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THE RELATION BETWEEN

NORTHERS AND MAGNETIC DISTURBANCES

AT HAVANA, CUBA.

PREPARED UNDER THE DIRECTION OF

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NOTE.

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ON THE RELATION BETWEEN NORTHERS AND MAGNETIC DISTURBANCES AT HAVANA, CUBA.

The data for an extended comparison of simultaneous magnetic and meteorological changes were first furnished by the observations of the Göttingen Association, taken from 1834 to 1841. In the discussion of these observations, Sir Edward Sabine presented the following as the result of such a comparison: "No connection or correspondence whatsoever was discovered between the indications of the magnetical and meteorological instruments, nor had the state of the weather any perceptible influence. It happened very frequently that an extremely quiescent state of the needle was preserved during the most violent atmospheric storm, and as with wind storms, so also thunderstorms, even when close at hand, exercised no perceptible influence on the magnetic instruments." How well this conclusion has been sustained by the comparison of subsequent magnetic and meteorological records made at different European observatories, may be seen from the following quotation from a recent paper by Balfour Stewart (see British Association Report, 1882):

"As a matter of fact, all attempts to trace a likeness between simultaneous magnetical and meteorological phenomena have been without success."

This lack of any well-defined correspondence with meteorological changes, together with their observed simultaneity at widely distant stations, has resulted in hypothetically assigning the causes of terrestrial magnetic perturbations almost entirely to solar or cosmical changes. Among others, in an address before the British Association, Prof. W. G. Adams, after a comparison of the magnetic records of distant stations, says: "It is clear that the cause or causes of magnetic disturbances are, in general, far distant from the earth's surface." Exceptions to this concurrent testimony are, however, not wanting.

One of the earliest and one of the most important of the attempts to connect magnetic disturbances with atmospheric changes was made by Father Secchi, who maintained: first, that the magnitude of the diurnal variation of the magnetic needle bears a definite relation to the direction of the wind, being greater for south winds than for north winds; and second, that magnetic disturbances occur at Rome with "bourrasques," or, as we call them, northers. Secchi's methods were severely criticized by J. Allan Broun, who claimed: first, that the supposed effect of the wind arose from the fact that the wind from a given direction was in predominance at times of increased magnetic activity; and second, a study of the observations at Singapore and Makerstown, during times of northers, failed to present the slightest evidence of a result like that of Secchi's.

More recently Father Benito Viñes, S. J., director of the magnetic and meteorological observatory at Havana, has re-affirmed the conclusion of Secchi. In his volume of Havana observations for 1873, he states that the cold northers at that place are accompanied by magnetic disturbances and suggests, as the cause of this relation, that the different electrical conditions of the warm and moist equatorial current and the dry cold air of the norther, produce differences of magnetic potential which are manifested by disturbances in the magnetic instruments. This conclusion, differing so widely from that of many other European meteorologists and

magneticians, would seem to deserve thorough investigation. The meteorological conditions at Havana are furthermore, in respect to the cold north winds termed northers, somewhat different from those of stations in western Europe, and the statement of a coincidence between *them* and *magnetic* changes is worthy of an independent investigation. It is the object of the present paper, by a careful examination of the Havana observations with the aid of additional information, obtained by the study of the tri-daily Weather Map and Monthly Weather Review of the United States Signal Service, to determine the nature of the connection, if any, existing between the northers and magnetic disturbances, and the weight of evidence supporting the hypothesis of Viñes. Only two years and a half of the Havana observations, namely, from July, 1872 to January, 1875, are available for the purpose of this investigation, as the observations since 1874 have not been published, but we have the same data for reviewing the hypothesis that Viñes had for maintaining it. The reports of the observatory, for the above-named years, contain all the magnetic and meteorological observations projected in monthly curves; while in the accompanying text the atmospheric conditions attending the principal magnetic perturbations are briefly reviewed. The magnetic outfit of the observatory consists of a declinometer and a bifilar magnetometer. No description of the construction, location, or environments of these instruments, a knowledge of which is so important in the discussion of magnetic observations, is contained in the reports. The only information obtained is that derived from the internal evidence of the observations themselves.

That the instruments are protected from mechanical vibration and consequent disturbance in the record during the prevalence of violent wind storms, seems to be assured by the fact that during many such storms the magnetic curves present only the regular diurnal changes. The question whether the instruments are subject to sudden and large changes of temperature, and, if so, the possibility of perturbations being occasioned, either by a change in the magnetism of the magnet bars, which the assumed temperature corrections do not entirely eliminate, or mechanically, by currents of air produced, can not be satisfactorily settled without a record of the temperatnres of the room. Finally, the question of the uncorrected errors produced in the motions of the needle by the effect of torsion, developed in the suspension threads during large changes of temperature and humidity, should receive especial examination in any discussion of the disturbances occurring at such times. But, as far as can be ascertained, no such investigation was instituted by Viñes, and his conclusions are consequently subject to the uncertainties which arise from the fact that all the sources of instrumental error may not have been eliminated.

In the subsequent discussion, however, we must proceed on the supposition that such mechanical disturbances do not take place, and that all the perturbations recorded in the observations and displayed in the curves are due to true magnetic changes. An inspection of the Havana magnetic curves shows the bifilar to be much more sensitive to disturbance than the declinometer. Many violent disturbances take place in the bifilar of which there is but little or no trace in the declinometer, while a disturbance in the declinometer rarely occurs without a concomitant variation in the bifilar. The condition of the bifilar has, therefore, been taken as the criterion of a magnetic disturbance. In general, days on which the range of the bifilar is greater than fourteen scale division, or fifteen and six tenths (15.6) minutes of arc, have been considered as days of disturbance. In a few instances in which the daily range during the month was found to be very small, ranges of only twelve or thirteen scale divisions, being relatively large, have been classed as disturbances. Upon this basis a tabulation of all disturbances has been made (see Table I.) in which the size of each is indicated by the range in scale divisions. Those months are omitted from the table in which the subsequent investigation

showed that no northers occurred, and which were consequently not pertinent to the discussion. The table contains also a list of the more prominent auroras occurring in the United States and Canada during the same period. Some of these, obtained from American journals, are quoted in the Havana observations, and the remainder are selected from the most extensive and brilliant of those recorded in the Monthly Weather Review and Chronological list of Auroras (Professional Paper No. III. of the United States Signal Service).

TABLE I.—*Showing range of the bifilar magnetometer in scale divisions on days of disturbance, together with a list of auroras.*

	1872.						1873.													
	Oct.		Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May.		Sept.		Oct.	
	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.
1			17	a					20	A	22	a	25	A						
2	17	a		a					13	A			17							
3	18		20		15	a	18				20		14		14			a		
4			14	a					28	a	19									
5	17	A	23				35	A			24	a								
6	17		21		14	a	17						19		17	a				
7			15				60	A									17	*		
8	15			a			16		17		37		14	a		a				
9			15	a	28	A*			23		36	a	14						20	
10			53	A							16	a								
11			27				18													
12	28						15		14											
13															16		19	A		
14	69	A			19												13			
15	19		14	}							17				20	A				
16	26	}		}							19									
17		}			22		16													
18	18	}	16				38	A					24	A						
19							24		17				17	A	16		15	A		
20									17	A			16	A	14	a	18	a		
21									15	A	26	A		a					19	a
22					16					a	29	A			16	a				a
23			24	a	18	a			13	A		a								
24				a			27		17	a	15	a						A		
25							23				15									
26		a	14				17	a							19					
27												a								
28	18	A													20	A				
29	14	A			18									a			16	A		
30													19	A				A		
31					14	a														

* Aurora in Europe.

A indicates auroras brilliant or extensive.

a indicates extent or brilliancy not reported.

} indicates that the range of the bifilar occupies two days.

TABLE I.—*Showing range of the bifilar magnetometer, &c.*—Continued.

	1873.				1874.													
	Nov.		Dec.		Jan.		Feb.		Mar.		Apr.		May.		Oct.		Nov.		Dec.	
	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.	Range of bifilar.	Auroras.
1	26										32									
2													16 }		63	A			13	A
3											21				28	A				
4					14		56						15		15	a	15			
5					12		17						15 }		18	a	13			
6											13	A								
7									36	A	24	A					15			
8			15								14									
9							15						14							
10																				
11		a†							22 }		18				18	a }	19			
12	21	a†														a				
13			17	A												a				a
14			15		27	A							15			a				
15					15	A									18					
16					24	A	13								14					
17									17											
18	13				13				13											
19							14										14			
20																			27	a
21																				
22																	28			
23					12															
24	28								14											
25			17										22		18	}	14			
26					35															
27									16		14						13			
28	15																			
29			16	}																
30																				
31																				

Auroras faint.—Monthly Weather Review.

Auroras faint.

No extensive auroras.

† Auroras in England.

A indicates auroras brilliant or extensive.

a indicates extent or brilliancy not reported.

} indicates that the range of the bifilar occupies two days.

For better study I have designated by a capital letter those auroras which are known from the above or other sources to have been brilliant or extensive, and by a small letter, those whose size and brightness was, in general, not recorded; the inference does not therefore necessarily follow that they were small or faint.

Of thirty-eight auroras marked *A*, thirty-six are coincident with magnetic disturbances, and of forty-three auroras marked *a*, twenty-seven are accompanied by disturbances. The significance of these auroras in the discussion will receive attention hereafter.

Having obtained, as in Table I., a list of the magnetic disturbances, the occurrence of northers was the next subject of examination. The characteristics of a norther as given by Viñes, are as follows:

For several days preceding there is a south wind, with maximum temperature and minimum pressure, At the moment of declaring itself the norther consists of a direct turn of the wind through the west to the north, rapid fall in temperature, tension of vapor and relative humidity, with rapid rise of the barometer. The norther is considered to continue as long as these conditions are presented. In many cases where the conditions of a norther at Havana, as above given, were only partly realized or were present in very small degree, the tri-daily Weather Maps and Monthly Weather Review of the United States Signal Service, were consulted for additional information concerning the atmospheric changes over a large area of country.

Independently of the comparison by Viñes, the relation of each norther to the oc-

currence or non-occurrence of magnetic disturbances was separately studied, and the characteristics of each case noted. The result of this examination is embodied in Table II. and list of northers. In Table II. the atmospheric conditions, on dates of magnetic disturbances, are presented in detail; when these indicate the existence of a norther the fact is noted in the last column of the table. Having found, as in Table II., the number of northers accompanied by magnetic disturbances, a list was then made (see page 10) of those northers during which the magnetic curves present only normal oscillations with no evidence of disturbing influences, and also of a few cases when the motion of the needle, though not normal, was not considered as disturbed by the foregoing classification.

TABLE II.—*Meteorological conditions on days of magnetic disturbance.*

Date.	Pressure.	Temperature.	Wind.	Remarks.
1872.				
October 2	Normal	Low and irregular.	North, very light	Not a norther.
October 3	Normal	Rapid afternoon descent.	Northeast and east	
October 5–6	Falling	Normal	East and northeast.	
October 7–8	Low	Normal	North	
October 12	Normal	Normal	North	
October 14 to 18	Rising till the 17th.	Restriction in daily range, but no large descent.	14th, north preceded by turn through the west; velocity high; 16th to 18th, east.	A norther on the 14th and 15th. Violent magnetic disturbance in Europe.
October 28	Normal	Very heavy fall.	North since 24th	
November 1	Normal	Normal	East	
November 3	Normal	Normal	East	
November 4	Normal	Normal	East	
November 5	Normal	Normal	East	
November 6	Normal	Normal	East	
November 7	Normal	Normal	East	
November 10–11	Rising	Falling	Variable and light.	
November 15–16	Rapid rise	Large fall	North, high velocity.	Perturbation very small; a steady rise in the curve of the bifilar from the 15th to the 23d, when a straight and rapid descent takes place; a norther begins on the 15th and continues to the 23d.
November 18	Falling	Very low; no diurnal range.	North, continues from 15th to the 23d.	
November 23–24	High and falling.	Regains its normal.	North with change to east; end of the eight days north wind.	
November 26	Normal	Normal	Variable and light.	
December 3	Normal	Normal	Northeast	
December 6	Normal	Normal	East	
December 9	Rising slightly	Restriction in range.	North, but light	
December 14	Falling	Normal	East	
December 17	Normal	Normal	East	
December 21–22	Rising	Falling	North, turn by the west, good velocity.	A norther.
December 23	Falling	Normal	East	
December 29	Normal	Low	North	Not a norther.
December 31	Falling	Normal	East, velocity high.	Disturbance small.
1873.				
January 3	Normal	Normal	North	
January 5	Rising	Falling	North, velocity high.	A norther.
January 6	Normal	Irregular	North, preceded by turn through the west.	
January 7–8	Normal	Falling	North, continues from 6th to 11th.	Conditions of a norther begin on the 6th and extend to the 11th.
January 11–12	Falling	Low	Northeast and east, high velocity.	
January 17	Rising	Falling	North, turn by the west.	A norther.

TABLE II.—*Meteorological conditions on days of magnetic disturbance.*—Continued.

Date.	Pressure.	Temperature.	Wind.	Remarks.
1873.				
January 18–19	Rising	Falling	North continues	
January 24–25	Rising	Falling	North	Fall in tension and humidity; a norther.
February 1	Rising	Restriction in range.	North	Coincident with norther beginning January 31st.
February 4	Normal	Normal	Northeast and east	
February 8–9	Rising	Falling	North	A violent norther.
February 19	Normal	Normal	Variable	
February 20	Falling	Normal	Variable	
February 21	Stationary	Normal	Variable	
February 23 24	Rising	Restriction in daily range.	North	A norther.
March 1	Normal	Normal	South	
March 3	Rising	Falling	North	A norther begins on the 3d.
March 4	Rising	Falling	North	
March 5	Rising	Rising	North	
March 8	Falling	Normal	East	
March 9	Falling	Normal	East	
March 10	Normal	Rising	Northeast	
March 15	Normal	Rising	East	
March 16	Normal	Rising	East	
March 21–22	Rising	Restricted range.	North, turn by the west.	A norther.
March 24–25	Normal	Normal	South	
April 1	Normal	Maximum high followed by sudden fall.	East and southeast	
April 2	Normal	Normal	North and east	Not a norther.
April 3	Rapid rise after p. m. minimum.	Normal	North and east	Not a norther.
April 6	Diurnal range large.	Normal	East	
April 8	Normal	Normal	East	
April 9	Steady rise	Irregular fall	East	
April 18	Normal	Low and irregular.	North	Fall in tension and humidity.
April 19	Rise	Low and irregular.	North	A norther begins on the 17th.
April 20	Large range	Normal	North	
April 30	Rapid rise after p. m. minimum.	Normal	North and east	
May 3	Normal	Maximum, with sudden fall, on 2d; small range on 3d.	North, preceded by south and turn through the west; velocity light.	A norther of small intensity.
May 6	Very low p. m. minimum.	Normal	East and northeast.	Not a norther.
May 13	Very low p. m. minimum.	Range small	East and northeast.	
May 15	Normal	Range large	South	
May 19	Normal	Irregular	East	
May 20	Normal	Irregular	Southeast	
May 22	Normal	Normal	Northeast	
May 26	Normal	Irregular	Northeast	
May 28	Irregular	Irregular	Northeast and east	
September 13	Normal	Normal	Variable	
September 29	Falling	Normal	Northeast	
				Seven other small perturbations during the month.
October 9	Normal	Normal	Northeast, preceded by east.	Not a norther.
October 21	Ascent beginning on the 19th.	Descent beginning on the 19th.	North and northwest from the 17th to 22d.	Condition of a norther, but beginning some days before; on the 19th a rapid but small oscillation begins in the bifilar with a steady upward tendency in the curve, continuing until the 21st, when a straight and rapid descent takes place.
November 1	Rising	Nearly normal	East	
November 13	Rapid rise	Rapid descent	North, preceded by west.	A norther.
November 19	Large rise	Rapid descent	North, preceded by west.	A norther.
November 25	Normal	Normal	Variable	

TABLE II.—*Meteorological conditions on days of magnetic disturbance.*—Continued.

Date.	Pressure.	Temperature.	Wind.	Remarks.
1873.				
November 29	High, the rise occurring on the 28th.	Low, the fall occurring on the 28th.	North, beginning on the 28th.	Norther begins on the 28th; a rise in the curve of the bifilar begins on the 28th and continues till the 29th, followed by a straight descent.
December 9	Normal	Irregular	Northeast	Not a norther.
December 14	Normal	Low	North, northeast, and east; high velocity.	A norther.
December 15		Almost normal.		
December 26	Rising	Heavy fall	North, preceded by west; high velocity.	A violent norther; the magnetic disturbance is very small.
December 28	Continued ascent.	Descent	North, preceded by west.	Norther; perturbation is quite small.
December 30–31	Stationary	Low	North	
1874.				
January 4–5	Normal	Normal	Variable	
January 15	Falling	Minimum	North	
January 16	Falling	Normal	East and south	
January 17–19	Rising	Normal	South and west	
January 24	Rising	Normal	Northeast	
January 27	Falling	Normal	East	
February 4	Normal	Diurnal range.	North	
February 5	Normal	Restricted	East	
February 10	High	Large descent	North	A norther.
February 17	Normal	Normal	East and north	
February 20	Normal	Normal	East	
March 7	Normal	Normal	North and east, velocity small.	Violent perturbations.
March 12–13	Rising	Descent	North	Descent in tension and humidity; a norther. Four other days of disturbance in March, but accompanied by no especial meteorological changes.
April 1	Slight rise	Normal	Variable	
April 2	Slight rise	Range restricted.	Variable	
April 3	Slight rise	Range restricted.	Northeast	
April 6	Falling	Normal	East and north	
April 7	Falling	Normal		
April 9	Normal, followed by rise on the 10th.	Normal: fall on the 10th.	South, turn to north on the 10th.	
April 13	Ascent	Normal	Violent northeast	
April 28	Descent	Normal	North	
May 3	Normal	Stationary	Variable	
May 4	Falling	High maximum	Variable	
May 5	Stationary	Low	West and northwest.	Descent in tension and humidity; norther begins on the 5th. Three additional perturbations in May, with no marked atmospheric changes.
May 6	Rising	Low	Northwest	
September 7	High	Descent	Mostly east	
September 11	Normal	Normal	Variable	
September 12	Rising	Low	Southeast	
September 29	Rising rapidly.	Normal during perturbation, falling immediately after.	Southwest, light, change to north after perturbation.	
October 12–13	Nearly stationary.	Descent	Northeast	Seven other days of disturbance not accompanied by marked atmospheric changes.
November 5–6	Normal	Normal	Northeast	
November 8	Normal	Normal	East, strong	
November 12	Normal	Normal	Northeast	
November 20	Normal	Descent after perturbation.	North, very light	
November 23	Falling	Normal	East and north	
November 26	Rise	Fall	North	A norther.
November 28–29	Falling	Normal	Mostly east	Norther begins *after* the disturbance.
December 3	Falling	Normal	Northeast and east	
December 21	Normal	Large descent	North	A norther.

List of northers with no magnetic disturbances accompanying, with an analysis of a few special coincidences.

October, 1872.—The grand magnetic disturbance, continuing from the 14th to the 18th, was simultaneous with a similar disturbance in Europe, supposed to be caused by a violent eruption on the sun. The disturbance in the magnetic curves is presumably not dependent upon the norther of the 14th and 15th, though simultaneous with it. On the 24th all the atmospheric conditions, except the pressure, indicate a norther, but no magnetic perturbation occurs.

November 1872.—15th and 16th, all the elements of a norther are present in great force. Beginning with a norther on the 15th the curve of the bifilar shows rapid oscillations, but, in general, of small range, with a steady upward tendency until the 23d, when there is a straight and rapid descent in the curve, coinciding with the ending of the north wind, followed by calm. A break in this wind occurred on the 23d, with calm or light east wind, during fourteen hours, not indicated by the magnet in any way, as far as shown by the observations. An oscillation on the 18th is sufficient to be classed as a disturbance. 28th, all the atmospheric conditions show a norther of great violence; no magnetic perturbation either at its beginning or during its continuance.

December, 1872.—12th, all the conditions of a norther are present, but no perturbation occurs. 26th, a violent norther, but the oscillation of the bifilar is not of sufficient range to be classed as a disturbance.

January, 1873.—16th, the conditions of a norther are present, but no magnetic disturbance occurs. 17th, the norther is renewed and continues till the 19th; a small magnetic perturbation takes place on the 17th, followed by a large disturbance on the 18th, coincident with a brilliant aurora. 31st, a norther but no magnetic perturbation takes place.

April, 1873.—A norther, beginning on the 17th, is accompanied on the 18th and 19th by violent disturbances in the bifilar magnetometer, coincident with brilliant and extensive auroras.

October, 1873.—On the 7th and 8th all the conditions of a norther—wind, temperature, pressure, tension of vapor, and humidity—are present, but no magnetic disturbance takes place. On the 19th all the meteorological elements show a norther; the curve of the bifilar contains no violent disturbance on this day, but shows a gradual rise until the 21st, when a direct descent of nineteen scale divisions takes place, some hours before the ending of the norther. Cold north wind blows from the 28th to the 31st, with velocity of 18 miles per hour, no perturbation accompanying.

November, 1873.—A violent norther on the 19th and 20th; the disturbance of the bifilar is very small, having a range of only thirteen scale divisions, followed by a condition of extreme quiescence on the 20th. The magnetic conditions accompanying the norther of the 28th and 29th are similar to those of November 15, 1872, and October 19, 1873, namely, a gradual rise in the bifilar curve begins with the advent of the norther and continues till near the end of the north wind, when a rapid descent takes place.

December, 1873.—26th, all the atmospheric conditions show a strong norther; the magnetic disturbance is very small. The conditions of a norther are renewed on the 28th, without magnetic disturbance.

January, 1874.—6th, 7th, and 8th, cold northwest wind, preceded by south, with all the atmospheric conditions of a norther, but the magnetic curve shows no disturbance.

February, 1874.—A norther beginning on the 8th continues through the 10th. The magnetic curve shows no disturbance at its advent, but a perturbation takes place a few hours before its ending.

April, 1874.—All the elements of a norther are present on the 10th, but without a magnetic disturbance accompanying; the bifilar curve shows, however, a rise at the beginning of the norther and gradually ascends till its ending, when a descent takes place. The second norther of the month reaches Havana on the 25th, and its effect on the meteorological records is evident until the 28th. The magnetic curve shows an action similar to that occurring during the norther of the 10th.

May, 1874.—A norther begins on the 5th and continues three days. The bifilar shows a continued disturbance from the 3d to the 6th, inclusive, of the same character before the arrival of the norther as after its appearance.

November, 1874.—A small norther is apparent on the 19th and 20th. The magnetic range on the 20th is sufficiently large to be classed as a perturbation, but the disturbance is by no means well marked, nor is it simultaneous with the beginning of the norther. A norther on the 25th and 26th is accompanied by a small disturbance on the 26th. The motion of the bifilar on the 27th and 28th, when no norther is present, is the same in character as that on the 25th and 26th. A norther on the 29th and 30th; no magnetic disturbance.

December, 1874.—A norther on the 7th and 8th is very well defined by the indications of all the meteorological observations, but the bifilar curves show a condition of extreme quiescence.

In order to draw any satisfactory conclusions from the conflicting data contained in the preceding tables the different phenomena must be collated and a numerical result obtained. Before this can be done, however, the treatment of the special cases given on page 10, for which no provision has been made, must be decided upon. In the examination of the magnetic bifilar curves as recorded during the presence of northers, a number of cases are observed, in which the curves, although not presenting fluctuations of sufficient magnitude to be termed a disturbance by the method adopted, show a gradual rise, corresponding to an increase of magnetic force, beginning with the norther and continuing till near its ending, when a rapid descent takes place. This peculiar rise and descent, though not described by Viñes, has received careful attention in order to discover any uniformity in its occurrence; out of the whole number of northers five were found accompanied by this magnetic action.

These cases, as well as those in which a large range was coincident with the beginning of the norther, are considered to show a disturbed condition of the terrestrial magnetism; but as they seem to be a distinct manifestation they are classed separately in the following summary, Table III.

This summary gives a total of thirty-eight northers, twenty-seven of which are accompanied by abnormal magnetic curves leaving eleven northers which occur without any connection, direct or indirect, with magnetic disturbance, the bifilar curves presenting only the normal daily oscillations.

The larger portion of the northers are thus found to be coincident with magnetic perturbations. The question now arises—what do these coincidences show? Do they, as Viñes would have us believe, give sufficient reason to suppose a physical connection between the two phenomena? As an answer to this question it is my purpose to suggest certain considerations obtained from the internal evidence of the observations themselves, which tend to render many of the above coincidences of very doubtful significance.

In concluding a recent paper on terrestrial magnetism*, Prof. A. Oberbeck writes: "If we once more look over all the phenomena just described, we find that the freely suspended needle owes its position of equilibrium to the combined action of a great number of different causes. The earth's magnetism proper, whose locus is beneath the earth's surface, the sun, perhaps affected in its action by the momentary con-

* Die zeitlichen Veränderungen des Erdmagnetismus. Halle, 1881.

dition of its surface, the moon, earth currents, auroras—all these must be taken into consideration in determining the resultant directing force which acts upon the magnetic needle."

This resumé of Prof. Oberbeck presents very forcibly the complexity of the oscillations of the magnetic needle and the extreme difficulty of their accurate and complete analysis.

TABLE III.—*Summary by months of northers and magnetic disturbances at Havana.*

Date.	Number of days magnetic disturbance of large range.	Total number of northers.	Northers accompanied by perturbations of large range.	Northers accompanied by gradual rise.
1872.				
October	13	2	1	
November	14	2	0	1
December	9	3	1	
1873.				
January	13	6	4	
February	11	2	2	
March	13	2	2	
April	10	1	1	
May	9	1	1	
October	2	2	0	1
November	5	3	2	1
December	6	3	2	
1874.				
January	8	1	0	
February	5	1	1	
March	7	1	1	
April	7	2	0	2
May	8	1	1	
November	8	3	2	
December	2	2	1	
Total	150	38	22	5

In attempting to verify the supposed relation of an additional phenomenon as an occasion of magnetic perturbation, care should be taken that the observations are freed from the effect of all other sources of disturbance. We can not obtain a satisfactory conclusion unless the observations can be so arranged that the mean of a long series will eliminate everything except the relation in question or else perturbations due to other independent causes can be thrown out.

In the present investigation the period of observation is so short that the totals given in Table III. may present a wholly misleading result, wherefore the only course remaining is to separate from the coincidences in the above summary all those which a study of the observations gives us reason to believe are accidental—the disturbances being traceable to causes independent of the accompaying norther.

Of these cases we notice:

First. The coincidence of October, 1872, in which the magnetic disturbance is due to a violent eruption on the surface of the sun, the disturbance being very remarkable in intensity and duration, and occurring simultaneously over the whole world.

Second. In the attempt to separate the magnetic disturbances into separate classes, according to the character of the phenomenon, for the purpose of better analyzing the forces acting upon the needle, the perturbations occurring with auroras, and which I will call "auroral," are especially distinct in their action and have well marked characteristics. In general the two phenomena were proportional in inten-

sity—the more extensive and brilliant the aurora, the more violent was the disturbance of the magnet.

In a portion of the coincidences between northers and magnetic disturbances the latter are of this "auroral" character.

Viñes, in explanation of the causes of his concluded relation, considers that the warm, moist, atmospheric currents, preceding a norther, are charged with electricity, and, after reaching high latitudes, are productive of auroras. If this be the case, coincidences between northers and auroras should occur and the "auroral" magnetic disturbance can not be considered to be independent of the norther. In fact the norther would have a well-defined relation as a concomitant of these phenomena.

That this supposition, however, is not well founded is apparent from the large number of northers occurring with no proximity to auroras and of auroras occurring with no relation to northers. Of the whole number of northers about twenty-three per cent. are accompanied by auroras, and if we take the percentage for the last year and a half of the observations, after the maximum of auroral frequency is past, this proportion is but ten per cent., indicating that the coincidences are accidental and due to the large number of auroras.

Furthermore the primary supposition, that the moist southerly currents are charged with electricity arising from evaporation over the Gulf of Mexico, is not supported by recent experiments.*

As far as observations extend, therefore, the evidence is against a connection of auroras and northers, and accordingly all the auroral magnetic disturbances should be separated from the table of coincidences.

Third. We notice a few instances in which a prolonged disturbance occurs, of the same character and intensity as during its continuance, before the arrival of the norther or after its ending; the advent of the norther apparently causing no change in the movement of the needle. Three of the coincidences given above, namely, those of February 10, May 5, and November 25, 1874, exhibited this characteristic to such a degree that they were considered to be very poor evidence of the supposed relation to the northers of those dates. I accordingly add them to the list of coincidences, which a close analysis makes of doubtful value in supporting this hypothesis.

Fourth. In addition to the northers treated by these considerations, there are periods in which the large numbers of magnetic perturbations renders an accidental coincidence with a norther so probable that such coincidences as occur at these times can not of course furnish any ground for supposing a physical relation. These should be eliminated, if possible.

The general problem to be solved is as follows:

In a total of n days two events occur, the one on a days, the other on b days; what is the probability that they will occur together on k days, or, in other words, that there will be k coincidences. This problem gives rise to the following formula based on the principles of the doctrine of chances: The probability, P, of k coincidences of a norther days with b magnetic perturbations, in a total of n days is

$$P = \frac{\lfloor a \quad \lfloor n-a \quad \lfloor b \quad \lfloor n-b}{\lfloor a-k \quad \lfloor k \quad \lfloor b-k \quad \lfloor n \quad \lfloor n-a-(b-k)}$$

in which $\lfloor a$ represents the continued product of the series of numbers from a to 1.

* Mr. S. H. Freeman, after very careful experiments at the Johns Hopkins University, obtained the result that "evaporation is at most a very insignificant source of the atmospheric electricity." (See American Journal of Science, third series, vol. 23, 1882, p. 428.) The same result has been obtained in still more recent experiments by Blake, Kalischer, and others. In a paper read before the Scottish Meteorological Society, March 17, 1884, Prof. Tait reviews the evaporation theory and other attempts to account for the origin of atmospheric electricity, and decides that experiments must be made on a far larger scale than heretofore attempted, before any real success in the solution of the problem can be attained.

It will be seen that the two events a and b enter the formula symmetrically as they should. The formula assumes an equal distribution of the two phenomena. But since the frequency of magnetic storms and of northers is not uniform for any considerable period of time, we are limited in its application to a value of n for which we may consider that the frequency will be practically constant. A month has been taken as the period for which this may be assumed; n will therefore be the number of days in each month; the values of a and b for any given period can be obtained from the preceding summary. With these values of a, b, and n, substitute now different values for k, from o to a, and compute the probability corresponding to each separate value. If now the observed number of coincidences is no greater than the number for which the computed probability, P, is a maximum, then they must be considered as accidental.* Thus, for December, 1872, it is shown that there is a maximum probability in favor of the coincidence in that month. Of three northers and nine days of disturbance, the probability of three coincidences is .02; of two coincidences, .18; of one coincidence, .46; of no coincidences, .34. The existing condition, that of one coincidence, is therefore that of maximum probability. This should accordingly be deducted from the total number of coincidences, in order to leave only those from which a physical connection can be inferred.

The twenty-two coincidences are thus, by the preceding analysis, reduced to eight cases which can be used to sustain the supposed relation between magnetic and atmospheric phenomena. It is, moreover, reasonable to suppose that if our data of auroras, solar eruptions, and other magnetic and electrical phenomena were more extended *some of these eight* would also be found due to such phenomena.

To recapitulate; after having separated those from which no conclusion can be inferred, we have found eleven northers producing no perturbations in the terrestrial magnetism at Havana; eight accompanied by large fluctuations which have not been traced to other sources for their origin; and five accompanied by a gradual rise in the bifilar curve, followed by a sharp descent near their ending. It is from these five that a connection is most likely to be found, if at all, but they are so few *in number, relatively to the whole number of northers, that it would seem we must* look still further for the explanation of their origin.

The present investigation can not, on account of the limited data at hand, be considered to furnish a conclusive answer to the question of a connection or correllation between northers and magnetic disturbances, but it simply aims to inquire whether the hypothesis of Viñes is well supported by a careful analysis of the observations upon which it is based and upon which it rests for its justification.

Though the evidence of a direct connection between northers and magnetism appears inconclusive, we have reason to believe, that some of the smaller magnetic variations, especially in horizontal force, may be due to the electric conditions of the atmosphere. That magnetic perturbations take place with a given distribution of pressure has been maintained, in an elaborate and carefully prepared memoir by Forssman,† and from the results of a long series of observations a connection between magnetic disturbances and the scintillation of the stars has been set forth by Montigny.‡ These discussions increase the belief that some, at least, of the many variations in the position of the magnetic needle may yet be successfully correlated with meteorological phenomena.

*If we differentiate the formula, considering k as a variable, we find that P is a maximum when $k = \frac{a\,b}{n}$. Hence this equation can be used to obtain k instead of the original formula.

†Forssman, L. A. Des relations de l'Aurore Boréale et des perturbations magnétiques avec les phénomènes météorologiques. [1871.]

‡Bulletin de l'Academie Royale des Sciences de Belgique. December, 1883.

that no sensible eleven-year periodicity in the frequency
be detected, or that, if such a period exists, it is so slig
in the mean of many years' observations. This same
essed by Prof. C. A. Young, as follows: "I am more
errestrial influence of sun spots amounts to anything wor
e direction of magnetism."†

suming that the monthly mean temperature is a fair te
iers, any indications of an eleven-year periodicity may p
wing table of winter temperatures from 1863 to 1875, inc

Monthly mean temperature, at Havana. Centi

	Jan.	Feb.	Mar.	Apr.	
.....	20.8	23.0	23.9	25.1	
.....	22.7	22.2	24.0	24.6	
.....	21.3	22.2	25.2	26.0	
.....	22.3	23.1	25.3	25.6	
.....	22.4	24.4	26.5	26.8	
.....	24.1	22.8	24.6	27.2	
.....	23.9	24.0	24.7	26.9	
.....	23.8	21.8	24.3	24.4	
.....	21.9	23.5	25.2	26.4	
.....	21.9	22.3	23.9	26.9	
.....	22.4	23.7	23.3	25.8	
.....	21.8	23.9	25.1	26.6	
.....	23.9	23.9	25.3	24.6	

e means in this table, with the exception of the years
ate a tendency towards a maximum temperature at the e
and a minimum temperature at the epoch of maximum
, 1866 and 1871, though close to the times of maximum
o conform to the periodicity indicated by the others.

February, 1875.—A norther on the 7th; small magnetic disturbance and aurora. Eight days of magnetic disturbance in the month.

March, 1875.—A norther on the 7th; magnetic disturbance and auroras. A norther on the 17th with magnetic disturbance. A norther on the 22d; no magnetic disturbance. Nine days of magnetic disturbance in the month.

April, 1875.—A norther on the 3d without magnetic disturbance. A norther on the 13th with magnetic disturbance. A norther on the 23d without magnetic disturbance. A norther on the 27th without magnetic disturbance. Five days of magnetic disturbance in the month.

May, 1875.—A norther on the 5th; the magnetic curves show a continued disturbance through the first thirteen days of the month during the prevalence of successive auroras.

October, 1875.—A slight norther on the 11th; a magnetic disturbance takes place on the 12th. A norther on the 16th without magnetic disturbance. A norther on the 23d; a magnetic disturbance on the 24th accompanies an aurora. Six days of magnetic disturbance in the month.

November, 1875.—A severe norther on the 11th without magnetic disturbance. Four days of magnetic disturbance in the month.

December, 1875.—A severe norther on the 7th continues till the 11th; a magnetic disturbance on the 6th. A norther on the 17th with magnetic disturbance. Six days of magnetic disturbance in the month.

In the above list of northers the magnetic disturbances occurring on the day preceding a norther, the day of its occurrence, or the day following, are carefully noted. In determining the probable occurrence of a magnetic disturbance at the time of a norther, the degree or closeness of the coincidence that is desired must be considered. Thus, if it is desired to determine the probable number of magnetic disturbance that will occur either on the day preceding a norther, or on the day of its advent, for the month of December, we have $k = \frac{6 \times 4}{31}$; one magnetic disturbance may, therefore, be expected to occur by chance on one of these days.

From an inspection of the list of northers, the results of the observations for the year 1875, may be summarized as follows:

1. For January, February, March, October, and December, the number of magnetic disturbances occurring near the times of northers is greater than can be accounted for by chance.

2. The time of such disturbances varies from the day preceding the norther to the day following the norther.

3. Numerous and severe northers occur without being accompanied by disturbances in the magnetic instruments.

From the last two of these facts we may conclude that the connection between northers and magnetic disturbances exhibited by the first is not direct, but incidental. The occurrence of a norther is not the sufficient condition of a magnetic disturbance, and therefore no prediction of one from the presence of the other is possible. The general connection, maintained by Father Viñes and sustained by our analysis of this year and the preceding years, namely, the frequent occurrence of magnetic disturbances at or near the advent of northers, still remains to be explained. This connection can, perhaps, be sufficiently and satisfactorily accounted for by the investigation of Forssman, already referred to. Dr. Forssman finds, from the mean of many observations at Toronto, that auroras and magnetic perturbations have a tendency to occur on the day after the passage of a low barometer at that place. They are consequently coincident with the advance over the southern states of areas of high pressure, which in the winter season are termed northers.