

ART. IV.—On Electrical currents circulating near the Earth's surface, and their connection with the phenomena of the Aurora Polar. —9th ARTICLE; by ELIAS LOOMIS, Professor of Natural Philosophy and Astronomy in Yale College.

IN vol. xxxii, pp. 324–335 of this Journal, I have shown the existence of a stream of electricity drifting across Central Europe in a direction from about N. 28° E. to S. 28° W. For several months I have been collecting the materials for a similar discussion in this country, and now present the results of these enquiries. My materials are derived from the magnetic observations made at Toronto, Cambridge and Philadelphia, from May 1840 to Dec. 1842, and during a portion of this time at Washington also. The observations at the first three stations were made with needles mounted in the manner recommended by Gauss; but those at Washington were made with a declination compass having a needle of eleven inches in length, whose motions were much less free than those of Gauss' construction, and which therefore did not give the time of the maxima and minima with equal precision. For this reason the last column in the following table contains a large number of blanks. The table exhibits a list of all those cases in which there was a well marked maximum or minimum value of the magnetic declination, and when this maximum or minimum value was of short duration. All the dates are expressed in the mean time of Göttingen.

OBSERVED DEFLECTIONS OF THE HORIZONTAL MAGNETIC NEEDLE.

	Toronto.		Cambridge.		Philadelphia.		Washington.	
	h.	m.	h.	m.	h.	m.	h.	m.
1840. May 29. Maximum,	10	55	10	55	10	55		
Minimum,	11	10	11	5	11	10		
Max.	11	35	11	25	11	30		
Min.	11	40	11	30	11	35		
Max.	11	50	11	35–40	11	45		
Min.	12	0	11	50	11	55		
Max.	12	15	12	5–10	12	15		
Min.	12	35	12	30	12	35		
Max.	13	45	13	40	13	45		
Max.	14	15–20	14	15	14	15		
Min.	15	0	15	0	15	0		
Min.	15	50	15	45	15	50		
Max.	15	55	15	55	15	55		
Min.	16	25	16	10	16	20		
Max.	16	35	16	35	16	35		
Min.	16	45	16	45	16	45		
Max.	17	0	16	55	17	0		
Min.	17	15	17	5	17	10		
Max.	17	25	17	15	17	20		
Min.	17	35	17	30	17	30–35		
Max.	18	5	18	0	18	5		
Max.	20	35	20	30	20	30–35		

Table continued.

			Toronto.		Cambridge.		Philadelphia.		Washington.		
			h.	m.	h.	m.	h.	m.	h.	m.	
1840.	May 30.	Max.	0	50-55	0	50	0	50			
		Min.	2	5	2	5	2	5			
		Max.	2	20	2	20	2	20			
		Max.	9	30	9	30	9	25			
		Min.	9	35	9	35	9	35			
	June 24.	Max.	16	40			16	35-40			
	June 25.	Min.	5	10			5	10			
	July 22.	Max.	16	25			16	25			
		Min.	19	0			19	0			
		Max.	19	20			19	20			
		Min.	19	40			19	40			
	July 23.	Max.	5	10			5	10			
	Aug. 28.	Max.	10	45-50	10	40-45	10	45			
		Min.	11	35	11	30-35	11	30-35			
		Max.	11	50	11	50	11	50			
		Min.	13	25	13	25	13	25			
		Max.	14	40	14	35-40	14	40			
		Min.	15	5	15	5	15	5			
		Max.	15	15	15	10	15	10			
		Min.	15	40	15	35	15	35			
		Min.	16	20-25	16	20	16	20			
		Max.	16	35	16	30	16	30			
		Min.	16	45-50	16	40	16	40-45			
		Max.	17	5	17	0	17	0-5			
		Min.	17	20	17	20	17	20			
		Max.	17	40	17	35	17	40			
		Min.	18	5	17	55	18	0			
		Max.	18	15	18	5	18	10			
		Min.	18	30	18	20	18	25			
		Max.	18	35	18	30	18	35			
		Min.	18	50	18	45	18	50			
		Max.	19	20	19	10	19	15			
		Max.	19	50	19	50	19	50			
		Max.	23	25	23	25	23	25			
	Sept. 23.	Max.	10	40	10	40	10	40	10	45	
		Max.	13	50	13	40-50	13	50	13	55	
		Min.	15	45-50	15	45	15	55	15	50	
		Min.	22	50	22	50-55	22	50	22	50	
	Sept. 24.	Min.	0	35	0	35	0	35	0	30	
		Min.	2	15	2	15	2	15	2	15	
		Max.	2	35	2	30	2	30-35	2	35	
		Min.	4	30	4	30	4	30	4	35	
	Oct. 21.	Max.	10	50	10	45	10	45	10	45-50	
		Min.	11	10	11	5	11	5			
		Max.	14	50	14	50	14	50			
		Min.	15	15	15	10-15	15	15			
		Max.	16	0	16	0	16	0			
		Min.	16	35	16	25-30	16	30	16	35	
	Oct. 22.	Min.	3	35	3	35	3	35			
	Nov. 23.	Max.	2	15	2	15	2	15	2	20	
	Dec. 23.	Max.	11	45	11	45	11	45	11	45	
		Max.	13	10	13	10	13	10	13	10	
		Min.	13	25	13	25	13	25	13	25	
		Max.	13	40	13	35	13	35	13	35	
		Min.	14	20	14	15	14	15	14	15	
		Max.	15	0	14	55	14	55-60	15	0	
		Max.	15	20	15	20	15	20			
		Min.	18	50	18	50	18	50	18	50	
			Max.	22	30	22	20	22	20-25	22	20-25

Table continued.

			Toronto.		Cambridge.		Philadelphia.		Washington.	
			h.	m.	h.	m.	h.	m.	h.	m.
1840.	Dec. 24.	Max.	1	30	1	30	1	30		
		Max.	2	55	2	55	2	55		
		Min.	3	5	3	5	3	5		
1841.	Jan. 20.	Max.	15	25	15	25	15	25		
	Jan. 21.	Min.	7	5	7	5	7	5	7	10
		Min.	8	50	8	50	8	50	8	50-55
	Feb. 26.	Max.	13	15	13	15	13	15	13	15
		Min.	13	50	13	40-50	13	50	13	50
		Max.	15	10-15	15	10	15	10	15	10
		Min.	15	35	15	30	15	30	15	30
		Max.	16	0-5	15	55-60	16	0	16	0
		Min.	21	30	21	30	21	30	21	30
	March 24.	Max.	12	5	12	0	12	5		
		Min.	12	20-25	12	20	12	20-25		
		Max.	12	40	12	40-45	12	40		
		Min.	15	25-30	15	25	15	25		
		Max.	15	45-50	15	45	15	45		
		Max.	16	25	16	20	16	25		
		Min.	18	25	18	25	18	25		
	April 21.	Max.	11	15	11	15	11	15	11	15
		Max.	14	50	14	50	14	50	14	45-50
		Max.	15	20	15	15	15	20		
		Min.	15	30	15	30	15	30		
		Max.	15	45	15	40	15	45		
		Min.	15	55	15	55	15	55	15	55-60
		Min.	18	20	18	20	18	20		
	May 28.	Max.	12	25	12	20	12	20-25	12	25
		Max.	13	45-50	13	45	13	45	13	50
		Min.	14	15	14	15	14	15	14	15
	June 23.	Max.	10	40	10	40	10	40	10	40
		Max.	12	10	12	10	12	10		
		Min.	19	10	19	5-10	19	10		
		Min.	23	15	23	10-15	23	15		
	June 24.	Max.	1	40	1	40	1	40		
		Min.	3	45	3	45	3	45		
	July 21.	Max.	14	35	14	30-35	14	30-35	14	35
		Min.	14	55	14	50	14	50	14	50
		Max.	15	25	15	20	15	25	15	25
		Min.	16	15	16	10	16	10-15	16	10-15
		Min.	17	45-50	17	45-50	17	50	17	50
		Min.	19	10-15	19	15	19	10-15	19	15
		Max.	20	0	19	55	20	0		
		Min.	21	15	21	15	21	15	21	15
	July 22.	Min.	3	40	3	40	3	40	3	35
	Aug. 27.	Min.	10	50	10	50	10	50	10	50
		Min.	12	55	12	50	12	50		
		Max.	13	15	13	15	13	15	13	15
		Max.	14	55	14	55	14	55	14	55
		Max.	17	30	17	25	17	25-30	17	30
		Min.	18	20	18	20	18	20	18	20
		Max.	19	30	19	25	19	30	19	30
	Aug. 28.	Max.	1	35	1	30-35	1	35	1	35
		Min.	7	40	7	35-40	7	40	7	40
	Sept. 22.	Max.	18	40	18	40	18	40		
	Sept. 23.	Min.	0	30	0	30	0	30	0	30
		Min.	3	10	3	10	3	10	3	10
	Oct. 20.	Max.	14	50	14	45	14	45	14	45-50
		Max.	18	45	18	40	18	45	18	45
		Min.	19	0	18	55	19	0	19	0
		Max.	19	10	19	5	19	5	19	5

Table continued.

			Toronto.		Cambridge.		Philadelphia.		Washington.	
			h.	m.	h.	m.	h.	m.	h.	m.
1841.	Oct. 20.	Min.	19	30	19	30	19	30		
		Max.	19	50-55	19	50	19	50	19	50-55
		Min.	22	5	22	5	22	5		
	Oct. 21.	Min.	0	5	0	5	0	5	0	5
		Max.	3	10	3	10	3	10	3	10
	Nov. 26.	Max.	14	40	14	35-45	14	30-40	14	40-45
	Dec. 22.	Min.	20	5	20	5	20	5	20	5
		Min.	22	15-20	22	15-20	22	15-20		
1842.	Jan. 19.	Max.	12	24	12	20	12	24		
		Max.	16	42	16	40	16	42		
	Feb. 25.	Min.	17	12-18	17	15	17	12-18		
		Min.	11	36	11	30	11	30		
		Max.	12	0-6	12	0	12	0-6	12	5-10
	Feb. 26.	Max.	15	0	15	0	15	0	15	0
		Min.	19	42-48	19	45	19	42-48	19	45
		Min.	0	0	0	0	0	0	0	0
	March 23.	Max.	13	0	13	0	13	0	13	0
		Min.	14	12	14	10	14	12	14	15
	March 24.	Max.	17	12-18	17	15	17	18	17	15
		Max.	4	0	4	0	4	0	4	0
	April 20.	Min.	8	36	8	35-40	8	36	8	30-35
		Max.	13	30	13	30	13	30	13	30
		Min.	14	0	14	0	13	54	14	0
	April 21.	Min.	15	48	15	50	15	48-54	15	50
		Max.	16	24-30	16	20-25	16	24	16	25
		Max.	19	30	19	30	19	30	19	30
	May 27.	Min.	19	48-54	19	55	19	54	19	55
		Max.	6	0	6	0	6	0	6	0
		Max.	14	54-60	14	55	14	54	15	0
	June 22.	Max.	19	24-30	19	25-30	19	24-30	19	30
		Min.	14	18-24	14	20	14	18	14	20
		Max.	15	6	14	55	15	6	15	5
	June 23.	Max.	16	42	16	40-45	16	42	16	45
		Max.	17	18	17	15	17	18	17	20
		Max.	17	54-60	17	50	17	54	17	55
	July 20.	Max.	19	36-48	19	30	19	36-42	19	45
		Max.	20	36	20	35	20	36	20	35
		Max.	0	0	0	0	23	54-60	0	0
	Aug. 26.	Max.	8	36	8	35	8	36	8	40
		Max.	13	18	13	15	13	18		
		Max.	11	48-54	11	45	11	48		
	Aug. 27.	Max.	14	18	14	10	14	12		
		Min.	14	30	14	25	14	30		
		Max.	15	36	15	30	15	30		
	Sept. 21.	Min.	4	0	3	55	3	54		
		Min.	12	54-60	12	55	12	54		
		Max.	13	30	13	20-25	13	24		
	Sept. 22.	Max.	17	54	17	45-50	17	48		
		Min.	19	24	19	15	19	18		
		Max.	21	54-60	21	55	21	54		
	Oct. 19.	Max.	4	0	3	55	3	54		
		Max.	8	12-18	8	10	8	12		
		Max.	13	30	13	25	13	24		
	Oct. 20.	Min.	18	0-6	18	0	18	0		
		Max.	21	24	21	25	21	24		
		Max.	22	24	22	25	22	24		
	Nov. 25.	Max.	0	30	0	30	0	30		
	Dec. 21.	Max.	15	18	15	15	15	18		
	Dec. 21.	Max.	14	48	14	45	14	48		
		Max.	17	48-54	17	45-50	17	48		

The following table shows in how many cases the maximum deviation of the magnetic needle occurred earlier at Cambridge, Philadelphia or Washington than it did at Toronto; in how many cases it occurred at the same instant; and in how many cases it occurred later than at Toronto. From May, 1840, to Dec. 1841, the observations at each station were made at intervals of 5 minutes; but in 1842 the observations at Toronto and Philadelphia were made at intervals of 6 minutes. The differences therefore in the times of maximum deviation are generally 0, or 5 or 10 minutes; but when at one of the stations the indications of the needle were sensibly the same at two successive observations, we may obtain differences of $2\frac{1}{2}$ or $7\frac{1}{2}$ minutes. In the few cases in which other differences are obtained, they have been classed with the numbers in the table to which they approached nearest.

Maximum deviation of the magnetic needle.

	Cambridge.	Philadelphia.	Washington.
12½ minutes earlier,	2		
10 " "	7		
7½ " "	6	1	1
5 " "	34	19	2
2½ " "	16	26	7
At the same instant,	44	70	28
2½ minutes later,	2	1	7
5 " "			5
Average result,	3 ^m -11 earlier.	1 ^m -40 earlier.	0 ^m -15 later.

These observations indicate that the maximum deviation of the magnetic needle advances like a wave over the earth's surface; and that the direction of its motion is from N. 68° E. to S. 68° W. A comparison of the Cambridge and Toronto observations indicates a velocity of progress amounting to 113 miles per minute; while a comparison of the Philadelphia and Toronto observations indicates a velocity of only 75 miles per minute.

The following table shows in how many cases the minimum deviation of the magnetic needle occurred earlier than at Toronto; in how many cases it occurred at the same instant; and in how many cases it occurred later than at Toronto.

Minimum deviation of the magnetic needle.

	Cambridge.	Philadelphia.	Washington.
15 minutes earlier,	1		
10 " "	6		
7½ " "	2		
5 " "	17	18	5
2½ " "	12	8	2
At the same instant,	40	56	21
2½ minutes later,	4	3	7
5 " "	1	0	3
7½ " "		1	
Average result,	2 ^m -29 earlier.	1 ^m -10 earlier.	0 ^m -04 later.

These observations indicate that the minimum deviation of the magnetic needle advances like a wave over the earth's surface; and that the direction of its motion is from N. 69° E. to S. 69° W. A comparison of the Cambridge and Toronto observations indicates a velocity of progress amounting to 156 miles per minute; while a comparison of the Philadelphia and Toronto observations indicates a velocity of only 103 miles per minute.

We thus see that the average progress of the maxima and minima deviations of the magnetic needle was very nearly in the same direction and with the same velocity. Assuming that the average direction of both classes of waves is the same, we find their progress to be from N. 68° E. to S. 68° W.; and the velocity of their progress deduced from a comparison of the Cambridge and Toronto observations is 134 miles per minute; while the velocity deduced from a comparison of the Philadelphia and Toronto observations is 89 miles per minute.

In my former article, p. 334, I found that in Central Europe, the deflections of the magnetic needle were propagated in a direction from N. 28° E. to S. 28° W. Mr. C. V. Walker determined that the direction of this motion in England was from N. 42° E. to S. 42° W.; and we now find this direction in the neighborhood of New York to be from N. 68° E. to S. 68° W.

At the time of a considerable number of the preceding observations, auroras were recorded at some one of the stations. The following are the auroral notices at Toronto, corresponding to some of the preceding dates. The dates are all given in the mean time of Göttingen.

Auroral observations at Toronto.

1840. May 29. 15^h. Faint light in north.
 15^h 16^m, faint streamers shot up from N.E. to altitude 60° ; a most brilliant aurora followed.
 16^h, aurora most brilliant.
 16^h 5^m, a perfect arch from N.W. to N.E. Splendid streamers rising from it, and almost a continued gleam of light from the incessant flashes or pulsations.
 17^h. Streamers disappeared; faint patches of light and a few pulsations.
 18^h. Very faint light arch, dark clouds rising in N. horizon.
 19^h. Bright aurora.
 20^h. Bright aurora.
- Aug. 28. 14^h 30^m. Splendid aurora.
 15^h. Aurora visible at intervals.
 17^h 30^m. Aurora very splendid.
 18^h. Auroral light obscured by the clouds.
 19^h. Overcast.
 21^h. Cleared up; aurora again visible.

1840. Oct. 22. From 15^h to 18^h faint auroral light.
 Dec. 23. 17^h. Bank of auroral light in N.; faint streamers.
 18^h. Auroral light in N. Patches of light and streamers.
 19^h. Faint auroral light in N.
 1841. April 21. 15^h. Auroral light in N. horizon; a few faint streamers rising from it.
 20^h. Faint auroral light to N.
 July 21. 17^h 30^m. Bright bank of auroral light in N.
 19^h. Faint auroral light in N.
 20^h. Faint auroral light in N.
 21^h. Faint auroral light in N.
 Oct. 20. 14^h 35^m. Auroral light in N.
 15^h 20^m. Very faint auroral light along N. horizon.

The following notices of the aurora were recorded at Washington. The dates are given in the mean time of the place.

Auroral observations at Washington.

1840. Aug. 28. From 8^h 30^m to 9^h 45^m P. M. the aurora distinctly visible, extending from N.E. by N. to N.W. by N.; faint appearances of it at irregular intervals, until 1^h 45^m A. M. of 29th.
 Sept. 23. At 10^h 40^m P. M. a segment of an auroral arch, extending from N.N.E. to N.N.W.; centre or highest point, N. by E.; altitude 8°.

The following auroral notices are from the register kept at New Haven by Mr. E. C. Herrick.

Auroral observations at New Haven.

1840. May 29. A conspicuous aurora. A narrow belt overhead between 9^h and 10^h; and after 10^h auroral waves as high as zenith.
 Aug. 28. A considerable aurora visible. An arch 40° high in N. between 10^h and 11^h. Few streamers.
 Oct. 22. A distinct aurora. An arch 2° or 3° high lying 30° or 40° along the northern horizon.
 Dec. 24. During most of the evening there seemed to be a faintly luminous vapor, particularly in the N., but also more or less elsewhere.
 1841. March 24. An auroral arch low in N. horizon all evening; about 2° high; bright. I saw no streamers.
 July 21. A faint auroral illumination at 10 P. M. and also at 2 A. M. of the 22d.
 Oct. 21. About 1 A. M. a brilliant auroral display, not extending higher than 40°; streamers rapidly shifting.
 1842. April 20. Slight aurora about 11^h, and faint traces through the night.

If now we make the comparison for those dates at which an aurora was recorded at Toronto, we shall find that the maxima and minima deviations of the magnetic needle occurred at Cam-

bridge on an average 3^m·88 earlier than at Toronto, and at Philadelphia 1^m·87 earlier than at Toronto. These results are a little greater than those obtained from a comparison of all the observations, and indicate a motion somewhat more nearly east and west; but the general character of the results is the same. We seem authorized then to infer that *in the eastern part of the United States the irregular deflections of the magnetic needle, whether attended or not by any auroral exhibition, are generally propagated in a direction from N. 68° E. to S. 68° W., and with an average velocity of about 112 miles per minute.*

During the exhibition of brilliant auroras, auroral beams do not ordinarily continue stationary for many minutes. They generally exhibit a movement of translation towards the south, and frequently also a movement to the east or west of the meridian. In order to determine whether there is any uniformity in the direction of this motion, I have collected together all the notices of this kind which I could find recorded in the *Am. Journal of Science*, in the Reports of the N. Y. Regents, and in various other works. The following is the result of this examination.

Notices of lateral displacement of the auroral beams.

From the American Journal of Science.

Vol. xiv, p. 92. 1827, Aug. 28. New York City. Waves of light began to flow from the eastern toward the western part of the luminous arch. The whole arch moved towards the south.

Vol. xiv, p. 94. Troy, N. Y. The flowing of the light from E. to W. was constant.

Vol. xiv, p. 104. Canandaigua, N. Y. About the time that the arch broke up into columns, it seemed to move back towards the north. Soon after it moved again to the south, apparently with a more rapid motion than ever.

Vol. xiv, p. 105. 1827, Sept. 9. Canandaigua, N. Y. A light cloud, moved gently to the west, and gradually put on the appearance of beams of light. Proceeding still west, and probably a little south, they seemed to lengthen and descend toward the western horizon. The movement westward was distinct, but not sufficiently so to enable me to estimate the rate of motion.

Vol. xiv, p. 106. *Ib.* The western motion of the fragments was perceptible, and was estimated at four degrees in thirty-two seconds.

Vol. xxvii, p. 113. 1833, May 17. Philadelphia, Pa. This arch passed gradually towards the south.

Vol. xxvii, p. 119. 1833, July 10. Philadelphia. Four beams were visible; the last beam vanishing after appearing to move westward.

Vol. xxix, p. 389. 1835, Nov. 17. New Haven, Conn. The zone moved slowly to the south, until about 9 o'clock. From this time it began to recede northward.

Vol. xxx, p. 135. 1835, Dec. 11. Toronto, Canada. All these rays moved in a very stately march from east to west.

Vol. xxx, p. 231. 1835, Sept. 4. New Haven, Conn. The streamers all moved to the east about 6° . Beams shot up about 30° high, and moved laterally to the east.

Vol. xxxii, p. 178. 1837, Jan. 25. New Haven. The twilight of the northern sky moved slowly southward.

Vol. xxxii, p. 221. 1836, Aug. 12. *Ib.* Over head the arch moved southward. In the east it also advanced southward.

Vol. xxxii, p. 222. *Ib.* Parallel fleeces, distinct from each other, were in slow motion toward the west.

Vol. xxxii, p. 225. 1836, May 8. New Haven. The arch advanced southward.—The bow moved slowly south.—The arch had advanced southward.

Vol. xxxii, p. 394. 1836, May 8. Toronto, Canada. A shining broad column of light passed very slowly and bodily to the westward.

Vol. xxxiii, p. 212. 1837, July 29. Burlington, Vt. A luminous arch moved slowly to the south.

Vol. xxxiv, p. 275. 1837, Nov. 14. Geneva, N. Y. A bright white streamer passed the north star, on its way to the west.

Vol. xxxviii, p. 262. 1839, Sept. 3. Nashville, Tenn. A westward motion was observed in three principal columns.

Vol. xxxviii, p. 376. 1839, Sept. 3. Middlebury, Vt. The belt moved south—rapidly at first, then more slowly.

Vol. xxxix, p. 194. 1840, May 29. New Haven. The belt drifted southward at the rate of about a degree per minute.

Vol. iii, n. s., p. 440. 1847, April 7. New Haven. The auroral belt moved southward from 77° above the N. horizon to 65° above the southern.

Vol. xiii, n. s., p. 427. 1852, Feb. 19. New Haven. Streamers began to shoot upward, having a horizontal movement from E. to W.

Vol. xiv, n. s., p. 131. 1852, April 22. New Haven. The whole beam slowly moved southward.

Vol. xxviii, n. s., p. 391. 1859, Aug. 28. New Haven. Auroral arch advanced 18° toward the south in fifteen minutes.

Vol. xxviii, p. 394. 1859, Aug. 28. West Point, N. Y. A yellowish cloud advanced southward with an even boundary.

Vol. xxviii, p. 394. *Ib.* The streamers in the north were numerous and were perceived universally to move towards the west.

Vol. xxviii, p. 395. *Ib.* The entire expanse of cloud in the south was making a similar progress west, at the rate of forty degrees in about two minutes. At 3 A. M. the streamers in the north moved across the constellation Cassiopea from west to east, contrariwise to the motion in every instance I have before observed in any aurora.

Vol. xxviii, p. 396. *Ib.* The southern streamers were also moving to the east.

Vol. xxviii, p. 404. 1859, Sept. 2. Havana, Cuba. The summit of the arch had a movement of translation toward the east. A brightness streamed from the north, moving towards the N.N.E.

Vol. xxviii, p. 406. *Ib.* Reiterated movement of translation of the whole aurora from E. to W., followed by a retrocession in the opposite direction.

Vol. xxix, p. 252. 1859, Aug. 28. Halifax, N. S. The streamers appeared to work from W. by N. to south. I think they worked along from E. to W., but another observer said from W. to E.

Vol. xxix, p. 257. 1859, Aug. 28. Steubenville, Ohio. At 7½ P. M. the aurora moved to the south. At 9 P. M. the light advanced again and passed clear to the south as before.

Vol. xxix, p. 258. 1859, Aug. 28. Burlington, N. J. An arch of light rose in the north, passed the zenith, and descended to within about 20° of the south horizon.

Vol. xxix, p. 260. 1859, Aug. 28. Sacramento, Cal. Lambent streamers were noticed to shift gradually from west to east and vice versa.

Vol. xxix, p. 263. 1859, Aug. 28. Galveston, Texas. Stately columns of light reaching up about 45° from the horizon, moved westward about one degree for every ninety seconds of time.—The columns drifted westward and faded.

Vol. xxx, p. 86. 1859, Aug. 28. Cleveland, Ohio. Bright rays suddenly shot up in quick successive flashes, reaching nearly to the zenith, and moving slowly to west.

Vol. xxx, p. 87. 1859, Sept. 1. Fort Bridger, Utah Ter. The light appeared to flow gradually from N.N.E. to the southern sky.

Vol. xxx, p. 345. 1859, Aug. 28. Gettysburgh, Penn. The streamers were visibly wafted round on the east and west to the S.E., S.W., and even south.

From New York Meteorology 1826-1850, by Franklin B. Hough.

Page 487. 1827, Aug. 28. Lowville, N. Y. The arc began to move in a southern direction. . . . it broke up into parallel pieces which moved majestically westward. . . . At 11 its motion was mainly south.

Page 487. 1827, Aug. 28. Pompey, N. Y. The arc gradually inclined towards the south.

Page 488. 1830, July 15. Fredonia, N. Y. A belt at right angles with the galaxy, moved towards the south.

Page 489. 1831, April 1. Albany, N. Y. Shot up into brilliant columns moving eastward.

Page 489. 1831, April 19. Utica, N. Y. A beautiful arc, elevated about 50°, gradually rose, passed the zenith, and descended into the south within 25° of the horizon.

Page 489. 1831, June 21. Albany, N. Y. Shot up into brilliant prismatic columns which moved from W. to E., preserving in their motion a parallel position. In one or two instances, a sudden and rapid motion in the opposite direction towards the west.

Page 489. 1831, July 3. Albany, N. Y. Shot up into columns which appeared to move slowly in some cases to the east.

Page 490. 1831, July 31. Johnstown, N. Y. An arch moved south about 20°.

Page 490. 1833, May 17. Johnstown, N. Y. Parallel columns of light moved rapidly from N. to S.

Page 491. 1835, Sept. 9. Albany, N. Y. A faint white arch in the northern hemisphere which moved towards and passed the zenith.

Page 491. 1836, April 12. Cazenovia, N. Y. A single beam from the horizon moved sensibly to the south.

Page 493. 1837, Nov. 14. Buffalo, N. Y. Red streams further east appeared moving slowly eastward.

Page 493. 1837, Nov. 14. St. Lawrence, N. Y. Tall columns of silvery light were seen in the northern horizon, sometimes shooting up to the zenith, and again moving slowly from E. to W. as if impelled by a gentle breeze.

Page 496. 1842, June 4. Rochester, N. Y. A fine arc rose N. of E. and moved southward. . . . Grew fainter, moved slowly southwards, extended down to the horizon, began to move in slow portions to the west.

Page 497. 1847, March 19. North Salem, N. Y. Streamers ascended to the height of 20° ; all of which had a slow motion to the eastward.

Page 497. 1847, March 19. Woodstock, Vt. Pillars moving sometimes eastward and then westward, and sometimes rapidly passing each other.

Page 498. 1847, Nov. 25. North Salem, N. Y. A few streamers rose to the height of 45° , having a slow motion westward.

Page 498. 1848, April 1. Rochester, N. Y. Luminous white pillars; white pencils in the N.E. gradually passing westward and vanishing west of north.

Page 498. 1848, April 6. New York City. Streamers shooting up and moving westward.

Page 499. 1849, March 18. North Salem, N. Y. Streamers shot up: at first generally white; occasionally a tinge of red. The whole had a slow motion to the west.

From Arago's Meteorological Essays.

Page 448. 1827, Aug. 27. New York. A great number of bright streamers, which underwent a very rapid horizontal or lateral movement from east to west.

Page 449. 1827, Aug. 28. New York. There were in the north two concentric arches. The upper arch rose gradually higher above the horizon; reached the zenith; passed beyond it and then broke up. Vertical columns of light, having rather a rapid movement of translation, carrying them from E. to W., showed themselves below the great arch.

From newspaper records.

1835, Nov. 18. Hanover, N. H. Very brilliant streamers appeared to chase each other, running rapidly from W. to E. and back again from E. to W.

1839, Sept. 3. Middlebury, Vt. The auroral belt moved south, rapidly at first, then more slowly. Five parallel streamers, about 3° long, moved to the west, but not so rapidly as to be directly seen in motion.

1839, Sept. 14. Middlebury, Vt. There were seen in the arch prismatic streamers in active motion. Some of the motions were from west to east.

1841, Nov. 18. New Haven, Conn. There were two zones in the north, and columns slowly moving eastward.

From the Record of Auroral Phenomena by Peter Force.

Page 37. 1821, April 27. Fort Enterprise, lat. $64\frac{1}{2}^{\circ}$, long. 113° W. A single column of aurora rose in the north, and traversed the zenith towards the south. It passed to the western horizon in ten minutes.

Page 42. 1820, Dec. 4. Ib. A broad arch passed gradually to the southward. . . . A bright arch had a direction from N. to S. . . . A well formed arch moved slowly to the southward.

Page 44. 1820, Dec. 11. Ib. The arches moved slowly to the southward.

Page 62. 1850, Jan. 1. Fort Franklin, lat. 65° , long. 123° W. The aurora changed its position, progressing regularly and gradually towards the south.

Page 102. 1820, Feb. 10. Winter Harbor, lat. $74\frac{1}{2}^{\circ}$, long. 110° W. A low arch to the westward, from which pencils appeared to proceed. These pencils had a slow, though very sensible, lateral motion from north to south and vice versa.

The preceding catalogue includes 36 cases in which the motion of auroral arches and beams was described as from N. to S., and only three cases of a motion from S. to N. In the aurora of Aug. 28, 1827, at Canandaigua, N. Y., the arch seemed to move back towards the north; and soon after it moved again to the south more rapidly than ever. In the aurora of Nov. 17, 1835, at New Haven, the auroral zone, after moving for some time toward the south, began to recede northward; and also in the aurora of Feb. 10, 1820, at Winter Harbor, the auroral pencils had a slow lateral motion from N. to S. and vice versa.

We may hence conclude that in the United States, great auro- ras almost invariably exhibit a motion from N. to S. with occasionally and temporarily a slight retrograde movement from S. to N.

The preceding catalogue includes 31 cases in which the motion of auroral beams was described as from E. to W.; and 15 cases of a motion from W. to E. If auroral streamers had a motion exactly from N. to S. then those streamers which were included between the N. and E. points of the horizon would have an apparent motion towards the E.; while those streamers which were included between the N. and W. points of the horizon would have an apparent motion towards the west. It seems probable that the apparent motion from E. to W. and from W. to E. is frequently due to an actual motion from N. to S.; but since the apparent motion towards the W. is twice as frequent as that towards the E. we must conclude that *the actual motion of the streamers is from about N.N.E. to S.S.W.*

We thus find a general correspondence between the direction of the electric currents which traverse the earth's surface during displays of the aurora, and the motion of the auroral beams. In the United States, the former move from about N. 68° E. to S. 68° W., while the latter move from about N. 30° E. to S. 30° W.