From the right spherical triangle *PBE*, figs. 2 and 3, we have—

$$(1) \quad \text{Cos } \delta = \cos \alpha \cos \beta.$$
$$(2) \quad \text{Cot } H.\ A. = \cot \alpha \sin \beta.$$

Let α and β be two variables in Cartesian rectangular coordinates. Assign δ a constant value and let α and β vary; then from the first of these equations a certain definite curve will be traced as shown in the diagram (see fig. 4), and by assigning arbitrary values to δ, from 0° up to 90°, a family of declination curves will be obtained. In the same manner there will result a family of hour angle curves (see fig. 5) by assigning arbitrary values to the hour angle *H. A.*, and then letting α and β vary. By constructing the two series of curves on the same set of coordinate axes these results follow.

Thus the plane area is divided into a series of curve line quadrilaterals which may be made as small as we please by tracing the curves at sufficiently small intervals.

If one value of δ and one of *H. A.* be given, then by means of these curves the position of a point is fixed in the plane. The rectangular coordinates of this point are the values of α and β corresponding to these values of δ and *H. A.* Conversely, if we know the values of α and β, we are enabled to plot the position in the plane, and we can read off δ and *H.A.* by means of the curves.

By means of this abacus, the azimuth and altitude of a star may be determined when its declination and hour angle and the estimated colatitude are given. Plot the position of the star by means of δ and *H. A.* curves, estimating the minutes by the eye, and read the rectangular coordinates of the point thus plotted, α on the vertical scale and β on the horizontal scale. The *H. A.* curves here represent meridians and the δ curves represent parallels of the celestial sphere. Now make $B = \lambda + \beta$, considering β negative if the latitude and declination are of contrary name. Plot the point which has α and B for rectangular coordinates, and, considering now the *H. A.* curves to represent verticals, and the δ curves to represent circles of equal latitude, read off the azimuth by means of the *H. A.* curves, and the altitude due to the estimated latitude by means of the δ curves.

This abacus will also serve to find:

(1) The time of rising and setting of a star and its azimuth in the horizon.

(2) The name of an observed star.

(3) The distance and great circle course between two points.

Through the initiative of Monsieur Eugène Pereire, President of the Administrative Council of the Compagnie Générale Transatlantique, this method has been published in rectangular coordinates on four grand-eagle pages on a scale of $\frac{12}{1000}$ of a meter to the degree, and may be purchased in France.

STUDIES ON THE THERMODYNAMICS OF THE ATMOSPHERE.

By Prof. FRANK H. BIGELOW.

I.—ASYMMETRIC CYCLONES AND ANTICYCLONES IN EUROPE AND AMERICA.

INTRODUCTORY REMARKS.

The synthetic construction of the correct statement of the mechanical problems involved in the cyclonic and anticyclonic circulations of the atmosphere depends upon the coordination of the data derived from observations of the velocity vectors, the pressures, and the temperatures prevailing in the moving air masses. In my International Cloud Report, 1898, and in the MONTHLY WEATHER REVIEWS for January, February, and March, 1902, the distribution of the velocity vectors for the United States was described; in the REVIEWS for January and February, 1903, the distribution of the pressures corresponding to these velocities was explained; in this present series of papers the results of my studies on the relation of the temperatures to the velocities and pressures will be summarized. It has been shown conclusively for the United States that there are no true local warm-centered and cold-centered cyclones or anticyclones in the atmosphere, and that all the theoretical discussions or theses founded on that basis are misdirected. The observations demonstrate that in the lower atmosphere the actual mechanism consists of rather deep warm and cold countercurrents of air, which underrun the prevailing eastward drift. The centers of gyration are uniformly in the region where these counterflowing currents meet each other, that is to say, on the edges rather than in the midst of the warm and cold regions. About one half of the cyclone is relatively warm and the other half cold, while the opposite half of the anticyclone is warm and its alternate half is cold. Thus, in the United States, the eastern and northern sectors of the cyclone with the western and northern sectors of the anticyclone are warm, while the western and southern sectors of the cyclone and the eastern and southern sectors of the anticyclone are cold. The warm air flowing from the southwest into the east of the cyclone and west of the anticyclone, and the cold air flowing from the northwest into the east of the anticyclone and the west of the cyclone, constitute two currents whose temperatures differ from each other and from the normal temperature of the prevailing eastward drift. These currents seek to equalize their different temperatures by interpenetration, and in so doing the circulating structures known as cyclonic and anticyclonic are established. The heat added to the tropical zones of the earth by the solar radiation is to a considerable extent transported into the temperate zones by long horizontal currents in the lower levels, and is there expended in generating local circulations. These penetrate the upper current of eastward drift and tend to retard its motion, slowing it down to the moderate velocities which have been found to exist within ten miles of the ground. This stratification and interpenetration of currents of different temperatures is the true source of the energy of storms. The heat energy derived from the condensation of aqueous vapor to water, and the energy produced by purely dynamic eddies are entirely secondary in importance to the thermodynamic energy obtained by the counterflow and underflow of warm southerly currents against the cold northerly currents and beneath the eastward flowing drift. In the present series of papers it is purposed to examine somewhat fully the thermodynamic conditions which exist in the atmosphere, especially in cyclones, anticyclones and tornadoes; at present the temperature data are inadequate for a satisfactory consideration of hurricanes and the general circulation, though something may also be done in that direction.

THE SUPPOSED DIFFERENCE IN THE TEMPERATURE DISTRIBUTION BETWEEN AMERICAN AND EUROPEAN CYCLONES AND ANTICYCLONES.

Certain discussions of the available temperature observations made at different levels in cyclones and anticyclones for the United States and Europe indicate that there is a serious disagreement in the results for the respective regions, as if these local circulations might really be different in some important respects. We should not expect to find any such divergence in the thermodynamics of the atmosphere when the observations and the computations have been accurately made, but as it is comparatively difficult to extract the exact truth of the matter from the actual observations, it will be proper to examine these observations carefully before admitting that any important difference in the structures actually exists. A suitable review of the literature may be found in Mr. Clayton's article,[1] from which the following few statements are compiled:

From a study of mountain observations, Professor Hann found

[1] Various researches on the temperatures in cyclones and anticyclones in temperate latitudes. By H. Helm Clayton. Beiträge zur Physik der freien Atmosphäre. Vol. I, pp. 93–106.

TABLE 1.—*Temperature-falls at Blue Hill.*

HIGH AREAS IN WINTER (OCTOBER TO MARCH).

Height in meters.	North (3).				East (9).				South (10).				West (3).				Mean.	
	F	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*T*	$\frac{\Delta T}{100}$
	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *C.*	° *C.*
4000	....	..	−21.2	− 7.9	....	..	−37.4	−18.8	....	..	−31.0	−17.9	....	..	−29.8	− 7.6	−13.1	−0.50
3800	−10.5	1	−19.8	− 7.3	−36.1	2	−35.2	−17.5	....	..	−28.9	−16.8	....	..	−28.0	− 6.6	−12.1	−0.55
3600	−18.7	3	−18.2	− 6.4	−32.0	2	−33.2	−16.3	....	..	−27.0	−15.7	....	..	−26.6	− 5.8	−11.1	−0.50
3400	−17.5	2	−16.8	− 5.6	−32.8	3	−30.9	−15.1	−20.5	1	−25.0	−14.6	....	..	−25.2	− 5.0	−10.1	−0.50
3200	−13.9	2	−15.2	− 4.7	−27.9	4	−28.7	−14.0	−20.6	1	−23.1	−13.6	....	..	−23.8	− 4.2	− 9.1	−0.50
3000	−13.7	2	−13.7	− 3.9	−32.1	5	−26.5	−12.7	−17.8	2	−21.3	−12.6	....	..	−21.8	− 3.1	− 8.1	−0.45
2800	−12.5	3	−12.2	− 3.1	−23.6	8	−24.5	−11.6	−19.2	3	−19.8	−11.7	....	..	−20.5	− 2.4	− 7.2	−0.40
2600	−10.2	3	−11.0	− 2.4	−15.0	5	−22.3	−10.4	....	..	−18.4	−10.9	−12.7	1	−19.0	− 1.6	− 6.4	−0.40
2400	−10.1	3	−10.2	− 2.0	−20.8	1	−20.4	− 9.3	....	..	−16.7	−10.0	−17.7	1	−17.7	− 0.9	− 5.6	−0.40
2200	− 6.4	1	− 9.4	− 1.5	−16.3	6	−18.5	− 8.3	−17.4	1	−15.8	− 9.4	−13.2	2	−16.1	0.0	− 4.8	−0.45
2000	− 6.9	5	− 8.8	− 1.2	−18.3	7	−16.5	− 7.1	+ 6.5	1	−13.7	− 8.3	....	..	−14.4	1,0	− 3.9	−0.60
1800	− 9.2	4	− 6.0	0.4	−12.5	6	−14.7	− 6.2	....	..	−11.6	− 7.2	−17.6	1	−12.4	2.1	− 2.7	−0.60
1600	− 8.2	4	− 4.2	1.4	−16.8	4	−12.6	− 5.0	+ 2.3	6	− 9.4	− 5.9	−12.0	2	−10.4	3.4	− 1.5	−0.40
1400	+ 0.2	1	− 3.0	2.0	−10.9	13	−11.3	− 4.3	− 4.5	8	− 6.8	− 4.5	− 8.5	3	− 9.2	3.9	− 0.7	−0.20
1200	− 5.7	3	− 2.6	2.1	−12.0	8	−10.4	− 3.8	− 5.8	6	− 5.3	− 3.7	− 7.4	7	− 8.6	4.2	− 0.3	−0.05
1000	+ 0.8	2	− 3.5	1.8	− 8.0	11	− 9.8	− 3.5	− 2.6	8	− 5.2	− 3.6	− 7.6	5	− 8.2	4.5	− 0.2	−0.15
800	− 3.1	4	− 4.6	1.1	− 5.0	13	− 8.7	− 2.8	− 6.6	13	− 5.8	− 3.9	− 9.5	7	− 7.2	5.0	0.1	−0.10
600	− 7.9	1	− 4.4	1.3	− 9.3	15	− 6.8	− 1.8	− 7.8	17	− 6.0	− 4.0	− 6.4	6	− 6.0	5.7	0.3	−0.45
400	− 3.7	4	− 3.6	1.7	− 4.1	16	− 4.3	− 0.4	− 5.0	16	− 5.2	− 3.6	− 3.3	1	− 3.7	7.0	1.2	−0.55
200	− 1.3	50	− 1.8	2.7	− 1.4	151	− 2.0	0.9	− 2.5	107	− 3.2	− 2.5	− 2.1	36	− 2.0	7.9	2.3	−0.60
0	38.7	50	38.7	3.7	35.6	151	35.6	2.0	30.7	107	30.7	− 0.7	48.2	36	48.2	9.0	3.5	....
																	Mean	−0.42

LOW AREAS IN WINTER.

Height in meters.	North (0).				East (5).				South (13).				West (7).				Mean.	
	F	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*F*	No.	Δ*T*	*T*	*T*	$\frac{\Delta T}{100}$
	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *C.*	° *C.*
4000	....	..	....	....	....	..	−28.7	−13.2	....	..	−45.0	−18.7	....	..	−24.0	−16.0	−16.0	−0.55
3800	....	..	....	....	....	..	−26.7	−12.0	....	..	−43.0	−17.6	....	..	−22.4	−15.1	−14.9	−0.45
3600	....	..	....	....	....	..	−25.2	−11.2	....	..	−40.8	−16.4	....	..	−20.9	−14.3	−14.0	−0.50
3400	....	..	....	....	....	..	−23.4	−10.2	....	..	−38.7	−15.2	....	..	−19.4	−13.5	−13.0	−0.55
3200	....	..	....	....	....	..	−21.4	− 9.1	−37.9	2	−36.4	−13.9	....	..	−18.0	−12.7	−11.9	−0.55
3000	....	..	....	....	....	..	−19.7	− 8.1	−35.2	2	−34.0	−12.6	− 4.9	1	−16.0	−11.6	−10.8	−0.55
2800	....	..	....	....	....	..	−17.8	− 7.1	−31.1	2	−32.0	−11.5	− 3.2	3	−14.2	−10.6	− 9.7	−0.50
2600	....	..	....	....	....	..	−15.8	− 6.0	−30.1	3	−29.6	−10.2	+ 1.1	3	−12.8	− 9.8	− 8.7	−0.60
2400	....	..	....	....	....	..	−14.0	− 5.0	−26.5	4	−27.0	− 8.7	+ 3.5	2	−11.2	− 8.9	− 7.5	−0.45
2200	....	..	....	....	−10.9	3	−12.0	− 3.9	−23.3	6	−24.8	− 7.5	− 9.6	4	−10.0	− 8.3	− 6.6	−0.45
2000	....	..	....	....	− 8.3	6	−10.3	− 3.0	−23.9	6	−22.7	− 6.3	− 4.5	5	− 9.2	− 7.8	− 5.7	−0.40
1800	....	..	....	....	− 6.5	3	− 9.2	− 2.3	−20.2	5	−20.3	− 5.0	−10.7	7	− 8.5	− 7.4	− 4.9	−0.20
1600	....	..	....	....	−10.7	3	− 9.3	− 2.4	−18.0	20	−18.0	− 3.7	− 9.5	5	− 8.4	− 7.3	− 4.5	−0.15
1400	....	..	....	....	− 8.6	7	− 9.8	− 2.7	−15.7	23	−16.0	− 2.6	− 7.2	7	− 8.4	− 7.3	− 4.2	−0.25
1200	....	..	....	....	−10.2	8	−10.0	− 2.8	−14.0	31	−13.8	− 1.4	− 8.2	8	− 7.9	− 7.0	− 3.7	−0.25
1000	....	..	....	....	−10.0	5	− 9.8	− 2.7	−10.3	22	−11.4	− 0.1	− 9.6	8	− 7.3	− 6.8	− 3.2	−0.40
800	....	..	....	....	−11.1	4	− 8.9	− 2.2	− 8.2	17	− 9.2	1.2	− 4.8	7	− 6.1	− 6.1	− 2.4	−0.40
600	....	..	....	....	− 6.5	8	− 7.5	− 1.4	− 8.0	21	− 7.3	2.2	− 5.5	11	− 5.0	− 5.5	− 1.6	−0.55
400	....	..	....	....	− 5.7	8	− 5.9	− 0.5	− 4.1	13	− 4.7	3.7	− 4.0	13	− 3.7	− 4.7	− 0.5	−0.65
200	....	..	....	....	− 2.2	62	− 3.0	0.1	− 1.6	185	− 2.4	5.0	− 1.9	109	− 2.0	− 3.8	0.8	−0.65
0	....	..	....	....	37.1	62	37.1	2.8	43.4	185	43.3	6.3	27.1	123	27.1	− 2.7	2.1	....
																	Mean	−0.43

that in the higher levels the temperature is relatively low over cyclones, but high over anticyclones, and thence he supposed that this apparent inversion must be due to dynamic actions, as of eddies or driven whirls in the prevailing eastward drift. To somewhat the same effect the investigations of Dechevrens, Berson, and Teisserenc de Bort have come, namely, that "cyclones average colder than anticyclones below nine kilometers." On the other hand, the investigations of Harrington, Rotch, Hazen, Clayton, Shaw, and Dines lead to the conclusion that "cyclones average warmer than anticyclones."

The discussion of the temperatures over Hald and Berlin by Grenander[2] is said to support Hann's proposition rather than the American view. It is worth while to find whether this contradiction can be readily reconciled. Without examining critically the observations themselves and the methods of reduction that have been employed, it is sufficient to remark that a very large number of observations is required to arrive at definitive results, and that both the annual and the diurnal variations of temperature must be eliminated from the temperature-falls from the surface. Mountain observations require a series of local corrections to be applied to reduce them to free air measures of temperature, and, generally, the observations must be distributed quite uniformly throughout the 24 hours. The tendency is to use an excess of daytime observations, and this will produce one-sided data in the strata up to at least the elevation of 3000 meters. In the following exposition it will be sufficient to employ the data contained in Grenander's paper and in the Blue Hill paper,[3] which have already been used in my discussion of the diurnal periods of the temperature. We shall expect to show that the structures of the American and European cyclones and anticyclones are practically the same, except possibly in the lower strata, within 2000 meters of the surface.

THE TEMPERATURE-FALLS AT BLUE HILL AND HALD-BERLIN.

The reader is referred to my paper on "The diurnal periods of the temperature"[4] for a description of the method employed in discussing the Blue Hill kite observations of 1897–1902.

[2] Les gradients verticaux de la température dans les minima et les maxima barométriques. Par S. Grenander. Arkiv för matematik, astronomi och fysik. Bd. 2, No. 7. (1905.)

[3] Observations at the Blue Hill Observatory, 1901–2, and appendix of the observations with kites, 1897–1902, with discussion by H. Helm Clayton.

[4] Monthly Weather Review, February, 1905.

TABLE 2.—*Temperature-falls at Blue Hill.*

HIGH AREAS IN SUMMER (APRIL TO SEPTEMBER).

Height in meters.	Center (1).				East (24).				South (12).				West (8).				Mean.	
	F	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*T*	$\frac{\Delta T}{100}$
	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *C.*	° *C.*
4000	.....	...	—37.4	—2.9	—48.3	1	—45.2	—8.4	.....	...	—43.3	—9.6	.....	...	—41.2	—4.8	—6.4	—0.80
3800	—38.9	2	—35.0	—1.5	—40.0	1	—42.1	—6.7	.....	...	—40.0	—7.7	—35.0	1	—38.7	—3.4	—4.8	—0.75
3600	—30.8	2	—32.6	—0.2	—45.2	1	—39.1	—5.1	.....	...	—36.7	—5.9	—35.2	1	—36.2	—2.0	—3.3	—0.75
3400	—31.8	4	—30.2	1.1	—33.2	1	—36.0	—3.3	—33.0	1	—33.5	—4.1	—32.8	2	—33.8	—0.7	—1.8	—0.75
3200	—27.2	2	—28.2	2.3	.....	...	—33.0	—1.6	—30.7	2	—30.2	—2.3	—31.7	2	—31.5	0.6	—0.3	—0.70
3000	—27.7	5	—25.4	3.6	—32.6	7	—29.8	0.1	—26.1	1	—27.2	—0.6	.....	..	—29.0	2.0	1.1	—0.75
2800	—22.2	6	—23.3	4.9	—22.6	10	—27.3	1.5	—28.0	1	—24.6	0.8	.....	...	—26.6	3.3	2.6	—0.70
2600	—21.6	6	—21.2	6.1	—22.1	5	—24.5	3.1	—17.1	1	—22.0	2.3	—32.5	3	—24.4	4.6	4.0	—0.60
2400	—17.0	6	—19.4	7.1	—17.5	6	—22.2	4.4	—15.5	2	—20.0	3.4	—29.1	5	—22.2	5.8	5.2	—0.60
2200	—16.0	5	—17.3	8.3	—20.7	9	—19.9	5.7	— 7.7	3	—18.0	4.5	—22.0	7	—20.0	7.0	6.4	—0.60
2000	—18.2	5	—15.4	9.4	—18.0	9	—17.4	7.1	—12.7	5	—15.9	5.8	—18.6	8	—18.0	8.1	7.6	—0.60
1800	—14.9	11	—13.6	10.2	—18.7	15	—15.2	8.3	—15.2	6	—13.5	7.0	—17.4	7	—16.0	9.2	8.7	—0.55
1600	—11.4	8	—11.8	11.3	—15.3	16	—12.6	9.7	—16.1	7	—11.2	8.3	—14.3	8	—14.6	10.0	9.8	—0.55
1400	—10.2	11	—10.0	12.3	—11.4	20	—10.2	11.0	— 7.6	15	— 9.1	9.4	—17.8	8	—13.5	10.6	10.8	—0.50
1200	— 7.1	13	— 8.5	13.2	— 8.3	28	— 7.4	12.5	— 6.8	10	— 7.2	10.5	—16.8	9	—12.0	11.4	11.9	—0.30
1000	— 7.1	16	— 7.9	13.6	— 4.7	35	— 6.7	13.0	— 5.7	17	— 6.0	11.2	—13.2	11	—10.7	12.1	12.5	—0.20
800	— 7.9	17	— 7.6	13.7	— 2.2	38	— 6.0	13.4	— 4.8	14	— 5.3	11.5	— 7.3	13	— 9.2	13.0	12.9	—0.30
600	— 1.9	24	— 6.1	14.5	+ 2.6	46	— 4.7	14.1	— 5.4	19	— 5.2	11.6	— 7.9	18	— 7.8	13.8	13.5	—0.45
400	— 4.3	25	— 4.3	15.5	— 1.9	46	— 2.5	15.3	— 5.3	19	— 4.6	11.9	— 8.4	10	— 6.2	14.7	14.4	—0.60
200	— 1.1	178	— 2.0	16.8	— 0.9	326	— 0.6	16.3	— 2.6	134	— 2.8	12.9	— 2.9	119	— 2.7	16.6	15.7	—0.55
0	64.3	178	64.3	17.9	62.0	326	62.0	16.7	58.1	134	58.1	14.5	64.6	119	64.6	18.1	16.8	.....
																	Mean	—0.62

LOW AREAS IN SUMMER.

Height in meters.	Center (4).				East (5).				South (22).				West (7).				Mean.	
	F	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*F*	No.	ΔT	*T*	*T*	$\frac{\Delta T}{100}$
	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *F.*		° *F.*	° *C.*	° *C.*	° *C.*
4000	.....	...	—44.0	—9.8	.....	...	—38.8	—6.0	.....	...	—48.2	—3.6	.....	...	—46.5	—9.0	—7.1	—0.60
3800	.....	...	—42.3	—8.9	.....	...	—36.4	—4.6	.....	...	—45.0	—2.1	.....	...	—44.8	—8.0	—5.9	—0.55
3600	—41.8	1	—40.4	—7.8	—38.8	2	—34.6	—3.6	—35.6	1	—43.2	—0.8	—41.5	1	—43.0	—6.0	—4.8	—0.60
3400	.....	...	—38.8	—7.0	—31.3	1	—32.2	—2.3	—37.9	5	—41.0	0.4	—38.8	2	—40.7	—5.7	—3.6	—0.55
3200	—37.3	1	—37.0	—6.0	—33.3	2	—30.5	—1.4	—42.0	6	—38.8	1.6	—35.5	4	—38.4	—4.4	—2.5	—0.60
3000	—35.5	3	—35.0	—4.8	—31.8	3	—28.6	—0.3	—31.9	13	—36.1	3.1	—39.0	3	—36.4	—3.3	—1.3	—0.50
2800	—33.2	3	—33.2	—3.8	—35.5	4	—26.8	0.7	—35.2	11	—34.6	4.0	—28.6	6	—34.0	—2.0	—0.3	—0.60
2600	—28.9	4	—31.0	—2.6	—29.1	2	—24.8	1.8	—30.9	14	—32.7	5.1	—26.3	4	—31.5	—0.6	0.9	—0.60
2400	—29.7	6	—28.6	—1.3	—25.4	2	—23.2	2.7	—31.2	17	—30.4	6.3	—24.7	9	—29.6	0.5	2.1	—0.65
2200	—26.8	7	—26.0	0.2	—21.5	3	—21.0	3.9	—28.8	18	—28.2	7.5	—23.0	12	—27.2	1.8	3.4	—0.60
2000	—23.7	7	—23.5	1.6	—15.3	4	—19.4	4.8	—25.9	18	—25.8	8.9	—26.7	9	—25.0	3.0	4.6	—0.68
1800	—25.3	3	—20.7	3.1	—15.4	4	—17.0	6.2	—24.0	23	—23.4	10.2	—25.9	12	—23.2	4.0	5.9	—0.65
1600	—16.0	3	—18.0	4.6	—14.9	5	—15.1	7.2	—20.4	18	—20.8	11.6	—20.6	9	—20.8	5.3	7.2	—0.65
1400	—14.1	6	—15.7	5.9	—17.6	5	—13.3	8.2	—18.2	25	—18.1	13.1	—20.3	12	—18.2	6.8	8.5	—0.60
1200	—13.6	5	—13.2	7.3	—11.1	6	—11.6	9.1	—16.7	22	—15.6	14.5	—18.8	11	—16.0	8.0	9.7	—0.55
1000	—12.1	6	—11.0	8.5	— 5.5	3	— 9.7	10.2	—14.2	25	—13.0	16.0	—13.7	12	—14.6	8.8	10.8	—0.65
800	— 9.7	3	— 9.2	9.5	—10.1	8	— 7.8	11.3	—11.0	33	—10.5	17.3	—12.9	10	—12.0	10.2	12.1	—0.75
600	— 7.4	5	— 6.8	10.8	— 5.7	8	— 5.7	12.5	— 8.9	38	— 8.0	18.8	— 5.9	12	— 7.8	12.3	13.6	—0.80
400	— 3.4	8	— 4.3	12.2	— 5.8	11	— 3.5	13.6	— 5.5	40	— 5.3	20.2	— 3.0	11	— 4.0	14.7	15.2	—0.60
200	— 3.4	73	— 2.0	13.5	— 2.7	82	— 1.6	14.7	— 2.7	341	— 2.7	21.7	— 1.6	138	— 2.0	15.8	16.4	—0.60
0	58.2	73	58.2	14.6	60.1	82	60.1	15.6	73.7	341	73.7	23.2	62.5	145	62.5	16.9	17.6	.....
																	Mean	—0.63

It is convenient to utilize the same data for discussing the distribution of temperature in the several strata of cyclones and anticyclones up to the height of about 4000 meters, for the sake of eliminating the diurnal variation. This was done by taking the mean values of the temperatures as observed at the several ascensions, which were distributed in the different hours of the day. While the distribution among the 24 hours is not completely uniform, it is probable that a fairly satisfactory elimination of the diurnal temperature variation in the levels from the surface to 3000 meters has been accomplished in my computations, by taking the average daily values as they exist in this report for the winter months (October to March) and the summer months (April to September), thus making two groups for the five years of observations. The number of available observations is not nearly great enough to give definitive mean values, but the results here explained probably indicate quite sufficiently the typical conditions that require to be known as the basis of a theoretical discussion of the thermodynamics of storms.

Table 1, temperature-falls at Blue Hill, winter high areas and low areas, and Table 2, summer high areas and low areas, summarize the data. The temperature-falls are given for the N. E. S. W. sectors, and for the center when possible. These sectors group the data according to my subareas as follows: For center we take subareas (1, 2, 3, 4), for north (9, 10, 17, 18), east (7, 8, 15, 16), south (5, 6, 13, 14), west (11, 12, 19, 20). The areas at the time of observation at Blue Hill were located in respect to these subareas by studying the corresponding weather maps and selecting the most conspicuous high area or low area for the center.

EXPLANATION OF TABLES 1, 2, 3, AND 4.

The first column of Table 1 gives the height in meters, the second, *F*, the mean temperature-falls in Fahrenheit degrees, as determined by the number of observations recorded in column three; these temperature-falls were plotted on diagrams and average curves were drawn through the points, from which the values of ΔT found in column four were scaled, and these should represent more exact values than can be obtained from the limited number of observations at our disposal. At the bottom of columns *F* and ΔT is found the mean surface temperature, determined by the numerous readings made at the Blue Hill valley station. In column five, marked *T*, are given the corresponding temperatures themselves in centigrade degrees, being transformed from the Fahrenheit degrees re-

TABLE 3.—*Temperature-falls at Hald and Berlin.*

HIGH AREAS IN WINTER (OCTOBER TO MAY 15).

Height in meters.	North.		East.		South.		West.		Mean.	
	ΔT	T	ΔT	T	ΔT	T	ΔT	T	T	$\frac{\Delta T}{100}$
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
6000	−31.6	−27.0	−34.0	−33.2	−25.3	−24.5	−25.7	−21.6	−26.6	−0.75
5800	−30.0	−25.4	−32.5	−31.7	−23.9	−23.1	−24.4	−20.3	−25.1	−0.70
5600	−28.3	−23.7	−31.0	−30.2	−22.7	−21.9	−22.9	−18.8	−23.7	−0.80
5400	−26.7	−22.1	−28.7	−27.9	−21.7	−20.9	−21.4	−17.3	−22.1	−0.80
5200	−25.5	−20.9	−26.7	−25.9	−20.3	−19.5	−19.8	−15.7	−20.5	−0.70
5000	−24.2	−19.6	−24.8	−24.0	−19.1	−18.3	−18.6	−14.5	−19.1	−0.60
4800	−22.8	−18.2	−23.6	−22.8	−18.1	−17.3	−17.5	−13.4	−17.9	−0.55
4600	−21.6	−17.0	−22.4	−21.6	−17.1	−16.3	−16.3	−12.2	−16.8	−0.75
4400	−19.8	−15.2	−21.0	−20.2	−15.7	−14.9	−15.0	−10.9	−15.3	−0.65
4200	−18.6	−14.0	−20.0	−19.2	−14.7	−13.9	−14.0	−9.9	−14.0	−0.45
4000	−17.5	−12.9	−18.8	−18.0	−13.7	−12.9	−12.6	−8.5	−13.1	−0.50
3800	−16.4	−11.8	−18.0	−17.2	−12.8	−12.0	−11.6	−7.5	−12.1	−0.45
3600	−15.4	−10.8	−17.2	−16.4	−11.9	−11.1	−10.6	−6.5	−11.2	−0.50
3400	−14.3	−9.7	−16.4	−15.6	−10.9	−10.1	−9.5	−5.4	−10.2	−0.55
3200	−13.2	−8.6	−15.1	−14.3	−9.8	−9.0	−8.6	−4.5	−9.1	−0.55
3000	−12.2	−7.6	−14.0	−13.2	−8.7	−7.9	−7.4	−3.3	−8.0	−0.40
2800	−11.2	−6.6	−13.1	−12.3	−8.4	−7.6	−6.9	−2.8	−7.2	−0.40
2600	−10.3	−5.7	−12.3	−11.5	−7.8	−7.0	−6.3	−2.2	−6.6	−0.40
2400	−9.4	−4.8	−11.4	−10.6	−7.2	−6.4	−5.4	−1.3	−5.8	−0.45
2200	−8.1	−3.5	−10.7	−9.9	−6.7	−5.9	−4.4	−0.3	−4.9	−0.40
2000	−7.1	−2.5	−9.8	−9.0	−6.2	−5.4	−3.6	0.5	−4.1	−0.35
1800	−6.5	−1.9	−8.8	−8.0	−5.5	−4.7	−2.9	1.2	−3.4	−0.35
1600	−6.0	−1.4	−7.9	−7.1	−4.9	−4.1	−2.3	1.8	−2.7	−0.35
1400	−5.3	−0.7	−6.8	−6.0	−4.3	−3.5	−1.9	2.2	−2.0	−0.30
1200	−4.6	0.0	−5.6	−4.8	−3.9	−3.1	−1.6	2.5	−1.4	−0.30
1000	−4.0	0.6	−4.6	−3.8	−3.4	−2.6	−1.3	2.8	−0.8	−0.40
800	−3.2	1.4	−3.4	−2.6	−2.8	−2.0	−0.9	3.2	0.0	−0.35
600	−2.4	2.2	−2.2	−1.4	−2.3	−1.5	−0.6	3.5	0.7	−0.35
400	−1.5	3.1	−1.2	−0.4	−1.7	−0.9	−0.4	3.7	1.4	−0.30
200	−0.7	3.9	−0.5	0.3	−0.8	0.0	−0.2	3.9	2.0	−0.30
0	0.0	4.6	0.0	0.8	0.0	0.8	0.0	4.1	2.6	.....
					Mean gradient up to 4000 meters.....					−0.40

LOW AREAS IN WINTER.

Height in meters.	North.		East.		South.		West.		Mean.	
	ΔT	T	ΔT	T	ΔT	T	ΔT	T	T	$\frac{\Delta T}{100}$
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
6000	−33.4	−26.5	−33.8	−29.6	−34.4	−27.8	−35.5	−29.0	−28.2	−0.75
5800	−31.7	−24.8	−32.4	−28.2	−33.2	−26.6	−34.0	−27.5	−26.7	−0.70
5600	−29.8	−22.9	−31.0	−26.8	−32.0	−25.4	−32.8	−26.3	−25.3	−0.65
5400	−28.2	−21.3	−29.7	−25.5	−30.8	−24.2	−31.8	−25.3	−24.0	−0.65
5200	−27.0	−20.1	−28.0	−23.8	−29.2	−22.6	−31.0	−24.5	−22.7	−0.50
5000	−26.1	−19.2	−26.6	−22.4	−28.3	−21.7	−30.3	−23.8	−21.7	−0.50
4800	−24.8	−17.9	−25.7	−21.5	−26.9	−20.3	−29.6	−23.1	−20.7	−0.55
4600	−23.8	−16.9	−24.3	−20.1	−25.8	−19.2	−28.8	−22.3	−19.6	−0.65
4400	−22.5	−15.6	−23.0	−18.8	−24.2	−17.6	−28.0	−21.5	−18.3	−0.65
4200	−21.1	−14.2	−21.4	−17.2	−22.8	−16.2	−26.9	−20.4	−17.0	−0.55
4000	−19.9	−13.0	−20.2	−16.0	−22.0	−15.4	−26.0	−19.5	−15.9	−0.55
3800	−18.7	−11.8	−19.0	−14.8	−21.0	−14.4	−24.7	−18.2	−14.8	−0.60
3600	−17.4	−10.5	−17.9	−13.7	−20.0	−13.4	−23.4	−16.9	−13.6	−0.65
3400	−16.0	−9.1	−16.5	−12.3	−18.8	−12.2	−22.2	−15.7	−12.3	−0.60
3200	−14.7	−7.8	−15.2	−11.0	−17.7	−11.1	−21.0	−14.5	−11.1	−0.55
3000	−13.5	−6.6	−14.2	−10.0	−16.6	−10.0	−19.7	−13.2	−10.0	−0.65
2800	−12.5	−5.6	−13.4	−9.2	−15.4	−8.8	−17.8	−11.3	−8.7	−0.65
2600	−11.3	−4.4	−12.6	−8.4	−14.2	−7.6	−15.9	−9.4	−7.4	−0.55
2400	−10.5	−3.6	−11.3	−7.1	−13.0	−6.4	−14.6	−8.1	−6.3	−0.60
2200	−9.8	−2.9	−10.2	−6.0	−11.8	−5.2	−13.1	−6.6	−5.1	−0.55
2000	−8.4	−1.5	−9.2	−5.0	−10.8	−4.2	−12.0	−5.5	−4.0	−0.45
1800	−7.8	−0.9	−8.0	−3.8	−9.8	−3.2	−11.0	−4.5	−3.1	−0.55
1600	−6.6	0.3	−7.0	−2.8	−8.8	−2.2	−10.0	−3.5	−2.0	−0.50
1400	−5.8	1.1	−5.9	−1.7	−7.7	−1.1	−8.8	−2.3	−1.0	−0.60
1200	−5.4	1.5	−4.7	−0.5	−6.4	0.2	−7.3	−0.8	0.2	−0.55
1000	−4.8	2.1	−3.2	1.0	−5.2	1.4	−6.0	0.5	1.3	−0.50
800	−3.6	3.3	−2.6	1.6	−4.2	2.4	−4.7	1.8	2.3	−0.50
600	−2.4	4.5	−1.8	2.4	−3.1	3.5	−3.8	2.7	3.3	−0.55
400	−1.3	5.6	−1.1	3.1	−2.1	4.5	−2.3	4.2	4.4	−0.50
200	−0.6	6.3	−0.5	3.7	−0.7	5.9	−0.9	5.6	5.4	−0.35
0	0.0	6.9	0.0	4.2	0.0	6.6	0.0	6.5	6.1	.....
					Mean gradient up to 4000 meters.....					−0.55

corded in column four, and the temperature for each stratum is computed by adding the temperature-falls ΔT, as reduced to centigrade degrees, to the surface temperature T. At the head of each section group is given the number of ascensions employed, as 3 for north, 9 for east, 10 for south, etc. In the last columns of each general group are given the mean temperatures of the sectors on the several levels, and the mean gradients per 100 meters. The gradients in the several sectors can be readily computed from the temperatures recorded for every 200-meter level up to 4000 meters. It should be noted that the data are entirely lacking for the north sector, except for the winter high areas, where three ascensions were available, and that observations in the central area are found only for the summer half of the year. This failure to record the temperature in the north sector is due to two causes, (1) the general passage of the centers of pressure to the north of Blue Hill, and (2), especially, the class of winds prevailing in that sector, which are usually unfavorable for kite ascensions.

For the European cyclones and anticyclones I have employed the data found in Grenander's paper. The temperature-falls in winter low and high areas at Hald and Berlin (Table 3) were taken from the tables and diagram without change. For these the results are recorded in Tables 3 and 4, where ΔT is the temperature-fall from the surface and T the corresponding temperature at every 200-meter level. In order to eliminate the diurnal variation from the surface mean temperatures, upon which every thing depends, it was necessary to interpolate a few of the missing night temperatures as in Table 5.

There is, of course, some uncertainty in this connection, but not nearly enough to modify the conclusions based upon these surface means. It is much better to obtain approximate mean temperatures for the 24 hours than to employ those belonging exclusively to the day hours. In the summer months the Hald and the Berlin temperatures were treated separately (see Table 4) and the adopted temperatures are the mean values of the two stations in the several 200-meter levels. The column T is the mean of the Hald and Berlin columns, with interpolations, and ΔT is computed from T.

TEMPERATURE-FALLS FROM THE SURFACE.

There are two ways in which the data of these tables can be conveniently arranged for discussion, (1) by exhibiting the temperature-falls on a diagram, and (2) by constructing the temperatures prevailing in the horizontal sections at different elevations. Fig. 1 represents the American and European temperature-falls in high and low areas, in winter and summer. It shows at a glance that the high areas (full lines) are not all cold as compared with the low areas, nor the low areas (dotted lines) all warm as compared with the high areas. On the other hand the north and west of the high areas are warm, while the south and east are cold, both winter and summer. In the lower levels, 1000 to 2000 meters, there is some entanglement of the gradient lines, and while there may be a tendency for the dotted lines of the low areas to cross the full lines of the high areas from right to left, there is nothing very decisive about the relation. In the American areas the temperatures of the high areas generally have a small gradient in the levels 1000 to 2000 meters, and there is, also, some indication of the same tendency in the European high areas. Attention is directed to chart 14, International Cloud Report, 1898, where a corresponding vertical change in the velocities was recorded, indicating that this stratum has a steady velocity throughout its depth in accordance with this local temperature distribution. In the winter both the European and American temperatures have about the same extreme differences, approximately 10° C. above the 2000-meter level, though below it the American exceed the European by about 4° C. The American circulation near the surface in winter is usually more active than the European. In the summer the American temperature divergence seems to be rather less, about 2°, than the European, though this difference may really be due to an inadequacy in the results of the observations in hand, and may be changed by increasing their number. On the whole there are indications that the temperature spread is wider at the 3000-meter level than at any height above or below, and this implies that the local circulation is greater at this level

Fig. 1.—American and European Temperature-falls, ΔT, in High and Low Areas, in Winter and Summer.

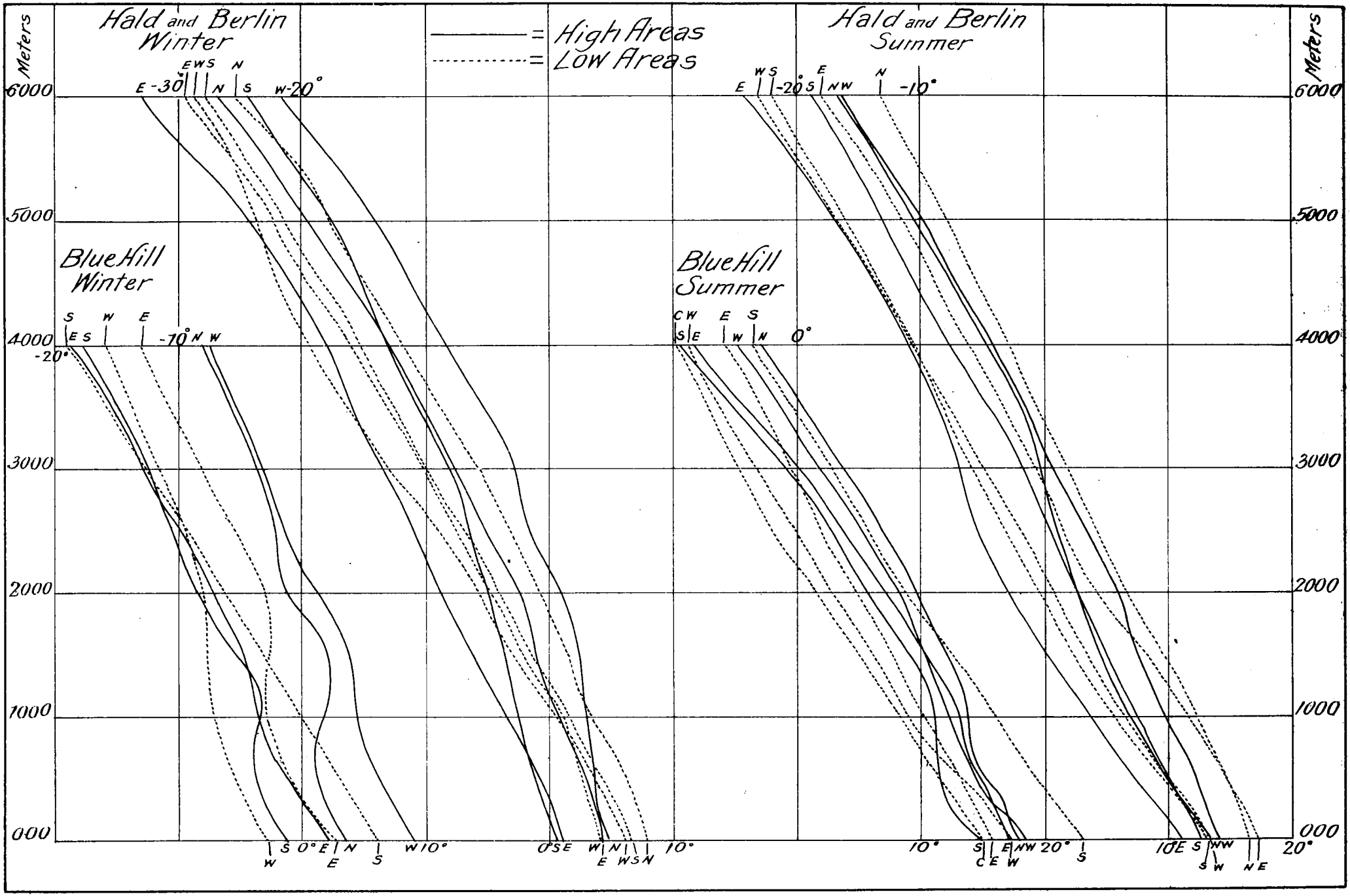

Fig. 2.—American and European Temperature-falls, ΔT, in Warm and Cold Areas, in Winter and Summer.

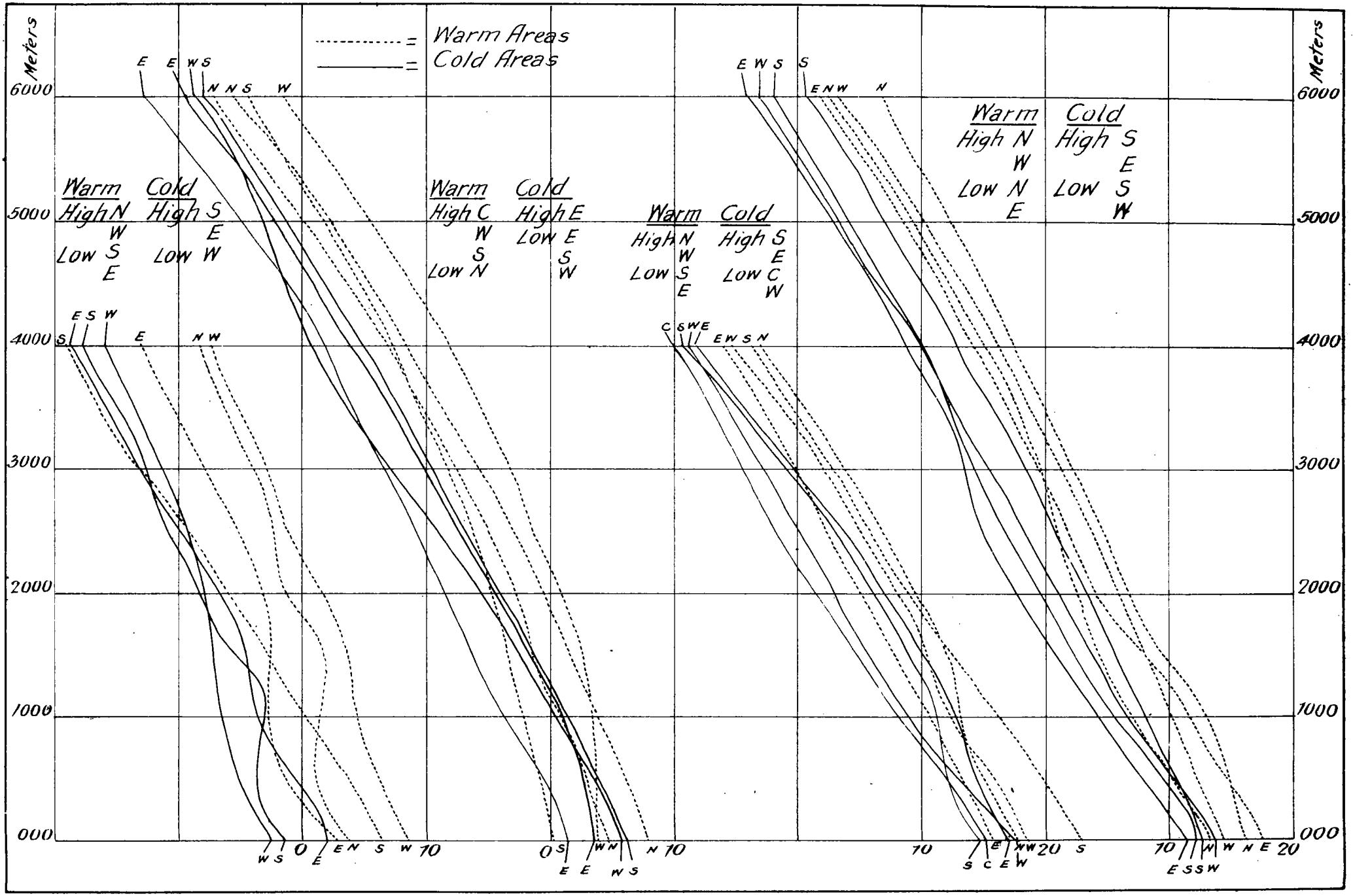

FIG. 3.—The Distribution of Temperature in the High and Low Pressure Areas of North America.

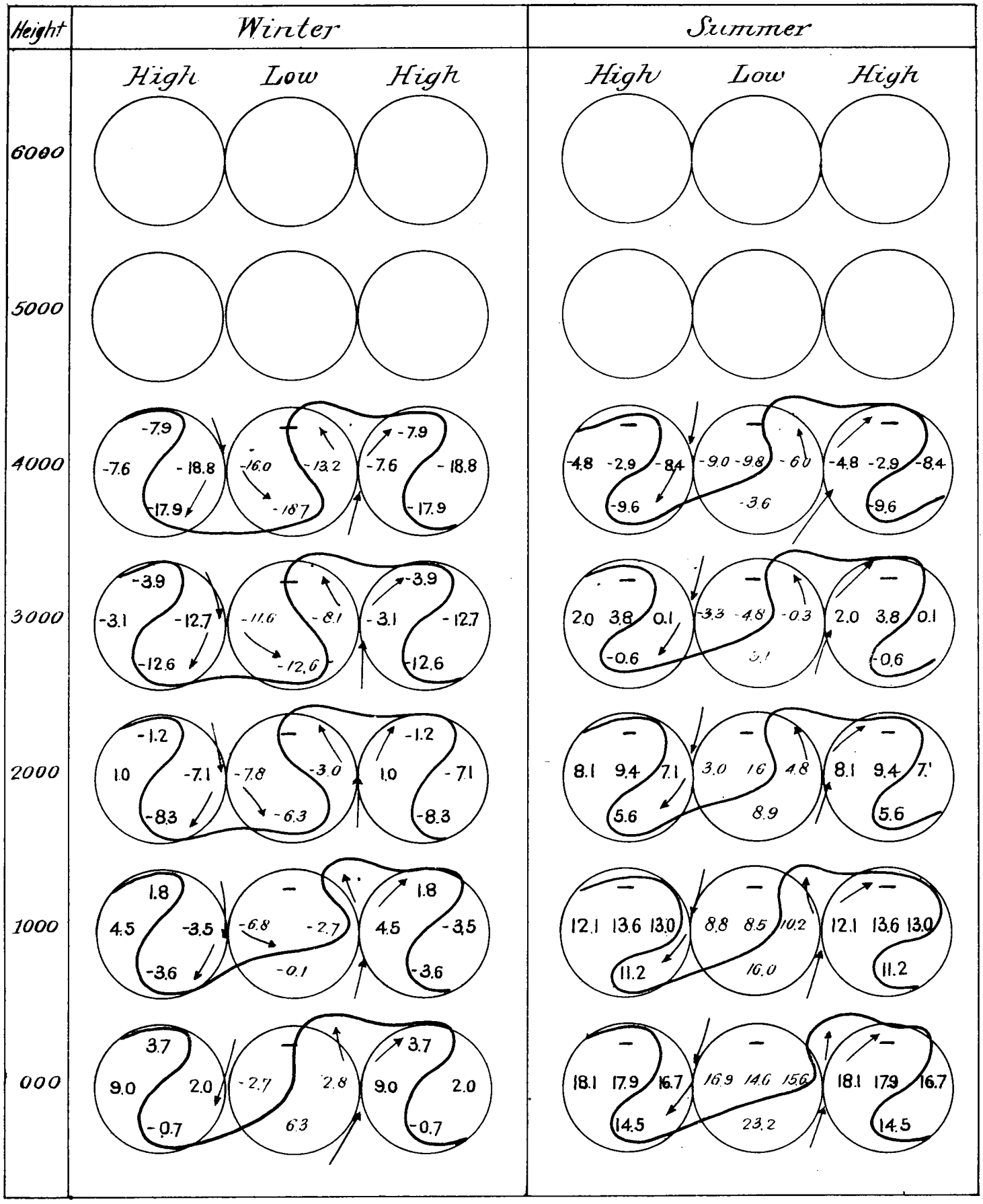

Fig. 4.—The Distribution of Temperature in the High and Low Pressure Areas of Europe.

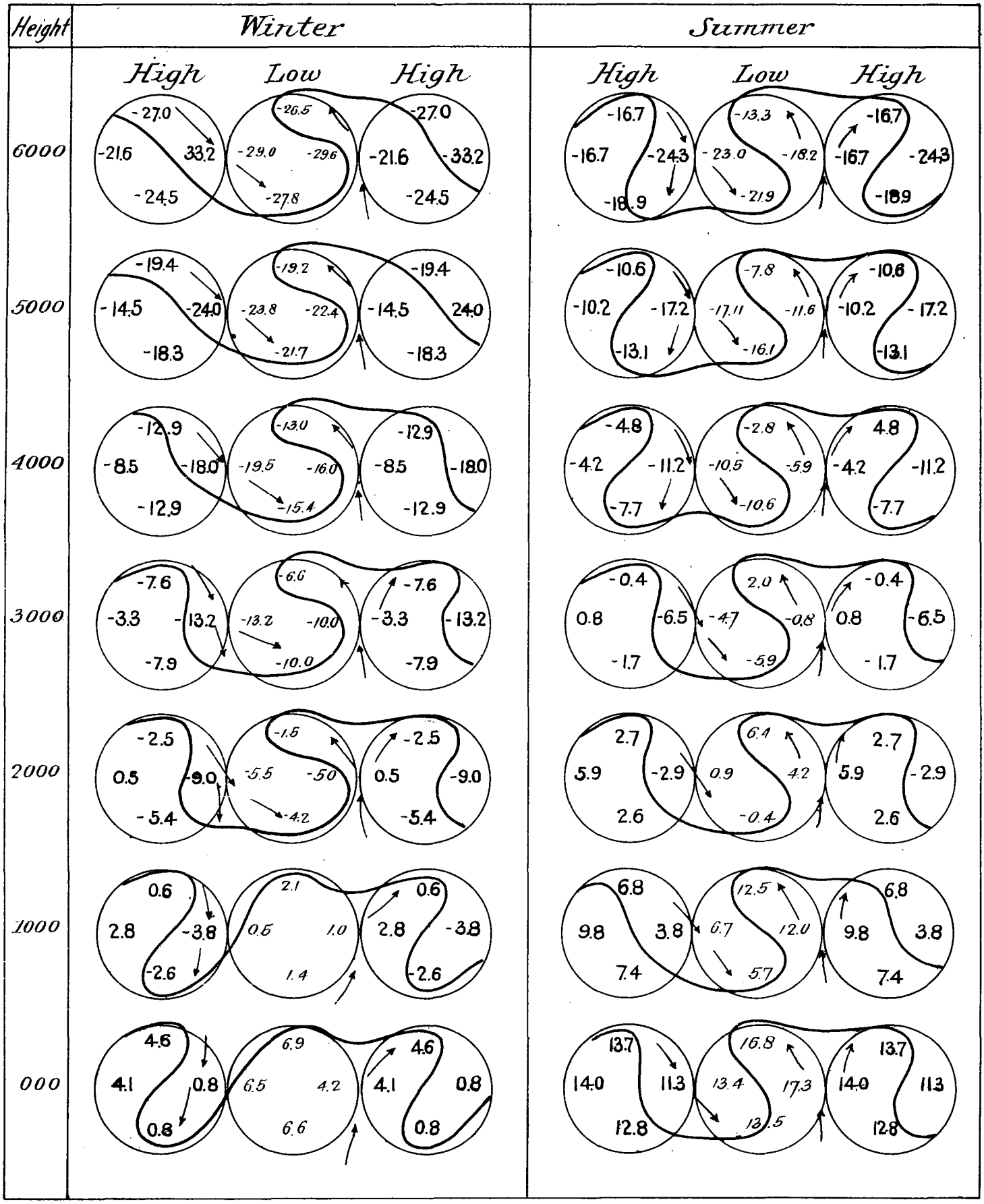

TABLE 4.—*Temperature-falls at Hald and Berlin.*

HIGH AREAS IN SUMMER (APRIL TO SEPTEMBER).

Height in meters.	North.				East.				South.				West.				Mean.	
	Hald	*Berlin*	ΔT	T	*Hald*	*Berlin*	ΔT	T	*Hald*	*Berlin*	ΔT	T	*Hald*	*Berlin*	ΔT	T	T	$\frac{\Delta T}{100}$
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
6000	—15.9	—17.5	—30.4	—16.7	—25.4	—23.1	—35.6	—24.3	—18.2	—19.5	—31.7	—18.9	—16.4	—16.9	—30.7	—16.7	—19.2	—0.65
5800			—29.2	—15.5			—34.0	—22.7			—30.5	—17.7			—29.4	—15.4	—17.9	—0.65
5600			—27.9	—14.2			—32.4	—21.1			—29.3	—16.5			—28.0	—14.0	—16.6	—0.65
5400			—26.7	—13.0			—31.0	—19.7			—28.1	—15.3			—26.7	—12.7	—15.3	—0.65
5200			—25.5	—11.8			—29.7	—18.4			—27.0	—14.2			—25.4	—11.4	—14.0	—0.60
5000	— 9.7	—11.5	—24.3	—10.6	—18.5	—15.9	—28.5	—17.2	—12.2	—14.0	—25.9	—13.1	— 9.6	—10.7	—24.2	—10.2	—12.8	—0.60
4800			—23.2	— 9.5			—27.3	—16.0			—24.9	—12.1			—22.9	— 8.9	—11.6	—0.60
4600			—22.1	— 8.4			—26.1	—14.8			—23.8	—11.0			—21.6	— 7.6	—10.4	—0.60
4400			—20.9	— 7.2			—24.9	—13.6			—22.7	— 9.9			—20.4	— 6.4	— 9.2	—0.60
4200			—19.7	— 6.0			—23.7	—12.4			—21.6	— 8.8			—19.3	— 5.3	— 8.1	—0.55
4000	— 3.6	— 6.0	—18.5	— 4.8	—12.8	— 9.6	—22.5	—11.2	— 6.4	— 9.0	—20.5	— 7.7	— 4.5	— 3.9	—18.2	— 4.2	— 7.0	—0.50
3800			—17.3	— 3.6			—21.3	—10.0			—19.2	— 6.4			—17.2	— 3.2	— 6.0	—0.55
3600			—16.2	— 2.5			—20.2	— 8.9			—17.9	— 5.1			—16.2	— 2.2	— 4.9	—0.50
3400			—15.3	— 1.6			—19.3	— 8.0			—16.7	— 3.9			—15.2	— 1.2	— 3.9	—0.50
3200			—14.6	— 0.9			—18.5	— 7.2			—15.5	— 2.7			—14.2	— 0.2	— 2.9	—0.45
3000	1.2	— 2.0	—14.1	— 0.4	— 8.5	— 4.5	—17.8	— 6.5	— 0.7	— 2.6	—14.5	— 1.7	0.1	1.5	—13.2	0.8	— 2.0	—0.40
2800			—13.5	0.2			—17.3	— 6.0			—13.6	— 0.8			—12.1	1.9	— 1.2	—0.40
2600			—12.9	0.8			—16.9	— 5.6			—12.8	0.0			—11.0	3.0	— 0.4	—0.40
2400			—12.3	1.4			—16.2	— 4.9			—12.1	0.7			—10.0	4.0	0.4	—0.40
2200			—11.7	2.0			—15.3	— 4.0			—11.2	1.6			— 9.0	5.0	1.2	—0.45
2000	4.5	0.8	—11.0	2.7	— 5.4	— 0.3	—14.1	— 2.9	3.7	1.5	—10.2	2.6	5.2	6.6	— 8.1	5.9	2.1	—0.45
1800			—10.3	3.4			—12.9	— 1.6			— 9.3	3.5			— 7.4	6.6	3.0	—0.50
1600			— 9.6	4.1			—11.6	— 0.3			— 8.3	4.5			— 6.6	7.4	4.0	—0.45
1400			— 8.8	4.9			—10.2	1.1			— 7.4	5.4			— 5.8	8.2	4.9	—0.50
1200			— 7.9	5.8			— 8.9	2.4			— 6.4	6.4			— 5.0	9.0	5.9	—0.55
1000	7.4	6.1	— 6.9	6.8	2.2	5.3	— 7.5	3.8	7.2	7.5	— 5.4	7.4	8.4	11.1	— 4.2	9.8	7.0	—0.60
800			— 5.7	8.0			— 6.1	5.2			— 4.4	8.4			— 3.3	10.7	8.2	—0.55
600			— 4.5	9.2			— 4.6	6.7			— 3.3	9.5			— 2.5	11.5	9.3	—0.60
400			— 3.2	10.5			— 3.1	8.2			— 2.2	10.6			— 1.6	12.5	10.5	—0.60
200			— 1.7	12.0			— 1.6	9.7			— 1.1	11.7			— 0.8	13.2	11.7	—0.65
0	13.5	13.9	— 0.0	13.7	9.1	13.5	0.0	11.3	10.5	15.1	0.0	12.8	11.4	16.5	0.0	14.0	13.0	.....
									Mean gradient up to 4000 meters									—0.50

LOW AREAS IN SUMMER.

6000	—17.0	— 9.5	—30.1	—13.3	—18.9	—17.5	—35.5	—18.2	—22.0	—21.8	—35.4	—21.9	—24.5	—21.4	—36.0	—23.0	—18.1	—0.50
5800			—29.0	—12.2			—34.1	—16.8			—34.3	—20.8			—35.3	—21.9	—17.1	—0.45
5600			—27.9	—11.1			—32.8	—15.5			—33.1	—19.6			—34.1	—20.7	—16.2	—0.50
5400			—26.7	— 9.9			—31.4	—14.1			—31.9	—18.4			—32.9	—19.5	—15.2	—0.50
5200			—25.6	— 8.8			—30.1	—12.8			—30.7	—17.2			—31.7	—18.3	—14.2	—0.50
5000	—12.1	— 3.5	—24.6	— 7.8	—11.9	—11.3	—28.9	—11.6	—16.3	—15.9	—29.6	—16.1	—19.3	—14.8	—30.5	—17.1	—13.2	—0.55
4800			—23.8	— 7.0			—27.7	—10.4			—28.5	—15.0			—29.2	—15.8	—12.1	—0.55
4600			—22.9	— 6.1			—26.5	— 9.2			—27.4	—13.9			—27.9	—14.5	—11.0	—0.60
4400			—21.8	— 5.0			—25.4	— 8.1			—26.3	—12.8			—26.5	—13.1	— 9.8	—0.60
4200			—20.7	— 3.9			—24.3	— 7.0			—25.2	—11.7			—25.2	—11.8	— 8.6	—0.55
4000	— 7.5	2.0	—19.6	— 2.8	— 6.4	— 5.4	—23.2	— 5.9	—11.0	—10.2	—24.1	—10.6	—12.7	— 8.2	—23.9	—10.5	— 7.5	—0.50
3800			—18.7	— 1.9			—22.2	— 4.9			—23.1	— 9.6			—22.8	— 9.4	— 6.5	—0.50
3600			—17.8	— 1.0			—21.1	— 3.8			—22.2	— 8.7			—21.7	— 8.3	— 5.5	—0.55
3400			—16.8	0.0			—20.1	— 2.8			—21.3	— 7.8			—20.5	— 7.1	— 4.4	—0.50
3200			—15.8	1.0			—19.1	— 1.8			—20.4	— 6.9			—19.3	— 5.9	— 3.4	—0.50
3000	— 3.1	7.0	—14.8	2.0	— 1.5	0.0	—18.1	— 0.8	— 5.8	— 5.9	—19.4	— 5.9	— 6.4	— 3.0	—18.1	— 4.7	— 2.4	—0.50
2800			—14.0	2.8			—17.2	0.1			—18.3	— 4.8			—16.9	— 3.5	— 1.4	—0.45
2600			—13.2	3.6			—16.3	1.0			—17.2	— 3.7			—15.8	— 2.4	— 0.5	—0.50
2400			—12.3	4.5			—15.4	1.9			—16.1	— 2.6			—14.7	— 1.3	0.5	—0.55
2200			—11.4	5.4			—14.3	3.0			—15.0	— 1.5			—13.6	— 0.2	1.6	—0.60
2000	1.2	11.8	—10.4	6.4	4.0	4.4	—13.1	4.2	— 0.2	— 0 5	—13.9	— 0.4	— 0.9	2.7	—12.5	0.9	2.8	—0.60
1800			— 9.2	7.6			—11.5	5.8			—12.8	0.7			—11.4	2.0	4.0	—0.60
1600			— 8.0	8.8			— 9.8	7.5			—11.6	1.9			—10.4	3.0	5.3	—0.65
1400			— 6.7	10.1			— 8.1	9.2			—10.4	3.1			— 9.2	4.2	6.6	—0.65
1200			— 5.4	11.4			— 6.6	10.7			— 9.1	4.4			— 8.0	5.4	7.9	—0.65
1000	6.3	18.7	— 4.3	12.5	10.2	13.7	— 5.3	12.0	5.2	6.2	— 7.8	5.7	4.3	9.0	— 6.7	6.7	9.2	—0.65
800			— 3.4	13.4			— 4.2	13.1			— 6.4	7.1			— 5.3	8.1	10.4	—0.60
600			— 2.5	14.3			— 3.2	14.1			— 4.8	8.7			— 4.0	9.4	11.6	—0.60
400			— 1.7	15.1			— 2.1	15.2			— 3.3	10.2			— 2.7	10.7	12.9	—0.65
200			— 0.8	16.0			— 1.0	16.3			— 1.7	11.8			— 1.4	12.0	14.1	—0.60
0	12.4	21.2	0.0	16.8	14.9	19.6	0.0	17.3	13.0	14.0	0.0	13.5	12.4	14.4	0.0	13.4	15.3	.....
									Mean gradient up to 4000 meters.....									—0.57

than above or below it, a result indicated by the observed velocities as shown on chart 68 of my Cloud Report. It is hardly possible to consider the temperatures for the upper levels, 4000 to 6000 meters, as sufficiently reliable to base special emphasis upon the wide divergence of the European temperatures in those levels, and the lines should probably be drawing together more rapidly than here shown. From other considerations it may be inferred that the temperature differences generally disappear in the neighborhood of the cirrus levels 9000 to 10,000 meters. While there is a tendency in the lower levels for the temperatures of the high areas to diminish less rapidly than those of the low areas, there is yet but little to justify the view that anything like an inversion of temperature occurs, such as Professor Hann found in mountain stations and ascribed to dynamic actions, or such as Bjerknes and Clayton assume to exist in their theories of cold-center and warm-center cyclones superposed upon each other. This will be seen more clearly in the exhibit of figs. 3 and 4. We may safely infer from fig. 1 that there is little to distinguish the temperature distribution in European cyclones and anticyclones from that prevailing in the American high and low areas.

Using the same temperature-falls we now discuss the relation according to actual warm and cold areas, as shown in

fig. 2, where the dotted lines indicate the warm areas and the full lines the cold areas. Hence we adopt the following arrangement: (See Table 6.)

TABLE 5.—*Surface temperatures in centigrade degrees for day and night at Hald and Berlin.*

HIGH AREAS.

Station.	Winter.				Summer.			
	N.	*E.*	*S.*	*W.*	*N.*	*E.*	*S.*	*W.*
Hald day	5.1	3.8	1.1	1.3	14.9	10.4	14.0	12.6
Hald night	2.1	(0.0)	−1.7	5.1	(12.0)	(7.8)	(6.9)	(10.2)
Berlin day	6.6	1.7	1.9	4.2	17.1	16.6	18.5	19.0
Berlin night	4.6	−2.5	1.8	5.9	10.6	10.3	11.6	14.0
Means	4.6	0.8	0.8	4.1	13.7	11.3	12.8	14.0

LOW AREAS.

Station.	*N.*	*E.*	*S.*	*W.*	*N.*	*E.*	*S.*	*W.*
Hald day	6.1	5.5	5.2	4.5	14.6	15.8	14.0	12.8
Hald night	(4.0)	3.7	6.0	5.8	10.1	14.0	12.0	(12.0)
Berlin day	12.8	2.7	8.6	9.2	26.5	20.9	15.5	14.9
Berlin night	4.7	4.7	(6.6)	(6.5)	15.8	18.3	12.5	(14.0)
Means	6.9	4.2	6.6	6.5	16.8	17.3	13.5	13.4

TABLE 6.—*Distribution of the sectors by warm and cold areas.*

Blue Hill, winter.		Hald and Berlin, winter.	
Warm areas.	Cold areas.	Warm areas.	Cold areas.
High north.	High east.	High north.	High east.
High west.	High south.	High south.	Low east.
Low east.	Low west.	High west.	Low south.
Low south.	Low north.	Low north.	Low west.
Blue Hill, summer.		**Hald and Berlin, summer.**	
High north.	High east.	High north.	High east.
High west.	High south.	High west.	High south.
Low east.	Low north.	Low north.	Low south.
Low south.	Low west.	Low east.	Low west.

This summary shows that as a whole the warm and cold temperatures are about equally distributed between the high areas and low areas, especially in the levels above 1000 meters. Below that level, in the stratum near the ground, there is much less regularity in the distribution, and this probably means that the true cyclonic and anticyclonic action is disturbed by coming in contact with the ground, and by the adjustment to surface conditions. *It also shows that the surface temperatures are not entirely reliable as records of the real distribution prevailing in the free air, and it implies that for accurate forecasting it will be necessary to change from the exclusive use of surface temperature charts to those determined by observations in the free air at somewhat moderate elevations, such as can be easily obtained by kite flights up to 1000 or 2000 meters.*

TEMPERATURE DIFFERENCES AT THE SAME ELEVATION.

The results of the computations may be exhibited even more clearly by plotting the temperatures on the several 1000-meter levels, and drawing a line to separate the high temperature from the low temperature regions. Fig. 3 shows the distribution for the American and fig. 4 for the European cyclonic and anticyclonic regions. The loss of the data in the north sector of the American cyclone makes this line of demarcation uncertain in that area, but by analogy with the European data and from what we know of conditions at the surface it is probably quite like that indicated in the diagram. In spite of the fact that we have been using an insufficient amount of observations to render the temperature distribution entirely normal, it is yet evident that the *distribution is fundamentally the same in the American and European circulation. There is an inflow of cold air from the northwest between the centers of barometric high and low pressure, and an inflow of warm air from the south, likewise between the centers of low and high pressure. There are no cold-center anticyclones in any level, nor any warm-center cyclones in any level. There is no inversion of type from the surface to the highest level reached, with the possible exception of the surface and the 1000-meter level of the European cyclones in the winter.* I am at a loss to explain this last result, and suspect that it may be due to our imperfect elimination of the diurnal temperature variation from the data contained in Grenander's paper, or in the Hald and Berlin reports. This exception seems to constitute the basis for the claim that has been advanced for Professor Hann's theory that the warm-center cyclone below is replaced by a cold-center cyclone above, and that this inversion of temperature implies a dynamic system as the source of the level cooling. The fact is that the cool northwest winds in the upper levels follow the stream lines marked out in the diagrams of the Weather Bureau International Cloud Report, as given in chart 15, or in the MONTHLY WEATHER REVIEW, March, 1902. *They become more and more sinuous in descending from the cirrus levels to the surface, or below the strato-cumulus level, 3000 meters, curling more decidedly in an anticyclonic rotation with a tendency to divide into two branches. The southerly winds in the same way divide into two branches one curling into the cyclone on the northeast and the other into the anticyclone on the northwest of the respective centers.*

The mechanical cyclone and anticyclone, with centers of high and low pressure at the boundary between these cold and warm currents, are the dynamic effect of the vertical and horizontal motion of these currents of different temperature, just as has been explained in my previous papers. The observed vectors of velocity are such as to produce or accompany the temperature distribution here described, and the cold and the warm currents having different temperatures bear within themselves the source of the energy of storms. The fact is that storms are produced by *horizontal convection* more than by *vertical convection*. The latent heat of condensation is an additional source of energy, and the underflowing of warm currents beneath the eastward drift is another small source of energy, but these are distinctly subordinate to the horizontal or lateral convection between these counterflowing masses or sheets of air. The cyclone and anticyclone are the dynamic effects of this thermodynamic energy, and this function constitutes the true problem in meteorology for study. It is, therefore, evident that the different statements found in the literature of the subject regarding the cyclone being cooler than the anticyclone in the upper levels, have been imperfect and rough efforts to reach the facts here shown. Since the counterflow does have somewhat different configurations in the several levels, there is a difference of temperature to be obtained on proceeding from the surface upward over the same sector. But it is not proper to compare the temperatures of cyclones as a whole, from level to level, nor of anticyclones, without careful discrimination as to the subareas which are involved. It is important, likewise, to obtain the gradients over the warm and cold areas, separately, rather than over the cyclones and anticyclones taken as wholes, as was done in Tables 1, 2, 3, 4.

VERTICAL TEMPERATURE GRADIENTS PER 100 METERS.

Taking the mean gradients over the high areas and the low areas for the American and European temperatures, and limiting the means to the 4000-meter level for the sake of the comparison, we obtain from Tables 1, 2, 3, 4:

Winter.			Summer.		
	High areas.	Low areas.		High areas.	Low areas.
	° *F.*	° *F.*		° *F.*	° *F.*
American	− 0.42	− 0.43	American	− 0.62	− 0.63
European	− 0.40	− 0.55	European	− 0.50	− 0.57

TABLE 7.—*Temperatures and gradients in the American and European cyclones and anticyclones arranged by the warm and cold areas.*

Height in meters.	Blue Hill, winter.				Hald and Berlin, winter.				Blue Hill, summer.				Hald and Berlin, summer.			
	Warm.		Cold.		Warm.		Cold.		Warm.		Cold.		Warm.		Cold.	
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
6000	.....	.....	.....	.....	—24.9	—0.75	—29.0	—0.70	.....	.....	.....	.....	—16.2	—0.60	—22.0	—0.60
5800	.....	.....	.....	.....	—23.4	—0.80	—28.5	—0.70	.....	.....	.....	.....	—15.0	—0.65	—20.8	—0.65
5600	.....	.....	.....	.....	—21.8	—0.70	—27.1	—0.70	.....	.....	.....	.....	—13.7	—0.65	—19.5	—0.65
5400	.....	.....	.....	.....	—20.4	—0.65	—25.7	—9.65	.....	.....	.....	.....	—12.4	—0.60	—18.2	—0.60
5200	.....	.....	.....	.....	—19.1	—0.60	—24.2	—0.60	.....	.....	.....	.....	—11.2	—0.55	—17.0	—0.55
5000	.....	.....	.....	.....	—17.9	—0.55	—23.0	—0.55	.....	.....	.....	.....	—10.1	—0.55	—15.9	—0.60
4800	.....	.....	.....	.....	—16.8	—0.60	—21.9	—0.60	.....	.....	.....	.....	— 9.0	—0.60	—14.7	—0.55
4600	.....	.....	.....	.....	—15.6	—0.65	—20.7	—0.60	.....	.....	.....	.....	— 7.8	—0.55	—13.6	—0.60
4400	.....	.....	.....	.....	—14.3	—0.65	—19.5	—0.60	.....	.....	.....	.....	— 6.7	—0.55	—12.4	—0.60
4200	.....	.....	.....	.....	—13.0	—0.60	—18.3	—0.55	.....	.....	.....	.....	— 5.6	—0.60	—11.2	—0.60
4000	—11.9	—0.50	—17.6	—0.55	—11.8	—0.50	—17.2	—0.50	— 4.3	—0.70	— 9.2	—0.70	— 4.4	—0.50	—10.0	—0.55
3800	—10.9	—0.45	—16.5	—0.55	—10.8	—0.55	—16.2	—0.55	— 2.9	—0.60	— 7.8	—0.65	— 3.4	—0.50	— 8.9	—0.55
3600	—10.0	—0.50	—15.4	—0.50	— 9.7	—0.55	—15.1	—0.55	— 1.7	—0.65	— 6.5	—0.75	— 2.4	—0.50	— 7.8	—0.55
3400	— 9.0	—0.50	—14.4	—0.50	— 8.6	—0.55	—14.0	—0.60	— 0.4	—0.60	— 5.0	—0.70	— 1.4	—0.50	— 6.7	—0.50
3200	— 8.0	—0.55	—13.4	—0.55	— 7.5	—0.55	—12.8	—0.60	0.8	—0.65	— 3.6	—0.70	— 0.4	—0.40	— 5.7	—0.50
3000	— 6.9	—0.45	—12.3	—0.50	— 6.4	—0.40	—11.6	—0.60	2.1	—0.55	— 2.2	—0.65	0.4	—0.45	— 4.7	—0.45
2800	— 6.0	—0.45	—11.3	—0.45	— 5.6	—0.40	—10.4	—0.60	3.2	—0.60	— 0.9	—0.70	1.3	—0.40	— 3.8	—0.45
2600	— 5.1	—0.45	—10.4	—0.50	— 4.8	—0.40	— 9.2	—0.55	4.4	—0.55	0.5	—0.65	2.1	—0.40	— 2.9	—0.45
2400	— 4.2	—0.50	— 9.4	—0.40	— 4.0	—0.40	— 8.1	—0.60	5.5	—0.60	1.8	—0.65	3.0	—0.45	— 2.0	—0.50
2200	— 3.2	—0.45	— 8.6	—0.45	— 3.2	—0.45	— 6.9	—0.50	6.7	—0.55	3.1	—0.65	3.9	—0.45	— 1.0	—0.55
2000	— 2.3	—0.50	— 7.7	—0.40	— 2.3	—0.35	— 5.9	—0.50	7.8	—0.60	4.4	—0.60	4.8	—0.55	0.1	—0.55
1800	— 1.3	—0.50	— 6.9	—0.40	— 1.6	—0.35	— 4.9	—0.50	9.0	—0.50	5.6	—0.70	5.9	—0.55	1.2	—0.55
1600	— 0.3	—0.25	— 6.1	—0.40	— 0.9	—0.35	— 3.9	—0.60	10.0	—0.55	7.0	—0.65	7.0	—0.55	2.3	—0.60
1400	0.2	—0.15	— 5.4	—0.35	— 0.2	—0.20	— 2.7	—0.60	11.1	—0.50	8.3	—0.65	8.1	—0.55	3.5	—0.60
1200	0.5	—0.20	— 4.8	—0.30	0.2	—0.25	— 1.5	—0.60	12.1	—0.45	9.6	—0.40	9.2	—0.55	4.7	—0.60
1000	0.9	—0.20	— 4.6	—0.10	0.7	—0.40	— 0.3	—0.55	13.0	—0.40	10.4	—0.40	10.3	—0.50	5.9	—0.65
800	1.3	—0.35	— 4.3	—0.15	1.5	—0.35	0.8	—0.50	13.8	—0.55	11.2	—0.50	11.3	—0.50	7.2	—0.70
600	2.0	—0.50	— 3.8	—0.25	2.2	—0.35	1.8	—0.55	14.9	—0.55	12.2	—0.60	12.3	—0.50	8.6	—0.65
400	3.0	—0.65	— 2.9	—0.55	2.9	—0.30	2.9	—0.40	16.0	—0.70	13.4	—0.60	13.3	—0.55	9.9	—0.70
200	4.2	—0.65	— 1.8	—0.65	3.5	—0.30	3.7	—0.35	17.4	—0.65	14.6	—0.55	14.4	—0.55	11.3	—0.75
0	5.5	.....	— 0.5	.....	4.1	.....	4.4	.....	18.7	.....	15.7	.....	15.5	.....	12.8	.....

The American mean gradient is about the same for high and low areas at all seasons of the year, though the summer gradient is greater than the winter in the ratio of 3 to 2. This is a function of the observed difference of velocity for these two seasons. The European gradient is larger in cyclones than in anticyclones for both seasons, and there is not so much difference between them in the summer as in the winter. These variations depend upon the local conditions which control the origin and mixing of the countercurrents themselves. Surveying the gradient lines as a whole, I believe that they show that, after escaping from the surface confusion, the lines spread gradually up to 3000 meters, or the strato-cumulus level, where the difference is a maximum and that they then draw slowly together up to about the cirrus level where the eastward drift is usually undisturbed. This conforms to my solution obtained for the local cyclonic velocities, which showed that the *maximum gyration is in the cirro-cumulus level, and that it diminishes downward and upward without reversal.*[5] The discussion of these velocities and temperatures, together with the corresponding pressures will be undertaken in a later paper of this series. It is now evident that any adiabatic solution of the problem is inadequate, and that the omission of the heat added, $J\ Q=0$, is fatal to a satisfactory discussion of natural cyclones and anticyclones, because the observed gradients differ from the adiabatic gradient, 0.987 degree centigrade per 100 meters. Furthermore, the surrounding of fixed masses of air with artificial boundaries for the sake of a ready integration, also takes the problem out of the class of those required in meteorology, and makes merely special ideal cases which are out of our consideration. It has seemed to me proper to wait for the acquisition of approximate values of the velocity, temperature, and pressure before trying to do anything with the analytical solutions. Since it is the divergence of the local temperatures away from the mean temperature of the atmosphere which produces the local circulations, we should evidently compute the gradients in the warm and cold areas regardless of their distribution around the centers of pressure.

[5] Compare chart 68, International Cloud Report, figs. 6, 7; and Tables 11, 12, Monthly Weather Review, March, 1902.

TABLE 8.—*Temperature differences, cold minus warm areas.*

Height.	Winter.		Summer.	
	Blue Hill.	Hald and Berlin.	Blue Hill.	Hald and Berlin.
	° F.	° F.	° F.	° F.
6000	....	—5.0	.....	—5.8
5000	.....	—5.1	.....	—5.8
4000	—5.7	—5.4	—4.9	—5.6
3000	—5.4	—5.2	—4.3	—5.1
2000	—5.4	—3.6	—3.4	—4.7
1000	—5.5	—1.0	—2.6	—4.4
0	—6.0	+0.3	—3.0	—2.7

VERTICAL TEMPERATURE GRADIENTS IN THE WARM AND COLD AREAS.

By taking the mean temperatures at the different levels, arranged according to the warm and cold area groups indicated in Table 6, we obtain the temperatures and gradients of Tables 7 and 8. There are several results which can be readily seen on the face of the tables: (1) The temperatures at Blue Hill, Hald and Berlin are in sufficient agreement as to the absolute values in the several levels, to enable us to infer that the American and European systems are in harmony so far as the temperature is concerned. (2) The difference between the temperatures in the warm and cold areas is about 5.4° on the 4000-meter level, and it diminishes toward the surface, except at Blue Hill in winter. For Hald and Berlin in winter there is the anomalous inversion already mentioned. For summer, at all stations, the temperature difference is about 3° in the lower levels. (3) The gradient at Blue Hill in winter is —0.65° near surface, —0.20° at the 1000-meter level, and —0.50° at 4000 meters. Hald and Berlin show a compara, tively steady increase of the gradient from the surface—0.35°, to —0.75° at 6000 meters, with a slight diminution in the 1000 to 2000-meter stratum for the warm areas; in the cold areas the gradient is about —0.60° in the upper levels throughout a deep stratum. In summer the gradient at the surface is about —0.60°, at the 1000-meter level —0.40°, and at 4000 meters —0.65, at Blue Hill; at Hald and Berlin there is a diminution of the gradient up to the 3000-meter level and an increase up to the 6000-meter level for warm and cold areas. These facts are of special significance in the thermodynamics of

cyclonic circulations. These *temperature* gradients may profitably be compared with the gradients in high or low *pressure* areas taken as a whole. The departure of the temperature in each sector from the prevailing mean air temperature is evidently the basis for a thermodynamic discussion of the cyclonic problem.

RESULTS.

We conclude that there is no fundamental difference in the structure of American and European cyclones and anticyclones. The observed temperature distribution is in harmony with the observed atmospheric currents, and is due to an intermixture of currents from warm and cold latitudes, the energy of storms being thus referred to the heat transported from different latitudes. The pressure centers of motion occur on the boundaries of these countercurrents, and thus represent the dynamic effects of the thermodynamic energy. Instead of vertical convection being the primary cause of storms it is rather horizontal convection, interchange of heat energy on the same levels, as suggested in my preceding papers. There is no evidence of the superposition of cold-center cyclones upon warm-center cyclones, as expounded by Clayton or by Bjerknes and Arrhenius, nor are there purely dynamic vortices in a rapid stream as supposed by Hann, nor are there cyclonic vortices caused by atmospheric islands of high pressure obstructing a rapidly flowing eastward drift as explained by Shaw, or by Hildebrandsson in his report to the International Committee, 1905.

ATMOSPHERIC ELECTRICITY.

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The study of meteorology may be pursued with two entirely different ends in view. We may pursue it for utilitarian purposes, or we may pursue it as a pure science for the knowledge to be derived from it. It must be admitted that there are a number of so-called meteorologists whose point of view is the former, and whose highest ambition is the production of an almanac giving the state of the weather for each day a year in advance. Although some of the great advances of knowledge which have been of practical use to mankind have been made by the utilitarian student, yet experience has shown that without the pure scientist little real advance can be made. The true men of research, working for the sake of science itself, have always been the pioneers to open up new country and reveal new treasures, which the utilitarian has then appropriated and used. In meteorology we must not expect and seek for merely practical knowledge, but must investigate the atmosphere in a truly scientific manner, considering no phenomenon found in it to be unworthy of investigation. Thus although the electrical conditions of the atmosphere on a fine day are insignificant in comparison with the great motions of the atmosphere, or with the local conditions which determine the climate and weather of any place, yet meteorology can not be complete without a true knowledge of these conditions. While meteorologists must always be more concerned with the great changes in the motion, temperature, pressure, and humidity of the air, they must also not forget that electricity plays an important part in natural phenomena. Since the time of Franklin great progress has been made in our knowledge of the electrical conditions of the atmosphere, but so far the progress has led to no utilitarian results, and the problems of the thunderstorm are not yet solved. In the present article an attempt is made to sketch, in as few words and as simply as possible, the lines along which research has traveled.

One of the first lessons we learn on being introduced to the science of electricity is that a positively charged body placed between two others, one having a positive and the other a negative charge, will tend to move toward the latter. This we are told is due to the "electrical field" set up by the oppositely charged bodies.

The experiments of Franklin showed that such an electrical field exists in the atmosphere during thunderstorms. Later observers have shown that not only during thunderstorms, but also under normal circumstances, there is an electrical field in the lower atmosphere, such that a positively charged body would be attracted toward the surface of the earth. The electrical field of the lower atmosphere points to the permanent presence of a layer of negative electricity on the surface of the earth with a corresponding positive charge somewhere above the surface, but exactly where this positive charge is has been the subject of much controversy.

For a long time it was thought that the negative charge on the earth is a charge left there when the earth first became a separate member of the solar system. If that had been so then the corresponding charge of positive electricity would be somewhere right outside the earth and its surrounding atmosphere, in fact somewhere in cosmical space. We should thus have expected an electrical field, similar to that found near the surface of the earth, extending with only slightly diminished intensity to heights much greater than those of our atmosphere; but observations made in balloons have proved most conclusively that the electrical field found near the surface has nearly disappeared at a height of four and one-half miles (reached by Gerdien, November 5, 1903). This means that the outside positive charge corresponding to the negative charge on the surface of the earth is not outside the atmosphere, but is *distributed through the whole mass of air in the lower atmosphere.*

This result leads us to consider under what conditions electricity can exist in the atmosphere. Until 1900 the conception was firmly held by physicists that the air of the atmosphere in its normal state is a perfect nonconductor of electricity, and that if a charged body, perfectly insulated, were placed in air quite free from dust the charge would be retained indefinitely. That such a body never does permanently keep its charge was always ascribed to the presence of dust in the air. It was supposed that particles of dust coming into contact with the body take a part of the charge and are then repelled, and that thus in course of time the charge is in this way entirely dissipated on to the dust of the air. But in 1900 Elster and Geitel in Germany and C. T. R. Wilson in England showed that not only does a perfectly insulated body in perfectly pure air lose its charge, but that the presence of dust diminishes the rate of loss instead of increasing it.

Just before this time new ideas had been formed as to what takes place during the discharge of electricity through gases. It had been demonstrated that most, if not all, the phenomena then known to accompany the discharge of electricity through gases could be explained by assuming that an electrically neutral molecule of a gas can be split up into two other molecules or two atoms, each of which carries an electrical charge, one negative and the other positive. To these charged molecules the name "ion" had been given, an "ion" being understood to be any small material particle, generally of molecular dimensions, which carries a charge of electricity.

Elster, Geitel, and Wilson at once pressed this theory into service to explain the results of their experiments. They assumed that a small proportion of the molecules of ordinary air are always being split up into ions. Thus when a charged body is introduced into air the electricity on it attracts ions of the opposite sign which neutralize the charge, or in other words the charge is dissipated. Numerous experiments were made to prove or disprove this theory, but it has withstood all the tests and is now generally accepted. Elster and Geitel proceeded to work out in full the bearings of this new theory on the problems of atmospheric electricity. It at once became obvious that if there are always both kinds of ions in the atmosphere the negative charge on the earth will attract the positive ions toward itself, become neutralized and so disap-