-1.0	1.0	0.0	-0.4	0.0	-2.0	3.0	-1.5	-0.1

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), BERLIN,
MUNICH, STRASSBURG, AND VIENNA.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	-0.3	2.2	3.7	5.3	5.4	5.0	6.1	5.3	6.5	2.9	0.4	1.2	3.2
1-2	2.5	n 1.8	5.5	5.8	5.2	5.4	x 6.3	5.6	5.7	3.9	3.8	4.0	4.7
2-3	4.3	n 4.2	x 6.2	5.1	4.7	5.7	5.4	5.5	5.9	4.8	5.7	5.6	5.2
3-4	5.7	5.9	x 6.5	5.8	5.9	5.9	5.7	n 5.4	5.5	5.7	6.4	6.4	5.9
4-5	6.3	6.4	x 7.0	6.8	6.2	6.0	6.3	5.7	n 5.4	6.2	6.9	6.9	6.4
5-6	7.1	6.7	7.3	7.2	6.7	6.5	6.2	6.1	n 5.8	6.5	7.1	x 7.4	6.7
6-7	7.7	7.6	7.5	7.6	7.3	7.1	7.5	6.9	6.8	n 6.7	7.6	x 8.0	7.4
7-8	x 8.0	7.7	6.8	7.8	7.2	7.4	7.5	7.8	7.2	6.9	n 6.7	7.1	7.3
8-9	7.3	6.0	n 3.6	5.6	7.3	x 8.3	7.6	8.0	6.0	7.0	5.2	6.5	6.6
9-10	5.4	5.2	n 1.5	4.1	6.3	7.8	7.5	x 8.0	4.5	6.5	4.6	2.8	5.3
10-11	1.7	3.9	n-0.1	2.9	5.1	x 6.3	3.0	5.5	2.3	5.7	3.8	2.3	3.4
11-12	n-1.1	0.7	-1.0	0.6	1.3	3.3	1.1	1.6	0.9	x 3.9	1.8	1.8	1.1
12-13	-1.6	n-3.5	-1.4	-1.1	-1.6	-2.4	-1.6	-0.6	0.7	0.5	x 1.2	0.6	-0.9
13-14	0.4	-0.3	1.0	x 1.4	n-2.2	-0.4	0.1	-0.3	0.7	0.6	-1.3	-0.3	0.0
14-15	0.0	1.2	n-1.5	x 1.5	-0.5	0.1	0.0	-0.4	0.6	-0.4	-0.1	-0.2	0.1
15-16	...	0.0	...	1.5	0.0	0.3	0.0	-0.5	0.7	0.0	1.0	-0.7	-0.8

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), ENGLAND.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	2.8	0.0	6.6	9.1	4.2	4.7	6.4	5.6	4.6	2.8	5.7	5.6	4.9
1-2	n 3.6	4.5	3.7	x 5.3	5.1	5.1	4.6	4.9	4.7	4.3	4.4	4.4	4.6
2-3	5.2	5.1	5.6	x 5.9	5.5	5.3	5.8	n 4.5	5.3	5.8	5.5	5.7	5.4
3-4	6.1	6.0	6.4	6.4	5.5	5.7	5.7	n 4.9	6.0	5.7	5.9	x 7.1	6.0
4-5	6.5	6.8	6.2	7.0	6.9	6.5	n 5.9	6.1	6.1	6.1	6.7	x 7.7	6.5
5-6	n 6.0	6.8	6.9	7.1	6.4	6.9	7.1	6.8	6.6	6.8	x 8.4	7.5	6.9
6-7	n 6.5	7.0	n 6.5	6.6	x 8.4	7.7	6.7	7.1	7.1	7.1	7.5	7.5	7.1
7-8	6.5	7.3	6.5	5.5	7.9	x 8.1	7.5	7.1	7.7	7.3	n 4.8	5.4	6.8
8-9	6.5	6.2	4.8	5.1	7.3	x 8.3	6.7	7.4	6.9	7.1	n 2.6	2.7	6.0
9-10	5.9	5.5	4.4	n 1.5	7.3	7.3	4.1	7.5	6.0	x 7.8	2.5	1.9	5.1
10-11	3.8	4.3	2.2	n 0.2	2.5	4.7	1.9	6.0	4.0	x 6.4	1.6	1.5	3.3
11-12	2.2	1.8	n-1.2	-0.3	0.3	0.1	-0.3	1.4	0.4	x 4.2	0.9	0.6	0.8
12-13	0.6	0.6	n-2.5	0.5	-0.3	-2.2	-0.3	-1.4	0.3	x 3.6	0.5	-0.8	-0.1
13-14	-0.2	0.2	n-0.9	2.0	-0.5	-0.5	-0.5	-0.6	-0.4	x 1.7	1.0	-0.3	1.0
14-15	-0.3	n-3.6	0.0	...	-1.3	-1.2	0.6	0.3	-0.5	0.7	0.6	x 0.9	-0.3
15-16	-0.5	0.0	0.5	...	-0.3	0.0	0.0	-0.5	-1.0	0.0	1.0	0.9	0.0

x and n mark respectively the maximum and minimum values in each row.

TABLE X.—*continued.*

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), HAMBURG.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	°	°	°	°	°	°	°	°	°	°	°	°	°
0-1	2.5	3.0	4.5	7.7	7.0	5.0	6.5	7.4	7.0	1.4	-1.3	3.5	4.5
1-2	6.5	3.0	6.5	x 7.0	6.5	3.2	x 7.0	5.8	5.5	n 1.8	2.8	4.0	5.0
2-3	6.3	x 7.0	6.5	5.7	n 4.5	5.0	5.4	5.8	5.0	4.8	4.7	x 7.0	5.6
3-4	4.4	5.7	x 7.0	6.3	n 3.5	5.5	6.1	5.2	6.5	6.8	6.0	5.0	5.7
4-5	6.6	6.0	7.0	x 7.7	n 5.0	6.8	5.9	5.6	6.8	6.0	7.0	7.0	6.5
5-6	x 7.5	6.3	n 5.0	6.3	5.5	6.4	6.1	6.6	7.2	7.0	7.0	7.0	6.5
6-7	7.7	n 4.0	5.0	5.0	x 8.0	6.8	6.5	7.4	7.0	7.4	5.5	7.0	6.4
7-8	7.0	5.0	n 3.5	4.3	x 10.0	6.8	7.0	5.8	8.0	6.6	5.8	5.0	6.2
8-9	5.0	5.3	n 2.5	4.7	8.0	7.5	6.9	6.4	4.0	7.5	x 8.5	4.5	5.9
9-10	1.0	8.0	n 0.0	5.5	4.5	x 8.3	7.4	6.0	2.3	7.7	7.0	1.0	4.9
10-11	n-1.0	6.5	2.0	0.0	0.5	5.8	4.7	3.7	-0.8	x 7.5	6.5	...	3.2
11-12	1.0	-1.0	-1.0	n-2.0	-0.5	2.3	-1.7	2.3	0.0	x 3.5	2.0	...	0.4
12-13	x 2.0	n-8.0	0.0	...	-1.0	-4.6	-4.0	-1.3	0.0	x 2.0	-1.5	...	-0.6
13-14	x 3.0	1.0	2.0	...	-1.5	-2.0	n-2.0	-1.0	1.0	2.0	0.0	...	0.3
14-15	0.0	x 2.0	n-2.0	...	-1.0	0.3	-1.0	-1.0	1.0	x 2.0	...	...	0.0
15-16	...	...	...	...	...	...	0.0	...	0.0	1.0	...	...	0.3

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), UCCLE.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	°	°	°	°	°	°	°	°	°	°	°	°	°
0-1	-2.8	1.0	4.4	3.7	5.1	3.8	6.1	3.8	6.7	0.2	2.8	-1.1	2.8
1-2	2.7	n 1.0	6.7	x 7.0	2.8	6.0	4.7	2.6	3.5	4.6	1.5	5.5	4.1
2-3	4.0	n 2.0	6.7	4.2	5.8	x 7.0	5.8	4.8	5.0	6.2	5.5	6.0	5.3
3-4	6.0	4.0	7.6	6.8	4.4	n 3.0	4.7	5.6	5.5	7.0	6.0	x 9.0	5.8
4-5	7.5	6.5	x 8.0	6.7	7.2	7.0	6.5	n 5.0	n 5.0	6.8	6.0	x 8.0	6.7
5-6	6.8	n 5.0	8.4	6.0	7.0	7.0	6.5	7.0	n 5.0	6.2	7.0	x 9.0	6.7
6-7	x 8.0	6.5	7.3	7.0	7.6	7.0	7.5	6.4	7.0	6.4	7.5	n 6.0	7.0
7-8	8.2	7.5	n 4.3	5.3	8.2	7.5	x 9.0	8.3	7.0	7.9	8.0	4.5	7.1
8-9	7.3	6.0	n 2.4	5.0	8.8	x 9.0	7.5	6.2	6.5	7.5	8.5	5.5	6.7
9-10	5.5	8.0	n 0.0	3.3	6.0	x 8.5	6.5	7.5	8.0	6.7	8.0	3.5	6.0
10-11	0.5	7.0	n 0.0	1.4	3.4	x 8.5	1.0	6.8	7.5	7.0	4.5	3.0	4.2
11-12	1.5	n-3.0	0.3	-1.0	2.2	3.0	-1.8	6.5	x 7.0	4.5	0.5	2.5	1.9
12-13	-1.0	1.5	1.0	1.0	0.3	-2.0	-0.3	2.0	x 7.0	0.0	1.5	n-3.0	0.7
13-14	0.8	3.0	-1.5	4.3	-1.0	n-3.0	-0.8	-0.5	-1.0	-1.0	x 4.5	...	0.1
14-15	2.0	3.0	0.5	n-1.7	-0.7	0.0	0.0	-1.0	-1.0	x 4.5	0.0	...	0.5

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), PARIS.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.	°	°	°	°	°	°	°	°	°	°	°	°	°
0-1	2.2	2.3	3.4	4.3	2.4	4.3	3.0	1.1	4.8	0.6	1.1	2.4	2.7
1-2	3.5	n 0.3	x 6.0	5.4	5.0	5.2	4.7	4.8	4.7	3.8	2.0	3.4	4.1
2-3	5.1	4.8	5.5	n 3.8	4.6	4.8	4.5	4.7	x 5.6	3.9	4.6	4.1	4.7
3-4	5.5	5.5	x 6.7	5.8	4.9	5.6	5.4	5.3	n 4.6	5.1	5.5	6.4	5.5
4-5	7.2	6.3	x 7.8	6.1	6.3	5.4	5.5	5.5	n 5.2	6.6	6.4	6.2	6.2
5-6	6.8	6.4	x 7.7	6.8	6.6	7.2	6.4	n 6.1	6.7	6.9	6.5	6.2	6.7
6-7	x 8.3	6.2	7.5	6.9	7.3	8.6	7.0	7.0	7.5	6.6	n 6.1	6.3	7.1
7-8	8.1	x 8.3	n 5.3	7.7	8.1	5.8	8.0	7.3	7.3	7.7	7.7	6.9	7.4
8-9	7.1	6.6	n 2.7	7.8	8.8	5.0	7.8	7.9	6.8	7.6	x 8.5	7.1	7.0
9-10	6.2	4.9	n 1.0	6.8	6.6	3.8	7.7	x 8.4	3.9	7.6	6.4	7.1	5.9
10-11	1.3	6.0	0.7	3.9	3.0	n 0.6	4.1	x 8.0	5.3	6.5	4.3	5.8	4.1
11-12	-1.8	1.6	-1.6	-0.5	-0.8	-1.2	n-2.5	4.3	3.4	x 5.7	0.8	2.0	0.8
12-13	0.0	0.6	1.5	-1.0	n-2.0	0.0	-0.7	-0.6	-0.2	x 2.8	1.8	0.5	0.2
13-14	1.5	0.3	0.0	-1.0	n-2.0	1.0	0.0	-0.7	-1.2	1.4	-0.2	x 1.6	0.1
14-15	...	0.0	1.0	0.5	0.5	0.0	0.7	0.0	n-1.0	-0.8	n-1.0	x 1.8	0.2
15-16	...	...	...	1.0	0.0	...	0.0	...	...	0.0	2.0	-2.0	0.2

x and n mark respectively the maximum and minimum values in each row.

TABLE X.—*continued.*MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), ENGLAND,
HAMBURG, PARIS, AND UCCLE.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year
km.													
0-1	1°8	1°4	6°0	6°5	4°2	4°9	5°4	4°2	5°0	1°2	2°5	4°0	4°0
1-2	3°8	n 2°4	4°9	5°7	4°7	4°8	x 5°2	4°8	4°7	3°8	3°1	4°1	4°6
2-3	5°2	5°0	x 5°8	4°9	5°3	5°2	5°2	n 4°7	5°4	5°0	5°0	5°3	4°9
3-4	5°7	5°5	6°7	6°2	n 5°0	5°5	5°5	5°2	5°7	5°9	5°8	x 6°8	5°8
4-5	6°8	6°5	6°9	6°6	6°6	6°4	5°9	n 5°7	5°9	6°4	6°6	x 7°2	6°5
5-6	6°6	n 6°4	7°1	6°8	6°5	6°9	6°5	6°5	6°6	6°8	x 7°3	7°1	6°7
6-7	6°6	n 6°2	6°7	6°6	x 7°9	7°3	6°9	7°1	7°2	6°8	6°7	7°0	6°9
7-8	8°2	7°4	n 5°6	6°2	x 8°2	7°7	7°8	7°2	7°6	7°4	6°3	5°9	7°1
8-9	6°6	6°2	n 3°8	6°2	x 8°0	7°7	7°2	7°3	6°6	7°4	6°0	4°5	6°5
9-10	5°6	5°8	n 2°8	4°3	6°4	6°9	6°5	7°4	5°3	x 7°8	5°1	3°8	5°6
10-11	2°1	4°8	n 1°5	1°7	2°6	4°3	3°0	6°5	3°9	x 6°7	3°4	3°2	3°6
11-12	1°1	1°0	-1°0	-0°5	0°4	0°3	n-1°6	2°8	1°1	x 4°6	1°0	1°2	0°9
12-13	0°2	0°1	-1°0	0°0	-0°6	n-2°3	-0°7	-0°7	0°4	x 1°3	0°0	-0°1	-0°3
13-14	0°4	0°9	-0°6	1°7	n-1°0	-0°9	-0°6	-0°7	-0°5	x 1°4	0°8	0°4	0°0
14-15	0°1	-0°4	0°0	-0°8	n-0°9	-0°8	0°3	-0°1	-0°5	x 0°9	-0°1	1°3	-0°1

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), PAVLOVSK.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	-1°2	2°6	2°4	5°2	5°0	8°3	9°7	4°8	6°2	2°4	2°4	1°3	4°1
1-2	2°5	n 0°5	3°7	3°5	5°5	5°0	6°2	x 6°5	5°3	4°5	2°7	5°7	4°3
2-3	x 6°2	4°5	5°3	5°8	6°0	5°2	5°8	5°7	n 4°0	4°7	5°5	6°0	5°4
3-4	5°8	5°5	n 5°0	5°5	5°7	5°3	n 5°0	x 6°4	5°7	6°0	5°3	5°8	5°6
4-5	5°5	x 7°0	5°3	6°7	5°8	6°2	6°4	6°9	5°3	6°3	5°7	n 3°5	5°9
5-6	7°0	6°0	x 7°4	6°3	6°6	6°5	7°2	6°4	6°5	6°0	n 5°8	6°2	6°5
6-7	7°5	7°5	x 8°0	6°0	6°7	6°8	7°2	6°8	7°0	7°2	n 4°7	6°0	6°8
7-8	6°7	x 8°0	6°3	6°0	6°2	7°5	6°6	7°6	7°0	7°8	n 4°8	6°0	6°7
8-9	4°8	6°0	x 7°0	6°5	4°2	4°7	6°2	5°2	6°2	x 7°0	5°2	n 3°0	5°5
9-10	3°3	2°5	1°0	x 5°7	1°2	4°3	3°8	3°5	5°0	4°2	5°0	n-0°4	3°3
10-11	2°0	-1°0	n-3°0	3°5	1°6	-0°3	2°4	x 4°2	4°0	0°0	-2°0	0°5	1°0
11-12	1°0	1°0	-0°5	-1°0	-0°3	-1°5	-0°8	x 2°5	n-2°5	0°0	0°3	0°0	-0°1
12-13	-5°0	-1°0	0°0	...	0°0	-1°5	-2°3	-1°8	0°0	0°0	-0°3	...	-1°2
13-14	...	-1°0	1°0	...	0°3	-1°0	0°0	-2°8	0°0	...	1°0	...	-0°3
14-15	...	...	1°0	...	-1°0	0°5	-0°5	-1°2	0°0	...	1°0	...	0°0

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.), KOUTCHINO.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	-1°3	-2°9	-11°6	5°8	8°6	7°6	6°4	9°0	5°2	5°1	4°7	0°0	3°1
1-2	5°0	1°0	2°5	6°0	x 8°6	6°0	5°0	6°5	6°5	4°6	n-2°0	0°5	4°2
2-3	3°0	5°0	x 7°0	n 2°0	5°9	5°7	5°4	6°1	3°5	4°0	4°0	3°0	4°6
3-4	5°0	5°0	6°0	4°6	x 7°5	5°3	5°0	5°9	4°5	n 4°4	5°0	6°0	5°4
4-5	5°0	n 4°0	7°0	6°4	6°3	6°7	5°0	6°0	6°5	5°3	7°0	x 7°5	6°1
5-6	x 8°0	6°0	7°0	6°6	7°0	6°3	n 5°0	7°6	6°5	6°7	6°0	n 5°0	5°6
6-7	8°0	6°5	x 9°0	n 3°7	8°0	7°2	6°0	6°9	7°5	7°0	7°0	6°0	6°9
7-8	10°0	7°5	8°0	x 10°3	8°7	7°5	n 6°0	7°1	7°0	8°3	7°5	7°0	7°8
8-9	8°0	6°5	x 8°5	6°4	n 5°3	8°0	7°0	6°5	7°5	7°3	x 8°5	7°5	7°3
9-10	7°0	4°5	x 8°5	4°3	5°0	8°3	n 4°0	4°4	7°5	5°0	6°0	6°5	5°9
10-11	2°0	2°0	n-2°0	-1°7	2°5	x 5°3	2°0	3°8	5°0	3°5	2°5	1°5	2°2
11-12	-2°0	-1°0	n-6°0	-1°0	1°5	1°4	x 2°0	1°3	0°5	-0°5	1°0	-3°0	-0°5
12-13	...	1°0	-3°0	-2°0	-3°0	-3°7	0°0	-1°7	2°0	-1°0	-3°0	-1°0	-1°4
13-14	...	2°0	-1°5	...	-2°0	2°7	0°5	0°3	1°0	0°5	0°0	0°0	0°4
14-15	...	...	2°0	...	0°0	0°4	-0°5	-1°0	-1°0	-0°5	0°0	3°0	0°3

x and n mark respectively the maximum and minimum values in each row.

TABLE X.—*continued.*

MONTHLY VALUES OF GRADIENTS OF TEMPERATURE (°C. per km.),
MILAN AND PAVIA.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
km.													
0-1	0.4	0.0	2.5	5.9	6.5	6.3	7.1	3.3	6.6	6.2	3.5	3.3	4.3
1-2	2.4	6.3	6.8	6.7	x 8.0	6.2	7.5	6.7	7.3	4.2	3.6	n 1.0	5.6
2-3	5.4	4.4	7.3	5.7	7.0	5.3	x 8.0	6.2	6.6	5.7	5.6	n 4.0	5.9
3-4	n 5.3	6.0	6.6	5.4	x 8.0	5.7	7.0	6.1	6.1	6.1	6.0	7.0	6.3
4-5	6.9	6.6	7.7	6.8	7.0	5.8	6.0	5.5	n 5.1	5.9	7.2	x 10.0	6.7
5-6	7.4	n 5.0	7.3	6.3	5.5	7.5	7.0	6.7	6.5	7.0	6.8	x 9.0	6.8
6-7	x 8.3	6.7	x 8.3	n 5.2	7.0	7.0	8.0	7.0	6.1	8.1	7.8	8.0	8.2
7-8	n 4.0	7.7	8.0	x 9.9	8.0	7.8	8.0	7.7	7.5	6.7	7.8	9.0	7.7
8-9	8.6	6.0	n 3.5	5.6	5.5	8.0	5.5	7.7	6.2	8.2	7.4	x 9.0	6.8
9-10	7.2	8.5	n 2.0	4.2	3.0	x 8.7	3.5	8.1	4.5	7.8	7.6	...	5.9
10-11	7.7	7.0	0.0	3.0	n-3.0	6.3	3.5	x 8.9	4.3	7.1	5.4	...	4.6
11-12	-0.6	6.0	...	2.5	1.0	4.8	4.0	4.0	2.8	5.6	-0.5	...	3.0
12-13	-2.7	5.0	...	-0.7	1.0	...	0.5	-2.6	0.2	0.2	-1.0	...	0.0
13-14	-1.5	-4.0	...	1.0	0.0	...	-1.5	-0.8	-0.5	-1.8	0.3	...	-1.0
14-15	1.5	-3.0	...	0.0	0.0	...	-1.0	-0.7	0.0	-1.0	0.0	...	-0.5

TABLE XI.

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS (with Approximate
Values for Ascending Saturated Air in *Italic*), BERLIN.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72.0			82.2			81.1			71.9		
1-2		4.8	5.8		6.1	5.2		5.5	5.3		3.9	5.8
2	67.2			76.1			75.6			68.1		
2-3		5.2	6.5		4.7	5.6		4.5	5.6		4.8	6.4
3	62.0			71.4			71.1			63.3		
3-4		6.2	6.8		5.7	5.8		5.8	5.8		6.3	6.7
4	55.8			65.7			65.3			57.0		
4-5		7.0	7.4		5.6	6.2		6.2	6.2		6.1	7.3
5	48.9			60.1			59.2			50.9		
5-6		7.2	8.2		6.5	6.8		6.5	6.8		7.5	7.9
6	41.7			53.6			52.7			43.4		
6-7		7.6	8.7		7.3	7.6		6.9	7.7		8.1	8.6
7	34.1			46.3			45.8			35.3		
7-8		7.1	9.2		7.4	8.3		7.2	8.3		7.7	9.0
8	27.0			38.9			38.6			27.6		
8-9		4.9	9.4		7.9	9.0		6.5	9.0		6.1	9.3
9	22.1			31.0			32.1			21.5		
9-10		3.4	9.6		7.5	9.4		5.7	9.4		3.9	9.6
10	18.7			23.6			26.4			17.7		
10-11		2.8	...		4.7	...		3.3	...		2.5	...
11	15.9			18.9			23.1			15.2		
11-12		1.1	...		0.8	...		0.3	...		0.9	...
12	14.6			18.1			22.8			14.3		
12-13		1.0	...		-1.5	...		0.0	...		-1.2	...
13	13.6			19.6			22.8			15.5		
13-14		4.0	...		-1.0	...		-0.2	...		-0.3	...
14	9.6			20.6			23.0			15.8		
14-15		2.5	...		-0.1	...		0.3	...		0.2	...
15	7.1			20.7			22.7			15.6		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS (with Approximate
Values for Ascending Saturated Air in *Italic*), MUNICH.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72·1			85·3			84·5			74·2		
1-2		4·0	5·8		5·2	5·0		5·0	5·0		4·2	5·6
2	68·1			80·1			79·5			70·0		
2-3		5·8	6·5		6·1	5·4		5·4	5·4		5·3	6·2
3	62·3			74·0			74·1			64·7		
3-4		6·7	6·8		6·1	5·6		5·5	5·6		6·0	6·5
4	55·6			67·9			68·6			58·7		
4-5		6·2	7·4		5·9	6·0		5·4	5·9		6·9	7·1
5	49·4			62·0			63·2			51·9		
5-6		7·1	8·2		6·7	6·6		5·7	6·5		7·3	7·8
6	42·3			55·2			57·5			44·6		
6-7		7·6	8·7		6·7	7·4		6·6	7·2		7·2	8·5
7	34·7			48·5			50·9			37·4		
7-8		7·7	9·2		7·4	8·1		7·1	7·9		6·6	8·8
8	27·0			41·1			43·8			30·8		
8-9		4·3	9·4		7·5	8·8		7·4	8·6		6·3	9·2
9	22·7			33·6			36·4			24·5		
9-10		1·9	9·6		7·9	9·2		7·4	9·0		4·2	9·5
10	20·8			25·7			29·0			20·3		
10-11		1·0	...		5·5	...		5·2	...		2·8	...
11	19·8			20·2			23·8			17·5		
11-12		0·4	...		3·7	...		4·0	...		1·2	...
12	19·4			16·5			19·8			16·3		
12-13		-4·4	...		-3·1	...		-1·7	...		0·8	...
13	23·8			19·6			21·5			15·5		
13-14		-2·2	...		-0·7	...		0·5	...		0·3	...
14	26·0			20·3			21·0			15·2		
14-15		1·0	...		0·4	...		0·4	...		1·5	...
15	25·0			19·9			20·6			13·7		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, STRASSBURG.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	71·8			81·7			84·5			74·6		
1-2		4·6	...		5·2	...		4·7	...		2·9	...
2	67·2			76·5			79·8			71·7		
2-3		5·2	...		4·9	...		6·2	...		5·3	...
3	62·0			71·6			73·6			66·4		
3-4		6·0	...		5·8	...		5·6	...		6·2	...
4	56·0			65·8			68·0			60·2		
4-5		7·0	...		6·3	...		5·8	...		6·6	...
5	49·0			59·4			62·2			53·6		
5-6		7·4	...		6·6	...		6·1	...		6·7	...
6	41·6			52·8			56·1			46·9		
6-7		7·3	...		7·0	...		7·1	...		7·6	...
7	34·3			45·8			49·0			39·3		
7-8		6·9	...		7·4	...		7·3	...		7·6	...
8	27·4			38·4			41·7			31·7		
8-9		4·9	...		7·9	...		7·3	...		7·1	...
9	22·5			30·5			34·4			24·6		
9-10		3·8	...		6·5	...		6·1	...		6·2	...
10	18·6			24·0			28·3			18·3		
10-11		3·2	...		4·9	...		5·0	...		4·2	...
11	15·4			19·1			23·3			14·1		
11-12		1·0	...		-0·1	...		3·1	...		1·6	...
12	14·4			19·2			20·2			12·5		
12-13		-3·3	...		-1·8	...		1·2	...		0·8	...
13	17·7			21·0			19·0			11·7		
13-14		0·2	...		-0·3	...		1·0	...		-0·9	...
14	17·5			21·3			18·0			12·6		
14-15		-0·2	...		-1·0	...		-0·1	...		-0·3	...
15	17·7			22·3			18·1			12·9		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, VIENNA.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72.2			82.9			83.0			72.1		
1-2		3.7	...		5.7	...		6.1	...		2.9	...
2	68.5			77.2			76.9			69.2		
2-3		4.7	...		6.2	...		5.1	...		5.6	...
3	63.8			71.0			71.8			63.6		
3-4		5.8	...		5.4	...		5.0	...		6.3	...
4	58.0			65.7			66.8			57.4		
4-5		6.6	...		6.3	...		5.6	...		7.1	...
5	51.4			59.4			61.2			50.3		
5-6		6.9	...		6.9	...		6.0	...		7.2	...
6	44.5			52.5			55.2			43.1		
6-7		7.6	...		8.1	...		6.6	...		8.0	...
7	36.9			44.4			48.6			35.1		
7-8		8.5	...		7.2	...		7.8	...		7.1	...
8	28.4			37.1			40.9			28.1		
8-9		6.2	...		7.5	...		7.2	...		6.0	...
9	22.2			29.6			33.7			22.1		
9-10		4.8	...		7.2	...		6.3	...		4.3	...
10	17.4			22.4			27.4			17.8		
10-11		2.6	...		4.9	...		4.7	...		1.5	...
11	14.8			17.5			22.7			16.3		
11-12		-0.7	...		1.9	...		0.8	...		-0.1	...
12	15.5			15.6			21.9			16.4		
12-13		-1.2	...		-2.4	...		0.7	...		-0.4	...
13	16.7			18.0			21.2			16.8		
13-14		1.2	...		-3.6	...		0.1	...		-0.1	...
14	15.5			21.6			21.1			16.9		
14-15		1.4	...		0.0	...		-0.5	...		-0.4	...
15	14.1			21.6			21.6			17.3		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS (with Approximate Values for Ascending Saturated Air in *Italic*), BERLIN, MUNICH, STRASSBURG, AND VIENNA.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72.1			82.9			83.1			73.2		
1-2		4.4	5.6		5.6	5.1		5.1	5.1		3.5	5.6
2	67.8			77.3			78.0			69.7		
2-3		5.2	6.5		5.3	5.4		5.4	5.4		5.2	6.5
3	62.6			72.0			72.6			64.5		
3-4		6.1	6.8		5.8	5.7		5.5	5.7		6.2	6.8
4	56.5			66.2			67.1			58.3		
4-5		6.7	7.3		6.2	6.0		5.8	6.0		6.7	7.3
5	49.8			60.0			61.3			51.6		
5-6		7.1	7.9		6.5	6.5		6.1	6.4		7.2	7.9
6	42.7			53.5			55.2			44.4		
6-7		7.6	8.6		7.3	7.2		6.8	7.1		7.8	8.6
7	35.1			46.2			48.4			36.6		
7-8		7.4	9.0		7.4	8.2		7.3	8.0		7.3	9.0
8	27.7			38.8			41.1			29.3		
8-9		5.1	9.3		7.7	8.7		7.0	8.6		6.3	9.3
9	22.6			31.1			34.1			23.0		
9-10		3.6	9.6		7.2	9.1		6.3	8.9		4.3	9.6
10	19.0			23.9			27.8			18.7		
10-11		2.2	...		4.8	...		4.5	...		2.6	...
11	16.8			19.1			23.3			16.2		
11-12		0.1	...		1.9	...		2.1	...		0.8	...
12	16.7			17.2			21.2			15.4		
12-13		-2.0	...		-1.9	...		0.2	...		0.1	...
13	18.7			19.1			21.0			15.3		
13-14		0.7	...		-0.8	...		0.3	...		-0.4	...
14	18.0			19.9			20.7			15.7		
14-15		0.4	...		-0.1	...		+0.1	...		-0.1	...
15	17.6			20.0			20.6			15.8		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, ENGLAND.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72·6			81·9			83·7			73·3		
1-2		4·5	...		4·9	...		4·6	...		4·1	...
2	68·1			76·9			79·1			69·2		
2-3		5·5	...		5·5	...		5·2	...		5·5	...
3	62·6			71·4			73·9			63·7		
3-4		6·3	...		5·6	...		5·5	...		6·4	...
4	56·4			65·8			68·4			57·3		
4-5		6·7	...		6·4	...		6·1	...		7·0	...
5	49·7			59·3			62·3			50·3		
5-6		6·9	...		6·8	...		6·7	...		7·3	...
6	42·8			52·5			55·6			43·0		
6-7		6·7	...		7·6	...		7·1	...		7·2	...
7	36·1			44·9			48·5			35·8		
7-8		6·4	...		7·8	...		7·4	...		5·6	...
8	29·6			37·0			41·0			30·2		
8-9		5·4	...		7·4	...		7·1	...		3·9	...
9	24·2			29·6			33·9			26·3		
9-10		3·8	...		6·2	...		7·1	...		3·4	...
10	20·4			23·4			26·8			22·9		
10-11		2·2	...		3·0	...		5·5	...		2·3	...
11	18·2			20·4			21·3			20·6		
11-12		0·1	...		0·0	...		2·0	...		1·2	...
12	18·1			20·4			19·3			19·4		
12-13		0·5	...		-0·9	...		0·8	...		0·1	...
13	17·6			21·3			18·5			19·3		
13-14		0·4	...		-0·5	...		0·2	...		0·2	...
14	17·2			21·8			18·3			19·1		
14-15		-1·8	...		-0·6	...		0·2	...		0·4	...
15	19·0			22·4			18·1			18·7		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, HAMBURG.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	68·5			78·5			81·1			73·4		
1-2		5·5	...		5·6	...		4·4	...		4·4	...
2	63·0			72·9			76·7			69·0		
2-3		6·4	...		5·0	...		5·2	...		6·0	...
3	56·6			67·9			71·5			63·0		
3-4		6·3	...		5·0	...		6·2	...		5·1	...
4	50·3			62·9			65·3			57·9		
4-5		6·9	...		5·9	...		6·1	...		6·9	...
5	43·4			57·0			59·3			50·9		
5-6		5·9	...		6·0	...		6·9	...		7·2	...
6	37·5			51·0			52·4			43·7		
6-7		4·7	...		7·1	...		7·3	...		6·7	...
7	32·8			43·9			45·1			37·0		
7-8		4·3	...		7·9	...		6·8	...		5·9	...
8	28·5			36·0			38·3			31·1		
8-9		4·2	...		7·5	...		6·0	...		6·0	...
9	24·3			28·5			32·3			25·1		
9-10		4·5	...		6·7	...		5·3	...		3·0	...
10	19·9			21·8			27·0			22·1		
10-11		2·8	...		3·7	...		3·5	...		2·8	...
11	17·1			18·1			23·5			19·3		
11-12		-1·3	...		0·0	...		1·9	...		1·5	...
12	18·4			18·1			21·6			17·8		
12-13		-4·0	...		-3·2	...		0·2	...		0·3	...
13	22·4			21·3			21·4			17·5		
13-14		1·5	...		-2·8	...		0·7	...		1·5	...
14	20·9			24·1			20·7			16·0		
14-15		0·0	...		-0·6	...		0·7	...		0·0	...
15	20·9			24·7			20·0			16·0		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, UCCLE.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	70·2			81·1			83·1			73·8		
1-2		4·9	...		4·5	...		3·6	...		3·2	...
2	65·3			76·6			79·5			70·6		
2-3		4·3	...		6·2	...		5·3	...		5·2	...
3	61·0			70·4			74·2			65·4		
3-4		6·1	...		4·0	...		6·0	...		7·0	...
4	54·9			66·4			68·2			58·5		
4-5		7·1	...		6·9	...		5·6	...		7·2	...
5	47·8			59·5			62·6			51·3		
5-6		6·5	...		6·8	...		6·1	...		7·6	...
6	41·3			52·7			56·5			43·7		
6-7		6·9	...		7·4	...		6·6	...		7·2	...
7	34·4			45·3			49·9			36·5		
7-8		5·7	...		8·2	...		7·7	...		6·9	...
8	28·7			37·0			42·1			29·6		
8-9		4·5	...		8·4	...		6·7	...		7·1	...
9	24·3			28·6			35·4			22·5		
9-10		3·8	...		7·0	...		7·4	...		5·7	...
10	20·5			21·6			28·0			16·8		
10-11		2·8	...		4·3	...		7·1	...		2·7	...
11	17·7			17·3			20·9			14·1		
11-12		-1·2	...		1·1	...		6·0	...		1·5	...
12	18·9			16·2			14·9			12·6		
12-13		1·2	...		-0·7	...		3·0	...		-0·8	...
13	17·7			16·9			11·9			13·3		
13-14		1·9	...		-1·6	...		-0·8	...		2·7	...
14	15·8			18·5			12·7			10·6		
14-15		0·6	...		-0·2	...		0·8	...		1·0	...
15	15·2			18·7			11·9			9·6		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, PARIS.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	73·0			81·7			83·8			75·6		
1-2		3·9	...		5·0	...		4·4	...		3·0	...
2	69·1			76·7			79·4			72·6		
2-3		4·7	...		4·6	...		4·7	...		4·6	...
3	64·4			72·1			74·7			68·0		
3-4		6·0	...		5·3	...		5·0	...		5·8	...
4	58·4			66·7			69·7			62·2		
4-5		6·8	...		5·7	...		5·8	...		6·6	...
5	51·7			61·0			63·9			55·7		
5-6		7·0	...		6·7	...		6·6	...		6·5	...
6	44·7			54·3			57·3			49·2		
6-7		6·9	...		7·6	...		7·0	...		6·9	...
7	37·8			46·7			50·3			42·3		
7-8		7·1	...		7·3	...		7·4	...		7·6	...
8	30·7			39·3			43·0			34·7		
8-9		5·7	...		7·2	...		7·4	...		7·6	...
9	25·0			32·1			35·6			27·2		
9-10		4·2	...		6·0	...		6·6	...		6·6	...
10	20·8			26·1			29·1			20·6		
10-11		3·5	...		2·6	...		6·6	...		3·8	...
11	17·3			23·5			22·5			16·8		
11-12		-0·2	...		-1·5	...		4·5	...		0·3	...
12	17·5			25·0			18·0			16·5		
12-13		0·4	...		-0·9	...		-0·7	...		0·8	...
13	17·1			25·9			18·7			15·7		
13-14		-0·2	...		-0·3	...		-0·2	...		1·0	...
14	17·3			26·2			18·9			14·7		
14-15		0·5	...		0·4	...		-0·6	...		0·4	...
15	17·8			25·8			19·5			14·3		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS (with Approximate Values for Ascending Saturated Air in *Italic*), ENGLAND, HAMBURG, PARIS, AND UCCLE.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	72·1			81·4			83·6			74·1		
1-2		4·3	5·7		4·9	5·2		4·4	5·0		3·7	5·5
2	67·8			76·5			79·1			70·4		
2-3		5·2	6·6		5·2	5·5		5·0	5·3		5·2	6·4
3	62·6			71·3			74·1			65·2		
3-4		6·1	6·9		5·3	5·6		5·6	5·4		6·1	6·7
4	56·5			66·0			68·5			59·1		
4-5		6·7	7·4		6·3	6·1		6·0	5·9		6·9	7·2
5	49·8			59·7			62·5			52·1		
5-6		6·8	8·0		6·6	6·6		6·6	6·4		7·0	7·8
6	43·0			53·1			55·9			45·2		
6-7		6·5	8·6		7·4	7·3		7·0	6·9		6·8	8·6
7	36·5			45·7			48·9			38·4		
7-8		6·4	9·0		7·9	8·2		7·4	7·8		6·8	9·0
8	30·1			37·8			41·5			31·7		
8-9		5·4	9·3		7·6	8·7		7·1	8·3		5·7	9·3
9	24·7			30·2			34·4			26·0		
9-10		4·3	9·6		6·6	9·1		6·8	8·9		4·8	9·6
10	20·4			23·6			27·6			21·2		
10-11		2·7	...		3·3	...		5·7	...		2·9	...
11	17·7			20·3			21·8			18·3		
11-12		-0·2	...		-0·3	...		2·8	...		1·1	...
12	17·9			20·6			19·0			17·2		
12-13		-0·3	...		-1·2	...		0·3	...		0·0	...
13	18·2			21·8			18·7			17·1		
13-14		0·7	...		-0·8	...		0·1	...		0·5	...
14	17·5			22·6			18·6			16·6		
14-15		-0·4	...		-0·5	...		0·1	...		0·4	...
15	17·9			23·1			18·5			16·2		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, KOUTCHINO.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	67·4			83·4			80·2			66·3		
1-2		3·2	...		6·5	...		5·9	...		1·2	...
2	64·2			76·9			74·3			65·1		
2-3		4·7	...		5·7	...		4·5	...		3·3	...
3	59·5			71·2			69·8			61·8		
3-4		5·2	...		5·9	...		4·9	...		5·3	...
4	54·4			65·3			64·8			56·5		
4-5		5·8	...		6·0	...		5·9	...		6·5	...
5	48·6			59·3			58·9			50·0		
5-6		6·5	...		6·1	...		6·9	...		6·3	...
6	42·1			53·2			52·0			43·7		
6-7		6·4	...		7·1	...		7·1	...		7·0	...
7	35·7			46·1			44·9			36·7		
7-8		8·6	...		7·4	...		7·5	...		8·2	...
8	27·1			38·8			37·4			28·5		
8-9		7·1	...		6·8	...		7·1	...		8·0	...
9	20·0			32·0			30·3			20·5		
9-10		5·8	...		5·8	...		5·6	...		6·5	...
10	14·2			26·2			24·7			14·0		
10-11		-0·6	...		3·3	...		4·1	...		2·0	...
11	14·8			22·9			20·6			12·0		
11-12		-2·7	...		1·6	...		0·4	...		-1·3	...
12	17·5			21·3			20·2			13·3		
12-13		-1·3	...		-2·2	...		-0·2	...		-2·0	...
13	18·8			23·5			20·4			15·3		
13-14		0·3	...		0·4	...		0·6	...		0·0	...
14	18·5			23·1			19·8			15·3		
14-15		2·0	...		0·0	...		-0·8	...		1·5	...
15	16·5			23·1			20·6			13·8		

TABLE XI.—*continued.*

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, PAVLOVSK.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	65·3			75·8			79·0			63·8		
1-2		2·6	...		5·6	...		5·4	...		3·6	...
2	62·7			70·2			73·6			60·2		
2-3		5·2	...		5·7	...		4·8	...		5·9	...
3	57·5			64·5			68·8			54·3		
3-4		5·3	...		5·3	...		6·0	...		5·6	...
4	52·1			59·2			62·7			48·7		
4-5		6·3	...		6·1	...		6·2	...		4·9	...
5	45·8			53·1			56·5			43·8		
5-6		6·6	...		6·8	...		6·3	...		6·3	...
6	39·3			46·3			50·2			37·5		
6-7		7·2	...		6·9	...		7·0	...		6·1	...
7	32·1			39·4			43·2			31·4		
7-8		6·8	...		6·8	...		7·5	...		5·8	...
8	25·4			32·7			35·7			25·5		
8-9		6·5	...		5·0	...		6·1	...		4·3	...
9	18·9			27·7			29·6			21·2		
9-10		3·1	...		3·1	...		4·2	...		2·6	...
10	15·8			24·6			25·4			18·6		
10-11		—0·2	...		1·2	...		2·7	...		0·2	...
11	16·0			23·4			22·7			18·4		
11-12		—0·2	...		—0·9	...		0·0	...		0·4	...
12	16·2			24·3			22·7			18·0		
12-13		—0·5	...		—1·3	...		—0·6	...		—2·7	...
13	16·7			25·6			23·3			20·7		
13-14		0·0	...		—0·2	...		—1·4	...		1·0	...
14	16·7			25·8			24·7			19·7		
14-15		1·0	...		—0·3	...		—0·6	...		1·0	...
15	15·7			26·1			25·3			18·7		

SEASONAL VALUES FOR TEMPERATURES AND GRADIENTS, ITALY.

Height.	I.—Feb., Mar., Apr.			II.—May, June, July.			III.—Aug., Sept., Oct.			IV.—Nov., Dec., Jan.		
km.	°A.			°A.			°A.			°A.		
1	75·3			84·7			87·9			74·8		
1-2		6·6	...		7·2	...		6·1	...		2·3	...
2	68·7			77·5			81·8			72·5		
2-3		5·8	...		6·8	...		6·2	...		5·0	...
3	62·9			70·7			75·6			67·5		
3-4		6·0	...		6·9	...		6·1	...		6·1	...
4	56·9			63·8			69·5			61·4		
4-5		7·0	...		6·3	...		5·5	...		8·0	...
5	49·9			57·5			64·0			53·4		
5-6		6·2	...		6·7	...		6·7	...		7·7	...
6	43·7			50·8			57·3			45·7		
6-7		6·7	...		7·3	...		7·1	...		8·0	...
7	37·0			43·5			50·2			37·8		
7-8		8·6	...		7·9	...		7·3	...		6·9	...
8	28·4			35·6			43·0			30·9		
8-9		5·0	...		6·3	...		7·4	...		8·3	...
9	23·4			29·3			35·6			22·6		
9-10		4·9	...		5·1	...		6·8	...		7·4	...
10	18·5			24·2			28·8			15·2		
10-11		3·3	...		2·3	...		6·8	...		6·6	...
11	15·2			21·9			22·0			8·6		
11-12		4·3	...		3·3	...		4·1	...		—0·6	...
12	10·9			18·6			17·9			9·2		
12-13		2·2	...		0·8	...		—0·7	...		—1·9	...
13	8·7			17·8			18·6			11·1		
13-14		—1·5	...		—0·8	...		—1·0	...		—0·6	...
14	10·2			18·6			19·6			11·7		
14-15		—1·5	...		—0·5	...		—0·6	...		0·8	...
15	11·7			19·1			20·2			10·9		

from 3-6 km. is greater in winter than in summer. The maximum seasonal value is in period II. from 7-8 km.

(6) *Hamburg*.—The maximum temperature occurs in October from 1-9 km., and the minimum in March up to 7 km. Above 9 km. the maximum changes to September and July, and above 7 km. the minimum to January, February, and October. Period I. is much the coldest up to 11 km., and period III. the warmest up to 13 km. Above 11 km. period IV. becomes the coldest. The gradient from 2-5 km. is less in summer than in winter. The maximum seasonal value is in period II. from 7-8 km.

(7) *Paris*.—The maximum temperature occurs in August up to 10 km., and above 10 km. in June. The minimum occurs in March up to 9 km., and above this in January and October. Period I. is much the coldest up to 9 km., and period III. the warmest up to 10 km. Above 9 km. period IV. becomes the coldest, and above 10 km. period II. the warmest. The gradient from 3-5 km. is less in summer than in winter. The maximum seasonal value occurs both in period IV. from 7-9 km. and period II. from 6-7 km.

(8) *Uccle*.—The maximum temperature occurs in August up to 11 km., except at 1 km., and the minimum in March up to 9 km. Above 11 km. the maximum occurs in July, and above 9 km. the minimum in January, June, and November. Period I. is the coldest up to 8 km., and period III. the warmest up to 11 km. Above 8 km. period IV. becomes the coldest, and above 11 km. period I. the warmest. The gradient from 3-5 km. is less in summer than in winter. The maximum seasonal value is in period II. from 8-9 km.

(9) *Koutchino*.—The maximum temperature occurs in July at all heights; the minimum in February up to 6 km., in March from 7-10 km., and in January and February above 10 km. Period I. is the coldest up to 9 km., above which period IV. becomes the coldest. Period II. is the warmest throughout. This result is what might be expected for a continental region where the warming is mainly due directly to solar radiation and no large masses of water retard the process. The gradient is greater in winter than in summer from 7-10 km., a somewhat remarkable result. The maximum seasonal value occurs in period I. from 7-8 km.

(10) *Pavlovsk*.—The maximum temperature occurs in August up to 11 km., and in June and July above this level. The minimum occurs in December up to 8 km., and in February, March, and April at greater heights. Period IV. is the coldest up to 7 km., above which period I. becomes the coldest. Period III. is the warmest up to 10 km., and period II. above 10 km. The gradient in summer is nowhere markedly less than in winter. The maximum seasonal value is in period III. from 7-8 km.

(11) *Italy*.—The maximum temperature occurs in August up to 8 km., above which it changes to September. The minimum occurs in March up to 10 km., and in January and February at greater heights. Period I. is the coldest up to 8 km., above which period IV. becomes the coldest. Period III. is the warmest at all heights except at 12 km. The gradient is greater in winter than in summer from 4-7 km. The maximum seasonal value is in period I. from 7-8 km.

(12) *Central Europe*.—The maximum temperature occurs in August up to 9 km., in September at greater heights. The minimum in March from 2-8 km., in January from 9-11 km., in February at 12 km., and in December at 13-15 km. Period III. is the warmest at all heights. Period I. is the coldest up to 9 km., and period IV. above

this level. The gradient is greater in winter than in summer from 3-7 km. The maximum seasonal value is in period II. from 8-9 km. From 7 km. upwards the temperature differences (period III.-period II.) exceed the values (period IV.-period I.).

(13) *N. W. Europe*.—The maximum temperature occurs in August up to 11 km., except at 2 km., where it is in October; above 11 km. it is in July. The minimum temperature occurs in March up to 9 km., and in January above 9 km. Period I. is the coldest up to 11 km.; period IV. above 11 km. Period III. is the warmest up to 11 km.; period II. above 11 km. The gradient is greater in winter than in summer from 2-6 km. The maximum seasonal value is in period II. from 7-8 km. From 5 km. upwards to 11 km. the temperature differences (period III.-period II.) exceed the values (period IV.-period I.). We notice that in general the relative warmth of period III. extends to greater heights than the relative cold of period I. This agrees roughly with the heights at which the stratosphere is reached in the two periods.

In general, August is the warmest month, and March the coldest month in the troposphere, except close to the earth's surface. There is, therefore, a greater retardation in the date of minimum temperature in the upper atmosphere than in the date of maximum, which agrees with theory, inasmuch as convection is effective in carrying warmth upwards, but cannot be an agent in transmitting the surface cold to higher levels.

The maximum seasonal values of the gradients for the different places have been brought together into one table (Table XII.), and the heights at which they are found are also given. The heights are generally 1-2 km. greater in summer than in winter. The

TABLE XII.—MAXIMUM VALUES OF GRADIENT FOR DIFFERENT SEASONS, AND HEIGHTS AT WHICH IT IS FOUND.

	I. Feb., Mar., Apr.		II. May, June, July.		III. Aug., Sept., Oct.		IV. Nov., Dec., Jan.	
	Maxi- mum Gradient.	Height.	Maxi- mum Gradient.	Height.	Maxi- mum Gradient.	Height.	Maxi- mum Gradient.	Height.
	°C. per km.	km.	°C. per km.	km.	°C. per km.	km.	°C. per km.	km.
Berlin	7.6	6-7	7.9	8-9	7.2	7-8	8.1	6-7
Strassburg	7.4	5-6	7.9	8-9	7.3	7-9	7.6	6-8
Munich	7.7	7-8	7.9	9-10	7.4	8-10	7.3	5-6
Vienna	8.5	7-8	8.1	6-7	7.8	7-8	8.0	6-7
Mean	7.6	6-7	7.7	8-9	7.3	7-8	7.8	6-7
Paris	7.1	7-8	7.6	6-7	7.4	7-9	7.6	7-9
Hamburg	6.9	4-5	7.9	7-8	7.3	6-7	7.2	5-6
Uccle	7.1	4-5	8.4	8-9	7.7	7-8	7.6	5-6
England	6.9	5-6	7.8	7-8	7.4	7-8	7.3	5-6
Mean	6.8	5-6	7.9	7-8	7.4	7-8	7.0	5-6
Pavlovsk	7.2	6-7	6.9	6-7	7.5	7-8	6.3	5-6
Koutchino	8.6	7-8	7.4	7-8	7.5	7-8	8.2	7-8
Italy	8.6	7-8	7.9	7-8	7.4	8-9	8.3	8-9

x and n mark respectively the maximum and minimum values in each row.

greatest of the maximum values occur generally in period II., but for Vienna, Koutchino, and Italy, in period I.

From the seasonal values we see that the adiabatic gradient for ascending saturated air agrees very closely with the actual values from 1-7 km. in summer, but in winter the approximation is nowhere so close.

This is no doubt due partly to the greater effect of solar radiation in summer, which tends to neutralise the effect of atmospheric radiation, in diminishing the gradient in the atmosphere below this level. The fact that *the actual gradient in summer is less than that in winter from 3-7 km. indicates that the condensation of water-vapour governs very strictly the value of the vertical temperature gradient.*

The same applies to the values for N.W. Europe, but the close approach to adiabatic values extends up to 8 km., and there is a very close approximation to the adiabatic gradient between 4 and 5 km. in winter, where the maximum value for the season occurs. For Central Europe the corresponding height is 6-7 km. For early summer the maximum value is from 8-9 km. for Central Europe, and from 7-8 km. for N.W. Europe, while in August to October it is from 7-8 km. for both regions.

The temperatures in period I. are almost identical for the two regions up to 6 km., above which Central Europe becomes the colder. In period II., on the other hand, Central Europe becomes the warmer up to 10 km. This indicates a retardation of the time of maximum temperature in the troposphere in N.W. Europe. At greater heights Central Europe is considerably cooler. In period III. Central Europe is the cooler up to 9 km., above which it becomes the warmer. This agrees with theory, inasmuch as a continental region should be cooled and heated more rapidly than an oceanic, and the surface effects ought to extend throughout the troposphere. The fact that in the stratosphere over Central Europe III. is the warmest and IV. the coldest period indicates that cooling may take place more rapidly than warming in that region.

As the pressure at the times of the ascents varied considerably it became necessary to correct the values of the temperature on this account, before analysing the results. The average value of the pressure at sea-level for the ascents used for the means for **Berlin, Munich, Strassburg, and Vienna** are (700 mm. +) :—

	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	66.2	65.5	61.8	61.0	64.2	60.8	61.0	62.6	58.9	64.2	57.9	60.7
Difference from yearly mean	+4.1	+3.4	-0.3	-1.1	+2.1	-1.3	-1.1	+0.5	-3.2	+2.1	-4.2	-1.4
Average difference of monthly mean from yearly mean.*	+2.4	+1.2	-1.2	-1.4	-1.4	-0.5	-0.6	-0.5	+0.8	+0.2	-0.1	+1.6
Variation from average	+1.7	+2.2	+0.9	+0.3	+3.5	-0.8	-0.5	+1.0	-4.0	+1.9	-4.1	-3.0

* Hann, *Die Verteilung des Luftdruckes.*

The average for the year at the times of the registering balloon ascents is 762.1, and does not differ appreciably from the long period average 762.4 given by Hann.

For a continent the following corrections have been used. The amounts given are

the values of the correction to be applied for a sea-level pressure 10 mm. in excess of the average :—

Height in kilometres }	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correction A	-0.4	-1.3	-1.6	-1.8	-1.7	-1.6	-1.6	-1.2	-0.3	+0.6	+1.6	+2.5	+3.2	+3.0	(+3.0)	(+3.0)

The corrections have been obtained by using the table given below, p. 132, in which the ascents with pressures below 750 (mean 745 mm. nearly) and above 770 (mean 775 mm. nearly) have been used.

For **England, Hamburg, Paris, and Uccle** the corrections used have been taken to be the mean of those found above and those given for England by W. H. Dines.*

The latter gives the values shown in the first line of the following table :—

Height in kilometres.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Correction D	-1.1	-2.3	-2.6	-3.4	-3.7	-4.0	-4.3	-3.7	-2.0	-0.3	+1.1	+2.3	+3.1	+2.6	(+2.6)	(+2.6)
Mean of A and D	-0.7	-1.8	-2.1	-2.6	-2.7	-2.8	-2.9	-2.4	-1.1	+0.2	+1.4	+2.4	+3.2	+2.8	+2.8	+2.8

The mean pressures at sea-level at the times of the ascents are (700 mm. +) :—

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Mean	64.5	69.0	58.3	58.6	63.1	63.4	62.6	64.6	63.0	64.6	57.5	56.3
Difference from yearly mean	2.4	6.9	-3.8	-3.5	1.0	1.3	0.5	2.5	0.9	2.5	-4.6	-5.8
Average difference . . .	1.1	0.8	-0.9	-0.9	-0.1	0.4	0.2	-0.1	0.8	-0.9	-0.6	0.3
Variation from average . .	1.3	6.1	-2.9	-2.6	1.1	0.9	0.3	2.6	0.1	3.4	-4.0	-6.1

The average for the year at the times of the registering balloon ascents is 762.1, which agrees very closely with the normal for the year.

The corrections applied are shown in Tables XIII., and the corrected means in Tables XIV.

TABLE XIII.—CORRECTIONS TO BE APPLIED TO THE MEAN MONTHLY TEMPERATURES FOR THE DIFFERENCE OF PRESSURE FROM THE AVERAGE FOR THE MONTH.
BERLIN, MUNICH, STRASSBURG, AND VIENNA.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
km.												
1	-0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	0.0	+0.2	-0.1	+0.2	+0.1
2	-0.2	-0.3	-0.1	0.0	-0.5	+0.1	+0.1	-0.1	+0.5	-0.2	+0.5	+0.4
3	-0.3	-0.4	-0.1	0.0	-0.6	+0.1	+0.1	-0.2	+0.6	-0.3	+0.7	+0.5
4	-0.3	-0.4	-0.2	-0.1	-0.6	+0.1	+0.1	-0.2	+0.7	-0.3	+0.7	+0.5
5	-0.3	-0.4	-0.2	-0.1	-0.6	+0.1	+0.1	-0.2	+0.7	-0.3	+0.7	+0.5
6	-0.3	-0.4	-0.1	0.0	-0.6	+0.1	+0.1	-0.2	+0.6	-0.3	+0.7	+0.5
7	-0.3	-0.4	-0.1	0.0	-0.6	+0.1	+0.1	-0.2	+0.6	-0.3	+0.7	+0.5
8	-0.2	-0.3	-0.1	0.0	-0.4	+0.1	+0.1	-0.1	+0.5	-0.2	+0.5	+0.4
9	-0.1	-0.1	0.0	0.0	-0.1	0.0	0.0	0.0	+0.1	-0.1	+0.1	+0.1
10	+0.1	+0.1	+0.1	0.0	+0.2	0.0	0.0	+0.1	-0.2	+0.1	-0.2	-0.2
11	+0.3	+0.4	+0.1	0.0	+0.6	-0.1	-0.1	+0.2	-0.6	+0.3	-0.7	-0.5
12	+0.4	+0.5	+0.2	+0.1	+0.9	-0.2	-0.1	+0.2	-1.0	+0.5	-1.0	-0.8
13	+0.5	+0.7	+0.3	+0.1	+1.1	-0.3	-0.2	+0.3	-1.3	+0.6	-1.3	-1.0
14	+0.5	+0.7	+0.3	+0.1	+1.0	-0.2	-0.2	+0.3	-1.2	+0.6	-1.2	-0.9
15	+0.5	+0.7	+0.3	+0.1	+1.0	-0.2	-0.2	+0.3	-1.2	+0.6	-1.2	-0.9
16	+0.5	+0.7	+0.3	+0.1	+1.0	-0.2	-0.2	+0.3	-1.2	+0.6	-1.2	-0.9

* "Vertical Temperature Distribution," *Phil. Trans.*, vol. cxxi., Series A, p. 262.

TABLE XIII.—*continued.*
ENGLAND, PARIS, HAMBURG, AND UCCLE.

Height.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
km.												
1	-0.1	-0.4	+0.2	+0.2	-0.1	-0.1	0.0	-0.2	0.0	-0.2	0.3	0.4
2	-0.2	-1.1	0.5	0.5	-0.2	-0.2	-0.1	-0.5	0.0	-0.6	0.7	1.1
3	-0.3	-1.3	0.6	0.5	-0.2	-0.2	-0.1	-0.5	0.0	-0.7	0.8	1.3
4	-0.3	-1.6	0.8	0.7	-0.3	-0.2	-0.1	-0.7	0.0	-0.9	1.0	1.6
5	-0.4	-1.6	0.8	0.7	-0.3	-0.2	-0.1	-0.7	0.0	-0.9	1.1	1.6
6	-0.4	-1.7	0.8	0.7	-0.3	-0.3	-0.1	-0.7	0.0	-1.0	1.1	1.7
7	-0.4	-1.8	0.8	0.8	-0.3	-0.3	-0.1	-0.8	0.0	-1.0	1.2	1.8
8	-0.3	-1.5	0.7	0.6	-0.3	-0.2	-0.1	-0.6	0.0	-0.8	1.0	1.5
9	-0.1	-0.7	+0.3	0.3	-0.1	-0.1	0.0	-0.3	0.0	-0.4	0.4	0.7
10	0.0	0.1	-0.1	-0.1	0.0	0.0	0.0	0.1	0.0	+0.1	-0.1	0.1
11	+0.2	0.9	-0.4	-0.4	+0.2	+0.1	0.0	0.4	0.0	0.5	-0.6	-0.9
12	+0.3	1.5	-0.7	-0.6	+0.3	+0.2	+0.1	0.6	0.0	0.8	-1.0	-1.5
13	+0.4	2.0	-0.9	-0.8	+0.4	+0.3	+0.1	0.8	0.0	1.1	-1.3	-2.0
14	+0.4	1.7	-0.8	-0.7	+0.3	+0.3	+0.1	0.7	0.0	1.0	-1.1	-1.7
15	+0.4	1.7	-0.8	-0.7	+0.3	+0.3	+0.1	0.7	0.0	1.0	-1.1	-1.7
16	+0.4	1.7	-0.8	-0.7	+0.3	+0.3	+0.1	0.7	0.0	1.0	-1.1	-1.7

The effect of the correction for Central Europe is to diminish the deficiency of temperature in September, and to accentuate slightly the minimum in March. For N.W. Europe the effect is the same in autumn, but the temperature in March is raised, while that in February is lowered. March, however, remains the coldest month of the year, and September colder than August or October.

The corrected values have been analysed, and the results are given in Table XV., which contains the values of P_1 , P_2 , P_3 , a_1 , a_2 , a_3 , the constants in the sine series.

$$T = T_0 + P \sin(nt + a_1) + P_2 \sin(2nt + a_2) + P_3 \sin(3nt + a_3).$$

First we notice that the amplitude of the whole year variation is *considerably less for N.W. Europe than for Central Europe*. The difference diminishes up to 3 km., remains small and nearly constant from 3 to 5 km., and then increases rapidly up to 9 km., above which it diminishes again, and changes sign at 12 to 14 km.

The effect is due mainly to the low temperatures over Central Europe in winter. The values for summer differ little for the two regions. The smallness of the difference between 3 and 5 km., *i.e.* in the region of the intermediate and lower clouds, is a remarkable feature. It appears to be due to the smaller range in height of the cloud level between winter and summer over N.W. Europe. This diminishes the rate at which the annual variation decreases with altitude; which is in accordance with the reasoning given above in connection with the annual range, see pp. 75, 76.

The maximum value of the amplitude of the whole year term is at 7 and 8 km. for Central Europe. For N.W. Europe it occurs at 6 km. This is due mainly to the remarkable falling off in winter in the gradient above 6 km., which becomes much less than the value for saturated air rising adiabatically.

If there is a greater amount of water-vapour present in the air over N.W. Europe, this would shield the upper layers from the radiation from the warmer earth and atmosphere below, and consequently tend to diminish the temperature of the upper layers. Radiation can therefore only account for the difference if the earth's surface is at a much lower temperature over Central Europe than over N.W. Europe. It is very improbable that the actual difference is sufficient to account for the effect noted. It seems more likely that *the effect is due to the difference in the origin of the currents*

TABLE XIV.—TEMPERATURE—CORRECTED FOR VARIATION OF PRESSURE FROM THE NORMAL. MEANS FOR BERLIN, MUNICH, STRASSBURG, VIENNA (200° +).

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	69.1	69.7	71.5	75.1	79.4	85.5	83.7	86.1	81.5	81.9	76.3	74.3
2	66.5	68.6	65.9	69.3	73.8	80.2	77.5	80.4	76.1	77.9	72.8	70.6
3	62.1	63.4	59.7	64.2	69.0	74.5	72.1	74.8	70.3	73.0	67.3	65.1
4	56.4	57.5	53.1	58.3	63.1	68.6	66.4	69.4	64.9	67.3	60.9	58.7
5	50.1	51.1	46.1	51.5	56.9	62.6	60.1	63.7	59.5	61.1	54.0	51.8
6	43.0	44.4	38.9	44.4	50.2	56.1	53.9	57.6	53.6	54.6	46.9	44.4
7	35.3	36.8	31.4	36.8	42.9	49.0	46.4	50.7	46.8	47.9	39.3	36.4
8	27.4	29.2	24.8	29.0	35.9	41.6	38.9	43.0	39.5	41.1	32.4	29.2
9	20.2	23.5	20.4	23.3	28.9	33.2	31.2	35.3	33.1	33.8	26.6	22.4
10	15.1	19.2	18.8	19.3	23.5	25.4	23.7	27.4	28.3	27.5	22.7	18.1
11	13.6	16.0	18.9	17.5	18.8	19.5	20.6	22.0	25.6	22.0	18.3	14.5
12	15.1	13.7	19.7	17.2	18.0	16.0	22.2	20.8	25.0	18.3	15.9	12.9
13	16.9	18.2	21.5	18.9	19.7	18.6	23.5	21.2	24.0	16.4	14.6	11.0
14	16.7	18.4	19.8	17.5	21.8	18.9	24.1	21.4	23.4	15.5	15.6	11.9
15	17.2	18.1	21.3	15.4	22.4	17.3	24.1	21.5	22.0	16.8	15.1	12.4
16	...	...	...	17.1	21.8	17.1	25.6	23.2	23.5	16.0	14.8	14.4

TEMPERATURES OBTAINED FROM GRADIENTS ABOVE 8 KM., AND CORRECTED FOR VARIATION OF PRESSURE.

9	20.2	23.4	21.1	23.4	28.9	33.2	31.2	35.1	33.1	34.2	26.8	22.4
10	15.0	18.4	19.7	19.3	22.9	25.4	23.7	27.2	28.3	27.9	21.9	19.3
11	13.5	14.8	19.8	16.4	18.2	19.0	20.6	21.8	25.6	22.4	17.6	16.7
12	14.7	14.2	20.9	15.9	17.2	15.6	19.5	20.2	24.3	18.7	15.5	14.6
13	16.4	17.9	22.4	17.0	19.0	17.9	21.0	20.9	23.3	18.3	14.0	13.8
14	16.0	18.2	21.4	15.6	21.1	18.4	20.9	21.2	22.7	17.7	15.4	14.2
15	16.0	17.0	22.9	14.1	21.6	18.3	+20.9	21.6	22.1	18.1	15.5	14.4
16	...	17.0	...	12.6	21.6	18.0	20.9	22.1	21.4	18.1	14.5	15.1

MEANS FOR ENGLAND, HAMBURG, PARIS, UCCLE (200° +).

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1	72.9	72.0	70.5	73.9	79.6	82.0	82.5	85.0	81.0	84.3	76.4	73.5
2	69.0	68.9	65.9	68.5	74.8	77.1	77.2	79.9	76.3	80.1	73.7	70.1
3	63.7	63.7	60.2	63.6	69.5	71.9	72.0	75.2	70.9	75.0	68.8	65.0
4	58.0	57.9	53.7	57.6	64.4	66.4	66.5	69.8	65.2	68.9	63.2	57.5
5	51.1	51.4	46.8	51.0	57.8	59.9	60.6	64.1	59.3	62.5	56.3	51.3
6	44.5	44.9	39.7	44.2	51.3	53.9	54.1	57.6	52.7	55.6	49.4	44.3
7	37.9	38.6	33.0	37.7	43.4	45.8	47.2	50.4	45.5	48.8	42.8	37.4
8	29.8	31.5	27.3	31.3	35.2	38.2	39.4	43.4	37.9	41.6	36.3	31.2
9	23.4	26.1	23.1	24.8	26.9	30.5	32.3	36.6	31.3	35.0	29.4	25.8
10	18.0	21.1	20.1	19.9	20.6	23.4	25.7	29.3	25.9	29.5	19.4	20.4
11	16.2	16.4	18.2	17.9	18.2	19.2	23.0	23.1	22.3	22.0	19.7	17.6
12	15.3	16.3	19.1	14.8	17.9	19.2	24.8	20.3	21.1	17.4	18.9	15.7
13	15.2	17.3	19.9	19.3	18.6	20.3	25.7	21.2	20.3	15.5	17.8	15.9
14	15.3	16.2	20.5	20.6	19.5	20.9	25.9	21.7	20.9	13.0	16.7	15.8
15	16.0	16.8	21.1	21.2	20.1	22.6	25.1	23.0	21.7	13.6	16.4	13.2
16	18.4	18.7	21.5	21.6	21.7	22.3	24.4	24.8	22.5	13.0	15.7	16.7

VALUES OBTAINED FROM GRADIENTS ABOVE 8 KM., AND CORRECTED FOR VARIATION OF PRESSURE.

9	23.4	26.1	23.1	24.8	27.4	30.5	32.3	36.4	31.3	34.6	29.7	25.9
10	17.9	21.1	19.9	20.1	21.1	23.7	25.8	29.4	26.0	27.3	24.1	21.5
11	16.0	17.1	18.1	18.1	18.7	19.5	22.8	23.2	22.1	21.0	20.2	17.3
12	15.0	16.7	18.8	18.4	18.4	19.3	24.5	20.6	21.0	16.7	18.8	15.5
13	14.9	17.1	18.7	18.2	19.1	21.7	25.2	21.5	20.6	15.7	18.5	15.1
14	14.5	15.9	19.4	16.6	20.0	22.6	25.8	22.1	21.1	14.2	17.9	15.0
15	14.4	16.3	19.4	17.4	20.9	23.4	25.5	22.2	21.6	13.3	18.0	13.7

affecting the two regions, and that the relative warmth above 6 km. over N.W. Europe is due to the fact that the air arriving there has come from the south, and is, in fact, potentially warm air flowing over the potentially colder air beneath.

The amplitude is small in both regions above 10 km. Over Central Europe at 13 km. it is less than that of the semi-annual term.

The phase of the whole year term diminishes up to 3 km., above which it remains nearly constant up to 11 km., with a peculiar minimum at 10 km. for Central Europe and 9 km. for N.W. Europe. Above 11 km. the phase increases, indicating that the

TABLE XV.—VALUES OF THE CO-EFFICIENTS IN THE SERIES FOR THE ANNUAL TEMPERATURE VARIATION.

Mean of Berlin, Munich, Strassburg, and Vienna.							Mean of England, Hamburg, Paris, and Uccle.					
Height.	P ₁ .	P ₂ .	P ₃ .	a ₁ .	a ₂ .	a ₃ .	P ₁ .	P ₂ .	P ₃ .	a ₁ .	a ₂ .	a ₃ .
km.	°A.	°A.	°A.				°A.	°A.	°A.			
1	7.87	0.98	0.27	247 15	177 50	277	6.67	0.44	1.20	236 30	176 35	19 50
2	6.55	1.00	1.07	238 10	146 25	347	6.13	0.69	1.38	229 0	173 0	23 30
3	6.38	1.04	1.19	237 50	147 20	4	6.23	0.75	1.24	228 10	83 50	9 30
4	6.72	1.06	1.34	238 0	139 0	15	6.51	0.70	1.50	231 30	161 50	11 50
5	7.18	1.04	1.67	238 0	127 30	24	6.98	0.59	1.44	231 30	144 50	16 20
6	7.73	0.94	1.87	238 15	118 30	24	7.06	0.58	1.52	232 10	130 50	20 40
7	8.13	0.61	2.10	238 10	106 30	24	6.80	0.48	1.43	229 45	114 40	11 20
8	8.13	0.44	2.10	237 30	138 10	17	6.48	0.12	0.90	227 15	358 0	344 5
9	7.17	0.53	1.72	237 20	279 30	8	5.58	0.65	0.90	223 0	351 30	309 50
10	5.27	1.70	1.25	234 15	280 5	358	4.25	1.83	0.79	228 5	341 40	323 50
11	3.77	2.35	0.58	237 35	294 25	348	3.22	0.81	0.72	228 25	328 40	241 40
12	3.40	2.55	0.49	248 15	327 50	339	2.90	1.12	1.46	246 30	39 10	279 0
13	3.47	3.03	0.39	284 40	349 0	11	3.13	1.23	1.64	278 30	34 10	235 30
14	3.65	2.18	0.50	281 30	2 20	35	3.90	1.36	1.82	288 50	38 0	207 50
15	3.13	2.33	0.52	280 50	3 40	6	4.58	1.65	1.01	290 40	17 30	212 30

VALUES ABOVE 8 KM. OBTAINED BY USING GRADIENTS.

9	7.07	0.71	1.72	237 10	276 20	2 20	5.52	0.48	0.85	223 40	350 0	308 50
10	5.20	1.73	1.00	232 50	279 40	353 40	4.20	0.90	0.80	222 30	335 0	343 50
11	3.72	2.12	0.25	229 50	305 40	316 50	3.04	0.73	0.73	232 0	322 50	242 0
12	2.50	1.02	0.37	238 0	330 10	157 10	2.85	0.80	1.32	262 50	13 20	88 10
13	2.33	2.86	0.45	276 30	343 0	13 20	3.53	1.03	1.30	271 50	51 0	252 50
14	2.47	2.07	0.65	274 0	346 50	17 30	4.22	1.42	1.25	272 10	62 10	247 20
15	2.50	2.01	0.55	271 10	346 40	352 0	4.67	1.27	1.00	278 40	56 50	252 10

times of maximum and minimum temperature at a given level are close to the solstices for the stratosphere.

The amplitude of the semi-annual term, P₂, is a maximum in both regions at 2–4 km., where the whole year term, P₁, is a minimum. P₂ diminishes to a minimum at 8 km., both for central and for N.W. Europe, and about this level the phase changes by about 180°. It appears probable, therefore, that the semi-annual variation vanishes at 7–8 km., and reappears at greater heights, with sign changed. In the lower layers the variation has maxima in June and December, minima in March and September.

The minimum in September is a remarkable feature, which is found also in the height of the stratosphere. The probable explanation of the phenomenon is suggested in section I. (d). That it is not simply due to a peculiarity in the pressure distribution at the time of the ascents is shown by the fact that it persists very markedly even when corrections have been applied on this account.

The amplitude and phase of the third term, corresponding with a four monthly period, are remarkably regular throughout. They correspond with minima near the end of March, July, November, and maxima near the end of May, September, January.

The amplitudes and phases at 1, 2, 3 km. agree very closely with those found for Berlin from the kite observations. The latter values come between those for Central and N.W. Europe; nearer to those for Central Europe, as would be expected. The amplitudes for the second and third terms are less for the kite observations, showing that these values are affected by accidental causes in the case of the registering balloon results. The phases, however, agree moderately well, showing that the principal features are true for the balloon results even though they are exaggerated.

I. (c).—DIURNAL VARIATION OF TEMPERATURE.

Clayton concluded, from a discussion of kite ascents made at Blue Hill, that the most marked feature in the diurnal temperature variation in the free atmosphere was the increase in the semi-diurnal term and the vanishing and reappearance with changed phase of the diurnal term in the first 1000 m. Wundt,* using observations made at Hald, in Jutland, obtained results for 1200 m., from which the following expression for the variation has been calculated—

$$T = T_m + 0.55 \sin(nt + 248^\circ) + 0.05 \sin(2nt + 349^\circ),$$

time being measured from midnight and the amplitudes being expressed in degrees C.

For the autumn of 1902, his results, which he regards as more trustworthy than the general means, give

$$T = T_m + 0.35 \sin(nt + 229^\circ) + 0.13 \sin(2nt + 217^\circ).$$

The richest material for a discussion of diurnal variation is contained in the *Ergebnisse der Arbeiten des K. Preuss. Aër. Observatoriums* at Lindenberg (Berlin, prior to 1905). The results for the five years 1903–1907 have been used to obtain the variation at 1 and 2 km. height.

If T_0 is the mean temperature (at Potsdam) for the twenty-four hours in the middle of which the kite ascent is made, and T_1 , T_2 the temperatures at 1000 m., 2000 m., respectively, then the following Table XVI. gives the values of $T_0 - T_1$ for different values of T_0 . The mean values of $T_0 - T_2$, which were treated in the same manner, have been added to the Table, as well as the mean values for $T_0 - T_1$ for those cases in which the wind at 1000 m. exceeded 8 m/s.

TABLE XVI.—VARIATION OF THE GRADIENT OF TEMPERATURE WITH THE TEMPERATURE AT GROUND LEVEL.

T_0	<0° C.	0°–5°.	5°–10°.	10°–15°.	15°–20°.	>20°.	Mean.	Mean for Wind, >8 m/s.	Mean for $T_0 - T_2$.
Year.									
1903	–0.82	3.92	4.47	5.55	5.63	3.49	4.44	4.53	8.79
1904	2.22	2.50	4.21	5.48	6.43	5.42	4.42	4.33	8.23
1905	1.37	3.21	4.64	5.45	5.34	4.78	4.30	4.44	9.55
1906	2.19	4.64	3.22	5.69	5.93	5.48	4.66	4.12	9.64
1907	3.40	2.56	5.52	4.93	5.34	5.08	4.50	...	9.58
Means 1903–1907	2.03	3.40	4.48	5.39	5.69	5.05	...	4.34	9.32
...	±0.14	±0.09	±0.09	±0.09	±0.10	±0.19	...	...	...

* *Met. Zeit.*, 1908.

By using these results to correct the values of $T_0 - T_1$ at different hours of the day, the following values were obtained, Table XVII. The values of $T_0 - T_2$ were dealt with in a similar manner. The sixth column gives similar values for Pavlovsk for 1902-1903. The values for Lindenberg are corrected also for the variation from year to year.

TABLE XVII.—HOURLY VALUES OF THE DIFFERENCE BETWEEN THE TEMPERATURE AT HEIGHTS OF 1 KM. AND 2 KM., AND THE MEAN TEMPERATURE FOR THE DAY AT GROUND LEVEL.

Hour.	Corrected $T_0 - T_1$.	Number of Cases.	Wind, > 8 m/s. $T_0 - T_1$.	Number of Cases	Pavlovsk $T_0 - T_1$.	Number of Cases.	$T_0 - T_2$.	Number of Cases.
0	3.71	47	2.74	17	5.20	2	9.35	12
1	5.90	21	4.30	1	3.13	3	10.67	7
2	5.33	6	9.60	1	...	...	...	...
3	5.60	2	...	...	5.60	1	10.44	2
4	4.54	5	4.03	3	...	...	...	...
5	5.96	9	4.38	5	1.00	1	11.74	3
6	5.45	15	6.29	7	7.30	1	9.22	5
7	5.74	9	4.75	2	3.65	2	9.44	1
8	4.47	81	4.82	62	4.30	2	8.82	5
9	4.80	892	4.61	486	3.42	6	9.54	320
10	4.38	498	3.98	175	4.36	8	9.16	382
11	4.50	193	4.28	58	3.68	13	8.97	170
12	3.93	130	4.06	36	2.22	13	9.01	77
13	2.84	31	3.52	12	3.08	9	10.42	21
14	3.43	35	3.41	14	4.17	9	9.00	13
15	4.07	82	3.76	29	3.90	12	9.03	36
16	3.63	37	3.63	10	2.64	20	9.36	28
17	4.11	31	3.63	10	2.73	23	9.57	17
18	4.02	33	3.72	11	3.26	21	10.00	12
19	3.12	42	2.57	11	4.11	15	10.71	15
20	4.36	11	4.68	5	4.92	9	10.05	3
21	4.70	7	6.30	1	2.51	8	11.07	1
22	6.25	7	7.00	1	5.90	3	11.47	1
23	4.72	8	4.68	5	3.03	3	13.34	1

The values were analysed according to the method of least square for observations of different weight, the weight being taken to be the number of cases contributing to the hourly value.

The results are :—

$$\begin{array}{lcl}
 \left. \begin{array}{l} \text{Berlin} \\ \text{and} \\ \text{Lindenberg.} \end{array} \right\} \begin{array}{l} (1) \text{ all cases. } T_0 - T_1 = 4.39 \pm 0.083 - (0.87 \pm 0.13) \sin(x + 197^\circ) \\ \quad \quad \quad \quad \quad \quad \quad \quad - (0.14 \pm 0.10) \sin(2x + 123^\circ) \\ (2) \text{ wind } T_0 - T_1 = 3.97 \pm 0.15 - (0.84 \pm 0.23) \sin(x + 173^\circ) \\ \quad > 8 \text{ m/s. } \quad \quad \quad \quad \quad \quad \quad \quad - (0.35 \pm 0.15) \sin(2x + 102^\circ) \\ (3) T_0 - T_2. \quad T_0 - T_2 = 9.84 \pm 0.23 - (0.64 \pm 0.31) \sin(x + 270^\circ) \\ \quad \quad \quad \quad \quad \quad \quad \quad - (0.25 \pm 0.23) \sin(2x + 72^\circ) \end{array} \\
 \text{Pavlovsk.} \quad \quad \quad T_0 - T_1 = 3.86 \pm 0.27 - (0.72 \pm 0.36) \sin(x + 233^\circ) \\ \quad \quad \quad \quad \quad \quad \quad \quad - (0.13 \pm 0.29) \sin(2x + 10^\circ)
 \end{array}$$

The following Table gives the amplitude and phases of the first and second terms of the sine series for a number of places :—

	a_1 .	A_1 .	a_2 .	A_2 .
Equatorial Ocean	0.72° C.	243°	0.23° C.	80°
Kew	2.8	224	0.45	48
Ben Nevis (1343 m.)	0.62	227	0.17	49
Free Atmosphere, Berlin 1 km.	0.87	197	0.14	123
" " " 1 " (wind > 8 m/s.)	0.84	173	0.35	102
" " " 2 "	0.64	270	0.25	72
" " Pavlovsk 1 km.	0.72	233	0.13	10

The variation of the temperature in the free atmosphere is theoretically connected with the variation of pressure. Mountain observations* lead to the conclusion that the amplitude of the diurnal variation of pressure diminishes with height, vanishes and reappears with a change of phase of 180° . The semi-diurnal term, on the other hand, has its amplitude roughly proportional to the pressure, and its phase diminishes gradually with increasing height.

If these conditions hold also in the free atmosphere, the phases of the diurnal variations of pressure and temperature ought to differ by 180° in the lower layers and ought to agree after the change in the pressure variation, *i.e.* the phase of the variation of temperature ought not to change materially from its surface value. The observations are in fair agreement with this conclusion.

The phases of the semi-diurnal variations of temperature and pressure ought to differ at the surface by 90° nearly, the latter (pressure) being the larger. In the upper layers this difference ought to diminish.

The phase of the semi-diurnal variation of temperature found above is subject to a considerable probable error, but the results indicate a tendency in it to approach the value found for the phase of the pressure variation from mountain observations. Thus at Kew the phases actually differ by about 100° , while the phase at 1000 m. differs by only 20° – 30° from the phase of the variation of pressure observed at 1000 m. in the Alps.†

It was remarked above that Dines found a difference of about 5° C. in summer between temperatures obtained from balloons sent up in the morning and those obtained from balloons sent up at night. The two series of balloons sent up for each of twenty-four consecutive hours at Manchester, however, gave no definite indication of a regular diurnal variation. It is certain that the variation cannot be great. Air would take at least twenty-four hours to cool 1° C. by radiation in the lower half of the atmosphere, and the cooling would be considerably slower at altitudes of 5 to 10 km.‡ Thus, if air were warmed up to any extent by solar radiation, it would not be cooled again by radiation, and it would not be possible to maintain a steady condition, because the air cannot move an appreciable distance to cooler regions in the course of a day. There is very little variation of mean temperature at 10 km. height over the European area. Moreover, since the warming would be for the whole mass of air over a large area there is no possibility of a cooling by convection at the *same level* although the *mass* of air might be cooled by rising. The latter would not, however, produce a variation of temperature at a *given level*, and, in fact, it could not occur, because the effect would be cumulative and inconsistent with steady conditions. *The rate of cooling by radiation sets an effective limit to the diurnal variation of temperature in the higher atmosphere.*

I. (d).—THE STRATOSPHERE. (Isothermal or Advective Region.)

Perhaps the most remarkable phenomenon, revealed by the investigation with registering balloons, is the comparatively sudden decrease of the gradient of temperature at a height which varies with the time and latitude. Frequently, the gradient

* On the Pic du Midi, 2860 m., the daily variation of pressure is given in mm. by

$$\Delta p = 0.19 \sin(nt + 180^\circ) + 0.25 \sin(2nt + 124^\circ),$$

and that of temperature by

$$\Delta T = 1.8 \sin(nt + 251^\circ) + 0.6 \sin(2nt + 80^\circ).$$

Met. Zeit., 1908. See also Hann, *Lehrbuch*, p. 605.

† Hann, *Lehrbuch*, p. 605.

‡ Gold, *Proc. Roy. Soc., Series A*, vol. 82, Oct. 1908.

vanishes and changes sign abruptly. Above this height, which may be regarded as the height of an irregular but roughly horizontal surface dividing the atmosphere into two regions, the temperature at any time varies very little in a vertical direction, showing on the average a very slight tendency to increase. The absence of regular vertical variation of temperature in the upper region led to the name "isothermal layer or region," to distinguish it from the lower atmosphere in which the vertical variation is about 6° C. per km.

The actual cessation of the fall of temperature was noticed by Teisserenc de Bort* in June 1899 and again in March 1902. It was discussed shortly afterwards by Assmann,† who made special experiments to see if it could be due to insufficient ventilation.

Teisserenc de Bort found the height at which the change occurred to be about 11 km. on the average. He discovered also that the height was greater near centres of high pressure than near centres of low pressure, the average heights for the two cases being 12.5 and 10 km. respectively. Later observations confirm the general character of these results. It may be asked if this effect is due to the slope of the isobaric surface, which is lower over a cyclone than over an anticyclone. This is not the case. The difference of pressure over the two regions would not be more than 20 to 30 mm. at a height of 10 km., while the difference of pressure between 10 and 12 km. is 50 mm.

This excludes the hypothesis that the air in the upper region is an inert isothermal mass, consisting always of the same air, lifted up and down by the disturbances in the lower part of the atmosphere. There must be interchange of air between the two regions (or rapid motion in the upper region which would, however, be inconsistent with its generally isothermal condition).

The absence of vertical temperature gradient implies that general direct convection in the upper region is absent; but the occurrence of irregularities in occasional ascents indicates that there is in places limited convection; and the considerable inversion of temperature, frequently found at the dividing surface, suggests that there may be oblique convection similar to that for anticyclones in the lower atmosphere. Any fall of temperature arising from such convection would tend to disappear, owing to the effect of radiation, and the same is true if temperature rises. In general, however, interchange of air in the upper region would be mainly by horizontal motion or "advection," and the two regions might be appropriately named "advective" and "convective" regions. The earlier names for the upper region were "isothermal layer" or "upper inversion." Recently Teisserenc de Bort has introduced the names "stratosphere" and "troposphere," to denote the upper and lower regions respectively, and these terms are becoming generally adopted.

The height of the dividing surface between the two regions will be denoted by H_c and the temperature at this height by T_c . As there are occasions when the gradient diminishes gradually without changing abruptly, it becomes necessary to adopt some convention as to what values are to be taken for H_c , T_c in these cases. In this discussion the value of H_c has been taken in such cases as the height at which the gradient fell to 2° C. per km. or less and did not increase above this value for a complete kilometre change of height at higher levels. The value of T_c is taken to be that corresponding with the height H_c .

* "Séances" 1899, etc., *Annuaire de la Société Météorologique*, 1902.

† *Ergebnisse Aer. Obs.*, Berlin, 1902. *Berlin Ber.*, 1902.

Although H_c varies with the latitude, the observations available are insufficient to enable an accurate expression for the relation to be obtained. Teisserenc de Bort* found from simultaneous ascents at Trappes and at Kiruna on the Arctic Circle that the value of H_c was nearly the same for the two places, but the value of T_c was slightly lower for Kiruna. Towards the Equator, on the other hand, the value of H_c is considerably greater than for temperate latitudes. Rotch and Teisserenc de Bort failed to reach it over the equatorial Atlantic with balloons rising to 15 km. On June 19th, 1906, a temperature of 201° A. was found at 15 km. in latitude 1° 46' N. On July 20th, 1906, the stratosphere was reached in latitude 37° N., the values of H_c , T_c being 15 km. and 192° A. respectively. In August and September 1907, temperatures of 203° A. were found in latitudes 13° N. and 19° N. at heights of 15 km., but the stratosphere was again not reached. On September 9th, 20th, 22nd, 1907, the stratosphere was reached in latitudes 25° N., 32° N., and 33° N., the corresponding values of H_c , T_c being 14.1 km., 213° A.; 14.5 km., 216° A.; and 13.7 km., 211° A. respectively.†

In 1908 the "Aerologische Expedition des K. Aer. Obs., Lindenberg," to East Africa, sent up balloons from Lake Victoria Nyanza, on the Equator, and two of these reached the stratosphere on August 30th and September 5th. The values of H_c , T_c were 17.2 km., 190° A., and 15.4 km., 203° A. respectively. The chain of experimental evidence for the existence of the phenomenon over the earth's surface was thus completed by a remarkably bold piece of scientific exploration.‡

The stratosphere has also been reached near Toronto in Canada, at an average height of 13 km., between February and October 1911.§

The following Table (XVIII.) gives the mean values of H_c , T_c for a number of stations, derived from the means for the individual months. The total number of

TABLE XVIII.—MEAN HEIGHT AND TEMPERATURE OF THE BASE OF THE STRATOSPHERE.

	Berlin.	Munich.	Strassburg.	Vienna.	Mean.
H_c	10.43 km.	10.73 km.	10.72 km.	10.33 km.	10.55 km.
T_c (200°+)	15°.4	16°.2	15°.3	16°.8	15°.9
Number	79	76	86	58	299
Latitude	52° 15'	48° 10'	48° 35'	48° 15'	...
	England.	Hamburg.	Paris.	Uccle.	Mean.
H_c	10.60 km.	10.13 km.	10.55 km.	10.93 km.	10.55 km.
T_c (200°+)	17°.2	18°.1	16°.7	13°.0	16°.3
Number	150	35	90	33	308
Latitude	52°	53° 40'	48° 50'	50° 50'	...
	Pavlovsk.	Koutchino.	Italy.	Zurich.	
H_c	9.6 km.	10.5 km.	11.0 km.	10.2 km.	
T_c (200°+)	19°	15°	14°	19°	
Number	41	28	46	15	
Latitude	59° 40'	55° 45'	45° 30'	47° 25'	

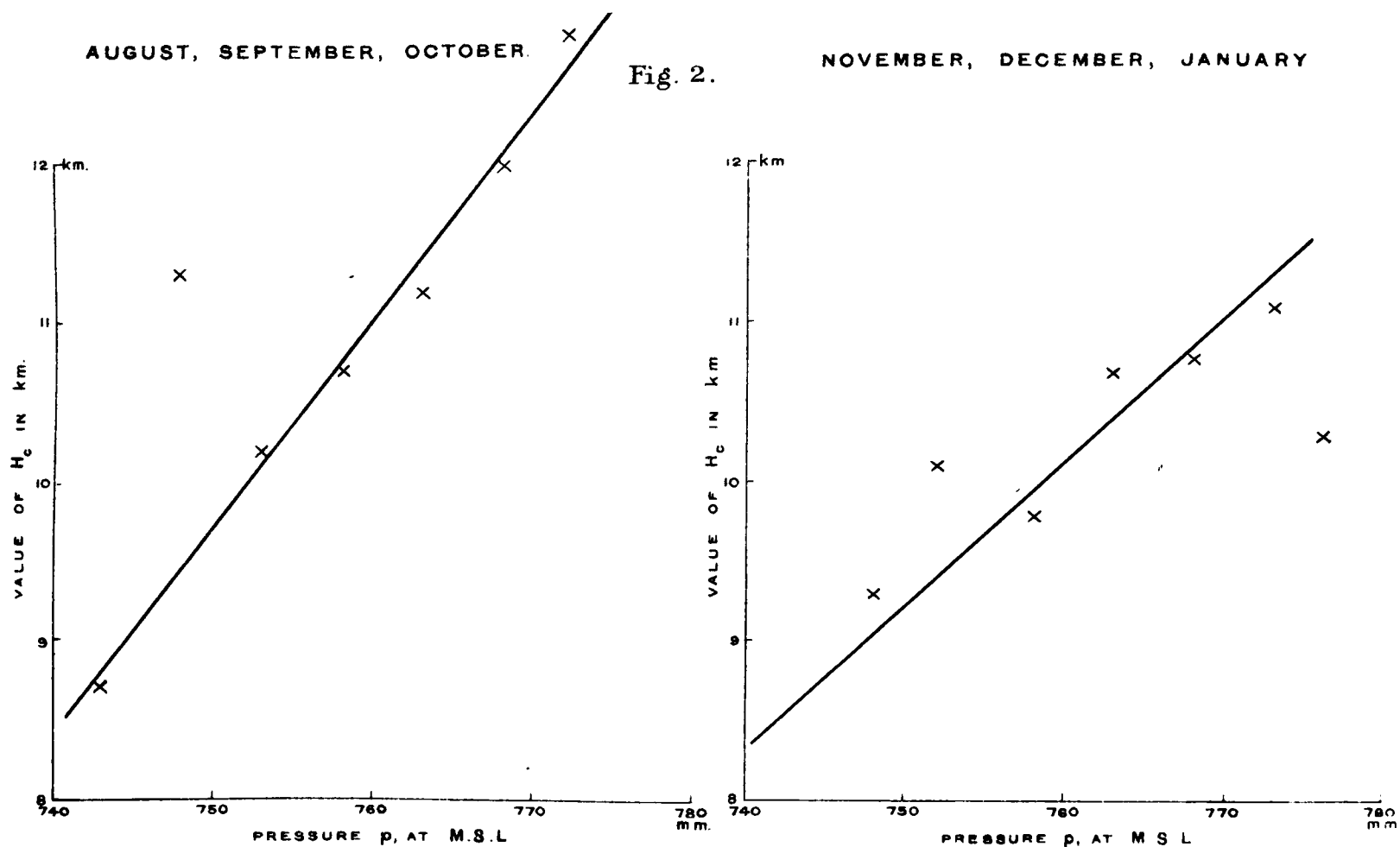
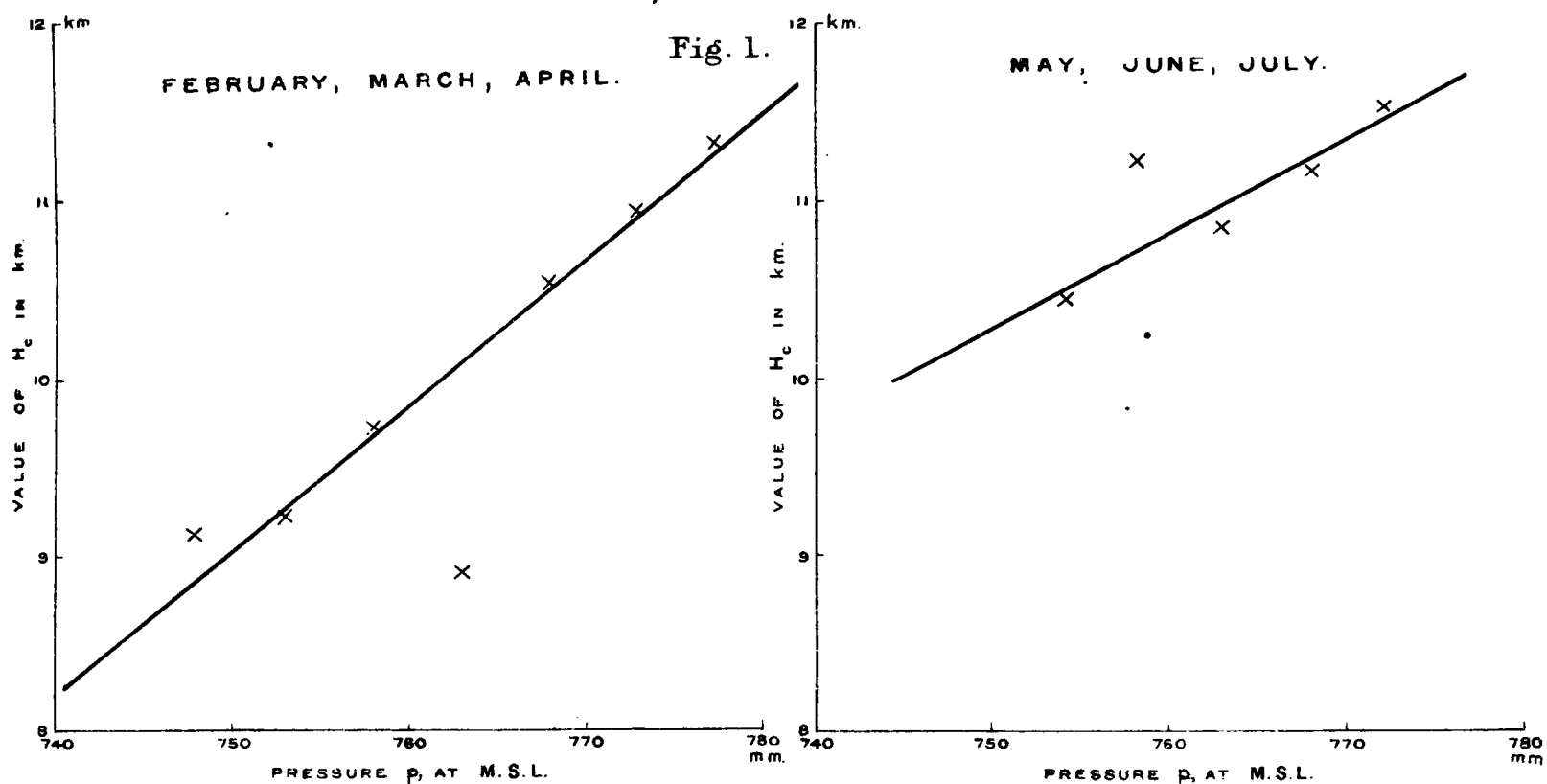
* C. R., 145, 1907. *Met. Zeit.*, 1907.

† *Travaux Scient. de l'Obs. de Trappes*, "Étude de l'Atmosphère par Sondages Aériens," 1909.

‡ *Bericht über der Afr. Expedition*, by Dr A. Berson, edited by Professor R. Assmann, 1910.

§ *Nature*, December 7, 1911, p. 180.

CONNEXION BETWEEN H_c AND PRESSURE p , AT MEAN SEA LEVEL, (M.S.L.)
STRASSBURG, , BERLIN, VIENNA.



CONNEXION BETWEEN T_c AND PRESSURE p , AT MEAN SEA LEVEL, (M.S.L.)

STRASSBURG, BERLIN, VIENNA.

Fig. 3.

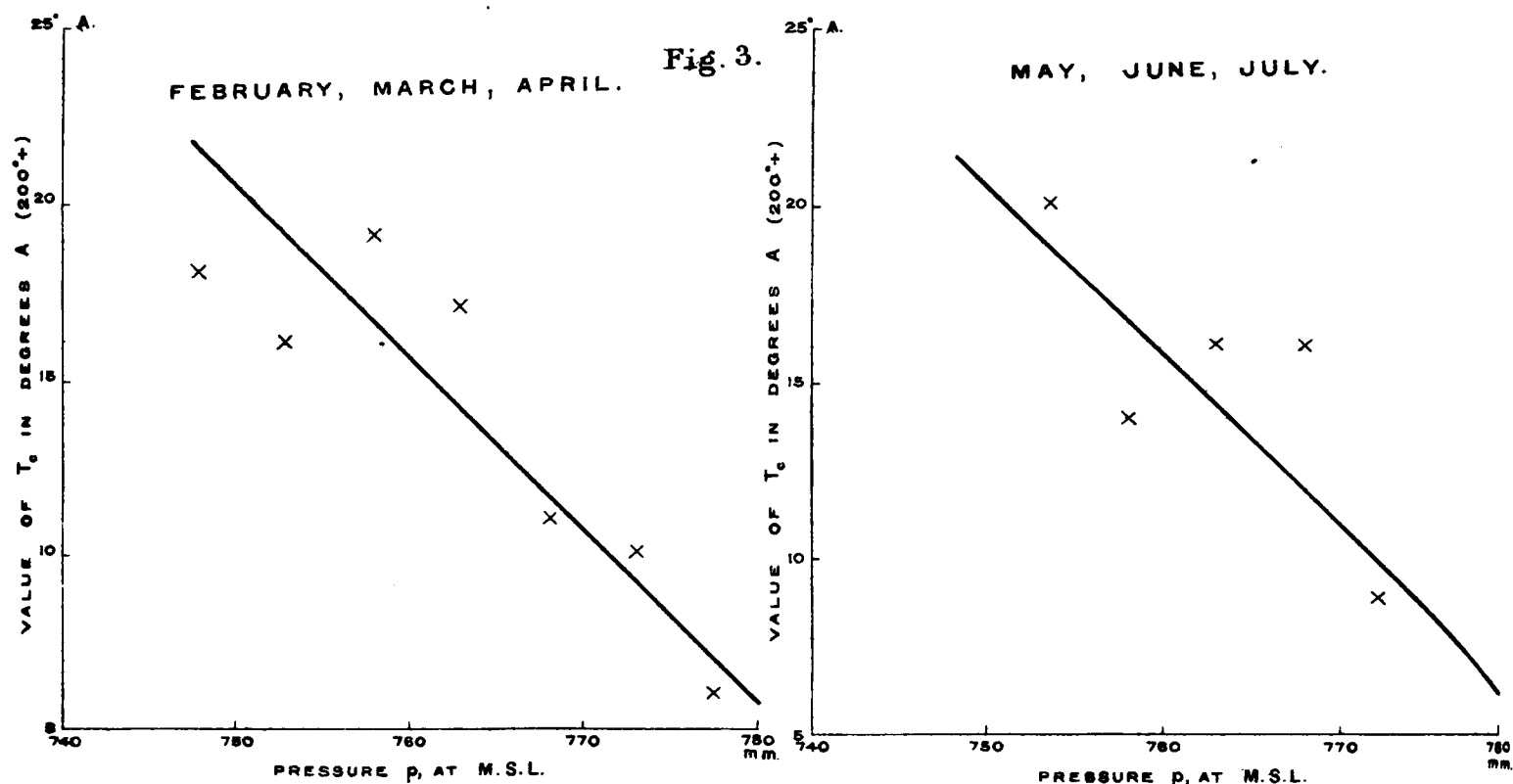
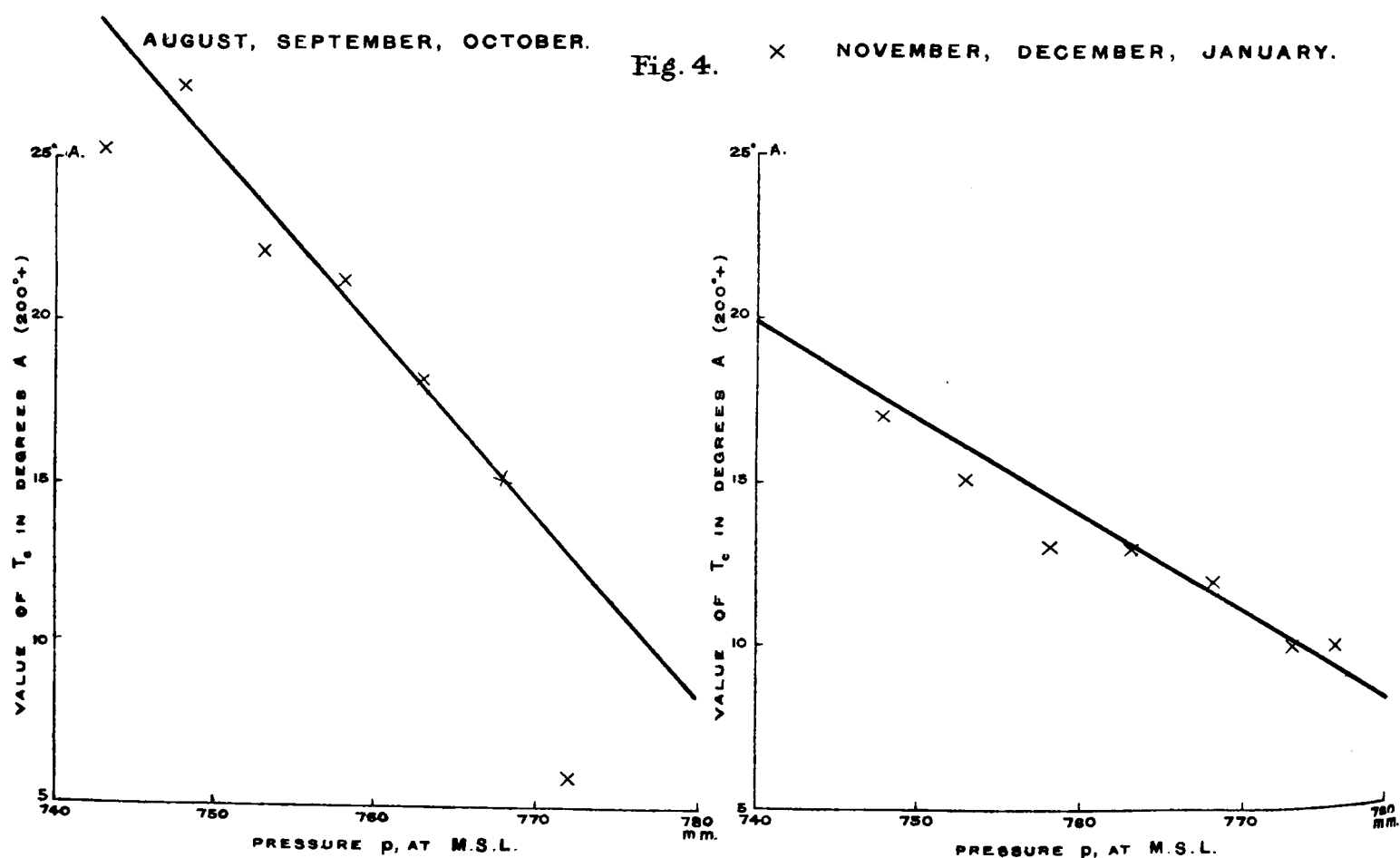


Fig. 4.



observations is also given. (These numbers differ slightly from the numbers included below in the discussion under variation with pressure, because the pressures were in general taken only for international days, while some additional ascents are included here. The differences are slight.)

The mean values for Central Europe are practically identical with those for N.W. Europe. The difference in mean latitude for the two regions is about 2° . The value of H_c for Vienna is low for the latitude, that for Koutchino high. The values of H_c for Strassburg and Munich are both greater than that for Paris. The value of H_c for England is relatively high: that for Italy is highest of all, which is in agreement with the general result that H_c increases towards the Equator. For Pavlovsk the value of H_c is 1 km. less and that of T_c is 3° more than the averages. The continental stations have slightly lower values of T_c .

As will be shown below, the value of H_c ought to increase and that for T_c to diminish if the humidity of the atmosphere increases while the temperature remains constant. It might, therefore, be expected that near an ocean, H_c would be greater and T_c less than for a continental region. The values in the Table do not furnish decisive evidence on this point, and the high values obtained at Koutchino and in Canada are contradictory to the view. The value for England, on the other hand, supports it.

The observations for Berlin, Strassburg, and Vienna were grouped together, and the monthly means for H_c , T_c and the pressure at Mean Sea Level at the times of the ascents obtained. The individual values of H_c , T_c for four periods of three months each were then arranged in groups for different values of the pressure. Table XIX. shows the results.

TABLE XIX.—BERLIN, STRASSBURG, AND VIENNA.
VARIATION OF H_c AND T_c WITH THE PRESSURE AT MEAN SEA LEVEL.

Period.		Pressure.	> 775 mm.	775-770.	770-765.	765-760.	760-755.	755-750.	750-745.	< 745.
I.	February	H_c (km.)	11.3	10.9	10.5	8.9	9.7	9.2	9.1	...
	March	T_c ($200^{\circ}+$)	6°	10°	11°	17°	19°	16°	18°	...
	April	p (mm.)	778	773	768	763	758	753	748	...
	41 cases	No.	2	3	5	11	8	4	4	...
II.	May	H_c (km.)	...	11.5	11.1	10.8	11.2	10.4	...	...
	June	T_c ($200^{\circ}+$)	...	9°	16°	16°	14°	20°	...	...
	July	p (mm.)	...	772	768	763	758	754	...	...
	51 cases	No.	...	3	14	12	14	8	...	...
III.	August	H_c (km.)	...	12.8	12.0	11.2	10.7	10.2	11.3	8.7
	September	T_c ($200^{\circ}+$)	...	6°	15°	18°	21°	22°	27°	25°
	October	p (mm.)	...	772	768	763	758	753	748	743
	69 cases	No.	...	5	14	21	21	4	2	2
IV.	November	H_c (km.)	10.3	11.1	10.8	10.7	9.8	10.1	9.3	7.6
	December	T_c ($200^{\circ}+$)	10°	10°	12°	13°	13°	15°	17°	28°
	January	p (mm.)	776	773	768	763	758	753	748	741
	55 cases	No.	1	5	15	10	9	6	6	3

These values are plotted in the diagrams, figs. 1, 2, 3, 4, and lead to the following values for the factors α , β in the equations:—

$$\begin{aligned}\delta H_c &= \alpha \delta p \\ \delta T_c &= -\beta \delta p\end{aligned}$$

for the four periods I.-IV. Here p is pressure at Mean Sea Level, in mm., and H_c , T_c in km. and degrees A. respectively.

Period.	I.	II.	III.	IV.
α	0.08	0.05	0.13	0.09
β	0.50	0.48	0.56	0.28

These values of α, β have been used to correct the monthly values of H_c, T_c for the difference of the monthly pressure from the average for the year. Table XX. gives the results.

TABLE XX.—BERLIN, STRASSBURG, AND VIENNA.
VALUES OF H_c, T_c , CORRECTED FOR DIFFERENCE OF PRESSURE FROM THE NORMAL.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean pressure (700 mm. +)	65	66	60	60	65	62	59	63	58	64	58	59	61.6
Uncorrected H_c . . .	10.2	10.3	9.1	9.8	10.9	11.6	10.5	11.4	10.5	11.5	10.2	10.4	10.53
„ T_c . . .	13°	12°	17°	16°	14°	14°	19°	18°	23°	14°	16°	13°	16°
Number of cases . . .	19	9	14	14	19	16	16	28	19	22	18	18	212
Corrected H_c . . .	9.9	9.9	9.2	9.9	10.7	11.6	10.6	11.2	11.0	11.2	10.5	10.6	10.5
„ T_c . . .	14°	14°	16°	15°	16°	14°	18°	19°	21°	16°	17°	14°	16°
Smoothed H_c . . .	10.1	9.7	9.6	10.0	10.7	11.1	11.0	11.0	11.1	11.0	10.7	10.4	10.5
„ T_c . . .	14°	15°	15°	16°	15°	16°	17°	19°	19°	18°	16°	15°	16°

The values of H_c are in km., those for T_c in degrees A (200° +). The smoothed values have been obtained by using the formula

$$\text{smoothed value of } b = \frac{a + 2b + c}{4}.$$

Putting the corrected values into a sine series

$$P_1 \sin (nt + \alpha_1) + P_2 \sin (2nt + \alpha_2),$$

we find the following values for the coefficients, time being measured from January 1st :—

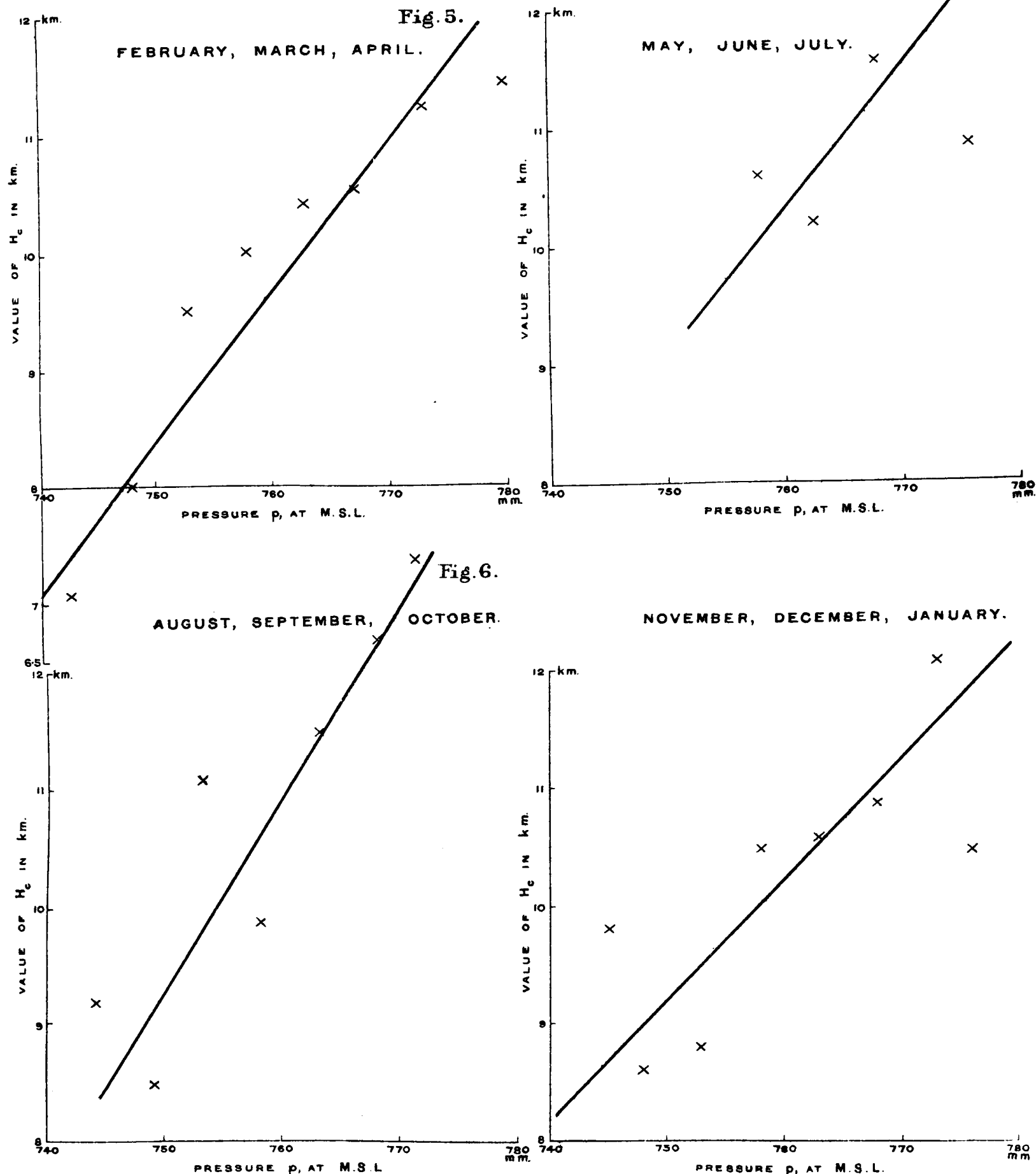
Coefficients.	P_1 .	α_1 .	P_2 .	α_2 .
H_c	0.78 km.	228°	0.38 km.	108°
T_c	2°.3	225°	1°.4	113°.

Thus the minimum value of H_c in the whole year variation comes about the 12th of February, that of T_c about the 15th, the maxima about the 13th and 15th of August respectively.

In the half-yearly variation the minima for H_c occur very nearly on the 23rd of March and the 24th of September, or closely at the equinoxes. The corresponding maxima occur nearly at the solstices. The values for T_c are about two days earlier in each case. The effect of the half-yearly variation is to make the dates of minima later and those of maxima earlier both for H_c and for T_c . *Thus the variation during spring and summer is more rapid than during autumn and winter.*

A similar process was applied to the values for Paris, Hamburg, and Uccle, and the following results obtained, Table XXI. :—

CONNEXION BETWEEN H_c AND PRESSURE p , AT MEAN SEA LEVEL, (M.S.L.)
PARIS, HAMBURG, UCCLE.



CONNEXION BETWEEN T_c AND PRESSURE p , AT MEAN SEA LEVEL, (M.S.L.)
PARIS, HAMBURG, UCCLE.

Fig. 7.

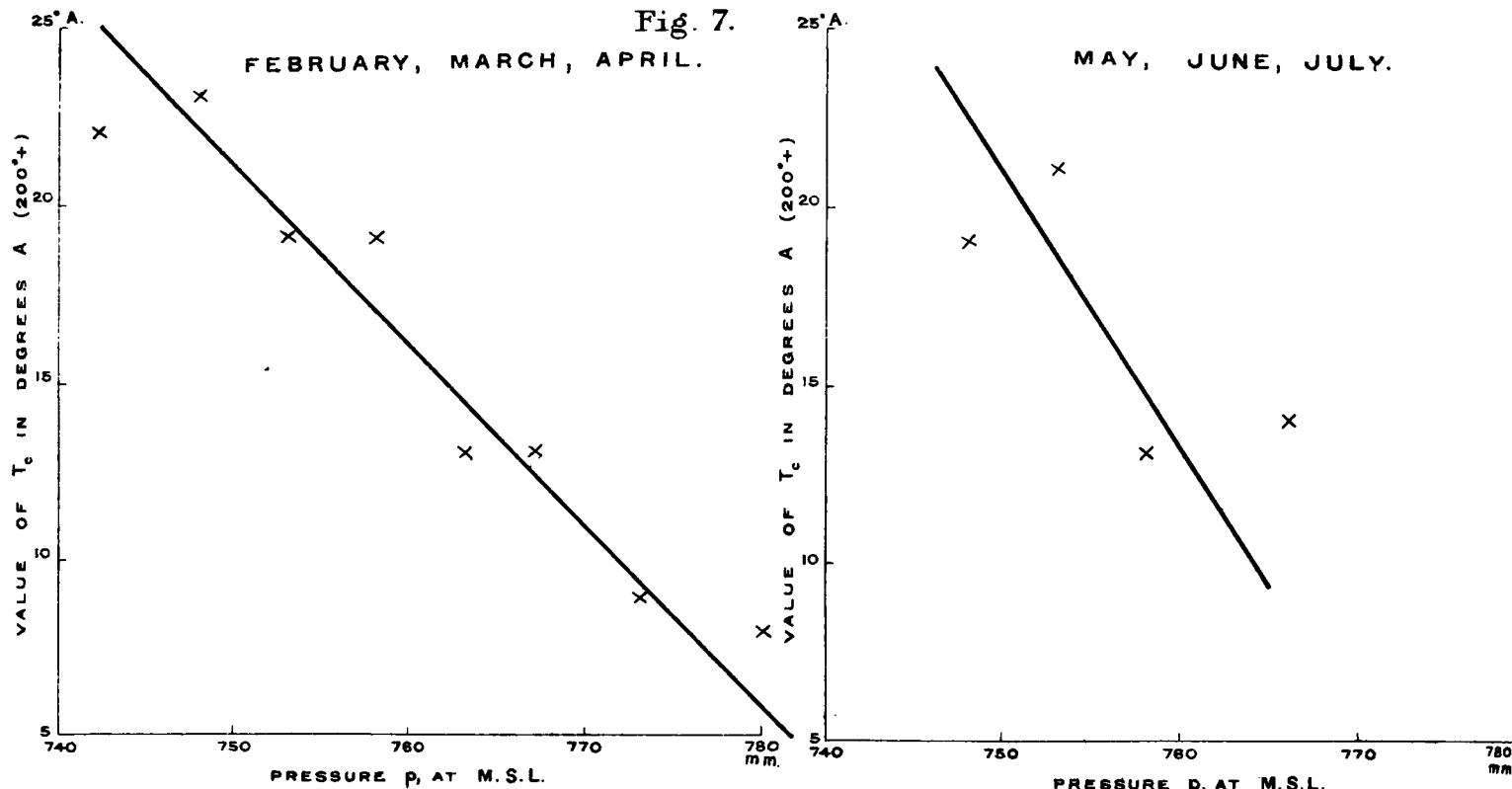


Fig. 8.

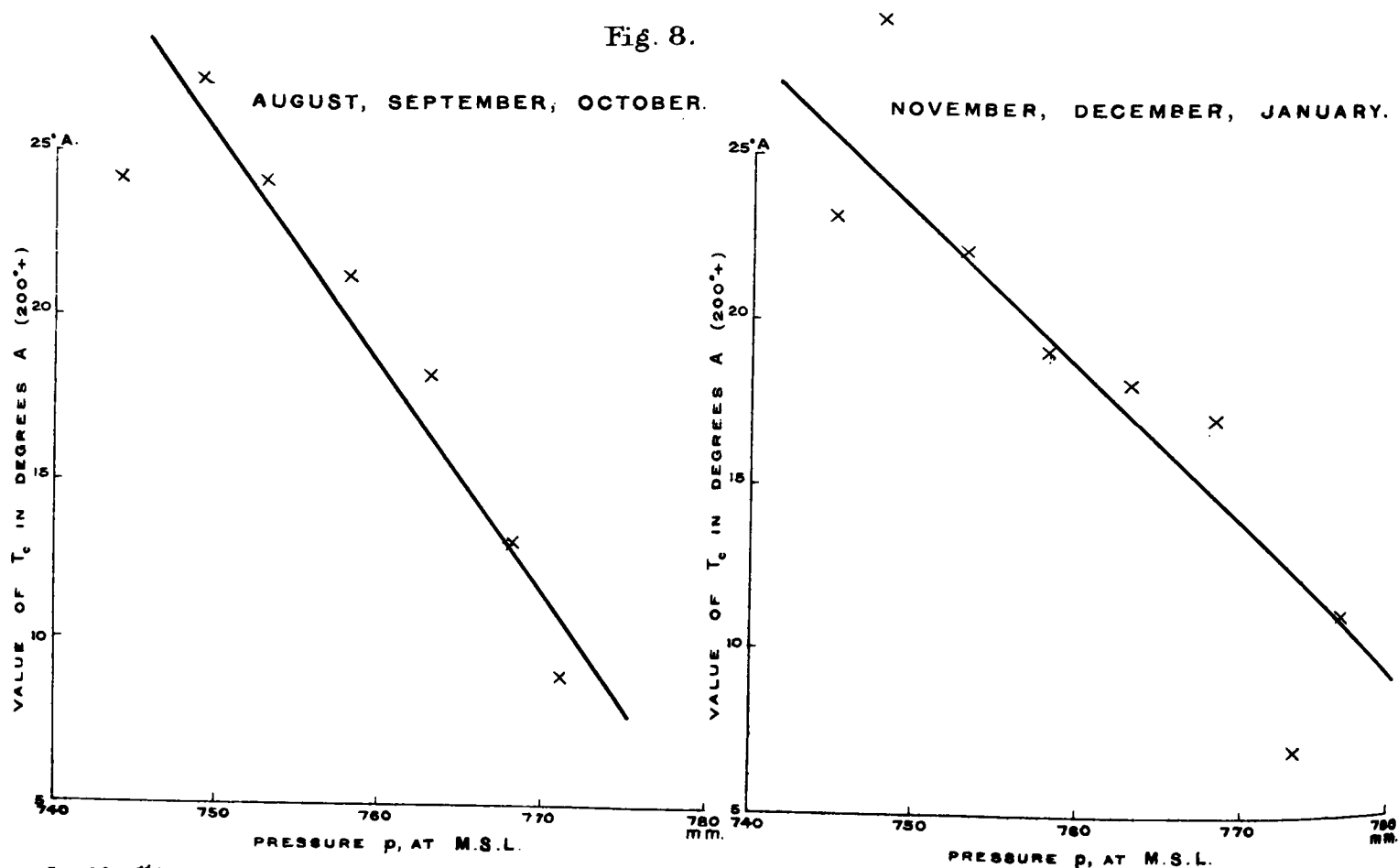


TABLE XXI.—HAMBURG, PARIS, UCCLE.
VARIATION OF H_c , T_c , WITH THE PRESSURE AT MEAN SEA LEVEL.

Period.	Pressure (700 mm. +)	>75.	75-70.	70-65.	65-60.	60-55.	55-50.	50-45.	<45.
I.	February	H_c (km.)	11.4	11.2	10.5	10.4	10.0	9.5	8.6
	March	T_c (200°+)	8°	9°	13°	13°	19°	19°	23°
	April	p (mm.)	780	773	767	763	758	753	748
	36 cases	No.	2	4	2	14	5	5	3
II.	May	H_c (km.)	10.9	...	11.6	10.2	10.6	...	...
	June	T_c (200°+)	14°	...	13°	22°	19°	...	...
	July	p (mm.)	776	...	768	763	75.8	...	...
	42 cases	No.	1	...	14	15	12	...	...
III.	August	H_c (km.)	...	13.0	12.3	11.5	9.9	11.1	8.5
	September	T_c (200°+)	...	9°	13°	18°	21°	24°	27°
	October	p (mm.)	...	771	768	763	758	753	749
	47 cases	No.	...	3	12	15	10	5	1
IV.	November	H_c (km.)	10.5	12.1	10.9	10.6	10.5	8.8	8.6
	December	T_c (200°+)	6°	2°	12°	13°	14°	17°	24°
	January	p (mm.)	776	773	768	763	758	753	748
	33 cases	No.	1	2	8	8	5	3	3

These values are plotted in the diagrams, figs. 5, 6, 7, 8, and the following values have been obtained for the constants α , β for the four periods I.-IV.:—

Period.	I.	II.	III.	IV.
α	0.13	0.13	0.16	0.11
β	0.50	0.78	0.70	0.48.

These values are considerably in excess of the values found above for Berlin, Strassburg, and Vienna, especially for α in periods I. and II. The value for case II. depends upon observations with a comparatively small range of pressure, so that much importance could not be attached to the difference if it stood alone. But as all the values support each other, there results the rule that *for more northerly stations lying nearer the principal paths of depressions arising in the Atlantic the variations in the height of the stratosphere are greater than for Central Europe for equal ranges of pressure variation.*

By using the values of α , β to correct the monthly means, the following results were obtained:—

TABLE XXII.—HAMBURG, PARIS, UCCLE.
VALUES OF H_c , T_c , CORRECTED FOR DIFFERENCE OF PRESSURE FROM THE NORMAL.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean pressure (700 mm.+)	62	67	54	61	65	63	63	64	61	63	60	58	61.8
Uncorrected H_c	10.1	10.9	8.4	10.3	11.0	10.6	10.8	11.5	10.4	12.0	11.1	9.9	10.58
„ T_c	14°	12°	19°	15°	15°	19°	20°	17°	20°	15°	12°	17°	16°
Number of cases	16	11	8	17	13	11	18	21	14	12	9	8	158
Corrected H_c	10.1	10.2	9.4	10.4	10.6	10.4	10.6	11.1	10.5	11.8	11.3	10.3	10.6
„ T_c	14°	15°	15°	15°	18°	20°	21°	19°	19°	16°	11°	15°	16°
Smoothed H_c	10.2	10.0	9.9	10.2	10.5	10.5	10.7	10.8	11.0	11.4	11.2	10.5	...
„ T_c	15°	15°	15°	16°	18°	20°	20°	20°	18°	16°	13°	14°	...

We note that the range of the corrected values of H_c is exactly the same as in the case of Berlin, Strassburg, Vienna, while both minimum and maximum are 0.2 km. greater, or, in the case of the smoothed values, 0.3 km. The high maximum in June

does not appear, but the secondary minimum in September is more marked. The curve is flatter in the lower part, so that the mean is very little greater than that for Central Europe (Berlin, Strassburg, Vienna).

The lowest value of T_c occurs in November, but this is probably due to a few exceptionally low values in that month. The highest values, however, also occur earlier than for Central Europe, so that there may be a real acceleration of date. The constants in the sine series have the values given in the Table.

Constants.	P_1 .	a_1 .	P_2 .	a_2 .
H_c	0.62 km.	200° 10'	0.29 km.	217° 30'
T_c	3° 4	270° 50'	1° 3	53° 30'.

Thus the amplitude of the whole year variation of H_c is less than for Central Europe, and its maximum occurs nearly a month later. Therefore, any acceleration of date must arise from the semi-annual term, whose maxima occur nearly two months earlier than for Central Europe.

For T_c , the amplitude of the annual variation, is greater and the date of maximum earlier than for Central Europe.

TABLE XXIII.—VARIATION OF H_c , T_c , WITH THE PRESSURE AT MEAN SEA LEVEL.

Period.	Pressure (700 mm +).	>75.	70-75.	65-70.	60-65.	55-60.	50-55.	45-50.	<45.
ENGLAND.									
I.	February	H_c (km.)	11.4	...	10.7	10.7	9.8	7.0	8.8
	March	T_c (200° +)	7°	...	15°	20°	16°	24°	20°
	April	p (mm.)	783	...	768	763	759	755	748
	28 cases	No.	3	...	7	6	3	1	2
II.	May	H_c (km.)	...	11.9	11.7	11.0	10.4	10.5	8.5
	June	T_c (200° +)	...	16°	15°	17°	19°	17°	25°
	July	p (mm.)	...	772	768	762	758	753	749
	34 cases	No.	...	4	8	4	8	9	1
III.	August	H_c (km.)	12.0	11.8	11.7	11.3	10.8	...	...
	September	T_c (200° +)	10°	17°	17°	18°	18°	...	...
	October	p (mm.)	776	773	768	763	758	...	...
	52 cases	No.	1	6	15	21	9	...	...
IV.	November	H_c (km.)	13.0	11.1	11.0	9.9	9.6	10.1	7.9
	December	T_c (200° +)	3°	16°	15°	19°	18°	18°	24°
	January	p (mm.)	779	773	768	764	757	752	748
	36 cases	No.	2	4	7	2	5	4	10
MUNICH.									
I.	February	H_c (km.)	12.0	10.5	10.3	8.9	9.4	9.4	8.4
	March	T_c (200° +)	8°	6°	18°	16°	16°	19°	20°
	April	p (mm.)	780	775	768	763	758	754	750
	15 cases	No.	1	1	2	4	3	2	2
II.	May	H_c (km.)	...	...	11.6	11.0	11.8	11.5	...
	June	T_c (200° +)	...	...	19°	16°	11°	27°	...
	July	p (mm.)	...	...	768	763	758	755	...
	16 cases	No.	...	...	7	3	5	1	...
III.	August	H_c (km.)	...	13.5	12.2	11.5	11.8	9.3	...
	September	T_c (200° +)	...	8°	16°	20°	15°	24°	...
	October	p (mm.)	...	773	768	763	758	754	...
	27 cases	No.	...	2	7	9	7	1	...
IV.	November	H_c (km.)	...	11.1	11.3	11.6	10.2	9.2	7.7
	December	T_c (200° +)	...	13°	10°	12°	14°	21°	26°
	January	p (mm.)	...	771	768	763	757	751	748
	18 cases	No.	...	4	5	2	3	1	2

For England and Munich the results were treated separately in order to see how far individual stations gave results agreeing with the mean values for the other stations in the same region. The results of the arrangement in pressure groups are shown in Table XXIII. for both places.

The following are the values of α , β obtained by plotting these results:—

Periods.	I.	II.	III.	IV.
England $\left\{ \begin{array}{l} \alpha \\ \beta \end{array} \right.$	0.07 0.30	0.09 0.25	0.08 0.10	0.13 0.30
Munich $\left\{ \begin{array}{l} \alpha \\ \beta \end{array} \right.$	0.10 0.38	0.01 0.00	0.13 0.20	0.11 0.34

The values of α are on the average slightly greater for England than for Munich, but, with the exception of period II., the values of β are less.

These values were used to correct the value of H_c , T_c , and the results are given in the following Table:—

TABLE XXIV.—VALUES OF H_c , T_c , CORRECTED FOR DIFFERENCE OF PRESSURE FROM THE NORMAL.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
ENGLAND.													
Mean pressure (700 mm. +)	67	68	61	55	61	60	62	65	65	67	51	54	61
Uncorrected H_c	11.1	10.4	10.2	9.6	10.9	11.1	10.5	11.5	10.9	12.8	9.1	9.1	10.6
„ T_c	15°	13°	17°	19°	16°	15°	23°	18°	19°	12°	22°	17°	17°
Number of cases	11	6	11	11	13	14	7	18	26	8	8	17	150
Corrected H_c	10.3	9.9	10.2	10.0	10.9	11.2	10.4	11.2	10.6	12.3	10.4	10.0	10.6
„ T_c	17°	15°	17°	17°	16°	15°	23°	18°	19°	13°	19°	15°	17°
Smoothed H_c	10.1	10.1	10.1	10.3	10.8	10.9	10.8	10.9	11.2	11.4	10.8	10.2	...
„ T_c	16°	16°	16°	17°	16°	17°	20°	20°	17°	16°	17°	17°	...
MUNICH.													
Mean pressure (700 mm. +)	67	65	61	58	64	62	64	63	62	63	57	62	62
Uncorrected H_c	10.0	9.9	9.1	9.5	11.5	11.5	11.7	12.1	10.3	11.6	10.5	11.0	10.7
„ T_c	13°	13°	16°	19°	17°	17°	14°	15°	24°	14°	18°	14°	16°
Number of cases	5	5	5	5	7	6	3	14	5	8	6	7	76
Corrected H_c	9.5	9.6	9.2	9.9	11.5	11.5	11.7	12.0	10.3	11.5	11.1	11.0	...
„ T_c	15°	14°	16°	17°	17°	17°	14°	15°	24°	14°	16°	14°	...
Smoothed H_c	9.9	9.5	9.5	10.2	11.1	11.6	11.7	11.5	11.0	11.1	11.2	10.7	...
„ T_c	15°	15°	16°	17°	17°	16°	15°	17°	19°	17°	15°	15°	...
H_c corrected by difference between monthly pressure departure and average departure	9.8	9.8	9.1	9.7	11.5	11.5	11.7	11.8	10.4	11.5	11.1	11.2	...
Average departure	3	2	-1	-2	-2	-1	-1	-1	1	0	0	2	...

In the last row but one the corrected value of H_c has been obtained by using the difference between the actual departure of the monthly pressure from the annual mean and the average value of this departure. The result is to retard slightly the times of maximum and minimum compared with those obtained by correcting in the usual manner. The corrected values of H_c , T_c have been analysed, and the results are given later Table XXVII. (p. 117).

For Pavlovsk the observations were not sufficiently numerous to admit of grouping according to four periods, and the situation of the station is such as to render incorporation with the results for other stations, a process likely to lead to misleading values. The same is true of Koutchino. For these stations therefore, and for Zurich and Italy, the values have been treated for the periods I., November to April; II., May to October. Table XXV. shows the results.

TABLE XXV.—VARIATION OF H_c , T_c , WITH PRESSURE OF MEAN SEA LEVEL.

Period.	Pressure (700 mm. +)	>75.	70-75.	65-70.	60-65.	55-60.	50-55.	45-50.	<45.	
PAVLOVSK.										
I.	November to April.	H _c (km.)	9.5	...	10.5	9.8	9.9	8.2	...	9.2
		T _c (200° +)	15°	...	14°	25°	21°	17°	...	14°
		p (mm.)	782	...	768	762	760	753	...	744
		No.	2	...	4	1	2	4	...	1
II.	May to October.	H _c (km.)	...	9.0	10.6	10.8	9.6	10.2	8.9	...
		T _c (200° +)	...	24°	16°	19°	21°	22°	23°	...
		p (mm.)	...	772	767	763	758	753	749	...
		No.	...	4	3	5	7	5	3	...
KOUTCHINO.										
I.	November to April.	H _c (km.)	11.7	...	10.0	10.0	10.4	...	...	9.8
		T _c (200° +)	9°	...	16°	11°	10°	...	...	8°
		p (mm.)	777	...	768	763	759	...	...	733
		No.	1	...	4	2	3	...	...	1
II.	May to October.	H _c (km.)	...	...	11.7	10.5	10.7	10.1	10.7	...
		T _c (200° +)	...	...	15°	19°	18°	25°	16°	...
		p (mm.)	...	...	768	763	758	753	749	...
		No.	...	...	4	3	4	4	2	...
ITALY AND ZURICH.										
I.	November to April.	H _c (km.)	...	11.3	11.1	11.9	11.0	9.2	...	...
		T _c (200° +)	...	8°	8°	9°	13°	26°	...	...
		p (mm.)	...	771	768	762	758	752	...	...
		No.	...	1	6	3	4	4	...	...
II.	May to October.	H _c (km.)	...	12.2	12.2	10.8	9.9	...	...	...
		T _c (200° +)	...	12°	12°	18°	22°	...	...	...
		p (mm.)	...	771	768	763	759	...	...	...
		No.	...	2	9	16	6	...	...	...

It will be seen that at Pavlovsk there is a falling off in the value of H_c at very high pressures. This appears to be largely due in the case of May–October to the fact that there was a northerly current at the time, when three out of the four values were obtained in May 1909. Possibly in the case of November–April the fact that the observations at high pressure were obtained in February and March influences the results in the same direction.

The values when plotted lead to the following values of α , β for the two periods:—

Period.	I.	II.
Pavlovsk { α	0.08	0.10
{ β	0.1	0.3
Koutchino { α	0.01	0.07
{ β	-0.3	0.4
Italy and { α	0.10	0.18
Zurich { β	0.6	0.9

The values for Italy are decidedly the greater. The negative β value for Koutchino in winter indicates that *rising pressure there is accompanied by rising temperature in the stratosphere*. Table XXVI. shows the results obtained by using these corrections.

TABLE XXVI.—VALUES OF H_c , T_c , CORRECTED FOR DIFFERENCE OF PRESSURE FROM THE NORMAL.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
PAVLOVSK.													
Mean pressure (700 mm. +)	61	73	63	61	66	58	57	60	57	57	60	54	61
Uncorrected H_c . . .	9'4	9'7	9'4	10'4	8'8	9'3	10'4	10'4	10'1	10'2	8'7	8'7	9'6
„ T_c . . .	16°	15°	15°	15°	23°	22°	21°	20°	22°	20°	22°	22°	19°
Number of cases . . .	2	2	3	3	6	3	5	7	2	4	3	1	41
Corrected H_c . . .	9'4	8'7	9'2	10'4	8'3	9'6	10'8	10'5	10'5	10'6	8'8	9'3	...
„ T_c . . .	16°	16°	15°	15°	25°	21°	20°	20°	21°	19°	22°	21°	...
Smoothed H_c . . .	9'2	9'0	9'4	9'6	9'2	9'6	10'4	10'6	10'5	10'1	9'4	9'2	...
„ T_c . . .	17°	16°	15°	18°	22°	22°	20°	20°	20°	20°	21°	20°	...
KOUTCHINO.													
Mean pressure . . .	67	59	64	57	66	57	57	60	55	58	71	58	61
Uncorrected H_c . . .	10'5	10'7	10'0	9'8	9'7	11'4	10'7	10'7	11'0	10'7	10'9	9'9	10'5
„ T_c . . .	7°	11°	8°	18°	17°	14°	28°	20°	16°	19°	13°	7°	15°
Number of cases . . .	1	2	2	3	2	3	2	5	2	3	2	1	28
Corrected H_c . . .	10'4	10'7	10'0	9'8	9'4	11'7	11'0	10'8	11'4	10'9	10'2	9'9	...
„ T_c . . .	5°	12°	7°	19°	19°	12°	26°	20°	14°	18°	10°	8°	...
Smoothed H_c . . .	10'4	10'5	10'1	9'8	10'1	11'0	11'3	11'0	11'1	10'9	10'3	10'1	...
„ T_c . . .	8	9	11	15	17	18	23	21	18	17	13	9	...
ITALY AND ZURICH.													
Mean pressure . . .	65	60	60	61	61	64	61	65	62	68	61	(63)	63
Uncorrected H_c . . .	11'2	13'3	8'9	11'4	8'4	11'1	10'6	12'1	10'3	12'2	10'7	(10'9)	10'9
„ T_c . . .	5°	3°	15°	16°	24°	13°	15°	13°	22°	11°	14°	(14°)	14°
Number of cases . . .	2	1	3	6	1	4	3	8	12	5	6	0	51
Corrected H_c . . .	11'0	13'6	9'2	11'6	8'8	9'9	11'0	11'7	10'5	11'3	10'9	(10'9)	...
„ T_c . . .	6°	1°	13°	15°	22°	14°	13°	15°	23°	16°	13°	(14°)	...
Smoothed H_c . . .	11'6	11'9	11'1	10'3	9'8	9'9	10'9	11'2	11'0	11'0	11'0	(10'9)	...
„ T_c . . .	7°	5°	11°	16°	18°	16°	14°	17°	19°	17°	14°	(12°)	...

We notice that in general α is greatest in Period III. August–October and least in Period II. May–July. On the whole, it is greater in summer than in winter, and the same is true of β . Thus *a given change of pressure produces a greater effect on the height and temperature of the stratosphere in summer than in winter and a greater effect on the height in August to October than for other periods, and correspondingly a less effect in May to July.*

Collecting the results of the analysis we obtain the following:—

TABLE XXVII.

		P_1 .	α_1 .	P_2 .	α_2 .
H_c {	Berlin, Strassburg, Vienna	0·78 km.	228°	0·38 km.	108°
	Munich	1·05 km.	235°	0·59 km.	157°
	Paris, Hamburg, Uccle	0·62 km.	200°	0·29 km.	218°
	England	0·59 km.	225°	0·27 km.	241°
T_c {	Berlin, Strassburg, Vienna	2°·3 C.	225°	1°·4 C.	113°
	Munich	1°·2 C.	248°	1°·6 C.	287°
	Paris, Hamburg, Uccle	3°·4 C.	271°	1°·3 C.	54°
	England	1°·3 C.	252°	1°·2 C.	50°

The agreement between the values for England and for the Paris group is very close, with the exception of the amplitude of the whole year variation of T_c . The maxima for H_c appear to occur earlier in England, but the differences are not greater than would be accounted for by exceptional values. On the whole, we may say that the annual variation of H_c is between 1 and 2 km. and of T_c about 3° to 4° . The maxima of T_c occur slightly earlier than for H_c , tending towards the solstices.

The fact that at nearly all the stations and groups of stations H_c has a maximum in October and T_c in September is in itself a decisive refutation of the hypothesis that the change in the gradient of temperature is due to the effect on the instruments either of solar or of terrestrial radiation. The value of T_c is certainly slightly greater in summer than in winter, but the annual range of about 4° C. is not more than may be accounted for by the increased radiation from the earth and lower atmosphere in summer. The difference between the temperatures at which the stratosphere would be kept in radiation equilibrium in the two seasons depends upon the changes of temperature and humidity in the troposphere. An increase of temperature increases both H_c and T_c ; an increase of humidity also increases H_c , but diminishes T_c . *If the humidity remains constant*, the absorption by the stratosphere of radiation from the earth and lower atmosphere increases proportionally to the intensity of full radiation at the temperature at the earth's surface. If the latter is denoted by I , the absorption is $0.20 \pi I$ nearly per column of unit cross-section.* Thus, since T_c will be approximately proportional to the 4th root of this

$$\frac{\delta T_c}{T_c} = \frac{\delta T}{T}$$

where T refers to the earth's surface. But $T_c = \frac{3}{4} T$ nearly, and consequently $\delta T_c = \frac{3}{4} \delta T = 12^\circ$ C. about. The corresponding variation in H_c would be less than 1 km. *Thus the effect of humidity on T_c in summer is to reduce it by about 8° C. below the value it would have for a constant amount of water vapour, the same in summer as in winter.*

The values of H_c and T_c in the different pressure groups were corrected for the annual variation by the application of a correction for each period, and in this way a fresh classification according to pressure groups, but practically independent of the annual variation, was obtained. The Table shows the corrections used.

Place.	Period.	I.	II.	III.	IV.
Berlin, Strassburg,	$\left\{ \begin{array}{l} H_c \text{ (km.)} \\ T_c \end{array} \right.$	+ 0.7 + 1°	- 0.4 0°	- 0.5 - 3°	+ 0.1 + 1°
Vienna.					
Hamburg, Paris,	$\left\{ \begin{array}{l} H_c \text{ „} \\ T_c \end{array} \right.$	+ 0.6 + 1°	- 0.1 - 4°	- 0.5 - 2°	0.0 + 3°
Uccle.					
Munich.	$\left\{ \begin{array}{l} H_c \text{ „} \\ T_c \end{array} \right.$	+ 0.1 0.0	0.0 0.0	- 0.1 0.0	0.0 0.0
England.	$\left\{ \begin{array}{l} H_c \text{ „} \\ T_c \end{array} \right.$	0.6 + 1°	- 0.2 - 1°	- 0.8 0°	+ 0.4 0°

The following Table XXVIII. gives the results obtained. The values may be regarded as the best obtainable from the available data.

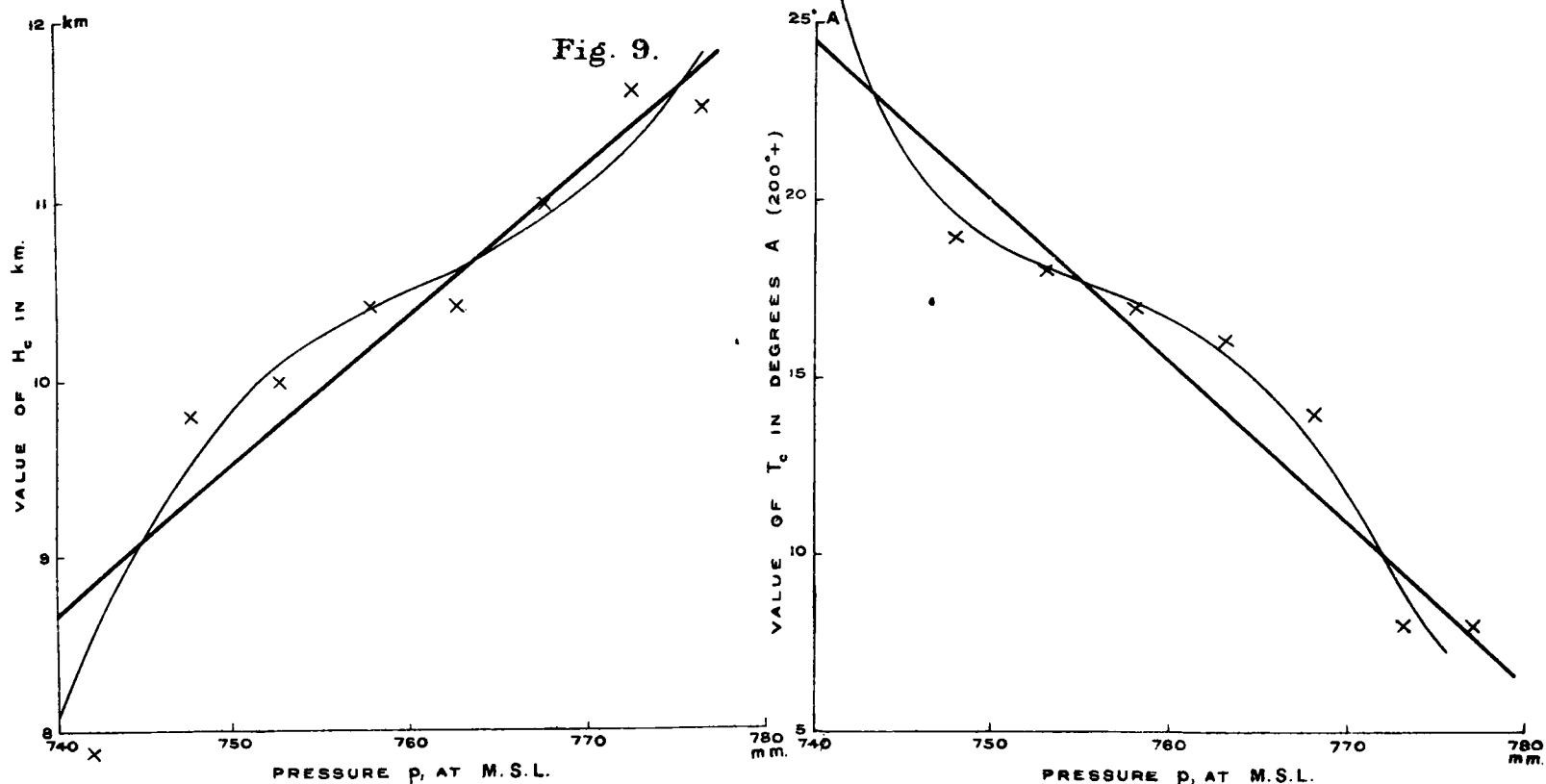
The values have been plotted in the diagrams, figs. 9, 10, 11, 12. In the case of Central Europe it will be seen that while for H_c the points at higher pressures lie very approximately on a straight line, the point at the lowest pressure is very much

* Gold, *Proc. Roy. Soc.*, vol. 82, p. 66.

VARIATION OF H_c AND T_c WITH PRESSURE p , AT MEAN SEA LEVEL (M.S.L.)

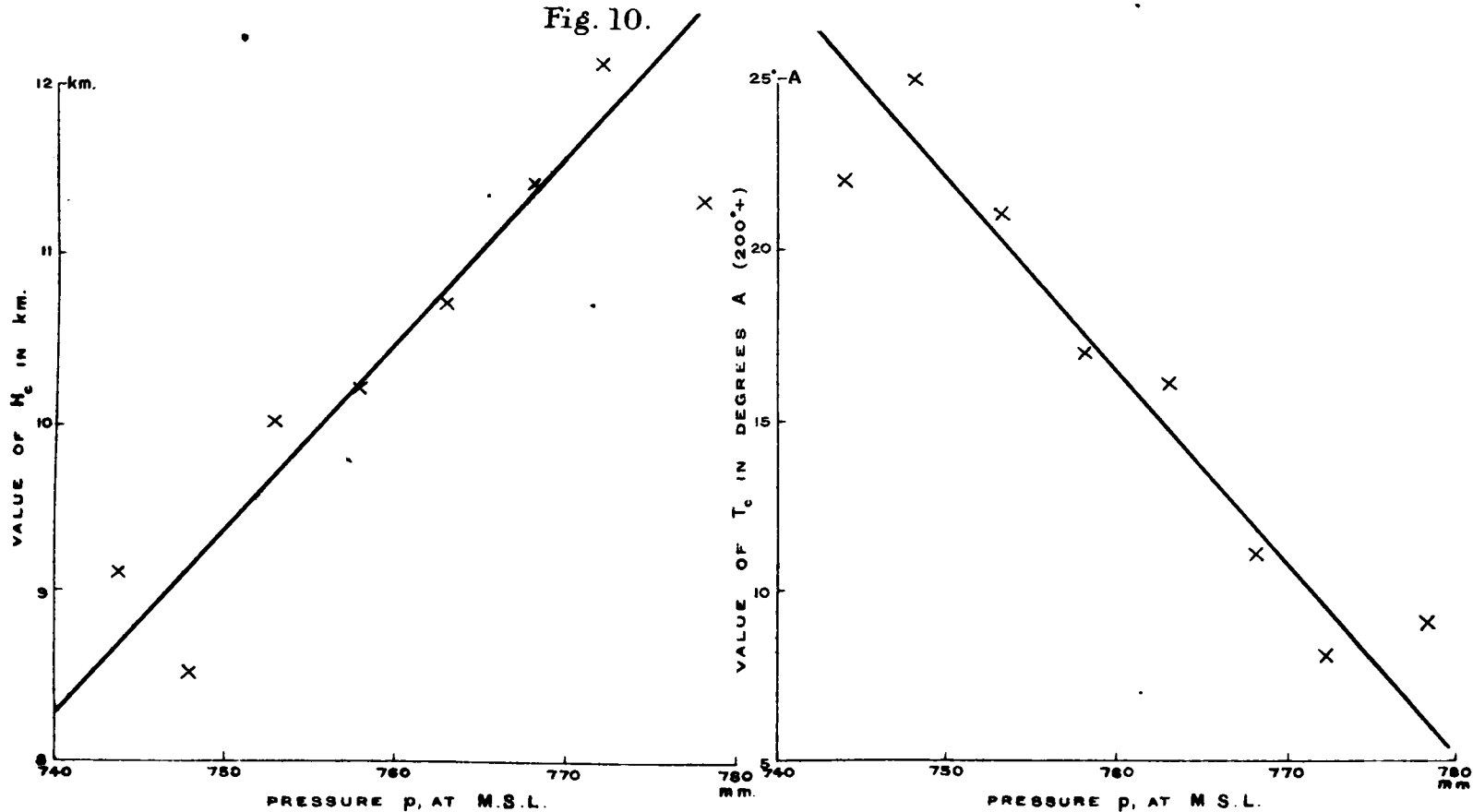
CORRECTED FOR ANNUAL VARIATION.

PARIS, HAMBURG, UCCLE.



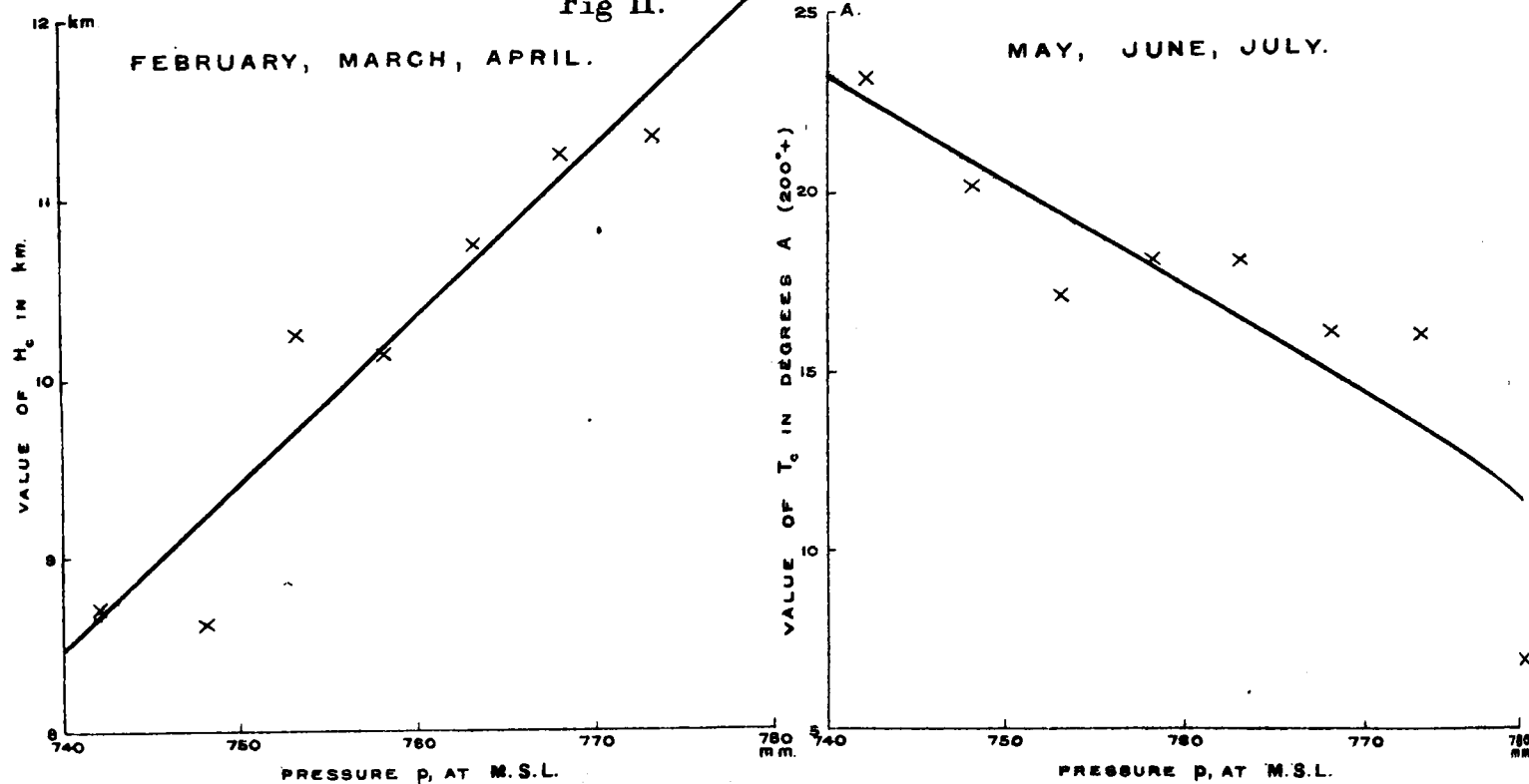
STRASSBURG, BERLIN, VIENNA.

Fig. 10.



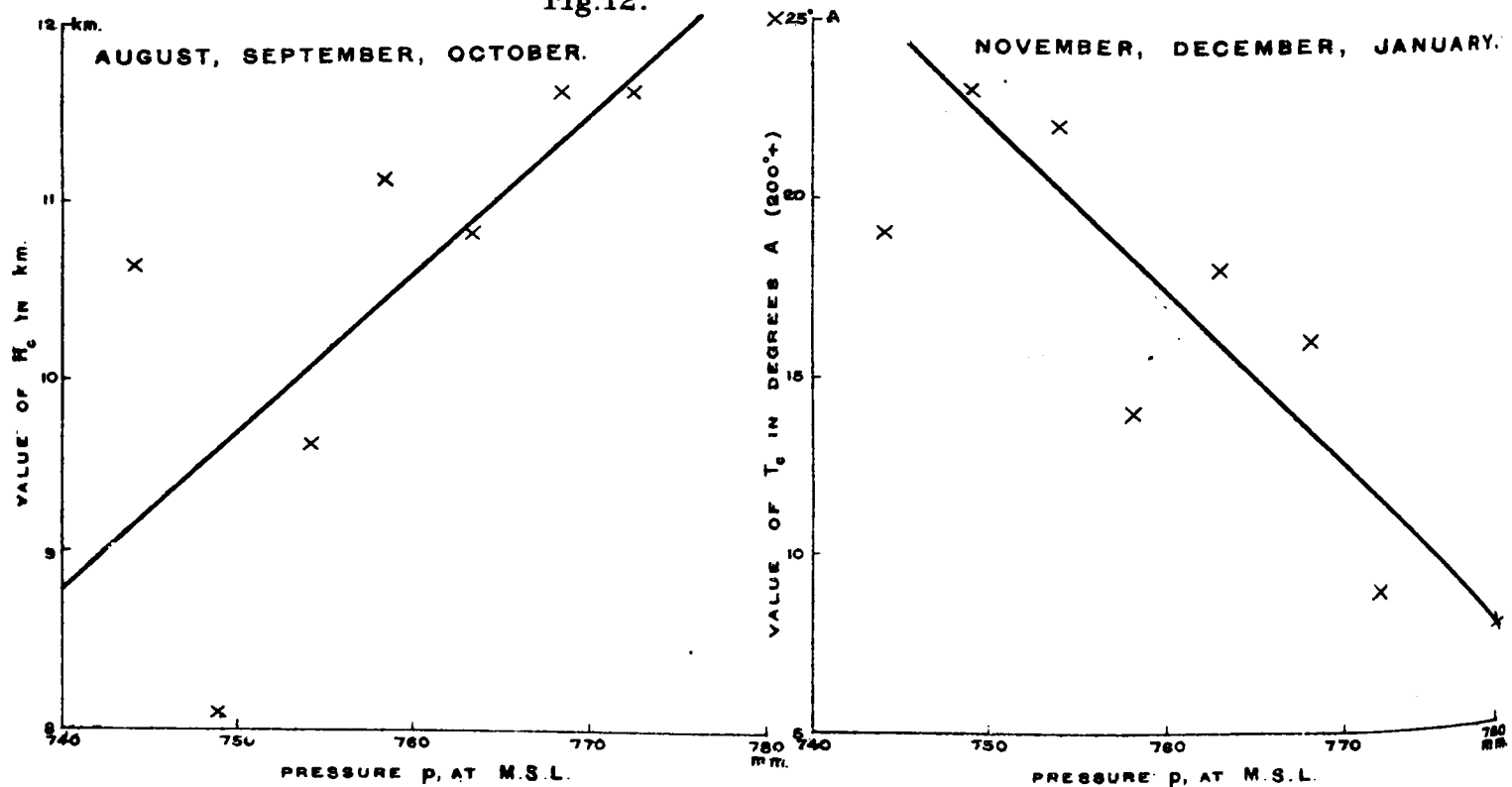
VARIATION OF H_0 AND T_0 WITH PRESSURE p , AT MEAN SEA LEVEL (M.S.L.)
CORRECTED FOR ANNUAL VARIATION.
ENGLAND.

Fig 11.



MUNICH.

Fig.12.



below it, and indicates that the variation of H_c with p is not linear. The curve of best fit appears to have a point of inflexion near the place of average pressure and to be decidedly steeper on the side of lower pressure. The same applies also to T_c . The effect is not present in the results for N.W. Europe, and it may be due to a difference in character of the cyclones which pass across Central Europe.

TABLE XXVIII.—VARIATION OF H_c , T_c , WITH THE PRESSURE AT MEAN SEA LEVEL.
CORRECTED FOR ANNUAL VARIATION.

	Pressure (700 mm. +).	>75.	70-75.	65-70.	60-65.	55-60.	50-55.	45-50.	<45.
Berlin, Strassburg, Vienna.	H_c (km.)	11.5	11.6	11.0	10.4	10.4	10.0	9.8	7.9
	T_c (200°+)	8°	8°	14°	16°	17°	18°	19°	26°
	p (mm.)	777	773	768	763	758	753	748	742
	No.	3	16	48	54	52	22	12	5
Hamburg, Paris, Uccle.	H_c (km.)	11.3	12.1	11.4	10.7	10.2	10.0	8.5	9.1
	T_c (200°+)	9°	8°	11°	16°	17°	21°	25°	22°
	p (mm.)	778	772	768	763	758	753	748	744
	No.	4	9	36	52	32	13	7	5
Munich.	H_c (km.)	12.0	11.6	11.6	10.8	11.1	9.6	8.1	10.6
	T_c (200°+)	8°	9°	16°	18°	14°	22°	23°	19°
	p (mm.)	780	772	768	763	758	754	749	744
	No.	1	7	21	18	18	5	4	2
England.	H_c (km.)	12.3	11.3	11.2	10.7	10.1	10.2	8.6	8.7
	T_c (200°+)	7°	16°	16°	18°	18°	17°	20°	23°
	p (mm.)	780	773	768	763	758	753	748	742
	No.	6	14	37	33	25	14	5	16

The values of α , β obtained from the diagrams are as follows :—

	Berlin, Strassburg, Vienna.	Paris, Hamburg, Uccle	England.	Munich.
α	0.08	0.10	0.09	0.09
β	0.46	0.57	0.29	0.48

Both coefficients are greater for the Paris group than for the Berlin group, but for England the value of β is decidedly smaller. The mean values for Munich agree very well with the values for the group.

If a change of pressure takes place adiabatically, the equation connecting the variations of pressure and temperature dp , dT is

$$KR \, dp/p = c_p \, dT/T$$

where $K = \frac{1}{427}$, $R = 29.27$, $c_p = 0.239$.

Thus, if $T = 216^\circ \text{ A}$, $dT = 62 \frac{dp}{p}$,

and if $p = 200 \text{ mm.}$, this becomes

$$dT = 0.31 \, dp.$$

Hence we deduce that the variations in T_c over England for variations of the pressure at Mean Sea Level are of the same magnitude, but **opposite in sign**, to the changes which would be produced in air at the level at which the stratosphere begins if it were subjected to an equal change of pressure which took place adiabatically.

Since the changes of pressure at a fixed level at 10 km. height are of about the same magnitude as the changes at the earth's surface, owing to the higher temperature of the air over the places of higher pressure, changes in the opposite direction can be produced only by ascent or descent of the air considered. Thus, if the non-seasonal changes of temperature in the stratosphere are the adiabatic changes due to varying pressure, the pressure in the stratosphere falls by an amount equal to that by which the pressure in the troposphere increases. Therefore, if pressure increases at the earth's surface *the increase in the mass of air in the troposphere is equal to twice the increase in the total mass of a vertical column in the atmosphere and also equal to twice the mass which the stratosphere loses.* Hence changes of pressure at the earth's surface are connected with changes in the opposite direction in the stratosphere, which give rise to currents flowing between the stratosphere and troposphere.

Over the Continent the value of β is greater, so that the variations of T_c are 1.5 times as great as those produced by changes of pressure equal to the changes at the earth's surface. The general deduction remains unaffected.*

The values of H_c , T_c from January 1906 onwards for Berlin, Munich, Strassburg, Vienna, Hamburg, Paris, Uccle, Zurich were grouped *according to the character of the gradient of pressure. When there was a well-defined gradient for a general northerly current in the neighbourhood of a station at the time of the ascent, i.e. if the isobars were directed from north to south with low pressure to the east, the type was classed as "North," and similarly for other directions. When no such definite general type prevailed the type was classed as "X."* Case X corresponds, therefore, with intermediate regions between two high or two low pressures and with the central areas of cyclones and anticyclones. The year was divided into the two periods May–October and November–April. The following Table shows the values of H_c , T_c for the different types in the two seasons, together with the mean value of the pressure and the number of cases:—

TABLE XXIX.

	Type.	North.	East.	South.	West.	X.
I. November to April 165 cases	H_c T_c p (mm.) No.	8.67 km. 18° 759 mm. 9	10.16 km. 14°.6 763 mm. 20	9.89 km. 15°.2 760 mm. 45	10.11 km. 14°.9 759 mm. 55	10.19 km. 13°.6 764 mm. 36
II. October to May 216 cases	H_c T_c p No.	10.57 km. 19° 762 mm. 43	11.49 km. 15° 767 mm. 26	11.53 km. 16° 763 mm. 26	11.41 km. 17° 762.5 mm. 29	11.55 km. 15° 763 mm. 92

In both seasons the values of H_c vary very slightly except for type N, for which they are distinctly lower than for other types, even those with approximately the same mean pressure. The value of T_c is correspondingly higher. It is also slightly higher for south and west types than for east or X.

The values for the different types were then arranged according to the pressure at the time of the ascent. We may, if we adopt the conventional classification of cyclone and anticyclone, take the following table of correspondence. In the Table, N_+ refers to

* As H_c increases, the pressure at the base of the stratosphere falls, but less than it would if there were no associated change of pressure at M.S.L. The value of α indicates that the amount of fall is diminished by one third, and that it is twice the amount of increase at M.S.L.

cases of type north in which pressure exceeded 765 mm., N_0 to cases in which pressure is between 755 mm. and 765 mm., N_- to cases below 755 mm., and similarly for other types.

X for $p < 750$ = Cyclone Central.		X for $p > 770$ = Anticyclone Central.	
N_+ = East of Anticyclone.	S_+ = West of Anticyclone.	W_+ = North of Anticyclone.	E_+ = South of Anticyclone.
N_- = West of Cyclone.	S_- = East of Cyclone.	W_- = South of Cyclone.	E_- = North of Cyclone.

N_0 = intermediate region, with cyclone to east of anticyclone.

S_0 = " " " west "

W_0 = " " " north "

E_0 = " " " south "

The following Table shows the results for Period I., November–April :—

TABLE XXX.

	N_+	N_0	N_-	E_+	E_0	E_-	S_+	S_0	S_-
H_c (km.)	10.7	8.4	7.6	10.4	10.4	8.7	10.9	9.4	9.9
T_c (200° +)	10°	18°	24°	13°	16°	18°	13°	17°	14°
p (mm.)	770	761	750	768	762	744	768	761	752
No.	3	2	4	11	6	3	11	21	13

	W_+	W_0	W_-	X_1	X_2	X_3	X_4	X_5	X_6
H_c (km.)	11.1	10.7	8.8	11.3	10.4	10.4	9.3	9.4	7.9
T_c (200° +)	10°	13°	21°	10°	12°	12°	16°	22°	24°
p (mm.)	773	761	748	773	768	763	758	751	745
No.	14	22	19	10	9	5	7	2	3

The values for case X have been arranged according to pressure groups. X_1 is for pressure >770 , X_6 for pressure less than 750, X_2 for pressure 765–770, and so on.

There is a very marked difference between N_- and S_- both in H_c and T_c . This indicates that the stratosphere is much lower on the west of a cyclone than on the east, and has a much higher temperature. Perhaps even more remarkable are the low values for H_c and the high value for T_c for S_0 , showing that further to the east of the cyclone there is a fall in the level and a rise in the temperature of the stratosphere.

Again, E_- and W_- have practically the same value, showing that there is little difference between the north and south sides of cyclones so far as the height and

temperature of the stratosphere are concerned. In both regions the height is greater than on the west side and less than on the east side. Thus low-pressure areas in winter appear to be associated with a "wave" in the surface between troposphere and stratosphere. The crest of the wave is immediately in front of the cyclone, the trough is immediately in the rear.

For the season May to October ascents are more numerous, and the values for different pressure groups are given (Table XXXI.). The suffixes 1, 2, 3, . . . , 6 correspond with pressures >770 , 765-770, . . . , <750 .

TABLE XXXI.

Type.	N ₁ .	N ₂ .	N ₃ .	N ₄ .	N ₅ .	E ₁ .	E ₂ .	E ₃ .	E ₄ .
H _c (km.)	11.5	11.2	10.6	10.0	10.0	11.4	11.5	11.5	11.7
T _c (200°+)	11°	17°	20°	23°	23°	11°	16°	13°	9°
p (mm.)	773	768	763	758	754	772	768	762	760
No.	1	12	15	11	4	3	16	5	2

Type.	S ₁ .	S ₂ .	S ₃ .	S ₄ .	S ₅ .	W ₁ .	W ₂ .	W ₃ .	W ₄ .	W ₅ .
H _c (km.)	13.7	12.6	11.2	10.5	11.0	13.6	12.4	11.5	10.6	11.2
T _c (200°+)	7°	10°	18°	18°	33°	-1°	12°	17°	22°	15°
p (mm.)	772	768	763	758	753	772	768	763	758	754
No.	2	6	10	7	1	1	5	13	9	1

Type.	X ₁ .	X ₂ .	X ₃ .	X ₄ .	X ₅ .	X ₆ .
H _c (km.)	12.7	12.1	11.3	11.3	10.2	...
T _c (200°+)	9°	14°	17°	15°	19°	...
p (mm.)	773	768	763	758	753	...
No.	7	22	25	35	3	...

In this season the difference between N₋ and S₋ is still considerable, but it is less marked than the difference between N₊ and S₊, indicating that the difference between the east and west of an anticyclone is greater than the difference between the west and east of a cyclone—the reverse of the result for winter. The variation of H_c with pressure in type E is inappreciable, while for W it is very marked.

Thus at the south of a cyclone the stratosphere is at a lower level than at the north, while for an anticyclone the result is the reverse. By plotting the values given above, the values of H_c and T_c for definite pressures for each type were obtained. The results are given in Table XXXII., the suffix indicating the pressure to which the values refer.

These values have been plotted in the diagrams, figs. 13, 14, 15, 16, giving sections across the pressure distribution in a north to south direction and in a west to east direction.

In winter the section from north to south shows the symmetry mentioned above, both for the high- and for the low-pressure areas, and as well for height as for temperature, except near the region of highest pressure, where H_c is greater and T_c less on the north than on the south side. The section from west to east is much steeper on the east side of the high pressure; but what is perhaps most remarkable is the very

RELATION BETWEEN H_0 AND DISTRIBUTION OF PRESSURE.- SUMMER.

Fig. 13.

SECTION NORTH TO SOUTH.

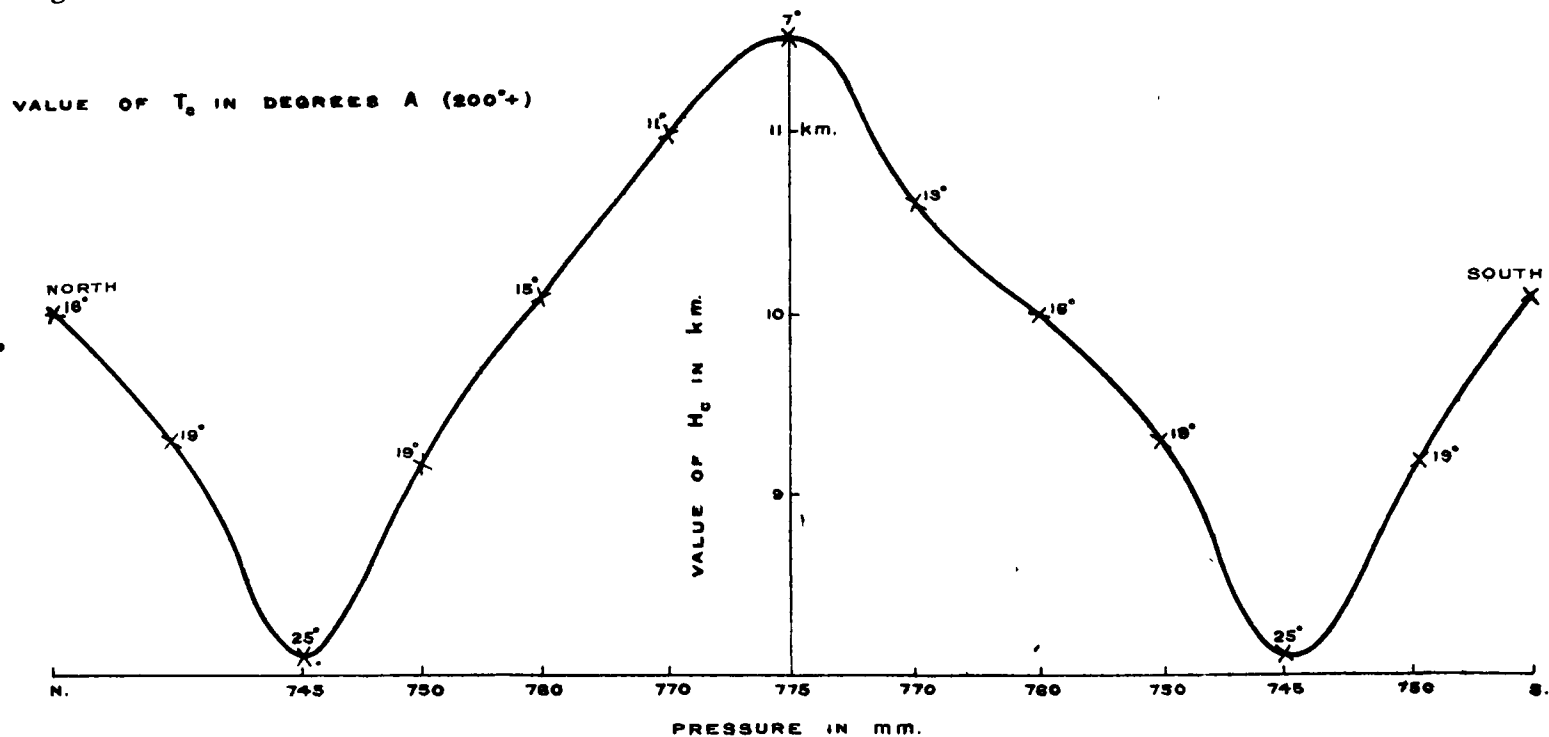
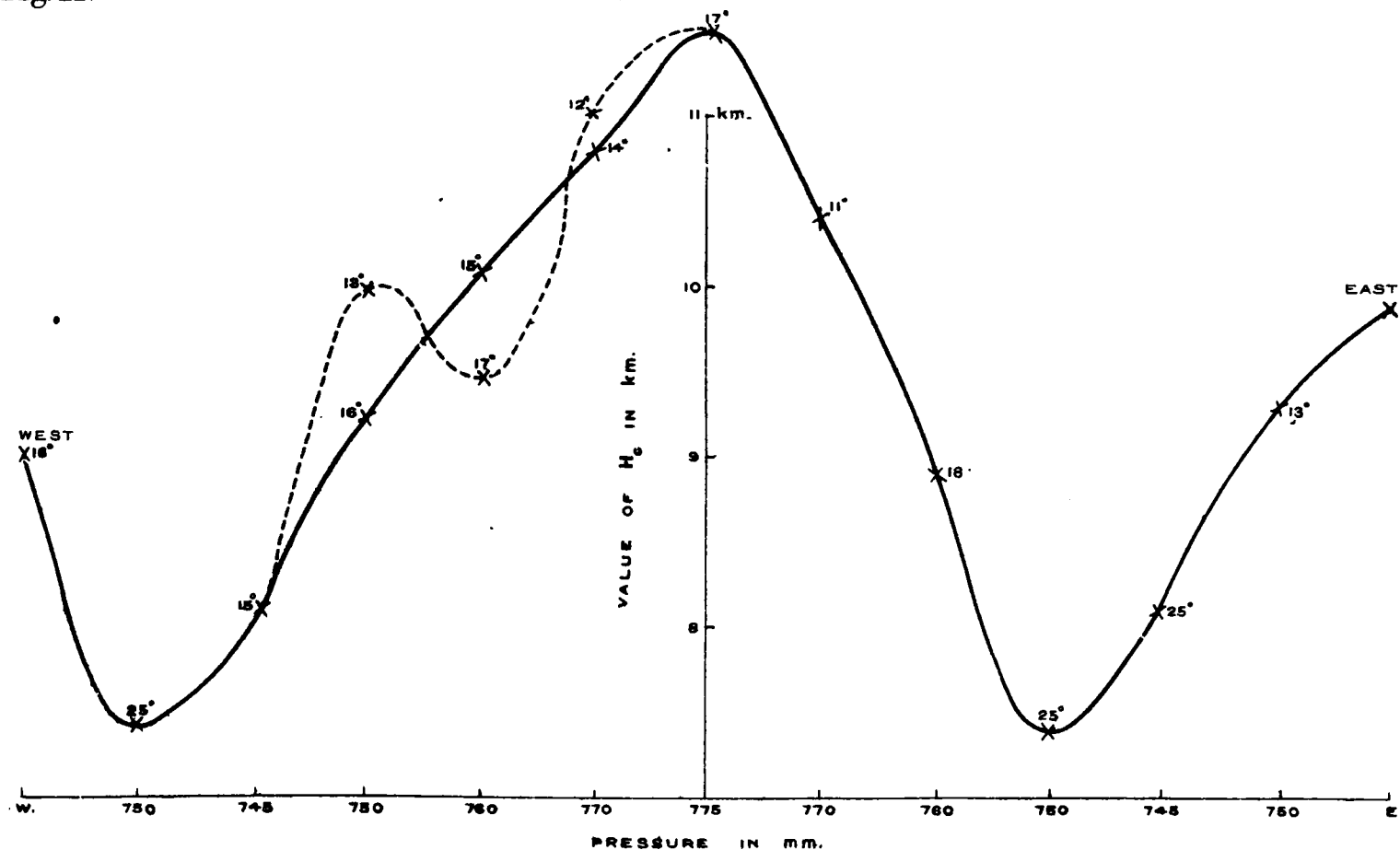


Fig. 14.

SECTION WEST TO EAST.



RELATION BETWEEN H_c AND DISTRIBUTION OF PRESSURE.-WINTER.

Fig.15.

SECTION WEST TO EAST.

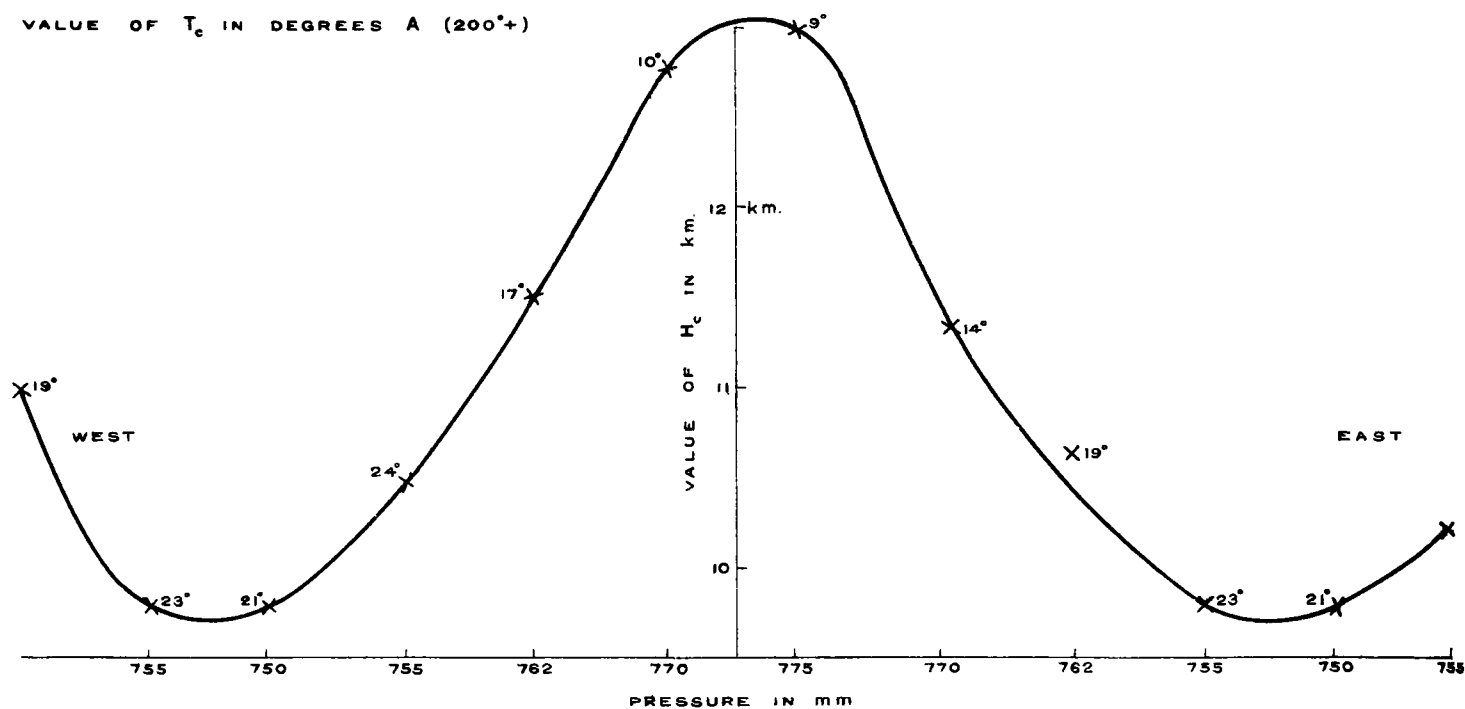
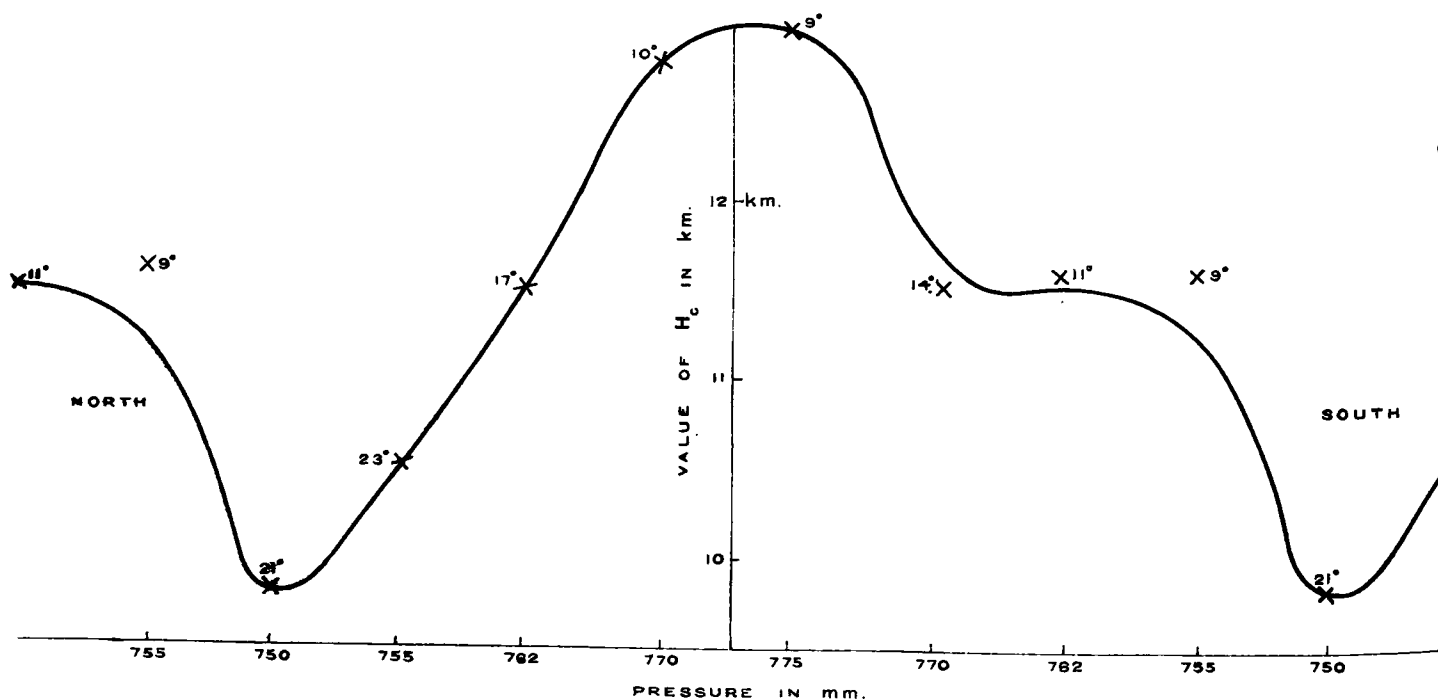


Fig.16.

SECTION NORTH TO SOUTH.



low value of the temperature to the east of the low pressure, just in front of the cyclone as it were. The actual figures founded on forty-five observations, 11, 21, 13 in the three groups, indicate a secondary wave in front of the low pressure. This is shown by a pecked line in fig. 14. These values are given first in Table XXXII.; the alternative values for cases S, are taken from the line which passes best through the points in the diagram giving the relation between pressure and H_c , T_c .

In summer, conditions are reversed. The section from west to east is nearly symmetrical, the crest being sharper and the trough flatter than in winter. The

TABLE XXXII.

WINTER. NOVEMBER TO APRIL.

Type.	X ₇₇₅	N ₇₇₀	W ₇₇₀	N ₇₆₀	W ₇₆₀	N ₇₅₀	W ₇₅₀	X ₇₄₅
H _c (km.)	11·5	10·4	11·0	8·9	10·1	7·4	9·2	8·1
T _c (200°+)	7°	11°	11°	18°	15°	25°	19°	25°
SUMMER. MAY TO OCTOBER.								
Type.	X ₇₇₅	N ₇₇₀	W ₇₇₀	N ₇₆₂	W ₇₆₂	N ₇₅₅	W ₇₅₅	X ₇₅₀
H _c (km.)	13·0	11·3	12·8	10·6	11·5	9·8	10·5	9·8
T _c (200°+)	9°	14°	10°	19°	17°	23°	23°	21°
WINTER. NOVEMBER TO APRIL.								
Type.	S ₇₅₀	E ₇₅₀	S ₇₆₀	E ₇₆₀	S ₇₇₀	E ₇₇₀		
H _c (km.)	10·0 or 9·3	9·3	9·5 or 9·9	10·0	11·0 or 10·8	10·6		
T _c (200°+)	13° or 16°	19°	17° or 15°	16°	12° or 14°	13°		
SUMMER. MAY TO OCTOBER.								
Type.	S ₇₅₅	E ₇₅₅	S ₇₆₂	E ₇₆₂	S ₇₇₀	E ₇₇₀		
H _c (km.)	10·5	11·6	11·5	11·6	12·8	11·5		
T _c (200°+)	24°	9°	17°	11°	10°	14°		

section from north to south is very flat in the region to the south of the high pressure, and on this side the most marked change of temperature is found.

Thus south in summer and west in winter correspond, a result in agreement with the general meteorological character of the European area in these two seasons, and evidence of the reality of the features found in the variation of H_c and T_c with pressure distribution.

It has been suggested that the cause of the sudden change in the temperature gradient, which might be expected to diminish gradually, is the formation of a veil of Ci. or Ci.S. If this were the case, the annual variation in the height of

these clouds ought to show the same peculiarities as the annual variation in H_c . The annual variation in the height of Ci., Ci.S., Ci.Cu. is given in fig. 17. The observations used are those for the international year 1896-1897. The curves do not show the very marked minima in March and September which occur in the H_c diagram, but there are indications of a peculiarity of this kind, more pronounced in the Ci.S. and Ci.Cu. curves than in that for Ci. proper. The annual range is about the same as for H_c , 2.5 km. nearly. The actual values of the heights are, however, much less than those of H_c . Thus, while the results point to some common cause for the variation in H_c and in the height of the clouds, they indicate that the formation of clouds is not a usual cause of the sudden decrease and change of sign in the temperature gradient.

One of the most remarkable features is the large variation sometimes found in T_c and H_c from one day to the next. This has been most marked in England, and the general agreement in results from different stations proves that it cannot be attributed to instrumental errors. For example, on April 1, 2, 3, 1908, the values of H_c T_c were

		H_c	T_c	
April 1	. . .	10.5	15°	Manchester
„ 2	. . .	12	17°	Pyrton Hill
„ 3	. . .	7	24°	Manchester.

The result is not surprising, since the English stations are subject to more frequent and rapid changes in the pressure distribution than the Continental stations.

The theory of the general circulation developed by Oberbeck* indicated that even at moderate heights quite close to the equator the upper current would have a westerly component, and this has been confirmed by actual observations of such a wind by the "Aërologische Expedition nach Ostafrika" in 1908. There will therefore be side by side the westerly current of temperate latitudes and the westerly current over the equatorial regions, and they will be of different temperatures, *the equatorial current being the colder* at great heights. We shall therefore get wave motion at the interface between these currents, as shown by von Helmholtz † in his classical paper on rotating rings of air, and it is to be noted that the condition for stability is satisfied since the temperature (potential) increases in the direction of the earth's axis, the equatorial side having been shown by observation to be the colder. There will therefore be, in the upper air, bulges of the equatorial current towards temperate latitudes, especially near or in the stratosphere. These may either be of the character of standing waves caused by orographical or thermal peculiarities at the earth's surface or they may be progressive waves. The Azores anticyclone is probably an example of the former kind, the travelling anticyclones of temperate latitudes examples of the latter. (The great Siberian anticyclone is caused mainly by the thermal conditions at the earth's surface there, and complicates the general circulation in the winter of the Northern Hemisphere.) It is not suggested that all anticyclones are caused by the bulging of the cold equatorial current towards temperate latitudes. The more northerly ones probably arise from more local conditions.

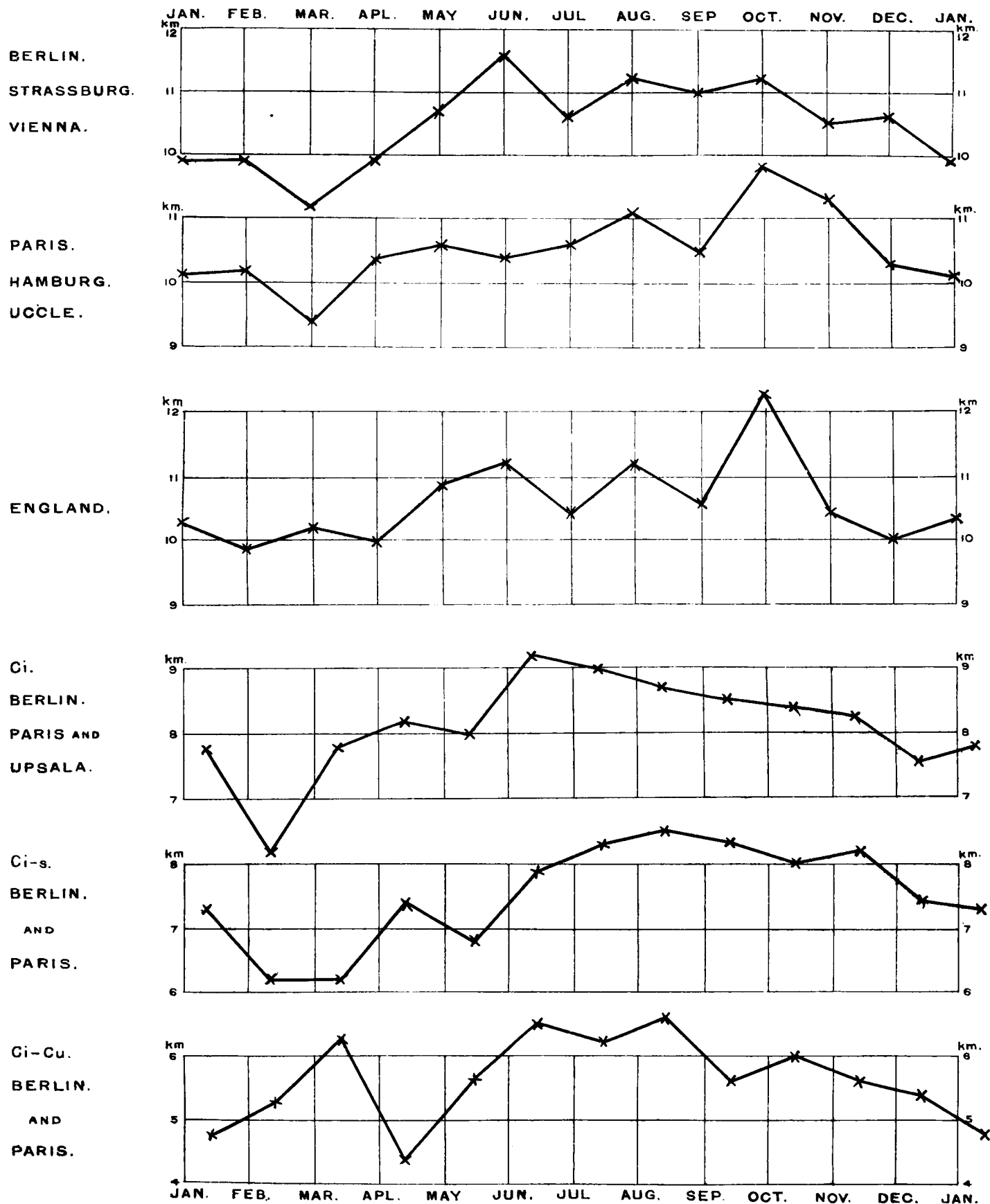
Where the equatorial air encroaches on temperate latitudes, the value of H_c would be increased and that of T_c diminished below its average value, and the effect would

* Sitz. d. K. Preuss. Akad. d. Wiss., 1888.

† Sitz. d. K. Preuss. Akad. d. Wiss., 1888, 1889.

ANNUAL VARIATION IN VALUE OF H_c AND IN HEIGHT OF CLOUDS.

Fig. 17.



persist until radiation restored the normal conditions. If we consider an anticyclone produced in the manner described, the equatorial air would enter the anticyclonic area from W. or S.W., descend spirally, and leave from a N.E. direction. *Thus the value of H_c should be less on the S. or S.E. side of an anticyclone than on the N. or N.W.* The effect on T_c would be the reverse. Moreover, *H_c would be greater for an intermediate region if the anticyclone was to the South and the cyclone to the North, than when the anticyclone was to the North and the cyclone to the South*, because the latter feature of the pressure distribution indicates a bulge equator-wards in the interface between the two streams, and the air in the stratosphere will be almost entirely that from higher latitudes. Consequently, also, *the value of H_c should be less on the S.W. side of a cyclone than on the N.E., and less on the S. side of a cyclone than on the N. side of an anticyclone.* This agrees with the facts described above, based on the actual results of the balloon observations. H_c is considerably greater down to the region of average pressure for the N. side of an anticyclone than for the S., especially in summer when the Siberian anticyclone is absent, and the circulation is more regular around the pole. Also, it is greater on the W. side than on the E. H_c is also less on the W. side of a cyclone than on the E., and greater on the N. than on the S.

The fact that H_c has minimum values in March and September when equatorial temperatures are highest appears at first to be contrary to this view. But the first effect of the increased equatorial temperature will be to increase the strength of the trade winds*; and as at the same time there is in progress a transference of air across the equator to the Southern Hemisphere, a transference which can only be made through the upper return current, there will be a deficiency of descending air to the North, and the equatorial cold air will encroach less than usual on the Northern Stratosphere. Naturally, if the earth were symmetrical, it would be expected that the process in September would be the reverse of this. But the autumnal transference of air to the Northern Hemisphere will be initially much more intense towards the great Asiatic continental region, and, in a less degree, to North America, than to the Atlantic and European area, and the result may well be that the equatorial current again encroaches less than usual on that region. If such is the case, it may be expected that the value of H_c over the Asiatic area will not show the September minimum, and that if it occurs over America it will at least be less marked than over Europe. The high value of H_c in October indicates that in that month the encroachment has become more general.

It may be remarked that September is a month of minimum rainfall per day, between months of relatively high rainfall, at Kew, Valencia, and Vienna†—a peculiarity which it shares with the earlier months of the year. At Manila, lat. 15° N., an almost complete reversal of direction of clouds and winds occurs towards the end of September; over square No. 39 lat. 15° N. long. 25° W., a similar change occurs at the end of August; in both cases the cirrus begin to move from a S. to S.E. direction instead of E. to N.E.

The results of observations made with pilot balloons to heights greater than H_c point to a decrease in wind velocity on entering the stratosphere.

* Over the Atlantic the N.E. trade wind is strongest in April, but has a secondary maximum in February. It is weakest in October, but the value in September exceeds the values for August and October.

† This peculiarity is not found at Pavia.

The following Table illustrates this :—

Date.	Place.	H _c .	Layer in which Wind Decreased.	Decrease in Velocity.	Velocity in Stratosphere.
		km.	km.	m/s.	m/s.
July 28, 1908	Ditcham	12	11-13	18	3
July 29, "	"	13 (?)	12-13	9	13
July 31, "	"	12.5 (?)	11-13	6	27
Feb. 6, "	Munich	12	11-13	15	18
July 2, "	"	11.6	12-16	10	7
Oct. 2, "	"	13.2	11.6-14.7	8	8

On July 31 and September 30, 1908, the velocity was observed up to 12.9 and 13.6 km. respectively, and showed no falling off, but a steady increase. The values of H_c were 13.2 and 13.6 km. There is little doubt, therefore, that the falling off in velocity is associated closely with the stratosphere.

On July 28 the maximum wind at Ditcham was 24 m/s. from N.N.W., and at Munich on the same day the wind at 12 km. was 21 m/s. from N. by W., indicating that the current extended right across the intervening region, just beneath the stratosphere.

The attempts to furnish a reasonable explanation of the existence of the stratosphere on theoretical grounds led to various suggestions. Trabert* showed that if there were a decrease of temperature in a horizontal direction in passing eastwards over Europe, and if the air moving eastwards also had a small ascending motion, then the adiabatic fall of temperature would not exist in a vertical direction. It appears probable, however, that the causes which produced a horizontal decrease of temperature in one layer would also produce a similar decrease in the layer above it, and in that case Trabert's effect would vanish.

Fenyi† considered the question of the absorption of solar radiation in the upper atmosphere. He concluded that, if the phenomenon were due to this, there must be absorption of dark radiation, since the ultra-violet radiation would be insufficient even if it were all absorbed.

Humphreys‡ pointed out that if the effective radiating power of the earth and atmosphere were the same as that of a black body at temperature T₁, the effect on any radiating and absorbing matter near enough to the earth for the radiating surface to be regarded as an infinite plane would be to keep the matter at a constant temperature such that the radiation from it would be half the radiation from it at temperature T₁. If the radiating matter were such as to admit of the application of Stefan's law, its temperature would be T' where $T' = \frac{1}{2}T_1^4$. The observed value of T agrees with the value deduced from this equation by giving T₁ the value estimated by Abbott and Fowle§ from the value of the solar constant, regard being paid to the proportion of the incident solar radiation which is reflected and does not affect the temperature of the earth.

Gold|| developed the radiation theory about the same time, and dealt more fully with the details of the process.

The following is an outline of the theory of the phenomenon : Any layer of air is dependent for its average temperature on (1) solar radiation ; (2) radiation from the

* *Mrt. Zeit.*, 1907.

† *Met. Zeit.*, 1907.

‡ *Astrophysical Journal*, 1909.

§ *Annals of Observatory of Smithsonian Instit.*, vol. ii.

|| *Proc. Roy. Soc.*, Series A, vol. 82, Oct. 1908.

solid earth; (3) radiation from the atmosphere above and beneath it; (4) convection, including in this the energy arising from the condensation of convected water-vapour.

The loss or gain of heat in the layer by conduction is infinitesimal. Loss or gain by air carried horizontally may contribute for a particular region, but may be excluded in a consideration of average conditions, in the first instance.

The only way in which the layer can lose heat is by radiation. Apart from local dynamical effects, convection can only add heat to the upper parts of a convective system. Thus the loss by radiation must balance the gain from the causes enumerated. Of these, (2) and (3) are the most important at high levels, and a consideration of these alone will supply a lower limit to the temperature of any layer, which must be very near to the actual value. The necessary conditions for convection to be possible are

$$\int(P_{\lambda}+V_{\lambda})d\lambda>\int(Q_{\lambda}+G_{\lambda})d\lambda \quad . \quad . \quad . \quad . \quad . \quad I.$$

and

$$\int (\mathbf{X}_\lambda + \mathbf{Y}_\lambda + \mathbf{E}_{\lambda'} + \mathbf{S}_{\lambda'}) d\lambda < \int \mathbf{K}_\lambda d\lambda \quad . \quad . \quad . \quad . \quad \text{II}.$$

expressing that the inward radiation across any plane must exceed the outward and that the radiation from any layer must exceed the absorption by it.

P_λ, Q_λ are the intensities of radiation of wave-length λ , arising from the atmosphere itself, downwards and upwards.

V_{λ} is the downward intensity of solar radiation, subtracting radiation reflected or diffused to space.

G_{λ} is the upward radiation from the earth.

X_λ , Y_λ the atmospheric radiation absorbed in a layer.

E_{λ}' , S_{λ}' the terrestrial and solar radiation absorbed in a layer.

K_λ the radiation from the layer.

In order to satisfy condition II. it is clearly necessary that

$$\int (X_\lambda + Y_\lambda) d\lambda < \int K_\lambda d\lambda.$$

If the atmosphere is divided into layers in which the pressure changes by dp , and if b is the coefficient of absorption for wave-length λ , so that $b dp$ is the absorption for a stream passing perpendicularly through the layer, then

$$X_\lambda = f(p_1, p_2) + f(p', p_1) - f(p', p_2)$$

$$Y_\lambda = g(p_3, p') + g(p', p_1) - g(p_3, p_1)$$

$$K_\lambda = f(p', p_1) + g(p', p_1)$$

where

$$f(p_1, p_2) = 2\pi \int_{p_2}^{p_1} \int_1^\infty I_\lambda \frac{b dx}{x^2} e^{-u(p, p_1)} dp$$

$$g(p_3, p_1) = 2\pi \int_{p_1}^{p_3} \int_1^\infty I_\lambda \frac{b dx}{x^2} e^{-u(p_1, p)} dp$$

and

$$u(p, p_1) = \int_p^{p_1} bx dp; \text{ and } I_\lambda \text{ is radiation intensity.}$$

By using these results with the experimental values found by Paschen, Rubens and Aschkinass, Arrhenius, and others for the absorption of water vapour and CO_2 , values were found for the limit above which convection would not be possible, on the hypotheses (1) that the intensity of radiation of a full radiator at the temperature found in any

layer at pressure p is given by the relation $I \propto p$; (2) that $b = \frac{a}{q-p}$ where a and q are constants, depending upon the amount of water vapour present and the rate at which it varies with altitude. The result is, that convection must persist to heights greater than that for which pressure is half its surface value, p_0 , and less than those for which it is equal to $\frac{1}{4} p_0$. These correspond to temperatures of 240° A. and 203° A. for a surface temperature of 285° A. Actually, I varies more slowly than p , and may be expressed in the form $I = a_1 p + \beta_1 p^2 + \gamma_1 p^3$. If this value is used, the limits of height become greater, but the temperatures change very little, and we deduce that the temperature of the stratosphere for temperate latitudes must be below 240° A. and above 203° A. The actual results indicate that the average value will be nearer the lower limit, because for the atmosphere above the lower level (or 240° A.) the excess of radiation over absorption is $0.20 \pi I$, while the radiation and absorption balance almost exactly at the higher level, apart from absorption of solar radiation, which we may take as not greater than $0.05 \pi I$ for the atmosphere above 10 km. Thus we may conclude that the actual temperature of the stratosphere will be nearly $203^\circ + \frac{1}{4} (240 - 203^\circ) = 212^\circ \text{ A.}$, which agrees very closely with the average value found above, viz., 216° A.

The theory indicates that if convection were absent and if the absorption of solar radiation did not increase with height, the normal state would be one in which the gradient of temperature diminished gradually to a very small value. The rapidity of the change which is frequently observed is due to convection in the troposphere; but even if convection were absent, the atmosphere would be in an approximately isothermal condition in the upper layers. The effect of radiation will always be in the direction of destroying any rapid change in the gradient.

If the value of the absorbing power b increases, the value of H_e is increased while that of T_e is diminished. If the temperature increases in the troposphere, the values both of H_e and of T_e are increased. This is therefore the explanation of the variation with latitude of H_e , T_e , since we know that the humidity, and therefore b , increases towards the equator. But the condition I. above has also to be satisfied. The outward radiation must be as great as the inward. Now, if the atmosphere is a "gray" body, i.e. if each layer of it radiates throughout the spectrum with an intensity proportional to that of a black body at the same temperature, any increase in b diminishes the outward radiation; and if the effect is great enough to counterbalance the effect of increased temperature, it will also counterbalance the effect of the increased temperature on the outward radiation. Therefore, the outward radiation over the equator would be less than for temperate latitudes, which is a very improbable result. We conclude that the atmosphere is not a "gray" body, but must have nearly perfect transparency for some spectral regions.

The suggestion that cirrus clouds shield the upper air over the equator from the radiation from below is open to the same objection. If they shield the stratosphere, they diminish also the outward radiation to space, and the temperature of the region beneath would increase until a balance was restored, either by increased atmospheric circulation or by radiation or both.

The stratosphere over the equator must be reached at a height above the level at which the surface temperatures of temperate latitudes are reached, greater than the value of H_e for temperate latitudes, since the air contains a greater percentage of

water vapour. Thus if H_c is 11 km. for temperate latitudes of temperature 285° A., it must exceed 14 km. over the equator if the temperature there is 303° A. and the mean gradient up to 3 km. is 6° C. per km.

Although the air over the equator is actually of lower temperature than for higher latitudes, it is of higher potential temperature than any other air except that at the same level in higher latitudes. It is therefore difficult to see how the equatorial cold air can descend again since by hypothesis the effect of radiation will be to *increase its temperature as it moves polewards over regions where the temperature of the stratosphere is normally higher.*

The explanation may be either (1) that north and south of the equator there exist belts in which the *potential* temperature is higher from 8–14 km. than that of the equatorial air above 15 km.; or (2) that the stratosphere in temperate latitudes is not actually in a steady thermal condition, but is losing heat gradually by radiation, and at the same time gradually sinking downwards. The absence of regular vertical temperature gradient would be due to the fact that the sinking was *en masse* and not convectional. It would not be inconsistent with the general explanation of the isothermal condition of the stratosphere given above. The air at the lower part of the stratosphere would be gradually absorbed by the troposphere.

The difference in the values of H_c , T_c over cyclonic and anticyclonic regions are, as explained above, due to dynamical causes. The effect of radiation is to diminish the differences observed.

Humidity.—It has been suggested that the upper limit of the troposphere may be also the upper limit of the water vapour atmosphere. But it appears certain that at this upper limit the atmosphere must always be saturated with water (ice) vapour, and that in the stratosphere the water vapour atmosphere will be such that the difference of vapour pressure between two points will be equal to the weight of the vapour in the intervening column. For the processes of diffusion and of convection of water vapour alone would tend to produce a water vapour atmosphere, in which the amount of vapour present at any height in the troposphere would be more than sufficient to produce saturation at that height for the temperature in the actual atmosphere. The only process which prevents the atmosphere being saturated at all heights is the descent of air carrying with it the water vapour it contained at the beginning of the descent,—an amount insufficient to saturate it at lower levels. But at the upper limit of the troposphere there can be no considerable descent of air from above, and the air arriving there from below will necessarily be saturated, since it must contain sufficient water vapour to saturate it at the lowest temperature to which it has been exposed, *i.e.* T_c . The actual amount of water vapour present is small compared with the amount present near the earth's surface; but a small amount of water vapour is sufficient, at ordinary temperatures at least, to produce considerable absorption of terrestrial radiation, and the absorption extends through a large part of the spectrum of radiation at terrestrial temperatures. In fact, it is probably chiefly due to the presence of this water vapour that it is possible to obtain theoretical results agreeing with the observed facts by using the assumption that the absorption, and therefore also the radiation, is sufficiently extensive to warrant the application of Stefan's law. It follows, also, from this reasoning, that the mean amount of vapour present at any height above the lower

cloud level will be at least half the sum of the amount for saturation at that height, and the amount necessary for saturation at the height H_c .

Thus the average relative humidity will be a minimum near the earth's surface, but it must exceed half the value necessary to produce saturation at the lower cloud level, at 2 km. say, *i.e.* it must exceed 30 per cent. on the average. At 2 km. the average value must exceed 50 per cent., and above this level it increases until it reaches 100 per cent. at the height of the stratosphere H_c .

I. (e).—TEMPERATURES UNDER CYCLONIC AND ANTICYCLONIC CONDITIONS.

One of the most important questions which arise refers to the possible difference in the vertical gradient of temperature over cyclones and anticyclones. Hann* deduced from mountain observations that the gradient was less for anticyclones than for cyclones, and the difference was so considerable that the mean temperature of the atmosphere up to 3·5 km. was 5° C. higher over anticyclonic regions than it was over cyclonic. Grenander† used the observations made in the free atmosphere at Hald and Berlin, and found similar results both for winter and summer. The following Table gives the mean fall of temperature between the surface and 5 km. for the different quadrants in winter, and the mean values for summer, taken from Grenander's results:—

Quadrant.	Winter.					Summer.
	N.	E.	S.	W.	Mean.	Mean.
Anticyclonic	°C. 24·3	°C. 25·0	°C. 19·4	°C. 18·9	°C. 21·0	°C. 27·4
Cyclonic	26·5	26·9	28·7	30·6	27·7	29·9

The mean temperatures at different heights, calculated from Grenander's results, are as follows:—

ANTICYCLONES.

	Winter.					Summer.
	N.	E.	S.	W.	Mean.	Mean.
Surface about 60 m. . . .	°C. 78·7	°C. 74·7	°C. 74·4	°C. 76·3	°C. 76·2	°C. 89·5
1 km.	74·4	70·0	71·1	75·2	73·2	82·4
2 „	71·3	64·9	68·4	72·7	70·2	77·3
3 „	66·3	60·4	65·3	68·8	66·2	73·3
4 „	61·1	55·7	60·5	63·6	61·3	68·4
5 „	54·4	49·7	55·0	57·4	55·2	62·1

CYCLONES.

	Winter.					Summer.
	N.	E.	S.	W.	Mean.	Mean.
Surface	°C. 79·9	°C. 77·5	°C. 79·8	°C. 78·8	°C. 77·0	°C. 88·7
1 km.	75·0	74·2	74·2	72·4	72·2	81·7
2 „	70·7	68·4	68·8	66·4	67·1	75·2
3 „	66·2	63·2	63·1	58·9	61·6	69·7
4 „	59·4	57·1	57·5	52·5	55·4	64·7
5 „	53·4	50·6	51·1	48·2	49·3	58·8

* Sitz. Wiener Akad., 1891.

† Arkiv. für Matematik, Sc, 1905.

These results indicate that on the average the cyclones are colder than the anticyclones both in winter and in summer, the principal difference of temperature being found in the W. quadrant, while in the E. quadrant in winter cyclones are actually warmer than anticyclones. This is due partly to the fact that the cyclones have their lowest mean temperature in this quadrant, and partly to the fact that, on the whole, anticyclones have their highest mean temperature in the same quadrant.

The N. quadrant of the cyclone is throughout very considerably warmer than the E. quadrant of the anticyclone, indicating that the direction of the gradient between these two regions would be reversed at moderate heights. For example, if the surface pressures were 750, 760 mm., the pressures over the two regions at 5 km. would be the same, 396 mm. nearly.

Berson deduced, from the manned-balloon ascents, the following values for the height of the 0° C. isotherm for different pressure distributions :—

	Front of Anticyclone.	Anticyclone.	Back of Anticyclone.	Front of Cyclone.	Back of Cyclone.
Height	2850	2800	1580	2390	1120

If "front" and "back" be taken to be the same as E. and W., the results agree with those of Grenander for cyclones, although the difference is considerably greater. But for anticyclones the difference between "front" and "back" is exactly the reverse of Grenander's results, and is much more accentuated. Grenander's results, however, refer to the winter, and the majority of the manned-balloon ascents were made in summer.

Hanzlik,* using chiefly mountain observations, has arrived at the interesting conclusion that, in layers up to 3 km. at least, anticyclones in Europe are of two kinds. Some are warmer and others colder than the normal.

A warm anticyclone is either the later development of an anticyclone previously cold, which has become stationary with rising pressure in the centre, or it arrives in the European area as a warm anticyclone with slow indefinite translatory motion in the centre.

The cold anticyclone, on the other hand, remains cold if it moves quickly; but if it remains stationary for some time, it gradually changes into a warm anticyclone.

Von Bezold deduced from the Berlin manned-balloon ascents that even up to 8 km. anticyclones were warmer than cyclones. The following Table gives the values of the gradient for the different layers :—

	Height in Kilometres.							
	0-1.	1-2.	2-3.	3-4.	4-5.	5-6.	6-7.	7-8.
Anticyclonic . . .	3·8	4·0	5·3	5·4	6·4	7·2	7·1	7·7
Cyclonic	6·1	5·5	5·7	5·3	6·5	6·7	6·4	6·2
Intermediate . . .	5·6	7·2	5·7	3·9	6·9	...	...	...

Thus the temperature falls by 4°·2 C. less in anticyclones than in cyclones in the first 5 km., after which the difference diminishes, but is still 2°·5 C. at 8 km.

The results from registering balloons have been taken for those cases in which the pressure, reduced to sea level, exceeded 770 mm. and for those in which it was less than 750 mm., in order to obtain quite distinct distributions.

* *Denkschrift, Wien.*, 1908.

Table XXXIII. gives the mean gradients for different layers up to 14 km. and the mean temperatures at the various heights.

TABLE XXXIII.

Height.	Gradients.				Temperatures.			Gradients for Ascending Saturated Air.	
	Pressure <750.	No. of Cases.	Pressure >770.	No. of Cases.	Pressure <750.	Pressure >770.		Pressure <750.	Pressure >770.
0	...	...	...	...	77.2	76.0	...	...	...
1	3.9	15	-0.45	51	73.3	76.5	0-1	5.7	5.9
2	5.5	15	2.6	51	67.8	73.9	1-2	6.3	5.7
3	5.6	15	4.45	51	62.2	69.4	2-3	6.6	5.9
4	6.4	15	5.65	51	55.8	63.8	3-4	7.3	6.2
5	6.45	15	6.4	51	49.3	57.3	4-5	7.8	6.8
6	6.45	15	6.8	51	42.9	50.6	5-6	8.4	7.4
7	7.25	15	7.2	51	35.6	43.5	6-7	8.9	7.9
8	6.35	15	7.8	51	29.3	35.7	7-8	9.3	8.5
9	4.3	15	7.4	50	25.0	28.3	8-9	9.5	9.1
10	2.7	15	6.5	48	22.3	21.7	9-10	9.6	9.7
11	1.4	14	5.6	46	20.9	16.1			
12	0.0	11	3.4	43	21.0	12.7			
13	0.0	9	1.0	35	21.0	11.7			
14	-0.2	8	-0.7	29	21.2	12.4			

If a correction is applied to the temperature owing to the irregular distribution of the ascents throughout the year and to the fact that four of the low-pressure cases are for Pavlovsk, which has a mean surface temperature about 5° C. below that of the other places, the surface temperatures for the low and high pressures become 81.8 and 78.4 respectively.

If we apply corrections to the gradient also, to allow for the unequal distribution and for the undue influence of Pavlovsk, we obtain, as corrected values for the gradients in the two cases, the values in Table XXXIV.

TABLE XXXIV.—CONNECTION BETWEEN TEMPERATURE AND PRESSURE AT MEAN SEA LEVEL, CORRECTED FOR ANNUAL VARIATION.

	General Results.						Dines' Results for England.					
	Gradients.		Temperatures.				Gradients.		Temperatures.			
	Pressure <750.	Pressure >770.	T ₁ .	T ₂ .	T ₃ .	T ₂ -T ₁ .	Pressure <750.	Pressure >770.	T ₁ '.	T ₂ '.	T ₃ '.	T ₂ '-T ₁ '.
0			81.8	78.4	80.1	-3.4			80	82	82	2
1	5.1	0.6	76.7	77.8	77.0	1.1	5	3	76	79	78	3
2	6.5	3.7	70.2	74.1	72.7	3.9	6	5	70	77	74	7
3	5.6	4.8	64.6	69.3	67.5	4.7	6	5	64	72	68.5	8
4	6.4	5.8	58.2	63.5	61.7	5.3	7	5	56	67	62.5	11
5	6.3	6.4	51.9	57.1	55.4	5.2	7	6	49	61	56	12
6	6.4	6.7	45.5	50.4	48.6	4.9	7	7	42	54	50	12
7	7.0	7.2	38.5	43.2	41.4	4.7	8	7	34	47	42.5	13
8	6.6	7.6	31.9	35.6	34.0	3.7	6	7	28	40	36	12
9	4.5	7.4	27.4	28.2	27.2	0.8	2	7	25	33	29	8
10	3.4	5.9	24.0	22.3	22.2	-1.7	1	7	24	26	23	2
11	1.7	4.8	22.3	17.5	19.0	-4.8	1	5	24	21	19	-3
12	0.1	2.8	22.2	17.5	18.7	-7.5	-1	4	24	17	18	-7
13	-1.2	1.0	23.4	13.7	19.7	-9.7	0	2	25	15	18	-10
14	0.3	-0.5	23.1	14.2	19.6	-8.9	1	0	23	15	19	-8

The column T_1 gives the corrected mean temperature for pressure < 750 , T_2 that for pressure > 770 , T_3 is the approximate mean temperature of the intermediate regions deduced from T_1 , T_2 , and the general mean T_m , on the assumption that the influence of T_1 , T_2 in forming the general mean is approximately proportional to the number of observations. The result is interesting as showing that anticyclonic regions are not only warmer than regions of low pressure, but also warmer, up to 10 km., than the intermediate regions, which appear to be colder at 9–10 km. than regions of high or low pressure.

We may compare these results with the values found by Dines* from 150 ascents in England, given in Table XXXIV. The differences appear to be twice as great as those over the continent.

If, in the centre of an anticyclone, b is the excess of pressure at any height above the normal pressure B for that height, and ρ is the density there, the value of the ratio $b/\rho d$ may be taken as a measure of the intensity of the anticyclone, where d is the mean distance of the isobar B from the centre of the anticyclone. Now, as long as the temperature near the centre of an anticyclone remains higher than that in surrounding regions, the value of $b/\rho d$ increases with increasing height, and consequently the anticyclone increases in intensity. If b_1 , d_1 are corresponding quantities for a cyclone, $b_1/\rho d_1$ increases with increasing height so long as the cyclone is colder than its surroundings. The values found above indicate that this is the case up to 8–10 km. Even at 14 km. the pressure over the anticyclonic region exceeds that over the cyclonic by more than 1 mm., which is as efficient in producing motion as a difference of 7 mm. at the surface. The difficulty that arises is to discover a means by which air can be brought into the anticyclone and out of the cyclone in the upper air, and to make these results accord with the results of cirrus observations, which imply a definite outward motion over cyclonic regions and an inward motion over anticyclonic. At the same time it must be remembered that the cirrus observations do not imply that the anticyclone becomes a cyclone at the cirrus level, or conversely; the direction of rotation is the same for the cirrus as at the surface, according to Hildebrandsson's results, and this can be the case only if the direction of the gradient of pressure remains the same.

The results imply that the motion has a component across the isobars from the *lower* to the *higher* pressure. The difficulty of explaining this result was felt by earlier writers. Hann† expressed the opinion that the outward motion in cyclones was due to the centrifugal force of the motion exceeding the gradient. Although it is difficult to see how the necessary wind would be produced to bring about this state of affairs, it is at least a possible condition. If cyclones decreased in intensity with increasing height, and the air rising from the lower levels retained its angular momentum, it would indeed furnish a reasonable explanation.

The case of anticyclones is more difficult, because the effect of centrifugal force is to assist the gradient of pressure in producing flow outwards.

Gold‡ showed that in anticyclones there is a limit to the gradient and velocity for the motion to be steady and along the isobars. The approximate radii of isobars at the earth's surface in lat. 50° , differing from the pressure at the centre by 1, 2, 3, 4, 5 mm., are 260, 370, 450, 520, 580 km. for this limiting case. If the gradients are less than

* *Phil. Trans. A.*, vol. ccci.

† *Barometric Gradient and Wind Velocity*, M.O. No. 190.

‡ *Lehrbuch*, p. 406.

these, there will be a steady motion with correspondingly small velocities. If the gradients are greater than these, the motion cannot under any circumstances be steady, and there will always be an outward component in the wind, because the centrifugal force, due to the increased velocity, will more than counterbalance the increase in the force arising from the earth's rotation. The only possible case where there can be flow from low to high pressure for anticyclonic motion is when air enters a region where the gradients are less than the limiting gradients, with a velocity also less than that corresponding to the limiting gradient, but greater than that corresponding to steady motion for the actual gradient in the region. In that case the effect of the earth's rotation would be to make the air flow inward towards the centre. It seems improbable, however, that such a state could persist for any time, because the results of observation show that the wind usually adjusts itself to the gradient, provided it is at a sufficient height above the earth's surface to be practically free from the effects of surface friction and irregularities.

It seems more probable either (1) that anticyclones and cyclones arriving in the European area are in general dissipating systems, which are replaced continuously by other systems arriving from what may be called productive regions; or (2) that there is interchange with regions in which the surface temperature or the temperature gradient is sufficiently different to produce mean temperatures greater in low-pressure areas and less in high-pressure areas than are found over Europe.

There is another way of regarding these results first pointed out by Shaw*; the results obtained indicate that the changes of pressure are as great in *absolute magnitude* at 9 km. as at the surface. Thus the *dynamical origin* of differences of pressure may be above 9 km., while the *physical and thermodynamical results* are exhibited in the strata below. At the same time it must be remembered that a difference of pressure originating at 9 km. would result in a difference three times as great at the earth's surface if there were no compensating thermal change in the intervening layers.

The results of observations of pilot balloons at Ditcham,† July 27–30, 1908, and at Munich,‡ during the same period, and September 30 to October 2, 1908, indicated that even to greater heights than 10 km. the wind had a component directed outwards from the region of high pressure, or was parallel to the general direction of the surface isobars and in the sense of the gradient wind at the surface. On January 3, 1908, on the other hand, the direction of the wind over Munich changed after 3–4 km., and the flow above this height up to 8 km. was directed inward towards the region of the surface high pressure. The English ascents indicate that the relative coldness of cyclones extends to a higher altitude there than over the Continent, and this tends to support the idea that the energy of the cyclonic motion, which is greater there, is gradually converted into the potential energy of the anticyclone. Finality can be reached only by an examination of individual cases in which the observations are extensive enough to furnish a good representation of the distribution of pressure and wind at great heights.

The results so far obtained show the need that exists for a series of ascents in the middle of the great Atlantic low-pressure system simultaneously with ascents in Europe and America. The general drift of registering balloons is from high to low pressures, although there are exceptions, which are possibly due to the balloon entering at high

* *Nature*, Nov. 1911.

‡ *Registrierballonfahrten*.

† *Quart. Journ. Roy. Met. Soc.*, 1908.

altitudes a westerly current, which is caused by the general temperature and pressure distribution over the earth, and may at times remain unaffected by shallow disturbances near the surface. The greater relative humidity over cyclones would tend to diminish the intensity in the upper air, but it is quite insufficient to bring about a reversal of gradient between high- and low-pressure areas.

For the surface layers, Gold * showed (1) that near the centre of cyclones the gradient of temperature up to 2 km. coincided very nearly with the adiabatic gradient for saturated air; (2) that in winter the gradient in the central region of anticyclones up to 3 km. was quite irregular, temperature increasing and decreasing in different layers in different ascents, but, on the whole, varying little from the surface value; (3) that in summer the gradient in the central regions of anticyclones was regular in the first kilometre and nearly equal to the adiabatic gradient for dry air, but that above this level the fall of temperature was frequently arrested, showing that the vertical circulation was purely a surface phenomenon, and was not connected in any way with a general descending current of air. This shows that the air up to a height of 3 km. in anticyclones is practically an inert mass, taking little part in the general circulation.

The result may be compared with the deduction arrived at by Shaw and Lempfert † from a consideration of the air currents at the surface. They say, "We have failed to identify the central areas of well-marked anticyclones as regions of origin of surface air currents. . . . These latter are for the most part inert and comparatively isolated masses of air, taking little part in the circulation which goes on around them." . . . "The areas of descending air seem to be (a) the shoulders or protuberances of anticyclones, in particular the regions of comparatively high pressure between two consecutive cyclonic depressions, and therefore also between two anticyclones; or (b) the extension of an anticyclone between a depression and its secondary." If there is descending air in the upper atmosphere over an anticyclone (as indeed there must be if it maintains or increases its intensity), this air will not be considerably affected by radiation between 5 and 10 km., and the temperature gradient will remain nearly adiabatic, and will therefore allow a constant flow downwards. But when the air enters the region between the surface and 5 km. it will begin to be cooled by radiation, and the cooling will increase with approach to the surface, although in the surface layers themselves convection may reverse the process. Such cooling would be an effective bar to further direct downward convection, and would allow only a gradual oblique convection by which the descending air would be transferred to the earth's surface, being cooled sufficiently by radiation in its progress to enable the convection to take place.

II. (a).—THE CONNECTION BETWEEN THE DIRECTION OF FLIGHT OF BALLOONS REACHING THE STRATOSPHERE AND THE DIRECTION OF THE "GRADIENT" WIND.

It is a matter of some interest to know what relation, if any, exists between the direction of the general gradient wind and the direction of the place of fall of the balloon measured from the place of ascent. The results of 354 ascents from 1906–1910, in all of which the stratosphere was reached, were grouped (as described above, pp. 120, 121) according to the four directions of the general gradient wind and the indeterminate

* *Barometric Gradient and Wind Force*, M.O. 190.

† *Life-History of Surface Air Currents*, M.O. 174, p. 24.

cases X for the two seasons November to April and May to October. The results from England were excluded on the ground that the balloons travelling in certain directions are almost certain not to be recovered, and the values would in consequence be biased inasmuch as it is only the balloons recovered which contribute results.

The Table shows the number of cases for the different directions for the two seasons.

	North.	East.	South.	West.	X.
I. November to April . .	8	17	41	55	30
II. May to October . .	40	23	29	34	77
Year	48	40	70	89	107

The balloons fell in the different quadrants, as shown in Table XXXV. The results are plotted in the diagrams, figs. 18, 19, in which the length of each line represents the percentage of balloons falling in the corresponding quadrant, and the direction of the line shows the mean direction for that quadrant. A direction due North is reckoned in the first quadrant, and so on.

TABLE XXXV.

I. NOVEMBER TO APRIL.

DIRECTION OF PLACE OF FALL OF BALLOONS FOR DIFFERENT DIRECTIONS
OF THE GRADIENT WIND.

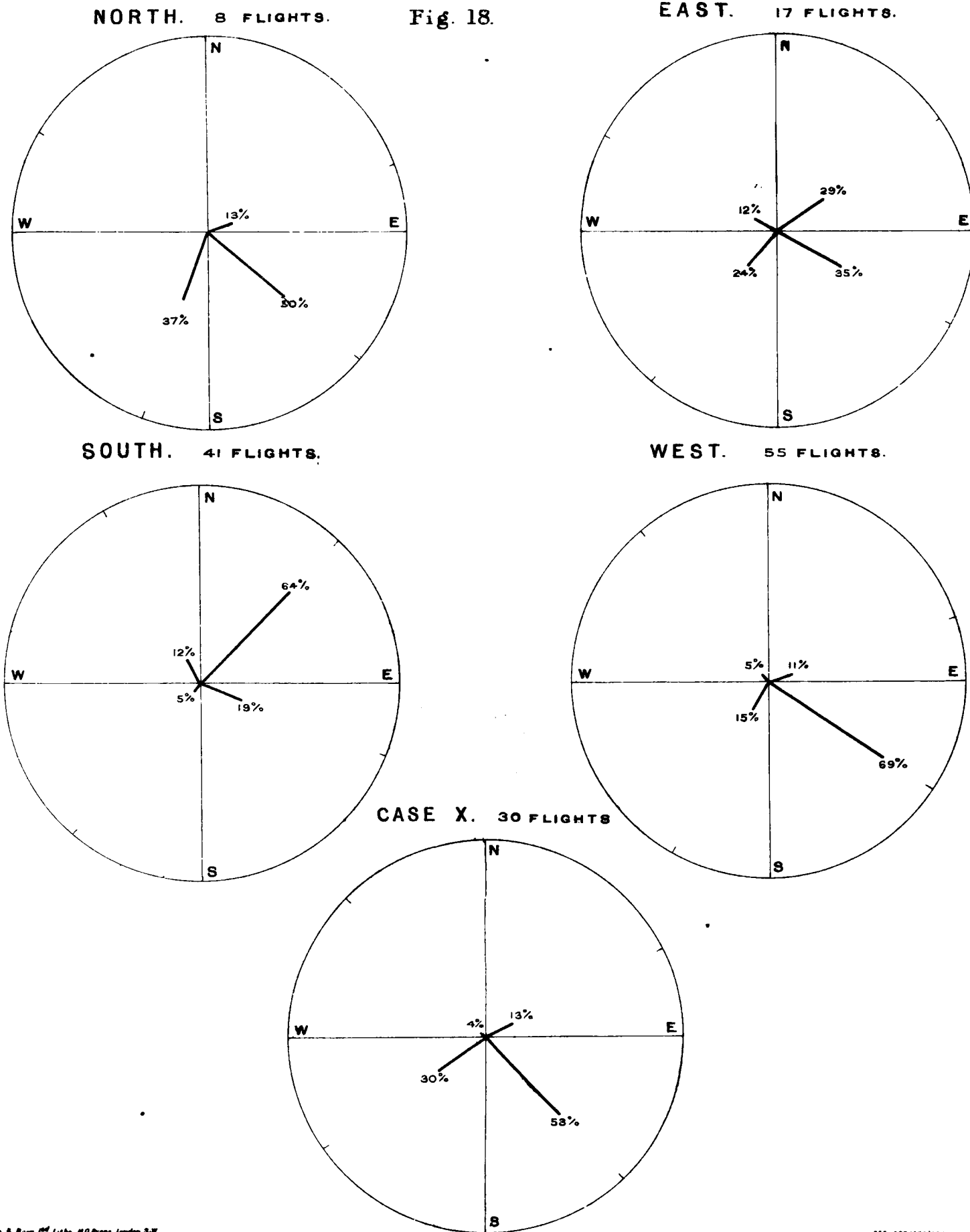
	North.	East.	South.	West.	X.	Totals.
Quadrants 1. N.E.	1	5	26	6	4	42
" 2. S.E.	4	6	8	38	16	72
" 3. S.W.	3	4	2	8	9	26
" 4. N.W.	0	2	5	3	1	11
II. MAY TO OCTOBER.						
Quadrants 1. N.E.	6	2	19	8	26	61
" 2. S.E.	20	2	5	23	29	79
" 3. S.W.	12	16	3	3	19	53
" 4. N.W.	2	3	2	0	3	10
III. YEAR.						
Quadrants 1. N.E.	7	7	45	14	30	103
" 2. S.E.	24	8	13	61	45	151
" 3. S.W.	15	20	5	11	28	79
" 4. N.W.	2	5	7	3	4	21
" 1 and 4	9	12	62	7	34	124
" 2 and 3	39	28	18	72	73	230
" 1 and 2	31	15	58	75	75	254
" 3 and 4	17	25	12	14	32	110

Of the 89 cases "West," 63 fell between N.E. and S.E.; of the 48 cases "North," 24, or exactly half, fell between S.E. and S.W.; of the 40 cases "East," 16 fell between N.W. and S.W. (12 in Period II., 4 in Period I.); and of the 70 cases "South," 29 fell between N.E. and N.W.

Perhaps the most interesting feature is the fact that with a general gradient for East winds, the majority of the balloons fell east of the starting-point in winter; while in summer only 4 out of 23 fell to the E., indicating that an Easterly current in winter

DIRECTION OF PLACE OF FALL OF BALLOON FOR DIFFERENT DIRECTIONS OF GENERAL GRADIENT WIND - NOVEMBER TO APRIL.

Fig. 18.

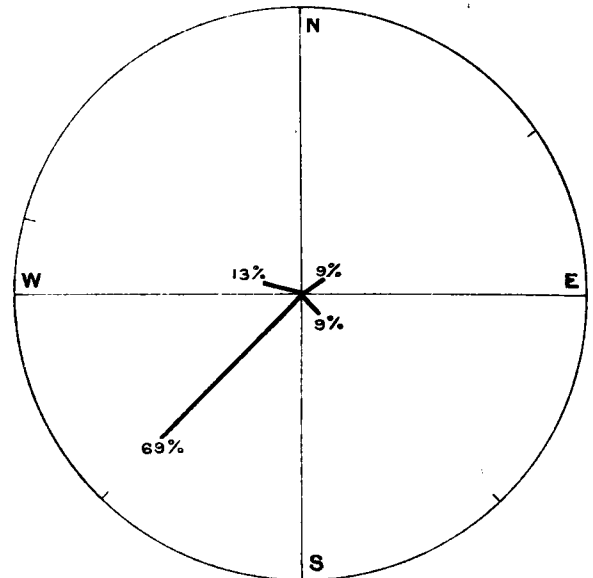
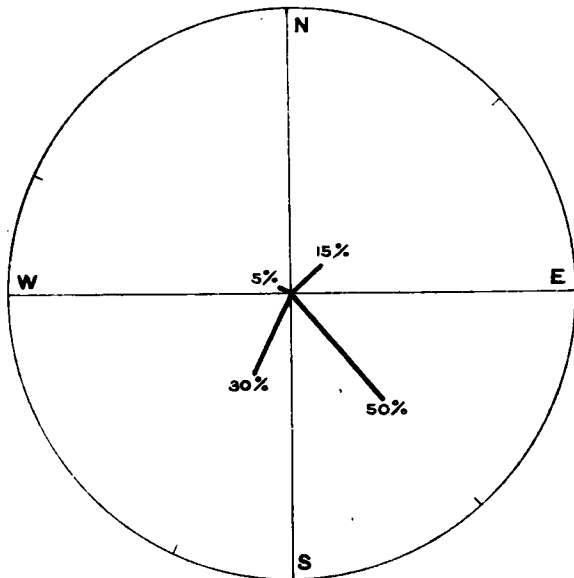


DIRECTION OF PLACE OF FALL OF BALLOON FOR DIFFERENT
DIRECTIONS OF GENERAL GRADIENT WIND - MAY TO OCTOBER.

NORTH. 40 FLIGHTS.

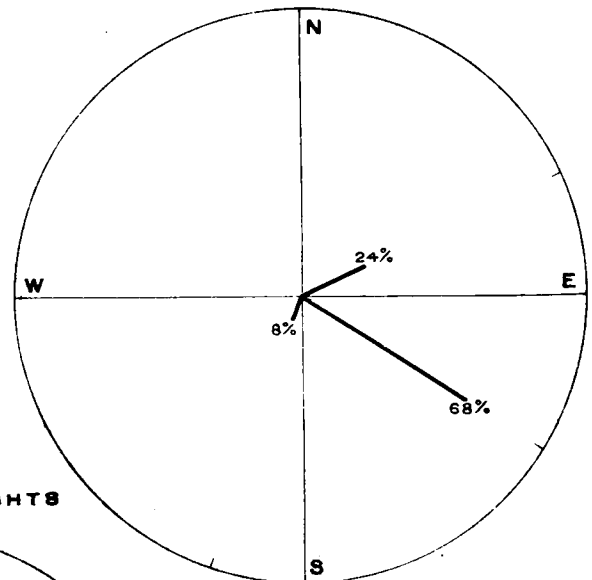
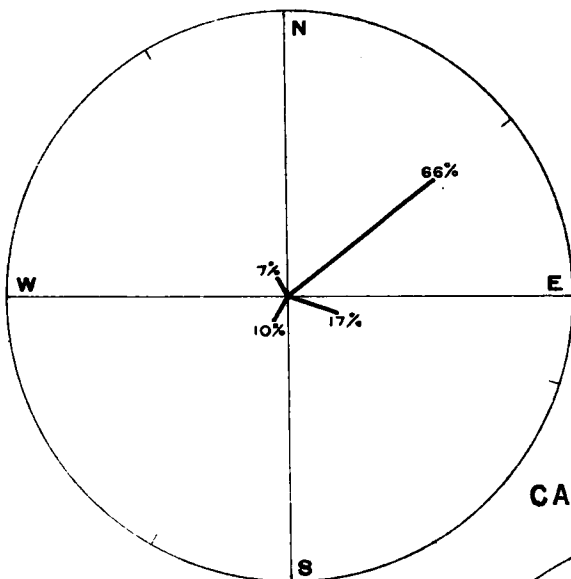
Fig. 19.

EAST. 23 FLIGHTS.

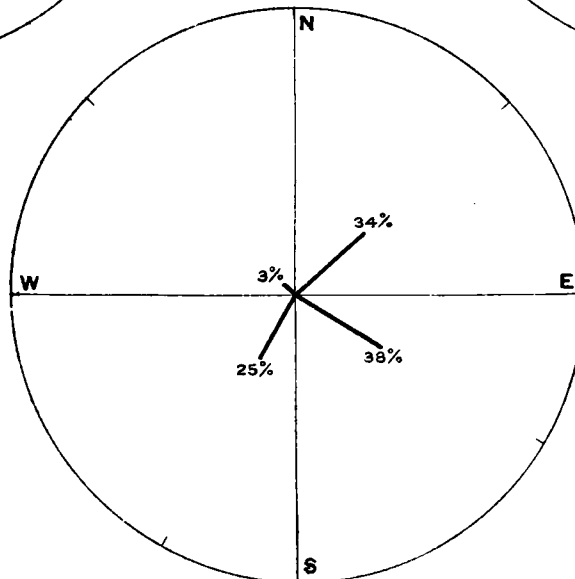


SOUTH. 29 FLIGHTS.

WEST. 34 FLIGHTS.



CASE X. 77 FLIGHTS



is a surface phenomenon, and the gradient of temperature from South to North rapidly reverses the direction of the pressure gradient, so that Westerly winds prevail through the greater part of the flight of the balloons. In summer this is no longer the case.

For all the cases except "South," the majority of the balloons are found to the South of the place of ascent, and for all the cases except "East" in summer, the majority of the balloons fall to the East, indicating that the drift of the air over Europe tends to be from N.W. to S.E. This is probably due in part to the effect of temperature on the isobaric distribution at higher levels. In the winter months the general gradient over Europe at 4 km. is for W.N.W. winds, although at sea level it is for W.S.W.

The result is important in connection with the international ascents at places which lie within reach of the sea or of mountainous regions. *It becomes possible to give the probable direction in which the balloon will fall by means of an isobaric map for the morning of the ascent.*

II. (b).—WIND.

One of the earliest attempts to discover the way in which the velocity of the wind changed with altitude in the free atmosphere by the use of recording instruments appears to have been made by Archibald, whose results were communicated to the British Association at Montreal in 1884. He concluded that the velocities V , v at heights H and h above the surface were connected by the equation

$$V/v = (H/h)^x$$

where x diminished with height, but tended to a value nearly equal to $\frac{1}{4}$.

Berson* found the following values for the ratio of the mean velocity in layers 500 m. thick to the mean wind for the day at Potsdam. The latter was 5.5 m.p.s.

Layer.	0-0.5.	0.5-1.0.	1.0-1.5.	1.5-2.0.	2.0-2.5.	2.5-3.0.	3-4.	4-5.	Above 5 km.
Ratio .	1.77	1.82	1.85	1.95	2.08	2.16	2.45	3.05	4.46
Ratio 2 .	...	1.00	1.02	1.07	1.14	1.19	1.35	1.68	2.45
No. of cases	54	54	55	49	41	38	36	19	10

The ratio (2) is formed with the velocity in the layer 0.5-1.0 as standard. The results show a very slow increase up to 2-3 km., after which the change takes place more rapidly. It appears probable that the values up to 3 km. are those appropriate to the pressure distribution at the surface, and indicate that the ratio of the gradient of pressure to the density remains nearly constant up to that height. The larger values in the upper layers show that the intensity increases with height, which is in accordance with the observations of temperature, since these show that the places with higher pressure have also higher temperature in the upper air.

Gold† showed from a consideration of kite observations that the major part of the increase in the first 2000 m. took place in the layers immediately above the surface. For Berlin, 75 per cent. of the total increase occurred in the first 160 m.

He found, too, that the velocity increased up to 500 m. almost without exception, but that at greater heights numerous cases occurred where the velocity decreased as the height increased. Thus at Oxshott, between 500 m. and 1000 m. the velocity

* *Wissenschaftliche Luftfahrten*, iii.

† *Barometric Gradient and Wind Force*, M.O. 190.

decreased in eight cases, remained constant in seventeen cases, and increased in twenty-three cases out of a total of forty-eight; while at Blue Hill the corresponding numbers were seven, four, and ten out of a total of twenty-one. The change depends on the direction of the wind. Both at Oxshott and Berlin the velocity almost invariably decreased between 1.5 and 2 km. in the case of S.E. winds, while S.W. winds showed the greatest increase near the surface. It was also found that the kite observations over Berlin furnished conclusive evidence that the wind at 1000 m. altitude agreed both in magnitude and direction with the theoretical velocity deduced from the condition for steady horizontal motion along the isobars, viz. :—

$$\frac{(\omega r \sin \lambda \pm v)^2}{r} = \frac{1}{\rho} \frac{\delta p}{\delta r} + \frac{(\omega r \sin \lambda)^2}{r}$$

where p is pressure, ρ density, v velocity of the air, λ is latitude, ω the angular velocity of the earth about its axis, and r the radius of curvature of the path of the moving air.

Egnell* deduced from the observations of clouds that the velocity increases with the height, so that it remains nearly inversely proportional to the density, i.e. the velocity V is given by $V = V_0 \rho_0 / \rho$, where ρ is density, and V_0, ρ_0 are the values of V and ρ near the surface.

The law appears to agree moderately with the observations from pilot balloons. The following Table gives the values of $V\rho$ in arbitrary units (metres per sec. \times pressure in metres $\times T_0/T$) deduced from ten sets of observations at Munich,† of which seven reached 12 km. :—

Height	.	.	.	1	3	5.5	8	10.5	12 km.
$V\rho$	.	.	.	50	48	45	53	45	37

Observations made by Cave‡ in July 1908 furnish in the same units at the same heights the following values :—

$V\rho$	.	.	.	.	34	55	59	65	50	43
$V\rho$ (May 1909)§	.	.	.	.	85	54	36	36	33	19

The second row gives values for seven ascents in May 1909. Observations at Strassburg in 1908, 1909 give the following values :—

$V\rho$	.	.	.	.	.	42	37	42	41	41	25
No. of cases	.	.	.	.	.	11	11	11	11	11	11
$V\rho$	.	.	.	.	.	45	35	41	39	39	25
No. of cases	.	.	.	.	.	18	18	18	18	16	11

The first row gives results from eleven ascents which reached 12 km. The second includes seven additional ascents which reached 8 km. or more. Both sets show a reduction in $V\rho$ at 3 km., which may be due to the fact that the greater number of the ascents are in summer, when convection tends to diminish the vertical increase of velocity.

The law implies that the mean gradients of pressure have the same value in the upper air as near the surface, and this can be the case only if the mean temperature over high pressure is greater than it is over the low pressure, i.e. if the horizontal gradients of pressure and temperature are in the same sense. It was seen from the

* *Comptes rendus*, 1903. *International Cloud Observations*, 1896-7. *Trappes*.

† *Registrierballonfahrten*, 1907-1908.

‡ *Quart. Journ. Roy. Met. Soc.*, 1908.

§ *Weekly Weather Report*, 1909.

results for temperature that this was the case. It remains to be seen if the observed difference of temperature is sufficient to make the gradient of pressure constant.

If p and $p + \delta p$ are the pressures at two places at the surface, then the corresponding pressures at a height z are pe^{-u} , $(p + \delta p)e^{-(u+\delta u)}$, where $u = \int \frac{g}{kT} dz = \int \frac{T_0}{HT} dz$, T being temperature, and H the height of the homogeneous atmosphere, 8 km. nearly.

If the difference of pressure is the same as at the surface

$$e^{-u}\delta p - pe^{-u}\delta u = \delta p, \text{ i.e. } \delta p = -pe^{-u}(1 - e^{-u})^{-1}\delta u.$$

But

$$\delta u = - \int \frac{T_0 dz \delta T}{HT^2} = -t_0 \int \frac{T_0 dz}{HT^2}$$

where t_0 is approximately the mean value of δT .

Put $T = T_0(1 - \alpha z)$ and $\alpha H = \frac{1}{8}$ corresponding with a constant vertical fall of temperature at a rate of $5^\circ.7$ C. per km.

$$\begin{aligned} \text{Then } u &= -(\alpha H)^{-1} \log(1 - \alpha z) \\ \delta u &= -t_0(\alpha H)^{-1}(1 - \alpha z)^{-1} \\ e^{-u} &= (1 - \alpha z)^8. \end{aligned}$$

The condition cannot be satisfied exactly at all heights with such a distribution, but if t_0 be determined so that it is satisfied at a height H , say, it will be approximately true for intermediate heights, and the value of t_0 will indicate if the condition is likely to be satisfied, regard being paid to the results of observations.

If $z = H$, $\alpha H = \frac{1}{8}$, $T_0 = 273$, the condition $\delta p = pe^u(1 - e^{-u})^{-1}\delta u$ becomes

$$t_0 = \frac{74\delta p}{p}.$$

Thus if $\delta p = 20$ mm., $t_0 = 2^\circ$ C. nearly.

Now the actual mean difference in temperature up to 8 km. between regions where pressure >770 mm. and regions where it <750 is approximately 4° C., or practically double the amount necessary to make $V\rho$ constant. The value of $V\rho$ ought, therefore, to be greater at 8 km. than near the surface. The results indicate that this is the case; and they show, further, that $V\rho$ diminishes at greater heights. But this is entirely in accordance with the results for temperature, which showed that δT , and therefore also t_0 and δp , diminished above a height of 8 km. Of course, as long as δT remains positive, $\delta p/\rho$ will increase, and therefore V will increase. But the results for temperature show that δT is positive up to 10 km., after which it becomes negative. The observations of temperature and wind are therefore in general agreement, indicating an increase in $V\rho$ up to 8 km. and an increase in V up to 10 km., with a rapid decrease of both at greater heights.

The direction of the upper wind usually veers from that at the surface, i.e. if the wind is W . at the surface, the upper wind comes from some point N . of W . This is partly due to the fact that surface friction opposing the motion makes the steady state one in which the direction of the wind is between that of the gradient and the isobars. The smaller the friction, the closer does the direction for the steady state approach that of the isobars.

The following values for the rotation of the upper wind from that at the surface are deduced from Berson's results:—

Height	.	.	0·5	1	1·5	2	2·5	3	4	5 km.
Rotation	.	.	8°	15°	21°	28°	35°	39°	40°	43°
No. of cases	.	.	58	58	58	51	43	39	35	22

In comparing these results with those obtained from kites, it is to be remembered that a balloon does not rise vertically, but is carried along by the moving air and partakes of any natural curvature of path this may have in its horizontal progress.

Similar results found by White, Pring, and Petavel* show a smaller increase between 1 and 1·5 km., after which the increase is rapid.

Height	.	.	0·5	1	1·5	2	2·5 km.
Rotation	.	.	11°	18°	20°	30°	40°

The authors do not state if these results are the mean values of the rotation irrespective of sign or not.

The following values have been found for the deviation up to 3 km. from the observations made in England in 1906-7-8.† The values are the means of the individual cases, rotation in a clockwise direction (veering) being counted +. The values are arranged according to the direction of the surface wind, S.W. winds being counted W. and so on. Only those observations are used in which the wind at 1000 m. was not less than 5 m/s. **The values of R are the angles made by the upper wind with the surface wind.‡**

DEVIATION OF THE UPPER WIND IN ENGLAND.

(R = Rotation in degrees, N = Number of cases.)

Heights.		0·5 km.	1·0 km.	1·5 km.	2·0 km.	2·5 km.	3·0 km.
WINTER (October-March).							
W.	{ R.	15°	22°	22°	19°	18°	17°
	{ N.	76	76	41	14	5	4
N.	{ R.	6°·5	13°·5	12°	10°	-5°	0°
	{ N.	37	37	22	10	4	2
E.	{ R.	18°	25°	17°	19°	22°	27°
	{ N.	37	37	18	10	7	5
S.	{ R.	16°	26°	32°	36°	37°	45°
	{ N.	61	61	41	23	13	11
SUMMER (April-September).							
W.	{ R.	5°·5	9°·5	11°	13°	6°·5	7°
	{ N.	133	133	93	55	26	19
N.	{ R.	2°	3°	-4°	-6°	-2°	-19°
	{ N.	48	48	29	20	12	9
E.	{ R.	12°	19°	21°	33°	41°	18°
	{ N.	39	39	31	20	14	11
S.	{ R.	12°	26°	32°	41°	45°	55°
	{ N.	67	67	41	19	11	10
YEAR (Numbers = Sums of Winter and Summer).							
W.	.	9°	14°	14°·5	14°	8°	8°
N.	.	4°	8°	3°	-1°	-3°	-15°
E.	.	15°	22°	20°	28°	35°	21°
S.	.	14°	26°	32°	38°	41°	50°
Mean of all cases	.	10°	17°	18°	20°	21°	20°
Mean of yearly means	.	10°·5	17°·5	17°·4	19°·8	20°·3	16°
Total N.	.	300	298	269	202	142	102

* *Quart. Journ. Roy. Met. Soc.*, 1908.

† *Weekly Weather Report.*

‡ See also Köppen's *Three Years' Simultaneous Kite Ascents near Berlin, Hamburg, St Petersburg.*

Similar results from Berlin (Lindenberg) for 1906 are as follows* :—

Heights.		0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.
WINTER.							
W.	{ R. . . .	25°	31°	31°	31°	33°	31°
	{ N. . . .	76	75	59	39	26	18
N.	{ R. . . .	17°	20°	23°	22°	13°	29°
	{ N. . . .	18	18	15	12	8	5
E.	{ R. . . .	36°	39°	45°	48°	53°	53°
	{ N. . . .	27	27	26	20	15	12
S.	{ R. . . .	43°	50°	53°	55°	57°	50°
	{ N. . . .	55	55	53	42	33	23
SUMMER.							
W.	{ R. . . .	10°	13°	15°	10°	15°	14°
	{ N. . . .	64	63	62	44	41	25
N.	{ R. . . .	10°	15°	18°	18°	17°	23°
	{ N. . . .	24	24	22	18	14	9
E.	{ R. . . .	17°	18°	28°	41°	34°	7°
	{ N. . . .	22	22	19	15	7	3
S.	{ R. . . .	18°	28°	27°	27°	37°	34°
	{ N. . . .	14	14	13	12	8	7
YEAR (Numbers = Sums of Winter and Summer).							
W.	. . . .	18°	23°	23°	20°	23°	22°
N.	. . . .	13°	17°	20°	20°	15°	25°
E.	. . . .	27°	30°	38°	45°	46°	44°
S.	. . . .	38°	46°	48°	49°	53°	46°
Mean of all cases	.	23°	29°	31°	32°	34°	33°
Mean of yearly means.	.	24°	29°	32°	34°	34°	34°
Total N.	.	498	498	316	171	92	71

These results show how much the rotation depends on the wind direction and on the situation. At both places, S. winds show a greater rotation and a more regular increase than winds from other directions. This is probably due, in part at least, to the fact that the general drift of the upper air is from W. to E. The rotations for Berlin are in nearly all cases greater than in England, but S. winds in summer form an exception. The difference in the upper layers is greatest in the case of N. winds, which back slightly in the upper air in England, both in winter and in summer.

The rotation is larger in winter than in summer, indicating that in the latter season convection is more vigorous in equalizing the wind in the lower layers. The departures of the wind at higher levels from the direction at 500 m. show that this must be the case, since these departures tend to be slightly larger in summer than in winter. S. winds again form an exception, and have total rotations slightly larger in summer than in winter in England.

The same observations were used to obtain the increase of the velocity with height.

The following Table gives in metres per second the mean observed surface wind and the mean excess of the observed wind at each height above the surface wind at the time of observation. The number of observations in England is slightly less than before, because in some cases the direction only was observed at ground level.†

* *Ergebnisse der Arbeiten des Aëron. Obs.* The observations after April, 1905, were made at Lindenberg.

† The absolute values of the velocities are not inter-comparable, because ascents are not made in strong winds in England, and the anemometers are of different types and have not been compared.

INCREASE IN WIND VELOCITY (metres per second).

(B = Berlin, E = England. N = Number of Observations for England.

 V_s = Velocity at the Surface).

Height.		Surface.	0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.
		V_s	Values of $V - V_s$.					
WINTER.								
W.	{ B.	7.5	7.8	8.0	8.0	8.7	9.6	10.5
	{ E.	5.9	7.2	9.6	10.5	10.8	...	...
	{ N.	59	59	59	32	7	...	...
N.	{ B.	5.8	3.8	4.1	5.2	5.7	6.8	7.2
	{ E.	5.5	5.3	5.8	7.5	7.2	11.8	14.4
	{ N.	30	30	30	16	6	2	2
E.	{ B.	5.6	5.4	5.7	5.4	5.8	5.3	5.5
	{ E.	6.3	6.3	7.2	6.6	6.9	4.2	2.8
	{ N.	37	37	37	18	10	7	5
S.	{ B.	5.9	7.5	7.2	7.7	7.7	9.4	10.0
	{ E.	4.9	6.4	7.8	8.2	7.1	5.8	7.0
	{ N.	50	50	50	29	15	9	7
SUMMER.								
W.	{ B.	6.2	4.5	6.1	6.3	6.6	7.6	8.2
	{ E.	5.9	5.3	6.9	8.3	8.5	9.1	8.7
	{ N.	107	107	107	67	38	26	11
N.	{ B.	4.9	2.9	3.9	4.3	3.8	3.9	5.9
	{ E.	5.8	4.1	5.3	5.1	4.5	4.8	8.4
	{ N.	39	39	39	21	14	7	4
E.	{ B.	5.2	2.5	3.4	3.6	3.9	4.4	9.3
	{ E.	5.4	3.5	4.4	4.3	5.1	5.6	6.2
	{ N.	33	33	33	25	18	14	11
S.	{ B.	5.6	3.3	3.5	5.5	4.2	5.6	5.0
	{ E.	4.1	5.0	8.3	9.8	7.9	7.8	7.3
	{ N.	61	61	61	37	16	8	7
YEAR.								
W.	{ B.	6.9	6.3	7.1	7.1	7.5	8.5	9.2
	{ E.	5.9	6.0	7.8	9.1	8.8	9.1	8.7
N.	{ B.	5.3	3.3	4.0	4.6	4.5	5.0	6.4
	{ E.	5.7	4.6	5.6	6.1	5.3	6.4	10.4
E.	{ B.	5.4	4.1	4.7	4.6	5.0	5.0	6.3
	{ E.	5.9	5.0	5.9	5.3	5.7	5.2	5.1
S.	{ B.	5.9	6.7	6.4	7.3	7.0	8.7	9.0
	{ E.	4.4	5.6	8.1	9.1	7.5	6.7	7.1
Mean of means { B.		5.9	5.1	5.6	5.9	6.0	6.8	7.7
{ E.		5.5	5.3	6.9	7.4	6.8	6.9	7.8
Means for all winds irrespective of magnitude for Berlin, 1905-6-7.		4.9	4.3	4.6	4.3	4.8	5.6	6.4

The velocity therefore increases with height, but there is little change between 1 and 2 km. The smallest increase is in N. and E. winds, but in summer the increase in E. winds is progressive throughout. The increase in the first 500 m. is always less

in summer than in winter, corroborating the results found from the rotation with regard to the effect of convection. The following Table gives the results for Berlin deduced from those cases only in which a height of 3 km. was reached, and the wind at 1 km. was 5 m/s and upwards:—

DEVIATION IN DEGREES AND INCREASE IN VELOCITY IN METRES PER SECOND
OF THE WIND OVER BERLIN.

Height.	Surface.	0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.
W. { R. . . .	V_s	16°	20°	21°	19°	20°	22°
44 cases. { $V - V_s$. . .	5.9	5.3	6.9	6.7	7.0	8.2	8.9
N. { R. . . .	...	18°	23°	25°	24°	25°	25°
14 cases. { $V - V_s$. . .	5.6	4.3	4.8	5.3	5.5	5.9	6.8
E. { R. . . .	...	26°	27°	34°	37°	39°	44°
16 cases. { $V - V_s$. . .	5.3	5.4	5.3	5.6	6.1	6.3	6.3
S. { R. . . .	...	35°	45°	44°	45°	46°	46°
30 cases. { $V - V_s$. . .	5.7	6.4	5.3	6.0	6.9	8.2	9.0
Mean of all { R. . . .	...	24°	29°	30°	30°	31°	33°
104 cases. { $V - V_s$. . .	5.7	5.5	5.9	6.1	6.6	7.6	8.3

Thus, except for E. winds there is no change in the rotation between 1 and 2 km., and for W. winds there is no change in the velocity in the same layer.

The following Table gives the frequency of different rotations for a height of 500 m. at Berlin (Lindenberg):—

Deviation in Degrees.	-45°.	-34°.	-23°.	-11°.	0.	11°.	23°.	34°.	45°.	56°.	68°.	79°.	90°.	101°.	Total.
W.	...	...	5	4	35	24	37	10	16	5	2	...	1	...	139
N.	...	...	2	3	15	7	8	...	5	...	2	...	...	...	42
E.	1	...	...	1	11	3	13	4	9	1	2	2	2	...	49
S.	1	...	5	1	4	...	13	8	21	3	6	2	5	1	70

The irregularities probably arise through the tendency of the observers to estimate in even "points" when the direction is nearly half-way between two points. The most frequent deviation for E. and W. winds is then 1 point (11°), for N. winds nothing, and for S. winds 3 points (34°). In addition to showing the smallest deviation, N. winds show greater regularity than the others, while E. and S. winds show the least.

Berson's results lead to the following values for the total rotation in cyclones and anticyclones:—

Height.	0.5 km.	1.0 km.	1.5 km.	2.0 km.	2.5 km.	3.0 km.	4.0 km.	5.0 km.
Cyclones . . .	4°	0°	-2°	-2°	2°	3°	-4°	-7°
Anticyclones . .	10	27	33	43	50	57	58	63

The horizontal motion of the balloon would tend to increase the rotation in anticyclones and to diminish it in cyclones, and this probably accounts for the large difference found. Berson concluded that only part of the difference could be accounted for in this way, and that there was a considerable difference after correcting for this

effect. The results of kite observations do not agree with this conclusion. The mean rotations, deduced from the Berlin observations in 1905, are as follows :—

Height.	1 km.	2 km.	Number of Cases.	
			1 km.	2 km.
Anticyclonic	25°	33°	54	26
Cyclonic	27°	37°	110	52

or including only those cases which reached 2 km. :—

Anticyclonic	30°, 33°
Cyclonic	30°, 37°.

These values agree very nearly with the general mean values found above, *i.e.* 29°, 32°. Two cases, in which the wind was very weak and completely changed its direction, have been excluded. It may be said, therefore, that the mean rotation of the wind in the first 2 km. is practically independent of the direction of curvature of the isobars.

The increase in velocity, expressed in terms of the ratio of the observed wind, under different pressure conditions, is, according to Berson, as follows in different layers (A = anticyclonic, C = cyclonic) :—

Height.	-0.5 km.	-1.0 km.	-1.5 km.	-2.0 km.	-2.5 km.	-3.0 km.	-4.0 km.	-5.0 km.	>5.0 km.
Ratio A. . {	1.61 ...	1.67 ...	1.66 1.00	1.86 1.11	1.96 1.17	2.03 1.22	2.40 1.44	3.15 1.89	4.07 2.44
Ratio C. . {	1.96 ...	2.00 ...	2.09 1.05	2.17 1.09	2.45 1.23	2.49 1.25	2.66 1.33	3.57 1.79	5.03 2.52

Thus at all heights the ratio is greater in C. than in A. The second rows have been introduced to show that the ratio to the wind in the layer 0.5–1.0 km. is practically the same for the two cases, so that the difference arises in the surface layer.

The kite observations for 1905 lead to the following results for the velocity in m/s in the two cases :—

	Velocity.			Ratio.	
	Surface.	1 km.	2 km.	1 km.	2 km.
A. { (1)	3.6	7.1	8.4	1.97	...
(2)	4.1	8.2	8.4	2.00	2.05
C. { (1)	5.6	10.7	10.7	1.91	...
(2)	5.9	10.5	10.7	1.78	1.82

The rows (1) include all observations ; (2) those only in which the ascent reached 2 km. The surface wind is the mean of the values at the time of observation. The ratio is less in C. than in A., but the method of obtaining the surface value is different from that used by Berson, so that it is not quite certain that the results are contradictory. The results seem to imply that the difference is largely accidental and that the real difference is small. It would, of course, be natural to suppose that the surface friction and irregularities would produce a diminution in velocity which increased at a greater rate than the velocity itself, and this would accord with Berson's results.