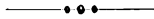


T H E

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[T H I R D S E R I E S.]



ART. I.—*Contributions to Meteorology: being results derived from an examination of the observations of the United States Signal Service, and from other sources*; by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Fourteenth paper, with Plates I, II, III.

[Read before the National Academy of Sciences, New York, Nov. 18, 1880.]

THE object of this paper is to investigate the course and velocity of storm centers in Tropical regions and also in the middle latitudes, and hence to deduce the causes which control their movements.

Course and velocity of storm centers in Tropical regions.

In my fifth paper (this Journal, vol. xii, p. 15,) I gave a table showing the course of those hurricanes which have originated near the West India Islands. That table was prepared in pursuance of a plan to determine the course of storms under the greatest variety of circumstances; and since the table exhibited but a small part of the information which I desired to obtain, I did not attempt to develop the conclusions which it naturally suggested. Soon after the publication of that paper, I prepared another table showing the course of hurricanes in the India and China Seas; but as this did not furnish all the information that I desired, I have hitherto withheld it from publication in expectation of more complete information. The system of International Meteorological observations has in part supplied the desired information, so that I propose now to consider the results already attained.

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I have compared all the storm tracks delineated on the maps of the Monthly Weather Review, and also those delineated on the International charts. I first examined the storms which have prevailed in the neighborhood of the American continent, confining myself to those cases in which the storm center (during at least a part of its course) was south of the parallel of 30° latitude. I have divided these storms into three classes; I, those whose course was for some days towards the west; II, those whose course was towards some point between the south and east; III, those whose course was towards some point between the north and east.

The following table shows the leading particulars respecting the first of these classes. Column 1st shows the number of reference; column 2d shows the dates of beginning and end of the observed movement as long as the course continued westerly; column 3d shows the latitude at the beginning and end of this portion of the path; column 4th shows the longitude at the beginning and end of this portion of the path; column 5th shows the prevalent direction of the path while moving westerly; column 6th shows the average velocity of progress of the storm center (in miles per hour) while the course continued westerly; column 7th gives a brief indication of the subsequent course of each storm. On plate I these tracks are delineated and are designated by the same numbers as in the table.

American storms advancing Westerly.

No.	Date.	Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
1	1873. June 1.1- 2.3	24-32	80- 86	N.N.W.	12.5	Became extinct.
2	Oct. 2 - 4.2	22-24	82- 86	N.W.	9.5	Moved N.E.
3	1874. Feb. 7 - 8.1	24-27	82- 83	N.N.W.	15.4	Moved N.E.
4	July 2.3- 4.2	27-29	87- 98	W.N.W.	13.1	Became extinct.
5	Sept. 4.3- 5.3	25-32	65- 70	N.N.W.	22.5	Moved N.E.
6	1875. Sept. 8.3-17.1	14-29	59- 96	W.N.W.	13.2	Moved N.E.
7	1876. Sept. 15 -18.1	21-43	69- 80	N.N.W.	25.9	Moved E.
8	1877. Sept. 22.2-30.3	12-26	65- 88	W.N.W.	11.1	Moved N.E.
9	1878. Aug. 12 -18	14-21	75- 97	W.N.W.	14.4	Unknown.
10	Sept. 1 - 8	11-28	59- 81	W.N.W.	9.3	Moved N.
11	Sept. 12 -18	14-29	47- 60	N.W.	9.6	Moved N.E.
12	Sept. 24 -30	14-28	70- 73	N.N.W.	5.3	Moved N.E.
13	Sept. 29 -34	22-30	58- 70	N.W.	9.1	Moved N.E.
14	Oct. 9 -13	15-26	40- 52	N.W.	7.2	Moved N.E.
15	Oct. 13 -18	17-30	36- 55	N.W.	13.2	Moved N.
16	Nov. 25 -30	15-17	52- 73	West.	11.7	Unknown.
17	1879. Aug. 13 -17	18-30	60- 77	N.W.	8.2	Moved N.E.
18	Aug. 15 -16	14-14	43- 51	West.	?	Unknown.
19	Aug. 20 -23	16-29	87- 94	N.W.	8.2	Moved E.
20	Oct. 3 - 7	15-31	78- 90	N.W.	8.1	Became extinct.
21	Oct. 10 -17	14-43	70- 90	N.W.	11.1	Moved E.
22	1880. Aug. 6 -14.2	12-32	77-103	W.N.W.	12.9	Disappeared.
23	Aug. 15 -19	13-20	62- 78	W.N.W.	12.0	Moved N.E.
24	Aug. 24 -31	26-33	60- 89	W.N.W.	10.0	Disappeared.

The general results of this table correspond very closely with those deduced from the table in my 5th paper. The lowest latitude of any storm center shown in this table is $10^{\circ}6'$ N. The lowest latitude shown in my 5th paper was $10^{\circ}3'$ N. The average velocity of these storms while moving westerly was 11.9 English statute miles per hour; the average velocity of the storms mentioned in my 5th paper while moving westerly was 17.4 miles per hour. In nine of these cases the course of the storm became due north before reaching the parallel of 30° .

Storm No. 18 apparently moved directly west; and storms Nos. 9 and 16 apparently moved for a day or two a little south of west. The table in my 5th paper shows 31 cases in which the course of storms was towards the north of west, and only two cases in which the course was south of west, viz: one case in which the course was two degrees south of west, and the other eleven degrees south of west. From the two tables we perceive that the cases in which tropical storms move in a direction north of west are fifteen times as frequent as the cases in which they move in a direction south of west, and in none of the cases here reported was the southerly motion very decided. Since in the middle latitudes the average progress of storm centers corresponds pretty nearly with the average direction of the wind, it might have been inferred that within the region of the northeast trade winds the average progress of storms should be towards the southwest.

In order to determine whether, during the period here considered, there may not possibly have been other storms which moved in a direction south of west, I have made a careful comparison of the International Observations. Five-sixths of all the storms enumerated in the table on page 2, occurred in the months of August, September and October. I therefore selected these three months for special comparison. For the years 1876, 7, 8 and 9 the barometric curves were drawn for these months for all the stations reported in the International Bulletin between the equator and lat. 26° N.

An examination of these curves shows that at all of these stations the fluctuations of the barometer are very small, particularly for the stations nearest to the equator. At Paramaribo, lat. $5^{\circ}45'$ N. the entire range of the barometer for these twelve months was only 0.20 inch, and there was no oscillation which can be identified with an oscillation at either of the other stations. At Bridgetown, lat. $13^{\circ}4'$ N., the entire range of the barometer for these twelve months was 0.23 inch. Two or three of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations. The track of storm No. 9 can apparently be traced back to Bridgetown on the 10th of Aug., 1878. At Fort de France, lat. $14^{\circ}40'$ N.,

the entire range of the barometer for these twelve months was 0.42 inch, and six or seven of the barometric oscillations at this station can probably be identified with oscillations at some of the other stations.

Besides the areas of low barometer enumerated in the table on page 2, there are but few others during this period which can be traced with confidence from one station to another. In 1876, the number of stations of observation in the tropical regions was small, and the storm of Sept. 15-18 is the only one which can be satisfactorily traced from these observations.

In 1877, the center of storm No. 8 passed at a considerable distance from all of the reporting stations, and is only obscurely indicated by the published observations. On the 26th of August, a small but well-marked barometric depression occurred almost simultaneously at all of the stations from Fort de France to Havana. On the 17th and 18th of October, there was a noticeable fall of the barometer, which apparently advanced from San Juan de Porto Rico to Havana.

In 1878, from Sept. 15th to 16th, a small barometric depression traveled from Bridgetown to Santiago de Cuba. From the 2d to the 3d of October, a small barometric depression traveled from Fort de France to Nassau. On the 21st of October, there was a decided barometric depression at Vera Cruz and Havana, which advanced northerly along the coast of the United States, and was marked by great violence.

In 1879, from the 16th to the 18th of August, a small barometric depression traveled from Bridgetown to San Juan de Porto Rico. This was perhaps a continuation of No. 18, of the table on page 2, and if so, it shows that this storm veered a little to the north of west, like most of the storms of this region. On the 28th of August, a small barometric depression appeared almost simultaneously at all the stations from Navassa to Tlacotalpam, on the coast of Mexico. This depression apparently advanced northward, but the published observations are not sufficient to enable us to trace its course satisfactorily.

This examination has disclosed a few barometric depressions in addition to those enumerated in the table on page 2, but their courses were generally towards the north of west. We therefore seem authorized to conclude that nearly all the areas of low barometer which occur within the tropics and advance westward, in the neighborhood of the West India Islands, instead of following the ordinary course of the Trade Winds, advance in a direction somewhat north of west.

American storms advancing in a Southeasterly direction.

During the colder months of the year, storms while crossing the United States frequently advance, during a portion of their

course, in a direction from northwest to southeast. This direction is not confined to any particular section of the country, but occurs most frequently in the region between the Rocky Mountains and the Mississippi River. This course is seldom maintained as far south as the parallel of 30° , and after reaching its most southerly point, the storm frequently changes its course towards the northeast. The following table shows those cases in which storms have advanced towards the southeast as far as the parallel of 28° . The arrangement is similar to that of the preceding table. The first six columns describe each storm as long as its course continued southeasterly; the last column gives some indication of the subsequent course of each storm. The tracks of these storms are all delineated on Plate II, and are designated by the same numbers as in the table.

American storms advancing Southeasterly.

No.	Date.	Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
1	1874. Feb. 17.2-18.2	$33^{\circ}-27^{\circ}$	$86^{\circ}-79^{\circ}$	S.E.	21.8	Unknown.
2	April 15.3-16.3	41-26	101- 89	S.E.	21.1	Unknown.
3	1875. Jan. 15.1-16.2	44-27	106- 91	S.E.	27.1	Unknown.
4	1876. Feb. 3 - 4.1	33-28	98- 80	S.E.	28.4	Unknown.
5	March 6.2-12.1	47-27	127- 89	S.E.	15.7	Unknown.
6	May 6.3- 7.3	33-27	100- 93	S.E.	25.0	Unknown.
7	1877. Jan. 4.2- 5.3	46-28	100- 90	S.S.E.	40.4	N.E.
8	Mar. 21.2-24.1	42-28	100- 95	S.S.E.	22.5	N.E.
9	Dec. 19 -20	44-28	102- 98	S.E.	10.0	N.
10	Dec. 22 -27.2	47-27	102- 95	S.E.	29.7	N.E.
11	1878. Feb. 1.1- 2.3	33-26	96- 84	S.E.	18.3	N.E.
12	Aug. 20.2-24.2	38-22	83- 81	S.S.E.	15.1	Became extinct.
13	Nov. 16.2-17.2	28-24	102- 93	S.S.E.	24.0	N.E.
14	1879. Jan. 6.3- 7.3	38-27	110- 98	S.E.	39.2	N.E.
15	Jan. 8.3-11.1	49-27	119- 98	S.E.	30.4	N.E.
16	May 4.1- 6.1	34-24	101- 96	S.S.E.	16.1	Became extinct.

We see from this table that the average velocity of these storms while pursuing their course towards the southeast, was twenty-four miles per hour, which differs but little from the average velocity of storms in other parts of the United States. The lowest latitude attained by any of these storms was $22\frac{1}{2}$ degrees; and in only three cases did the low center reach the parallel of 25 degrees. In eight cases the storm center, after completing its course towards the southeast, changed its course and proceeded towards the north or northeast. In two of the remaining cases the intensity of the storm declined in advancing southward, and they apparently became extinct soon after the dates given in the table. The same was probably true in the six remaining cases, but the observations are not sufficient to establish this with certainty.

Storm No. 12 was quite peculiar, having pursued a path almost directly opposite to that of ordinary storms. During the afternoon of Aug. 20th, 1878, there was an area of low pressure (29.75) over West Virginia, being part of a greater depression whose center was over Newfoundland, and there was a slight tendency to the formation of an independent system of circulating winds. Owing to a slight increase of pressure on the north side, this low area was crowded southward, and in the afternoon of Aug. 21st assumed the character of an independent low area (29.78) with a feeble system of circulating winds. At 7.35 A. M. Aug. 22d, this low center had been crowded south to lat. 30° , the greatest observed depression being now 29.88. After this the pressure increased, and the low center could not be distinctly traced. This example appears to illustrate the general character of areas of low pressure, and shows that their progressive movement is not due to a simple drifting of the atmosphere, but rather to a diminution of pressure on one side of the low area and an increase of pressure on the other side. In the present case, there was scarcely any appreciable diminution of pressure on the south side, and only a slight increase of pressure on the north side.

American storms advancing Northerly and Easterly.

The storms which cross the United States north of the parallel of 38° degrees, generally pursue a course a little to the north of east; while those which come from the region south of lat. 38° degrees generally pursue a course nearly northeast, especially in the neighborhood of the Atlantic coast. During the summer months few storm-centers travel south of the parallel of 38° , and during this period the average course of storms is almost exactly towards the east.

The following table shows those cases in which storms have traveled northward and eastward, and came from a point as far south as lat. 26° . The arrangement of the table is similar to that of the preceding. Columns 3 and 4 show the position of the storm-center at the beginning and end of the northeasterly motion, as far as is indicated by the observations; column 7th shows the lowest pressure reported, and column 8th gives a brief indication of the previous course of the storm. On Plate III these tracks are delineated and are designated by the same numbers as in the table.

We see from this table that storms of this class occur most frequently in the autumn, and least frequently in summer. One of these storms began near lat. 15° ; two began near lat. 20° ; and seventeen of them began south of lat. 24° .

American storms advancing Northerly and Easterly.

No.	Date.	Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest Barom.	Previous course.
1	1872. Nov. 6.1- 7.3	26-47	95-65	E.N.E.	60.4	29.71	Unknown.
2	Nov. 7.3- 9.3	25-30	95-78	E.N.E.	21.1	29.74	Unknown.
3	Dec. 9.2-13.3	26-47	101-57	N.E.	28.6	29.86	Unknown.
4	Dec. 23.2-27.2	25-44	95-58	N.E.	29.8	29.17	Unknown.
5	1873. Feb. 19.1-22.1	21-45	98-64	N.E.	35.1	29.17	Unknown.
6	May 4.1-10.1	24-43	98-81	N.E.	15.8	29.57	Unknown.
7	Sept. 18.1-20.1	24-34	92-74	N.E.	24.3	29.57	Unknown.
8	Sept. 22.3-24.1	25-36	86-72	N.E.	28.5	29.78	Unknown.
9	Oct. 5.1- 8.2	25-43	87-62	N.E.	32.9	29.02	Towards N.W.
10	Dec. 24.2-27.1	24-43	88-62	N.E.	30.4	29.37	Unknown.
11	1874. Jan. 5.2- 9.1	25-49	87-68	N.N.E.	18.0	29.42	Unknown.
12	Feb. 7.2-11.1	25-46	82-58	N.N.E.	25.0	28.95	Towards N.W.
13	April 17.3-24.1	24-46	94-59	N. & N.E.	29.7	29.36	Unknown.
14	Sept. 2.3-10.2	22-50	99-89	North.	21.5	29.47	Unknown.
15	Sept. 27.1-30.2	25-50	87-66	N.N.E.	26.0	28.94	Unknown.
16	Dec. 18.2-21.1	25-39	96-62	N.E.	34.6	29.33	Unknown.
17	1875. Nov. 6.1- 7.3	25-31	98-78	E.N.E.	32.9	29.82	Unknown.
18	1876. Oct. 19.1-21.1	21-32	82-72	N.N.E.	19.5	29.51	Not traceable.
19	1877. Sept. 16.1-21.3	25-31	96-76	E.N.E.	10.7	29.40	Unknown.
20	1878. Jan. 6.1-12.2	24-46	100-56	N.E.	26.4	28.85	Not traceable.
21	Feb. 26.2-28.1	24-30	92-71	E.N.E.	31.1	29.71	Came from N.W.
22	Mar. 17.1-17.2	23-25	85-78	E.N.E.	?	29.79	Not traceable.
23	Mar. 19.3-22.3	25-27	95-78	East.	15.0	29.71	Came from W.
24	July 2.1- 2.3	25-27	85-78	E.N.E.	22.9	29.77	Not traceable.
25	Sept. 24 -33	15-32	76-61	N. & N.E.	10.1	29.70	Not traceable.
26	Oct. 21.1-24.2	20-38	81-57	N. & E.	27.5	28.83	Not traceable.
27	Nov. 13.3-20.1	22-44	97-57	E. & N.E.	24.5	29.83	Not traceable.
28	Nov. 17.2-21.1	24-47	93-57	N.E.	40.3	29.47	Came from N.W.
29	1879. Nov. 19.1-20.3	23-49	74-60	N.N.E.	48.8	29.00	Not traceable.
30	1880. Jan. 24 -28.1	21-36	86-75	N.	14.3	29.68	Not traceable.
31	March 7.3- 9.2	26-32	99-74	E.N.E.	38.0	29.86	Not traceable.
32	May 3.1- 6.2	26-47	93-59	N.E.	23.8	29.79	Unknown.
33	Aug. 19 -20	20-27	78-74	N.N.E.	12.4	29.86	Towards N.W.

Three of these storms had been traveling towards the north-west, previous to the dates given in the table, and two of them came from the northwest; but in the other cases the barometric depression was too small to allow us to trace their course previous to the dates here given. For most of the cases in the last half of the table this is clearly shown by the International Observations, and we may therefore infer it to be true in the other cases. As long as these storms continued south of lat. 30°, the barometric depression was generally small, but it increased as the storm advanced northward. In fifteen cases the barometer fell below 29.5 inches, and in four cases it fell below 29.0 inches. The average velocity of progress of these storm-centers while advancing northward and eastward was 26.9 miles per hour. From a comparison of these three tables we perceive that the American storms which originate between the equator and lat. 20° N. generally travel towards a point

between north and west, but occasionally they advance almost exactly northward.

Course of hurricanes originating near the Bay of Bengal, China Sea, etc.

The following table contains various particulars respecting those hurricanes in Southern Asia and its vicinity, whose paths have been best determined. It includes all those which were most carefully investigated by Henry Piddington, together with those which have been since investigated by Blanford, Elliott and others. Column 1st gives the number of reference; column 2d shows the date of commencement, so far as indicated by the published observations; column 3d shows the latitude of the storm's center when it first became violent; column 4th shows the average course of the storm while advancing westward; column 5th shows the velocity of progress in English statute miles per hour while moving westward; column 6th shows the latitude at which the course of the storm became due north; column 7th shows the velocity while moving north; column 8th shows the average course of the storm after turning eastward; column 9th shows the hourly velocity of progress while moving eastward; column 10th shows whether rain was mentioned as accompanying the storm, and whether the rain-fall was violent or not; column 11th indicates the name of the person by whom the phenomena of the storm were investigated. (P.) stands for Henry Piddington; (B.) for Henry F. Blanford; (E.) for J. Elliott; (R.) for William C. Redfield; (F.) for J. Floyd; (M.) for Matthew F. Maury; (L.) for G. von Liebig; (G.) for Colonel J. E. Gastrell and Henry F. Blanford; and (W.) for W. G. Willson. Column 12th shows where the record of the investigation may be found. J. A. S. stands for Journal of the Asiatic Society of Bengal; J. S. for the American Journal of Science; S. D. for Maury's Sailing Directions; the other references are to special reports made by the investigators to the Government of Bengal.

It will be seen that 52 per cent of these cases occurred in the months of September, October and November, and 43 per cent occurred in the months of April, May and June, leaving only 5 per cent of the cases for the six remaining months of the year. Of the West India hurricanes reported in my fifth paper, 88 per cent occurred in the months of August, September and October, leaving only 12 per cent for the remaining nine months of the year: that is, the Asiatic hurricanes occur in the spring almost as frequently as in the autumn; but the American hurricanes are almost exclusively confined to the period near the autumnal equinox.

Course of Hurricanes originating near the China Sea, Bay of Bengal, etc.

No.	Date of Commencement.		Latitude of Origin.	Course while moving Westward.	Velocity in miles per hour.	Latitude when moving North.	Velocity moving North.	Course while moving Eastward.	Velocity moving Eastward.	Rain-fall.	Investigator.	Where recorded.
1	1803.	Sept. 21	16°0	W. 15 N.	9.1					Heavy	P.	J. A. S., v. 11
2	1810.	Sept. 28	18°1	W. 12 S.	7.3					Heavy	P.	J. A. S., v. 11
3	1835.	Aug. 5	20°5	W. 18 N.	17.0					Heavy	R.	J. S., v. 35
4	1838.	April 8	22°6					S. 37 E.	5.0	Hail	F.	J. A. S., v. 7
5	1839.	June 3	20°0	W. 13 S.	3.9					Violent	P.	J. A. S., v. 8
6		Sept. 20	22°0	W. 52 N.	9.5					Violent	P.	J. A. S., v. 9
7		Nov. 12	13°3	W. 23 N.	6.2					Heavy	P.	J. A. S., v. 9
8	1840.	April 27	11°6	W. 54 N.	9.8					Violent	P.	J. A. S., v. 9
9		Sept. 22	15°6	W. 83 N.	10.0					Violent	P.	J. A. S., v. 10
10	1841.	May 15	10°0	W. 25 N.	14.7					Heavy	P.	J. A. S., v. 11
11	1842.	June 2	20°5	W. 69 N.	4.8					Violent	P.	J. A. S., v. 11
12		Oct. 1	17°7	W. 31 N.	7.5	24.3	4.6			Violent	P.	J. A. S., v. 12
13		Oct. 22	12°0	West.	12.1					Violent	P.	J. A. S., v. 12
14	1843.	May 20	8°8	W. 38 N.	12.1					Heavy	P.	J. A. S., v. 13
15		Nov. 28	6°1	W. 40 N.	4.6					Rain	P.	J. A. S., v. 14
16	1844.	Nov. 9	11°1	W. 16 N.	3.4					Heavy	P.	J. A. S., v. 14
17	1845.	Oct. 7	17°1	W. 19 N.	13.5					Rain	P.	J. A. S., v. 18
18		Nov. 29	6°7	W. 12 N.	6.0					Violent	P.	J. A. S., v. 14
19	1847.	April 16	7°9	W. 86 N.	9.4					Violent	P.	J. A. S., v. 17
20		Nov. 18	17°0	W. 49 N.	6.2	18.5	5.8	N. 53 E.	5.0	Rain	P.	J. A. S., v. 18
21	1848.	Oct. 12	17°8	W. 50 N.	4.8					Rain	P.	J. A. S., v. 18
22	1850.	April 23	8°7	W. 50 N.	8.1	18.0	9.1			Violent	P.	J. A. S., v. 20
23		Nov. 17	12°2	W. 70 N.	6.0					Heavy	P.	J. A. S., v. 23
24	1851.	May 2	10°6	W. 54 N.	3.6					Violent	P.	J. A. S., v. 21
25		Oct. 21	17°6			17.6	10.9	N. 42 E.	5.7	Rain	P.	J. A. S., v. 23
26	1852.	May 12	15°7			20.0	10.1			Rain	P.	J. A. S., v. 24
27	1854.	April 22	13°2					N. 39 E.	9.8	Heavy	P.	J. A. S., v. 27
28	1856.	Dec. 7	10°0	W. 24 N.	11.7					Violent	M. S. D., v. 1	
29	1858.	April 9	14°2					N. 39 E.	12.1	Violent	L.	J. A. S., v. 27
30	1864.	Oct. 3	16°0	W. 56 N.	9.2	21.3	12.0	N. 29 E.	15.0	Violent	G.	Report.
31	1869.	May 13	16°0	W. 44 N.	7.6	20.5	14.0	N. 25 E.	17.0	Rain	B.	Report.
32		June 5	16°4	W. 83 N.	4.0	24.0	9.5	N. 39 E.	11.0	Violent	B.	Report.
33		Oct. 7	20°5	W. 34 N.	12.5					Violent	B.	Report.
34	1870.	Nov. 4	16°5	W. 11 N.	12.0					Violent	B.	Report.
35	1872.	April 28	7°5	W. 50 N.	5.0					Heavy	B.	Report.
36		June 28	20°5	W. 21 N.	7.1					Violent	B.	Report.
37		Sept. 19	21°0			23.0	12.7	N. 43 E.	13.7	Violent	B.	Report.
38	1874.	May 3	9°0	W. 39 N.	7.0					Violent	B.	Report.
39		Oct. 13	16°6	W. 60 N.	6.9	22.1	8.3	N. 40 E.	9.4	Violent	W.	Report.
40	1876.	Oct. 6	14°4	W. 25 N.	7.5	17.6	6.0	N. 16 E.	8.0	Heavy	E.	Report.
41		Oct. 27	11°0			14.0	10.0	N. 17 E.	20.0	Violent	E.	Report.
42	1877.	May 14	9°3	W. 63 N.	5.0	15.0	7.9	N. 45 E.	10.4	Violent	E.	Report.

The lowest latitude of any storm-path here recorded is 6°1', and there are fourteen cases as low as 12°. The lowest latitude of any of the West India hurricanes is 10°3', and there are only three cases as low as 12°.

Hard gales and violent squalls of wind do, however, sometimes occur directly under the equator. This is shown by various logs quoted in Piddington's Memoirs. The following is an

example from the log-book of the Winifred, quoted in Piddington's 11th Memoir, pages 30 to 40:

1843, Nov. 26,	lat. 9° 40' N.	Dark and threatening—strong, heavy squalls.
Nov. 27,	" 7 4 N.	Sudden and dangerous gusts and violent squalls.
Nov. 28,	" 4 27 N.	Heavy rain and most terrific squalls.
Nov. 29,	" 1 20 N.	Succession of dangerous squalls.
Nov. 30,	" 1 1 S.	Dismal weather and violent squalls.
Dec. 1,	" 3 15 S.	Dark, gloomy weather and violent squalls.

The following is from the log-book of the Fyzul Curreem, for the same period:

1843, Nov. 27,	lat. 5° 11' N.	Heavy squalls, N.N.W.
Nov. 28,	" 2 6 N.	Fresh gale, west.
Nov. 29,	" 0 54 S.	Gale from west, increasing steadily to midnight.
Nov. 30,	" 3 50 S.	Steady at west.
Dec. 1,	" 5 39 S.	Strong sea from W.S.W.
Dec. 2,	" 6 41 S.	Heavy head sea.

The courses of these storms while moving westward, range from 13 degrees south of west to 86 degrees north of west. In two cases the course was reported to be south of west, and in one case it was exactly west, which result accords very closely with that before found for West India hurricanes. The average velocity of progress of these storms while advancing westward was 8.1 English statute miles per hour, which is less than half the average velocity of West India hurricanes.

The average latitude of the storm-centers when the course became due north was 19.8, and the latitudes range from 14° to 24° 3, which is ten degrees more southerly than the latitude before found for the West India hurricanes. The average velocity of progress of these storms when advancing northward was 9.3 miles per hour.

The average course of these storms after turning eastward, was 35° east of north, and their velocity of progress was 9.8 miles, which is scarcely half of the velocity found for West India hurricanes.

Column 10th shows that rain accompanied every one of these storms, and generally the rain-fall was excessively great. These observations were generally made from vessels on the ocean, and the amount of the rain-fall could not be measured, but the rain was generally characterized by the strongest terms which the English language furnishes, such as: very heavy rain—constant heavy rain—ceaseless rain—excessively heavy rain—incessant heavy rain—sheets of rain—deluge of rain—rain poured down in torrents—dense, thick, impenetrable rain—rain with a vengeance—rain and very large hail—rain and sleet—hard sleet—torrents of rain and sleet, etc.

When a storm-center passed overland, where a rain-gauge was observed, the measurements showed that the preceding terms were no exaggeration. The following table shows the amount of rain-fall in twenty-four hours at certain stations:

Rain-fall in Tropical Cyclones.

Date.	Place.	Lat.	Long.	Rain, Inches	Authority.
1839. June 4	Dacca	23° 7'	90° 5'	6·00	Piddington, 1st Memoir. p. 37
1842. June 3	Calcutta	22° 5'	88° 3'	5·17	7th Memoir. p. 35
June 3	Kissenuggur	23° 4'	88° 4'	9·00	7th Memoir. p. 42
Oct. 3	Pooree	19° 8'	85° 9'	5·10	9th Memoir. p. 27
1843. May 23	Cannanore	11° 9'	93° 2'	5·95	10th Memoir. p. 32
May 23	Madras	13° 1'	80° 3'	10·50	10th Memoir. p. 20
May 23	Hyderabad	25° 3'	68° 4'	9·00	10th Memoir. p. 29
1851. May 5	Madras	13° 1'	80° 3'	11·44	21st Memoir. p. 17
1864. Oct. 6	Contai	21° 8'	87° 8'	10·00	Rep. of Gastrell & Blanford, p. 82
Oct. 6	Bograh	24° 8'	89° 4'	7·10	p. 82
Oct. 6	Goalparah	26° 2'	90° 7'	60·00	p. 82
Oct. 6	Moisgunj	23° 4'	88° 5'	7·50	p. 82
1874. May 4	Madras	13° 1'	80° 3'	7·10	Willson's Report, p. 127
Oct. 15	False Point	20° 3'	86° 8'	6·30	p. 9
Oct. 15	Jellalore	21° 5'	86° 9'	5·82	p. 9
Oct. 15	Midnapore	22° 4'	87° 2'	10·27	p. 8
Oct. 16	Burdwan	23° 2'	87° 9'	7·43	p. 8
Oct. 16	Lalgolla	24° 5'	88° 3'	16·30	p. 8
Oct. 16	Jungipore	24° 5'	87° 8'	8·00	p. 8
Oct. 16	Bood Bood	23°	88°	8·40	p. 8
Oct. 17	Rungpore	25° 9'	89° 3'	6·97	p. 9
1876. Oct. 7	Vizagapatam	17° 7'	83° 4'	5·60	Elliott's Report, p. 48
Oct. 8	Vizagapatam	17° 7'	83° 4'	12·60	p. 48
Nov. 1	Noakholly	22° 8'	91° 0'	5·12	p. 153
Nov. 1	Putuakhally	22° 3'	90° 4'	5·85	p. 153
1877. May 18	Madras	13° 1'	80° 3'	13·01	p. 42
May 20	Gya	24° 6'	85° 1'	5·06	p. 75
May 20	Nowada	23° 9'	88° 4'	8·00	p. 75
May 20	Aurungabad	19° 9'	75° 3'	8° 68	p. 75
May 20	Rajmahal	25° 0'	87° 7'	5·20	p. 75
May 20	Raigunge	25°	88°	5·71	p. 75
May 20	Jawai	25°	91°	9·70	p. 75
May 21	Barrh	25° 5'	85° 7'	6° 43	p. 77
May 21	Chanchal	25° 0'	88° 2'	6° 14	p. 77
May 21	Rungpore	25° 9'	89° 3'	11° 16	p. 77
May 21	Kurigram	25°	89°	5° 70	p. 77
May 21	Bogdogra	25°	89°	12° 19	p. 77
May 21	Julpigoree	26° 5'	88° 7'	5° 53	p. 77
May 21	Boda	26°	89°	8° 52	p. 77
May 21	Cooch Behar	26° 3'	89° 5'	9° 77	p. 77
May 21	Dhubri	26° 0'	90° 0'	5° 60	p. 77
May 21	Jawai	25°	91°	14° 20	p. 77

From this table we see that these hurricanes were accompanied by an amount of rain such as seldom occurs, even within the tropics, and we seem authorized to conclude that excessive rain invariably accompanies the most violent hurricanes. This conclusion accords with that deduced from the investigation of the West India hurricanes.

I next examined all the maps of the International Observations for additional materials, showing the course of storms in Southern Asia and the adjacent oceans. The following are the most important cases which I have found :

Asiatic storms moving Westerly.

No.	Date.	Latitude. beg. end.	Longitude. beg. end.	Course.	Vel., miles.	Subsequent course.
1	1878. Sept. 15-19	16-29	134-124	N.W.	10.8	Moved N.E.
2	Oct. 7- 9	19-19	122-112	West	14.3	Unknown.
3	Nov. 17-21	12-15	95- 82	West	6.6	Disappeared.
4	Nov. 29-38	10-18	97- 83	W & N.W.	5.8	Disappeared.
5	1879. May 17-26	14-35	85- 75	S.&W.&N.	12.4	Disappeared.
6	May 30-32	20-22	88- 90	West	7.2	Disappeared.

Asiatic storms moving Southeasterly.

7	1877. Dec. 27-30	27-20	65- 80	E.S.E.	18.1	Moved N.E.
8	1878. Feb. 6-12	39-22	60- 92	E.S.E.	16.7	Disappeared.
9	May 3- 8	33-17	77- 79	South	10.0	Disappeared.
10	June 2- 7	66-26	110-112	South	15.4	Moved N.E.

Asiatic storms moving Northeasterly.

11	1879. Mar. 2- 6	6-34	118-152	N.E.	21.8	Unknown.
12	Mar. 15-22	10-40	113-157	N.E.	15.4	Unknown.

In several of these cases the depression of the barometer, so far as reported, was not very great, and the storms do not appear to have been of remarkable violence, nevertheless the results here found accord reasonably well with those before found, except that the velocities while the storms were moving easterly, are greater than the average of those shown in the table on page 9.

On comparing all these tables it is remarkable that but few cases have been found in which a storm-center has advanced towards any point between west and south. Including the table in my fifth paper, we have found 98 cases of tropical storms which advanced westerly, and of these only five moved towards any point between south and west. The first of these advanced in a direction about two degrees south of west; the second advanced eleven degrees south of west; the third advanced twelve degrees south of west; the fourth advanced thirteen degrees south of west; and the fifth, starting from lat. 30°, advanced for three days in a direction nearly south, then one day nearly west, and subsequently towards the northwest.

I next endeavored to ascertain what was the prevalent direction of the wind which preceded each of these tropical storms, and also the prevalent wind which succeeded the low center, and how these two winds generally compared in respect of force. It is impossible to make a satisfactory comparison from the observations in the International Bulletin, on account of the small number of stations, and because the observations are reported only once a day. The following tables show the direction and force of the wind in the case of five of the low areas

enumerated on page 2, for the stations nearest the center of low pressure. The numbers without brackets show the velocity of the wind in miles per hour; the numbers in brackets show the force of the wind estimated in units of Beaufort's scale (1 to 10). In each line the direction and force for one day are printed in large type, to indicate the day when the barometer at that station was lowest.

1876, *September.*

	14th.	15th.	16th.	17th.	18th.	19th.
Kingston	Calm	S.E.5	S.E.8	S.E.8	Calm	Calm
Nassau	N.E.(3)	N.E.(8)	S.E.(6)	S.(3)	N.E.0	N.E.(5)

1878, *August.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.2	E.12	S.E.4	S.E.8	S.E.0	S.E.2
Navassa	S.E.12	N.E.10	N.19	S.E.29	E.17	E.17
Kingston	Calm	Calm	Calm	S.E.10	S.E.20	Calm
Nassau	S.E.(1)	N.E.(2)	N.E.(2)	S.E.(1)	S.E.2	S.E.(2)
Havanna	E.4	E.S.E.4	E.S.E.3	E.N.E.4	E.9	S.E.16

1878, *September.*

	3d.	4th.	5th.	6th.	7th.	8th.
Navassa	S.19	N.20	S.22	S.E.20	E.14	E.15
Santiago de Cuba	N.E.7	N.6	S.E.(6)	S.E.4	S.E.6	Calm
Kingston	Calm	Calm	E.3	S.13	S.E.18	Calm

1878, *September.*

	24th.	25th.	26th.	27th.	28th.	29th.
San Juan	N.E.6	S.E.11	S.E.1	S.E.6	S.E.4	S.E.4
Navassa	N.W.12	N.N.E.18	E.8	N.W.12	S.25	S.15
Santiago de Cuba	N.(1)	N.N.E.8	N.N.E.(1)	N.(1)	N.W.(1)	S.W.(1)

1879, *October.*

	10th.	11th.	12th.	13th.	14th.	15th.
San Juan	S.E.4	S.E.7	S.E.0	S.E.0	S.E.0	S.E.0
Navassa	N.E.5	E.10	S.E.16	E.20	S.E.15	S.E.18
Santiago de Cuba	N.7	N.2	S.E.10	S.E.6	S.E.8	S.E.6
Kingston	Calm	Calm	S.E.4	S.E.18	S.E.6	Calm
Nassau	N.E.	N.E.	N.E.	E.	S.E.	S.13.
Havanna	E.N.E.10	E.6	E.N.E.8	E.12	E.20	S.S.E.18

It will be seen that in every case the passage of the low center was followed by a southerly wind, and in two-thirds of the cases this had been immediately preceded by a northerly wind; and in nearly every case the southerly wind which followed

the low area was stronger than the northerly wind which preceded it. This result, I believe, accords with what has generally been observed in tropical cyclones, and appears to suggest the explanation of the origin of the cyclone, and the direction of its progressive movement. The prevalent direction of the wind in the neighborhood of the West India Islands, is from the northeast. Occasionally a strong wind sets in from a southerly quarter. The interference of these winds gives rise to a gyration, and sometimes rain-fall is the result. When rain commences, the latent heat which is liberated, causes the wind to flow in from all quarters, by which the rain-fall is increased; and since the winds are deflected by the rotation of the earth, an area of low pressure is produced, and the force of the winds is maintained as long as the rain-fall continues. The effect of this strong wind from the south is to transport the low center in a northerly direction; and by the combined action of this south wind and the normal wind from the northeast, the center of low pressure is usually carried in a direction between the north and west.

The following summary presents some of the results derived from this investigation:

1. The lowest latitude in which a cyclone has been found near the West India Islands is ten degrees, and the lowest latitude in the neighborhood of Southern Asia is six degrees. Violent squalls and fresh gales of wind have however been encountered directly under the equator.

2. The ordinary course of tropical hurricanes is towards the west-northwest. In a few cases they seem to have advanced towards a point a little south of west, and in a few cases their course has been almost exactly towards the north.

3. Tropical hurricanes are invariably accompanied by a violent fall of rain. This rain-fall is never less than five inches in twenty-four hours for a portion of the track, and frequently it exceeds ten inches in twenty-four hours.

4. Tropical storms are generally preceded by a northerly wind, and after the passage of the low center the wind generally veers to the southeast at stations near the center; and the southerly wind which follows the low center is generally stronger than the northerly wind which preceded it. This fact appears to suggest the explanation of the origin of the cyclone and the direction of its progressive movement.

5. None of the storms which have pursued a southeast course across the United States and its vicinity, have been traced further south than latitude $22\frac{1}{2}$ degrees, and only three have been traced as far south as latitude 25 degrees. These storms during their progress southward generally decline in intensity. Some of them decline to such an extent that their course can

no longer be traced, while others change their course and turn towards the northeast. In my eleventh paper I have shown that storms which advance from north to south across the United States, are generally attended by a very slight fall of rain; and this seems to explain the fact that they generally decline in intensity as they advance southward.

Storms in the Middle latitudes advancing in a Westerly direction.

The infrequency of the cases in which tropical storms have advanced towards the southwest, has led me to search for corresponding cases in the middle latitudes of America and Europe. For this purpose I have examined all the cases in which the charts of the U. S. Signal Service indicate the movement of a storm center towards any westerly point. I have also examined Hoffmeyer's daily charts from Dec., 1873, to Oct., 1876; the charts of the Deutsche Seewarte from Jan., 1876, to March, 1879, and from Jan., 1880, to April, 1880; also the charts of the International Observations from Nov., 1877, to Dec., 1879. Many of the cases of this description which are shown on the charts of the U. S. Signal Service are cases in which the depression of the barometer was small, when there was no single well-defined storm center, but there were two or three centers of slight depression within a few hundred miles of each other, so that a slight change in the force of the winds would cause one of the centers to predominate a little, and thus the center of greatest depression might be carried in an unusual direction.

The following table shows the most decided cases in which storm-centers in the United States have advanced in a westerly direction:

Storms in the United States advancing Westerly.

No.	Date.	Latit'e. beg. end	Long. beg. end	Course.	Vel., miles.	Lowest barom.	Subsequent course.
1	1873. Oct. 20.1-21.3	39-46	75-86	N.W.	20.7	29.35	Unknown
2	1874. May 9.1- 9.3	49-42	97-104	S.W.	37.3	.29	N.E.
3	1876. Jan. 8.3- 9.1	44½-43	84-87	S.W.	22.2	.14	E.N.E.
4	Feb. 25.3-26.3	41-38½	95-97	S.S.W.	8.5	.40	Eastward
5	June 17.3-18.2	44-47	86-88	N.W.	12.7	.37	Southerly
6	Sept. 16.1-17.3	25-41	77-79½	N.N.W.	28.8	.47	Eastward
7	1877. Feb. 21.2-22.1	48-41½	89-93	S.S.W.	33.9	.35	Eastward
8	Nov. 22.3-24.3	32-42	79½-84	N.N.W.	15.7	.63	Disappeared
9	1878. Feb. 19.2-20.1	43-34	95-98	S.S.W.	43.0	.33	N.E.
10	Mar. 10.1-11.1	43-42	96-104	W.S.W.	18.0	.47	Eastward
11	Mar. 23.1-24.1	50-42	57½-72	S.W.	36.7	.22	E.N.E.
12	April 28.2-29.1	37-41	77-79½	N.N.W.	18.5	.58	Disappeared
13	June 22.2-23.1	42-44	76-79	N.N.W.	15.7	.60	E.N.E.

The number of these cases is 13; and 4 of these pursued a course about N.N.W.; 2 advanced towards the N.W.; 1 towards the W.S.W.; 3 towards the S.W.; and 3 towards the S.S.W. Case No. 1 was particularly noticed in my seventh

and eleventh papers. It was there shown that this storm was accompanied by an excessive fall of rain; also that the winds on the east side were uncommonly strong, and observations of the upper clouds indicated that these winds extended to an unusual height above the earth's surface. Nos. 5, 6, 8, 12 and 13 were also accompanied by a great fall of rain, especially No. 6, and in all of the cases the winds from the south and east were remarkably strong. This will appear more distinctly from the following table, in which column second shows the highest wind reported for cases 1, 5, 6, 8, 12 and 13 at the given dates from any quarter between N. and W.; and column third shows the highest wind from any quarter between S. and E.

Highest winds reported.

Date.	N. and W.	S. and E.	Date.	N. and W.	S. and E.
1873. Oct. 20.1	N. 28	S.E. 32	1877. Nov. 22.2	N.W. 25	S.E. 20
20.2	N. 36	E. 42	22.3	N.W. 16	S.E. 22
20.3	N. 28	S.E. 32	23.1	N. 15	S.E. 32
21.1	N. 32	S. 24	23.2	N.W. 16	S.E. 30
21.2	N. 20	S. 28	23.3	W. 12	E. 32
21.3	N. 32	S. 32	24.1	N.W. 12	E. 44
1876. June 17.3	N. 24	S.E. 29	24.2	N. 10	E. 42
18.1	N.W. 30	S.E. 32	24.3	N.W. 8	E. 28
18.2	N.W. 38	S.E. 24	1878. April 28.2	N. 20	E. 18
Sept. 16.2	N.W. 24	E. 24	28.3	N. 15	E. 14
16.3	N.W. 10	E. 32	29.1	N.W. 12	E. 30
17.1	W. 13	E. 24	June 22.2	N. 20	E. 48
17.2	N.W. 10	E. 16	22.3	N.W. 12	E. 40
1877. Nov. 22.1	N.W. 13	S.E. 32	23.1	W. 12	E. 17

The average of the greatest velocities for the northwest quarter is 19 miles per hour, and for the southeast quarter it is 29 miles per hour.

In the following table, column second shows the highest wind reported for cases 2, 3, 4, 7, 9, 10 and 11 at the given dates for any quarter between S. and W.; and column third shows the highest wind reported from any quarter between the north and east.

Highest winds reported.

Date.	S. and W.	N. and E.	Date.	S. and W.	N. and E.
1874. May 9.1	S.W. 30	N.E. 12	1877. Feb. 22.1	S. 21	N. 25
9.2	S. 32	N.E. 12	1878. Feb. 19.2	S. 27	N.E. 8
9.3	S. 40	E. 17	19.3	S. 22	E. 15
1876. Jan. 8.3	S. 25	N.E. 26	20.1	S.W. 32	N. 18
9.1	S.W. 18	N.E. 29	Mar. 10.1	S. 20	N.E. 40
Feb. 25.3	S. 22	N.E. 44	10.2	W. 30	N.E. 55
26.1	S. 14	N.E. 50	10.3	S. 11	N.E. 36
26.2	S. 24	N.E. 44	11.1	S.W. 8	E. 16
26.3	S. 18	N.E. 44	24.1	S.W. 22	N. 40
1877. Feb. 21.3	S. 21	N. 20			

The average of the greatest velocities for the southwest quarter is 23 miles per hour, and for the northeast quarter it is 29 miles per hour. There are several instances in which the mode of comparison here adopted does not fairly indicate the relative force of the winds on the opposite sides of a low center, especially when the low center happens to be situated near the margin of the Signal Service map, but the average of the results when the storms were advancing towards the northwest, and also when they were advancing towards the southwest, appears very decided, and seems to indicate distinctly that the centers of least pressure advanced in that direction towards which the winds pressed in with the greatest force.

In my first paper I gave the result of two years' observations, which showed that the average velocity of the wind on the west side of a low center (within the isobar 29·90) was 10·1 miles, and on the east side 8·3 miles; being 22 per cent greater on the west side than on the east side. We have now found that when a low center advances westward, the velocity of the wind is generally greatest on the east side of the low center. The progressive movement of storms probably depends upon meteorological conditions which prevail at a considerable distance from the low center. Hoffmeyer's charts and the International maps sometimes inform us what these conditions are. The following summary shows certain conditions which prevailed at each of the cases contained in the table on page 15, as far as is shown by the maps which I have received.

- No. 3. High on the north and east (765) with low (735) near South Greenland.
- No. 4. High on the northeast (775 to 785) with low (735) near Newfoundland.
- No. 5. High on the east (770) with low (740) near Iceland.
- No. 6. High on the northeast (775) with low (750) over the Atlantic.
- No. 8. High on the northeast (30·40) with low (29·80 to 29·20) over the Atlantic.
- No. 9. High on the east (30·20) with low (29·20) near Newfoundland.
- No. 10. High on the northeast (30·60) with low (29·40) over the Atlantic.
- No. 11. High on the north and northeast (30·20) with low (29·00) over Northern Europe.
- No. 12. High on the north and northeast (30·20) with low (29·40) near South Greenland.
- No. 13. High on the north and east (30·20 to 30·40) with low (29·60) near Iceland.

Thus we see that in the preceding cases there generally prevailed a considerable area of low pressure over the Atlantic Ocean, while on its western or northwestern side a cold wind from the north, with high pressure, was forcing its way southward, and this may be presumed to have crowded westward the low areas prevailing at the same time over the United States.

The following summary presents some of the conditions prevailing at these dates on the Western side of these low areas.

No. 1. Low center (29·70) on the Northwest side which gradually approached and coalesced with No. 1.

No. 2. Isobars protruded very much towards S.W.

No. 3. Isobars protruded very much towards S.W.

No. 6. Low center (29·50) on the Northwest side.

No. 7. Isobars protruded towards S.S.W.

No. 8. Low center (29·50) on the Northwest side.

No. 9. Isobars protruded to a great distance towards S.W.

No. 10. Low center (29·80) in the Gulf of Mexico.

No. 11. Isobars protruded to a great distance towards S.W.

No. 12. Low center on the N.W.

No. 13. Subordinate low center on the N.W.

Thus we see that while on the East side of these low areas there were causes which tended to increase the pressure on that side, there were different conditions on the Western side which tended to divert the winds Westward, and this is apparently the most important reason why, in these cases, the centers of least pressure advanced Westward.

Storms advancing Westerly over Europe and the Atlantic Ocean.

The following table shows the most decided cases in which storm centers have advanced in a Westerly direction over Europe and the Atlantic Ocean.

European storms advancing Westerly.

No.	Date.	Latitude. beg. end.	Longitude. beg. end.	Course.	Vel. miles.	Low't bar'm	Subsequent course.
1	1875. Mar. 14-16	50° -46°	37°W.-43½°W.	S.W.	8·3	730	Absorbed
2	Dec. 17-19	64° -64°	29°W.-43°W.	West	8·8	720	Easterly
3	1876. April 19-20	52° -56°	3°W.-5°W.	N.N.W.	12·2	735	N.E.
4	June 19-20	57½°-60½°	23½°W.-27°W.	N.W.	10·1	730	Subdivided
5	June 22-23	57½°-59°	26°W.-33½°W.	N.W.	12·1	740	Disappeared
6	Sept. 9-12	55° -60°	21°E.-7°E.	N.W.	8·0	735	Subdivided
7	Sept. 22-23	54½°-56°	26½°W.-30°W.	N.W.	6·7	740	Subdivided
8	Oct. 20-21	56½°-64°	34½°W.-49°W.	N.W.	28·7	720	Eastward
9	Nov. 12-14	50° -52°	7°W.-16°W.	W.N.W.	8·8	730	Northward
10	Dec. 21-23	53° -56°	1°W.-8°W.	W.N.W.	3·8	729	Southerly
11	1877. April 4- 8	56° -50°	9°W.-13°W.	S.S.W.	4·8	733	N.E.
12	May 3- 6	52° -64°	44°E.-18°E.	N.W.	17·2	744	Disappeared
13	July 15-16	54° -54°	2°W.-5°W.	West	3·4	737	N.E.
14	Aug. 9-9½	54° -57°	0-4°W.	N.W.	19·2	745	Disappeared
15	1878. Mar. 31-32	59° -59°	10°E.-0°	West	14·3	729	North
16	May 30-32	60° -60°	27°E.-17°E.	West	7·1	741	N.E.
17	Nov. 4- 6	54° -59°	25°E.-19°E.	N.N.W.	8·6	737	N.E.
18	Nov. 11-13	59° -49°	7°E.-3°E.	S.S.W.	14·4	733	S.E.
19	Nov. 14-16	47° -54°	10°E.-4½°E.	N.N.W.	11·5	734	South
20	Dec. 10-11	52° -56½°	25°E.-23°E.	N.N.W.	14·9	739	N.E.
21	1880. Feb. 16½-17	54° -56°	7½°W.-10°W.	N.W.	17·2	720	Unknown

The first eight cases are derived from an examination of Hoffmeyer's charts. Six of these cases occurred near the middle of the Atlantic ocean; one on the western borders of Europe, and the other in the eastern part of Europe. They are cases in which the depression of the barometer was consid-

erable; in which the low center was pretty sharply defined; and in which no neighboring low center is represented on Hoffmeyer's maps. Cases 9 to 21 have been derived from the charts of the Deutsche Seewarte, and all have been carefully compared with the International Observations, excepting No. 21, for which the International Observations have not yet been received. Of these 21 cases, 14 advanced towards some point between north and west, 3 advanced towards some point between south and west, and 4 advanced almost exactly west.

I have endeavored to compare the force of the wind on that side of each low area towards which the storm was advancing, with the force on the opposite side according to the observations delineated on Hoffmeyer's charts. The number of the observations over the Atlantic Ocean is so small that the results for that region are not entitled to much weight. The following shows the comparison of the observations within the isobar 750 for cases 3 and 6, the force of the winds being represented by the numbers of Beaufort's scale (0 to 6).

		Front.	Rear.			Front.	Rear.
1876.	April 19	1·76	2·27	1876.	Sept. 10	2·20	3·33
	Sept. 9	1·42	1·50		Sept. 11	1·83	2·87

Thus we see that on the rear of these low areas the average force of the wind was 38 per cent greater than on the front side.

The following summary shows the state of the barometer on the east side and also on the west side of storms Nos. 1–8 and Nos. 15–20.

<i>On the East side of the low area.</i>		<i>On the West side of the low area.</i>	
1	775 on the north and east increasing to 780 on the northeast.	29·4 to 29·0 in the United States. Isobars protruded westward.	
2	735 on the east.	29·6 to 29·2 near Newfoundland.	
3	770 on the east.	755 to 740 near Newfoundland.	
4	765 to 770 on the east.	29·6 in the United States. Isobars protruded westward.	
5	770 on the northeast side.	755 to 745 near Hudson's Bay.	
6	770 on the east and 750 on the north-northeast.	765 to 770 on the west, with 755 to 735 near Newfoundland.	
7	765 on the east and southeast.	755 to 750 on the northwest.	
8	770 to 775 on the east.	Subordinate low (735) near South Greenland. Also 745 in the United States.	
15	30·4 to 30·6 on the east.	29·7 to 29·4 near Newfoundland.	
16	Barometer slightly below normal throughout nearly all of Asia.	29·7 near Greenland.	
17	30·6 on the east.	30·2 falling to 30·0 on the west. Also 29·6 near Newfoundland.	
18	30·4 on the southeast.	30·4 on the southwest.	
19	30·4 on the east.	Subordinate low (29·4) on the north-west side; also 29·1 in Greenland.	
20	30·8 to 31·0 on the east.	29·8 to 30·0 on the west and northwest.	

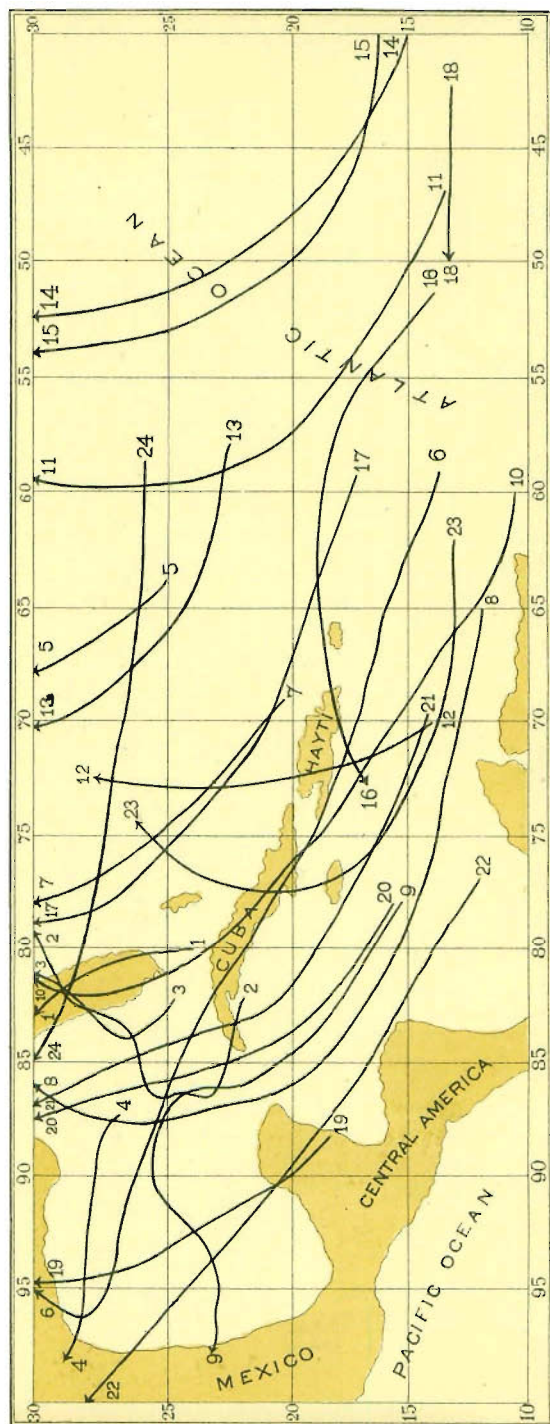
In all but two of these cases there was an area of high pressure on the east side of the storm center, and in several of the cases this pressure was above 30·5 inches. Such a pressure is

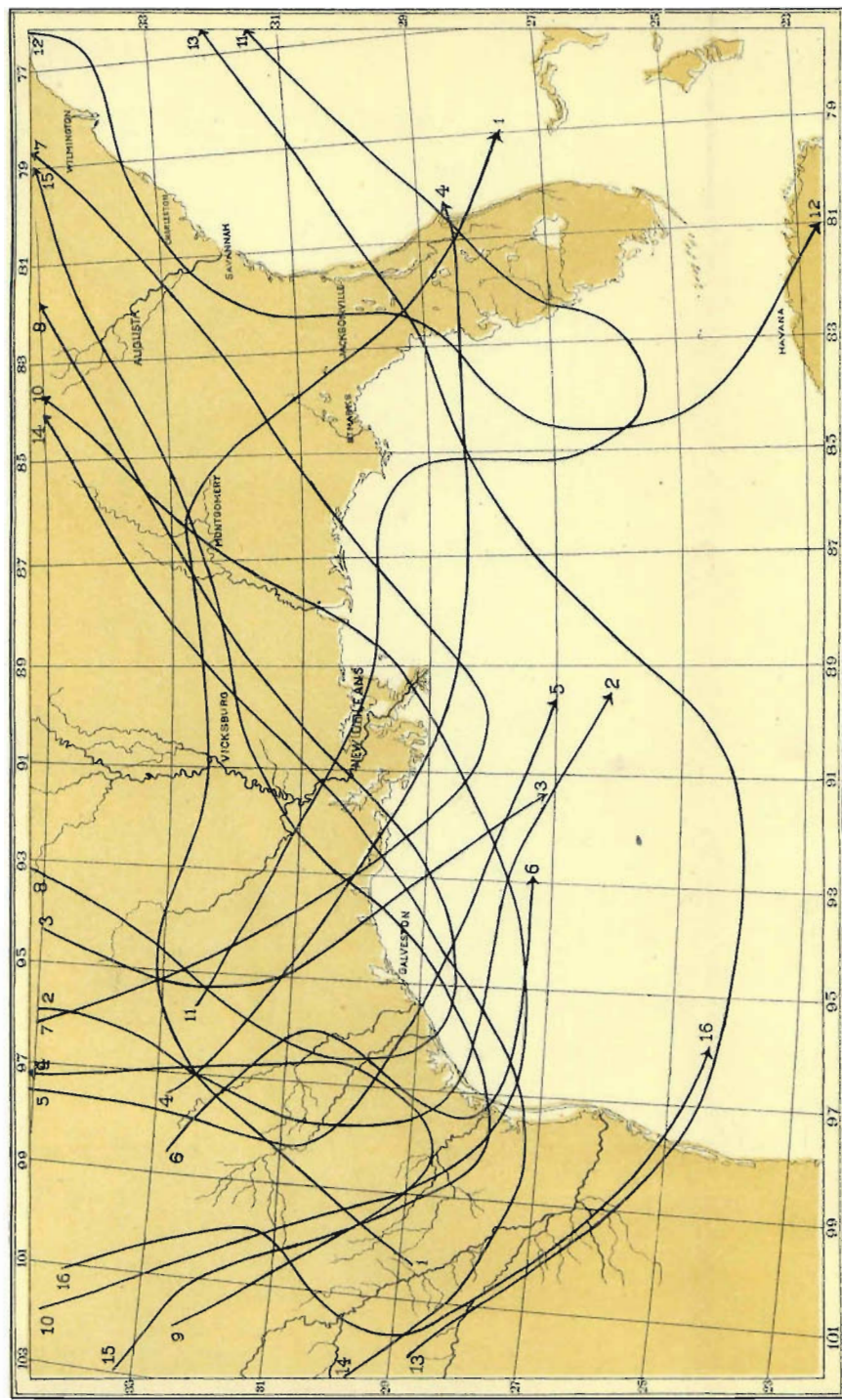
sufficient to produce a wind of considerable force. On the west side of these storm centers there was generally a second area of barometric depression, and in several cases the two depressed areas approached each other until they coalesced, by which means the eastern low center was apparently transported westward. Nos. 1, 2, 8 and 19 were of this description, and probably also No. 5. In several other cases the two low areas approached each other until they formed a single low area of an elongated form, with two low centers which remained for several days distinct from each other. Such were Nos. 3, 4, 7 and 15. In No. 6 the storm was apparently diverted Northward by the low area on the north-northeast. In No. 16 the pressure was generally below 30 inches throughout north America, the North Atlantic Ocean, as well as Europe and Asia. In such a case, slight local causes are sufficient to divert the winds in a new direction. In No. 17 there was apparently an area of low pressure on the north beyond the stations of the International Observations. In No. 18 there was a high area on the southeast and another on the southwest, and the low area pushed in between them. In the United States it is frequently observed that when two areas of high pressure approach within a few hundred miles of each other, a low center is developed between them. A similar case occurred in No. 6 between Sept. 11th and 12th. In No. 20 the observations do not indicate any decided low center on the north or west, yet the pressure was every where either below or but little above the normal over the North Atlantic Ocean and North America.

Thus we see that in Europe and over the Atlantic Ocean as well as in the United States, the influence of one area of low pressure upon another is a very common cause of abnormal movements of storm centers.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

NOTE.—Since the preceding was in type, I have received Hoffmeyer's charts for November, 1876, from which it appears that on the 12th of November, 1876, there was an area of low pressure (730 to 725) west of Ireland; and the apparent westward movement of No. 9 on page 18 was plainly due to the influence of this low center. I have also received the International Bulletin for October, 1880, from which it appears that on February 16th there was a low center (28.40) west of Ireland, and the apparent westward movement of No. 21 on page 18 was plainly due to the influence of this low center.





TRACKS OF AMERICAN STORMS ADVANCING NORTHEASTERLY

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PLATE III.

