

T H E

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



ART. I.—*Contributions to Meteorology*; by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Eighteenth paper. With a Map (Plate I).

[Read before the National Academy of Sciences, Nov. 14, 1882.]

Mean annual rain-fall for different countries of the globe.

MY sixteenth paper of "Contributions to Meteorology" contained a table showing the annual rain-fall for 713 stations from various parts of the globe, and also a chart showing the lines of equal rain-fall as well as I could determine them from the observations then collected. I however distinctly stated that for certain portions of the globe, and especially for the southern hemisphere, the observations were too few to enable us to draw the lines of equal rain-fall with confidence; and I requested that if any person should discover serious defects in my chart, he would communicate to me the observations which indicate these defects. In response to this request I have received communications from numerous sources, of which the following are the most important: The Meteorological Service of the Dominion of Canada; the Meteorological Institute of Norway; the United States Signal Service; Dr. Alexander Woeikoff of St. Petersburg; Dr. A. von Danckelman of Leipzig; Dr. Benjamin A. Gould of Cordoba; Professor Orville A. Dewey of Rio de Janeiro; Dr. Mauricio F. Draenert of Bahia; and Henry B. Joiner of S. Paulo, Brazil. I have also received the published observations of rain-fall from a large number of

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countries, of which those from Mexico, Japan, the East Indian Archipelago, and Australia, and those contained in the second edition of Schott's Rain Tables, have proved of the greatest value for my present purpose. I have carefully considered the criticisms which have been made upon my first paper, particularly those of Dr. Woeikoff (this Journal, May, 1882) and those of the editor of *Nature* (June 29, 1882).

The accompanying table shows the most important observations which I have thus far received, many of them being from new stations, while those from stations included in my former paper exhibit the results of a more extended period of observation. Column 1st contains the reference number; column 2d gives the name of the station; column 3d gives its elevation above the sea expressed in English feet; column 4th gives the latitude of the station and column 5th its longitude from Greenwich; column 6th shows the number of years of observation represented; column 7th shows the mean annual rain-fall expressed in English inches; and column 8th gives the authority for the results. In the last column, Schott's T. 2d ed. stands for Tables of the precipitation in rain and snow in the United States, by Charles A. Schott, 1881; Bol. Met. Mex. stands for Boletín Meteorológica Mexicana; Revista Ci. Mex. stands for Revista Científica Mexicana; Rev. de Engenh. stands for Revista de Engenharia; S. Paulo R. Co. stands for São Paulo Railway Company; Zeitsch. stands for Zeitschrift der Österreichischen Gesellschaft für Meteorologie; En. Met. Com. 28 stands for Contribution to the Meteorology of Japan No. 28, issued by the English Meteorological Committee; Q. J. Met. Soc. stands for Quarterly Journal of the London Meteorological Society; A. v. Danckelman stands for Meteorologischen Beobachtungen von Dr. A. von Danckelman; Russ. Met. Obs. stands for Russell's Rain Observations in New South Wales. The other abbreviations will probably be understood without particular explanation. This table might have been very much enlarged, but I have confined myself to those stations which were regarded as specially useful in revising my rain-chart. With the aid of the new materials thus collected I have prepared a new chart of the rain-fall which is believed to represent pretty well all the observations contained in my two tables.

If these two charts are carefully compared, a general resemblance will be readily perceived, particularly in the Northern Hemisphere. In North America there is a little change between Lake Superior and Hudson Bay; also in Yucatan and Central America. In South America the changes are much greater. The observations from the Argentine Republic indicate that the line of 50 inches rain-fall crosses the meridian of 60° in about latitude $27\frac{1}{2}^{\circ}$ S.; and although the number of ob-

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
1	Fort Peel's River	--	67° 32' N	134° 30' W	2½	53.88	Schott's T., 2 ^d ed.
2	York Fact'y. Hud. B.	55	57° 0' N	92° 26' W	4	24.73	Canada Met. Obs.
3	Dunvegan. N.W.Ter.	1000	56° 0' N	118° 20' W	--	15.26	Can. Met. Office.
4	Belle Isle	405	51° 53' N	55° 22' W	--	55.07	do.
5	Lilloet. Brit. Col.	--	50° 42' N	122° 2' W	3	15.26	Canada Met. Obs.
6	Spence's Bridge, B.C.	760	50° 25' N	121° 30' W	4	10.14	do.
7	Nicola Lake, Br. Col.	2100	50° 16' N	120° 43' W	3	11.99	do.
8	Meadow Lea, Man.	825	50° 7' N	97° 40' W	--	24.64	Can. Met. Office.
9	Ossowa, Manitoba	--	50° 6' N	98° 15' W	--	27.14	do.
10	Poplar Heights, Man.	--	50° 5' N	97° 50' W	2	25.45	Canada Met. Obs.
11	Rockwood, Manitoba	--	50° 5' N	97° 12' W	2	17.60	do.
12	Mazatlan, Mex.	249	23° 11' N	106° 0' W	2	45.91	Bol. Met. Mex.
13	Zacatecas, Mex.	8187	22° 44' N	102° 33' W	3	25.65	do.
14	San Luis Potosi, Mex.	6202	22° 9' N	100° 58' W	3	16.30	do.
15	Pabellon, Mex.	6314	22° 4' N	102° 11' W	3	20.82	do.
16	Leon, Mex.	5901	21° 6' N	101° 30' W	3	28.26	do.
17	Guanajuato, Mex.	6761	21° 1' N	100° 48' W	1	20.65	do.
18	Jalisco, Mex.	--	20° 55' N	105° 12' W	1	49.41	do.
19	San Juan del Rio	--	20° 24' N	99° 39' W	1	22.33	do.
20	Campeche, Mex.	--	19° 54' N	90° 24' W	1	45.56	do.
21	Teziutlan, Mex.	--	19° 46' N	97° 22' W	3	66.12	do.
22	Patzcuaro, Mex.	7015	19° 31' N	101° 31' W	2	44.77	do.
23	Mirador, Mex.	3600	19° 15' N	96° 40' W	12	83.86	Schott's T., 2 ^d ed.
24	Puebla, Mex.	7112	19° 3' N	98° 11' W	3	40.24	Bol. Met. Mex.
25	Tuxpam, Mex.	--	19° 0' N	97° 7' W	3	59.61	do.
26	Colima, Mex.	1664	18° 46' N	103° 20' W	12	41.73	Revista Ci. Mex.
27	Tlacotalpam, Mex.	11	18° 37' N	95° 39' W	2	90.28	Bol. Met. Mex.
28	Oaxaca, Mex.	5072	17° 3' N	96° 40' W	3	30.21	do.
29	Aspinwall, N. Gren.	7	9° 23' N	79° 53' W	6	121.60	Schott's T., 2 ^d ed.
30	Heredia, Costa Rica	3837	10° 0' N	84° 0' W	1	47.64	do.
31	Caracas, Venezuela	2923	10° 31' N	66° 55' W	1	37.01	Smith. Rep., 1867.
32	Medellin, Colombia	--	6° 38' N	76° 35' W	2	63.36	Sig. Ser. Int. Obs.
33	Paramaribo	--	5° 49' N	55° 12' W	2	91.03	do.
34	Manaos, Brazil	121	3° 8' S	60° 0' W	1	55.20	Zeitsch., viii, 267.
35	Fortalera, Ceara	--	3° 43' S	38° 29' W	28	58.62	W. M. Roberts.
36	Iquitos, Peru	320	3° 44' S	73° 8' W	1½	103.28	Schott's T., 2 ^d ed.
37	Pernambuco	10	8° 4' S	34° 52' W	4	108.40	Zeitsch. xiv, 216.
38	S. Bento das Lages	98	12° 37' S	38° 40' W	1½	80.80	Rev. de Engenh.
39	Bahia, Brazil	--	13° 0' S	38° 32' W	1	83.08	do.
40	Sabara, Brazil	2280	19° 54' S	44° 30' W	25	64.45	W. M. Roberts.
41	Rio de Janeiro, Brazil	--	22° 54' S	43° 8' W	17	43.78	do.
42	S. Paulo, Brazil	2393	23° 33' S	46° 37' W	3	53.23	Henry B. Joyner.
43	Serra do Cubatao	2625	23° 45' S	46° 30' W	6	137.80	do.
44	Santos, Brazil	0	24° 0' S	46° 22' W	8	94.50	S. Paulo Rw. Co.
45	Alto da Serra	--	24° 0' S	49° 20' W	9	140.30	Prof. O. A. Derby.
46	Salta, Rep. Argentina	--	24° 45' S	65° 27' W	4½	27.01	Dr. B. A. Gould.
47	Villa Formosa, R. Ar.	--	26° 12' S	58° 5' W	2½	72.72	do.
48	Tucuman, Rep. Arg.	141	26° 46' S	65° 29' W	4½	35.40	do.
49	Corrientes, R. Arg.	--	27° 19' S	58° 56' W	7	58.58	do.
50	Pilciao, R. Arg.	--	27° 30' S	66° 36' W	5	39.17	do.
51	Santiago del Estero	--	27° 44' S	64° 23' W	6	19.92	do.
52	Goya, R. Arg.	--	29° 12' S	59° 22' W	6	46.22	do.
53	Saladillo, R. Arg.	--	29° S	67° W	3	17.87	do.
54	Rioja, R. Arg.	--	29° 18' S	67° 22' W	2½	11.93	do.
55	Curuzu Cuatia, R. A.	--	29° 54' S	58° 9' W	1½	51.46	do.
56	Villa Hernandarias	--	31° 15' S	59° 41' W	5	39.80	do.
57	Concordia, R. Arg.	--	31° 23' S	58° 2' W	3	46.10	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
58	Cordoba, Rep. Arg.	1240	31° 25' S	64° 11' W	9½	27.80	Dr. B. A. Gould.
59	San Juan, Rep. Arg.	--	31° 27' S	68° 20' W	5	2.83	do.
60	Parana, Rep. Arg.	--	31° 44' S	60° 24' W	6	36.77	do.
61	Mendoza, Rep. Arg.	2559	32° 53' S	68° 52' W	4	7.15	do.
62	Rosario, Rep. Arg.	--	32° 55' S	60° 39' W	5	38.50	do.
63	Rio Cuarto, R. Arg.	--	33° 7' S	64° 21' W	1	29.21	do.
64	Nueva Palmira, R. A.	--	33° 47' S	58° 16' W	4½	27.24	do.
65	Tatay, Rep. Arg.	--	34° 14' S	59° 54' W	5½	33.78	do.
66	S. Antonio d'Areco	--	34° 15' S	59° 30' W	3	31.38	do.
67	Chacara Matanzas	--	34° 25' S	58° 26' W	5	36.58	do.
68	25 de Mayo, R. Arg.	--	35° 20' S	62° 0' W	1½	37.48	do.
69	Salado, Rep. Arg.	--	35° 40' S	59° 6' W	3½	30.94	do.
70	Dolores, Rep. Arg.	--	36° 19' S	58° 14' W	3½	33.27	do.
71	Tandil, Rep. Arg.	--	37° 13' S	59° 10' W	3½	34.45	do.
72	Bahia Blanca, R. Ar.	62	38° 44' S	62° 11' W	22	19.25	do.
73	Ushuaia, Rep. Arg.	--	54° 53' S	68° 10' W	3	19.72	do.
74	Alten, Norway	43	69° 58' N	23° 17' E	8	10.46	Dr. Henry Mohn.
75	Südvaranger, Norw.	66	69° 40' N	30° 11' E	7-8	14.39	do.
76	Tromsø, Norway	50	69° 39' N	18° 58' E	8-9	31.86	do.
77	Fagernes, Norway	25	68° 27' N	17° 28' E	8	19.72	do.
78	Lödingen, Norway	44	68° 24' N	16° 1' E	7	47.39	do.
79	Varø, Norway	39	67° 41' N	12° 37' E	2-3	24.19	do.
80	Bodø, Norway	15	67° 17' N	14° 24' E	12	32.39	do.
81	Ranen, Norway	43	66° 12' N	13° 32' E	8	39.74	do.
82	Brønø, Norway	35	65° 28' N	12° 14' E	8-9	32.65	do.
83	Ytterøen, Norway	249	63° 49' N	11° 14' E	9	21.04	do.
84	Christiansund, Norw.	50	63° 7' N	7° 45' E	18	33.47	do.
85	Köros, Norway	2064	62° 35' N	11° 23' E	7-8	15.73	do.
86	Aalesund, Norway	47	62° 29' N	6° 9' E	14	45.20	do.
87	Dovre, Norway	2110	62° 5' N	9° 8' E	10-11	14.30	do.
88	Domsten, Norway	36	61° 53' N	5° 40' E	5	74.02	do.
89	Florø, Norway	26	61° 36' N	5° 2' E	6	75.28	do.
90	Sogndal, Norway	109	61° 18' N	7° 3' E	9	27.97	do.
91	Flesje, Norway	16	61° 8' N	6° 27' E	8	52.75	do.
92	Grunheim, Norway	1251	61° 6' N	8° 58' E	8-9	21.35	do.
93	Leisdal, Norway	16	61° 6' N	7° 27' E	10	12.22	do.
94	Bird, Norway	419	60° 58' N	10° 35' E	5	23.86	do.
95	Bergen, Norway	57	60° 24' N	5° 20' E	14	72.24	do.
96	Kidsvold, Norway	615	60° 22' N	11° 13' E	10-11	30.84	do.
97	Ullensvang, Norway	35	60° 20' N	6° 40' E	6-7	39.69	do.
98	Hole, Norway	336	60° 4' N	10° 16' E	5	19.74	do.
99	Lauglien, Norway	926	60° 4' N	10° 31' E	6	41.08	do.
100	Bjornholt, Norway	824	60° 3' N	10° 39' E	--	42.02	do.
101	Christiania, Norway	80	59° 55' N	10° 45' E	42	26.93	do.
102	Aas, Norway	289	59° 37' N	10° 47' E	6	27.53	do.
103	Fredrikstad, Norway	18	59° 13' N	10° 56' E	3-7	31.60	do.
104	Valle, Norway	1039	59° 12' N	7° 32' E	3-4	36.80	do.
105	Skudesnes, Norway	13	59° 9' N	5° 16' E	14	42.84	do.
106	Sandøsund, Norway	27	59° 5' N	10° 28' E	14	23.15	do.
107	Mandal, Norway	54	58° 2' N	7° 27' E	14	44.88	do.
108	Dalmatow, Russia	--	56° 14' N	62° 37' E	14	12.64	Dr. A. Woeikoff.
109	Astrakhan, Russia	55	46° 21' N	48° 2' E	32	5.71	do.
110	Low, Syr Daria, Rus.	--	46° N	62° E	5	5.12	do.
111	F. Alexandrowski, R.	--	44° 27' N	50° 8' E	13	4.49	do.
112	Alexandropol, Russia	5010	40° 47' N	43° 35' E	18	14.96	do.
113	Krasnovodsk, Russia	--	40° 0' N	53° 9' E	3	15.37	Met. Annalen.
114	Ura Tübe, Russia	--	41° 30' N	68° 13' E	1	12.95	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
115	Taschkent, Russia	1588	41° 20' N	69° 18' E	8	12·28	Met. Annalen.
116	Samarkand, Russia	2378	39 39 N	66 57 E	1	13·54	do.
117	Pendshekent, Russia	3163	39 28 N	67 33 E	1	12·44	do.
118	I. Ashur Ade, Russia	--	36 54 N	53 50 E	6	17·80	Dr. A. Woeikoff.
119	Wernyj, Russia	2402	43 16 N	76 53 E	2	18·44	Met. Annalen.
120	Yokohama, Japan	--	35 27 N	139 40 E	4	85·27	En. Met. Com., 28.
121	Cape Sagami, Japan	--	35 8 N	139 41 E	4	48·14	do.
122	Awadji, Japan	--	34 37 N	135 0 E	3	38·13	do.
123	Rock Island, Japan	--	34 34 N	138 57 E	4	60·94	do.
124	Isumi, Japan	--	34 17 N	135 0 E	2	47·61	do.
125	Isaki, Japan	--	33 58 N	131 1 E	2	54·27	do.
126	Isauri Sima, Japan	--	33 53 N	132 38 E	1	28·16	do.
127	Oosima, Japan	--	33 28 N	135 52 E	4	71·43	do.
128	Siwo Misaki, Japan	--	33 26 N	135 46 E	4	64·78	do.
129	Nagasaki, Japan	--	32 43 N	129 46 E	4	40·64	do.
130	Saton Misaki, Japan	--	30 58 N	130 40 E	4	52·12	do.
131	Zikawei, China	--	31 12 N	121 26 E	8	42·44	Zeitsch., xvii, 16.
132	Hongkong, China	--	22 16 N	114 10 E	12	84·60	Zeitsch., viii, 72.
133	Manilla, Phil. Is.	--	14 36 N	120 40 E	19	75·05	Various sources.
134	Bangkok, Siam	--	13 43 N	100 25 E	10	67·04	Q J. Met. Soc. v. 88.
135	Saigun, Siam	--	10 48 N	106 40 E	1	58·42	Zeitsch., vii, 23.
136	Bohol, Phil. Is.	--	9 55 N	124 32 E	2	49·47	Zeitsch., v, 69.
137	Linao, Phil. Is.	--	8 5 N	125 45 E	1	150·72	do.
138	Serang, Java	102	6 7 S	106 8 E	3	82·05	Dr. P. A. Bergsma.
139	Onrust, Java	--	6 1 S	106 46 E	3	71·50	do.
140	Batavia, Java	23	6 11 S	106 50 E	3	73·31	do.
141	M. Cornelis, Java	46	6 13 S	106 54 E	3	81·74	do.
142	Buitenzorg, Java	869	6 36 S	106 47 E	3	203·24	do.
143	Tjandjoer, Java	1542	6 49 S	107 8 E	3	114·10	do.
144	Telaga P., Java	5105	7 10 S	107 25 E	2	167·01	do.
145	Soekawana, Java	5062	6 45 S	107 38 E	3	115·95	do.
146	Soemedang, Java	1450	6 50 S	107 57 E	2	122·09	do.
147	Manondjaja, Java	810	7 20 S	108 20 E	2	131·34	do.
148	Tjilatjap, Java	0	7 44 S	109 0 E	2	161·64	do.
149	Kedong K., Java	148	7 41 S	110 2 E	3	115·16	do.
150	Madjalengka, Java	472	6 48 S	108 15 E	2	138·43	do.
151	Tegal, Java	0	6 51 S	109 8 E	3	77·72	do.
152	Pekalongan, Java	0	6 53 S	109 40 E	3	104·97	do.
153	Pelantioengan, Java	2273	7 6 S	109 59 E	3	192·98	do.
154	Semarang, Java	13	6 58 S	110 25 E	3	90·91	do.
155	Rembang, Java	0	6 45 S	111 20 E	3	56·30	do.
156	Toeban, Java	0	6 52 S	112 5 E	3	62·80	do.
157	Oenarang, Java	1027	7 8 S	110 23 E	3	206·16	do.
158	Willem I., Java	1562	7 16 S	110 24 E	3	99·81	do.
159	Salatiga, Java	1933	7 20 S	110 30 E	3	117·72	do.
160	Magelang, Java	1257	7 29 S	110 13 E	3	137·13	do.
161	Djokjokarta, Java	371	7 48 S	110 21 E	3	95·79	do.
162	Patjitan, Java	23	8 12 S	111 5 E	2	79·10	do.
163	Klatten, Java	692	7 42 S	110 35 E	3	91·85	do.
164	Bojolali, Java	1300	7 32 S	110 35 E	3	127·56	do.
165	Soerakarta, Java	302	7 34 S	110 49 E	3	95·00	do.
166	Madioen, Java	220	7 37 S	111 31 E	2	69·96	do.
167	Ngawi, Java	203	7 24 S	111 26 E	3	90·83	do.
168	Malang, Java	1476	7 57 S	112 38 E	3	97·05	do.
169	Modjokerto, Java	95	7 28 S	112 25 E	3	73·31	do.
170	Soerabaja, Java	0	7 14 S	112 44 E	3	73·00	do.
171	Grissee, Java	0	7 10 S	112 39 E	3	69·06	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
172	Paseroean, Java	13	7° 38' S	112° 56' E	3	57·92	Dr. P. A. Bergsma.
173	Probolingo, Java	33	7° 44' S	113° 13' E	3	50·20	do.
174	Loemadjang, Java	177	8° 7' S	113° 14' E	2	68·35	do.
175	Besoeki, Java	7	7° 43' S	113° 41' E	3	52·28	do.
176	Sitoebondondo, Java	262	7° 41' S	114° 2' E	3	50·95	do.
177	Maësan, Java	1214	8° 0' S	113° 50' E	3	109·65	do.
178	Banjoewangi, Java	16	8° 13' S	114° 23' E	3	58·98	do.
179	Bangkalan, Madoera	16	7° 2' S	112° 44' E	3	84·33	do.
180	Pamekasan, Madoera	0	7° 10' S	113° 30' E	3	70·12	do.
181	Soemenep, Madoera	0	7° 3' S	113° 54' E	3	68·23	do.
182	Telok. B., Sumatra	0	5° 26' S	105° 16' E	3	89·68	do.
183	Benkoelen, Sumatra	0	3° 47' S	102° 14' E	3	124·41	do.
184	Padang, Sumatra	0	0° 58' S	100° 25' E	3	182·24	do.
185	Loeboeselassi, Sum.	1017	0° 57' S	100° 38' E	2	150·28	do.
186	Solok, Sumatra	1234	0° 48' S	100° 40' E	3	90·32	do.
187	Padang P., Sumatra	2560	0° 30' S	100° 30' E	2	211·14	do.
188	Fort de Kock, Sum.	3041	0° 21' S	100° 28' E	3	81·22	do.
189	Pajakombo, Sumatra	1630	0° 15' S	100° 47' E	3	86·42	do.
190	Rau, Sumatra	977	0° 32' N	100° 3' E	2	87·88	do.
191	Padang S., Sumatra	929	1° 23' N	99° 15' E	2	107·21	do.
192	Siboga, Sumatra	0	1° 44' N	98° 46' E	3	187·87	do.
193	Singkel, Sumatra	0	2° 17' N	97° 45' E	3	180·62	do.
194	Kotta Radja, Sumatra	0	5° 32' N	95° 20' E	3	69·18	do.
195	Edi, Sumatra	0	5° 53' N	97° 46' E	2	83·19	do.
196	Agnieta P., Sumatra	--	4° 9' N	98° 9' E	2	100·08	do.
197	Koela, S., Sumatra	--	4° 18' N	98° 3' E	2	99·41	do.
198	Medan, Sumatra	46	3° 35' N	98° 41' E	2	95·20	do.
199	Medan P., Sumatra	46	3° 35' N	98° 41' E	3	87·96	do.
200	Sipoet, Sumatra	--	3° 30' N	98° 38' E	2	122·44	do.
201	Bengkalis, Sumatra	0	1° 28' N	102° 6' E	2	105·32	do.
202	Djambi, Sumatra	--	1° 35' S	103° 36' E	3	102·09	do.
203	Palembang, Sumatra	--	2° 59' S	104° 45' E	3	120·16	do.
204	Tebing T., Sumatra	--	3° 36' S	103° 4' E	2	126·07	do.
205	Bandar, Sumatra	--	4° 5' S	103° 22' E	2	125·51	do.
206	Lahat, Sumatra	--	3° 48' S	103° 31' E	2	151·02	do.
207	Tandjong P., Riouw	0	0° 56' N	104° 25' E	3	105·79	do.
208	Muntok, Bangka	0	2° 3' S	105° 9' E	3	132·64	do.
209	Tandjong P., Billiton	0	2° 45' S	107° 33' E	3	129·84	do.
210	Singkawang, Borneo	0	0° 55' N	108° 59' E	2	111·56	do.
211	Pontianak, Borneo	--	0° 1' N	109° 20' E	3	121·58	do.
212	Sintang, Borneo	--	0° 7' N	111° 32' E	2	147·01	do.
213	Bandjermasin, Bor.	--	3° 19' S	114° 35' E	3	97·99	do.
214	Pengaron, Borneo	--	3° 15' S	115° 15' E	2	102·92	do.
215	Amoenthai, Borneo	--	2° 15' S	115° 10' E	2	97·52	do.
216	Barabei, Borneo	--	2° 17' S	115° 16' E	2	115·16	do.
217	Makassar, Celebes	0	5° 8' S	119° 24' E	3	131·81	do.
218	Pangkadjene, Celeb.	0	4° 51' S	119° 32' E	2	154·29	do.
219	Balang N., Celebes	0	5° 7' S	120° 14' E	2	101·42	do.
220	Menado, Celebes	13	1° 30' N	124° 50' E	2	98·86	do.
221	Ternate Island	10	0° 47' N	127° 22' E	2	93·51	do.
222	Amboina Island	0	3° 42' S	128° 10' E	3	165·44	do.
223	Banda Island	0	4° 32' S	129° 53' E	3	117·92	do.
224	Timor K. Island	49	10° 10' S	123° 34' E	2	52·36	do.
225	Kuka, Cen. Africa	--	13° 10' N	14° 30' E	--	33·00	Guyot's Phy. Atl.
226	Christiansb'g, W. Af.	--	5° 24' N	0° 10' W	--	144·00	do.
227	Gabun, W. Africa	287	0° 25' N	9° 35' E	4	94·17	Zeitsch. xvi-xvii.
228	Chinchoxo, W. Africa	39	5° 9' S	12° 3' E	2	42·41	A. v Danckelman.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years. Obs.	Rain. Inches.	Authority.
229	Palmerston, S. Aust.	70	12° 26' S	130° 52' E	10	63·69	Todd's Met. Obs.
230	Southport, S. Aust.	--	12 44 S	131 0 E	4	72·18	do.
231	Yam Creek, S. Aust.	--	13 29 S	131 35 E	4	54·43	do.
232	Pt. Macquarie, N.S.W.	--	31 25 S	152 54 E	16	63·75	Russ. Met. Obs.
233	Kurraj. Hts., N.S.W.	--	33 33 S	150 45 E	13	53·90	do.
234	Sydney, N.S.W.	--	33 51 S	151 12 E	22	51·46	do.
235	Botany, N.S.W.	--	33 56 S	151 12 E	11	53·30	do.
236	Cordeaux R., N.S.W.	--	34 19 S	150 44 E	9	59·89	do.
237	Cape St. Geo., N.S.W.	--	35 12 S	150 45 E	14	56·12	do.
238	Milton, N.S.W.	--	35 14 S	150 20 E	4	50·52	do.
239	Pine Creek, S. Aust.	--	13 52 S	131 56 E	4	46·38	Todd's Met. Obs.
240	R. Katherine, S. Aust.	--	14 23 S	132 17 E	4	43·91	do.
241	Daly Waters, S. Aust.	--	16 17 S	133 29 E	4	31·66	do.
242	Melrose, S. Aust.	--	32 46 S	138 8 E	12	26·82	do.
243	Pewsey Vale, S. Aust.	--	34 36 S	138 58 E	4	28·40	do.
244	Mt. Pleasant, S. Aust.	--	34 46 S	139 3 E	4	27·62	do.
245	Gummeracha, S. Aust.	--	34 47 S	138 55 E	11	32·94	do.
246	Charleston, S. Aust.	--	34 58 S	138 51 E	15	32·99	do.
247	Mt. Lofty, S. Aust.	--	35 0 S	138 43 E	21	42·37	do.
248	Mt. Barker, S. Aust.	--	35 4 S	138 51 E	19	29·59	do.
249	Willunga, S. Aust.	--	35 16 S	138 31 E	18	26·66	do.
250	Yankalilla, S. Aust.	--	35 25 S	138 19 E	12	27·12	do.
251	Penola, S. Aust.	--	37 21 S	140 50 E	19	28·25	do.
252	Mt. Gambier, S. Aust.	130	37 46 S	140 46 E	19	31·80	do.
253	C. N'thumbert'd, S.A.	117	38 4 S	140 39 E	13	28·03	do.
254	Maryland, N.S.W.	--	28 36 S	152 5 E	11	34·80	Russ. Met. Obs.
255	Tenterfield, N.S.W.	--	29 5 S	152 4 E	10	31·07	do.
256	Grafton, N.S.W.	--	29 43 S	152 56 E	10	36·90	do.
257	Armidale, N.S.W.	--	30 34 S	151 46 E	16	35·62	do.
258	Mudgee, N.S.W.	--	32 35 S	149 35 E	9	26·74	do.
259	W. Maitland, N.S.W.	--	32 47 S	151 35 E	12	35·37	do.
260	Newcastle, N.S.W.	--	32 55 S	151 50 E	19	47·64	do.
261	Orange, N.S.W.	--	33 18 S	149 9 E	10	39·18	do.
262	Mt. Victoria, N.S.W.	--	33 36 S	150 15 E	8	37·47	do.
263	Windsor, N.S.W.	--	33 36 S	150 49 E	18	33·61	do.
264	Young, N.S.W.	--	34 18 S	148 21 E	8	28·66	do.
265	Mossvale, N.S.W.	--	34 32 S	150 23 E	8	45·45	do.
266	Goulburn, N.S.W.	--	34 45 S	149 45 E	17	26·79	do.
267	Albury, N.S.W.	--	36 6 S	147 0 E	17	28·03	do.
268	Eden, N.S.W.	--	37 0 S	149 59 E	12	39·29	do.
269	Koorunga, S. Aust.	--	33 42 S	138 59 E	21	17·45	Todd's Met. Obs.
270	Bungaree, S. Aust.	--	33 44 S	138 31 E	20	21·61	do.
271	Clare, S. Aust.	--	33 50 S	138 37 E	18	24·93	do.
272	Auburn, S. Aust.	--	34 2 S	138 38 E	15	24·50	do.
273	Walleroo, S. Aust.	--	33 54 S	137 38 E	15	13·59	do.
274	Kapunda, S. Aust.	--	34 20 S	139 0 E	19	20·25	do.
275	Gawler, S. Aust.	--	34 35 S	138 45 E	18	18·97	do.
276	Adelaide, S. Aust.	--	34 57 S	138 35 E	41	21·31	do.
277	Strathalbyn, S. Aust.	--	35 16 S	138 55 E	19	18·84	do.
278	Goolwa, S. Aust.	--	35 29 S	138 47 E	16	17·21	do.
279	Meningie, S. Aust.	--	35 41 S	139 19 E	15	19·27	do.
280	Robe, S. Aust.	--	37 3 S	139 42 E	19	24·69	do.
281	Bourke, N.S.W.	--	30 3 S	145 58 E	8	15·45	Russ. Met. Obs.
282	Narrabri, N.S.W.	--	30 20 S	149 46 E	11	24·45	do.
283	Wilcannia, N.S.W.	--	31 31 S	143 23 E	8	11·09	do.
284	Cassilis, N.S.W.	--	32 0 S	150 0 E	10	23·72	do.
285	Seone, N.S.W.	--	32 4 S	150 53 E	7	22·27	do.

Mean Annual Rain-fall for various Stations.

No.	Station.	Elev. feet.	Lat.	Long.	Years Obs.	Rain. Inches.	Authority.
286	Muswellbr'k, N.S.W.	--	32 17 S	150 53 E	7	19-00	Russ. Met. Obs.
287	Dubbo, N.S.W.	--	32 18 S	148 35 E	9	20-39	do.
288	Bathurst, N.S.W.	--	33 24 S	149 37 E	19	24-62	do.
289	Wentworth, N.S.W.	--	34 8 S	142 0 E	10	11-55	do.
290	Waggawagga, N.S.W.	--	35 8 S	147 24 E	7	23-89	do.
291	Murray Downs, "	--	35 16 S	143 41 E	16	15-59	do.
292	Queanbeyan, N.S.W.	--	35 20 S	149 15 E	10	23-91	do.
293	Deniliquin, N.S.W.	--	35 32 S	145 2 E	20	16-50	do.
294	Cooma, N.S.W.	--	36 12 S	149 9 E	16	19-09	do.
295	Charl. Waters, S. Au.	--	25 50 S	134 57 E	4	8-83	Todd's Met. Obs.
296	Peake, S. Aust.	--	28 4 S	135 50 E	4	7-00	do.
297	Strangw. Spr., S. A.	--	29 11 S	136 33 E	4	6-12	do.
298	Stuart's Creek, S. A.	--	29 45 S	137 5 E	3	8-17	do.
299	Farina, S. Aust.	--	30 4 S	138 14 E	1	6-59	do.
300	Arrowie, S. Aust.	--	30 53 S	139 19 E	3	7-49	do.
301	Beltana, S. Aust.	--	30 58 S	138 27 E	4	8-32	do.
302	Wirralpa, S. Aust.	--	31 1 S	138 52 E	4	6-94	do.
303	Wintabatingana, "	--	31 20 S	138 18 E	1	8-60	do.
304	Moonaree, S. Aust.	--	31 54 S	135 34 E	2	9-44	do.
305	Port Augusta, S. A.	--	32 29 S	137 45 E	20	8-70	do.
306	Moorna, S. Aust.	--	34 9 S	141 42 E	3	7-87	do.
307	Paringa, S. Aust.	--	34 10 S	140 44 E	7	9-94	do.
308	Goorimpa, N.S.W.	--	30 22 S	144 1 E	2	9-34	Russ. Met. Obs.
309	Tarella, N.S.W.	--	30 55 S	143 0 E	4	9-67	do.
310	Weinteriga, N.S.W.	--	32 8 S	142 52 E	4	9-26	do.
311	Teryawynia, N.S.W.	--	32 20 S	143 20 E	4	9-99	do.
312	Netley, N.S.W.	--	32 53 S	142 20 E	4	9-04	do.
313	Geraldton, W. Aust.	--	28 44 S	114 44 E	2	16-90	Fraser's Met. Ob.
314	Newcastle, W. Aust.	--	31 38 S	116 33 E	2	16-70	do.
315	Northam, W. Aust.	--	31 41 S	116 45 E	2	11-30	do.
316	York, W. Aust.	--	31 52 S	116 47 E	2	16-15	do.
317	Guildford, W. Aust.	--	31 55 S	115 56 E	2	38-25	do.
318	Perth, W. Aust.	--	31 57 S	115 52 E	4	32-58	do.
319	Freemantle, W. Aus.	--	32 2 S	115 42 E	2	26 45	do.
320	Pinjarra, W. Aust.	--	32 34 S	115 52 E	2	35-55	do.
321	Banburg, W. Aust.	--	33 18 S	115 32 E	2	41-90	do.
322	Vasse, W. Aust.	--	33 32 S	115 28 E	2	27-75	do.
323	Albany, W. Aust.	--	35 0 S	117 53 E	2	35-55	do.

servations from the interior of South America is very small, they seem to indicate that (with a few exceptions of limited extent) the entire central and northern portions of South America, east of the Andes, have a rain-fall exceeding 50 inches. The observations from Iquitos and San Antonio indicate a rain-fall of more than 75 inches for the eastern slope of the Andes; but many more observations are needed before the limits of the rain-fall of 50 inches and 75 inches can be satisfactorily assigned. In Europe the principal change is in Norway, the area of 25 inches rain-fall having been made too great on my former chart. In Central Asia I have made considerable change in the curve of 10 inches rain-fall, but this curve is one which it is specially difficult to trace satisfactorily, partly on account of the scarcity

of observations, but especially because there are very extensive regions where the rain-fall does not much exceed 10 inches. Some change has been made in the East Indian Archipelago required by the three years' observations of Dr. Bergsma. The changes in Central Australia are explained by the fact that when I prepared my former chart, the observations which were available were few in number and most of them included a period of only one year. The observations since received appear to indicate that throughout the whole interior of Australia, the average annual rain-fall is less than 10 inches. In Central Africa the present chart shows a greater rain-fall than the former one. Some of the changes are based upon new observations, and others have been made in deference to the judgment of my critics.

It is hoped that this revised rain-chart may be found less imperfect than the preceding. I do not expect, however, that it will be found perfect, and I urgently renew the request contained in my former paper that if any person whose attention is attracted to this map should discover in it serious defects, he will communicate to me the observations which indicate these defects. I propose hereafter to publish all additional observations of rain-fall which I may be able to obtain, so far as they indicate the necessity of changes in the present rain-chart, and if this chart should be found greatly in error, I intend to issue a revised edition of it.

Relation of rain-areas to areas of low pressure.

In former papers I have examined the cases in which a rain-fall of two inches in eight hours has occurred at any of the stations of the U. S. Signal Service, and also the cases in which the aggregate rain-fall at all the stations was unusually great. This examination has shown a marked difference between the effect of a great rain-fall in the northern and southern portions of the United States. South of the parallel of 36° we find that a rain-fall of two inches in eight hours occurs four times as frequently as it does north of that parallel, allowance being made for the difference in the number of stations. Also south of 36° these great rain-falls are not generally accompanied by any considerable depression of the barometer; but there is a cyclonic movement of the winds about the rain-area, accompanied by a small depression of the barometer. In a few cases the barometer stands above its mean height; the cyclonic motion of the winds is not distinctly marked, and the winds seem to be controlled by an area of high pressure prevailing north of 36° .

In the northern portion of the United States, great rain-falls appear to be always under the influence of an area of low pressure. The average distance of the principal rain-centers from

the center of low pressure is nearly 400 miles; they are generally on the east side of the low center, and are most frequently found nearly in the direction of the average progress of storm tracks. There is, then, an intimate connection between the rain-fall and the direction of a storm's progress; and the precipitation of the vapor of the air is apparently the chief source of that maintaining power which is necessary to sustain the action of violent storms. The direction of movement and rate of progress of an area of low pressure do not, however, depend simply upon the amount of rain-fall and position of the rain-areas within the limits of the area of low pressure, but also upon the existing distribution of pressure, temperature and humidity not only within the limits of the storm, but throughout an extensive region surrounding it on all sides.

In order to prosecute this enquiry under different geographical influences, I have prepared tables showing for a series of years the principal rain-falls in Europe. I selected from the Bulletin of International Meteorological Observations all those cases in which a rain-fall of two inches in twenty-four hours was reported at any station during the years 1878, 9 and 80. These cases are 233 in number, and the stations at which more than three cases of these great rain-falls occurred are shown in the following table. Column 2d shows the latitude of the station;

Station.	Lat.	Elev'n feet.	No. of Cases.	Station.	Lat.	Elev'n feet.	No. of Cases.
Trieste	45° 39'	85	26	Puy de Dome	45° 46'	4813	6
Udine	46 4	380	13	Moncalieri	44 59	853	6
Rochefort	45 56	30	12	Pola	44 51	105	6
Genoa	44 25	157	12	Com. de Greasque ..	43 25	1056	6
Valona	40 27	---	12	Mondovi	44 22	1824	5
Pic du Midi	42 16	7763	11	Carcassonne	43 13	384	5
Santiago	42 53	863	9	Bergen	60 24	49	4

column 3d its elevation in feet above the sea, and column 4th the number of cases in which a rain-fall of two inches in twenty-four hours was reported, at the station named.

The twelve cases of heavy rain reported at Rochefort are believed to be erroneous. They all occurred in the six months from June to November, 1880, and the error is supposed to have resulted from the fact that the rain-fall was measured in tenths of a millimeter, but was reported in such a way that the numbers were understood to represent millimeters, thus making the rain-fall ten times too great. Of the other thirteen stations, all but one are in the south of Europe, and show unequivocally the influence of local causes; two of the stations being on mountains and the others being in the neighborhood of mountains where the mean annual rain-fall is unusually great.

The following table contains a complete list of the cases for 1879. Column 1st gives the number of reference; column 2d, the date of observation; column 3d, the station of heavy rain-fall; column 4th, its latitude; column 5th, its longitude from Greenwich; column 6th, its elevation (in English feet) above sea level; column 7th, the rain-fall in twenty-four hours expressed in English inches; column 8th, the height of the barometer, reduced to sea level; column 10th, the direction of the wind at the date of observation; column 9th, its direction twenty-four hours previous; and column 11th, shows the direction of the given station from the center of low pressure with which it is believed to have been associated.

The average height of the barometer at the time of these heavy rains was 29·8 inches, and in only twenty-six cases was the barometer below 29·75 inches. In eleven cases the barometer at the station of greatest rain was above 30 inches; but in eight of these eleven cases, although the barometer was above its mean height, it was from three-tenths to seven-tenths of an inch lower than it was in some other part of Europe. Also in eight of these cases, there was a low center within a distance of about 1000 miles where the barometer was from a half inch to an entire inch lower than it was at the station of 2 inches rain-fall. Most of these eleven cases were therefore cases in which the influence of a low center was felt to an unusual distance. There were however two cases (Nos. 54 and 57) both on the same day, in which there was no considerable low center within a distance of 1000 miles, and these occurred in a region where a cyclonic movement of the winds of limited extent was formed between two centers of high pressure. We thus find that each of these cases of heavy rain occurred within an area where the barometer was depressed somewhat below its mean height, or where the barometer was relatively low when compared with neighboring areas of high pressure.

Within these areas of low pressure there was generally a cyclonic movement of the winds. This is indicated by the change in the direction of the winds shown in columns 9th and 10th. It will be seen that in eight cases the wind changed 180° in twenty-four hours; in seventeen cases the wind changed 135° in twenty-four hours; and in twenty-eight cases the wind changed 90° in twenty-four hours. There are, however, twelve cases in which no change in the direction of the wind was reported during these twenty-four hours, viz: Nos. 2, 4, 5, 8, 18, 20, 41, 60, 64, 66, 68 and 73. In eight of these cases the low center traveled very slowly, and the direction of the low center from the rain center changed but little in twenty-four hours; two of the remaining cases occurred on the summit of a mountain about which there is presumed to have been

Rain-fall of two inches in 24 hours.

No.	Date.	Station.	Lat.	Long. fr. Green.	Elev. feet.	Rain. inch's	Bar. red'd.	Wind.		From low.
								Prev. observ.	At date.	
1879.										
1	Jan. 2	Trieste, Austria	45 39	13 47 E	85	2.334	29.82	Calm	Calm	SE
2	4	Carlsruhe, Germ.	49 1	8 25 E	404	2.181	29.61	SW	SW	SW
3	6	Pic du Midi, France	42 16	0 8 E	7763	2.240	30.22	NNW	N	?
4	7	Pic du Midi, France	42 16	0 8 E	7763	2.212	30.07	N	N	?
5	10	Valona, Turkey	40 27	19 27 E	--	3.940	29.76	S	S	SE
6	30	Trieste, Austria	45 39	13 47 E	85	2.035	30.09	E	ENE	NE
7	Feb. 1	Nottingham, Eng.	52 57	1 10 W	174	2.770	30.08	ESE	SE	NE
8	9	Santiago, Spain	42 53	8 28 W	863	3.048	29.51	S	S	SE
9	10	Santiago, Spain	42 53	8 28 W	863	2.713	29.38	S	SW	SE
10	15	Trieste, Austria	45 39	13 47 E	85	2.063	29.51	Calm	E	NE
11	15	Monach, Hebrides	57 30	7 40 W	150	2.000	29.21	E	SSE	SE
12	15	Genoa, Italy	44 25	8 30 E	157	2.587	29.46	Calm	N	NE
13	17	Mont Louis, France	42 31	2 7 E	5203	2.917	29.71	SSW	WSW	S
14	Mar. 22	Genoa, Italy	44 25	8 30 E	157	2.657	29.58	Calm	S	E
15	23	Trieste, Austria	45 39	13 47 E	85	2.976	29.53	E	Calm	NE
16	26	Trieste, Austria	45 39	13 47 E	85	2.028	29.83	ENE	S	E
17	27	Trieste, Austria	45 39	13 47 E	85	3.511	29.63	S	E	SE
18	Apr. 3	Pic du Midi, France	42 16	0 8 E	7763	2.390	29.82	NW	NW	?
19	4	Pic du Midi, France	42 16	0 8 E	7763	2.469	29.95	NW	N	?
20	8	Nice, France	43 42	7 17 E	30	2.110	29.47	S	S	SE
21	8	Commune de Gr.	43 25	5 37 E	1056	2.252	29.47	SE	N	SE
22	16	Trieste, Austria	45 39	13 47 E	85	2.063	29.69	S	N	NE
23	21	Genoa, Italy	44 25	8 30 E	157	3.346	29.55	SW	NE	SE
24	22	Udine, Italy	46 4	13 14 E	380	2.252	29.70	S	SE	SE
25	29	Rome, Italy	41 54	12 29 E	207	2.598	29.69	W	N	SE
26	May 10	Puy de Dome, Fr.	45 46	2 58 E	4813	3.906	29.84	NW	NNW	SW
27	11	Cracow, Austria	50 4	20 0 E	721	2.467	29.68	ESE	NW	NW
28	20	Mondovi, Italy	44 22	7 48 E	1824	2.168	29.98	NNW	W	N
29	24	Moncalieri, Italy	44 59	7 41 E	853	2.098	29.91	SE	N	NE
30	26	Mondovi, Italy	44 22	7 48 E	1824	3.378	29.72	W	WNW	N
31	27	Mondovi, Italy	44 22	7 48 E	1824	2.091	29.69	WNW	N	SE
32	28	Szathmar, Austria	47 49	22 51 E	430	2.059	29.88	E	SW	SE
33	June 8	Santiago, Spain	42 53	8 28 W	863	2.241	29.82	SSW	W	SE
34	10	Eperies, Austria	48 58	21 15 E	820	2.045	29.90	SE	NW	SW
35	18	Hamburg, Germ.	53 33	9 58 E	66	3.366	29.62	SW	S	SE
36	July 2	Besançon, France	47 14	6 1 E	830	2.067	29.97	SW	SSW	SE
37	14	Nismes, France	43 51	4 21 E	187	2.760	29.95	S	N	SE
38	14	Geneva, Switz.	46 12	6 8 E	1339	2.551	29.90	NE	SW	SE
39	Aug. 3	Cambridge, Eng.	52 12	0 8 E	88	3.180	29.86	E	SE	NE
40	3	Cardington, Eng.	52 8	0 27 W	109	2.000	29.84	E	SE	NE
41	10	Besançon, France	47 14	6 1 E	830	2.421	30.08	S	S	?
42	17	Trieste, Austria	45 39	13 47 E	85	2.020	29.89	ESE	E	SE
43	17	Barcelona, Spain	41 23	2 11 E	98	2.908	29.99	SE	SSW	NE
44	18	Graz, Austria	47 4	15 28 E	1171	3.544	29.86	NE	SE	SE
45	18	Hermannstadt, Aus	45 47	24 13 E	1355	2.150	29.71	WNW	WNW	SE
46	Sept. 2	Bergen, Norway	60 24	5 18 E	49	2.401	29.72	NW	S	NE
47	9	Christiania, Nor.	59 55	10 44 E	134	2.043	29.50	ENE	SSW	NE
48	10	Umea, Sweden	63 50	20 17 E	--	2.389	29.42	SE	N	NE
49	15	Carcassonne, Fr.	43 13	2 21 E	384	2.217	29.90	E	W	S
50	15	Commune de Gr.	43 25	5 37 E	1056	2.170	29.96	SW	SE	SE
51	15	Marseilles, France	43 18	5 23 E	246	3.051	29.88	SE	E	SE
52	16	Marseilles, France	43 18	5 23 E	246	6.261	29.91	E	ESE	SE
53	18	Pola, Austria	44 51	13 53 E	105	2.028	29.97	ESE	WNW	SE
54	25	Avignon, France	43 57	4 38 E	66	5.836	30.09	E	N	NW
55	25	Milan, Italy	45 28	9 11 E	482	2.599	29.99	NE	E	NE
56	25	Christiania, Nor.	59 55	10 44 E	134	3.083	29.86	SSE	SSW	SE
57	25	Zurich, Switz.	47 22	8 33 E	1542	2.047	30.21	S	W	NE

Rain-fall of two inches in 24 hours—continued.

No.	Date.	Station.	Lat.	Long. fr. Green.	Elev. feet.	Rain. inch's	Bar. red'd.	Wind.		From low.
								Prev. observ.	At date.	
	1879.									
58	Sep. 26	Pola, Austria	44 51	13 53 E	105	3.962	29.85	SSE	WSW	NE
59	28	Nice, France	43 42	7 17 E	30	2.322	30.07	E	ESE	NW
60	Oct. 1	Santiago, Spain	42 53	8 28 W	863	2.091	30.03	SW	SW	SE
61	16	Bröno, Norway	65 30	12 0 E	36	2.087	29.80	NE	SW	NE
62	17	Cosenza, Italy	39 18	16 15 E	840	2.197	29.78	SE	NW	SW
63	18	Pola, Austria	44 51	13 53 E	105	2.008	29.85	WNW	SSW	SE
64	21	Carlsruhe, Germ.	49 1	8 25 E	404	2.020	29.79	SW	SW	SW
65	23	Valona, Turkey	40 27	19 27 E	--	2.360	29.88	SE	N	SW
66	28	San Fernando, Sp.	36 28	6 13 W	95	2.134	29.81	S	S	SE
67	29	Carcassonne, Fr.	43 13	2 21 E	384	2.106	29.85	ESE	E	NE
68	29	Perpignan, Fr.	42 42	2 54 E	98	2.102	29.86	SE	SE	NE
69	29	San Fernando, Sp.	36 28	6 13 W	95	3.183	29.78	S	SE	S
70	Nov. 1	Campo Major, Por.	39 2	6 59 W	945	2.296	29.79	ESE	SSW	E
71	2	Genoa, Italy	44 25	8 30 E	157	2.126	29.80	SW	S	NE
72	20	Genoa, Italy	44 25	8 30 E	157	3.165	29.88	NW	NE	NE
73	25	Helston, Eng.	50 5	5 17 W	--	2.400	30.32	E	E	NE
74	28	Santiago, Spain	42 53	8 28 W	863	2.024	29.30	NE	SSE	N
75	Dec. 4	Genoa, Italy	44 25	8 30 E	157	2.539	29.53	NE	N	SE
76	15	Bergen, Norway	60 24	5 18 E	49	2.500	30.29	SSE	SE	SE

a cyclonic movement of the winds nearly stationary as will be shown hereafter. In No. 2 there was a small barometric depression about 200 miles distant on the north side, and about this center there was a decided cyclonic movement of the winds. It seems probable that there was some change of wind at Carlsruhe during this period of twenty-four hours. In No. 41 the winds in France were light and a cyclonic movement of the winds was formed near Besançon resulting in a great rain-fall, but without any appreciable effect upon the barometer. We therefore conclude that each of these cases of great rain-fall (with perhaps one or two exceptions) occurred within an area of pressure somewhat below the mean, or at least a pressure relatively low, and that there was a cyclonic movement of the winds about this low center.

In order to show the position of these heavy rain-falls with respect to the centers of low pressure, I have prepared a chart of all these cases for 1879 similar to Plate I, which accompanied my seventeenth paper. Column 11th of the preceding table shows the quadrant in which each of these rain centers was situated, except that in a few cases the direction corresponded very nearly with one of the cardinal points, and this is indicated by the letters N, E, or S. There are also five cases marked with the character ? which will be considered hereafter. The following is a summary of the number of cases of great rain-falls for each of the four quadrants about the center of low pressure:

Northeast.	Southeast.	Southwest.	Northwest.
22	31	6	3

The three cases in which the great rain-fall took place on the N.W. side of the low center are Nos. 27, 54 and 59. May 11th there was a low center (29·37) about 200 miles southeast of Cracow, and during the preceding twenty-four hours the low center traveled only 275 miles, which is considerably less than the average velocity in this part of Europe for the month of May. Sept. 25th there was a high barometer (30·58) at Moscow, and another high (30·39) over Spain. Under the influence of these two areas of high pressure, a system of cyclonic winds was formed about the southeast part of France, resulting in a heavy rain-fall at various places in Switzerland and Northern Italy as well as at Avignon. This movement of the winds caused a considerable depression of the barometer (29·83) which was central over Northern Italy on Sept. 26th. Although the heaviest rain-fall may have occurred on the northwest side of this low center, very heavy rain also occurred on the northeast side of the low center. Sept. 28th there was a low center (29·80) southeast of Nice, and distant about 500 miles. During the preceding forty-eight hours, this low center traveled only 400 miles, or about eight miles per hour. Cases No. 27 and 59 appear to have been similar to that of Aug. 12, 1880, in Austria, where the principal rain-fall was on the west side of the low center and the low center remained nearly stationary for several days. It seems natural to conclude that the low center remained stationary *because* the principal rain-fall was on its west side.

The six cases in which the great rain-fall took place on the S.W. side of the low center are Nos. 2, 26, 34, 62, 64 and 65. Jan. 4th Carlsruhe was situated on the S.W. side of a low center (29·13 inches) at a distance of nearly 1000 miles; but on the 3d of January there was a decided cyclonic movement of the winds about the southern portion of the North Sea, accompanied by a slight depression of the barometer on the northwestern side of Carlsruhe, and the great rain-fall at Carlsruhe was probably the result of this local movement rather than the effect of that distant area of low pressure on the northeast side. No. 26, May 10th, was similar to the preceding case. A cyclonic movement of the winds covering nearly the whole of France was very decided, although the principal center of low pressure was distant 800 miles on the east side. No. 34, June 10th, was also similar to the preceding, the wind at Eperies having been S.E. June 9th and N.W. June 10th. No. 62, Oct. 17th, presents another similar case. The wind at Cosenza was S.E. on the 16th and N.W. on the 17th. In No. 64, Oct. 21st, rain was very general throughout nearly the whole of Europe, and it apparently resulted not so much from the existence of an area of low pressure over the Baltic Sea,

as from local cyclonic winds prevailing over Northern Italy and Austria, although the observations do not show any such system of winds near Carlsruhe. In these five cases the great rain-fall occurred at a distance of from 600 to 800 miles from the center of the low area in which it was included. In my seventeenth paper I have shown that in the United States, when a heavy rain-fall occurs at a distance of more than 500 miles south of a low center, the rain fall has apparently very little influence upon the direction in which the low center advances, or upon its rate of progress. A similar remark is applicable to Europe. In these five cases the rain-fall appeared to have very little influence upon the center of the principal low area in which the rain center was situated; but in four of the cases a subordinate low center was formed near the rain area. In the other case (No. 34) the local effect upon the barometer was not distinctly marked. In No. 65, Oct. 23d, the low center was about 100 miles N.E. of Valona. On the 22d the wind was S.E. and 1.30 inch of rain was reported; on the 23d the wind was north and 2.36 inches of rain were reported. The observations do not clearly show whether this rain fell chiefly before or after the change of wind.

Of the five cases in the table which are marked with an ? in column 11th, four occurred on the Pic du Midi. In each of these cases there were indications of a cyclonic movement of the winds around the Pyrenees. This is seen by comparing the direction of the winds at the nearest stations of observation on different sides of the mountains. The following table shows the four cases of 1879 and also all the cases in 1878 and 1880, in which the precipitation at this place amounted to two inches of water in twenty-four hours.

No.	Date.	Bilbao.	Tarbes.	Pic du Midi.	Toulouse.	Mont Louis.	Carcassonne.	Perpignan.	Barcelon.
1	1879. Jan. 6	NW	W	N	NW	NW	NW	NE	E
2	Jan. 7	NW	SSW	N	W	WNW	NE	E	E
3	April 3	NW	W	NW	W	W	W	NE	SE
4	April 4	NW	W	N	NW	NW	W	N	S
5	1878. Mar. 25	NW	WSW	NW	WNW	WSW	W	NW	NE
6	Dec. 2	NW	-	NNE	WNW	SW	E	N	WNW
7	1880. April 3	SW	NW	S	W	WSW	W	NE	S
8	April 27	NW	W	NNE	N	WNW	WNW	NW	E
9	May 6	NW	W	NE	SE	WNW	E	NW	S
10	May 7	NW	W	W	NNW	W	W	NW	SSW
11	Sept. 20	NW	W	W	NW	WSW	W	NE	SSE

In 1880, the direction of the wind on the Pic du Midi was not reported, and the winds shown for that station in 1880 are the directions of the lower clouds. At Mont Louis the lower clouds were reported from S. in case 1; from S.E. in case

6; from E. in case 8, and from E. in case 10. At Carcas-
sonne the lower clouds were reported from E. in case 2. In
most of these cases the evidence of a cyclonic movement of
the winds is very distinct. The observations at Barcelona
indicate a cyclonic movement about the eastern portion of the
Pyrenees in nine of the cases; the observations at Perpignan
indicate such a movement in five of the cases; the observa-
tions at Carcassonne indicate such a movement in three of the
cases; the observations of the clouds at Mont Louis indicate
such a movement in four of the cases; and the observations
on the Pic du Midi indicate such a movement in four of the
cases. For the eleven cases we may conclude that in eight of
them the cyclonic motion of the winds is distinctly marked;
while in three of them the evidence is not entirely clear. No.
41 occurred where the barometer was near its normal height
and was situated between two areas of low pressure. A local
circuit was formed near Besançon, resulting in a great rain-fall,
but without any appreciable effect upon the barometer.

Cyclonic movement of the winds about Trieste.

No.	Date.	Moncal- ieri.	Mondovi.	Milan.	Florence.	Padua.	Fesaro.	Udine.	Trieste.	Pola.	Graz.	Agram.	Krems- munster.
1879.													
1	Jan. 2	ESE	NE	W	SW	NW	S	Calm	Calm	S	WNW	NW	WNW
2	30	ENE	NW	SSE	W	NE	N	SE	ENE	ENE	SSE	E	ENE
3	Feb. 15	NNW	WSW	NNE	SE	NE	SE	NE	E	SE	WSW	E	NE
4	Mar. 23	W	NW	SE	E	NE	N	SE	Calm	SE	SW	SE	E
5	26	E	W	ESE	SE	NNE	E	E	S	SE	S	E	ENE
6	27	SSE	NNW	S	NW	NNE	NW	E	E	W	E	E	ENE
7	April 16	ENE	SW	E	E	N	N	SW	N	SE	WSW	SW	NE
8	Aug. 17	WSW	NW	ESE	S	SE	SE	SE	E	S	NE	SW	W
1878.													
9	April 24	NNW	SW	NE	SE	NNE	E	E	ENE	SE	SW	SE	SE
10	May 8	W	NW	E	WSW	SW	W	S	SW	SSW	NW	SW	W
11	25	SSE	NE	NE	SW	ENE	SE	S	SE	SE	SW	SW	WNW
12	June 5	SSE	N	SW	W	E	SW	SE	Calm	SSE	SSW	NE	W
13	15	SSW	ENE	N	SW	SE	S	SW	E	S	ESE	NE	WSW
14	July 26	SSW	NW	--	WSW	NNE	NE	N	ESE	Calm	E	NW	W
15	30	NE	NE	--	W	SE	E	Calm	NW	SE	NE	NE	W
16	Sept. 15	SW	NW	SE	SE	ENE	W	Calm	Calm	NE	E	NE	Calm
17	20	NW	N	ESE	NW	SE	NE	--	W	SE	SW	NE	Calm
18	24	NNW	NW	E	E	NE	--	E	SSE	SE	S	NE	W
19	Oct. 9	SE	N	E	ENE	E	--	E	Calm	SSE	E	NE	Calm
20	14	SSE	W	W	WNW	ENE	NW	NE	ENE	ENE	ENE	NE	ENE
21	21	NNW	NW	ENE	SE	N	E	Calm	Calm	S	S	SW	ENE
22	Nov. 14	NE	SE	W	SW	S	NW	N	SW	SSE	NE	NE	W
23	Dec. 17	ENE	Calm	NE	N	N	W	NE	Calm	SSE	S	SW	Calm
1880.													
24	July 31	NNW	WNW	S	S	NNW	NE	SW	N	SE	S	NE	WSW
25	Sept. 20	ENE	NE	ESE	SSE	E	S	SW	SW	SSW	SE	NE	WNW
26	Dec. 18	N	WNW	N	ENE	N	S	SW	Calm	SSE	SSW	E	ESE

In nearly all of the other cases in the table, the evidence of a cyclonic movement of the winds about the rain center is equally clear. In order to give a more distinct idea of the nature of the evidence, I subjoin the preceding table showing the direction of the winds at a few of the stations near Trieste at the time of the rain-fall of two inches at the latter place. The table shows all the cases which occurred at this station during the three years 1878, 1879 and 1880.

In nearly all of these cases the evidence of a cyclonic movement of the winds about a center not far from Trieste is unequivocal. The cases which appear most doubtful are Nos. 1 and 10. In No. 1 we find south winds at Pesaro and Pola opposed by northwest winds at Padua and Agram, which affords pretty good evidence of a cyclonic movement. In the case of No. 10 the low center was on the east side of the stations shown in the table; but at several stations farther east, the winds blew from an eastern quarter.

The preceding discussion appears to me to warrant the following conclusions.

1. Cases of very heavy rain-fall in Europe almost invariably occur within or near an area of low pressure, but a great rain-fall is frequently due to a local cyclone of moderate extent formed within or near a large area of low pressure. This remark applies not merely to those cases in the table in which the rain-center was on the west side of the center of low pressure, but also to many of the cases in which it was on the east side. Whenever the movement of the winds about a center of low pressure is feeble, there frequently results a local disturbance attended by a cyclonic motion of the winds and a considerable precipitation of vapor; and this is generally associated with a subordinate area of low pressure which sometimes extends and attains considerable magnitude. In many cases, this precipitation of vapor appears to be due to the influence of mountains by which the air when set in motion is deflected upward.

2. These rain-falls most frequently occur on the east side of an area of low pressure. In 1879, the cases in which a heavy rain-fall occurred on the east side of a low center, were nearly six times as numerous as those on the west side; and even if we count all those cases marked N or S, as having occurred on the west side of the low center, we shall still find the cases on the east side to be nearly four times as numerous as those on the west side.

3. Nearly four-fifths of the cases enumerated in the table on page 12 occurred at stations south of lat. 48° , so that the conclusions above stated apply primarily to southern Europe, and we cannot fail to notice a marked correspondence between the

effects of a heavy rain-fall in southern Europe, and in the southern part of the United States. In both countries the influence of a great rain-fall upon a center of low pressure is generally not very decidedly marked; while in the northern part of the United States, this influence is generally quite obvious and decided. In the United States, the parallel of 36° generally forms a satisfactory dividing line between these two classes of cases; but in Europe this dividing line is found in a much higher latitude, perhaps near the parallel of 48° . I have made an extensive collection of cases of heavy rain in Europe, north of this parallel, and have found a close correspondence with cases of heavy rain in the United States, north of the parallel of 36° . For the year 1880, in northern Europe (employing all cases in which the rain-fall amounted to as much as one inch in 24 hours), the rain-center occurred on the east side of the center of low pressure more than four times as frequently as it did on the west side; the rain-center was found in the northeast quadrant as frequently as in the southeast quadrant; the cases of one inch rain-fall in the northwest quadrant were only three in number, and in neither of these cases was the rain-center distant from the center of low pressure more than 150 miles. For all the cases in 1880 in northern Europe, the average distance of the rain-center from the center of low pressure was 420 miles, and the average pressure at the center was 740 millimeters or 29.13 inches.

MEAN ANNUAL RAINFALL.

