TRANSACTIONS

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ARTICLE I.

On the Diurnal Variation of the Horizontal Needle. By Alexander Dallas Bache, Professor of Natural Philosophy and Chemistry in the University of Pennsylvania. Read November 16, 1832.

During the month of August, and part of September, of this year, the usual summer vacation of the University permitted my absence from the city, and finding myself favourably situated for meteorological observations, I undertook to observe the diurnal fluctuation of the barometer and thermometer, and, ultimately, the hourly variation of the horizontal needle. It was a source of great regret to me, that, in these latter observations, I was not also furnished with a dipping needle, or with the means of directly measuring the variation of magnetic intensity: the observations could all have been accomplished with little more inconvenience than the hourly observations of the horizontal needle gave; and the last named subject is more interesting than the point which I was enabled to observe. This being the case, I had determined not to make public these observations, but to use

the experience obtained when occasion might offer an opportunity of prosecuting more extended researches. This resolution has given way to the consideration, that magnetic phenomena have not yet been observed with that closeness of scrutiny to which other branches of experimental science have been subjected; that the inconvenience of hourly observations by day and *by night* have prevented many from entering this particular field; and, finally, that my observations appear to warrant interesting deductions not afforded by the printed observations which I have been able to examine.

It would be out of place, in a brief essay like the present, to attempt a sketch of the observations, either systematic or casual, made upon the diurnal variation of the needle; the references which will be made to other experiments, for the purpose of a comparison of results, will supply the place of such an outline. In making such comparisons, it is hardly necessary to observe, that I disclaim any intention of claiming for my results any more weight than is due to careful and frequent observation during the time for which they were obtained.

In the following account, I purpose, first, to give a description of the instrument, and of its location, and of the mode of observing; next, to present the observations; and, lastly, the conclusions which they may warrant.

The needle was thirty-six inches long, .04 of an inch thick, broader, in its horizontal section, at the middle than at the two ends: it was supported by a steel pivot playing into a ruby cap, and was contained in a prismatic box of mahogany, covered by sliding plates of glass. The weight of the needle was three hundred and fifty-five grains. Attached to each end of the box was a brass arc, divided into degrees and tenths. The zero of each arc, and the pivot on which the needle rested, were in the same line; but the point in the ruby cap, upon which the needle rested, was found to be out of the line joining the two ends. On which account, as well as to render the observations more accurate, two readings were always made: one on the scale near the north pole, the other on that near the south pole of the needle. The nature of the suspension of this needle, though sufficiently delicate for the purposes immediately in view, did not warrant my using its oscillations to obtain the intensity; its shape and length rendering it, besides, un-

suitable to such observations, and inducing the fear that it might be liable to changes of magnetism, which would have been fatal to such results.

The relative amount of variation being the object sought, it was only necessary that the needle box should remain in a fixed position during the observations. Wishing, however, further to determine the mean variation of the place of observation, I employed, for tracing a meridian line, the best means which were at hand; namely, equal altitudes of the sun before and after noon, as shown by the passage of the bright image of a circular opening in a metallic plate attached to a style, over a horizontal circle, the centre of which corresponded with the vertical passing through the middle of the opening. This method is well known, and needs no particular description here; the platform used was of wood, the top planed and levelled by a spirit level. Only a portion of the form was truly level, and this portion was used in observing the altitudes. Concentric circles were drawn upon the platform, their centre being in the vertical passing through the centre of a round hole in a copper plate attached to a style; the style was fastened to the middle of the south side of the platform. The shadow of the plate first fell upon the edge of the platform at $10\frac{1}{2}$ A.M., and left it at 2 P.M.; nine observations were made of the passage of the centre of the image of the aperture over different circles, from which the meridian line was determined. The points given by seven observations were in the line; and of those given by two others, the farthest departed but one minute and a half from the same line. The limit of the error by this method is small, though much beyond that which other methods would have furnished. I repeat, however, that this error affects only the mean variation, and not the horary variations.

This platform, upon which the needle rested, was supported upon three posts, about six inches high, and firmly planted; to these it was attached by wooden pins: the same kind of pins had been used in the construction of the platform itself. The location of the platform was in a garden, more than forty feet from the house, and fifteen from a small paling which formed the inclosure. The garden was upon the side of a hill, the ground sloping towards a meadow: a hill enclosed

this gorge both on the east and west: behind the western hill the sun passed about eighteen minutes before the time of sunset.

The meridian line having been determined, the box containing the needle was placed upon it, the zero line coinciding with the meridian; the points at which the edge of the box was cut by the line were then marked, so that any change of position might be detected. A temporary inclosure of shingles was next placed around and over the platform, to defend both the platform and the needle from the sun and rain.

The labour of prosecuting hourly observations, by night as well as by day, could not well be endured by a single individual for any number of successive days; and mine, though extending through parts of ten days, would have met with more interruptions, but for the intelligent aid afforded by my friend and former pupil, John F. Frazer, who took a share in the labour of watching. It did not take many nights to perceive that the period from 1 A.M. to seven or eight o'clock, did not include any remarkable points; and when circumstances seemed to permit it, I did not continue the observations between those hours.

A few trials enabled me to determine that the space between the tenths on the scale was readily divisible by the eye into fourths, with accuracy as to the nearest quarter, both by my assistant and myself: the observed variation was therefore thus registered, and the limit of accuracy of one reading was one minute and a quarter. The observations have been turned into minutes and decimals of a minute. To show the errors of reading, no better test can be had than to compare the differences of two readings of both the north and south pole, when either one was at or near the same position. As the most unfavourable specimen of such readings, may be taken the time of the first twenty-four hours, when the observers were the least practised: such a specimen is given in the first table, and it is to be understood that the observations of subsequent days presented much smaller errors of observation, than the average of those there recorded. The observations were begun a few hours before noon, and each table comprehends twelve hours of two successive days.

The temperature of the air was noted at the same time with the variation; the place of the thermometer was in the shade near the

house, unless when specially noted to give the temperature of the needle itself. I regretted not having at command instruments to notice both these points at the same time; as the case was, I endeavoured to vary the observations, so as to procure, by separate observation, the same results as far as practicable. The character of the weather, the prevailing clouds, &c., were noted in the column of remarks. Observations were made also upon the barometer and dew point, which I may make the subject of a separate communication to the society.

In the table, under the column for the hour, M. is used to signify noon, and m. midnight. The days of the month are in the column of remarks.

TABLE I.

Hour. Mean time.	Variation. N. Pole W.	Variation. S. Pole E.	Differences.	Mean. N. Pole W.	Temp. Fah.	State of the Weather and Remarks.
	Deg. Min.	Deg. Min.		Deg. Min.	Deg.	
12 M.	3 29.6	3 25.7	3.9	3 27.6	74½	Aug. 29th. Cumulus. Moon near first quarter.
1 P.M.	3 28.3	3 25.0	3.3	3 26.6	76½	
2 P.M.	3 25.1	3 24.2	0.9	3 24.6	78⅛	
3 P.M.	3 23.5	3 21.8	1.7	3 22.6	78⅛	Cumulus. Clear before sun.
4½ P.M.	3 22.6	3 21.8	0.8	3 22.2		Sun striking on end of needle. Further covering added.
5½ P.M.	3 21.8	3 21.0	0.8	3 21.4	76	
6½ P.M.	3 20.2	3 17.3	2.9	3 18.7		Sun sets at 6 h. 33 m.
7 P.M.	3 20.2	3 17.3	2.9	3 18.7	74¾	Clear.
8 P.M.	3 22.6	3 21.8	0.8	3 22.2	71	Clear.
9 P.M.	3 28.3	3 27.2	1.1	3 27.7		Clear.
10 P.M.	3 27.5	3 26.4	1.1	3 26.9	69⅓	Clear.
11 P.M.	3 27.5	3 26.4	1.1	3 26.9	68¼	Clear.
12 m.	3 28.3	3 27.2	1.1	3 27.7	66⅞	Clear.
1 A.M.	3 28.3	3 27.2	1.1	3 27.7	66¼	Clear. Aug. 30th.
2 A.M.	3 26.7	3 25.7	1.0	3 26.2		Clear. Needle vibrating. Observation not good.
3 A.M.	3 23.5	3 22.6	0.9	3 23.0	66½	Hazy.
4 A.M.	3 21.0	3 20.3	0.7	3 20.6	66¼	Clear.
5 A.M.	3 21.0	3 20.3	0.7	3 20.6	66¼	Dense fog.
5½ A.M.	3 21.0	3 20.3	0.7	3 20.6	66¼	Dense fog. Time of sunrise.
6 A.M.	3 21.8	3 21.0	0.8	3 21.4	66	Fog less dense.
7½ A.M.	3 21.8	3 21.0	0.8	3 21.4	67¼	Foggy.
8½ A.M.	3 20.2	3 19.6	0.6	3 19.9		Foggy.
9 A.M.	3 21.0	3 18.9	2.1	3 19.9	70¾	Fog clearing off.
10 A.M.	3 25.9	3 24.2	1.7	3 25.0	72	Cumulus. Sun out. Fog gone.
11 A.M.	3 25.9	3 25.0	0.9	3 25.4	77½	Cumulus.
12 M.	3 27.5	3 25.0	2.5	3 26.2	78½	Cumulus.

The greatest difference of the numbers of the second and third column in the foregoing table is at the beginning, as might have been expected, where it amounts to nearly four minutes, and shows that the first two observations are of little value; the greatest subsequent variation from the mean difference is about one minute and a half.

To have a perspicuous view of the results of the observations for every twenty-four hours, I traced, at the close of each series, a curve, the ordinates of which represented the variation, and the equidistant abscissæ the hours. By writing, at the side of each ordinate, the remarks on the weather, the view was rendered more complete. To compare the progress of the variation with that of the temperature, a curve was traced below the former, in which the ordinates represented the temperatures. The crude observations suggested by the visible representation of the day's results, given in chart No. 1, (see Plate I.*) are not here added; it may not be amiss, however, to state, that my object at this time in tracing the curve of temperature, as well as that of variation, was to ascertain whether the directive force underwent correlative changes with the temperature, as the intensities were supposed to do by M. Kupffer from his first experiments.*

Two maxima of westerly variation, and two minima were distinctly seen in this day's results. The first maximum was at noon day; the second between midnight and 1 A.M. The first minimum was between $6\frac{1}{2}$ and 7 in the afternoon, and the second between $8\frac{1}{2}$ and 9 in the morning. There is, on the contrary, but one tide of temperature, rising until between 2 and 3 in the afternoon, descending with variable rapidity until 6 in the morning, half an hour after sunrise. The descent of the curve is interrupted by the fog, and it was not unnatural to suppose this to have its effect on the hour of the minimum. The hour of evening minimum variation differs, it will be observed, from that obtained by Canton and Gilpin, suggesting a close attention to the results furnished by the subsequent observations.

In the following tables the mean of the observed variations shown by the north and south pole of the needle is given. The hours from

* Recherches sur les Variations de la durée Moyenne des oscillations horizontales de l'aiguille aimenté, &c. A. T. Kupffer, Annales de Chim. et de Phys. vol. 35 (1827).

noon to midnight of the 30th of August are in one column; and in the parallel column, those from midnight to noon of the 31st.

TABLE II.

Hour.	Variation. N. Pole W.	Temp.	Remarks.	Hour.	Variation. N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 26.2	78½	Aug. 30. Clear.	12 m.	3 26.9	71⅜	Aug. 31. Fog.
1 P.M.	3 25.8	80⅜	Sun under cloud. Sky generally clear.	1 A.M.	3 25.4	70¾	Fog. Therm. hung near needle box. Temp. the same as before removal.
2 P.M.	3 25.8	79¼	Clear.	2 A.M.	3 23.8	71¾	
3 P.M.	3 27.0	80	Clear.	3 A.M.	3 22.2	71⅜	
4½ P.M.	3 23.9	81½	Clear.	4 A.M.	3 22.2	71¾	
				5 A.M.	3 21.0	71⅜	
5½ P.M.	3 23.9	79¼	Clear.	5½ A.M.	3 20.3	72¼	Hazy.
				6 A.M.	3 20.7	72½	
6½ P.M.	3 21.9	75⅞	Clear.	6½ A.M.	3 19.9	72	Mist.
7 P.M.	3 19.9	73⅝	Clear.	7½ A.M.	3 18.7	72¾	
8 P.M.	3 26.2	73	Sky cloudless.	8 A.M.	3 19.1		
9 P.M.	3 28.5	71⅜	Sky cloudless.	9 A.M.	3 18.7	77¾	
10 P.M.	3 28.5	70½	Sky cloudless.	10 A.M.	3 19.9	77⅝	Sun gleams out. Therm. removed to house.
11 P.M.	3 26.9	70¾	Stars not visible through fog. Wind variable.	11 A.M.	3 23.8	80⅜	Sun out. Cumulus.
11½ P.M.	3 26.9	71⅜		11½ A.M.			Variation greater than at 11.
12 m.	3 26.9	71⅜		12 M.	3 26.3	81½	Cumulus. Sky generally clear.

The curves in No. 2, Plate I.*, are those of the variation and temperature from the table just given. We see that the general features are the same, but the details vary very much. We may trace the causes of these variations in the curves of temperature, though the knowledge which we possess on the subject of the variation of the needle does not permit us to do so for it. Both days were clear about noon, with flying clouds (cumulus); the second was a day of settled weather succeeding the first, and the maximum temperature was higher; but about noon in No. 2, the sun was frequently obscured by clouds, and the hour of maximum was removed to between 4 and 5 P.M. No. 1 was de-

scending to the sunrise minimum, when the observation at 3 A.M. showed a rise of temperature, and a haze is noted at the same time; No. 2 in like manner is descending to the same minimum, when, at between 10 and 11 P.M., an irregular rise commences, and a fog is noted, varying only in density, until late in the morning: this fog checked more or less completely the powerful radiation from the earth, which was going on before the screen of fog was interposed between the earth and sky.

It is worthy of note, that in No. 1, at the observation preceding the remark "hazy," we find the memorandum, "needle vibrating."

TABLE III.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 26.3	81½	Aug. 31.				Sept. 1.
1 P.M.	3 25.4	83					
2 P.M.	3 26.5	84⅞	Shower comes up, lasts 4m.; recommences at 2h. 11m. and rains until 2h. 27m.				
2½ P.M.	3 10.7	84⅞	Ceases to rain for an instant, then recommences.				
3 P.M.	3 25.8	82¼	Sun out.				
4 P.M.	3 23.8	85¼	Sun under a cloud.				
5½ P.M.	3 23.2	84¼	Sun under a cloud. Gust to N. of W.				
5⅘ P.M.	3 10.3	79¾	Rain just begun.				
6 P.M.	3 14.3	78½	Heavy part of gust has passed. Thunder to S.E.				
7 P.M.	3 32.0 3 36.8	77¾	Needle vibrating. No rain. Much thunder and lightning.				
8 P.M.	3 32.4	78⅝	Raining steadily. Gust has entirely passed.	8 A.M.	3 23.8	71¾	Clear.
9 P.M.	3 31.7	77¾	Not raining. Cloudy.	9 A.M.	3 18.3	64	Cloudy. Therm. placed in compass box.
10 P.M.	3 32.0	75	Cloudy.	10 A.M.	3 19.1	65	Cumulus. Sky generally clear.
11 P.M.	3 26.5	75	Raining slightly.	11 A.M.	3 19.9		
12 m.	3 26.2	71	Perfectly clear. Wind N. W.	12 M.	3 20.4	67	Approximate, calculated from that at 12½ P.M.

The meteorological phenomena of this day were particularly interesting, and will be referred to in detail: the curves of observations are on No. 3, Plate I.* The variation evidently diminishing at midnight, and the sky being clear, the observations were intermitted until 8 A.M. Great pains were bestowed in noting the fluctuations before, during, and after the shower and the gust in the afternoon; the periods of change being seized for observation.

TABLE IV.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.	Sept. 1.		Deg. Min.	Deg.	Sept. 2.
			Clear. Therm.	12 m.	3 34.9	58	Cloudless night.
12½ P.M.	3 21.0	67½	on the platform	12½ A.M.			Cloudless.
			with needle.				
1 P.M.				1 A.M.	3 33.2	58	Cloudless.
1½ P.M.	3 21.9	68	Clear.	1½ A.M.			
2 P.M.				2 A.M.	3 32.0	56	Cloudless.
2½ P.M.	3 21.4	70	Stratus to west.	2½ A.M.			
3 P.M.	3 22.2	69¾	Clear.	3 A.M.	3 32.0	48	Cloudless.
4 P.M.				4 A.M.	3 32.0	47	Cloudless.
5 P.M.	3 22.6		Clear.	5 A.M.	3 31.7	46½	Cloudless.
5½ P.M.				5½ A.M.	3 32.0	44	Cloudless.
6 P.M.	3 15.1	69	Clear.	6 A.M.	3 30.8	47	Clear.
6½ P.M.			Sun sets.	6½ A.M.	3 21.9	48	Clear.
7 P.M.	3 14.7	67½	Cloudless.	7 A.M.			
7½ P.M.				7½ A.M.	3 19.1	58	Clear.
8 P.M.	3 16.0	62½	Cloudless. Moon in first quarter.	8 A.M.	3 12.6	61	Clear.
8½ P.M.				8½ A.M.	3 10.6	64	Clear.
9 P.M.	3 28.5		Cloudless.	9 A.M.	3 12.6	66	Clear.
10 P.M.	3 28.9	60	Cloudless.	10 A.M.	3 13.5	72	Clear.
11 P.M.	3 34.9	59½	Moon sets. Cloudless night.	11 A.M.	3 15.1	76	Clear.
				11½ A.M.	3 12.7	76	Clear.

The weather of the first part of this twenty-four hours was slightly affected by the storm of the day before; there was a stratus to the west at 2½ in the afternoon, which, when it disappeared, left a cloudless day, succeeded by a perfectly clear and still night. The thermometer was, throughout the observations, placed in the inclosure containing

the platform, and half hourly observations were resorted to about some of the times remarked by former observations as containing maxima or minima of variation.

The curves given by these observations are traced on No. 4, Plate I.* The free radiation of heat during the night from the earth, caused a great depression in the temperature of the air near to it, the sunrise minimum of the thermometer being as low as 44°, the maximum of the day having been 69¾°.

TABLE V.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	Sept. 3.
12 M.	3 18.7	76	Sept. 2. Clear.				
12½ P.M.	3 19.9	77½	Clear.				
1 P.M.	3 25.4	80½	Clear.				
1½ P.M.	3 25.4	80	Clear.				
2 P.M.	3 25.4	81	Clear.				
2½ P.M.	3 26.9	79½	Clear.				
3 P.M.	3 26.9	79½	Clear.				
3½ P.M.	3 26.9	79½	Clear.				
4 P.M.	3 26.9	79½	Clear.				
5 P.M.	3 25.4	76	Clear.				
6 P.M.	3 23.0	70	Clear.				
6½ P.M.	3 23.0		Sun sets. Sky generally clear. Cirrus and light cumulus.				
7 P.M.	3 25.4	63	Clear.				
8 P.M.	3 29.3	60	Cloudy. Moon wading through dark cirro-cumulus.	8 A.M.	3 26.2	64	Therm. near house. Cloudy. Dark cumulo-stratus.
9 P.M.	3 29.3	58	Cloudy.	9 A.M.	3 21.9	64	Cloudy. Wind N. E.
10 P.M.	3 27.7	58	Clouds more dense.	10 A.M.	3 22.6		Cloudy.
11 P.M.	3 26.2	58	Moon dips behind hill.	11 A.M.	3 23.0	65½	Cloudy.
				12 M.	3 22.6	65½	Raining.

The night maximum having decidedly passed before 11 P.M., the observations were not made after that hour during the night. The curves of variation and temperature are traced on No. 5, Plate II.*

TABLE VI.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	T mp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 22.6	65½	Sept. 3. Raining.	12 m.	3 30.1	60½	Sept. 4.
1 P.M.	3 23.0	65½	Rain ceased. Rain recommenced.	1 A.M.	3 29.3	60½	Raining fast. Wind draws more to south.
2 P.M.	3 26.9	66	Not raining. Nimbus high.				
3½ P.M.	3 26.9	64½	Not raining.				
5 P.M.	3 26.2	66					
6 P.M.	3 21.9	65					
6½ P.M.	3 23.4	65					
7½ P.M.	3 24.6	64					
8 P.M.				8 A.M.	3 16.0	64½	Nimbus.
8½ P.M.	3 26.2	63		8½ A.M.			
9½ P.M.	3 24.6	63		9½ A.M.	3 16.8	66½	Drizzle.
10½ P.M.	3 27.7	62	Slight rain. Wind S. E.	10½ A.M.			
11 P.M.				11 A.M.	3 18.3	67½	Slight rain.
12 m.	3 30.1	60½		12 M.	3 21.0	68½	Slight rain. Clouds lighter than at last observation.

This table will be found interesting, as showing the effect of a steady rain upon the variation. The maximum being passed at 1 A.M., the observations were discontinued until 8 in the morning. The results are traced on No. 6, Plate II.* The thermometer was not in the needle inclosure, but in a fair exposure on the outside of the house.

TABLE VII.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 21.0	68½	Sept. 4. Gentle rain.	12 m.	3 26.9	69	Sept. 5. Fog less dense. Wind N. of W.
1 P.M.	3 21.4	69½	Not raining. Nimbus.	1 A.M.	3 26.2	68	Needle vibrating slightly. Fog more dense. Air almost still.
2 P.M.							
2½ P.M.	3 21.8	71½	Sun gleams out. Nimbus. Cumulus. Wind S.W.				
4 P.M.	3 25.8	74	Cumulus. Cumulo-stratus.				
5 P.M.	3 25.8	73½	Cumulus.				
6 P.M.	3 24.6		Cumulus. Sun sets in clouds.				
7 P.M.	3 25.8	68	Clear. Cumulus scattered.				
8 P.M.	3 25.8	68	Clear. Fog collecting in valley.	8 A.M.	3 24.9	62½	Needle vibrating. Cloudless. Wind N. W.
9 P.M.	3 26.6	68	Fog in valley.	9 A.M.	3 20.3	63	Clear generally. Cumulus.
10 P.M.	3 26.6	68	Fog dense. Moon obscured.	10 A.M.	3 22.2	64	Clear generally.
11 P.M.	3 26.2	68	Dense fog. Wind hauling to W.	11 A.M.	3 24.3	64½	Clear generally.
12 m.	3 26.9	69	Fog less dense. Wind N. of W.	12 M.	3 24.6	65½	Scattered cumulus.

The weather was very unsettled during these twenty-four hours; there was a rain, then the sky cleared; a fog, which occupied the former part of the night, was dispersed before 8 o'clock in the evening. The wind, at first S. E., shifted to S. W., gradually drew more to the W. and N., and finally settled at N. W. The thermometer was observed on the outside of the house. The curves of variation and temperature are traced on No. 7, Plate II.*

The weather now became settled, and the observations for every hour are given in the following table.

TABLE VIII.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 24.6	65½	Sept. 5. Scattered Cumulus. Wind N.W.	12 m.	3 34.9	54	Sept. 6. Clear.
1 P.M.	3 25.5	66	Ditto.	1 A.M.	3 30.1	53	Clear. Moon (in 2d quarter) sets.
2 P.M.	3 25.8	66½	Ditto.	2 A.M.	3 31.7	52½	
3 P.M.	3 25.8	67½	Ditto.	3 A.M.	3 32.8	45½	Cloudless. Therm. in inclosure with needle box.
4 P.M.	3 26.5	68	Ditto.	4 A.M.	3 32.8	44½	
4¾ P.M.	3 26.2	67½	Ditto.	5 A.M.	3 31.7	44	
6 1/12 P.M.	3 21.0	64	Wind has lulled. Sun behind hill.	6 A.M.	3 30.5	47½	
7 P.M.	3 19.9	63½		7 A.M.	3 21.7	55	
8 P.M.	3 25.8	60½	Cloudless.	8 A.M.	3 21.4	62	Therm. removed to house, where it stood at 59½.
8½ P.M.				8½ A.M.	3 22.2		
9 P.M.	3 26.2	57	Cloudless.	9 A.M.	3 21.0	60½	Slight haze (stratus).
10 P.M.	3 26.2	57	Cloudless.	10 A.M.	3 21.7	62	Ditto.
11 P.M.	3 32.1	55½	Scattered cumulus to S.	11 A.M.		63	
12 m.	3 34.9	54	Clear.	12 M.	3 22.2	64	Stratus. Cumulus. Wind W.

From 3 until 8 A.M. the thermometer was in the inclosure with the needle. On its removal to the house, it fell 2½° below its temperature at the former station.

These curves are given in No. 8, Plate II.*

The afternoon of September 6th was clear, with occasional cirrus and collecting cumulus; dew was deposited immediately at sun set, and a dense fog occupied a part of the morning of the 7th. It was proposed to make at least one day's observations with the needle exposed to the direct action of the sun, and by mistake the covering was removed before twelve o'clock on the 7th, as will be seen by the remark in the subjoined table. The curve (No. 9, Plate III.*) representing the observations of this day, terminates at the observation for 9½ A.M.

TABLE IX.

Hour.	N. Pole W.	Temp.	Remarks.	Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.			Deg. Min.	Deg.	
12 M.	3 22.2	64	Sept. 6. Stratus. Cumulus. Wind W.	12 m.	3 26.6	54	Sept. 7.
1 P.M.	3 22.6	65		1 A.M.	3 26.2	53	
2 P.M.	3 22.6	66					
3 P.M.	3 22.6	67					
4 P.M.	3 22.6						
5¾ P.M.	3 21.0	67	Dark cumulo-stratus to W.	5½ A.M.	3 24.1	54	Low stratus driving fr. E. High cumulus fr. S.W.
6 P.M.	3 21.4	64½	Cirrus.				
6½ P.M.	3 23.0	62¾	Dew deposited at sunset.				
7½ P.M.	3 23.0	58	Cirrus. Rare Cumulus.				
8 P.M.				8 A.M.	3 22.2	60	Dense fog.
9 P.M.	3 26.6	54	Cloudless.	9 A.M.	3 23.3	64	Fog has disappeared.
9½ P.M.				9½ A.M.	3 23.5		Clear. Cumulus sometimes over sun.
9¾ P.M.				9¾ A.M.	2 57.8		Roof removed, variation diminished rapidly, and at 9¾ had increased again to 2 57.8.
10 P.M.	3 26.6	54		10 A.M.	2 58.2	66½	
11 P.M.	3 26.6	52	Very slight haze.	11 A.M.	3 16.0	67	
12 m.	3 26.6	54	Cumulo-stratus to W. Wind drawing to S. of W.	12 M.	3 33.2	69	Vibrating.

On the removal of the covering from the needle, much water was evaporated from the bottom and sides of the box, collecting in drops on the glass at the N. and S. ends of the box; this was wiped off as it collected, by removing the glass. The sudden diminution of variation, and its rapid increase, are points worthy of remark.

The remaining observations were made with the sun upon the needle, a thermometer being inclosed in the box so as to have, hourly, the temperature of the needle. A day intervened between the last observations and those in the table which follows; during that day the

box became thoroughly dry, and at night the needle was covered over to prevent a reduction of temperature which would have produced a deposit of dew upon it. The effects shown in the following table are therefore due to comparatively sudden variations of temperature.*

The broken lines representing the observations will be found on No. 10, Plate III.*

TABLE X.

Hour.	N. Pole W.	Temp.	Remarks.
	Deg. Min.	Deg.	
7½ A.M.	3 17.5		Sept. 8. Clear. Needle covered.
8½ A.M.	3 06.0		Needle uncovered.
9½ A.M.	3 13.5		Hazy. Cumulus.
10 A.M.	3 22.2	94	Vibrating between 3° 20′.6 and 3° 23′.8. Therm. in needle box.
11 A.M.	3 39.6	104	Scattered cumulus.
12 M.	3 32.2		Vibrating between 3° 38′.3 and 3° 26′.2. Scattered cumulus. Sun occasionally clouded.
1 P.M.	3 38.3	97	Ditto.
2 P.M.	2 59.2	94	
3 P.M.	2 59.2	86	Sun under a cloud.
4 P.M.	2 59.2	82	Cloudy.
6¾ P.M.	2 26.0	67	Sun has set clear.
8 P.M.	2 44.9	60	Cumulus. Cumulo-stratus.
10 P.M.	2 52.0	54	

The first conclusion which I would draw from a review of the entire series of observations is, that *there were, for the time embraced by them, two maxima and two minima of westerly variation, within every twenty-four hours.* This fact is distinctly shown in each of the curves, and will be pointed out particularly by endeavouring to determine the hours of maximum and minimum variation.

This result agrees with that obtained by Mr Canton, from his extended series of observations, and subsequently by Mr Gilpin. Col. Beaufoy, still later (1813 to 1822), had evidence of the occurrence of the same maxima and minima, though he seems not to have been able to fix the time of the evening minimum.

* Very little consideration will serve to show that these effects cannot be ranked with those recorded by Mr Fox in the Philosophical Magazine for October 1833.

The observations of Capt. Parry and Lieut. Foster at Port Bowen, are of the more interest, that, from the peculiarity of their situation, there was but one point of maximum and one of minimum variation during twenty-four hours. These observations were made nearly every hour of the *day and night.* The latitude of Port Bowen is 73° 14′ N., and the variation of the needle 124° W.

As far as the observations of Lieut. Hood, at Fort Enterprize, warrant any conclusion, it is coincident with that just noticed; the point of maximum easterly variation and that of minimum easterly variation are clearly shown in his observations. Fort Enterprize is in latitude 64° 28′ N., and the mean variation is about 36° 24′ E.

The second conclusion which the foregoing observations seem to me to warrant is, that, through the irregularities which they present, there is shown *a general horary variation as the primary phenomenon and the effects of meteorological changes as modifying causes;* often overcoming the diurnal variation, and impressing their own alterations upon the variation of the needle.

To examine the first part of this deduction, I will follow, in their general features, the several curves traced to represent the observations, omitting No. 3 on account of its peculiarities.

1. The variation is at its maximum during the day, at or near the hour of highest temperature. The greatest difference between these times is two hours and a half. But the day maximum seems subject to great changes of position; in one case occurring at noon, in another not until 5 P.M. These deductions are shown in the tabular view which follows.

Number of Curve.	Hour of Maximum Variation.	Hour of Maximum Temp.	General character of the weather.
No. 1.	12 M.	2⅓ P.M.	Nimbus before noon, and clear just before noon.
No. 2.	3 P.M.	4½ P.M.	Clear, with floating clouds.
No. 4.	3 to 5 P.M.	2½ P.M.	Generally clear, follows unsettled weather.
No. 5.	2½ to 4 P.M.	2 P.M.	Clear. Needle stationary from 2½ to 4 P.M. No proper maximum.
No. 6.	2 to 3½ P.M.	2½ to 4 P.M.	Raining in the morning. Weather variable.
No. 7.	4⅓ P.M.	4 P.M.	Cloudy. Weather variable.
No. 8.	4 P.M.	3⅔ P.M.	Clear.
No. 9.	1 to 4 P.M.	4 P.M.	Cloudy. The observation of the needle at 4 P.M. was uncertain.

2. The westerly variation decreases from this variable maximum to a minimum, which is near the hour of sunset. The time of this minimum is included within the narrow limits of $5\frac{3}{4}$ and 7 o'clock.*

Number of Curve.	Hour of Minimum Variation.	Hour of Sunset.	Remarks.
	H. Min.	H. Min.	
No. 1.	6 45 P.M.	6 33 P.M.	Clear in the afternoon and at sunset.
No. 2.	7 00 P.M.	6 32 P.M.	Sun sets clear.
No. 4.	7 00 P.M.	6 29 P.M.	Sun sets clear.
No. 5.	6 20 P.M.	6 28 P.M.	Cirrus.
No. 6.	6 00 P.M.	6 27 P.M.	Cloudy. Weather variable.
No. 7.	6 00 P.M.	6 26 P.M.	Sun sets in clouds.
No. 8.	6 45 P.M.	6 24 P.M.	Sun sets clear. Sinks below hill at 6h. 5m.
No. 9.	5 45 P.M.	6 23 P.M.	Sun sets in clouds.
No. 10.	7 16 P.M.	6 21 P.M.	Sun sets clear. The hour of minimum is calculated, the observations show that it was after $6\frac{3}{4}$h.

3. The variation increases from the minimum just determined to a variable maximum which is reached at or about midnight. On the nights when the weather was not variable, this appears, from the following table, to be true.

Number of Curve.	Hour of Maximum Variation.	Remarks.
	H. Min.	
No. 1.	12 40 A.M.	Clear.
No. 2.	9 25 P.M.	Succeeded by a fog.
No. 4.	11 10 P.M.	Clear.
No. 5.	8 15 P.M.	Cloudy. Clouds increase in density after this hour.
No. 6.	12 00 m.	Raining before and after this hour.
No. 7.	12 00 m.	Fog.
No. 8.	11 40 P.M.	Clear.
No. 9.		Stationary from 9 until 12.

4. From this maximum there is a descent, more or less irregular, to a morning minimum, between 8 and 9 o'clock.

* This places the evening minimum at a much earlier hour than that given by other observers, and from results which I have obtained since, in the city of Philadelphia, I am inclined to suppose it to have resulted from some peculiarity in the locality or season.

Number of Curve.	Hour of minimum westerly variation.		Remarks.
	H.	Min.	
No. 1.	8	52	Fog clearing away.
No. 2.	9	00	Fog not breaking until near ten.
No. 3.	9	00	Cloudy.
No. 4.	8	30	Clear. The curve seems to indicate that the true minimum was earlier than 8 h. 30 m. or at 8 h. 2 m.
	8	02	
No. 5.	9	00	Cloudy.
No. 6.	8	00	Nimbus. There is a doubt if the true minimum was observed.
No. 7.	9	00	Cloudless.
No. 8.	9	00	Slight haziness.
No. 9.	8	00	Dense fog, which entirely disappeared before 9 o'clock.

It cannot be affirmed that this minimum was not placed at this particular hour, by the effect of the weather, for there are but two observations when the weather was clear, and but three when it was steady, in one of which (No. 6) the minimum may have occurred before any observation was made. It agrees, however, with the recorded observations of others. The observed minima did not depart in any two observations more than one hour from each other.

In order to determine these points still more unexceptionably, and with the further view of observing the effect of meteorological causes, I have taken the mean of the results of eight of the days of observation, including No. 3, for each hour. They are given in the following table; and curve No. 11, Plate III.* is traced from them. The last column of the table shows the number of observations from which each mean has been deduced, giving, therefore, the relative authority of each.

When the observations were made at the half hours, the mean of half an hour before and half an hour after was taken, as the number for the variation or temperature at the hour. A similar calculation was made for the variation at any particular hour, when no observation had been made, whenever the interval between two observations did not exceed an hour and a half. The mean temperature of the day having varied considerably in the changes of weather, it was thought more correct to enter into the columns of temperature, at the several hours on which observations were not made, an average of the next preceding and succeeding observation, whenever the intervals

were considerable. After making this correction, the daily maximum appears to be nearly at the hour on which it occured in clear weather.

Table of Mean Variation and Temperature from noon of August 29th to noon of September 7th, 1832.

Hour.	N. Pole W.	No. of Obs.	Temp. Fahr.	No. of Obs.	Hour.	N. Pole W.	No. of Obs.	Temp. Fahr.	No. of Obs.
	Deg. Min.		Deg.			Deg. Min.		Deg.	
12 M.	3 23.3	9	71.2	9	12 m.	3 29.3	8	63.0	8
1 P.M.	3 24.1	9	72.6	9	1 A.M.	3 28.3	7	61.6	7
2 P.M.	3 24.5	9	73.5	9	2 A.M.	3 28.4	4	60.1	3
3 P.M.	3 24.9	9	73.5	7	3 A.M.	3 27.5	4	57.8	4
4 P.M.	3 24.7	9	74.0	6	4 A.M.	3 26.9	4	57.4	4
5 P.M.	3 24.4	8	73.5	6	5 A.M.	3 26.2	4	57.0	4
6 P.M.	3 20.5	9	70.5	8	6 A.M.	3 25.1	4	58.3	4
7 P.M.	3 22.8	9	68.7	9	7 A.M.	3 20.7	4	63.3	4
8 P.M.	3 25.4	9	66.3	9	8 A.M.	3 20.7	9	65.4	8
9 P.M.	3 27.8	9	64.5	7	9 A.M.	3 19.2	9	66.2	9
10 P.M.	3 27.8	9	63.7	9	10 A.M.	3 20.2	8	67.9	7
11 P.M.	3 28.3	9	63.2	9	11 A.M.	3 21.4	7	67.7	8

The two tides of variation appear distinctly from the mean results, and with but slight irregularities in their increase or decrease. The day maximum is at 3 P.M. The evening minimum at 7, or with probably more truth, as shown by the dotted lines in No. 11, Plate III.*, at 6 h. 26 m. The night maximum is at midnight. The morning minimum at 9 o'clock.

The mean variation, according to this table, for the place of observation, is 3° 24′.7.

The greatest observed variation 3° 34′.9, and the least 3° 10′.6 including all the curves traced. The first of these is the midnight maximum of No. 8, and the second the morning minimum of No. 4. The latitude of the place, which was about one mile from the village of West Chester, is about 39° 58′, and its longitude about 21 miles west from Philadelphia.

The effect of ordinary meteorological phenomena upon the variation was first noticed, I believe, by Mr Christie, who gives a table illustrative of the effect produced by the occurrence of a rain; he has not, that I am aware, followed up the observation to which I allude. Lieut. Foster infers that ordinary meteorological phenomena do not affect the variation of the needle; a result which the different nature of the

instruments used or the localities of observation may perhaps be found to explain. In regard to the latter point, there was of course a marked difference in the nature of the meteorological phenomena at the two places. In the whole of the abstract of the meteorological observations given by Lieut. Foster, there is no record of rain, and no notice of thunder storms, while my results, obtained during part of the last month of summer and of the first of autumn, were diversified by steady rains, showers, fogs, &c.

In showing the effects of meteorological phenomena on the variation, I purpose to appeal to the direct evidence afforded by curve No. 3 (Plate I.*); the peculiarities of the other curves may afford collateral testimony, but comparatively of less value. The morning of August 31st was clear with flying white clouds; towards two o'clock a dark cloud came up from the westward and a shower fell; this was not accompanied by thunder or lightning, and soon passed over. Just at the beginning of this shower the variation was 3° 26′.5 W., and as soon as it had ceased, the needle was again observed and was found but 3° 10′.7 W. In saying that there was no extraordinary electrical excitement during this shower, I do not mean to assert that the changes of the variation were not due to the usual electrical changes which always attend such phenomena. Being unprovided with means of estimating electrical changes, I only refer to the visible indications of lightning. The sun now shone out, and at 3 P.M. the variation had increased to 3° 25′.8. Towards 4 P.M. clouds began to gather, and at 5 h. 20 m. black clouds to the N. W. indicated an approaching gust. At the moment the rain commenced the needle was noted, the variation had decreased, between 5 h. 30 m., the time of the last observation, and 5 h. 48 m., 13 minutes. The rain was violent, accompanied by thunder and lightning. At 7 P.M. the rain had ceased, and the gust had passed to the eastward, the needle vibrated violently between 3° 32′ W. and 3° 37′ W. Such irregularities are conclusive as to the influence of the phenomena attending a shower and a gust. The variations noticed will be seen, from curve No. 3, to precede the effects produced on the thermometer; after a general coincidence, the curves depart from each other, the curve of variation rising abruptly, and that of temperature but slightly.

The ill sustained nightly maximum of No. 2 was accompanied by a fog; so was the variable nightly part of curve No. 7, where a fog began to collect at eight in the evening. The nightly rise of curves No. 5 and No. 9, ceased with the coming up of clouds and of haze. The well sustained height of No. 2 was during a clear night, as was the case with No. 4.

The steady rain of Sept. 3d and 4th, does not seem materially to have affected the regularity of the curve.

In conclusion, I would make two brief remarks. The first relates to the observation of two tides of variation while there is but one of temperature. This would seem to be adverse to the supposed influence of heat were it not that we find the same agent producing two fluctuations of the barometer; when we shall be as well acquainted with the effects of local and of general variation of temperature upon the magnet, as we are of its effects upon atmospheric air, the question will be near to its solution.

The second remark relates to the effect of the electrical changes in the atmosphere, or of changes of temperature upon the needle; the meteorological phenomena noticed to affect the variation, probably act through, if they are not produced by one or both of these changes. The experiments of Cavallo have shown, at least with regard to the parts of the atmosphere not very far from the earth's surface, that there is perpetual electrical excitement, and frequent change. If his experiments had led to any conclusions other than the most general, they might perhaps have thrown light upon our subject. Where so much yet remains to be known, even the imperfect labour here presented may not be without its fruits.