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WEATHER BUREAU

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MONTHLY WEATHER REVIEW

VOLUME 45, No. 5

MAY, 1917



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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 45, No. 5
W. B. No. 620.

MAY, 1917.

CLOSED JULY 3, 1917
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INTRODUCTION.

As explained in this introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS TO THE MONTHLY WEATHER REVIEW are published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Beginning August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology*.—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology*.—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere*.

SECTION 4.—*Rivers and floods*.

SECTION 5.—*Seismology*.—Results of observations by Weather Bureau observers and others as reported to the Washington office.

SECTION 6.—*Bibliography*.—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month*.—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian

Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1916. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but *all students of atmospheric science are cordially invited to contribute such additional articles as seem to be of value.*

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.

The Meteorological Service of Cuba.

The Meteorological Observatory of Belén College, Habana.

The Government Meteorological Office of Jamaica.

The Meteorological Service of the Azores.

The Meteorological Office, London.

The Danish Meteorological Institute.

The Physical Central Observatory, Petrograd.

The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

CORRIGENDA.

REVIEW, March, 1917:

Page 100, column 1, next to last line's first word: "Summer".

REVIEW, April, 1917:

Page 151, column 2, equations (2), for " $b^2=c^2+b/2$ " read " $b^2=c^2+b^2$ ".

Page 155, figure 4, for "scale in figure 4" read "scale in figure 3."

Page 156, column 2, line 28, for "there were more NE. winds" read "there was more NE. wind".

Page 157, column 1, line 6 from bottom, for "offshore" read "onshore".

Page 168, figure 1. The scale of miles should be divided by "10" to read 4, 2, 0, and 4 miles, respectively.

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1917.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., June 27, 1917.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1917, 45:2.

The monthly means and departures from normal values in Table 1 show that direct solar radiation averaged below its normal intensity at all the stations except Madison, Wis., where it was very close to normal.

At Washington hazy conditions prevailed from May 9 to 28, inclusive, and were specially marked from the 16th to the 18th, inclusive. Between these latter dates a smoke cloud that originated from forest fires in Minnesota advanced from the Upper Lakes region to the middle Atlantic coast. The low radiation intensities at Washington, and probably also at the other stations, are to be attributed to the prevailing atmospheric conditions.

TABLE 1.—Solar radiation intensities during May, 1917.

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.											
Date.	Sun's zenith distance.										
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°	
	Air mass.										
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	
May 2.....	1.20	1.17	1.06	0.96	0.86	0.79	0.74	0.69	.....	.....	
9.....	.....	0.58	0.54	0.49	0.45	0.41	0.37	0.34	0.31	.....	
10.....	1.25	1.09	0.93	0.77	0.66	0.59	0.54	0.49	0.45	.....	
11.....	.....	1.08	0.86	.....	.....	.....	.....	.....	.....	.....	
15.....	1.12	1.07	0.88	0.72	0.59	0.52	0.47	0.43	0.40	.....	
16.....	.....	0.72	0.57	.....	0.40	0.37	.....	.....	.....	.....	
18.....	0.90	0.54	0.40	.....	.....	.....	.....	.....	.....	.....	
23.....	1.24	1.07	0.92	0.89	0.82	0.75	0.68	0.63	.....	.....	
24.....	.....	.....	0.62	0.54	.....	.....	0.31	.....	.....	.....	
26.....	1.41	1.24	.....	1.00	0.92	0.85	0.78	.....	.....	.....	
30.....	.....	.....	0.98	0.90	.....	.....	.....	.....	.....	.....	
Monthly means.....	1.18	1.01	0.79	0.80	0.69	0.63	0.61	0.50	0.47	(0.31)	
Departure from 9-year normal.....	-0.12	-0.11	-0.18	-0.09	-0.08	-0.06	-0.08	-0.05	-0.02	-0.11	
P. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	
May 1.....	1.22	1.13	1.05	0.97	0.89	0.82	0.76	0.70	0.64	.....	
2.....	1.23	1.04	.....	.....	.....	.....	.....	.....	.....	.....	
15.....	0.87	.....	.....	.....	.....	.....	.....	.....	.....	.....	
18.....	0.61	0.54	0.41	.....	0.32	.....	.....	.....	.....	.....	
23.....	1.26	1.17	1.08	1.00	0.93	0.86	.....	.....	.....	.....	
25.....	1.00	0.74	0.62	0.52	.....	.....	.....	.....	.....	.....	
Monthly means.....	1.03	0.92	0.79	0.83	0.71	(0.84)	(0.76)	(0.70)	(0.64)	.....	
Departure from 9-year normal.....	-0.09	-0.06	-0.04	+0.05	-0.01	+0.10	+0.12	+0.07	+0.16	.....	

TABLE 1.—Solar radiation intensities during May, 1917.

Madison, Wis.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 2.....	1.33	1.24	1.15	1.06	0.97	0.92	0.88	0.84	0.80	0.77
5.....	1.39	1.30	1.22	1.12	1.04	0.94	0.89	0.84	0.80	0.77
7.....	1.23	1.14	1.06	0.98	0.90	0.83	0.77	0.72	0.68	0.64
9.....	1.23	1.14	1.06	0.98	0.90	0.83	0.77	0.72	0.68	0.64
10.....	1.47	1.34	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58
11.....	1.40	1.22	1.08	0.98	0.90	0.80	0.72	0.64	0.58	0.54
12.....	1.26	1.16	1.08	0.98	0.90	0.80	0.72	0.64	0.58	0.54
14.....	1.28	1.03	0.83	0.72	0.64	0.58	0.54	0.50	0.46	0.42
23.....	1.28	1.03	0.83	0.72	0.64	0.58	0.54	0.50	0.46	0.42
24.....	1.29	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58	0.54
25.....	1.29	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58	0.54
28.....	1.29	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58	0.54
29.....	1.29	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58	0.54
Monthly means.....	1.33	1.19	1.00	0.93	0.94	(0.96)				
Departure from 7-year normal.....	+0.01	-0.01	-0.06	-0.02	+0.03	+0.09				
P. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 7.....	1.26	1.10	1.01	0.92	0.84	0.77	0.72	0.68	0.64	0.61
9.....	1.28	1.10	1.01	0.92	0.84	0.77	0.72	0.68	0.64	0.61
Monthly means.....	(1.27)	(1.10)	(1.01)							
Departure from 7-year normal.....	+0.21	+0.17								

Lincoln, Nebr.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 5.....	1.35	1.22	1.10	1.00	0.90	0.80	0.72	0.64	0.58	0.54
6.....	1.41	1.30	1.14	1.04	0.96	0.88	0.80	0.72	0.64	0.61
7.....	1.30	1.14	1.04	0.96	0.88	0.80	0.72	0.64	0.61	0.58
11.....	1.22	1.16	1.04	0.96	0.88	0.80	0.72	0.64	0.61	0.58
14.....	1.22	1.16	1.04	0.96	0.88	0.80	0.72	0.64	0.61	0.58
15.....	1.19	1.06	0.88	0.77	0.72	0.68	0.64	0.60	0.56	0.52
16.....	1.21	1.06	0.88	0.77	0.72	0.68	0.64	0.60	0.56	0.52
17.....	1.36	1.18	1.03	0.90	0.80	0.72	0.64	0.60	0.56	0.52
28.....	1.18	1.03	0.90	0.80	0.72	0.64	0.60	0.56	0.52	0.48
31.....	1.18	1.03	0.90	0.80	0.72	0.64	0.60	0.56	0.52	0.48
Monthly means.....	1.26	1.13	1.06	0.90	(0.84)	(0.68)				
Departure from 2-year normal.....	-0.08	-0.09	-0.10	-0.14	-0.14	-0.21				
P. M.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
May 15.....	1.01	0.87	0.75	0.66	0.58	0.52	0.46	0.40	0.34	0.29
16.....	0.98	0.70	0.60	0.52	0.46	0.40	0.34	0.29	0.24	0.20
17.....	1.10	1.00	0.85	0.75	0.65	0.56	0.48	0.40	0.34	0.29
22.....	1.29	1.04	0.80	0.67	0.62	0.57	0.52	0.46	0.40	0.34
31.....	0.94	0.76	0.67	0.62	0.57	0.52	0.46	0.40	0.34	0.29
Monthly means.....	1.06	0.83	0.76	0.65	0.60	(0.52)				
Departure from 2-year normal.....	-0.10	-0.15	-0.10	-0.09	-0.10	-0.13				

Skylight polarization measurements at Washington give a mean of 48 per cent, with a maximum of 62 per cent on the 23d. These values are only slightly below

May averages for Washington. Measurements at Madison give a mean of 54 per cent, with a maximum of 64 per cent on the 5th.

Table 3 shows a deficiency in the total radiation for the month of 7 per cent at Washington and an excess of 10 per cent at Madison.

TABLE 2.—Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.	Dates.	A. M.	P. M.
1917.	mm.	mm.	1917.	mm.	mm.	1917.	mm.	mm.	1917.	mm.	mm.
May 1	10.21	4.75	May 2	4.95	3.99	May 5	4.57	7.29	May 1	3.15	1.07
2	4.17	3.99	5	3.15	4.17	6	4.17	4.17	2	2.62	2.16
9	6.50	3.99	7	4.37	3.99	7	4.37	4.17	16	4.57	1.88
10	4.57	4.37	9	4.75	4.17	11	6.27	4.75	17	3.00	1.68
11	6.27	3.99	10	3.99	4.17	14	5.16	4.17	26	3.45	3.99
15	5.36	3.00	11	4.37	4.95	15	5.16	4.75	28	3.63	1.60
16	7.29	5.66	12	4.57	5.36	16	5.56	7.87	31	3.15	3.45
18	9.14	9.14	14	5.36	7.04	17	10.97	7.29			
23	13.13	4.17	23	2.87	4.57	22	6.02	4.17			
24	5.56	3.81	24	3.63	5.79	28	7.04	8.81			
25	5.16	4.95	25	6.02	6.76	31	8.48	9.14			
26	5.56	9.14	28	6.02	5.79						
30	7.87	9.14	29	7.57	9.83						

TABLE 3.—Daily totals and departures of solar and sky radiation during May, 1917.

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Wash- ington.	Madison.	Lin- coln.	Wash- ington.	Madison.	Lin- coln.	Wash- ington.	Madison.	Lin- coln.
1917.	calories.	calories.	calories.	calories.	calories.	calories.	calories.	calories.	calories.
May 1	444	372	.....	-23	-82	.....	-23	-82	.....
2	630	563	.....	101	107	.....	138	25	.....
3	547	528	.....	75	71	.....	213	96	.....
4	90	314	.....	-385	-144	.....	-172	-48	.....
5	52	389	.....	-426	-70	.....	-598	-118	.....
6	394	367	.....	-86	-93	.....	-684	-211	.....
7	328	696	.....	-154	235	.....	-838	24	.....
8	190	501	.....	-295	40	.....	-1,133	64	.....
9	429	684	.....	-58	222	.....	-1,191	286	.....
10	538	651	.....	49	188	.....	-1,142	474	.....
11	563	702	.....	72	238	.....	-1,070	712	.....
12	488	614	.....	-5	150	.....	-1,075	862	.....
13	574	697	.....	79	232	.....	-996	1,094	.....
14	623	649	.....	126	183	.....	-870	1,277	.....
15	690	605	.....	191	139	.....	-679	1,416	.....
16	479	662	.....	-20	195	.....	-699	1,611	.....
17	408	593	.....	-91	125	.....	-790	1,736	.....
18	589	577	.....	90	108	.....	-700	1,844	.....
19	606	610	.....	108	140	.....	-592	1,984	.....
20	502	537	.....	4	67	.....	-588	2,051	.....
Decade departure	.....	.....	.....	.....	.....	.....	554	1,577	.....
21	516	55	.....	19	-416	.....	-569	1,635	.....
22	406	200	.....	-90	-272	.....	-659	1,363	.....
23	546	712	.....	50	239	.....	-609	1,602	.....
24	526	713	.....	30	239	.....	-579	1,841	.....
25	427	683	.....	-68	208	.....	-647	2,049	.....
26	596	136	.....	102	-340	.....	-545	1,709	.....
27	516	540	.....	22	62	.....	-523	1,771	.....
28	156	692	.....	-337	213	.....	-860	1,984	.....
29	236	594	.....	-256	113	.....	-1,116	2,097	.....
30	680	123	.....	189	-359	.....	-927	1,738	.....
31	376	243	.....	-114	-241	.....	-1,041	1,497	.....
Decade departure	.....	.....	.....	.....	.....	.....	-453	-554	.....
Excess or deficiency since first of year.	.....	.....	.....	.....	.....	.....	-2,541	+2,172	.....
Per cent.	.....	.....	.....	.....	.....	.....	-5.0	+4.4	.....

NOTE.

There is evidence that the records of total solar and sky radiation at Lincoln, Nebr., and of the intensity of direct solar radiation at Santa Fe, N. Mex., are inaccurate. Publication of these data is therefore deferred until the instrumental constants have been redetermined.

CITY SMOKE AND DAYLIGHT ILLUMINATION INTENSITIES.

By HERBERT H. KIMBALL, Professor of Meteorology, and ALFRED H. THIESSEN, Meteorologist.

[Weather Bureau, Washington, May 24, 1917.]

One of us¹ has already called attention to the considerable diminution in daylight illumination, especially in winter, in cities where soft coal is burned, due to the presence of smoke in the atmosphere. At Salt Lake City, Utah, this effect is specially marked in the early morning hours, and when the wind is light it sometimes persists for a considerable time. In order to determine the extent of the diminution, photometric measurements were made by Mr. Thiessen with the Sharp-Millar photometer described in the MONTHLY WEATHER REVIEW for December, 1914, 42:648-653, the instrument having been lent him by the central office of the Weather Bureau for this purpose.

In this study a comparison is made between the readings obtained at Salt Lake City on four different days, as follows: February 15 and 16, 1916, which were cloudless, but with much smoke in the atmosphere, and September 1 and 28, 1916, on which neither cloud nor smoke was observed. The readings are given in Table 1.

It will be noticed that each series of readings usually includes three independent photometric determinations. The mean of each series has been reduced to foot-candles of illumination by a factor derived from the constants given in the REVIEW for December, 1914, 42:650. The milk glass screen and blue glass VI_A, there described, have always been used. Column 4 of Table 1, headed "Scr.," indicates when screen L or D has also been used.

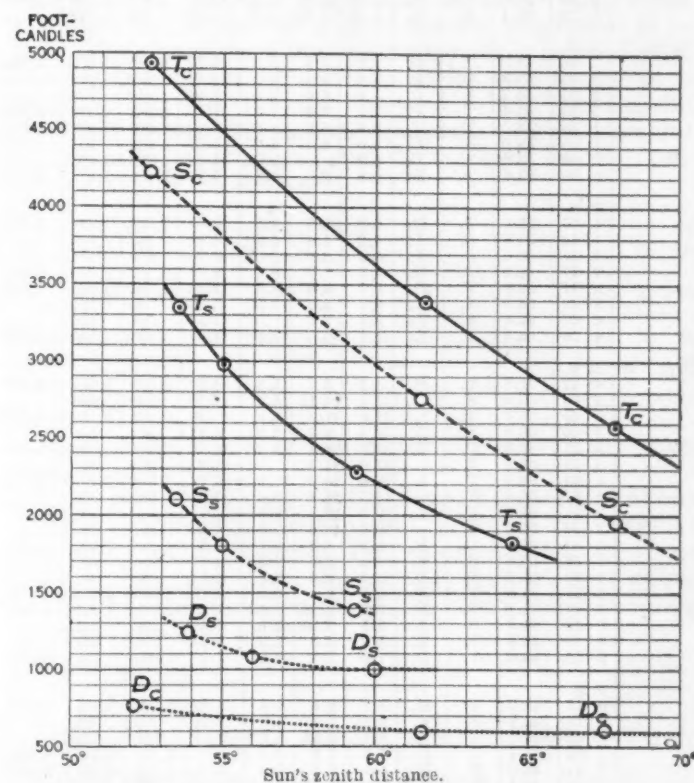


FIG. 1.—Comparison of illumination intensities at Salt Lake City, Utah, with clear and with smoky sky:

- T_c = Total illumination, with clear sky;
- T_s = Total illumination, with smoky sky;
- S_c = Direct solar illumination, with clear sky;
- S_s = Direct solar illumination, with smoky sky;
- D_c = Diffuse sky illumination, with clear sky;
- D_s = Diffuse sky illumination, with smoky sky.

¹ Kimball, Herbert H. The meteorological aspect of the smoke problem. Smoke Investigation Bulletin No. 5, Mellon Institute of Industrial Research and School of Specific Industries, University of Pittsburgh, 1913; also MONTHLY WEATHER REVIEW, January, 1914, 42:29-35.

TABLE 1.—Photometric determinations of daylight intensity on a horizontal surface at Salt Lake City, Utah, latitude, $40^{\circ} 46'$; longitude, $111^{\circ} 54'$.

Date.	(1) (2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
	Sun's—		Exp.	Ser.	Photometer readings.				I	IR ²	L.R ²
	Hour angle.	Zenith distance.			1	2	3	Means.			
1916.	H. m.	°							Ft.-cand.	Ft.-cand.	Ft.-cand.
Feb. 15	A. M.										
	2 35	64.5	T.	L.	8.02	7.95	8.00	7.99	1,867	1,822	1,650
	2 47	62.2	T.	L.	11.10	11.10	12.00	11.40	2,664	2,600	
	2 55	61.8	S.	L.	4.30	4.30	4.00	4.20	982	958	1,740
	1 55	59.9	T.	L.	12.00	12.00	12.50	12.17	2,844	2,776	
	1 52	58.6	S.	L.	4.41	4.32	4.50	4.41	1,061	1,036	1,150
	1 42	58.6	T.	L.	9.20	9.20	10.00	9.47	2,231	2,177	
	1 41	58.5	S.	L.	4.50	4.45	4.50	4.48	1,047	1,022	1,020
	1 17	56.2	T.	L.	8.70	8.90	8.70	8.77	2,050	2,001	
	1 12	55.3	S.	L.	4.30	4.11	4.45	4.29	1,003	979	1,540
	0 57	53.3	T.	L.	12.00	12.00	11.70	11.90	2,781	2,714	
	0 57	53.3	S.	L.	5.10	5.18	5.10	5.13	1,109	1,170	
Feb. 16	A. M.										
	0 52	54.7	T.	L.	14.50	14.75	13.90	14.38	3,365	3,284	1,980
	0 47	54.4	S.	L.	6.20	5.60	5.40	5.73	1,339	1,307	1,710
	0 29	53.8	T.	L.	12.50	12.50	13.00	12.67	2,968	2,897	
	0 25	53.7	S.	L.	5.00	5.20	5.40	5.20	1,215	1,186	1,920
	0 07	53.4	T.	L.	15.00	15.00	15.60	15.20	3,552	3,467	
	0 04	53.4	S.	L.	6.70	7.00	6.70	6.80	1,589	1,551	
	P. M.										
	0 08	53.4	T.	L.	15.00	15.00	15.00	15.00	3,506	3,422	2,120
	0 10	53.4	S.	L.	5.80	5.50	5.80	5.70	1,332	1,300	2,670
	0 10	53.6	T.	L.	15.00	15.00	17.00	15.83	3,692	3,603	
	0 22	53.6	S.	L.	4.80	4.40	4.45	4.55	1,063	1,037	2,040
	0 38	54.1	T.	L.	14.00	14.10	14.10	14.07	3,295	3,216	
	0 40	54.2	S.	L.	5.20	5.30	5.00	5.17	1,208	1,179	1,780
	0 53	54.8	T.	L.	12.50	13.00	12.50	12.67	2,968	2,897	
	0 55	54.8	S.	L.	4.70	4.80	5.00	4.83	1,129	1,112	1,670
	1 13	56.0	T.	L.	11.30	11.80	13.00	12.03	2,811	2,744	
	1 18	56.4	S.	L.	4.80	4.50	4.80	4.70	1,098	1,072	
Sept. 1	A. M.										
	3 03	52.0	T.	D.	7.9	7.8	7.9	7.87	6,192	6,303	5,290
	2 53	50.3	S.	L.	4.2	4.4	4.2	4.27	998	1,016	
	2 28	46.2	T.	D.	4.0	3.9	3.9	3.93	918	935	
	2 23	45.4	S.	L.	7.7	7.8	7.7	7.73	6,082	6,192	5,260
	1 33	38.6	T.	D.	9.6	9.0	9.6	9.40	7,396	7,529	6,570
	1 28	38.0	S.	L.	4.0	4.1	4.0	4.03	942	959	
	0 43	33.9	T.	D.	4.2	4.2	4.2	4.20	982	1,000	6,770
	0 40	33.8	S.	L.	9.8	9.5	9.8	9.70	7,634	7,772	
	P. M.										
	1 07	35.9	T.	D.	9.8	9.7	9.5	9.67	7,608	7,745	6,740
	1 12	36.3	S.	L.	4.2	4.4	4.0	4.20	982	1,000	
	2 17	44.5	T.	D.	3.5	3.4	3.5	3.45	806	821	
	2 17	44.5	S.	L.	8.2	8.2	8.5	8.30	6,530	6,648	5,830
	3 17	54.4	T.	D.	5.7	6.0	5.8	5.83	4,587	4,670	3,950
	3 19	54.7	S.	L.	2.9	3.2	3.0	3.03	708	721	
	4 07	63.6	T.	D.	2.5	2.5	2.5	2.50	584	595	3,300
	4 00	63.8	S.	L.	16.9	16.5	17.1	16.83	3,826	3,895	
Sept. 28	A. M.										
	4 13	71.5	T.	D.	3.2	3.3	3.3	3.27	2,573	2,581	2,060
	4 03	69.8	S.	L.	15.1	15.15	15.2	15.15	489	490	
	3 49	67.3	T.	D.	11.0	11.0	12.0	11.33	2,648	2,656	2,100
	3 46	66.8	S.	L.	2.5	2.3	2.3	2.37	554	556	
	3 25	63.3	T.	D.	14.0	14.5	14.0	14.17	3,312	3,322	2,860
	3 15	61.6	S.	L.	14.0	14.5	17.0	14.25	460	461	3,320
	3 03	59.7	T.	D.	16.0	16.0	17.0	16.33	3,816	3,827	
	2 57	58.8	S.	L.	15.5	15.5	16.0	15.67	506	508	
	2 31	54.9	T.	D.	19.0	19.5	19.0	19.17	4,480	4,493	3,890
	2 28	54.5	S.	L.	19.0	19.0	17.5	18.50	4,878	4,893	4,270
	2 03	51.2	T.	D.	6.2	6.2	6.2	6.20	624	626	
	1 54	50.1	S.	L.	2.5	2.7	2.8	2.67	601	603	
	1 16	46.2	T.	D.	2.8	2.5	2.4	2.57	5303	5,319	4,720
	1 11	45.8	S.	L.	6.9	6.5	6.8	6.73	5,728	5,745	5,160
	0 53	44.5	T.	D.	7.2	7.25	7.4	7.23	5,996	5,998	
	0 49	44.3	S.	L.	2.5	2.55	2.6	2.55	755	757	
	0 18	43.9	T.	D.	3.2	3.3	3.2	3.23	6,082	6,100	5,340
	0 15	43.0	S.	L.	7.6	7.8	7.8	7.73			
	P. M.										
	0 15	43.0	T.	D.	8.5	8.6	8.8	8.63	6,790	6,810	6,040
	0 18	43.9	S.	L.	3.55	3.0	3.3	3.28	766	768	
	1 02	45.1	T.	D.	3.4	3.25	3.75	3.47	811	813	
	1 06	45.4	S.	L.	7.0	7.1	6.8	6.97	5,484	5,500	4,690
	1 44	49.0	T.	D.	6.1	6.2	6.2	6.17	4,854	4,869	4,110
	1 48	49.4	S.	L.	3.6	3.4	3.65	3.55	760	762	
	2 23	53.8	T.	D.	18.0	18.2	17.9	18.03	4,214	4,227	3,400
	2 24	54.0	S.	L.	12.7	12.7	12.7	12.70	2,968	2,977	2,170
	2 56	58.6	T.	D.	12.7	12.7	13.8	13.87	3,248	3,258	2,450
	2 58	58.9	S.	L.	13.8	14.0	13.8	13.87	795	797	
	3 17	62.0	T.	D.	3.5	3.4	3.4	3.43	2,734	2,742	1,950
	3 19	62.3	S.	L.	11.2	12.0	11.8	11.67	2,453	2,460	1,660
	3 35	64.9	T.	D.	10.0	10.0	10.2	10.07	795	797	
	3 40	65.8	S.	L.	3.4	3.5	3.3	3.40			

Column 3 of Table 1, headed "Exp.," indicates by *T* and *S*, respectively, whether the photometer was exposed to the total hemispherical vault of the sky, including that part occupied by the sun, or to the sky alone. In the latter case a screen was interposed between the instrument and the sun. In column 10, the illumination intensity, *I*, has been reduced to intensity for mean solar distance of the earth by multiplying it by the square of the earth's radius vector, *R*². The illumination intensity, *I*_s, due to direct solar radiation alone, and likewise reduced to mean solar distance, is given in the last column of Table 1. It has been obtained by subtracting the diffuse sky illumination from the total illumination.

The data of columns 10 and 11 for the two clear days, and likewise for the two smoky days, have been grouped by the zenith distance of the sun at the time of the measurements, and the means of each group are plotted in figure 1.

From the curves thus constructed the comparisons given in Table 2 between the total, the direct solar, and the diffuse sky illuminations, on clear and on smoky days, have been obtained. From these comparisons it appears that on a smoky day the total daylight illumination is about two-thirds and the direct solar illumination is about one-half what it is on a clear day, while the diffuse sky illumination is about one and two-thirds times the illumination from a clear sky. As a result of the above the diminution in daylight illumination will be relatively less in rooms on the shaded sides of buildings than in rooms on the sunny side.

The diminution in the total, and in the direct solar, illumination is generally intensified with increase in the sun's zenith distance, while at the same time the increase in the intensity of diffuse skylight becomes less marked.

The smoke cloud at Salt Lake City rises to a height of about 400 feet above the level of the business streets. Often the sky is clear at the time of the 6 a. m. (8 a. m. 75th meridian time) observation, but becomes smoky by 7 a. m., and when the wind is light it remains smoky all day long. Such days may be called "dark days." February 16, 1916, was a dark day, and February 15 was dark until about noon.

From November 1 to March 31 the number of days with light smoke averages 82, and with dense smoke 25, making in all about 107 smoky days out of a total of 151 days. When the smoke is dense artificial light must be used quite late in the morning and early in the evening, and sometimes throughout the day. This means a very considerable expense to the private family as well as to the manufacturer and merchant and is directly chargeable to the smoke.

TABLE 2.—Comparison of illumination intensities on clear and smoky days at Salt Lake City, Utah.
[Unit: Foot-candle.]

Sun's zenith distance.	Total illumination.			Solar illumination.			Sky illumination.		
	Clear sky.	Smoky sky.	Ratio, smoky to clear.	Clear sky.	Smoky sky.	Ratio, smoky to clear.	Clear sky.	Smoky sky.	Ratio, smoky to clear.
53.5	4,740	3,360	0.71	4,050	2,100	0.52	730	1,270	1.74
55.0	4,460	2,980	0.67	3,780	1,800	0.48	700	1,140	1.63
59.0	3,770	2,320	0.62	3,110	1,400	0.45	640	1,000	1.56
61.5	3,400	2,070	0.61						
64.5	2,990	1,820	0.61						
Means			0.64			0.48			1.64

The total and direct solar illumination intensities of September 1 and 28 average a little higher than those

for Mount Weather, Va., at the same season of the year, as published in the REVIEW for December, 1914, above referred to. The diffuse sky illumination, however, is markedly less.

markedly less. It is of interest to note that the results of this investigation show about the same percentage of diminution in daylight illumination under the city smoke cloud as was given by a comparison between the decomposition of oxalic acid at Pittsburgh, Pa., and at Sedgwick, Pa., the latter a suburb of Pittsburgh.²

ON HORIZONTAL HALOS.

By Y. TSUJII.

[Reprinted from Journal of the Royal Meteorological Society of Japan, May, 1917, 36: 53.]

Horizontal halos are produced by the refraction of the sun's rays at the surface of frost crystals of tabular form deposited on the surface of snow or ground, or [at the surface] of freshly fallen snow crystals. The author of this article describes 50 cases of ground halos observed at Ueda in Nagano prefecture, central Japan. In a general consideration of these optical phenomena he has deduced the equation for them in the following way:

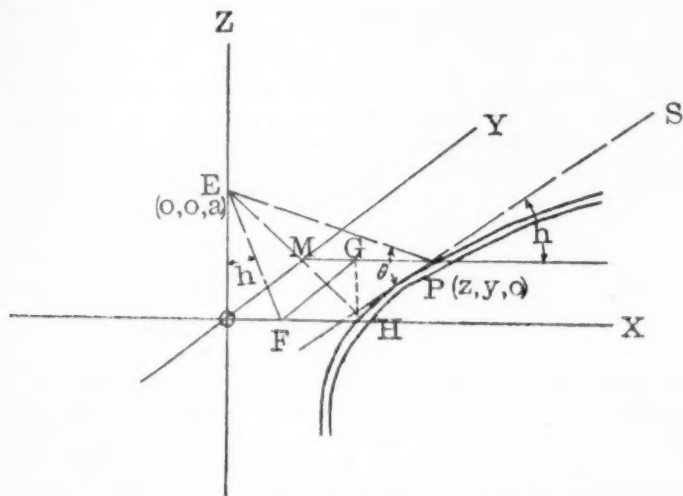


FIG. 1.—Construction illustrating Tsujii's demonstration on ground halos.

In figure 1 let θ be the angle of deviation of the solar rays through an ice prism. Taking the vertical through the observer as Z-axis and X and Y axes in the plane of the halo, we get as the equation of the halo

$$(a^2 + x^2 + y^2)^{\frac{1}{2}} \cos \theta = (x - a \tan h) \cos h,$$

where a is the height of the observer's eye, and h the sun's altitude.

Transforming the origin of the coordinates to the center of symmetry the equation becomes,

$$\frac{\frac{\xi^2}{\cos^2 \theta \sin^2 \theta}}{(\cos^2 h - \cos^2 \theta)^2} - \frac{\frac{\eta^2}{\sin^2 \theta}}{a^2 \cos^2 h - \cos^2 \theta} = 1.$$

The angle of deviation of the rays deduced from the observation of the horizontal halos is considerably greater than 22° for the inner halo, and than 46° for the exterior halo. This shows that the explanation of the halos afforded by the geometrical method was unsatisfactory and must be founded on the principles of physical optics.—*T. Okada.*

SOLAR HALO AT VICKSBURG, MISS., APRIL 24, 1917.¹

By WILLIAM E. BARRON, Meteorologist.

[Weather Bureau Office, Vicksburg, Miss.]

Unusual halo phenomena were observed at Vicksburg, Miss., on April 24, 1917. Attention was first directed to the phenomena at 11:15 a. m., 90th meridian time, and they continued visible until 12:15 p. m. In the first place there was an ordinary halo usually mentioned as of 22° radius. The circle was well defined and the colors were brilliant. But the most striking phenomenon was a circumhorizontal arc, such as is described in the MONTHLY WEATHER REVIEW, July, 1914, page 440. The colors of this arc were most brilliant, showing all of the spectral colors over a belt estimated at 3° in width, the red being nearest the sun, and the violet nearest the horizon. At times the band was broken owing to the shifting character of the clouds. Throughout the period there were six to seven tenths of cirrus clouds, those nearer the sun appearing to be of the more matted cirro-stratus type. During most of the appearance the arc was 40° to 50° in length, and at 11:35 a. m. extended from az. 523° to az. 43°. At about 11:40 a. m. a second complete circle was discovered, white in color and well defined, with its circumference passing through the sun, and its center north of the sun, probably in the circumference of the first circle.

It was some time before instruments could be gotten out with which to measure the angles and by that time the horizontal arc was becoming shorter, and there was some difficulty in using a transit on account of the lenses. The elevation of the red edge of the arc was found to be 25° . The elevation of the inside edge of the colored circle was found to be $50^{\circ} 30'$. These angles were measured at 11:55 a. m. and 12 noon, respectively. The angular elevation of the sun was not obtained at the time, but was obtained at the same time on the next day by computation from the shadows.

Elevation of sun at 11:55 a. m., 25th.....	70	39
Upper edge of arc at 11:55 a. m., 24th.....	25	00
Angular distance of arc.....	45	39
Elevation of sun at 12 noon, 25th.....	70	46
Inner edge of circle, at 12 noon, 24th.....	50	30
Radius of circle.....	20	16

No measurements of the white circle were made on account of its height.

Parhelia with prismatic colors were observed, one above and one to the north of the sun at 6:17 p. m. The angular distance was not measured, but was thought to be about 22° . At the same time there was a vertical light pillar, about the apparent width of the sun, and extending upward from it 8° or 10° .

HALO PHENOMENA APRIL 8, 1917, AT YORK, N. Y.¹

Mr. Milroy N. Stewart, of York, N. Y. (lat. N. $42^{\circ} 52' 30''$, long., $77^{\circ} 53'$) contributes the following notes of halo phenomena observed April 8, 1917:

At 10:55 a. m. I noticed the very bright upper and lower arcs of a 22° halo. This caused me to look for the circumscribed halo formed by the tangent arcs, and almost immediately the arc on the western side appeared and in a very few minutes the eastern limb was apparent. At

² See MONTHLY WEATHER REVIEW, January, 1914, 42:32.

¹ Published with approval of Division of Aerological Investigations.

11 a. m. the elliptical effect produced by the enveloping tangent arcs was very pronounced. The sun's altitude at this hour was $52\frac{1}{2}^{\circ}$, by computation. At this time both parhelia were visible—the southwestern one being about 36° from the sun, by measurement on a great circle. They continued visible until shortly after 11:15, at which time the northeastern parhelion was 37° from the sun's vertical.

At 11 a. m. there was also to be seen a part of the parhelic circle, extending from the sun to a distance of about 50° on either side. It became complete at 11:40 and lasted until shortly after noon.

There was also observed the right infralateral arc, rainbow-colored and nearly straight. Red and green

were the predominant colors. Its brightest part at 11 a. m. was at an altitude of 15° and was distant 44° from the sun's vertical. Another measurement at 11:45 gave the altitude as 24° . The measurements were made with an anglemeter, a modified sextant with one mirror. At 11:45 the arc was plainly convex toward the sun.

The difference in horizontal diameter of the inscribed and circumscribed halos, at 11 a. m., was about 3° .

At noon there remained only the 22° -halo and the parhelic circle.

It may be of interest to remark that there was observed on the previous evening the south paraselene, very bright, noticeably reddish, with a white tail of 1.5° extending south.

SECTION II.—GENERAL METEOROLOGY.

SUMMER TYPES OF RAINFALL IN UPPER PECOS VALLEY.

By CLEVE HALLENBECK, Observer.

[Weather Bureau Office, Roswell, N. Mex., Apr. 30, 1917.]

While there are but three recognized primary types of rainfall (cyclonic, convective, and orographic), subdivisions of these three types are necessary to the classification and description of the rains of any one locality. Thus, at Roswell two distinct types of cyclonic rainfall have been observed, one of which is confined to the colder half of the year, while the other may occur during any month, and this latter type can be further subdivided into two groups, one of which occurs during the summer and the other during the winter. All thunderstorms are classed as convective, but they may exhibit slightly different characteristics in different portions of the country; the thunderstorms occurring at this station being different in at least one particular from those observed by the writer in the Mississippi Valley and Eastern States. It seems, therefore, that accuracy in classification could be well served by recognizing subdivisions of the three primary types as long as such subdivisions exhibit individual characteristics.

The summer rains of the upper half of the Pecos Valley may thus be classified as follows:

Convective:

1. Thunderstorms.
2. Local showers.

Cyclonic:

3. Transitional rains.
4. Nonconvective rains.

The first group—thunderstorms—includes all rains of this type, both of purely convective and of cyclonic origin, as the term is generally defined. It might be remarked as an interesting point that the so-called "squall cloud" is seldom observed in thunderstorms occurring at this station. The writer has not once observed this cloud in any thunderstorm during the last two years, although the "squall wind" nearly always occurs. It is possible that in some of the storms the squall cloud may be present but hidden by a curtain of rain.

The second subdivision of convective rains—local showers—includes light rains of brief duration that occur at this station during the warmer half of the year, and which are of convective origin, although they occur at night as well as during the day, less frequently, however, at night. This type is well known at stations near the Gulf coast but, it is believed, is not of frequent occurrence in the elevated regions of the west. These local showers occur when conditions are favorable to the formation of thundershowers, and it may be that some of them are thunderstorms in the first stage of development. The majority of them, however, are not embryonic thunderstorms, as they are frequently observed to die out. As observed at this station, the rain falls from an unusually large cloud of cumulus formation, or from a patch of cloud covering only a portion of the sky, making a "trail" of precipitation of very limited breadth across the country. On one date in 1916 no less than five such clouds were observed at the same time in

different parts of the sky, from each of which rain was falling.

The two subdivisions of cyclonic rainfall are believed to be unusual types not generally known or recognized in other portions of the United States, and for this reason they are made the main subject of this discussion. They are primarily cyclonic, but under certain pressure conditions the topographic features of the Pecos Valley give them strikingly individual characteristics, which differentiate them from the usual type of cyclonic rains. These characteristics are outlined in the second paragraph following.

In figure 1 the relative amounts of rainfall and the relative hourly frequency of precipitation from the different types of rainstorms are presented. The left-hand portion of the figure gives the total amount of rain for each hour during the months May to September, inclusive, for the 12 years 1905 to 1916. The right-hand portion gives the total number of times rain has been recorded in each hour over the same intervals of time. It will be seen from this figure (and also from fig. 2) that each of the first three types has its own hours of maximum rainfall. This phase of the subject will be more fully discussed in a later paragraph; attention is invited to these figures at this point to give an idea of the relative importance of the different types of rainstorms.

The two subdivisions of cyclonic rainfall are so nearly alike that there is some doubt as to whether they should be differentiated, and, after noting their points of dissimilarity, they will be treated in the main as a single type. As observed at Roswell, they have the following characteristics in common:

1. The storm always approaches from the south.
2. The wind direction during the storm, and frequently for some time before, is northerly.
3. The barometric pressure, except for diurnal variation, is practically stationary.
4. The rain begins at night and is heaviest after midnight.
5. The velocity of the wind is greater toward the end of the rain than at the beginning.
6. These rains are confined to the warmer half of the year.
7. They occur only when there is a greater than normal pressure gradient from the middle plains region to Arizona.

The two differ in the following characteristics:

1. Group 3 is accompanied by thunder, while group 4 is not.
2. The average time of maximum precipitation intensity of group 3 is 10 p. m. to 2 a. m., while of group 4 it is 2 to 6 a. m.

It should be said that the above-named points are characteristic of the *typical* rains of this class, and not of every one of such rains that occur.

The rains of group 3 are called "transitional" rains because, while they closely resemble those of group 4, they are allied to thunderstorms, and are recorded as such. Their period of maximum intensity of precipitation, as well as their period of maximum frequency of precipitation, is intermediate between that of the noncon-

vective rains and that of thunderstorms. The writer believes that these rains begin as thunderstorms farther down the valley—probably in Texas—and by the time they reach this portion of the Pecos Valley they have developed into a form closely resembling the nonconvective rainstorms, with a front 50 to 150 miles in extent, and delivering general precipitation over both the valley slopes. By the time they reach Roswell they have lost their main convective characteristics. It will be shown later, however, that the rains of both group 3 and 4 partake to a limited extent of the nature of both convective and orographic rainfall.

A study of the original reports of cooperative stations in the valley was made in an effort to determine how far to the north and south of Roswell these rains extend and whether they present the same characteristics at other points in the valley than Roswell. Five of the above-named characteristics were verified for other stations as far south as Carlsbad and north as far as Fort Sumner. The third and fifth, of course, could not be verified from the cooperative reports.

The south-to-north movement of the storm was clearly demonstrated in this investigation, and in most cases the beginning of rain showed a regular rate of progress up the valley. In three instances, the beginning of rain was irregular, and in one storm the rain apparently began at the upper end of the valley and progressed southward. In all four of these cases the lower clouds, as observed at Roswell, moved from the south. A few storms of this class have been observed at this station, in which the southerly direction of the clouds changed through easterly to northerly toward the end of the rain, the change being attended by rising barometer.

It was more difficult to ascertain how far up and down the valley the northerly wind extended in these storms, as the observers record the prevailing direction for daylight hours while the rains occur usually at night. Sufficient data were obtained, however, to warrant the assumption that this wind may extend a distance of 150 miles, and possibly farther. For example, the cooperative observer (U. S. Reclamation Service) at Carlsbad, which is the most southerly station in the Pecos Valley in New Mexico, reported that during the record rain storm of August 7-8, 1916, the wind, which had been from the south and southeast, shifted to north at the beginning of the storm, and during the entire time of the rain it blew from the north and northeast. Inquiries sent to intermediate stations brought practically the same information.

In connection with rains of this type, I find such notes as these entered on the local record of this station: "Storm backed against the wind" and "the storm moved from south to north against the wind."

While the weather maps may show a pressure gradient over eastern New Mexico during these rains, the barometer at this station remains practically stationary during the storm and usually for 6 to 18 hours before. No heavy rains were found of record during which the barometer was rising or falling materially.

Tabulated data for 18 of these storms, each of which delivered one inch or more of rainfall at this station, gave the following results: Thirteen began at night and 5 in the afternoon; 15 delivered their heaviest precipitation at night (11 of these after midnight) while the remaining 3 showed no well-defined period of maximum rainfall; in 13 the wind was northerly throughout the storm (in 6, also northerly for some time before rain

began); in 3 it remained southerly throughout, and in the other 2 was variable; 6 of the storms were accompanied by thunder; 6 delivered "excessive" precipitation, each time at night and 4 of the 6 times after midnight. In no storm was "excessive" precipitation re-

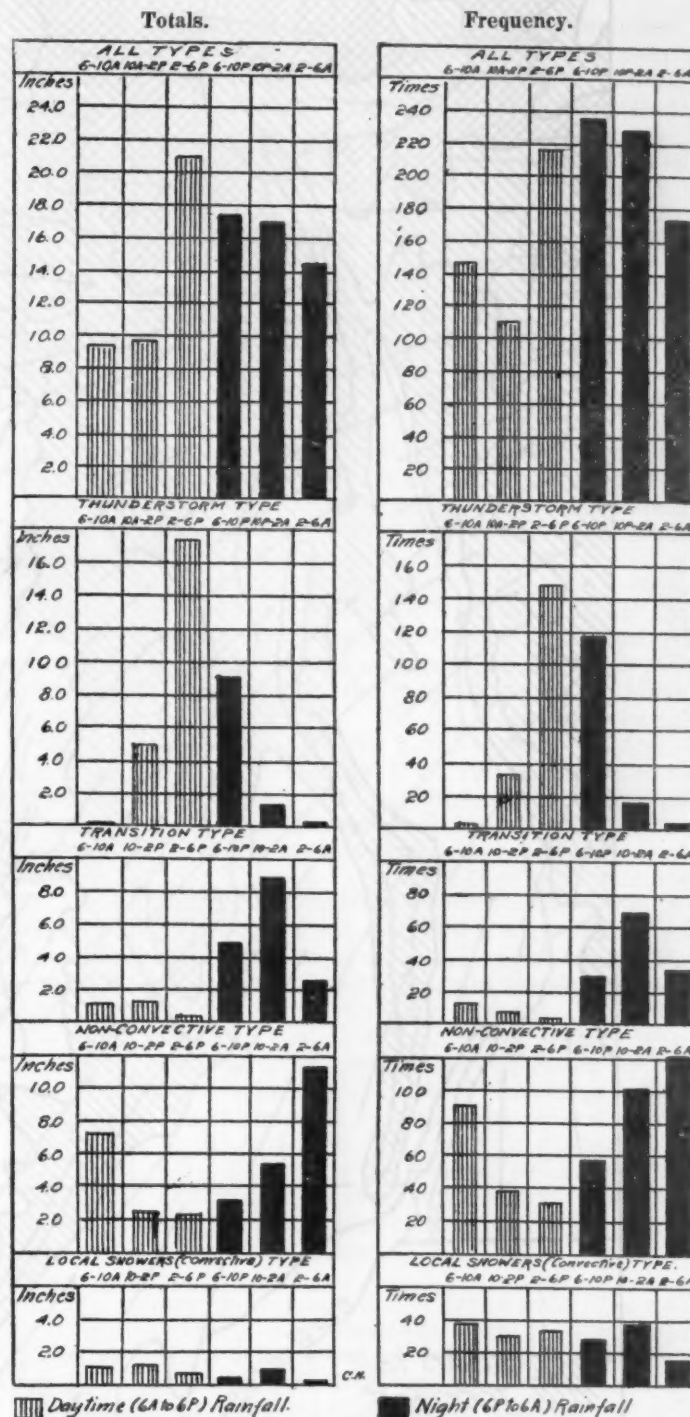


FIG. 2.—Total amounts and total hourly frequencies of precipitation for each of the four types of precipitation, by 4-hour periods, for the 12 years 1905 to 1916, inclusive, at Roswell, N. Mex.

corded with a southerly wind. During 15 of the 18 storms the pressure remained practically stationary at Roswell. All the storms moved from the south.

No rain storms of the type under discussion were found on the local records for the months November to March, inclusive, although they have occurred in April

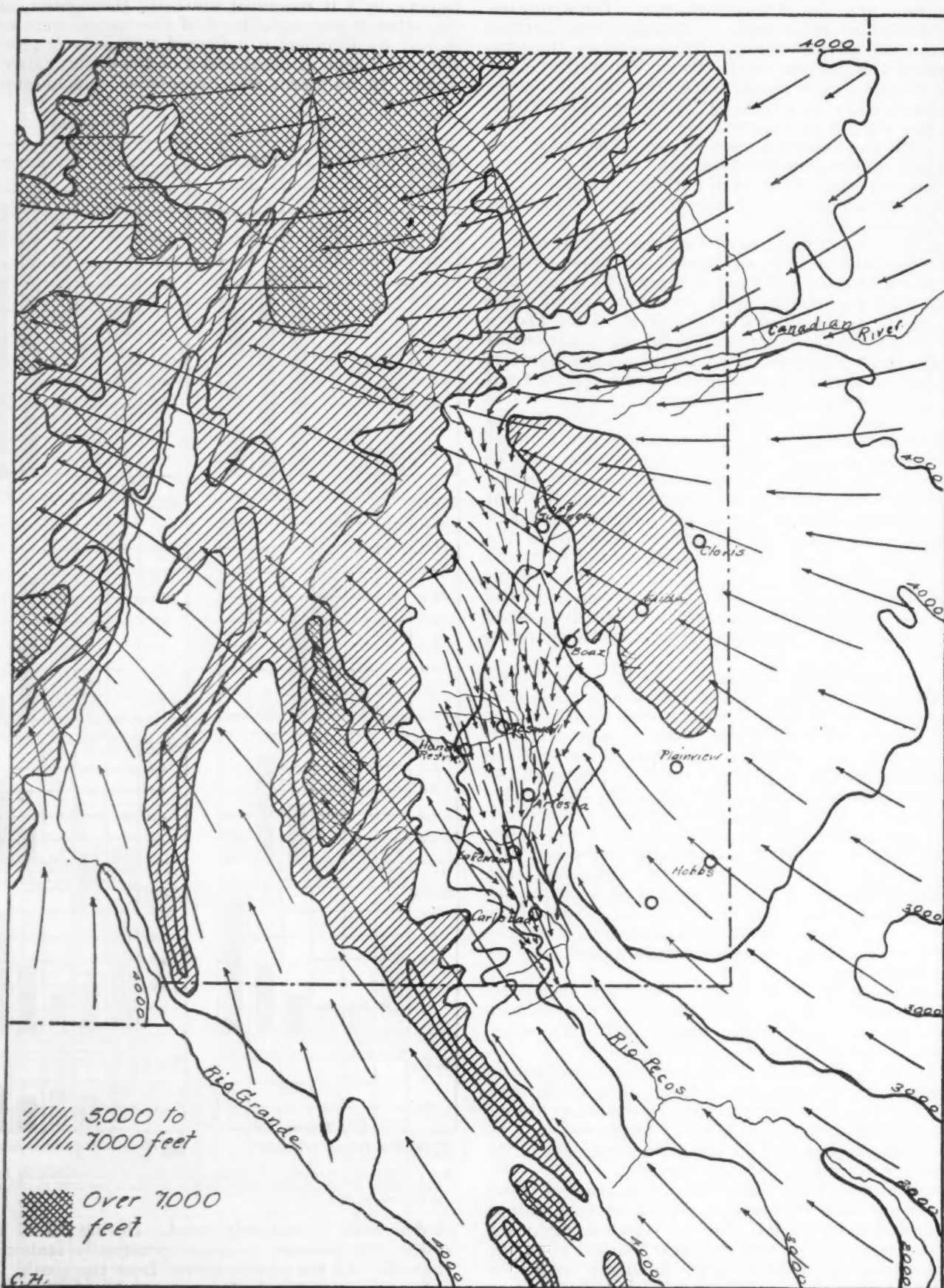


Fig. 3.—Hypsometric sketch map (contour interval, 1,000 feet) of southeastern New Mexico, showing the theoretical air movement across the region when under the influence of a high to the northeast, a low to the west, and the Gulf of Mexico. Long thin arrows—direction of lower clouds and the general surface wind. Short arrows—direction of the underrunning night current.

and October, which two months were not included in the data from which figures 1 and 2 were constructed.

Such of these storms as are accompanied by thunder exhibit no other thunderstorm characteristics. There is no abrupt shift in the direction of the wind and no increase in velocity at the beginning of the rain. Precipitation usually begins at a light rate, and is sometimes more than four hours in reaching its maximum intensity. The barograph shows no rise in pressure such as commonly attends a thunderstorm, although two cases were noted where the pressure was very unsteady throughout the storm. The thunder is seldom heavy, and is nearly continuous. In the storms of this class which have been observed by the writer the electric discharges apparently took place above the lower clouds, as no "zigzag" lightning was seen. In the storm of April 16, 1915, the thunder was in the form of what might be called "thunder waves" which moved rapidly from south to north at intervals of 15 or 20 minutes, each "crescendo" being attended by an increasing rate of precipitation and each "diminuendo" by a decreasing rate.

These cyclonic rains may occur when there is no clearly defined HIGH or LOW located as before described, but the most favorable condition is a moderate HIGH to the northeast and a LOW over Arizona. Since a LOW is practically permanent in the Southwest during the summer months, it is only necessary to supply the HIGH in order to have a pressure distribution favorable to such rains. When the HIGH is present the Arizona LOW is apparently deepened, but this no doubt is due to the increased gradient between the LOW and the middle Plains region. In this connection attention is invited to figure 5, which is a composite map of five pressure distributions attending five typical nonconvective rains in the upper Pecos Valley. Even in cases where these pressure areas are not clearly defined there is a greater than normal decreasing gradient from central Kansas to Arizona. The normal gradient varies somewhat during the season, being about 0.17 inch in May and 0.20 inch in July. The average during 18 rainstorms was 0.38 inch, or about double the normal gradient.

Since the barometer at Roswell remains nearly stationary on such occasions, it seems that the HIGH and the LOW are about balanced so far as their influence at this point is concerned. It has been repeatedly observed that if the HIGH be predominant northerly currents will prevail, day and night, both near the surface and at the elevation of the lower clouds, while if the LOW is the controlling feature the flow of air will be from the south and southeast at both elevations, day and night.

Theoretical explanation.

With these established facts in view—(a) the southerly movement of the rainstorm, (b) the northerly direction of the wind, (c) the maximum intensity and frequency of precipitation occurring at night, and (d) the attendant pressure distribution over the Southwest—the following explanation of these rains is offered:

Unless the air circulation in the Pecos Valley is controlled by a predominant high or low pressure area, the wind shifts from southerly to northerly at night and back to southerly in the forenoon. At Roswell the night shift in summer normally begins at about 9 p. m. and reaches north at about midnight. The daytime shift back to south begins two or three hours after sunrise and reaches south about noon. The shift to northerly is through west and to southerly is through east. The

daytime shift from north to south is more clearly marked than the night shift back to north. The diurnal changes are more pronounced in winter than in summer and during the latter season are nearly masked, in the prevailing hourly directions, by the predominant southerly winds.

Since the pressure distribution is such as to maintain, for the time, nearly stationary barometer at this point, the diurnal shifts of the wind occur without material modification. Or it may be said that the southwestern LOW controls the lower air movement during the day, while the HIGH to the northeast controls it at night. The flow of the air upslope toward the LOW would be reinforced during the day by the normal tendency to flow upslope during the day, while at night the outflow from the HIGH would be reinforced by the nocturnal tendency of the air to flow down the valley. This implies a deflection of the outflow from the HIGH contrary to the deflection caused by the rotation of the earth, but it is an observed fact that a HIGH over the middle Plains does produce northerly winds in the Pecos Valley, and materially prolongs the period of downslope winds at night. If the HIGH is absent, southerly winds will prevail throughout the night, with the possible exception of an hour or two in the early morning. This northerly wind, then, during rains of the nonconvective type, is a combination of air drainage and of outflowing air from the HIGH.

Under the particular pressure distribution in question, it seems that at the elevation of the lower clouds the southerly flow of air toward the LOW is maintained throughout the night as well as during the day, as is evidenced by the invariable southerly movement of the lower clouds when these rains occur. The northerly surface wind at night, then, whether it be considered as purely air drainage or as a part of the outflow from the HIGH or a combination of the two, is an underrunning wind flowing beneath the rain-bearing current from the south. The fact that such rains in their typical form occur only when the HIGH is present seems to indicate that in its absence the down-valley wind would not develop against the opposing southerly flow of air, specially in view of the fact that the general cloudiness at such times would retard the cooling of the lower air by radiation, and thereby prevent the formation of a purely drainage current. That this wind is not due to the cooling of the lower air by precipitation or by evaporation of precipitation, is shown by the numerous instances in which it starts some time before rain begins. In the two storms whose precipitation areas are charted in figure 4 this was true. In the storm of July 23-24, 1911, the wind was northerly 10 hours before rain began, and in that of August 7-8, 1916, it shifted out of the south three hours before the beginning of rain, although it did not reach due north until a few hours later.

If this underrunning wind is due to the HIGH, this presupposes that the outflow from the HIGH is cooler than the inflow toward the LOW, which is contrary to the idea that in summer the HIGH is the warmer. It is believed that this special case is an exception to the rule. It will be remembered that the condition being dealt with is essentially a *night* condition, and most pronounced in the latter part of the night. Radiation would be practically unchecked in the HIGH, while in the southerly rain-bearing current, which is, as a rule, cloud laden, radiation would be greatly retarded. Therefore it seems reasonable to assume that at night, and specially after midnight, the outflow from the HIGH is cooler than the air moving up the Pecos Valley. It was found that the average 8 a. m. temperatures, for a number of summer pressure distri-

butions of the type under discussion were 2 degrees to 5 degrees below normal over the area occupied by the HIGH, 1 degree to 2 degrees above normal in the Arizona LOW, and about normal over southeastern New Mexico and western Texas.

It is believed that this underrunning wind is effective in increasing the rate of precipitation, and that it may start precipitation. In several instances the beginning of rain was approximately coincident with the arrival of the northerly wind. In the case of the storm referred to in an earlier paragraph (p. 211) where the rain began first at the northern end of the valley and apparently "backed" southward (the rain clouds moving from the south), the rain and the northerly wind began at about the same time at Roswell, and if the same was true at other stations in the valley, then it seems safe to assume that the northerly wind underran and lifted up the southerly rain-bearing current and thereby started precipitation. If this is true, these cyclonic rains are allied in that one characteristic to cyclonic thunderstorms, and are to that extent convective.

The down-valley wind would, normally, be most completely established during the later hours of the night, and it is during those hours that such rains deliver their heaviest precipitation. It may be that the cooling of the rain-bearing current by radiation plays a part in producing precipitation, since its cumulative effect would become greatest during the latter part of the night.

In the case of these night rains, where the underrunning wind is established in the valley, three causes of condensation are active: the mechanical cooling of the moist air by its ascent up a comparatively steep slope, the further cooling of this air by radiation, and the cooling effect of being underrun and lifted up by the down-slope wind. And, since this underrunning current must reenter the prevailing circulation, it may in that way be a fourth cause of condensation, since it is, presumably, cooler than the moist air flowing upslope. All these, acting simultaneously, are sufficient to account for the heavy and sometimes excessive rainfall that this type of storm frequently delivers in the later hours of the night. It will be noted from the above that these rains, while primarily cyclonic, also partake of the nature of both convective and orographic rainfall.

An attempt is made in figure 3 (p. 212) to illustrate this theoretical air movement. On this figure the surface contours are drawn for every 1,000 feet elevation up to 7,000 feet. Higher elevations are not shown, but in the northern part of the State the land rises to 12,000 and 14,000 feet. It will be noted that the mountain range west of the Pecos Valley, while low (6,000 to 8,000 feet) is still 3,000 to 4,000 feet higher than the trough of the valley throughout its entire course, and that this course, which is southeast-northwest in Texas changes to south-north through New Mexico. The normal direction of winds over western Texas and eastern New Mexico, moving in toward a LOW centered over Arizona, should be southeasterly and it is observed that they take this direction over all of that region except the Pecos Valley in New Mexico, and with the possible exception also of portions of the Canadian and Grande Valleys. It is believed, therefore, that the range to the west is effective in deflecting the current to the right as it moves up the Pecos Valley, until by the time it reaches Roswell it is moving from the south (also south at Artesia, but south-southeast at Carlsbad).

It also seems probable that the high mountain ranges in the northern part of the State (12,000 to 14,000 feet) deflect the overflowing air from the HIGH toward the

left, so that it moves southward through the col connecting the Pecos and Canadian Valleys. This deflection, as remarked elsewhere, is contrary to the deflection due to the earth's rotation, but nevertheless it is believed that it occurs. The Canadian Valley is very nearly of the same elevation as the valley of the Pecos, while it is flanked on the west and northwest by mountains nearly twice as high as the range which borders the Pecos Valley on the west. This lower range without doubt deflects the wind moving up the Pecos Valley, and it seems reasonable to assume that the high ranges to the north would have a similar effect on the outflow from the HIGH.

In figure 3 a system of winds is represented as flowing toward the LOW from the coast regions of the Gulf and also from the HIGH, this movement being represented by the long arrows. These arrows represent the direction of the lower clouds as well as of the surface wind. The smaller arrows represent the underrunning drainage of air down the valley *at night*, which moves below and in an opposite direction to the prevailing system of winds. This, be it understood, represents the air movements only during rains of the type under discussion. Whether the prevailing southerly flow of air at the higher elevation continues during the night when the weather is clear, is not known. It is possible that similar night drainage may be found, under the proper pressure conditions, in the valleys of the Canadian and Grande, but such is shown here only for the valley of the Pecos.

While this is to an extent an idealized system of winds, the prevailing circulation conforms to the generally accepted theory of air movements under the given pressure distribution, while the northerly wind in the Pecos Valley is in accordance with observed conditions at this and other stations in the valley.

Further with regard to this underrunning wind as a factor in producing precipitation, it may be said that in a number of storms, where the wind was southerly at the start, the rate of precipitation at Roswell began to increase simultaneously with the shift of the wind to the north. In one heavy rainstorm, the wind shifted from northerly to southerly twice during the rain, and each shift was marked by a decrease in the intensity of the rain, which increased again with each shift back to northerly.

Among the numerous storms whose precipitation was charted were a few in which the area of heaviest rainfall was in the Canadian Valley, with a secondary area in the valley of the Pecos (e. g., May 13-14, 1911, May 28-29, 1911), and others where general rain occurred over western Texas and eastern New Mexico, but which was heaviest in the Pecos Valley (Sept. 11-12, 1912; Apr. 24-25, 1911; Apr. 13-18, 1915).

The conclusions reached by the writer—and they are supported by the available data—are (1) that these rains are primarily cyclonic, being produced by the mechanical cooling of warm, humid air moving upslope, under the existing pressure conditions, from the Gulf region; and (2) that the heavy nighttime precipitation in the Pecos Valley is due to the underrunning of the rain-bearing wind by the denser valley drainage, with the probable added effect of the cooling of the saturated air by radiation and by mixture with the underrunning wind.

It is only under certain pressure conditions that air is brought from the Gulf directly over western Texas and eastern New Mexico. When such conditions exist, the moisture-laden air ascends a gradual slope from sealevel to an elevation of 3,000 to 4,000 feet or more. In summer this nearly saturated air is further elevated in the

formation of convectional and cyclonic thunderstorms, and this may account for the heavy downpours that sometimes occur over the semiarid portions of these two States. But this does not explain the fact that when these rains are heavy they are often confined to certain river valleys and, under certain pressure conditions, are always heavier in the Pecos Valley than elsewhere.

Referring again to figure 1, it will be seen that the total rainfall at this station is much more irregularly distributed over the 24 hours than that of any one of the three principal types. This is due to the fact that each type has its own period of maximum and minimum rainfall. In figure 1, showing the total hourly rainfall, the three maxima, from 4 to 5 p. m., from 10 to 11 p. m., and from 2 to 4 a. m., mark the hours of maximum intensity of rainfall from the three principal types. The nonconvectional rains greatly preponderate during the hours 9 p. m. to noon, with their minimum amounts and minimum frequency at the time of maximum thunderstorm rainfall. No typical thunderstorm precipitation has occurred at this station, during the last 12 years, between the hours of 4 to 9 a. m., and no nonconvective rain of the transitional type has fallen between the hours of 1 to 5 p. m. Nonconvective rains of group 4 have occurred at all hours of the day, but most of the daytime precipitation delivered by storms of this class has been due to rains that began at night and continued during part or all of the following day.

Figure 2, which gives the amounts of rainfall and the total hourly frequency by 4-hour periods, shows more clearly than figure 1 the difference between the different types of rainfall. The total amounts and the total hourly frequency, as charted, are given in Table 1.

TABLE 1.—Total amounts and hourly frequencies of rainfall for the 4-hour periods, classified by types.

Types.	Total amounts.						Total.
	10 a. m.	2 p. m.	6 p. m.	10 p. m.	2 a. m.	6 a. m.	
Thunderstorms.....	0.02	4.93	17.45	9.14	1.68	0.08	33.30
Transitional rains.....	1.15	1.24	0.12	4.67	8.74	2.51	18.43
Nonconvective rains.....	7.17	2.15	2.05	3.04	5.73	11.46	31.60
Local showers.....	1.08	1.15	0.88	0.55	0.99	0.32	4.97
Total rainfall.....	9.42	9.47	20.50	17.40	17.14	14.37	88.30

Types.	Total hourly frequency.						Total.
	10 a. m.	2 p. m.	6 p. m.	10 p. m.	2 a. m.	6 a. m.	
Thunderstorms.....	1	33	147	119	18	2	320
Transitional rains.....	13	6	1	32	68	35	155
Nonconvective rains.....	93	39	32	57	103	121	445
Local showers.....	39	32	35	28	39	17	190
Total.....	146	110	215	236	228	175	1,110

For all rains during the period covered, a total of 39.39 inches has fallen from 6 a. m. to 6 p. m., and 48.91 inches from 6 p. m. to 6 a. m. During the same periods of time rain has been recorded in 471 hour-periods from 6 a. m. to 6 p. m., and in 639 hour-periods from 6 p. m. to 6 a. m., thus establishing the fact that in Summer both the amounts and the frequency of rainfall at this station are greater at night than during the day. The summer rains of this portion of the United States are essentially daytime rains, and the preponderance of night rains over the limited area occupied by the upper half of the Pecos

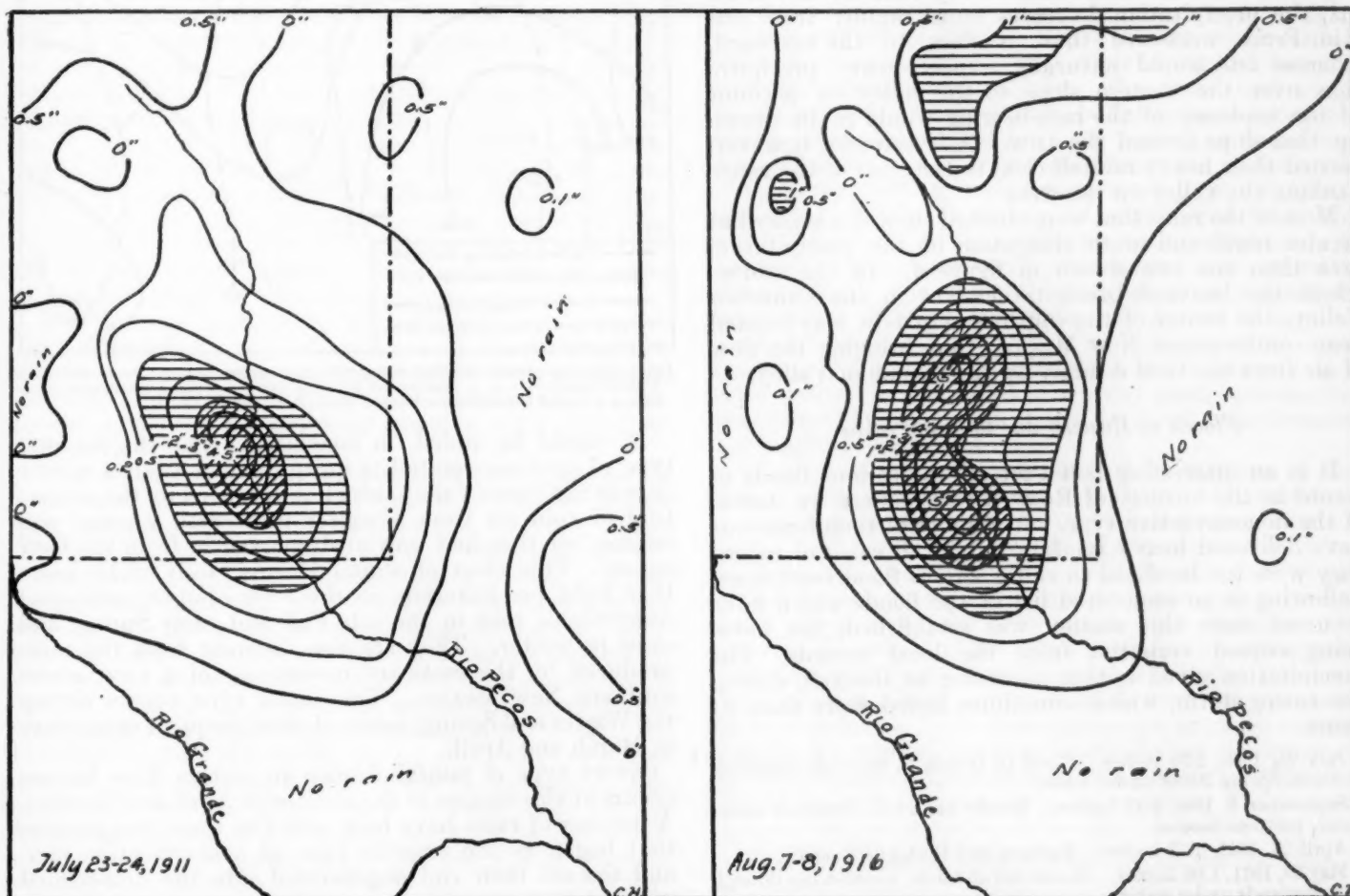


FIG. 4.—Total rainfalls over southeastern New Mexico and western Texas, resulting from two typical storms—July 23-24, 1911 and August 7-8, 1916.

Valley is wholly due to the occurrence of this peculiar type of nonconvective rainfall.

It might be argued that a comparison of the total amounts of rainfall delivered by nonconvective rains with the total hourly frequency indicates that the rains of this type are frequent, but light, while in this discussion emphasis has been placed upon the heavy rainfalls delivered by this class of storms. It is true that as regards the hourly rate of precipitation, most of these rains are light, although more than half of the heavy rains of 1 inch or more at this station were of this type. Precipitation occurring at the rate of 0.05 inch per hour is a light rain, but if it continues at that rate for 24 hours or more the accumulated depth amounts to a heavy rain. Typical storms of this class usually deliver heavy or excessive precipitation for 1 or 2 hours, while the actual duration of precipitation may extend over 12, 24, or 36 hours. In the storm of August 7-8, 1916, for example, "excessive" precipitation was recorded for 2 hours 20 minutes, without a break, while rainfall was recorded for 13 hours before it reached the "excessive" rate, and continued for nearly three hours after it fell below the "excessive" rate. This class of storm owes its importance chiefly to the fact that general precipitation is delivered over the upper Pecos Valley while thunderstorm rainfall, although it may occasionally be heavy, is much more localized.

Figure 4 presents the total precipitation from two typical nonconvective summer rainstorms. These two storms were selected from 18 that had been charted, not because they were extreme types as regards the distribution of precipitation, but on account of the heavy rainfall delivered. These two exhibit an observed characteristic of a number of the heavy rains of this class, viz, the precipitation decreases more rapidly from the Rio Pecos westward than it does to the eastward, whereas one would naturally expect heavy precipitation over the western slope of the valley on account of the tendency of the rain-bearing winds to be drawn up that slope toward the low. A few storms, however, carried their heavy rainfall clear to the crest of the range flanking the valley on the west.

Most of the rains that were charted showed a somewhat greater north-and-south elongation of the precipitation area than the two shown in figure 4. In the storms where the heaviest precipitation was in the Canadian Valley, the center of the southwestern low was located near southwestern New Mexico, thus bringing the flow of air from the Gulf directly up the Canadian Valley.

Floods at Roswell due to heavy rains.

It is an interesting fact that all the serious floods of record in the vicinity of Roswell were caused by storms of the nonconvective type. A number of thunderstorms have delivered heavy rainfall, but in all cases of record they were too localized to cause serious flood conditions. Following is an annotated list of the floods which have occurred since this station was established, the notes being copied verbatim from the local records. The precipitation given is that occurring at Roswell, during the entire storm, which sometimes lasted more than 24 hours.

July 25, 1905, 2.75 inches. Flood in Hondo at reservoir; lowlands of North Spring River under water.

September 1, 1908, 1.12 inches. Hondo bank full; lowlands under water, pastures flooded.

April 25, 1911, 1.71 inches. Pastures and lowlands flooded.

May 29, 1911, 1.66 inches. Hondo out of banks, overflowing through city, lowlands under water.

July 24, 1911, 0.58 inch. High water in Hondo; intake at dam gave way; flood waters also coming down Rocky Arroya; Berrendos bank-full; bridge at Urton's 4 feet under water.

[In this storm the heaviest precipitation was north of the station and between Roswell and the Capitan Mountains.]

June 12, 1913, 1 inch. Flood conditions in Rio Pecos; water 2.7 feet above flood stage.

October 25, 1914, 2.24 inches. No high water in Hondo; Pecos reported bank-full; lowlands along North Spring and Berrendos Rivers under water.

April 17, 1915, 4.91 inches. Lowlands under water; intake at Hondo Reservoir gave way, Hondo overran its banks along its entire course, flooding the city (Roswell) with 2 to 3 feet of water on the streets; basements and many lower floors flooded, including Federal building; several residences partly undermined. Cattle companies report thousands of sheep and large number of cattle drowned; fences and bridges swept away; boating on the business streets the popular pastime of the day.

August 8, 1916, 5.57 inches. Streets running curb-full; North Spring and Berrendos bottoms under several feet of water; thousands of birds drowned by over two hours excessive downpour; some bridges gone along the Berrendos, washouts reported on railroad; loss of live stock slight. Flood in Rio Pecos below highway bridge.

There also were a number of serious floods during the years prior to 1905, concerning which no reliable information is available. One, which occurred some time during the early fall of 1904, was of greater magnitude than that of April 17, 1915, during which the Hondo cut a new channel over part of its course through the city.

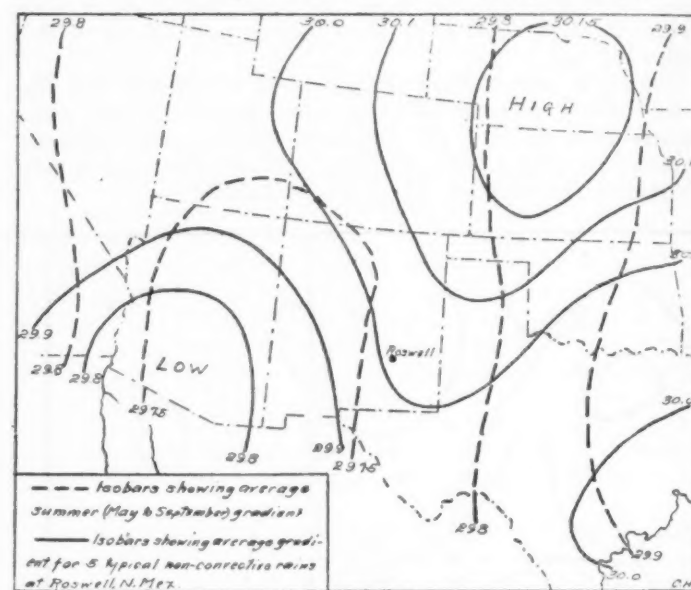


FIG. 5.—Average pressure gradient of Summer (May-September) over the southwestern United States (— — —) contrasted with the average pressure distribution in the case of 5 typical nonconvective rains at Roswell, N. Mex. (—).

It should be added, in conclusion, that the summer type of cyclonic rainfall is quite distinct from a winter type in the Pecos Valley, which is produced by the admixture of cold air from a winter high with warmer and moister air that had previously moved in from the Gulf region. This class of winter storms rarely yields more than light precipitation, in the form of slow, cold, and disagreeable rain in the late Fall and early Spring, and snow in winter. They are also different from the rains produced by the eastward movement of a low across southern New Mexico. This latter type occurs during the Winter and Spring, being of most frequent occurrence in March and April.

Every type of rainfall known to eastern New Mexico occurs at this station in the months of April and October. A number of rains have been noted in these two months that began as the summer type of nonconvective rain, and toward their end degenerated into the first-named winter type.

SHOWERS OF ORGANIC MATTER.

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INTRODUCTION.

The idea of organic matter and particularly of living things raining down from the sky, on first thought, is hard to entertain. There have been recorded in all periods of historic time, however, showers of one kind or another of animals and plants or their products—showers of hay, of grain, of manna, of blood, of fishes, of frogs, and even of rats. In ages past, these phenomena, actual or supposed, were all given supernatural significance; the blood rains terrorized the people, the manna rains inspired prayers of thanks—they were miracles. In latter days, the tendency among intellectuals who have given the matter no particular attention, has been to assume that since preternatural explanations had usually been invoked (and they certainly were incredible) therefore the showers themselves probably never occurred.

However, so many wonderful things occur in nature that negation of any observation is dangerous; it is better to preserve a judicial attitude and regard all [authentic] information that comes to hand as so much evidence, some of it supporting one side, some the other, of a given problem.

The evidence that counts the most is that which comes from those we have learned to respect and trust. I may say that two small bits of testimony as to living things falling in rain, given me by my father, and by my friend, Mr. A. N. Caudell, of the United States Bureau of Entomology, did more than all I had ever read to arouse my interest in the phenomena of organic showers. Mr. Caudell relates that at his former home in Oklahoma, on one occasion after a brief shower during an otherwise dry and hot period, numerous earthworms were found on the seat of an open buggy standing in the yard. Mr. Caudell's mother was reminded by this occurrence that years before, in their former home in Indiana, a live minnow was found after a rain in water held by the hollow in the top of a chopping block. The experience of my father that bears on this subject is that when in

North Dakota some years ago on coming indoors during a rain he found several earthworms on the brim of his hat. Here are facts vouched for by persons in whom I have every confidence, proving to a certainty that living animals do rain down.

How potent are such small phenomena, once fixed in the mind as well authenticated, to give one faith in the larger ones; but, on the other hand, how important is the conviction that some extensive, some really great happening of the same class really has occurred. When, therefore, I came upon the statement by the famous French scientist, Francis Castlenau, that he had seen fishes rain down in Singapore in such numbers that the natives went about picking them up by the basketful, I was ready to believe almost all the tales, both great and small, relating to showers of organisms.

And why should we not believe them? Surely not from any doubt as to the capacity of the wind to lift up, to transport, and to drop again, at more or less distant places, objects of the character and size usually mentioned as falling in organic showers. All strong winds have some lifting powers; we see papers carried into the air, blown hither and thither, and sometimes carried for long distances. Sheets of paper have been identified as falling at places 20 to 50 miles distant from their starting point. Through experiences, sometimes saddening ones, most of us have learned that the wind can very dexterously lift and transport such objects as hats, and I have known of a silk hat being taken from a dignified gentleman's head as he was walking in front of the Post Office Department in Washington and carried up, up, and away over the Star Newspaper Building (10 stories high). In the same city during the thunder squall of July 31, 1913, tin roofs were torn from many houses and blown into the streets.

These are things which straight blowing winds can do, but when winds begin to whirl, their lifting and carrying capacity increases enormously. The little dust whirls we see seem inoffensive things, but they have surprising power. I saw one travel down a row of shocks in a cornfield, lift every one of them, and scatter the stalks to the four quarters, doing in a minute work it would take a man a day to do or undo. Of course this whirl was larger than those we frequently see on hot summer days, but whirlwinds, waterspouts, dust storms, and tornadoes are essentially the same thing differing principally in dimensions. Wind whirls which may be said to be practically artificial in origin develop surprising power. Thus Theodore Dwight, of Stockbridge, Mass., states¹ that those created by the burning of wood piled in a clearing had sufficient force to lift trees 6 to 8 inches in diameter to a height of 40 to 50 feet.

All wind whirls are characterized by a more or less strong inflow of air along the surface from all directions to the base of the whirl, where the inflowing currents ascend. The gyratory velocity of a tornado may be as much as 310 miles per hour. This would give at the earth's surface an effective force in moving an object of about 300 pounds² for each square foot of surface exposed to the wind. The velocity of the ascending currents also runs high, but if put at 176 miles per hour would yield a lifting power of more than 90 pounds to the square foot. That these forces are actually exerted is shown by some of the remarkable doings of tornadoes. By the tornado at Beauregard, Miss., April 22, 1883, the solid iron screw of a cotton press, weighing 675 pounds,

¹ Tomlinson, Chas. The tempest, pp. 117-118.² Ferrel, Wm. A popular treatise on the winds. New York, 1889. pp. 377-378.

was carried 900 feet. During the tornado of April 16, 1875, at Walterborough, S. C., a piece of timber 6 inches square and 40 feet long, weighing 600 pounds, was carried a distance of 440 yards, and a chicken coop, 4 by 4 feet and 75 pounds in weight, was transported 4 miles. In the tornado at Mount Carmel, Ill., June 4, 1877, a piece of tin roof was carried 15 miles and a church spire 17 miles.

These examples are quite as marvelous as some of the seemingly miraculous showers recorded of old. The children of Israel believed in their manna because they gathered it with their own hands and ate of it, but surely their credulity would not have stood the test had some prophet told them that in years to come, in a land across the sea, chickencoops and church spires would rain down from the skies.

There is then, we must admit, no reason for general suspicion toward the accounts of organic showers. Like other records, they must be inspected and the good sifted from the mass. We may separate at once certain classes of alleged organic showers as spurious.

SPURIOUS SHOWERS.

Insect larvæ.—The rains of insect larvæ that have been investigated have proved to be merely the appearance in large numbers on the surface of the ground or upon snow of the larvæ of soldier beetles (*Telephorus*), or sometimes caterpillars, which have been driven from their hibernating quarters by the saturation of the soil by heavy rains or melting snow.

Ants.—Accounts of showers of ants have usually been founded on incursions of large numbers of winged ants, which of course need no assistance from the elements to follow out their habit of swarming forth periodically in immense numbers.

Honey; sugar.—Showers of honey and of sugar are popular names for what scientists know are exudations of certain plants, or of plant lice which feed on a great variety of plants and whose product is often known also as honey-dew.

Grains.—Showers of grain, usually considered miraculous, have in most cases been determined to be merely the accumulation by washing during heavy rains of either the seeds or root tubercles of plants of the immediate neighborhood.

Black rain.—Black rain is due to the precipitation from the atmosphere by falling water of soot, or in some cases of black dust. These showers are of interest, however, as illustrating the carrying power of the wind; a rain of soot observed in Ireland and over the Atlantic Ocean to the westward is pretty definitely known to have been carried by the wind from Wales.³ The showers of mud resulting from the precipitation of dark-colored dust or dirt are closely related to the organic showers discussed further on, as the material must have been derived from the earth's surface, transported and deposited in the same way, and in fact it is probable that all such rains bring with them some proportion of small organisms. In the case of a black snow, observed in New York in 1889, it was found that the color was due to "finely divided earth and vegetable mould."⁴ In this case it is certain that small organisms were included among the débris, for it would be impossible for the wind to sweep up enough vegetable mould to discolor a snowfall without at the same time taking up a considerable number of spores, seeds, fruits, and small animals.

Blood rains.—The most frequently reported showers that are spurious, at least in name, are the so-called blood rains. In all times the phenomena going under this name have frightened the people and have been taken as portents of terrific calamities. One of the famous plagues of Egypt was a bloody rain which prevailed throughout the whole land, continuing three days and three nights. Homer and Virgil both allude to blood rains, and, in fact, the general subject of preternatural rains was a favorite with the older writers.

But scientific investigation has done away with the element of mystery in these phenomena and has explained, with the others, the rains of blood. Some blood rains have been found to be the meconial fluid ejected by large numbers of certain lepidoptera simultaneously emerging from their chrysalides; other red rains are due to the rapid multiplication in rain pools of algæ and of rotifers containing red coloring matter; "red snow" results from the presence of similar organisms. But in no case have they rained down, except in the sense that their spores or eggs have at some time been transported, probably by the wind. The precipitation of moisture furnishes favorable conditions for their rapid development and multiplication.

There are several summaries of information relating to the anciently recorded showers of miscellaneous matter. Among them is that of Valentin Alberti, "Dissertatio historica physica de Pluvia prodigiosa", Leipzig, 1674; one by P. J. Hartmann, published as an appendix to the *Miscellanea Curiosa* * * * *Academiae Imperialis Leopoldinae* * * * Jena, 1689; another by J. C. Haebler, entitled "Dissertatio de pluviis prodigiis," published at Erfurt in 1695, and also one by C. G. Ehrenberg in 1847 (*Abh. Kgl. Preuss. Akad. Wiss. Berlin*).

For modern bibliographies covering the subject of organic showers, see: Fassig, O. L., *Bibliography of Meteorology*, United States Signal Service, *Showers of Miscellaneous Matter*, Part II, 1889, pages 367-391, and Stuntz, S. C., & Free, E. E., *Bibliography of Eolian Geology*, Bulletin 68, United States Bureau of Soils, 1911, pages 174-263.

Manna.—An account of manna "rains" certainly pertains to the discussion of showers of vegetable matter, for the substance manna consists of lichens of the genus *Lecanora*, but in none of the numerous recorded instances of manna "rains" is there any direct evidence that the substance really fell from the sky. These lichens form, small, round bodies that are easily blown over the surface of the ground and accumulate in depressions; they are very buoyant also and hence easily drifted into masses during the run-off of rain water. Manna "rains" have not occurred except in countries where these lichens are common, and as for statements of their falling down upon roofs or upon people, or for any other proofs that they really rained down, I have seen none.

TRUE SHOWERS.

Red rains; dust.—Other red rains are caused by the bringing down in rain water of atmospheric dust of a reddish color. This hue usually is noticed in rain falling in southern Europe at a time when the air is charged with sirocco dust. The composition of this dust has been extensively investigated and it has been found to contain spores, pollen grains, confervoid algæ, diatoms, infusoria, and rotifers. In 50 samples of sirocco dust from various parts of Italy pollen, spores, etc., were found in every one.⁵ In sirocco dust collected at Lyons, Ehrenberg claims to have found 111 different species of infusoria, and the total number of organisms enumerated by him from samples of such dust is 320.⁶ In the Lyons instance organic forms made up one-eighth of the entire mass of the dust. Since various estimates place the

³Symons's met. mag., February, 1908, 43: 2-4.

⁴MONTHLY WEATHER REVIEW, October, 1901, 29: 465-466.

⁵Tacchini, P. Ann., Met. Ital., 1879, pt. 1, pp. 63-115.

⁶Ehrenberg, C. G. Passat-staub und Blut-regen. Abh., Preuss. Akad., 1847.

amount of sirocco dust in a fall at from 5½ to 9 tons to the square mile, it will be seen that a fall of a ton of microscopic organisms per square mile is within the bounds of possibility.

It is not only the hot and dry sirocco that is laden with dust containing organisms, for indeed they are in the air everywhere at all times. The researches of MM. Miquel⁷ and Boudier⁸ in France, particularly have elucidated the nature of atmospheric dust. The atmosphere always is charged with a large number of organic entities. The vegetable constituents are chiefly bacilli and the spores of cryptogams, as of fungi, lichens, mosses, and algæ. There are also hairs of plants, fibers of cotton, flax, and hemp, pollens of every form, and starch grains. The animal remains include epithelial cells, hairs, shreds of feathers, bits of down and wool, scales of lepidoptera, and the eggs of infusoria. The quantity of suspended matter in the air is high in summer and low in winter, and less at high altitudes than in lower areas nearer the source of the bodies found.

Special forms of aeroscopes have been devised to collect samples of atmospheric dust. In one form described by Mr. Hubert Airy,⁹ were caught in the city of London, the following things additional to those just named: Living mites, entomostraca, and diatoms.

It appears, therefore, that a great variety of small organisms or their spores are present in the air at all times, that they are freely carried about by the winds, and are constantly being precipitated either in dust or in falling moisture. The possibilities for the distribution of these minute forms are practically unlimited, for dust clouds travel indefinite distances. In the United States a dust storm and mud shower was observed on the same day in Illinois, New York, Pennsylvania, and New Jersey.¹⁰ This shows transport of the material over a third of the breadth of the United States, if indeed all of it did not come from the western plains. A dust cloud a thousand, perhaps two thousand miles in length was observed at sea by J. Milne¹¹ when 200 to 400 miles distant from the coast of China, from whose loess plains it was probably derived. This dust contained shreds of plants. At times of great volcanic activity, dust clouds have encircled the world. There is, therefore, no limit to the distribution of atmospheric dust, and therefore probably none to that of the minute organisms that are one of its constant components.

Showers of plants and invertebrates.

Pollen falls, sulphur rains.—Pollen of various plants, as previously noted, is one of the most common constituents of atmospheric dust; for instance, Miquel found that there are often a thousand pollen grains to each cubic meter of air.¹² But pollen deserves more extended notice because it is really showers of pollen that have been so often reported as showers of sulphur. The yellow color suggested sulphur; pollen, especially of pine, is highly inflammable, the imagination supplied the smell of brimstone, and superstition jumped at the conclusion that the devil had been busy. The occasional phosphorescent appearance of pollen falls at night also has encouraged preternatural speculations.

The following is extracted from an account of a pollen shower in England¹³ in early June, a fall of fine yellow dust which coated the surface of rain water in barrels and pools, was taken by the uneducated for a fall of sulphur. It was said by the imaginative to smell "awful like brimstone" and to presage the end of the world. Examination of the dust under a microscope at once showed it to be the pollen of pine. Another writer adds:¹⁴

As this mystery, if it is not explained, may prove serious to the nervous, superstitious, or credulous part of the community, we may as well add that at this season districts in the neighborhood of fir (*Pinus sylvestris*) plantations run the risk of a thorough dusting of this powder if there is the slightest breeze, as the cones of the young Scots fir are thickly coated with yellow powder or pollen, which will give out a blinding saffron cloud on the slightest disturbance.

The appearance of a conspicuous movement of pollen has been well described by Dr. D. P. Thomson.¹⁵

On the afternoon of June 11, 1847, the wooded part of Morayshire appeared to smoke, and for a time fears were entertained that the fir plantations were on fire. A smart breeze suddenly got up from the north and above the woods there appeared to rise about 50 columns of something resembling smoke, which was wreathed about like waterspouts. The atmosphere now calmed and the mystery was solved, for what seemed smoke was in reality the pollen of the woods.

The ease with which pollen is taken up into the air together with the prodigal profusion with which it is produced make it easy to understand the frequency of the so-called sulphur rains. In March, 1879, several instances of yellow rain or snow occurred in the United States. Prof. W. H. Chandler of Lehigh University, South Bethlehem, Pa., writes that during Saturday night, March 16, 1879, there was a slight fall of snow in that section, and on Monday morning when the snow had melted, a yellow deposit was found covering the ground more or less. Upon examining the deposit, it was found to be the pollen of pine trees. The United States Signal Corps observer at New Orleans, reports light showers on the 17th of the same month, and states that "a peculiar feature of the rain was its yellow color, which was due to large quantities of the pollen of the cypress tree floating in the atmosphere." The United States Signal Corps observer at Lynchburg, Va., forwarded on March 21, 1879, a sample of the yellow deposit which had fallen with the rain the preceding night and " * * * it was found to consist * * * entirely of the characteristic triple-grained pollen of the pine."¹⁶ A pollen shower at Pictou, Nova Scotia, in June, 1841, was so heavy that bucketfuls were swept up on a ship. This material was entirely the pollen of pine trees.¹⁷ As showing how far pollen may be transported by the wind, it is noted that "A shower of this kind fell at Lund at the south of Sweden, which M. Agardh (Nova Acta, 12) found to contain the pollen of *Pinus sylvestris* or Scotch fir, borne on the wind from a forest about 35 miles distant."¹⁸

Hay.—The vegetable substance, which, after pollen, figures most frequently in the accounts of actual showers of organic matter, is hay. This should not be surprising, since the material is comparatively light and is available at the time of year when wind whirls are most frequent. The first step in the development of a shower of hay was observed by Prof. F. E. Nipher,¹⁹ who describes a whirlwind that picked up hay and carried it in the form of an

⁷ Ann., L'Observatoire de Montsouris, 1879, pp. 431-512.

⁸ Journ. pharm. chim., 4e Ser., 1876, 23: 340-345.

⁹ Nature, 1874, 9: 439-40.

¹⁰ MONTHLY WEATHER REVIEW, May, 1902, 30: 269.

¹¹ Nature, June 9, 1892, 46: 128.

¹² The spores of cryptogams may be 20 times as numerous. It is stated that on Reunion Island the spores of *Lycopodium* sometimes are present in the air in such quantity as to make breathing difficult.

¹³ Carpenter, P. H. Pine-pollen mistaken for flowers of sulphur. Nature, June 20, 1879, 20: 195-196.

¹⁴ Wilson, Andrew. Nature, July 17, 1879, 20: 267.

¹⁵ Thomson, D. P. Introduction to meteorology. Edinburgh, &c., 1849, p. 151.

¹⁶ MONTHLY WEATHER REVIEW, March, 1879, p. 16.

¹⁷ Bailey, J. W., in Amer. Jour. sci. and arts, 1842, 42: 195-197.

¹⁸ Thomson, D. P. Introduction to Meteorology, 1849, p. 151.

¹⁹ Nature, Sept. 11, 1879, 20: 456.

inverted cone about 200 feet high and 150 feet in diameter at the top. The whirl was followed for about half a mile when it disappeared over a hill. The complete phenomenon, on a small scale, is described as follows by Sir Francis Galton:²⁰

We had a curious sight * * * yesterday (July 26, 1891). It was a dead calm, but in a field just below the garden * * * the hay was whirled up high into the sky, a column connecting above and below, and in the course of the evening we found great patches of hay raining down all over the surrounding meadows and our garden. It kept falling quite four hours after the affair.

On June 30, 1892, a large quantity of hay was taken up by a whirlwind at Nether Priors, Essex, England, and fell at Belchamp, about 3 miles to the north.²¹ In two other cases noted, one in London,²² the other in Ireland,²³ the hay was seen floating at a great height in the atmosphere and then to fall.

Wheat.—In my introductory remarks I stated that most of the so-called showers of grain were spurious. However "in 1804 * * * a real rainfall of wheat took place in Andalusia, which had been carried by a hurricane across the Straits of Gibraltar, from a threshing floor at Tetuan."²⁴

Meteoric "paper."—A substance which has fallen from the sky, and has been called "meteoric paper," was proved in one case at least to be vegetable matter of terrestrial origin. Ehrenberg who investigated the case says²⁵ "On the 31st of January, 1687, a great mass of paper-like, black substance fell with a violent snow-storm * * * near the village of Rauden in Courland." Some of the substance was preserved and it was 152 years later that Ehrenberg examined it and found it to consist "of a compactly matted mass of *Conferva crispata*, traces of *Nostoc* and of about 29 * * * species of infusoria." This material was undoubtedly the crusts of dried algæ which form on the surface of the ground exposed by the evaporation of the water of shallow ponds. This paper-like substance could easily be lifted up by the wind and carried a long distance.

Jelly or "flesh."—Manna is the bread of organic showers; but what is the meat? Showers of flesh have often been recorded and they have proved to be precipitations of a glairy substance, which upon partial drying formed enough of a skin on the outside to induce people to call it flesh. When found fresh, this material has been compared to butter. Probably most if not all of it is the material known as zoogaea formed on the surface of water where bacteria are actively multiplying. The substance known as zoogen or zoiodin is probably the same. An extensive shower of such jelly-like material occurred in Bath County, Ky., in 1876, and was referred to as the dried spawn of fishes or of some batrachian.

Such spawn really has rained down also, if we may believe the account of M. Moreau de St. Mery, relating to an observation in San Domingo.²⁶

From November, 1785, to the 5th of May, 1786, there was experienced a terrible drought. The last day, viz, May 5, 1786, there fell during a strong east wind, in several parts of the city of Port au Prince * * * a great quantity of black eggs, which hatched the following day. M. Mozard preserved about 50 of these small animals in a flask half full of water, where they shed their skins several times. They resembled tadpoles.

Other jelly rains have proved to consist of the egg masses of midges, and of colonies of infusoria. A shower

of the latter is described as follows by L. Jenyns²⁷ in his article on a so-called storm of insects at Bath, England:

There had been a sudden squall of wind before there came a heavy rain, and my idea is that these organisms must have been lifted up by the force of the wind, acting in a gyratory manner, from some shallow pool in the neighborhood. * * * A boy at the station first noticed them (that is, the spherical masses in which the organisms were grouped) falling on his coat * * *; as the rain fell more heavily the platform * * * was covered with them.

Insects.—The popular designation of these infusoria as insects of course was due to the very wide misuse of this term. I have noted previously that the alleged showers of insect larvæ also were not genuine, but there have been apparently a few real rains of insects. Two which occurred in Germany are described as follows:²⁸

At Szentes, August 14, between 9 and 10 p. m. a deep-black cloud suddenly appeared in the evening sky. Soon thereafter began a downpour, not of rain, but of winged insects, which in a few minutes covered the ground a foot deep. At St. Catherine a. d. Lamming (Obersteiermark), on the 10th and 11th of August, insect rains also occurred, which while not so remarkable, still were very annoying. The insects were in part small neuropteroids and in part winged ants.

Accounts of three other showers which have been gleaned from French publications are circumstantial, and clearly show sustained transport of insects by the wind and their falling from the skies after the manner of rain:

Toward the end of May, M. L. Audé, * * * while returning from Mortagne to Herbiers, was caught in a violent storm from the north-east which, during a heavy rain, covered his conveyance with a multitude of *Gryllus*. The wind was cold and the Orthoptera falling in the midst of the rain appeared lifeless. These * * * are all in the larval state and are *Gryllus domesticus* of authors.²⁹

Rey de Morande in describing a shower of insects and spiders in Haute-Savoie, says:³⁰

On the night of January 29-30 [1869?], about 4:30 a. m., with a violent gust of wind which soon ceased, snow fell until day, and in the morning there were found on this snow a large quantity of living larvæ. * * * (The temperature for some days before had been very low.) * * * They appeared to be, for the most part, larvæ of *Trogosita mauritanica*, which are common in old trees in the forests in southern France. There were found also larvæ of a little moth * * * probably *Stibia stagnicola*. This shower of insects and spiders at an altitude of 1,000 to 1,200 meters, can not be explained except by transportation by a violent wind from central or southern France.

M. Tissot, * * * who observed the phenomenon, adds, that in November, 1854, several thousands of insects, mostly living, were thrown down by a violent wind in the vicinity of Turin. Some were larvæ and some adult and all appeared to be of a species of hemiptera that had never been collected except on the isle of Sardinia.

Molluscs.—Before leaving the consideration of invertebrates we may note that: "A shower of mussels, some weighting about 2 ounces, fell during a severe storm, on the 9th of August, 1834, in the United States.³¹ The following year another shower of molluscous animals, *Bulimus truncatus*, took place at Montpellier [France]."³²

Falls of vertebrate organisms.

The fall of vertebrate animals from the skies like rain is, of course, the most interesting of all the showers of organic matter, and—it must be admitted—the hardest to believe. Yet there cannot be the slightest doubt that there are genuine phenomena of this character, though perhaps not so numerous as the recorded instances. These occurrences, if observed by man, naturally make profound impressions and in the olden times especially, the tales of showers of fishes and the like were improved

²⁰ Nature, July 30, 1891, 44: 294.

²¹ Symons's met. mag., August, 1892, 32: 106-107.

²² Comptes rendus, 1861, 52: 106-109.

²³ Nature, 1875, 12: 279.

²⁴ Hartwig, G. The Aerial world, 1874, p. 194.

²⁵ Ann., Nat. Hist., 1839, 3: 185-186.

²⁶ Moreau de St. Mery. Descrip. de Saint Dominique, t. 2, p. 413, cited in P. H. Gosse, A Naturalist's sojourn in Jamaica, 1861, p. 430.

²⁷ Zoölogist, 1871, 6: 2286-7.

²⁸ Meteorol. Ztschr., Wien, 1901, 18: 426.

²⁹ Lucas, H. Bul., Soc. ent. France, 1858, p. xcvi.

³⁰ Rey de Morande. Bul. hebdom., Assoc. sci. de France, 1869, 5: 242.

³¹ Pittsburgh Gazette.

³² Athen. No. 373, December, 1834, p. 923. The last two citations from David Purdie Thomson, "Introduction to Meteorology," Ch. VIII, pp. 163-164.

by each teller, so that soon they reached the stage of the unbelievable.

Frogs, toads.—I quote only one of the older writers, Athenæus, who flourished about 200 A. D. He is the author of a polyhistorical work called the "Deipnosophists," in which he quotes about 800 authors, whose works he consulted at the Alexandrian Library, 700 of whom would have been unknown, except for the fortunate preservation of Athenæus' work. In a chapter entitled "De pluvius piscium," he says: ³³

I know also that it has very often rained fishes. At all events Phœnias, in the second book of his Eresian Magistrates, says that in the Chersonesus it once rained fish uninterruptedly for three days; and Phylarchus in his fourth book, says that people had often seen it raining fish, and often also raining wheat, and that the same thing had happened with respect to frogs. At all events Heraclides Lembus, in the 21st book of his history, says: "In Peonia and Dardania, it has, they say, before now rained frogs; and so great has been the number of these frogs that the houses and the roads have been full with them; and at first for some days the inhabitants, endeavoring to kill them, and shutting up their houses endured the pest; but when they did no good, but found that all their vessels were filled with them, and the frogs were found to be boiled up and roasted with everything they ate, and when besides all this they could not make use of any water, nor put their feet on the ground for the heaps of frogs that were everywhere, and were annoyed also by the smell of those that died, they fled the country."

For numbers of frogs and the far reaching effects of their fall ³⁴ this tale can scarcely be surpassed, but it will be well to recount some later instances, especially some of the more circumstantial ones. Holinshed ³⁵ informs us that in Great Britain—

frogs fell in Angushire during the time of Agricola. Frogs were reported to have descended, during the summer of 1846 over the Humber, upon the decks of vessels in the river and on the coast near Killinghome lights.

A later account ³⁶ recites that—

During the storm that raged with considerable fury in Birmingham (England) on Wednesday morning, June 30 [1892], a shower of frogs fell in the suburb of Moseley. They were found scattered about several gardens. Almost white in color, they had evidently been absorbed in a small waterspout that was driven over Birmingham by the tempest.

Several notices have from time to time been brought before the French Academy of showers of frogs having fallen in different parts of France. M. Duparque ³⁷ states in a letter that—

In August, 1814, after several weeks of drouth and heat, a storm broke one Sunday about 3:30 p. m., upon the village of Fremon, a quarter league from Amiens. This storm was preceded by bursts of wind so violent that they shook the church and frightened the congregation. While traversing the space separating the church from presbytery, we were soaked, but what surprised me was to be struck on my person and my clothing by small frogs. * * *. A large number of these small animals hopped about on the ground. On arriving at the presbytery, we found the floor of one of the rooms in which a window facing the storm had been left open covered with water and frogs. * * *

Showers of toads seem to be more common in some regions than those of frogs. I have seen accounts of 13 different occurrences of the kind in France. A French scientist M. Mauduy, curator of natural history at Poitiers, had personal experience with two such showers, which he narrates briefly as follows: ³⁸

On the 23d of June, 1809, during a hot spell, I was caught in a rain storm in which the very large drops were mixed little bodies the

size of hazelnuts, which in a moment, covered the ground, and which I recognized as little toads. * * *. The second occasion, occurred in August, 1822, during a stormy and very hot period; I was again surprised by a heavy shower of large drops mixed, as was the other, with little toads, some of which fell on my hat. This time the animals were the size of walnuts. I found that I was more than a league distant from any brook, river, or marsh.

A considerable discussion of the subject of rains of toads was carried on in 1834 in the French scientific magazine from which I have quoted. I cite two more bits of testimony by eye witnesses, one of which has been widely reproduced.

M. Heard, writes: ³⁹

In June, 1833, I was at Jouy near Versaille. I saw toads falling from the sky; they struck my umbrella; I saw them hopping on the pavement, during about 10 minutes in which time the drops of water were not more numerous than the toads. The space upon which I saw the multitude of these animals was about 200 fathoms.

M. Peltier in his oft-copied statement says: ⁴⁰

In support of the communication of Col. Marmier, I cite an incident I observed in my youth; a storm advanced upon the little village of Ham, Department of the Somme, where I lived, and I observed its menacing march, when suddenly rain fell in torrents. I saw the village square covered everywhere with little toads. Astonished by this sight, I held out my hand and was struck by several of the reptiles. The dooryard also was covered; I saw them fall upon the slate roof and rebound to the pavement. * * *. Whatever the difficulty of explaining the transport of the reptiles, I affirm, without doubt the fact which made such a profound impression upon my memory.

The most remarkable account of a shower of toads, that I have seen, so far, is the following: ⁴¹

In the summer of 1794 M. Gayet was quartered in the village of Lalain, Department du Nord, * * * near the territory which the Austrians, then masters of Valenciennes, had flooded with water from the Scarpe. It was very hot. Suddenly, at about 3 o'clock in the afternoon, there fell such an abundance of rain that 150 men of the grand guard, in order not to be submerged, were obliged to leave a large depression in which they were hidden. But what was their surprise when there began to fall on the ground all about a considerable number of toads, the size of hazelnuts, which began to jump about in every direction. M. Gayet, who could not believe that these myriads of reptiles fell with the rain, stretched out his handkerchief at the height of a man, his comrades holding the corners; they caught a considerable number of toads, most of which had the posterior part elongated into a tail, that is to say, in the tadpole state. During this rain storm, which lasted about half an hour, the men of the grand guard felt very distinctly on their hats and on their clothing the blows struck by the falling toads. As a final proof of the reality of this phenomenon, M. Gayet reports that after the storm the three-cornered hats of the men of the guard held in their folds some of the reptiles.

Fish.—For reports of the falling of frogs and toads from the skies, we have been far afield, for the very good reason that I have not found any cases reported for the United States. But for fishes, there are several reports. Before giving these accounts, allow me to introduce a few statements that tend to show how fishes get started on the aerial journeys that terminate in fish rains.

To show the tremendous power of waterspouts, we may quote M. Oersted's declaration ⁴² that "At Christiansoë a waterspout emptied the harbor to such an extent that the greater part of the bottom was uncovered." Naturally under such circumstances fishes and any other organisms in the water may change their habitat very abruptly. Waterspouts have been observed to accomplish the comparatively insignificant tasks of emptying fish ponds and scattering their occupants.

A prodigy of this kind is recorded to have occurred in France, at a town some distance from Paris, during a violent storm. When morning dawned, the streets were found strewn with fish of various sizes.

³³ Athenæus. The deipnosophists or banquet of the learned (Transl. by C. D. Yonge 1854). Book XV, pt. 2, pp. 526-527.

³⁴ Is it not much more reasonable to conclude that the plague of frogs reported by Heraclides Lembus was due to a migration, rather than to a precipitation of the batrachians?—C. A., Jr.

³⁵ Chron., Vol. II, p. 59. Thomson, David Purdie, Introduction to Meteorology. Ch. VIII, pp. 164-165, 1849.

³⁶ Symons's met. mag., August, 1892, 32: 107.

³⁷ L'Institut, 1834, 2: 354.

³⁸ L'Institut, 1834, 2: 409-410.

³⁹ L'Institut, 1834, 2: 353.

⁴⁰ L'Institut, 1834, 2: 346-7.

⁴¹ L'Institut, 1834, 2: 354.

⁴² Tomlinson, Charles. The Tempest, pp. 136-137.

The mystery was soon solved, for a fish pond in the vicinity had been blown dry, and only the large fish left behind.⁴³

So, during a storm on December 28, 1845, at Bas-senthwaite, England, fish were blown from the lake to dry land.⁴⁴

Proceeding now to the United States records, Mr. Thomas R. Baker⁴⁵ states that—

During a recent thunderstorm at Winter Park, Fla., a number of fish fell with the rain. They were sunfish from 2 to 4 inches long. It is supposed that they were taken up by a waterspout from Lake Virginia, and carried westward by the strong wind that was blowing at the time. The distance from the lake to the place where they fell is about a mile.

In the MONTHLY WEATHER REVIEW for June, 1901 (p. 263), is the note "Mr. J. W. Gardner, voluntary observer at Tillers Ferry, S. C., reports that during a heavy local shower about June 27 [1901] there fell hundreds of little fish (cat, perch, trout, etc.) that were afterwards found swimming in the pools between the cotton rows."

In all, I am acquainted with four records of falls of fishes in the United States, two in South America, eight in Great Britain, two in France, and six in India and neighboring countries. These are all well vouched for, or fairly modern and circumstantially related instances. The older, chiefly traditional, records would make a long list.

One of the most ancient records of fish having fallen from the atmosphere in Great Britain is the following: About Easter, 1666, in the parish of Stanstead, which is a considerable distance from the sea, or any branch of it, and a place where there are no fish ponds, and rather scarcity of water, a pasture field was scattered all over with small fish, in quantity about a bushel, supposed to have been rained down from a cloud, there having been at the time a great tempest of thunder, rain, and wind. The fish were about the size of a man's little finger. Some were like small whittings, others like sprats, and some smaller, like smelts. Several of these fish were sold publicly at Maidstone and Dartford.⁴⁶ A shower of herrings is recorded to have taken place near to Loch Leven, in Kinross shire, about the year 1825; the wind blew from the Frith of Forth at the time, and doubtless the fish had been thereby carried from the sea across Fifeshire to the place where they were found.⁴⁷ In 1828, similar fish fell in the county of Ross, 3 miles distant from the Frith of Dingwall.⁴⁸ On the 9th of March, 1830, in the Isle of Ula, in Argyleshire, after a heavy rain, numbers of small herrings were found scattered over the fields; they were perfectly fresh, and some not quite dead. On the 30th of June, 1841, a fish measuring 10 inches in length, with others of smaller size, fell at Boston; and during a thunderstorm, on the 8th of July, in the same year, fish and ice fell together at Derby.⁴⁹

A convincing statement of personal experience with a rain of fishes is that of John Lewis, of Abderdare, who says that while working, February 9:

I was startled by something falling all over me—down my neck, on my head, and on my back. On putting my hand down my neck I was surprised to find they were little fish. By this time I saw the whole ground covered with them. I took off my hat, the brim of which was full of them. * * * They covered the ground in a long strip about 80 yards by 12 yards, as we measured afterwards. * * * We gathered a great many of them * * * and threw them into the rain pool, where some of them now are. * * * It was not blowing very hard, but uncommon wet. * * * The person who took this testimony adds that he secured about 20 of the little fish, some of which were 4 and 5 inches long. A number of these fishes were exhibited for several weeks in the aquaria house of the Zoological Society in the Regent's Park, London.⁵⁰

The accounts of rains of fishes in South America are by Alexander von Humboldt,⁵¹ whose language relating to them is as follows:

⁴³ Reess' Cyclopaedia.

⁴⁴ Thomson, D. P. Introduction to Meteorology, 1849, pp. 163-164.

⁴⁵ Science, June 16, 1893, 21: 335.

⁴⁶ Hasted. History of Kent, cited by Thomson.

⁴⁷ Ed., Phil. Journ., 1826; cited by Thomson.

⁴⁸ Inverness Courier, April, 1828; cited by Thomson.

⁴⁹ Thomson, D. P. Introduction to Meteorology, 1849, p. 163.

⁵⁰ Tomlinson, Charles. The Rain-cloud and the Snow-storm, pp. 193-194.

⁵¹ Humboldt, Alexander von. On the constitution and mode of action of volcanoes in different parts of the earth. Ann. Phil., 1823, 22 (N. S., 6): 130.

When the earthquakes, which precede every eruption in the chain of the Andes, shake with mighty force the entire mass of the volcano, the subterranean vaults are opened and emit at the same time water, fishes, and tufa-mud. This is the singular phenomenon that furnishes the fish *Pimelodes cyclopum*, which the inhabitants of the highlands of Quito call "Prenadilla," and which was described by me soon after my return. When the summit of the mountain Carguairazo, to the north of Chimborazo and 18,000 feet high, fell, in the night between the 19th and 20th of June, 1698, the surrounding fields, to the extent of about 43 English square miles, were covered with mud and fishes. The fever which raged in the town of Ibarra seven years before had been ascribed to a similar eruption of fishes from the volcano Imbaburu.

There are several well authenticated reports of falls of fish in India, and this has given rise to the belief that the phenomenon is more frequent there than elsewhere. This may be true on account of the favoring circumstances of extensive river flood plains, numerous shallow water tanks, a fish fauna rich in shoal water forms, and a hot, whirlwind-breeding climate. Certainly the descriptions of fish rains in that part of the world are numerous, specific, and astonishing as to the magnitude of the phenomena.

One of the oldest reports, brief but with a humorous touch, I quote first. It is by Lieut. John Harriott,⁵² who says:

In a heavy shower of rain, while our army was on the march a short distance from Pondicherry, a quantity of small fish fell with the rain, to the astonishment of all. Many of them lodged on the men's hats. * * * They were not *flying fish*, they were dead and falling from the well-known effect of gravity; but how they ascended or where they existed I do not pretend to account. I merely relate the simple fact.

A very valuable account of a shower of fishes is that by J. Prinsep, editor of the Journal of the Asiatic Society of Bengal. He writes:⁵³

The phenomenon of fish falling from the sky in the rainy season, however incredible it may appear, has been attested by such circumstantial evidence that no reasonable doubt can be entertained of the fact. I was as incredulous as my neighbors until I once found a small fish in the brass funnel of my pluviometer at Benares. I have now before me a note of a similar phenomenon, on a considerable scale, which happened at the Nokulhatty factory, Zillah Dacca Jedalpur, in 1830.

Mr. Cameron, who communicated the fact, took the precaution of having a regular deposition of the evidence of several natives who had witnessed the fall made in Bengalee and attested before the magistrate; the statement is well worthy of preservation in a journal of science. * * * The shower of fish took place on the 19th of February, 1830, in the neighborhood of the Surbundy factory, Feridpoor (p. 650).

There are depositions of nine eye witnesses, of which I quote two:

Shekh Chaudari Ahmed, son of Mutiullah, inhabitant of Nagdi, relates in his deposition: "I had been doing my work at a meadow, where I perceived at the hour of 12 o'clock the sky gather clouds, and began to rain slightly, then a large fish touching my back by its head fell on the ground. Being surprised I looked about, and behold a number of fish likewise fell from heaven. They were saul, sale, guzal, mirgal, and bodul. I took 10 or 11 fish in number, and I saw many other persons take many."

Shekh Suduruddin, inhabitant of Nagdi, was called in and declared in his deposition saying: "On Friday, at 12 o'clock p. m., in the month of Phalgun * * * when I was at work in a field, I perceived the sky darkened by clouds, began to rain a little and a large fish fell from the sky. I was confounded at the sight, and soon entered my small cottage, which I had there, but I came out again as soon as the rain had ceased and found every part of my hut scattered with fish; they were boduli, mirgal, and nouchi, and amounted to 25 in number."

The large number of fishes that may rain down is illustrated by another Indian instance which was reported as follows:⁵⁴

On the 16th or 17th of May last a fall of fish happened in monza Sonare, pergunna Dhata Ekdullah, Zillah Futteppur. The zemindars

⁵² Harriott, John. Struggles through Life, 1809, v. 1, pp. 141-142.

⁵³ Prinsep, J. Fall of fish from the sky. Jour., Asiatic society of Bengal, 1833, 2: 650-652.

⁵⁴ Jour., Asiatic soc. of Bengal, 1834, 3: 367.

of the village have furnished the following particulars which are confirmed by other accounts. About noon, the wind being from the west, and a few distant clouds visible, a blast of high wind, accompanied with much dust, which changed the atmosphere to a reddish yellow hue, came on; the blast appeared to extend in breadth about 400 yards. * * * When the storm had passed over, they found the ground south of the village to the extent of two bigahs strewed with fish, in number not less than three or four thousand. The fish were all of the Chalwa species (*Clupea cultrata*), a span or less in length, and from $1\frac{1}{2}$ to $\frac{1}{2}$ seer in weight; when found they were all dead and dry. Chalwa fish are found in the tanks and rivers of the neighborhood; * * * the nearest water is about half a mile south of the village.

For the number of fishes that fell this account is not surpassed, but for all-around interest, and credulity inspired by the name of its distinguished author, the testimony of Francis de Castelnau, mentioned at the beginning of this paper, is supreme. The note is entitled "Shower of Fishes; earthquake at Singapore," and was published in 1861.⁵⁵

We experienced here an earthquake at 7:34 p. m., February 16, that lasted about two minutes; it was followed by hard rains, which on the 20th, 21st, and 22d became veritable torrents. The last day at 9 a. m. the rain redoubled in fury, and in a half hour our inclosed plot became a sea of water * * *

At 10 o'clock the sun lifted and from my window I saw a large number of Malays and Chinese filling baskets with fishes which they picked up in the pools of water which covered the ground. On being asked where the fishes came from, the natives replied that they had fallen from the sky. Three days afterwards, when the pools had dried up, we found many dead fishes.

Having examined the animals, I recognized them as *Clarias batrachus*, Cuvier and Valenciennes, a species of catfish which is very abundant in fresh water in Singapore, and the nearer Malayan Islands, in Siam, Borneo, etc. They were from 25 to 30 centimeters long, and therefore adult.

These silurids, the same as *Ophicephalus*, etc., are able to live a long time out of water, and to progress some distance on land, and I thought at once that they had come from some small streams near by; but the yard of the house I inhabited is inclosed in a wall that would prevent them entering in this manner. An old Malay has since told me that in his youth he had seen a similar phenomenon.

Other vertebrates.—Showers of vertebrates other than frogs, toads, and fishes are rare indeed. It was recorded in 1873 that a shower of reptiles fell in Minnesota,⁵⁶ and from the description it is evident the creatures were larvæ of a salamander, probably of *Amblystoma tigrinum*. The MONTHLY WEATHER REVIEW for May, 1894 (p. 215) states that during a severe hailstorm "at Boving, 8 miles east of Vicksburg, Miss., a gopher turtle 6 by 8 inches and entirely incased in ice fell with the hail."

This is a most remarkable occurrence, but what shall we say of a shower of birds, in which hundreds dropped dead in the streets of a Louisiana city? In the Baton Rouge, La., correspondence of the Philadelphia Times, some time in 1896, it is stated⁵⁷ that—

On Friday morning last early risers in the little capital [Baton Rouge, La.] witnessed a peculiar sight in the shape of a shower of birds that fell from a clear sky, literally cluttering the streets of the city. There were wild ducks, catbirds, woodpeckers, and many birds of strange plumage, some of them resembling canaries, but all dead, falling in heaps along the thoroughfares, the singular phenomenon attracting many spectators and causing much comment.

The most plausible theory as to the strange windfall is that the birds were driven inland by the recent storm on the Florida coast, the force of the current of air and the sudden change of temperature causing death to many of the feathered creatures when they reached Baton Rouge. Some idea of the extent of the shower may be gathered from the estimate that out on National Avenue alone the children of the neighborhood collected 200 birds.

This seems clearly not to have been a case of migrants becoming confused by city lights, nor killing themselves by flying against obstacles, mishaps which rather frequently occur to bird travelers. The phenomenon of migration among mammals gives rise to the only story of a

shower of those animals that I have seen. It is given by Charles Tomlinson, who writes:⁵⁸

In some countries rats migrate in vast numbers from the high to the low countries; and it is recorded in the history of Norway that a shower of these, transported by the wind, fell in an adjacent valley.

I have not seen the original of this tale, but it may have been prompted by the appearance, in large numbers, of lemmings which frequently migrate in hordes in Scandinavia. It is possible, of course, that during one of these migratory movements some of the animals were transported by a violent wind and precipitated as "a shower of rats."

WIND AS A DISTRIBUTING AGENT.

We have reviewed instances of the rain-like fall of various animal and plant bodies, of pollen, of hay, of diatoms, algæ, rotifers, of insects, frogs, toads, fishes, salamanders, turtles, birds, and rats. It remains to inquire what significance, if any, these phenomena have for the distribution of living things upon the earth.

Vertebrates.—In the case of vertebrates distribution by wind transport must be of practically no importance. Mammals and birds thus snatched up by the wind, if carried any distance, arrive dead. Batrachians also often are killed, and if not, usually must be carried for short distances only; the chances are also that they will reach an unfavorable environment and perish for that reason. Fishes, most of all, are fated to fall where they can not survive, and their inability to live long out of water strictly limits the possibilities of their deriving advantage by wind transport. In addition, it must be remembered that in all these groups instances of their being carried by the wind are really rare. All in all, we must conclude that the wind is a very unimportant factor in the distribution of vertebrate animals.

Plant seeds.—In the case of most seed-producing plants, although hundreds of species have seeds modified for wind transport, it has not been shown that they are especially successful in making rapid strides in distribution. Kerner says:⁵⁹

The distance to which specially adapted seeds may be carried by the wind is considerable, but in ordinary course is not attained. * * * Among the numerous species of fruits and seeds obtained from snow fields and glaciers high in the Alps not one was derived from a distant district.

Vogler,⁶⁰ who made a special study of the means of distribution of alpine plants, found that instances of spread by the wind to distances of from 3 to 40 kilometers were not rare, while "transport of seeds * * * to great distances, even hundreds of kilometers * * * is possible, but in the actual distribution of plants plays a minor rôle."

Spores, etc.—When we come to consider, however, the distribution of plants and animals that have spores, eggs, statoblasts, or other minute but resistant resting stages, it is apparent that winds are their most important means of spread.

The United States Bureau of Entomology has shown that winds are important in the distribution of mites (McGregor, E. A., & McDonough, F. L., Dept. Agr. Bul. 416, 1917, pp. 31-32), and the gipsy-moth (Collins, C. W., Dept. Agr. Bul. 273, 1915). Small larvæ of the last-named pest were found to be carried 13½ miles by ordinary winds. For a typical exposition of the agency of wind in distributing fungus spores, see Journ. agric. research, Washington, March, 1915, 3:493-525.

Reflect what opportunities are offered to the wind in every dry basin left by the evaporation of shallow pools. The drying of the water stimulates all the organisms to

⁵⁵ Comptes Rendus, 1861, 52:880-881.

⁵⁶ Am. sportsman, Oct. 11, 1873, No. 2, 3: 22.

⁵⁷ Gazette, San Jose, Cal., Nov. 4, 1896.

⁵⁸ Tomlinson, Charles. The rain cloud and the snowstorm, p. 194.

⁵⁹ Kerner. Natural history of plants, vol. 2, 1895, p. 861. Transl.

⁶⁰ Vogler. Flora, 1901, 69: 95.

produce their encysted forms. The bottom is crusted with matted algæ bearing their own spores or oögonia, resting stages which long retain their vitality and which are ready at any time to profit by wind transport. Among the algæ there may be flagellates, bacteria, diatoms, the spores of aquatic mosses, of horsetails, of club mosses, and quillworts, and the minute seeds of rushes. There may be also cysts of protozoa, gemmules of fresh-water sponges, the statoblasts of bryozoa, and the eggs of worms, leeches, crustacea, insects, and molluscs, all of which may be minute enough to be carried readily by the wind and resistant enough to survive the process. Untold numbers of these reproductive bodies may be gathered up by the wind and carried long distances. This goes far to explain the extremely wide, often cosmopolitan distribution of fresh water microorganisms.

It is not only aquatic organisms that have spores suitable for carriage by the wind, but also a long series of terrestrial ones including bacteria, algæ, fungi, mosses, liverworts, ferns, and club mosses. Dust-like seeds as those of orchids, broom-rapes, pyrolas, live-for-ever, etc., are almost as well adapted to wind transport as are spores. Perhaps the best illustration that can be given of the potency of the wind in distributing these plants is the part it played in the revegetation of the isolated volcanic island Krakatoa from which all life was extirpated by the 1883 eruption of almost unparalleled violence. From 16 to 30 per cent of the phanerogams established on Krakatoa 25 years after the catastrophe of 1883 were carried there by winds, as were all of the ferns (16 species) and lower cryptogams, almost without exception (more than 30 species). Between 49 and 63 per cent of its flora, therefore, is wind-borne. The first recolonization of the island in 1886 was entirely by wind-distributed species as algæ, bacteria, diatoms, liverworts, mosses, and ferns.⁶¹

The distribution of spores and other light reproductive cells does not depend on sporadic gusts of wind that suddenly pick up a quantity of these objects to later drop them as showers of organisms; there seem to be a certain number of them always in the atmosphere. In fact, aeroscopes reveal a steady fall of atmospheric dust, including minute organisms, that must be a far more important element in the distribution of such life than the more impressive but sporadic showers.

CONCLUSION.

It would appear, therefore, that the more spectacular the shower of organic matter the less its importance in the distribution of life. The rains of larger animals have attracted much attention and excited wonder, but in many cases the animals have been dead; in others they were doomed to die because of falling in an unsuitable environment. Not often are all the conditions propitious for the species to secure a new foothold.

The unobtrusive, but steady and widespread movement of minute eggs and spores by the atmosphere, however, is of great importance in distribution because these organic bodies are adapted to survive such transport; their numbers are so great and their dispersal so wide that some of them will necessarily fall in favorable places. The chances are, in fact, that every suitable environment will be populated. So far as mere preservation of species is concerned, we see here, as in other phases of biological investigation, the superiority of the pigmy over the giant, of insignificance over conspicuousness, of passivity and adaptability over strenuous effort. "Blessed are the meek, for they shall inherit the earth."

RECORDS AT THE ABBE METEOROLOGICAL OBSERVATORY, COMPARED WITH THOSE AT THE GOVERNMENT BUILDING, CINCINNATI.

By WILLIAM CHARLES DEVEREAUX, Meteorologist.

[Abbe Meteorological Observatory, Lafayette Circle, Cincinnati, Ohio, Apr. 11, 1917.]

During the 24 months from April 1, 1915, to March 31, 1917, both inclusive, complete weather records were made at the Government Building, Cincinnati, and at the Abbe Meteorological Observatory maintained by the United States Weather Bureau at Lafayette Circle, Clifton, Cincinnati, Ohio. The following pages present a discussion of these comparative observations.

LOCATIONS OF EXPOSURES.

The Government Building, Cincinnati, is located 900 yards from the Ohio River, which forms the southern boundary of the city, and is near the center of the principal business section. (See fig. 1). Moderately high hills form a semicircle around the business section, which lies on the comparatively level ground between the hills and the river. The Government Building stands some distance east of the center of the semicircle of inclosing hills; the nearest hill is northeast from the building, the ground beginning to rise rapidly within a distance of half a mile and reaching an altitude of 247 feet above the ground at the Government Building, or of 800 feet above sea level. The hills to the north are distant $\frac{1}{4}$ mile, to the west 2 miles, to the southwest in Kentucky $1\frac{1}{2}$ miles, and to the south $2\frac{1}{2}$ miles from the Government Building. The highest of these hills lies between 800 and 900 feet above sealevel.

The elevations of the instruments above the ground at the Government building are as follows: Barometer, 74 feet; raingage, 145 feet; thermometers, 152 feet; anemometer, 160 feet; and wind vane, 161 feet. Within a radius of 600 feet and from a point directly southwest to a point a little east of south, there are buildings considerably higher than the wind vane. To the east, north, and west the buildings are about the same height as the wind vane. The general surroundings are illustrated in figures 2 and 3.

The Abbe Meteorological Observatory is located on Lafayette Circle, in the suburb of Clifton, and is near the geographic center of the city. This is not the highest point in the city but is one of the highest, and the nearest hill of the same elevation is about 2 miles distant. The visible horizon of the Observatory is nearly level on all sides. The ground slopes away from the Observatory in all directions, and is mostly covered with trees. The only buildings in the vicinity of the Observatory are residences. The elevations of the instruments above ground are as follows: Barometer, 5.8 feet; raingage, 3.1 feet; thermometers, 10.8 feet; anemometer, 50.8 feet; and wind vane, 52.2 feet. (See figs. 1, 4, and 5.)

WIND RECORD.

In order to tabulate in detail the direction and velocity of the wind, a new form was prepared which shows the number of hours the wind blows from each direction, and the velocity of the wind from each direction. By the use of this form the percentage of time the wind blew from each direction and the mean velocity for each direction were obtained for each month, season, and the two years. Table 1 presents the form secured for March, 1916.

⁶¹ Ernst, A. The new flora of the volcanic island of Krakatau (Engl. transl. by A. C. Seward, 1908), pp. 60-68.

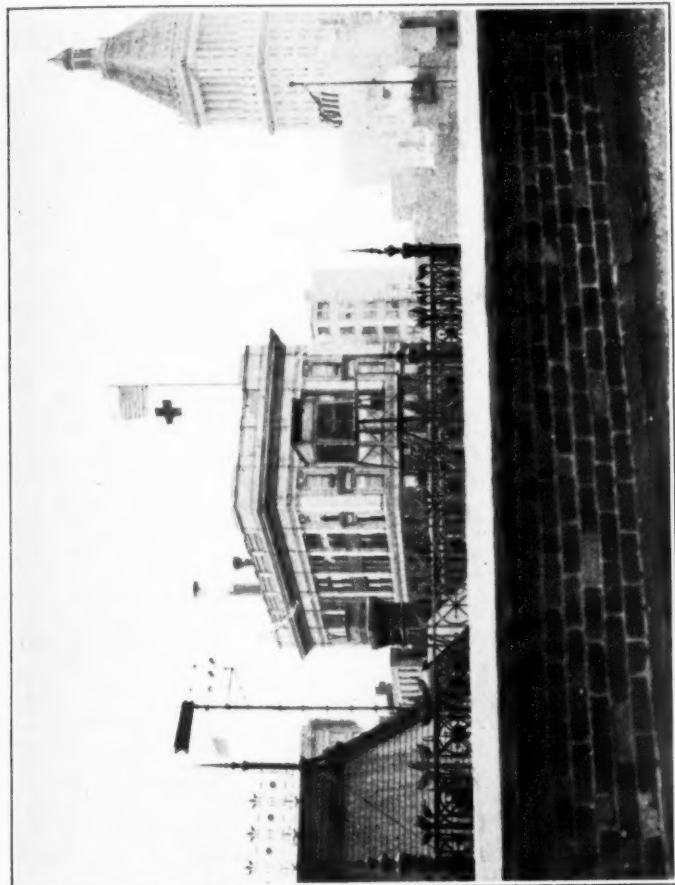


FIG. 2.—View of Weather Bureau instruments at Government building seen from neighboring roof and looking southward.

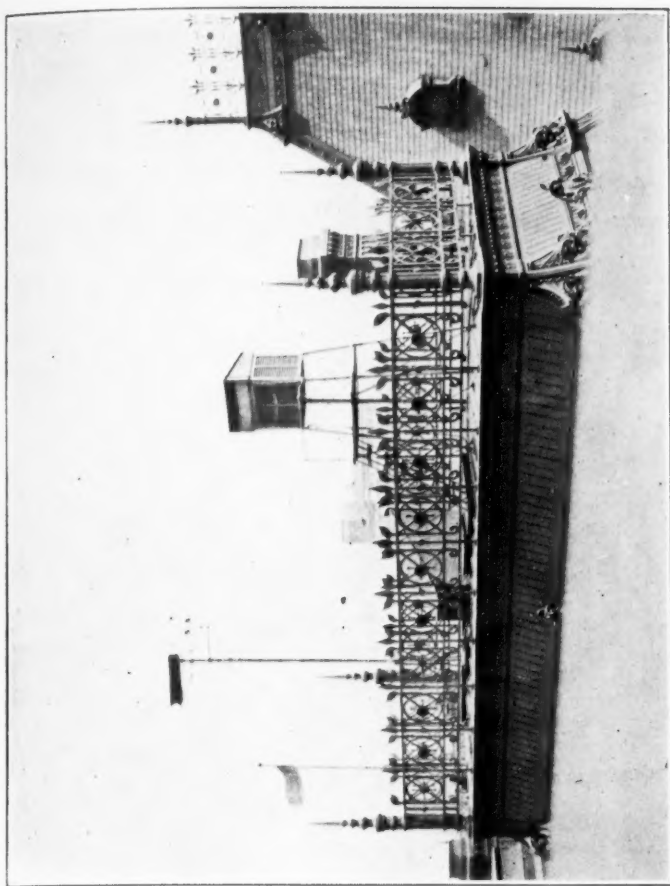


FIG. 3.—Same as in figure 2, but looking southeastward.



FIG. 4.—Abbe Meteorological Observatory, Cincinnati, looking northward at the south front.

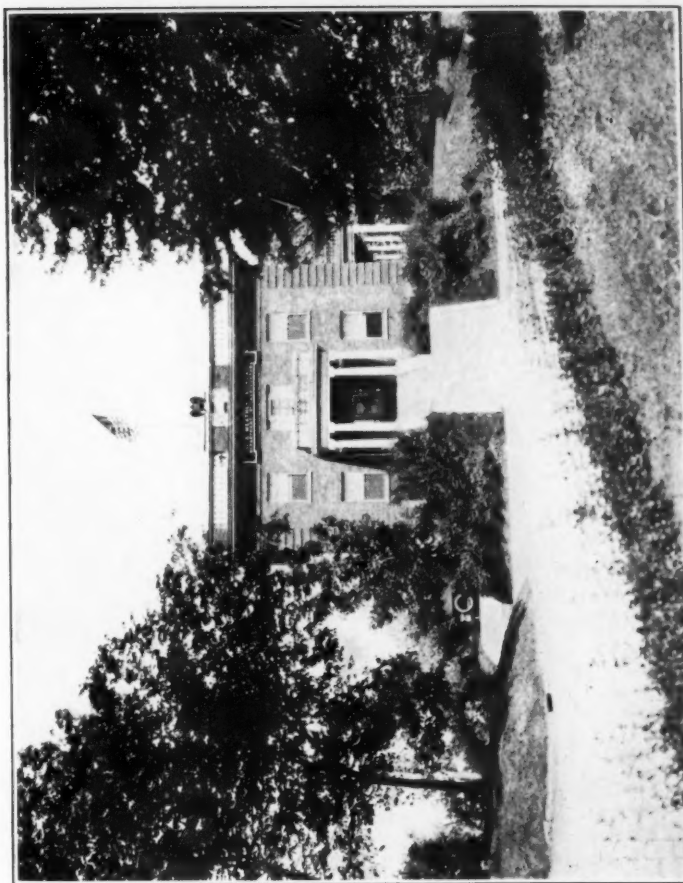


FIG. 5.—Same as in figure 4, but looking eastward at the west front.

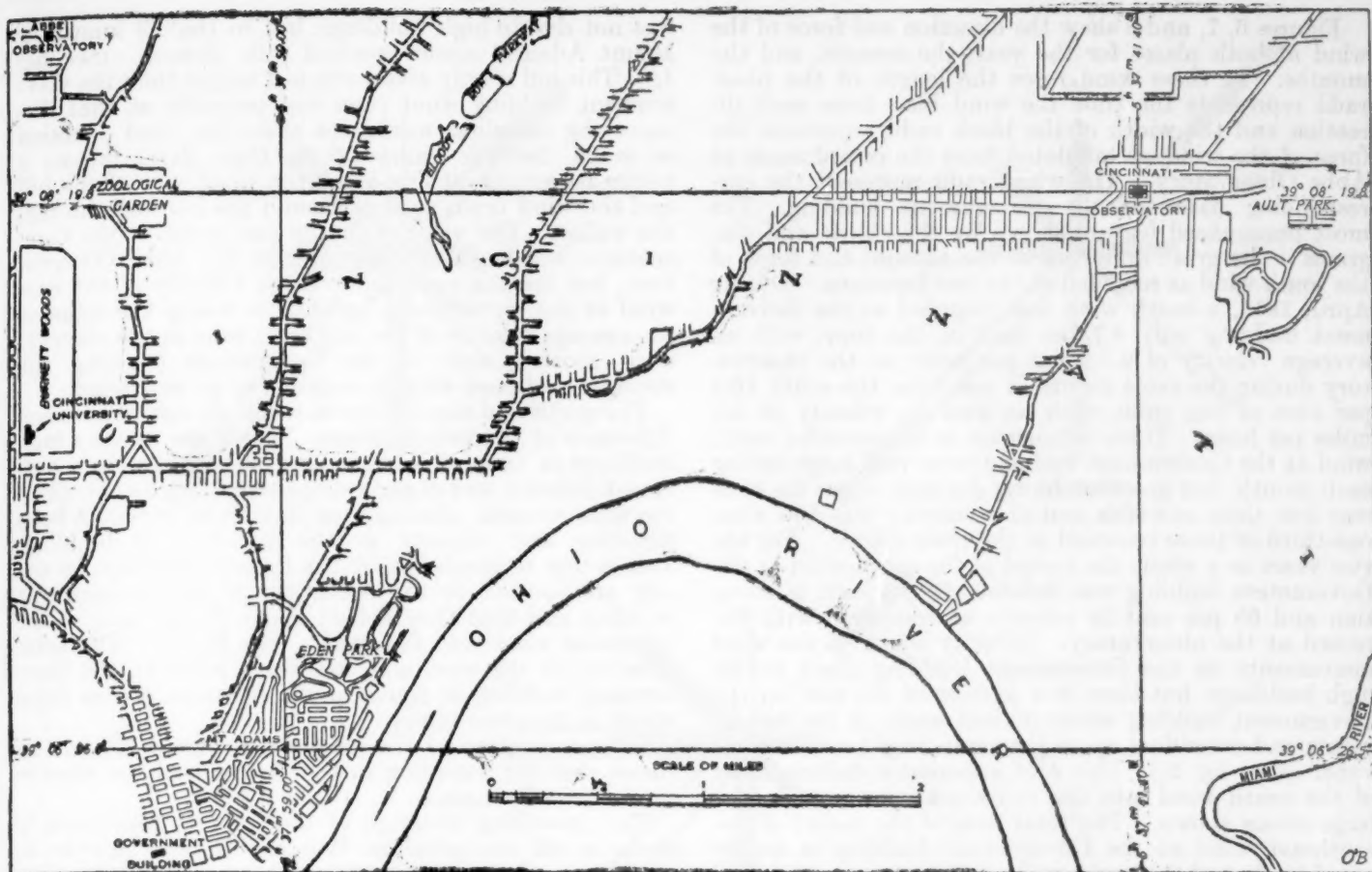


FIG. 1.—Outline map of Cincinnati, Ohio, showing locations of the Government Building, Abbe Meteorological Observatory of the Weather Bureau, the Cincinnati Observatory on Mount Lookout, and the position of the old Cincinnati Observatory on Mount Adams (in 1869-1873). Longitudes are west of Greenwich.

TABLE 1.—Wind duration in hours (H) and travel in miles (M) from each direction at the Government building, Cincinnati, daily during March, 1916.

Date.	N.		NE.		E.		SE.		S.		SW.		W.		NW.		Calm.		Total.		Max.
	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	H.	M.	
Mar. 1. 1916.																					
2.	10	75	7	47	3	11	17	148	3	10			1	6			0		24	175	18
3.	5	39	4	26									5	59	10	126	0		24	183	13
4.							2	7	2	13	11	89	9	99			0		24	250	24
5.	1	5	2	12	15	119					1	6	3	24	2	11	0		24	208	17
6.							8	58									0		24	177	14
7.									1	6	13	153	3	46			0		24	257	42
8.											11	96	12	219			0		24	321	35
9.											17	208	18	288	6	92	0		24	380	26
10.	18	177									4	62	5	42	2	15	0		24	265	24
11.	6	39	1	5	6	37	3	16	3	11			1	12	1	13	0		24	264	20
12.																	0		24		
13.					6	28	1	5	3	10	12	57	2	12			0		24	129	9
14.	20	197	1	9			2	5	1	1							0		24	175	15
15.	7	78													17	188	0		24	112	12
16.																	0		24	212	26
17.	4	28	12	76	6	58					3	18	12	102	9	53	0		24	266	18
18.	3	13			10	75	4	39							2	15	0		24	173	14
19.	9	67	2	8	4	13							1	6	7	55	0		24	177	13
20.					5	22	11	107	7	15	1	3			8	62	0		24	182	14
21.																	0		24	156	12
22.																	0		24	147	18
23.	7	95	2	12	1	10	17	115	6	16							0		24		
24.			1	4	16	105	7	41			4	58	7	194	1	16	0		24	141	16
25.					1	6	20	106	2	7	1	2					0		24	390	39
26.							20	99	1	3			3	12			0		24	150	12
27.					3	18											0		24	121	12
28.																	0		24	114	11
29.																	0		24		
30.	19	126	5	24							1	7	11	77			0		24	166	15
31.	14	51	6	36							2	14	14	113	6	56	0		24	195	15
	8	12	1	2			1	4	4	14	4	15	6	31	15	138	0		24	218	16
Sums.	134	1,024	45	267	80	523	123	813	37	116	109	970	127	1,466	90	853	0	0	744	6,032	
Per cent.	18.0		6.0		10.8		16.5		5.0		14.7		17.1		10.8		0				
Means.		7.6		5.9		6.5		6.6		3.1		8.9		11.5		9.5		0			

Figures 6, 7, and 8 show the direction and force of the wind at both places for the year, the seasons, and the months. In these wind roses the length of the black radii represents the time the wind blew from each direction and the width of the black radii represents the force of the wind, as tabulated from the record made at Abbe Observatory. The white radii represent the corresponding data for the Government building. The most pronounced feature shown by the charts and diagrams is the great difference in the amount and force of the south wind as recorded at the two locations. During April, 1915, a south wind was recorded at the Government building only 4.7 per cent of the time, with an average velocity of 2.1 miles per hour; at the observatory during the same month it was from the south 16.1 per cent of the time, with an average velocity of 5.5 miles per hour. These deficiencies in the recorded south wind at the Government building were very large during each month, but greatest during January, when the time was less than one-fifth and the velocity was less than one-third of those recorded at the observatory. For the two years as a whole the record of the south wind at the Government building was deficient 69 per cent in duration and 60 per cent in velocity as compared with the record at the observatory. Directly south of the wind instruments on the Government Building there are no high buildings, but there is a portion of the roof on the Government building about 50 feet south of the instruments and extending up to the same height as the wind vane. (See fig. 3.) This roof apparently deflects most of the south wind into the southeast, where there is a large excess shown. The total time of the record of the southeast wind at the Government building is nearly equal to that of the south and southeast wind combined as recorded at the Abbe Observatory.

Nearly 50 per cent of the northeast wind at the Government building was recorded as an east wind. This

was not due to high buildings, but to the hill known as Mount Adams,¹ about one-half mile distant. (See fig. 1.) This hill is only about 100 feet higher than the Government building wind vane and probably at that distance the hill alone would not affect the wind direction so much, but the valley of the Ohio River follows a northeast-southwest line along the south side of the hill and the wind tends to flow around the hill and through the valley. The velocity of the east wind at the Government building is greater than at the Abbe Observatory, but for the year the average velocity of the east wind at the Government building is nearly the same as the average velocity of the northeast wind at the observatory, showing that at the Government building the stronger northeast wind is recorded as an east wind.

The north and the northwest winds do not show much difference at the two locations. There are no very high buildings in these directions, and the hills are at a sufficient distance and of such shape that they do not affect the wind records. In the west there is an excess in both direction and velocity at the Government building. This is due to the fact that the highest buildings in the city are located to the southwest of the Government building and that they deflect about 50 per cent of the southwest wind into the west. (See fig. 2.) The total duration of the west and southwest wind at the Government building is equal to the duration of the same winds at the observatory.

An examination of the wind roses (figs. 6, 7, and 8) shows that the variation in the direction of the wind is similar for all seasons.

The prevailing direction of the wind at Cincinnati is given in all the previous Weather Bureau records as southeast. This is due to the poor exposure of the wind vane during the past years, and the records should be corrected to make the prevailing direction southwest the same as at most other places in the Ohio Valley.

TABLE 2.—Mean percentage frequencies and hourly velocities of the winds from each of the recorded directions for each month at the Abbe Meteorological Observatory and at the Government building, Cincinnati, for the period April 1, 1915, to March 31, 1917.

Abbe Meteorological Observatory.																			
Month.	N.		NE.		E.		SE.		S.		SW.		W.		NW.		Calms.	Annual mean velocity.	Maximum 5-minute velocity and direction.
	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.	Freq.	Vel.			
	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	%	Mi./hr.	Mi./hr.
January.....	5.5	7.7	10.8	7.4	5.2	4.3	6.6	6.2	21.4	9.4	30.3	12.1	9.3	10.0	10.7	8.6	.....	9.4	39 sw.
February.....	11.2	9.9	13.1	8.4	5.1	5.4	5.3	6.4	8.6	8.1	26.4	11.4	13.6	13.0	16.8	10.4	.....	10.1	38 w.
March.....	12.8	11.6	13.8	8.7	6.2	7.0	7.1	8.7	16.2	10.4	24.4	13.8	9.2	13.4	10.2	10.8	.....	11.1	52 w.
April.....	11.0	8.0	19.0	8.4	4.0	4.6	4.1	3.6	13.4	6.8	24.7	9.9	11.0	9.6	12.6	9.0	0.2	8.4	36 sw.
May.....	8.3	5.0	20.4	6.8	7.7	6.1	5.2	5.4	13.3	6.8	26.0	9.4	8.8	9.3	10.2	7.3	.....	7.4	36 sw.
June.....	7.6	5.4	17.8	4.5	7.2	4.8	7.5	4.8	17.0	6.2	23.8	7.0	8.4	6.1	10.3	5.9	0.3	5.8	37 nw.
July.....	11.6	4.1	24.9	3.8	8.8	4.0	3.3	2.8	12.8	4.2	23.6	5.3	6.2	5.0	7.4	4.2	1.4	4.4	44 nw.
August.....	8.6	5.5	23.6	5.5	5.3	4.0	3.8	3.6	12.6	4.2	30.0	6.2	8.2	5.3	7.2	4.7	0.6	5.3	28 w.
September.....	7.3	5.5	21.6	6.2	4.8	6.4	4.7	3.6	23.8	5.8	23.4	7.2	5.6	5.6	8.0	6.8	0.5	6.2	28 sw.
October.....	9.0	7.2	14.6	5.2	9.8	3.8	7.4	4.0	22.4	5.5	21.4	9.0	8.6	7.0	6.2	7.2	0.6	6.2	36 sw.
November.....	2.1	6.1	10.4	5.6	4.4	5.5	7.2	6.5	18.6	9.2	37.0	11.3	12.9	11.2	7.4	8.6	.....	9.4	40 w.
December.....	6.6	6.4	15.0	6.4	6.3	6.0	6.2	6.0	18.6	9.2	24.2	10.9	13.6	11.2	9.3	8.0	.....	8.9	35 sw.
Year.....	9.8	7.2	17.8	7.1	6.1	5.5	5.6	5.3	15.4	7.4	24.9	10.0	9.9	9.6	10.3	8.2	0.2	8.2	52 w.

Government Building.																			
January.....	4.4	6.8	4.7	6.4	9.4	6.2	24.4	5.4	3.5	3.2	22.0	7.4	19.5	10.8	11.9	8.9	.....	7.4	33 w.
February.....	10.8	7.4	9.1	6.3	7.5	6.8	12.6	6.4	1.8	3.4	17.0	7.6	22.6	12.0	17.6	9.8	.....	8.6	33 nw.
March.....	13.5	8.2	7.6	6.4	8.0	8.6	21.7	6.6	3.2	3.0	15.4	8.8	19.6	12.6	10.4	10.2	.....	8.7	42
April.....	10.6	5.6	11.7	6.5	9.1	7.6	14.5	4.4	4.2	2.6	19.6	7.6	16.8	10.2	13.1	7.8	0.4	7.1	33 sw.
May.....	7.6	4.6	10.8	6.4	13.5	7.2	15.7	5.8	5.0	3.0	18.4	7.6	16.4	10.0	12.4	7.4	0.2	7.0	38 w.
June.....	7.3	4.6	8.0	4.6	13.6	5.6	22.4	5.0	6.2	2.5	16.4	6.2	16.1	7.8	9.6	6.7	0.5	5.6	33 sw.
July.....	8.3	5.8	11.4	4.4	19.8	5.2	14.2	4.0	8.2	3.2	15.6	5.4	13.4	6.2	8.6	5.0	0.4	5.2	50 nw.
August.....	7.6	5.8	13.6	5.5	12.0	5.0	11.1	4.7	8.8	3.0	19.6	5.4	19.2	6.8	7.6	4.8	0.4	5.4	28 w.
September.....	7.0	5.4	12.3	10.2	11.8	6.2	20.6	4.0	8.2	3.3	18.6	6.4	13.0	6.4	7.8	7.2	.....	5.5	27 nw.
October.....	9.0	5.6	6.0	4.6	12.1	4.6	29.0	4.0	7.2	3.0	13.1	7.3	15.6	8.0	6.9	6.2	1.2	5.4	30 sw.
November.....	1.4	5.2	3.6	5.0	9.9	5.8	21.1	5.6	6.0	3.1	26.6	8.0	22.6	10.6	8.8	8.6	.....	7.4	30 w.
December.....	5.4	6.0	4.8	5.4	14.5	7.3	22.2	5.4	3.8	3.4	17.0	7.0	21.2	11.8	10.9	8.0	0.2	7.6	29 w.
Year.....	9.4	6.0	9.6	6.2	11.2	7.0	18.4	5.3	4.8	3.0	17.8	7.6	17.4	10.1	10.9	8.0	0.2	7.2	50 nw.

¹ Mount Adams was the site of the Cincinnati Observatory in 1869-1873 when Prof. Cleveland Abbe was director and making weather forecasts for the Cincinnati Chamber of Commerce.—C. A., Jr.

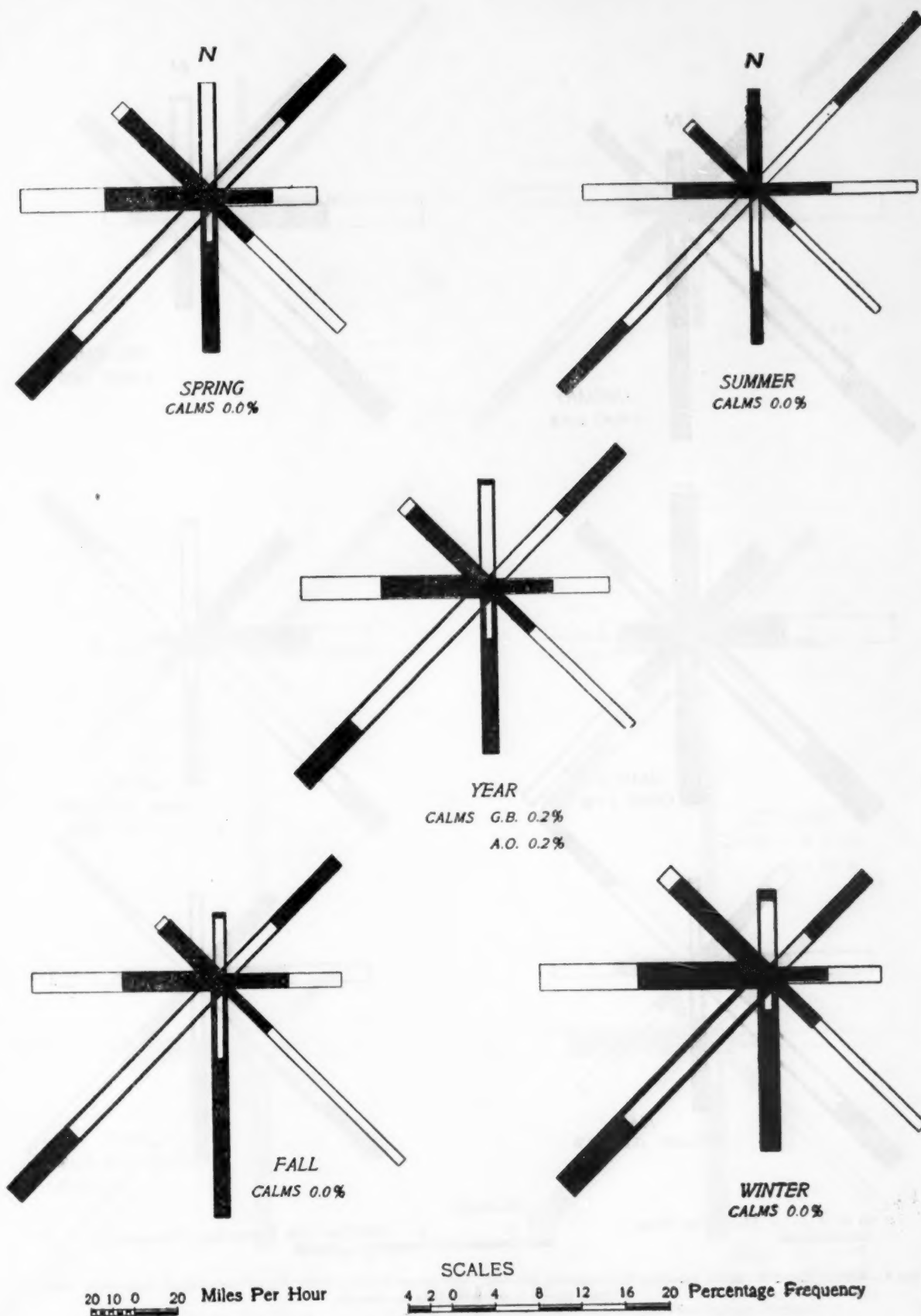


FIG. 6.—Seasonal direction-velocity windroses for Cincinnati, 1915-1917: Government building, white; Abbe Meteorological Observatory, black. Width of the ray is proportional to the velocity.

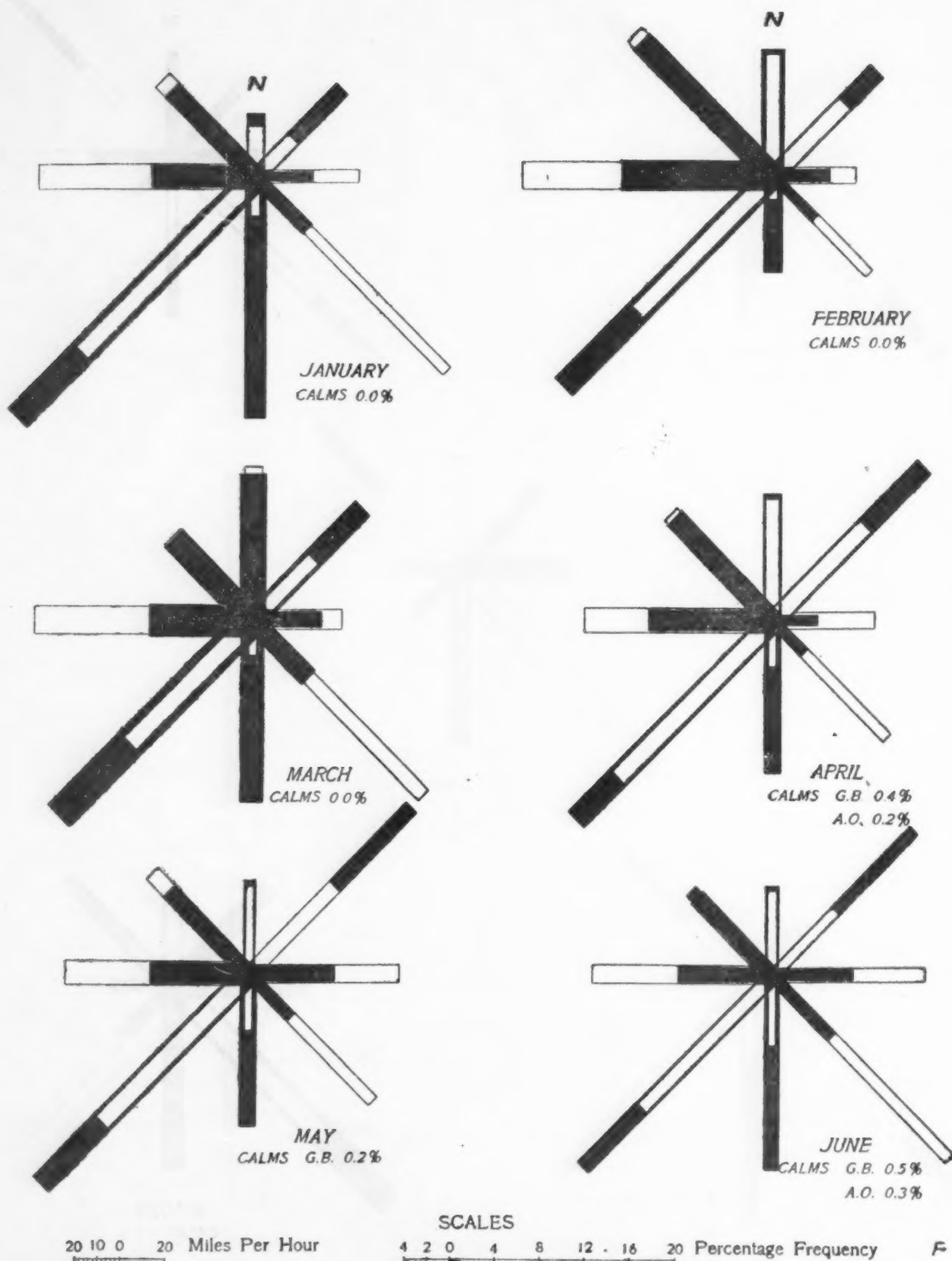


FIG. 7.—Monthly direction-velocity windroses for Cincinnati, 1915-1917: Government building, white; Abbe Meteorological Observatory, black. Width of the ray is proportional to the velocity.

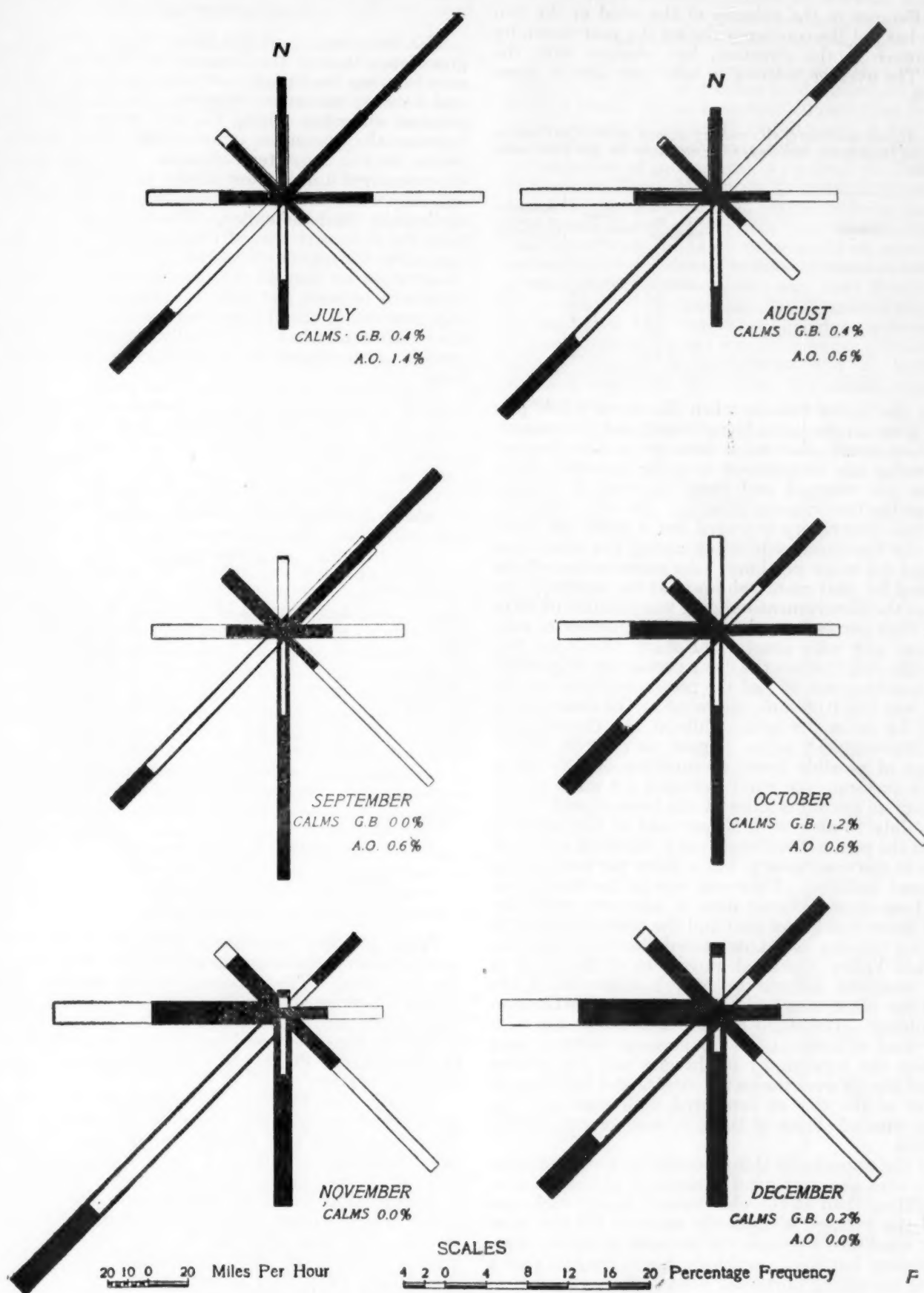


FIG. 8.—Monthly direction-velocity windroses for Cincinnati, 1915-1917, concluded: Government building, white; Abbe Meteorological Observatory, black. Width of the ray is proportional to the velocity.

The difference in the velocity of the wind at the two locations has not the constancy during the year shown by the difference in the direction, but changes with the season. The average velocity in miles per hour is given in Table 3.

TABLE 3.—Average velocities of all winds, by seasons, at the Abbe Observatory and the Government building, Cincinnati, for the two years under discussion.

Season.	Abbe Observatory.	Government building.	Difference at Government building.
	Mis./hr.	Mis./hr.	Mis./hr.
Winter.....	9.5	7.9	-1.6
Spring.....	9.0	7.6	-1.4
Summer.....	5.2	5.4	+0.2
Fall.....	7.3	6.1	-1.2
Year.....	8.2	7.2	-1.0

During the winter months when the storm winds prevail, the pressure gradients being strong and the amount of insolation small, the wind is stronger at the observatory. During the midsummer months, however, these conditions are reversed and then the wind is slightly stronger at the Government building. In July, 1915, the wind at the observatory averaged but 4 miles per hour, while at the Government building during the same time it averaged 5.6 miles per hour. An examination of the daily record for that month shows that the excess in the velocity at the Government building was greatest on days having a high percentage of the possible number of sunshine hours and with nearly stationary pressure. For example: On July 9, when the day's percentage of possible hours of sunshine was 99 and the pressure-change for the 24 hours was but 0.08 inch, the wind at the observatory averaged 3.3 miles per hour, while at the Government building it averaged 8 miles. Again, on July 15, with a percentage of possible hours of sunshine of 100 and a stationary pressure, the wind averaged 3.8 miles at the observatory as against 8 miles at the Government building. On July 16 also, with 93 per cent of the sunshine hours and the pressure still stationary, the wind averaged 4.2 miles at the observatory, but 9 miles per hour at the Government building. No storm was in the vicinity on any of these days. During July 8, however, while the sunshine hours was 41 per cent and the pressure rose 0.32 inch during the day as a low passed eastward from the upper Ohio Valley, the total movement of the wind at the two locations differed by only 2 miles, being 198 miles at the observatory and 200 miles at the Government building. The slight relative increase in the midsummer wind velocity at the Government building may result from the topography of the city and the greater heating of the air over the paved streets and buildings in the center of the city as compared with that over the grassy or wooded slopes of the hills and over the water in the Ohio.

One of the remarkable things shown by the wind roses (fig. 6) is that the west wind is stronger at the Government building than at the observatory during each season, and the average is distinctly stronger for the year. The east wind also averages the stronger at the Government building, but this is probably due to the fact that a portion of the strong northeast wind is there recorded as an east wind.

TEMPERATURE RECORD.

The temperature at the observatory averaged 2 degrees lower than at the Government building, the difference between maximum temperatures being 1.4 degrees and between minimum temperatures 2.7 degrees. The greatest difference during the two years was 8 degrees between the maximum temperatures and 8 degrees between the minimum temperatures. The greatest difference occurred during most of the months on clear days, specially when the weather was clear on the hill and fog and smoke filled the valley. During 88 per cent of the time the difference ranged between zero and 3 degrees, and either the maximum or minimum was highest at the observatory on only 43 days during the two years. The difference between the maximum temperatures was usually greatest in the Winter and least in the Summer—the reverse of what is generally expected. These extremes are compared by months in Table 4, which follows.

TABLE 4.—Comparison of extreme temperatures at the Abbe Observatory (O.) and the Government building (G.), April, 1915–March, 1917.

Month.	Maxima.						Minima.					
	Ex-treme.		Mean.		Daily difference.		Ex-treme.		Mean.		Daily difference.	
	O.	G.	O.	G.	Great-est.	Mean.	O.	G.	O.	G.	Great-est.	Mean.
April.....	89	91	64.9	66.0	6	1.1	23	28	45.0	47.2	6	2.2
May.....	89	90	72.0	73.2	4	1.2	38	40	52.6	55.1	7	2.5
June.....	92	91	77.8	79.0	3	1.2	48	53	58.8	61.0	5	2.2
July.....	98	99	86.5	87.6	3	1.1	54	57	65.7	68.6	7	2.9
August.....	96	97	81.7	82.8	3	1.1	43	46	63.2	66.1	6	2.9
September.....	90	92	76.9	78.2	4	1.4	36	39	56.7	59.2	7	2.5
October.....	88	88	67.8	69.0	5	1.2	27	33	45.1	48.0	7	2.9
November.....	76	78	55.7	57.4	5	1.7	14	17	36.4	39.2	7	2.8
December.....	63	65	39.9	41.6	5	1.7	1	7	24.4	27.4	7	3.0
January.....	70	71	44.6	46.4	8	1.8	-4	0	25.5	28.4	8	2.9
February.....	70	70	38.7	40.4	4	1.8	-9	-7	19.8	22.4	7	2.6
March.....	79	79	50.6	52.1	6	1.5	8	11	31.3	33.8	5	2.5
Mean.....			63.1	64.5		1.4			43.7	46.4		2.7

Mean 2-year temperature:
 Abbe Observatory..... 53.4
 Government building..... 55.4
 Difference..... 2.0

PRECIPITATION.

Table 5 below presents a comparison between the precipitation measurements at the two locations during the two years. The deficiency in the amount recorded at the Government building was 1.96 inches, or 5 per cent of the amount recorded at the Abbe Observatory, where the gage is exposed under more natural conditions. Our illustrations do not show the exposure of the rain-gage at either station.

Usually the greatest difference in the measured amounts of precipitation occurs in the summer months; the precipitation that occurs as snow about the Government building is measured in the neighboring parks and not at the gage at the Government building, where it is impossible to secure correct snow depths. During all the months except January and February the measured precipitation was greatest at the observatory. The greatest excess at the observatory occurred during September, 1915, and amounted to 1.02 inches, or 18 per cent of the monthly total.

TABLE 5.—Comparison of mean and extreme rainfalls at the Abbe Observatory (O.) and at the Government building (G.), April, 1915–March, 1917.

Month.	Mean totals.		Dif- fer- ence.	Greatest in 24 hours.		Greatest differences.							
						For the hour.				For the day.			
						Amounts.		Dif- fer- ence.	Amounts.		Dif- fer- ence.		
	O.	G.		O.	G.	O.	G.		O.	G.			
	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>	<i>Inch.</i>		
April.....	1.68	1.52	0.16	0.77	0.57	0.55	0.37	0.18	0.73	0.49	0.24		
May.....	5.02	4.81	0.21	2.34	1.75	0.83	0.44	0.39	2.29	1.71	0.58		
June.....	4.40	4.18	0.22	1.37	1.59	0.24	0.77	0.53	1.06	0.41	0.65		
July.....	3.36	3.04	0.32	1.44	1.36	0.43	0.00	0.43	1.43	0.35	1.08		
August.....	3.85	3.84	0.01	1.70	1.34	0.25	0.61	0.36	1.01	0.53	0.48		
September.....	4.47	3.55	0.08	2.32	2.04	0.78	0.47	0.31	1.36	0.89	0.47		
October.....	2.08	1.89	0.19	1.32	1.10	0.09	0.32	0.23	1.32	0.90	0.42		
November.....	2.10	1.94	0.16	1.27	1.09	0.25	0.19	0.06	1.23	1.02	0.21		
December.....	4.10	4.02	0.08	2.10	2.03	0.12	T.	0.12	1.28	1.49	0.21		
January.....	5.29	5.42	0.13	1.72	1.82	0.40	0.24	0.16	0.11	0.29	0.18		
February.....	1.62	1.82	0.20	1.13	1.29	0.11	0.42	0.31	0.76	1.18	0.42		
March.....	3.70	3.68	0.02	1.19	1.38	0.22	0.77	0.55	0.98	1.38	0.40		
Year.....	41.67	39.71	1.96	2.34	2.04	0.22	0.77	0.55	1.43	0.35	1.08		

The greatest amount of precipitation in 24 hours did not vary greatly at the two places, the greatest difference being 0.59 inch during May, 1916. During this month and also during several other months the greatest amount in 24 hours did not occur on the same day at the two places. A greater difference is shown when the same days are considered at each station. On July 28, 1915, the precipitation at the observatory was 1.43 inches and only 0.35 inch at the Government building, making a difference of 1.08 inches. On July 28 there was a rainfall of 0.48 inch at the observatory of which 0.43 inch fell in one hour, while none occurred at the Government building. The greatest difference for any hour during the two years occurred in March, 1917, when 0.22 inch fell at the observatory and 0.77 inch was measured at the Government building. The greatest amounts of precipitation for 5, 10, 15, and 30 minutes and for one and two hours during each month did not, as a rule, differ much at the two locations, but in several months the maximum amounts for those periods did not occur on the same day at the two places.

It will require several years of comparative records to determine accurately the percentage difference between the precipitation measurements at the Abbe Observatory and at the Government building, due to the difference in exposure of the raingages.

CLOUDINESS AND FOG.

The number of clear, partly cloudy, and cloudy days during the year at the two places were the same. There was more cloudiness and light fog during the early morning hours at the Government building than at the observatory, but this was due, at least in part, to the extra amount of local smoke that collected in the valley on mornings when the wind was very light. As soon as the velocity of the wind increased the smoke was mostly blown out of the valley. Under low atmospheric pressure, even with moderate wind velocity, the clouds were more dense at the Government building than at the observatory, as the local smoke tended to settle toward the ground instead of rising high in the atmosphere. On two occasions there were dense fogs on the hilltops and very little fog in the valley. On these occasions the pressure was moderately high, and the fogs on the hilltops were caused by the passing of low clouds which did not settle in the valley.

WINTER INDOOR ARIDITY IN TOPEKA, KANS.¹

By S. D. FLORA, Meteorologist.

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It is somewhat of a surprise to find that in the winter season a majority of persons in the northern part of the United States live in an indoor climate that is ultra-desert in regard to moisture conditions. A few years ago the writer was greatly interested in an account of the investigation of indoor aridity by Prof. R. DeC. Ward in Cambridge, Mass. (MONTHLY WEATHER REVIEW, September, 1908, 36:281–283), and determined—in the apparent absence of corresponding data for a western State where conditions were probably more acute on account of the atmosphere being drier—to make a series of humidity observations, both indoors and out, that should cover an entire winter. The program was interfered with by other duties, but it was carried far enough to indicate that indoor climate in Kansas was drier under ordinary circumstances than in Massachusetts, and in severely cold weather was even drier than the desert region of the Southwest.

TABLE 1.—Relative humidity indoors and outdoors at Topeka, Kans., November and December, 1909.

Date.	Temperature of office room.		Relative humidity.		Temperature outdoors.	State of weather.
	Dry-bulb.	Wet-bulb.	In-doors.	Out-doors.		
	° F.	° F.	%	%	° F.	
Nov. 18, 8 a. m.	71	55	33	77	27	Clear.
noon	72	53	25	49	43	Partly cloudy.
4 p. m.	72	54	28	47	53	Do.
19, 8 a. m.	71	53	29	76	38	Clear.
noon	72	54	30	46	54	Do.
4 p. m.	72	54	30	38	62	Partly cloudy.
20, 8 a. m.	72	58	40	93	47	Partly cloudy.
noon	71	57	39	60	59	Do.
4 p. m.	72	58	40	50	67	Do.
22, 8 a. m.	64	50	34	90	32	Cloudy.
noon	71	54	31	84	31	Do.
4 p. m.	72	57	39	70	37	Do.
23, 8 a. m.	75	55	25	85	23	Cloudy.
noon	73	55	28	70	40	Partly cloudy.
4 p. m.	72	54	30	56	48	Clear.
24, 8 a. m.	76	57	29	78	44	Clear.
noon	76	57	28	48	59	Do.
4 p. m.	76	59	32	46	65	Do.
25, noon	66	55	49	95	52	Cloudy.
26, 8 a. m.	66	56	53	83	58	Cloudy.
noon	74	62	52	79	66	Do.
4 p. m.	73	63	60	73	68	Partly cloudy.
27, 8 a. m.	73	62	53	81	61	Cloudy.
noon	72	61	52	79	64	Do.
4 p. m.	74	64	56	79	65	Do.
28, noon	60	55	38	92	38	Cloudy.
29, 8 a. m.	78	60	32	100	41	Foggy.
noon	70	66	39	90	44	Cloudy.
4 p. m.	72	58	40	97	46	Do.
30, 8 a. m.	82	62	31	100	46	Foggy.
noon	73	59	44	100	50	Cloudy.
4 p. m.	72	60	48	91	52	Do.
Dec. 1, 8 a. m.	74	60	44	100	49	Raining.
noon	76	59	35	69	52	Partly cloudy.
4 p. m.	74	58	37	74	50	Cloudy.
2, 8 a. m.	70	55	37	84	42	Cloudy.
noon	70	54	32	73	43	Do.
4 p. m.	73	56	33	67	45	Do.
3, 8 a. m.	67	53	36	80	41	Sprinkling.
noon	69	54	37	95	41	Do.
4 p. m.	74	58	37	99	41	Raining.
4, 8 a. m.	69	53	31	94	26	Sleet.
noon	72	52	22	100	23	Cloudy.
4 p. m.	71	52	25	89	22	Do.

¹ A summary of the results of these measurements was published in Bulletin, Kansas State Board of Health, Topeka, January, 1917, 13: 9–11. 8°.

TABLE 1.—Relative humidity indoors and outdoors at Topeka, Kans., November and December, 1909—Continued.

Date.	Temperature of office room.		Relative humidity.		Temperature outdoors.	State of weather.
	Dry-bulb.	Wet-bulb.	In-doors.	Out-doors.		
1909.						
Dec. 13, 8 a. m.	79	57	21	91	23	Cloudy.
noon	73	53	23	82	24	Snowing.
4 p. m.	75	55	23	88	29	Cloudy.
14, 8 a. m.	78	57	25	94	25	Cloudy.
noon	74	54	24	67	29	Partly cloudy.
4 p. m.	76	54	20	64	28	Clear.
15, 8 a. m.	78	55	19	97	17	Clear.
noon	72	52	22	68	26	Do.
4 p. m.	76	54	20	64	32	Do.
16, 8 a. m.	75	54	21	87	30	Cloudy.
noon	73	54	25	72	37	Do.
4 p. m.	74	53	21	63	36	Do.
17, 8 a. m.	68	50	23	80	7	Partly cloudy.
noon	70	50	19	61	11	Clear.
4 p. m.	74	52	18	47	13	Do.
18, 8 a. m.	75	51	15	80	6	Clear.
noon	73	52	19	80	12	Partly cloudy.
4 p. m.	73	51	17	65	18	Clear.
20, 8 a. m.	69	49	17	75	6	Clear.
noon	73	52	20	73	16	Do.
4 p. m.	73	53	23	72	22	Do.
21, 8 a. m.	71	50	18	79	11	Partly cloudy.
noon	73	51	18	69	19	Clear.
4 p. m.	73	53	22	75	26	Do.
22, 8 a. m.	69	49	20	96	14	Cloudy.
noon	73	52	20	92	18	Snowing.
4 p. m.	76	54	20	88	20	Do.
23, 8 a. m.	77	54	18	100	17	Cloudy.
noon	72	52	20	88	24	Do.
4 p. m.	76	54	20	79	31	Do.
24, noon	80	58	24	100	32	Cloudy.
27, 8 a. m.	77	55	21	84	17	Clear.
noon	74	52	16	65	26	Do.
4 p. m.	74	56	32	69	31	Do.
28, 8 a. m.	77	55	21	90	25	Cloudy.
noon	76	54	19	85	20	Partly cloudy.
4 p. m.	77	53	15	68	18	Clear.
29, 8 a. m.	74	51	15	93	-1	Clear.
noon	73	51	15	69	5	Do.
4 p. m.	76	52	14	54	8	Do.
30, 8 a. m.	74	51	15	72	19	Partly cloudy.
noon	74	52	18	69	33	Clear.
4 p. m.	73	53	23	62	37	Do.
31, 8 a. m.	77	55	21	87	28	Cloudy.
noon	75	54	22	69	39	Do.
Means, 8 a. m.	73.3	54.6	27.5	87.1	28.2	
noon	72.6	54.5	28.4	76.5	35.3	
4 p. m.	73.8	55.6	29.4	69.1	38.2	
Means of all observations. . .	73.2	54.8	28.4	77.6	33.9	
Means of December observations.	74	54	23	79	25	

TABLE 2.—Humidity of arid regions and indoor winter climate.

Stations.	Average annual relative humidity.	Average relative humidity during driest month of year, and month.
Yuma, Ariz.	43	35 per cent in June.
Santa Fe, N. Mex.	45	29 per cent in June.
Pueblo, Colo.	46	38 per cent in April.

Death Valley, Cal., from May to September, 1891..... 23%
 Indoors at Cambridge, Mass., November, 1899..... 30
 Indoors at Topeka, Kans., November and December, 1890..... 28
 Indoors at Topeka, Kans., December, 1909..... 23

It is apparent from a study of Table 1 that the chief cause of indoor aridity is the difference in temperature between the air indoors and out. This was specially noticeable on December 29, 1909, when the lowest

relative humidity indoors and the lowest temperature outdoors occurred. However, the outdoor humidity, specially the absolute humidity there, is also an important factor. The latter point is brought out more clearly by the means of the 8 a. m., noon, and 4 p. m. observations, which show that, while the relative humidity outdoors decreased during the day, indoors it increased. This was undoubtedly due to the fact that, as shown by computation, the absolute humidity increased from 1.54 grains per cubic foot at 8 a. m. to 1.81 grains at noon and 1.82 grains at 4 p. m. In other words, the more moisture in the air admitted to the room from outside the less the tendency to aridity after it was warmed up.

The indoor observations recorded in the tables were made with the Weather Bureau sling psychrometer in the front room of the suite occupied by the Weather Bureau (997 feet above sealevel), a room 14 by 18 feet, with a 10-foot ceiling, steam heated, with no provision for adding moisture to the air, and no arrangement for ventilation except through the windows. In general it is a well-lighted room and fairly well ventilated, and is in most respects typical of the ordinary office room. The outdoor observations were made 85 feet above the ground, in the instrument shelter on the roof, with the ordinary type of whirling psychrometer.

During the period covered by the observations the sling psychrometer was used to ascertain the relative humidity of living rooms in various parts of Topeka from time to time, and it was demonstrated that conditions in such rooms did not differ materially from those in the office room.

Specialists on throat diseases are agreed that air as dry as that found indoors in these observations is liable to set up an irritation in the delicate mucous lining of the air passages of the throat, which is at least an indirect cause of a great deal of catarrh, bad colds, and even tuberculosis, that are all too common in cold climates in the winter season.

Raising the humidity of a room by the familiar device of setting a pan of water on a stove or radiator is not nearly as easy as is commonly supposed. To raise the relative humidity of a room 14 by 18 feet, with a 10-foot ceiling, from 23 per cent to 79 per cent and maintain its temperature at 74°, requires the addition of the vapor from a little more than a quart of water. To raise its humidity even to 50 per cent would require the moisture from approximately 1½ pints of water.

Increasing the humidity of the air already in a room is, however, only the beginning of the trouble. The air must be renewed from time to time for ventilation. Good ventilation is said to require the addition of at least 25 cubic feet of fresh air per minute for each person in the room (Chambers' Encyclopedia under "Ventilation"). Under outside conditions similar to those shown in the December series of observations, to maintain a room at a temperature of 74° and a relative humidity of 50 per cent, and ventilate it properly for 4 persons for 16 hours of a day, would require the evaporation of almost 3 pints of water every hour, or 5½ gallons for the 16-hour day. To ventilate properly a school room with 40 pupils in it and maintain its temperature at 74° and its relative humidity at 50 per cent under similar weather conditions would necessitate the evaporation of almost a barrel of water each 8 hours, which would certainly be considered impracticable with present-day heating apparatus.

However, by keeping the temperature of the room at 65° instead of 74°, the amount of water vapor necessary to maintain the desired relative humidity of 50 per cent would be reduced almost half.

It is somewhat of a question whether it is desirable to maintain a relative humidity as high as 50 per cent in cold weather. Air at a temperature of 74° and a relative humidity of 40 per cent will become saturated when its temperature is reduced to about 48°, and it is not uncommon for the surface of window panes and walls of a room to become that cold when the outside temperature is as low as 0°F. In fact it was noted in making humidity observations in residences that, when the indoor humidity was as high as 50 per cent in cold weather, the windows and even painted walls of rooms were usually dripping with moisture. To pass from a stay in a room this damp into a piercing winter wind is something not many persons care to make a practice of.

The most obvious solution of the problem in the light of the foregoing would seem to be to keep living rooms from being excessively heated, since the difference of a few degrees makes a marked difference in the relative humidity, and to arrange that a reasonable quantity of water be evaporated in the room daily. It would hardly seem to be necessary to state that aridity in sleeping rooms may be entirely avoided by good ventilation and the absence of artificial heat.

THE PREPARATION OF PRECIPITATION CHARTS.

By WM. GARDNER REED and JOSEPH BURTON KINCER.

[Dated: Climatological Division, June 30, 1917.]

When the preparation of the Atlas of American Agriculture was undertaken by the United States Department of Agriculture, the importance of climate in its relation to agriculture was recognized and a section of the Atlas was very properly devoted to climate. This opportunity was taken to construct a new series of climatic charts with the aid of the data which have been accumulated since the existing maps were drawn. Particularly in the case of precipitation there was an opportunity to construct maps which should depict the conditions more accurately than had heretofore been possible. It seemed proper to review the principles upon which precipitation maps should be drawn and determine how far the data available would permit the construction of maps nearly approaching the ideal. Other climatological maps are now in preparation by the Weather Bureau, and the map of the annual precipitation over the United States was issued in "January, 1917," as "Advance Sheet No. 1: Precipitation" of the Atlas mentioned above.

There is probably no climatic factor concerning which so much has been written as precipitation. From the discussions of the subject it has been possible to formulate a set of rules for the construction of maps which present its distribution graphically.¹

1. Gage records, except such as have been shown to be in error, e. g., by comparison with neighboring records, should be regarded as the "control" of the map. In spite of the doubts as to whether gage readings agree with the actual precipitation there can be no doubt that these records are the only comparable numerical precipitation data in existence.

2. The data should refer to the same period, which should be as long as possible. This is desirable because of the differences in amount from year to year, and, to be comparable, records must cover the same years. The period selected should be one for which a very consider-

able number of records are available, because only by the use of many records can the geographical distribution adequately be shown.

3. When these data have been entered on a map there will appear many areas where the course of isohyets drawn to the data will remain in doubt. As there is no convenient artifice for representing "no data," and because the best approximations to the actual conditions in such regions can be made by meteorologists familiar with the data, it seems desirable that the maps should show the probable conditions where records are not sufficient to permit the portrayal of the actual conditions.

To fill these gaps, interpolations are necessary but, unless they be made wisely, the resulting map will not be a true picture of the conditions as they exist. The data upon which interpolations may be made vary greatly, not only in adequacy but in kind. The most useful data for interpolation are gage records covering a portion of the selected period. The precipitation for the whole period may then be deduced from these incomplete records by a comparison with neighboring complete records. Another kind of interpolation is based on analogy; for example, if the precipitation conditions on one mountain range have been determined by adequate gage readings, the same conditions may be inferred on a near-by range of the same elevation and similar exposure, covered with the same or closely allied vegetation and yielding a similar stream flow. Likewise, in the absence of more accurate information, precipitation conditions may be inferred as similar in neighboring valleys of the same mountain group if the elevation of these valleys and their vegetation are similar. Again, differences in vegetation and in the known laws of change in amount of precipitation with altitude, latitude, or distance from the ocean may be of assistance in indicating that a region is wetter or drier than a near-by region in which measurements are available.

In the preparation of a map which shall adequately represent the precipitation of a region, such as the United States, the following should be kept in mind:

1. On account of the great diversity of topography the map must be more or less generalized with the attendant sacrifice of accuracy of detail. In fact, it is probably better to regard any map as a general illustration and to refer to the actual data for detailed information.

2. The "control" of the map should be gage records, covering the same period of years.

3. If complete gage records for the period selected (which should be not less than 20 years) do not exist in sufficient number, the shorter records within the same period should be reduced to the complete period.

4. It must be remembered that in drawing an isohyet from one station to another interpolation is of necessity involved at all points between the stations. Therefore it is well to draw these lines having in mind the topography, the stream flow, and the natural and cultivated vegetation, and to give weight to these conditions in carrying the isohyets from station to station.

5. The object of a precipitation map is to show graphically the distribution of rainfall over the area for which the map is drawn. A map which does not accomplish this is not a good map, and saving clauses such as statements that the precipitation is greater or less than a certain amount should be avoided as far as possible. For example, it is literally correct to mark a region "10 inches plus," where the fall may be 40 inches, but such a practice may be greatly misleading under some condi-

¹ For a collection of expert opinions on the construction of rainfall maps see the MONTHLY WEATHER REVIEW, April, 1902, 30: 205-243, and 2 charts.—EDITOR.

tions. It is self-evident that no precipitation map can be complete in all details; some generalization is necessary, and the extent to which generalization is to be carried is largely a matter of opinion, although the scale of the map and the type of reproduction must be considered.

An examination of the rainfall data of the United States by one of the writers (Kincer) indicated that a large number of records were complete for the 20-year period, 1895-1914. It was therefore decided to adopt this period for the precipitation maps of the Atlas. There were available about 1,600 complete records covering this period and in addition about 2,000 of shorter lengths, from 5 to 19 years, within the same period.

The data from stations with 20-year records were not sufficient to construct a reliable map and so the 2,000 shorter records were employed to supplement them. These latter were reduced to the 20-year period, 1895-

most cases the original computations were found to be correct. The record was then examined in detail, and this examination usually showed particular years whose records seriously affected the average. In most cases the averages were evidently correct for the data as recorded, and as all the original records had been carefully checked both by the section directors and at the central office the explanation had to be sought elsewhere. In practically all these cases strictly local causes were found which indicated that these records were not truly representative of large areas, and it became necessary either to disregard them or to show small areas of precipitation different from the surrounding regions. As it is believed that a map of an area as large as the United States should depict mainly general conditions, it appeared better in most cases to disregard the erratic averages rather than to attempt to show small areas with precipitation markedly different from the surrounding regions.

TABLE 1.—Adjustment of the average monthly and annual precipitation at Greenfield, Ind., for the 11-year period from 1904 to 1914, inclusive, to the uniform 20-year period from 1895 to 1914, inclusive, by comparison with records made at Indianapolis and Maury, Ind., during the full 20-year period.

ELEVEN-YEAR MEANS, 1904-1914.													
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
(1) Greenfield.....	3.1	2.6	4.4	3.2	3.8	3.2	3.7	3.4	3.1	3.0	2.6	2.2	38.3
(2) Indianapolis.....	3.5	2.5	4.5	3.5	3.5	3.1	3.9	3.2	3.0	2.5	2.4	2.3	37.9
(3) Maury.....	3.8	2.8	4.9	3.9	4.1	3.1	3.7	3.8	2.9	3.4	2.2	2.7	41.3
PERCENTAGES FOR THE 11-YEAR PERIOD, 1904-1914.													
(4)=(1)÷(2).....	89	104	98	91	109	103	95	106	103	120	108	96	101
(5)=(1)÷(3).....	82	93	90	82	93	103	100	89	107	88	118	81	93
20-YEAR MEANS.													
(6) Indianapolis.....	3.1	2.3	4.3	3.0	3.5	3.2	3.9	3.1	3.3	2.6	3.0	2.6	37.9
(7) Maury.....	3.4	2.6	4.6	3.2	3.9	3.6	3.7	3.4	2.8	2.9	3.0	2.8	39.9
GREENFIELD'S ADJUSTED MEANS.													
(8)=(4)×(6).....	2.8	2.4	4.2	2.7	3.8	3.2	3.7	3.3	3.4	3.1	3.2	2.5	38.3
(9)=(5)×(7).....	2.8	2.4	4.1	2.6	3.6	3.7	3.7	3.0	3.0	2.6	3.5	2.3	37.1
MEANS OF (8) AND (9), OR ADJUSTED MEANS FOR GREENFIELD.													
(10).....	2.8	2.4	4.2	2.6	3.7	3.4	3.7	3.2	3.2	2.8	3.4	2.4	37.7

1914, by comparing identical years of the nearest stations having records covering the full period. As far as possible comparisons were made by determining the percentage relations between the full 20-year period and the portion of the full record covering the same years as were available for the shorter record. The short record was then corrected by increasing or decreasing its average by the percentage shown when the average for the short period of the 20-year record was compared with the 20-year average. In no case were records of less than five years used as a basis for this type of interpolation. Table 1 shows the method.

The 20-year averages for the long record stations and the adjusted averages for those of fewer than 20 years were entered on large topographic base maps of the United States, each at its proper location, and lines drawn showing areas of approximately equal precipitation.

Inconsistencies.—In drawing the isohyets the data for a small number of the stations appeared erratic. These cases were examined with great care, and the averages recomputed to detect possible arithmetical errors, but in

To meet the demands of those desiring rainfall statistics the meteorologists responsible for the collection of such data are required to prepare maps showing the different amounts of rainfall for widely extended regions, which will inevitably embrace large areas for which no data are available, because it is impracticable and in many cases impossible to get gage records in areas like the unpopulated mountainous regions of the western United States, where the very few inhabitants are all located in the valleys, avoiding the mountains and other inaccessible places. In these regions direct observations of rainfall are therefore unattainable, not only because of the lack of funds but because there are no means of securing records of precipitation, through no fault of those responsible for the collection of statistics.

The best procedure in attempting to depict rainfall in regions where no observations have been obtained is a matter of debate and difference of opinion. In the maps employed in ordinary cases the unreported regions in question can not be entirely omitted because, as previously stated, there is no convenient artifice by which to indicate that the precipitation is not known in certain

regions and that the amount we decide to indicate on the map may not be the correct amount. In many cases, also, the needs of the user of the map require that the best estimate of the rainfall be shown. The practice adopted for such regions depends to a considerable extent upon the use to which the map is to be put, the personality of the author of the map, and the limitations under which it is made. For example, much has been learned not only of the relation between rainfall and elevations, but studies in various parts of the country have shown how far the same types of vegetation are possible in different regions. In addition, it is clear that the best map of precipitation will be drawn when the compiler has in mind not only gage records but also all the other information available, whether quantitative or merely qualitative. The most useful rainfall map is that which gives the best picture of the actual conditions.

The relation between climatic factors and vegetation is exceedingly complex and, while it is perhaps generally true that the existence of a forested region indicates more rain than falls on near-by unforested areas, conditions of temperature and humidity, which can not safely be neglected, may account for all the differences observed.

The relations between rainfall and run-off have been studied in several localities in the United States, and while no general law has been determined it is obvious that in the long run no more water can be carried by the streams than falls on the watershed; and when two similar watersheds have similar stream discharges it is reasonably safe to assume they receive similar amounts of precipitation.

Some phases of the relation between rainfall and altitude are now known, but as a general rule precipitation increases with altitude *up to a limiting elevation*; the altitude of heaviest precipitation, however, is not well known and probably is not the same in different regions. Slope and direction of winds are also factors which must be considered. In the Sierra Nevada the zone of maximum rainfall occurs at an altitude varying from 4,000 to 6,000 feet.² This range presents a practically unbroken ridge extending across the path of the prevailing winds which blow directly from the ocean, and is therefore a very simple case. The relations are far from clear with more irregular mountain masses, especially such as are situated at some distance from the ocean, particularly those where the winds must cross considerable altitudes before reaching the mountains under consideration.

Perhaps the most important relation existing between topography and rainfall is the occurrence of "topographic barriers." In the absence of definite information to the contrary, it is not safe to assume that similar conditions exist in regions separated by mountain ranges. The practical difficulty is increased by the fact that it is nearly as unsafe to assume that different conditions exist on different sides of a mountain range. A mountain range usually limits the conditions, but this limitation does not mean that the conditions at given levels are not the same on both sides.

As long as the precipitation is stated in terms of depth of water, it is essential that the maps be based on gage measurements. It may be practicable to construct a map in terms of vegetation; from bare desert through sage brush desert, grassland, scattered trees, etc., up to dense forest. Such a map would be very useful and not misleading if its basis were properly explained; but the attempt to translate such data into terms of depth of water necessarily involves assumptions which are not fully warranted in the present state of our knowledge. In the preparation of rainfall maps many conditions

arise which must be decided more or less arbitrarily, although the decisions should be consistent among themselves. For example, the oft-cited case of Mount Washington may be considered. In this case there is no doubt that the precipitation on the summit is nearly double that of the surrounding region below. The mountain, even if the whole Presidential Range be included, covers so small an area that it is hardly more than a dot on any moderate sized map of the United States. The result is that the area of heavier fall must be exaggerated in size or ignored, unless the somewhat objectionable expedient of printing the figures on the map be adopted. Such areas may be omitted on the ground that there are doubtless other similar places without data, but this does not seem to be good practice, as precipitation data are scanty enough at best and all authentic records are needed to bring out the actual conditions. A similar situation exists in the case of small valleys surrounded by higher lands. Attempts to construct an adequate precipitation map of the western highland of the United States meet great difficulties. Considerable of the region is largely higher than the altitude of maximum precipitation in the Sierra Nevada, the topography is imperfectly known, the forest areas have been mapped liberally to say the least, the region is more or less arid with the resulting wide variations in precipitation both from time to time and from place to place, and finally the habitations and hence the rain gages are frequently located in places which are not typical of the area, if any typical places can be said to exist. The mountains to be sure, in some parts of the region, have heavier vegetation and greater run-off than the near-by valleys; but they are also regions of lower temperature and smaller exposed ground surface which, especially in a region of strong insolation, makes a vast difference in evaporation. The mountains may be regions of heavier precipitation than the neighboring lower levels, and they may not. In such cases of doubt it seems better that the isohyets be broadly generalized on the basis of the gage records and a statement made that the precipitation may vary locally in either direction from the amount indicated.

It is not practicable to carry on the map more information than the precipitation data, the topography, and enough "culture" to permit accurate location of places and of regions. There is, however, an enormous mass of additional information much of which is not subject to exact statement at present, which may assist in the location of isohyets between stations. The simplest of such cases is that of two regions separated by high mountains; here it is manifestly proper to carry the line around rather than over the mountains. In the western part of the country such cases arise continually. Certain mountain areas are known to be regions of heavy snowfall, particular valleys are known to be drier than the surrounding mountains, certain areas have climates which will or will not support certain natural vegetation or which will permit or prevent certain types of agriculture. All this information, while distinctly subordinate to gage records, helps to show on which side of the area the isohyet should be drawn. A gage record on one mountain mass will give an indication of the probable rainfall conditions of an adjacent area of similar topography and location where there is no record, and records for one portion of a plateau area suggests the conditions of other parts for which no records are available. It is essential, however, that such inferences be made with caution and careful consideration of all the information which has any bearing at all on the subject.

²A. J. Henry in MONTHLY WEATHER REVIEW, April, 1902, 30: 208.

SOME NEW INSTRUMENTS FOR OCEANOGRAPHICAL RESEARCH.

SUPPLEMENTAL NOTE.

In the April, 1917, issue of this REVIEW, p. 159 fig., appears an interesting contribution on the above subject by Dr. Hans Pettersson. As there stated in footnote 3 on page 162, the author's Table 1 and one illustration had been delayed in the mails. We here print both the missing items.

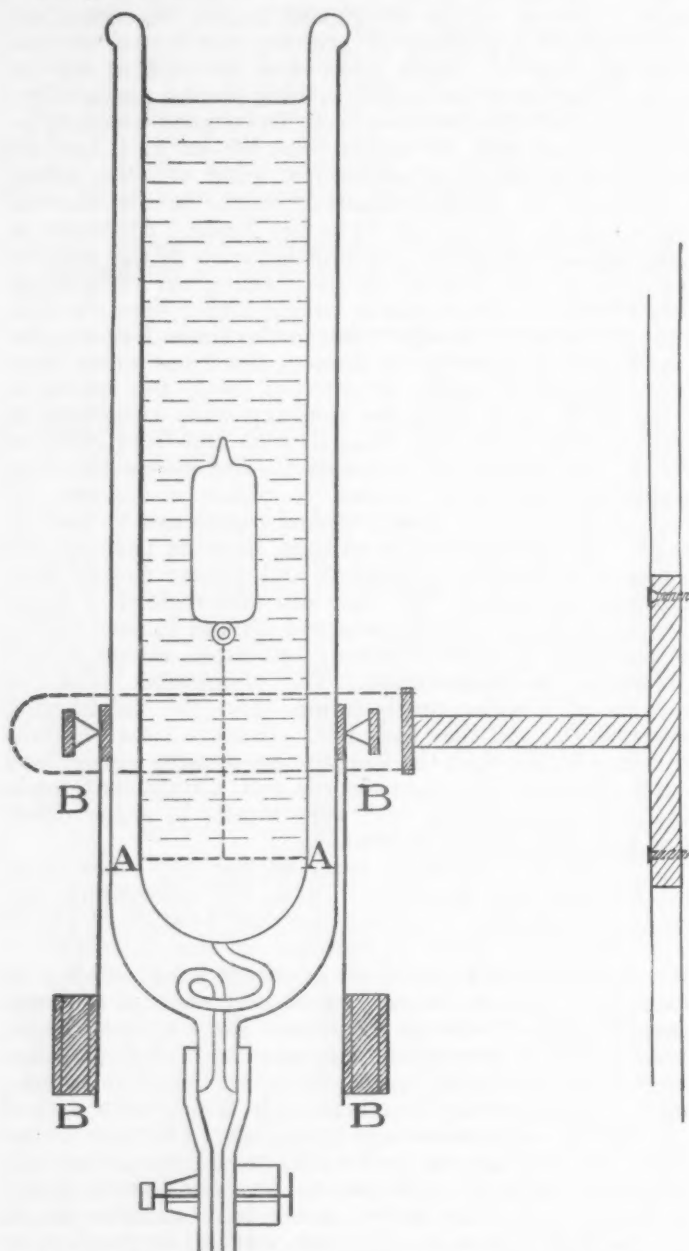


FIG. 5.—H. Pettersson's precision chain-compensated areometer, with gimbal suspension.
BBBB, gimbal mounting with counterpoises.
AA, Dewar flask vessel with float and chain.

The interested reader will recall that on page 162, column 2, Dr. Pettersson mentions a gimbal-mounted precision chain-compensated areometer of about 800 cu. cm. capacity suitable for the accurate daily work on shipboard of an hydrographical expedition. This instrument is here illustrated in figure 5.

TABLE 1.—Observations with chain-compensated gimbal areometer.

Depth.	Temperature.	Areometer reading.	Salinity (thousandths).	
			Observed.	Calculated.
meters.	° C.			
0	12.35	102	(29.51)	29.51
10	12.25	129.5	30.11	30.08
20	12.00	179.5	31.38	31.32
30	11.70	248	32.77	32.74
40	11.50	258	32.95	32.95
50	11.05	267	(33.06)	33.06
60	11.32	244	33.08	33.06

The work of this instrument is illustrated by Table 1, wherein the salinity (in thousandths), as observed with the instrument, is compared with the computed values.—*Editor.*

HAIL SQUALL OF MAY 1, 1917, AND ACCOMPANYING WEATHER, BALTIMORE, MD.

By Dr. LEONARD KEENE HIRSHBERG.

[1937 Madison Avenue, Baltimore, Md.]

For 60 hours before the hail squall here discussed there had been a mean, sluggish wind blowing across Baltimore from the east and southeast. Some humans seemed to be unpleasantly affected during those two and a half days. They seemed to be soggy, with uncomfortable chilly sensations and "headachy." As one intelligent gentleman of 40, supposedly in good health, reported, when he went to bed on those two nights the back of his house—turned toward the southeast—had a chill, unpleasant draught through it which seemed to be blowing faster than the 12 to 15 miles an hour indicated on the Weather Bureau anemometer. In his bedroom, at the front (northwest side) of his house, his usual blanket spread with two sheets, seemed too heavy and caused him to sweat like a consumptive. However, when he threw off either the sheets or the blanket he felt chilly and achy. Others also complained of much the same feelings during these two days.

On the afternoon of May 1 the writer went to the roof of a high building situated on a hill in the heart of Baltimore. The sun had shone in some fashion all these 60 hours, albeit not very clearly or brilliantly. As I looked over the city at 1:15 p. m. on this date I suddenly noticed that all the flags flying north of Lombard Street, which runs due east and west, drooped, while the flags flying at points south of that street continued to float pointing due northwest (southeast wind) as they had been doing for the past 60 hours. At the instant I called the attention of my two companions (Jesse Wilcox and W. Harry Noeth) to this phenomenon and as they confirmed the observation the drooping flags to the north floated up again but pointed oppositely to those on the south. Thus Lombard Street marked a dividing line between a northeast wind on its northern side and a southeast wind on its southern side. During the next five minutes the flags on the north slowly swung round into a southeast, some into a south, wind.

As we stood marveling at this odd situation we heard a dull rumble of thunder, the first thunder heard; and not until then did the none too brilliant sun and sky begin to be covered with clouds which came from nowhere else. The clouds seemed to form right before our eyes.

Between 1:25 and 1:30 p. m. there were two flashes of lightning, only one of which was forked and was due west of the city at the horizon; there were also four dull but not distant claps of thunder.

Just at 1:30 by the clock on the Baltimore Sun Building, and after the lightning and thunder had ceased, came a terrific shower with drops [seeming] as large as half-dollar pieces and with hailstones ranging from the size of a pea to small a cherry. The hail fell continuously for 11 minutes, until 1:41 p. m., accompanied by huge raindrops which continued to fall for two minutes after the hail stopped, i. e., until 1:43 p. m. The hailstones had an average diameter of one-fourth to one-half inch and the larger sized stones did not appear until seven minutes after hail began to fall.

After 1:43 p. m. there was a fall of atomized spray for one minute and then the sun came forth to shine more clearly and brilliantly than it had done for a week or 10 days past. All the rest of May 1 the atmosphere was remarkably dry and clear; the wind was a variable northerly one of not more than 8 or 10 miles per hour.

PHOTOGRAPHS OF THE ANTLER, N. DAK., TORNADO OF AUGUST 20, 1911.

By HOWARD E. SIMPSON, Special Meteorological Observer.

[University, N. Dak., May 9, 1917.]

Tornadoes are very infrequent in North Dakota, but three having been reported to the Weather Bureau since the establishment of its service in this State in 1891. Finley, in his map of tornado frequency, places the State outside of the tornado area. The occurrence of these three and of the well-known Regina tornado far to the northwest in Canada, shows that recent and more complete data would greatly extend the area of known distribution in the Northwest. This does not mean that there is an actual enlargement of the area distribution of tornadoes, or that they are on the increase. It simply means that before the region was settled no tornadoes were reported.

One of the North Dakota tornadoes had the distinction of being international in its course and of having its characteristics recorded in a series of three photographs. The distance traveled by the storm between photographs was about $1\frac{1}{2}$ miles; that by the photographer but a single village block.

The photographs are by Mr. W. H. Wegner, of Antler, N. Dak., to whom the Weather Bureau is indebted not only for the photographs, but for much of the information contained in this report.

The Antler tornado.

About 6:30 p. m. Sunday evening, August 20, 1911, a tornado approached the village of Antler, Bottineau County, N. Dak. (lat. $48^{\circ} 59' N.$, long. $101^{\circ} 16' W.$), from the west. At a point $1\frac{1}{2}$ miles west of the village it turned slightly to the northeast and passed within a short distance of the city limits. It crossed Antler Creek 2 miles north of the village and followed the general course of the creek northeastward across the international boundary line into Canada.

Due north of Antler the storm struck Manning's Grove, on Antler Creek, where a large number of people were picnicking among the trees. In the total destruction of the pavilion, where many had sought refuge,

and among the falling trees 22 were injured and 2 killed. Elsewhere two others were killed, and the property loss, chiefly in the form of farm buildings and grain in the field, probably exceeded \$100,000.

Since the storm passed so close to town, a number of persons viewed it at close range, yet outside of the danger zone. The photograph shown in figure 1 was taken from the western edge of town, when the storm was $1\frac{1}{2}$ miles to the west. Up to this point the storm was advancing almost due eastward upon the town, but here it veered off to the northeast, passing about 1 mile to the northwest of the photographer. Figure 2 shows the base of the funnel cloud at the point in its path nearest the village. Figure 3 shows the storm 2 miles distant and due north of the town. The photograph was taken just as it struck the grove on Antler Creek, where so many people were injured.

The first photograph of the tornado cloud is undoubtedly one of the best photographs of a tornado funnel ever published (Figs. 1, 4, and 5). The main overhanging storm cloud above a well-defined cloud level and the characteristic pendant funnel are well shown. The flying wisps beneath the cloud cover, the fuzzy margins of the funnel, and the low dust clouds trailing at its heel, all reveal the violent motion of the storm winds. The very local character of the destructive tornado winds is shown in the erect and motionless attitude of the young trees and bushes of the village, though a storm of the most violent type known to man is approaching at a distance of but $1\frac{1}{2}$ miles.

The tornado at this point was not accompanied by the usual thunderstorm, and the clouds stand out distinctly against the light background of the evening sky. The photograph presents, therefore, with remarkable clearness the essential features of a tornado cloud not masked by the usual thunderstorm accompaniment.

The second photograph (fig. 2) was taken looking toward the west-northwest; the storm was nearer, less than a mile distant, and moving diagonally toward the right across the field of vision. A distinct tendency for the funnel to drag like the trail rope of a balloon is evident, and while the front edge is clearly defined the rear is ragged and partly obscured by dust and rain. The trees in the village are practically stationary in the region of calm without the tornado.

The exposure for the third photograph (fig. 3) was made looking due north, just at the moment when the storm was taking its largest toll of life and limb at Manning's Grove, on Antler Creek, 2 miles north of town. The storm is moving diagonally across the field of vision toward the right. On reaching the creek, a few moments before, it is reported to have turned gray in color. The funnel is here seen to be lagging at a still greater angle from the vertical; it has a well-marked heel as well as trailing cloud, and seems to be preceded by rain falling from the front of the upper cloud. It is less compact and shows signs of disintegration. The front of the storm has here reached the international boundary line. The storm path could be traced but a short distance in Canada, and the breaking up in this picture is believed to be the beginning of its dissipation.

Figure 5 is from a double print combining an enlargement of the first photograph (fig. 4) of the tornado cloud with a later photograph of the identical foreground under light conditions more favorable for the bringing out of detail. In this double print neither negative has been retouched. The double print was made to satisfy local and popular interest.

Other tornadoes on August 20, 1911.

The Antler storm was the most destructive of several tornadoes experienced in Bottineau County between 5:30 and 6:30 p. m. on the same day. At least 6 different funnel-shaped clouds formed within the single tornadic area as it passed over this county. Three were reported as being seen from Antler and 6 funnel clouds are reported as having been plainly visible from Souris, 27 miles east and 5 miles south of Antler. Serious damage was reported from but one of these funnels, viz, one which appeared 4 miles southwest of Souris, where it destroyed one farmstead, killing one man and injuring several others. After moving along the ground for but a short distance the funnel rose into the overhanging cloud and disappeared, but reappeared again for a short time as it approached the slope of the Turtle "Mountains" 6 miles to the east.

SOME RESEARCHES IN THE FAR EASTERN SEASONAL CORRELATIONS.¹

(SECOND NOTE.)

By T. OKADA.

[Reprinted from Journal of the Royal Meteorological Society of Japan, May, 1917, 36:41-49.]

1. *Correlation between the July temperatures at San Francisco, Cal., and Erimo in northern Japan.*—It is a well-known fact that in the summer season the North Pacific HIGH area is a controlling agent of the air temperature on both sides of the North Pacific. A slight shifting to the westward of this action-center gives temperatures below the normal on the western coast of the United States, and the eastward shifting of the HIGH area gives abnormally low temperatures on the eastern coast of northern Japan.

An opposition is traced between the July temperatures (x , y) at San Francisco in California and Erimo in Hokaido. We give below the July temperatures and departures (Δx , Δy), etc., at both stations.

TABLE 1.—July temperatures at San Francisco and Erimo.

[x in the second column means the air temperature at San Francisco, and y in the third column that at Erimo.]

Year.	x	y	Δx	Δy	$\Delta x \Delta y$	$(\Delta x)^2$	$(\Delta y)^2$
	$^{\circ}C.$	$^{\circ}C.$					
1890.....	15.4	15.9	+1.1	+0.9	+0.99	1.21	0.81
1891.....	15.2	15.8	+0.9	+0.8	+0.72	0.81	0.64
1892.....	14.5	17.8	+0.2	+2.8	+0.56	0.04	7.84
1893.....	13.7	13.8	-0.6	-1.2	+0.72	0.36	1.44
1894.....	13.6	16.5	-0.7	+1.5	-1.05	0.49	2.25
1895.....	14.7	15.3	+0.4	+0.3	+0.12	0.16	0.09
1896.....	15.2	14.9	+0.9	-0.1	-0.09	0.81	0.01
1897.....	14.6	14.0	+0.3	-1.0	-0.30	0.09	1.00
1898.....	13.4	15.1	-0.9	+0.1	-0.09	0.81	0.01
1899.....	13.3	16.9	-1.0	+1.9	-1.90	1.00	3.61
1900.....	14.6	13.6	+0.3	-1.4	-0.42	0.09	1.96
1901.....	13.1	16.0	-1.2	+1.0	-1.20	1.44	1.00
1902.....	15.1	14.0	+0.8	-1.0	-0.80	0.64	1.00
1903.....	14.0	14.2	-0.3	-0.8	+0.24	0.09	0.64
1904.....	13.9	15.9	-0.4	+0.9	-0.36	0.16	0.81
1905.....	15.3	14.5	+1.0	-0.5	-0.50	1.00	0.25
1906.....	14.2	15.6	-0.1	+1.6	-0.16	0.01	2.56
1907.....	14.4	14.0	+0.1	-0.1	-0.10	0.01	1.00
1908.....	14.1	13.5	-0.2	-1.5	+0.30	0.04	2.25
1909.....	14.3	14.5	± 0.0	-0.5	± 0.00	0.00	0.25
1910.....	13.6	15.0	-0.7	± 0.0	± 0.00	0.49	0.00
1911.....	13.6	16.5	-0.7	+1.5	-1.05	0.49	2.25
1912.....	14.4	14.1	+0.1	-0.9	-0.09	0.01	0.81
1913.....	15.9	13.1	+1.6	-1.9	-3.04	2.56	3.61
1914.....	13.9	14.6	-0.4	+0.6	+0.16	0.16	0.16
Means.....	14.3	15.0					
Sums.....					-7.34	12.97	35.25

¹ The previous paper (first note) appeared in this REVIEW, January, 1916, 44: 17-21.—EDITOR.

The temperature data for Erimo have been taken from the Annual Reports of the Central Meteorological Observatory, Tokyo. The daily mean temperature has been calculated from the 6 daily observations, and approximates very closely the true mean temperature. The San Francisco data have been extracted from Prof. A. G. McAdie's "Climatology of California" and the Annual Reports of Chief of the Weather Bureau (4th edition). The mean temperatures at San Francisco given in Table 1 are the sum of the mean maximum and mean minimum temperatures divided by two, and are not reduced to the true mean temperatures as Hofrat Prof. J. von Hann² already remarked. Von Hann has given a small table of corrections to be applied to the many-years' means to reduce them to the true monthly means. But it must be remarked that generally the corrections are different from year to year. Hence the San Francisco temperatures given in the above table differ from the true monthly means, and the difference from the true mean temperature is different year for year. This is specially the case when a secular variation having an amplitude of the order of magnitude comparable to that of the variation under consideration, is superposed on the latter. In such a case the usual method for calculating the correlation coefficient gives an unduly small value.

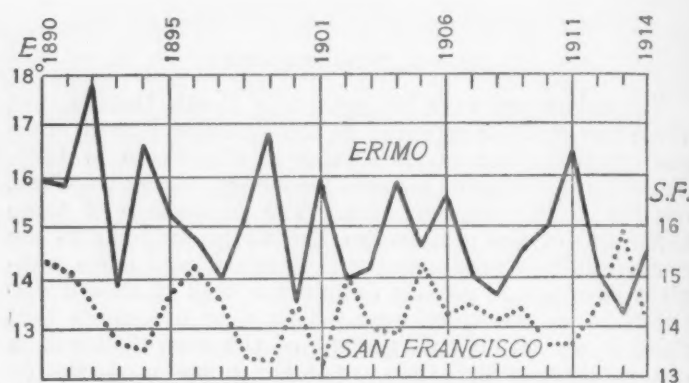


FIG. 1.—Graphic presentation of the fluctuations in the July temperatures at San Francisco, Cal., and Erimo, Hokaido, Japan, 1890-1914, inclusive.

From figure 1, which shows the above data in graphic form, we see that there is a well-established correlation between the July temperatures at San Francisco and Erimo; and the abnormally high temperature on the California coast is associated with abnormally low temperature of this [Japanese] shore of the Pacific.

But the correlation coefficient deduced from the data given in Table 1, is -0.34 and the probable error ± 0.119 . These values are simply suggestive of a connection between the July temperatures on both sides of the Pacific, but they are far from being conclusive of the connection. This apparent discrepancy between the conclusions arrived at by the graphic representation and the calculation, arises from the fact that the fundamental assumption for the calculation of a correlation coefficient is not fulfilled in the present case; that is to say, some unknown variations are superposed on the variation under consideration. Hence it will be rather advisable to compare the variation of temperatures year for year instead of the temperatures themselves. We give in Table 2 the variations of the July temperatures at San Francisco and Erimo. In this table δx means the varia-

² J. von Hann. Klimatologie von Kalifornien. Meteorol. Zeit., 1907, 455.
A. G. McAdie. Die wahre Mitteltemperatur von San Francisco, Kalifornien. Meteorol. Zeit., 1908, p. 330.



FIG. 1.—The Antler, N. Dak., tornado of August 20, 1911, looking west from Antler, distant 1½ miles. Enlarged from original of figure 4. Photograph by W. H. Wegner, Antler, N. Dak.

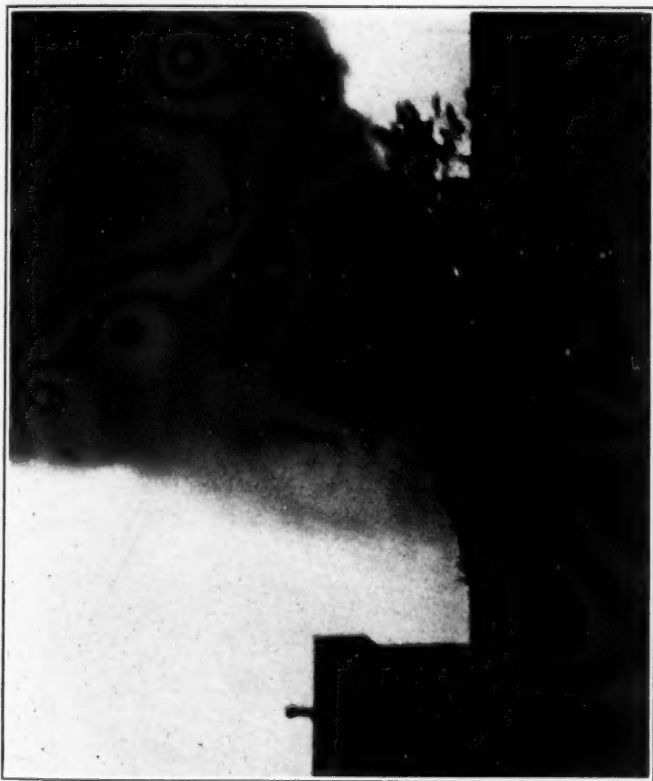


FIG. 2.—The Antler, N. Dak., tornado, looking west-northwest from Antler, distant 1 mile.



FIG. 3.—The Antler, N. Dak., tornado, looking north from Antler, distant 2 miles.



FIG. 4.—View of figure 1 on original scale, from a somewhat lighter print. The original print reveals some of the inner details of the funnel.



FIG. 5.—The Antler, N. Dak., tornado. Photograph in figure 4 enlarged and double printed, without retouching, with later photograph of identical foreground.

TORNADO AT ANTLER N. D. AUG. 20 1911. COPYRIGHT, 1911 BY W.H. WEGNER.

tions of the San Francisco temperatures and δy those of the Erimo temperatures.³

TABLE 2.—Correlation of variations of July temperatures at San Francisco (δx) and Erimo (δy).

Year.	x	y	Variations.				
			δx	δy	$\delta x \cdot \delta y$	$(\delta x)^2$	$(\delta y)^2$
1889	14.9	14.8					
1890	15.4	15.9	+0.5	+1.1	+0.55	0.25	1.21
1891	15.2	15.8	-0.2	-0.1	+0.02	0.04	0.01
1892	14.5	17.8	-0.7	+2.0	-1.40	0.49	4.00
1893	13.7	13.8	-0.8	-4.0	+3.20	0.64	16.00
1894	13.6	16.5	-0.1	+2.7	-0.27	0.01	7.29
1895	14.7	15.3	+1.1	-1.2	-1.32	1.21	1.44
1896	15.2	14.9	+0.5	-0.4	-0.20	0.25	0.16
1897	14.6	14.0	-0.6	-0.9	+0.54	0.36	0.81
1898	13.4	15.1	-1.2	+1.1	-1.32	1.44	1.21
1899	13.3	16.9	-0.1	+1.8	-0.18	0.01	3.24
1900	14.6	13.6	+1.3	-3.3	-4.29	1.69	10.89
1901	13.1	16.0	-1.5	+2.4	-3.60	2.25	5.76
1902	15.1	14.0	+2.0	-2.0	-4.00	4.00	4.00
1903	14.0	14.2	-1.1	+0.2	-0.22	1.21	0.04
1904	13.9	15.9	-0.1	+1.7	-0.17	0.01	2.89
1905	13.3	14.5	+1.4	-1.4	-1.96	1.96	1.96
1906	14.2	15.6	-1.1	+1.1	-1.21	1.21	1.21
1907	14.4	14.0	+0.2	-1.6	-0.32	0.04	2.56
1908	14.1	13.5	-0.3	-0.5	+0.15	0.09	0.25
1909	14.3	14.5	+0.2	+1.0	+0.20	0.04	1.00
1910	13.6	15.0	-0.7	+0.5	-0.35	0.49	0.25
1911	13.6	16.5	+0.0	+1.5	+0.00	0.00	2.25
1912	14.4	14.1	+0.8	-2.4	-1.92	0.64	5.76
1913	15.9	13.1	+1.5	-1.0	-1.50	2.25	1.00
1914	13.9	14.6	-2.0	+1.5	-3.00	4.00	2.25
Sum			-1.0	-0.2	-22.57	25.11	77.44

A glance at this table shows that in 25 cases we find 19 in which the signs are the reverse of each other and 6 in which they agree. Hence the probability of the opposition of the air temperatures at San Francisco and Erimo is 19/25ths, or 76 per cent. The correlation coefficient deduced from the above data is -0.51 and the probable error ± 0.102 . It may be therefore concluded that in July a temperature seesaw is fairly established on both sides of the North Pacific. When the July temperature at Erimo in northern Japan is higher than the average, the temperature at San Francisco in California is abnormally low, and vice versa.

2. Correlation between the April temperature at Irkutsk and the July temperature at San Francisco.—In the first note [M. W. R., January, 1916] of my researches on this subject I have traced a remarkable parallelism between the March barometric gradient at Zi-ka-wei near Shanghai and the July temperature on the east coast of northern Japan. This and the result given in the preceding paragraph induced me to search for an eventual correlation between the spring temperature on the Asiatic Continent and the summer temperature on the American coast of the North Pacific. After trials I have traced a marked opposition between the April temperature at Irkutsk in eastern Siberia and the air temperature at San Francisco for the following July. The temperature data for both stations are given in Table 3. The temperatures at Irkutsk have been taken from Annales de l'Observatoire

physique central Nicolas, the record beginning with 1887. Unfortunately the recent records are not within my reach. In the table z means the April temperature at Irkutsk and x the July temperature at San Francisco.

TABLE 3.—Correlation of April temperature at Irkutsk (z) and July temperature at San Francisco (x).

Year.	z	x	Departures.		$\Delta z \cdot \Delta x$	$(\Delta z)^2$	$(\Delta x)^2$
			Δz	Δx			
	$^{\circ}\text{C.}$	$^{\circ}\text{C.}$					
1887	1.7	13.7	+0.9	-0.7	-0.63	0.81	0.49
1888	-1.6	16.3	-2.4	+1.9	-4.56	5.76	3.61
1889	0.2	14.9	-0.6	+0.5	-0.30	0.36	0.25
1890	-0.3	15.4	-1.1	+1.0	-1.10	1.21	1.00
1891	-0.3	15.2	-1.1	+0.8	-0.88	1.21	0.64
1892	0.3	14.5	-0.5	+0.1	-0.05	0.25	0.01
1893	4.6	13.7	+3.8	-0.7	-2.66	14.44	0.49
1894	-0.8	13.6	-1.6	-0.8	+1.28	2.56	0.64
1895	2.0	14.7	+1.2	+0.3	+0.36	1.44	0.09
1896	1.4	15.2	+0.6	+0.8	+0.48	0.36	0.64
1897	1.0	14.6	+0.2	+0.2	+0.04	0.04	0.04
1898	1.9	13.4	+1.1	-1.0	-1.10	1.21	1.00
1899	3.9	13.3	+3.1	-1.1	-3.41	9.61	1.21
1900	-1.7	14.6	-2.5	+0.2	-0.50	6.25	0.04
1901	1.0	13.1	+0.2	-1.3	-0.26	0.04	1.69
1902	-0.8	15.1	-1.6	+0.7	-1.12	2.56	0.49
1903	0.6	14.0	-0.2	-0.2	+0.08	0.04	0.16
1904	-0.3	13.9	-1.1	-0.5	+0.55	1.21	0.25
1905	-1.5	15.3	-2.3	+0.9	-2.07	5.29	0.81
1906	4.5	14.2	+3.7	-0.2	-0.74	13.69	0.04
1907	1.9	14.4	+1.1	+0.0	0.00	1.21	0.00
Means	0.8	14.4					
Sums	17.7	93.1			16.59	68.34	13.59

$$r = -\frac{16.59}{(68.34)^{\frac{1}{2}} \times (13.59)^{\frac{1}{2}}} = -0.53, \quad E = \pm 0.6745 \frac{(1-r^2)}{\sqrt{21}} = \pm 0.106.$$

Looking at the columns showing the departures from the normal it will be seen that the signs are opposite in 15 cases, and the same in 6 cases out of the 21 cases under consideration. The correlation coefficient deduced from the above data is -0.53 and the probable error ± 0.106 .

Hence we may conclude that when the April temperature at Irkutsk is higher than the normal we may expect with a high degree of probability that the temperature at San Francisco in the following July will be abnormally low, and vice versa.

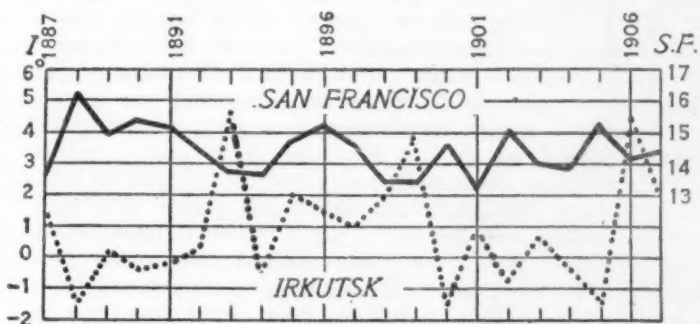


FIG. 2.—Graphic presentation of the opposition between the April temperature at Irkutsk and the temperature at San Francisco for the following July.

The above result will be of some interest on account of its bearing on the possibility of issuing a seasonal forecast on the Pacific coast of the United States, which Mr. A. G. McAdie³ has ardently advocated.

³ McAdie, A. G. Forecasting on the Pacific coast. MONTHLY WEATHER REVIEW, April, 1908, 36: 98-100.

³ Note by the Editor.—In the interest of clearness in notation the followingsystem has been adopted in this paper:

x = July temperatures at San Francisco, Cal.; Δx and δx = corresponding departures
 y = July temperatures at Erimo, Japan; Δy and δy = corresponding departures
 z = April temperatures at Irkutsk; Δz and δz = corresponding departures
 k = January-February pressure at Zi-ka-wei; Δk and δk = corresponding departures
 w = July-August pressure at Nemuro, Japan; Δw and δw = corresponding departures
 r = coefficient of correlation; E = probable error.

3. *Correlation between the winter barometric pressure at Zi-ka-wei near Shanghai and the summer barometric pressure at Nemuro in northern Japan.*—A marked opposition is traced between the barometric heights at Zi-ka-wei in January and February and those at Nemuro in July and August. We give below the barometric data for both stations. In this table k refers to Zi-ka-wei and w to Nemuro.

The last two columns contain the variations ($\delta k, \delta w$) of the barometric heights from year to year at both stations. The correlation coefficient deduced from these quantities is -0.41 . From the above results we may conclude that when the barometer stands higher than the average at Irkutsk in January and February we may expect that the pressure at Nemuro in the following July and August will be abnormally low.

TABLE 4.—Mean barometric pressures at Zi-ka-wei in January and February (k) and at Nemuro in July and August (w).

Year.	k	w	Δk	Δw	$\Delta k, \Delta w$	$(\Delta k)^2$	$(\Delta w)^2$	Annual variations.	
								δk	δw
	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.	mm.
1886.....	770.3	758.4	+1.2	+0.2	+0.24	1.44	0.04	.....	.....
1887.....	769.0	758.4	-0.1	+0.2	-0.02	0.01	0.04	-0.7	± 0.0
1888.....	769.4	756.6	+0.3	-1.6	-0.46	0.09	2.56	+0.4	-1.8
1889.....	770.4	757.4	+1.3	-0.8	-1.04	1.69	0.64	+1.0	+0.8
1890.....	768.1	759.2	-1.0	+1.0	-1.00	1.00	1.00	-2.3	+1.8
1891.....	769.3	757.4	+0.2	-0.8	-0.16	0.04	0.64	+1.2	-1.8
1892.....	768.6	757.9	-0.5	-0.3	+0.15	0.25	0.09	-0.7	+0.5
1893.....	769.7	757.8	+0.6	-0.4	-0.24	0.36	0.16	+1.1	-0.1
1894.....	769.1	756.6	± 0.0	-1.6	0.00	0.00	2.56	-0.6	-1.2
1895.....	768.1	758.8	-1.0	+0.6	-0.60	1.00	0.36	-1.0	+2.2
1896.....	769.4	758.3	+0.3	+0.1	+0.03	0.09	0.01	+1.3	-0.5
1897.....	769.3	758.2	+0.2	± 0.0	0.00	0.04	0.00	-0.1	-0.1
1898.....	767.3	757.8	-1.8	-0.4	+0.72	3.24	0.16	-2.0	-0.4
1899.....	769.0	757.8	-0.1	-0.4	+0.04	0.01	0.16	+1.7	± 0.0
1900.....	770.4	757.0	+1.3	-1.2	-1.56	1.69	1.44	+1.4	-0.8
1901.....	769.9	758.2	+0.8	± 0.0	0.00	0.64	0.00	-0.5	+1.2
1902.....	769.7	759.0	+0.6	+0.8	+0.48	0.36	0.64	-0.2	+0.8
1903.....	770.6	757.7	+1.5	-0.5	-0.75	2.25	0.25	+0.9	-1.3
1904.....	769.3	758.5	+0.2	+0.3	+0.06	0.04	0.09	-1.3	+0.8
1905.....	767.3	758.9	-1.8	+0.7	-1.26	3.24	0.49	-2.0	+0.4
1906.....	767.9	758.3	-1.2	+0.1	-0.12	1.44	0.01	+0.6	-0.6
1907.....	769.3	758.7	+0.2	+0.5	+0.10	0.04	0.25	+1.4	+0.4
1908.....	769.8	758.8	+0.7	+0.6	+0.42	0.49	0.36	+0.5	+0.1
1909.....	768.5	759.1	-0.6	+0.9	-0.54	0.36	0.81	-0.4	+0.3
1910.....	768.3	759.8	-0.8	+1.6	-1.28	0.64	2.56	-0.2	+0.7
Sums.....					-7.19	20.45	15.32		
Means....	769.1	758.2							

$$r = -\frac{7.19}{(20.45)^{\frac{1}{2}} \times (15.32)^{\frac{1}{2}}} = -0.41; \quad E = \pm 0.6745 \frac{(1-r^2)}{\sqrt{n}} = \pm 0.112.$$

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR MAY, 1917.

By H. C. FRANKENFIELD, Supervising Forecaster.

[Dated: Washington, June 9, 1917.]

GENERAL PRESSURE DISTRIBUTION OVER THE NORTHERN HEMISPHERE, EXCEPT EUROPE AND INTERIOR ASIA.

Over the northeastern portion of the North Pacific Ocean pressure was moderately low during the first two weeks of May, 1917, and moderately high during the second two weeks, followed by a falling tendency during the last three days of the month. These same conditions prevailed generally over the southeastern portion of the North Pacific Ocean, as indicated by the pressure at Honolulu. Over the northwestern portion of the North Pacific low pressure prevailed continuously. Marked low pressure conditions were also reflected later in the month over the northeastern portion of the North Pacific, but during the first two weeks high pressure prevailed over this section and extended over northern and central Alaska, continuing throughout the month with only a single interruption on the 18th and 19th. Over southern Alaska pressure was variable during the first 20 days of the month within quite narrow limits, but during the remaining days it was moderately high.

In the Pacific States there were alternating periods of pressure slightly above and slightly below the normal, each of several days duration as a rule, but none of great consequence.

Over the interior of the United States proper, from the Mississippi Valley westward, moderately high pressure prevailed almost uniformly during the first half of the month, while during the second half of the month low pressure ruled, with occasional intervals of pressure slightly above normal. To the eastward low pressure prevailed throughout practically the entire month; it was of abnormal persistence and extended over the entire eastern Canadian Provinces, markedly so over eastern Newfoundland. The last 10 days of the month were characterized by a series of disturbances of the Colorado type that move eastward and northeastward south of the high-pressure area, attended by widespread precipitation and severe local storms, with many disastrous tornadoes.¹

Over the North Atlantic Ocean pressure was also generally low during the first half of the month and slightly above normal during the second half over the north portion, and about normal over the southern portion. The persistence of the western and northwestern high pressure and the southern low pressure, coupled with the prevailing low pressure over the Atlantic Ocean, furnished a satisfactory explanation of the abnormally low temperatures that prevailed during much of the month.

STORM WARNINGS.

While there were no great storms during the month, there was a considerable number that required the display of storm warnings, specially the series of storms of the Colorado type that prevailed during the last 10 or 12 days of the month.

¹ For an extended and illustrated discussion of the weather conditions accompanying these storms and tornadoes see the REVIEW for June, 1917.

At the close of April storm warnings were displayed on the Great Lakes, a disturbance of marked intensity being central over that region. On the morning of May 1 warnings were changed to northwest for Lakes Michigan, Huron, and western Erie, and northwest warnings were ordered hoisted on northeast Lake Huron. Moderately strong winds occurred during the day and night following, except on Lake Michigan, where there were no high winds during the night and the warnings were accordingly lowered at 9 p. m. This storm also caused some moderately high winds of some duration along the New England coast during the night of the 1st, but they were not of a character sufficient to justify storm warnings.

On the morning of the 4th a southwestern disturbance was central over eastern Kentucky with a rather rapid northeastern movement, and accordingly southeast storm warnings were ordered at 11 a. m. from Hatteras, N. C., to Philadelphia, and northeast warnings northward to Portsmouth, N. H., with the information that the easterly winds would become strong and shift to west on the following day. During the next 24 hours fresh to strong northeasterly gales prevailed along the southern New England, New Jersey, and Delaware coasts, but there was nothing of consequence to the southward, the disturbance having diminished in energy and dividing into two sections. Northeast storm warnings were also ordered at 10:30 a. m. of the 4th on the Lower Lakes, strong northeast to north winds with rain or snow having been indicated. Only fresh to moderately strong northwest winds occurred.

On the morning of the 5th, with the bifurcated disturbance over western Pennsylvania and eastern North Carolina, the northeast storm warnings were continued from Sandy Hook to Portsmouth, N. H., and extended along the coast of Maine. Strong northeast winds occurred as forecast and continued until after the morning of the 6th.

On the morning of the 7th a disturbance that apparently moved from Arizona to the mouth of the Rio Grande and thence northeastward was central over northeastern Gulf of Mexico. Special observations indicated an increasing intensity of the disturbance, and accordingly at 3 p. m. northeast storm warnings were ordered from Charleston, S. C., to the Virginia Capes, and at 10 p. m., with the disturbance central on the South Carolina coast, the northeast warnings were extended northward to New York. On the morning of the 8th the storm was central near the North Carolina coast, with considerably increased intensity, and the northeast storm warnings were therefore extended northward along the New England coast from Bridgeport, Conn., to Boston. During the night of the 7th and on the 8th strong northeast to north winds prevailed from the South Carolina coast northward to Delaware. As the storm moved northeastward at a considerable distance from the coast, there were no strong winds north of the Delaware Capes until the 9th, and then only on the coast of Maine, where they continued until sometime during the night of May 10-11. Northeast storm warnings had been ordered along the eastern Maine coast at 12:30 p. m. of the 9th, and on the morning of the 10th the storm was central over Nova Scotia, with a barometer reading of 28.96 inches at Halifax.

On the morning of May 19 there was a well-defined disturbance over Wisconsin and upper Michigan, and as midday observations indicated a further development with an eastward movement, southwest storm warnings were ordered at 2:30 p. m. displayed from Harbor Beach to Oswego, N. Y., strong south and south west winds and thundersqualls being indicated. These occurred as forecast with wind velocities ranging as high as 56 miles an hour.

On the morning of the 21st another storm from the southwest was central over central Kansas with a northeastward movement, and small-craft warnings were ordered at 10 a. m. on Lakes Michigan, Huron, and Erie, and northeast storm warnings on Lake Superior from Duluth to Houghton. Special observations showed the rather rapid movement of the storm with increasing energy, and at 3 p. m. northeast warnings were ordered for the balance of Lake Huron while the warnings elsewhere on the Lakes, as far east as Erie, Pa., were changed to northeast. During the next 24 to 36 hours strong winds occurred as forecast, except on southern Lake Huron, where they were only fresh. On the morning of the 22d, with the storm central over Illinois, southeast warnings were ordered from Buffalo to Oswego for increasing east to south winds that would become strong and shift to north and northwest on the following day with gale force. Again the winds occurred as forecast, with a maximum velocity of 68 miles an hour from the southwest at Buffalo. At 3 p. m. of the 22d the warnings were changed from northeast to northwest on eastern Lake Superior, Lake Huron, and western Lake Erie, as strong northwest winds were indicated; they occurred during the succeeding 24 hours.

As this storm was not moving very far to the northward, southwest warnings were also ordered at 3 p. m. on the 22d from Tybee Island, Ga., to Eastport, Me., and moderately strong winds occurred as forecast.

On the morning of the 23d with the storm central over Ontario, the southeast warnings that were displayed from Buffalo to Oswego were changed to southwest; the southwest warnings on the Atlantic coast from Sandy Hook, N. J., to Nantucket were changed to northwest; and southwest warnings were continued on the New England coast north of Nantucket. At 3 p. m. of the 23d the southwest warnings from Buffalo to Oswego were changed to northwest and continued at 3 p. m. of the 24th. Southwest storm warnings were also ordered on the Atlantic coast from Delaware Breakwater to Atlantic City; but by the night of the 24th the storm had reached the St. Lawrence Valley with much decreased intensity, and all warnings were therefore lowered after a two-day period of strong winds.

On the morning of the 26th another storm of the western series was central over northwestern Iowa, and at 10:30 a. m. northeast storm warnings were ordered for Lake Superior and southeast warnings for Lake Michigan and northern Lake Huron. At 3 p. m. the southeast warnings were extended over southern Lake Huron and western Lake Erie, and at 10 p. m. over eastern Lake Erie and Lake Ontario, at which time the storm was central over Illinois with somewhat decreased intensity. Owing to the fact that another storm from the southwest closely followed this storm, there were no winds of consequence, nothing more than fresh winds having been recorded. On the morning of the 27th the second storm referred to in the preceding sentence was central over Oklahoma, and northeast warnings were ordered at 10:30 a. m. on Lakes Michigan and Huron,

and on Lake Erie from Detroit to Toledo. This storm passed over the Ohio Valley, and as no strong winds were indicated at the time, the warnings were ordered down at 10 p. m. of the 27th on Lake Michigan and on Lake Huron from Saginaw northward. However, at 8 p. m. of the 22d the storm was central over southern Illinois in such formation as to indicate an increase in intensity, and northeast warnings were therefore ordered from Sandusky to Oswego, N. Y., warnings still being displayed south of Saginaw as far as Toledo. Owing to the absence of a decided rise in pressure to the westward of this disturbance, no strong winds occurred.

On the morning of the 28th, with the storm central over southwestern Ohio, northeast warnings were ordered from Delaware Breakwater to Portland, Me., and southeast warnings from Baltimore to Charleston. The warnings were generally verified by the occurrence of strong winds and gales, Norfolk, Va., reporting a velocity of 60 miles from the southwest during the afternoon of the 28th. On the morning of the 29th, when the storm was central off the southern New England coast, the northeast warnings were extended along the Maine coast, east of Portland, and fresh gales occurred during the following 24 hours.

On the morning of the 30th still another of the southwestern storms was central over eastern Kentucky, and at 10:30 a. m. southeast warnings were ordered for Lakes Michigan and Huron, and small-craft warnings on Lake Superior. Special midday observations indicated the necessity of an extension of the warnings, and at 3 p. m. southeast warnings were ordered on Lake Erie from Detroit to Erie. The warnings for Lake Erie were justified, while those for Lake Michigan and Huron failed. On the morning of the 31st, with the storm central over southern Wisconsin, the Lake warnings were extended from Buffalo to Oswego, but only moderately strong winds occurred. The warnings on Lakes Michigan and Huron were also changed to southwest and northwest at 10:30 a. m. of the 31st, and small-craft warnings ordered on Lake Superior, but by evening it was apparent that no strong winds would occur, and the warnings were accordingly lowered at 9 p. m.

FROST WARNINGS.

Frost warnings were ordered almost daily for some section during the first two weeks of the month and others might have been ordered so far as indications of coming frost were concerned, but as the lateness of the season precluded any damage of consequence they were not ordered. This latter statement applies more directly to the Upper Lakes region, where heavy to killing frosts occurred quite often during the first two weeks of the month. Over other sections in the Washington forecast district frosts were not of consequence.

The coldest weather of the month in the Upper Lakes region occurred on May 23, when freezing temperatures and snows were quite general.

WARNINGS FROM OTHER DISTRICTS.

Chicago forecast district.—On the morning of May 1, frosts being general in the Plains States and the Missouri Valley, warnings were issued for portions of Illinois, Wisconsin, Iowa, and North Dakota, and on the morning of the 2d for eastern Wisconsin. These warnings were verified as a rule. On the 4th a disturbance was central over Tennessee, moving eastward, while high pressure and

abnormally low temperature prevailed in the States to the west and north. Frost warnings were issued for Illinois, Missouri, Iowa, Wisconsin, and extreme eastern Kansas, and were generally verified. Warnings were issued each day from the 5th to 13th, inclusive, for some portion of the upper Mississippi Valley or western Lakes region, and were partially verified. No further warnings of importance were issued until the 22d, when they were issued for Iowa, Wisconsin, and southeastern Minnesota. Frost occurred the following morning throughout the upper Mississippi Valley and western Lakes region. On the 23d, 24th, and 27th warnings were sent to the Wisconsin cranberry marshes. Warnings which were issued for portions of the Dakotas, the upper Mississippi Valley, and the western Lakes region on the 30th and 31st were not verified.—*Chas. L. Mitchell, Assistant Forecaster.*

New Orleans forecast district.—On the 29th the p. m. map showed an area of low pressure of some intensity central over extreme northwestern Texas. Southeast storm warnings were ordered for the Texas coast and were verified.

Frost warnings for extreme northwestern Oklahoma and the Texas Panhandle were issued on the 3d; for northwestern Arkansas and northeastern Oklahoma, on the 4th; for Arkansas, on the 5th, with warning of freezing in the Texas Panhandle; for Arkansas, Oklahoma, and northern and extreme western Texas, on the 6th, with warning of heavy frost in Oklahoma, northern Arkansas, and northwestern and extreme western Texas, and freezing in extreme northwestern Oklahoma and the northern portion of western Texas; for northern Arkansas and northeastern Oklahoma, on the 7th; for Arkansas and northeastern Oklahoma, on the 8th; for the Texas Panhandle and extreme northwestern Oklahoma, on the 11th; for northwestern Oklahoma and the northern portion of western Texas, on the 27th. The warning of the 6th was verified over the greater portion of the indicated area. At El Paso, Tex., the lowest May temperature of record, 44°F., was recorded. A slight rise in temperature prevented the verification of warnings for the 11th and 27th. All other warnings were justified.—*R. A. Dyke, Assistant Forecaster.*

Denver forecast district.—May, 1917, was characterized by a winter-like distribution of pressure; in fact, the weather of this month was more unsettled and unpleasant than in the average winter month. Storms developed in rapid succession in the western part of this district, and in not a few instances a new storm formed before the preceding storm had passed eastward beyond the district. The storms invariably crossed the district and generally in the southern part so that in addition to frequent precipitation there was a remarkable persistency of unseasonably cold weather.

On the morning of May 2 low pressure prevailed from Utah southeastward to central Texas, while moderately high pressure overlay the Pacific Northwest. Warnings of frost were issued for western Utah. Frosts occurred throughout Utah. On the 3d warnings of frost were issued for Colorado and northern New Mexico, the pressure at the time being lowest in Texas with isobaric loops extending westward to Arizona, while moderately high pressure prevailed north of the district. Frosts occurred in the area designated. In the Grand Valley fruit district the lowest temperature reported was 27° at Loma, and in the Gunnison fruit district, 26° at Paonia. On the 4th the pressure was relatively low west of the Continental Divide and high in the Pacific Northwest. Local frosts were forecast for Utah.

On the 5th freezing temperature was forecast for Colorado and northern New Mexico and occurred as forecast;

the lowest temperatures reported were: From the Grand Valley, 27° at Palisade; in the Gunnison district, 21° at Spring Creek and 26° at Santa Fe. At the time the forecast was issued low pressure prevailed in New Mexico and high pressure north of the district; the low was forced southward by the northern high pressure which moved to eastern Colorado, increasing in intensity. Warning of freezing temperature was therefore continued for eastern Colorado and New Mexico and warning of frost or freezing temperature for western Colorado. For El Paso the predicted minimum was 38°, and for Roswell, N. Mex., 28°. Reports of the following morning showed the minimum temperatures of 38° and 28°, respectively, both of these readings being the lowest of record for May. On the morning of the 16th an energetic low center was northeast of Montana with looped isobars extending to the southern limits of the district. In expectation of the eastward movement of the high from the middle Pacific coast frost warnings were issued for Utah and western Colorado. This warning was verified in localities.

On May 22 high pressure overlay Wyoming and the Dakotas, while relatively low pressure prevailed in the Southwest. Warnings of frost were issued for eastern Colorado and northern New Mexico; but the high moved toward the east and it is probable that frosts, if they occurred, were exceedingly light. On the morning of the 31st a low pressure area overlay New Mexico, and high pressure Montana and Wyoming. Warning of frost was issued for northeastern Colorado. At Denver the temperature reached 33°F., the lowest of record for June.—*Frederick H. Brandenburg, District Forecaster.*

San Francisco forecast district.—No marked storms moved in over this district from the ocean during May, but many depressions formed over the southern Plateau, causing cloudy and showery weather. Several of these depressions developed into quite severe storms after they crossed the Rockies. Light showers, mostly confined to the mountain and foot hill sections, were of frequent occurrence and thunderstorms accompanied by heavy rainfall occurred in the upper Sacramento Valley on the 25th. The forecasts of showers were more successful than the charts indicated, as most of the rain fell in sections from which reports are not received.

Killing frosts were forecast for Nevada on the 3d, 5th, and 16th, all of which were verified.

Northwest warnings were displayed at Point Reyes on the 24th, and a velocity of over 70 miles an hour occurred.—*G. H. Willson, District Forecaster.*

Portland, Oreg., forecast district.—Although May is generally a pleasant month in this forecast district, the weather this year was cooler than usual, due to the abnormal amount of cloudiness. The rainfall was nearly normal. During most of the month well-developed high-pressure areas lay over the North Pacific Ocean, while moderate low-pressure areas were present the greater portion of the time over the intermountain region and Southern Plateau States. This distribution of pressure gave the usual northwesterly winds, but the proximity of the disturbances to the southeastward and over the eastern portion of the district resulted in making this the cool, rainy month mentioned above. Night temperatures did not go very low, as a rule, but cloudiness prevented the usual afternoon "warming up" on fair days.

No storm warnings were issued during the month, and none were needed. One live-stock warning was sent out on the 8th, and as weather conditions changed very little during the remainder of the month, no other warnings were issued. This information was timely, and the service is, we believe, appreciated by the stockmen and farm-

ers. Forest Supervisor W. W. Cryder, of Pendleton, has written this office:

The stockmen and farmers have come to regard your predictions as extremely valuable and necessary to their business. I want you to feel that they appreciate very much what you are doing for them. We all know what a difficult season you have had to contend with, and understand clearly the reason why more forecasts have not been issued.

Fortunately, there were no very cold spells, and the principal losses to the stockmen were on account of scarcity and high prices of feed, some stock succumbing on account of lack of sufficient nourishing food.

Frost warnings were issued on 8 dates. Of these 5 were for general frosts, light west of the Cascade Mountains and

heavy to the eastward, and 3 were for local frosts. In western Washington and northwestern Oregon the warnings were generally failures, due to continued cloudiness; while most of the remainder were verified in part only, some were wholly accurate. Heavy frost occurred locally at Baker, in the Blue Mountains of northeastern Oregon, on the 16th, 19th, and 20th, without warning; and on the 16th an unforeseen minimum temperature of 30°, without warning, was reported from the Rogue River Valley, but fruit had reached such an advanced stage that no injury resulted.—*T. Francis Drake, Assistant Forecaster.*

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS DURING MAY, 1917.

By ALFRED J. HENRY, Professor in Charge.

[Dated: River and Flood Division, June 29, 1917.]

The month was free from floods of a general character, although several of the great rivers were in moderate flood throughout some part of their respective courses. The Mississippi was in flood between Quincy, Ill., on the north and Grafton, Ill., on the south, and it was also in flood for a short time in the stretch between Arkansas City, Ark., and New Orleans, La. The flood in the middle stretch of the river had its origin in the run-off from melting snow in Minnesota and Wisconsin, augmented by heavy rains in Missouri, Iowa, and Illinois during the last week of April. The run-off from the rainfall happened to synchronize with the run-off from snowfall above mentioned; hence the occurrence of a flood in the middle stretch of the river. The principal damage due to this flood was occasioned by the breaking of levees and the flooding of lands in certain drainage districts in the Hannibal, Mo., river district. The flood in the lower river was a continuation of the flood described in this REVIEW, April, 1917, 45:176.

The following account of the spring flood of 1917 in the Memphis district is of value in this connection.

HIGH WATER IN THE MEMPHIS DISTRICT, 1917.

The spring rise in the Mississippi River in the Memphis district was first indicated by a sharp rise at Cairo, Ill., on February 22, which reached Memphis on February 24, and Helena, Ark., February 25. The stages on those dates were considerably below the seasonal normal, but during the following 9 or 10 days the daily rise amounted to a foot or more, bringing the river to flood stage at New Madrid on March 13; Memphis, March 21; Helena, March 22.

The numbers of days from the beginning of the rise until the arrival of the flood crest were as follows: New Madrid, 42; Memphis, 44; and Helena, Ark., 47.

The maximum stages and dates, with the number of days above flood stage, are as follows:

New Madrid, Mo., 39.3 feet, April 4; above flood stage, 39 days.

Memphis, 40.1 feet, April 9; above flood stage, 32 days.

Helena, Ark., 49.9 feet, April 13; above flood stage, 36 days.

There is a remarkably close resemblance between the spring rise of the present year and that of 1907, except that the latter occurred somewhat earlier in the season. The crest stages at Cairo and Memphis were each only two-tenths of a foot higher in 1907 than the record for the present year, while at New Madrid the crest stages in both years were the same. Also the gage relation both as to height and time movement of the crest, were practically the same throughout the district while the area inundated was identical in both cases.

The overflowed territory in 1917 embraced all of the island plantations as well as the low lands on the east bank of the river, known as the Tennessee Bottoms, and all of the lands unprotected by levees in Arkansas and southeast Missouri, in all considerably less than during the February flood of 1916.

Owing to the high water, all levee and other river improvement work was suspended for a period of about 40 days and caused serious delay in farm work. In a few cases mills were obliged to close down for a time, but otherwise no serious inconvenience to mill owners occurred.

The first flood warning was issued on March 16, and on March 20 the information that a stage of 39 feet was probable, caused farmers and others occupying the territory liable to overflow at that stage to remove their stock and workmen to places of safety. One firm in Memphis having a large amount of cotton stored in a warehouse, having its floor on a level with a 38-foot stage on the Memphis gage, at once began moving the cotton and thereby saved it from injury. Without the

warning the loss would have amounted to several thousand dollars. One mill owner who heeded the warning constructed a temporary embankment about the plant, and as a result there was no suspension of work and there was no damage to the stock on hand.

The principal loss occasioned by the high water was the suspension of river improvement work and the consequent loss of wages and the delay in farm work that is keenly felt at this time. There was no real damage worth mentioning.—S. C. Emery, Meteorologist.

A few rivers in the Ohio Basin reached flood stage during the closing days of the month, but no damage was done.

The Columbia River was in flood in the upper reaches of the stream, and the flood continued into June. The lower Colorado was not in severe flood because the low temperatures over the higher portions of the watershed prevented a rapid melting of the winter's snowfall. The same cause, low temperature, was effective in retarding the annual flood in the Columbia.

Details as to dates of occurrence and crest stages observed in the various rivers throughout the country will be found in Tables 1 to 4, below.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

TABLE 1.—Flood stages in Atlantic Coast and Great Lakes drainage May, 1917.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
Connecticut.....	White River Junction, Vt.	Feet. 13	.....	.....	Feet. 12.0	3
Santee.....	Rimini, S. C.	12	.....	.....	10.9	10, 11
Do.....	Ferguson, S. C.	12	.....	.....	10.8	11
GREAT LAKES.						
Cass.....	Vassar, Mich.	14	.....	.....	13.9	25
Grand.....	East Lansing, Mich.	8	.....	.....	7.3	29

TABLE 2.—Floods in Ohio Basin, May, 1917.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
Monongahela.....	Fairmont, W. Va.	Feet. 25	28	28	Feet. 25.2	28
Do.....	Greensboro, Pa.	20	29	29	20.0	29
Do.....	Lock No. 4, Pa.	31	.....	.....	28.9	29
Little Kanawha.....	Glenville, W. Va.	22	29	29	22.3	29
Do.....	Creston, W. Va.	20	28	29	24.0	28
Hocking.....	Athens, Ohio.	17	.....	.....	15.1	29
Licking.....	Farmers, Ky.	25	.....	.....	20.9	29
Do.....	Falmouth, Ky.	28	.....	.....	26.7	28
Wabash.....	La Fayette, Ind.	11	.....	.....	10.3	24
Do.....	Mount Carmel, Ill.	15	.....	.....	14.1	31
West Fork of White.	Elliston, Ind.	19	28	31	23.0	30

TABLE 3.—Floods in Mississippi River and tributaries, May, 1917.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.		
			From—	To—	Stage.	Date.	
<i>Mississippi proper.</i>							
Mississippi	Keokuk, Iowa	Feet. 14			Feet. 13.5		
Do.	Warsaw, Ill.	17			16.6	2	
Do.	Quincy, Ill.	14	1	8	15.3	3	
Do.	Hannibal, Mo.	13	1	12	16.2	3, 4	
Do.	Louisiana, Mo.	12	1	11	15.2	3	
Do.	Grafton, Ill.	18	3	8	18.9	5	
Do.	Cape Girardeau, Mo.	30			27.7	5	
Do.	Arkansas City, Ark.	42	1	4	46.6	1	
Do.	Greenville, Miss.	42			40.4	1	
Do.	Vicksburg, Miss.	45	1	6	48.5	1	
Do.	Natchez, Miss.	46	1	8	49.3	1	
Do.	Baton Rouge, La.	35	1	11	37.9	1, 2	
Do.	Donaldsonville, La.	28	1	9	29.6	1, 2	
Do.	New Orleans, La.	18	1	7	18.2	1, 3, 4	
<i>Eastern tributaries.</i>							
St. Croix	Stillwater, Minn.	11	1	7	11.7	2	
Illinois	Beardstown, Ill.	12	1	13	12.7	5, 6, 7	
Do.	Pearl, Ill.	12	4	9	12.7	6	
Yazoo	Swan Lake, Miss.	25	1	3	26.2	1	
Do.	Yazoo City, Miss.	25	1	19	29.5	1, 2	
<i>Western tributaries.</i>							
Meramec	Pacific, Mo.	11	1	3	12.8	2	
Do.	Glencoe, Mo.	15			13.6	1	
Do.	Valley Park, Mo.	14	1	3	15.4	2	
Bourbeuse	Union, Mo.	10	1	1	10.5	2	
St. Francis	Marked Tree, Ark.	17	1	1	17.0	1	
Atchafalaya ¹	Simmesport, La.	41	1	7	41.7	1-3	
Do.	Melville, La.	37	1	15	39.6	1, 2	
<i>Missouri Basin.</i>							
Missouri	Running Water, S. Dak.	16			14.7	26	
Do.	Blair, Nebr.	15			14.6	29	
Do.	Kansas City, Mo.	22			19.9	31	
James	Huron, S. Dak.	9			8.6	1, 2	
Solomon	Beloit, Kans.	16	27	27	20.0	27	
Grand	Chillicothe, Mo.	18	1	8	25.1	4	
<i>Arkansas Basin.</i>							
White	Batesville, Ark.	23			21.2	5	
Do.	Georgetown, Ark.	22			20.8	12	
Black	Black Rock, Ark.	14	4	9	16.5	5	
Cache	Jelks, Ark.	9			8.6	1	
<i>Red River Basin.</i>							
Sulphur	Finley, Tex.	24			23.8	5	

¹ Tributary to Gulf of Mexico.

TABLE V.—Floods in Pacific Coast drainage, May, 1917.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.		
			From—	To—	Stage.	Date.	
<i>Sacramento Basin.</i>							
Kings.....	Piedra, Cal.....	<i>Feet.</i> 12			<i>Feet.</i> 11.1	14	
<i>Columbia Basin.</i>							
Columbia.....	Marcus, Wash.....	24	26	(*)	26.8	31	
Do.....	Wenatchee, Wash.....	40			37.0	31	
Do.....	The Dalles, Oreg.....	40			37.3	31	
Do.....	Umatilla, Oreg.....	25			22.7	31	
Do.....	Vancouver, Wash.....	15	15	(*)	21.7	31	
Kootenai.....	Bonniers Ferry, Idaho.....	26			23.6	30	
Pend d'Oreille.....	Newport, Wash.....	16	28	(*)	18.4	31	
Clearwater.....	Kamiah, Idaho.....	14	29	30	15.4	30	
Willamette.....	Portland, Oreg.....	15	15	(*)	21.0	31	

(*) Continued into June.

TABLE 4.—Floods in West Gulf and Colorado drainage, May, 1917.

River.	Station.	Flood stage.	Above flood stages—dates.		Crest.	
			From—	To—	Stage.	Date.
		<i>Feet.</i>			<i>Feet.</i>	
Trinity.....	Dallas, Tex.	25	29	29	27.6	29
Rio Grande.....	San Marcial, N. Mex.	11	1	(*)	14.7	20
Do.....	Rio Grande, Tex.	15	13	13	17.8	13
Colorado.....	Topock, Ariz.	14	21	31	20.4	25
Grand.....	State Bridge, Colo.	9	18	18	9.8	18
Gunnison, North Fork.....	Paonia, Colo.	9	15	31	9.2	18, 19
Green.....	Green River, Wyo.	9	.....	.....	8.4	24, 25
Do.....	Elgin, Utah.	13	21	25	13.7	23, 25

(*) Continued into June.

MEAN LAKE LEVELS DURING MAY, 1917.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., June, 1917.]

The following data are reported in the "Notice to Mariners" of the above date.

Data.	Lakes.*			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during May, 1917:	Feet. 602.38	Feet. 581.14	Feet. 572.93	Feet. 246.51
Above mean sealevel at New York				
Above or below—				
Mean stage of April, 1917	+0.10	+0.36	+0.36	+0.27
Mean stage of May, 1916	+0.42	+0.70	+0.07	-0.62
Average stage for May, last 10 years	+0.47	+0.65	+0.15	-0.36
Highest recorded May stage	-0.67	-2.38	-1.49	-2.44
Lowest recorded May stage	+1.56	+1.58	+1.62	+1.55
Average relation of the May level to—				
April level	+0.3	+0.3	+0.4	+0.5
June level	-0.4	-0.3	-0.1	-0.2

* Lake St. Clair's level: In May, 576.07 feet.

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR MAY, 1917.

W. J. HUMPHREYS, Professor in charge.

[Dated: Weather Bureau, Washington, D. C., July 3, 1917.]

TABLE 1.—Non-instrumental earthquake reports, May, 1917.

Date.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
CALIFORNIA.										
1917. May 11	H. m. 22 36	Markleeville..... Towle.....	38 42 39 14	119 46 120 48	5 5	1 2	M. s. 8	Rumbling...		W. S. Cayan. F. L. Harmon.
18	6 06	Calexico.....	32 41	115 30	3	1	1	Rumbling...	Sounds before shock.	C. N. Perry.
19	6 35	Yorba Linda.....	33 51	117 50	5	2	3	Faint.....	Awakened people.	W. A. Walker.
19	7 19	Yorba Linda.....	33 51	117 50	4	3	3	Faint.....		W. A. Walker.
20	9 45	Yorba Linda.....	33 51	117 50	5	1		Rumbling...	Shook buildings.	W. A. Walker.
27	9 30	Brawley.....	32 59	115 40	5	1		Loud.....		M. D. Witter.
28	6 07	Barrett Dam..... Blythe..... Brawley..... Calexico..... Coachella..... Indio..... Julian..... Mecca..... Mesa Grande..... Mount Wilson..... Nellie..... Point Loma..... Riverside..... Warner Springs.....	32 40 33 35 32 59 32 41 33 40 33 43 33 05 33 34 33 11 34 13 33 22 32 43 33 58 33 17	116 40 114 38 115 40 115 30 116 10 116 12 116 37 116 05 116 42 118 16 116 52 117 15 117 21 116 37	5 1 6 4-5 4-5 3-4 5 5 3 2 3-4 3 5 3	1 1 1 2 2 1 2 1 2 2 1 1 1 1	M. s. 42 20 1 00 10 3 1 1 00	None..... None..... Loud..... Rumbling..... None..... Rumbling..... None..... Rumbling..... None..... Faint..... None..... None..... None.....		R. Wieste. C. L. Suits. M. W. Witter. I. R. Ralston. Frank McCarroll. Bruce Drummond. J. H. L. Vogt. E. A. Palmer. E. H. Davis. Wendell P. Hoge. Esther Hewlett. F. J. Dick. Press report. J. A. Ream.
28	7 05	Calexico.....	32 41	115 30	3	1	12	None.....		H. M. Rouse.
28	10 17	Julian.....	33 05	116 37	5	1	10	Rumbling...		W. J. Norman.
31	2 10	Brawley..... Calexico.....	32 59 32 41	115 40 115 30	5 3	1 2	1	None..... Rumbling...		M. D. Witter. H. M. Rouse.
31	4 35	Cahuilla.....	33 32	116 43	5	1	4			Dr. W. L. Shawk.
MISSOURI.										
9	9 —	Hendrickson.....	36 50	90 26	4	1	1 —	Rumbling...		Geo. Magill.
9	15 —	Hendrickson.....	36 50	90 26	3	1				Geo. Magill.
NEW YORK.										
22	8 59	Alexandria Bay..... Canton..... Malone..... Watertown.....	44 22 44 36 44 51 43 57	75 54 75 10 74 18 75 53	3 4 4-5 4-5	1 1 1 1	6 12 10	Rumbling... Faint.....	A few people awakened..... Many awakened.....	Douglas F. Manning. U. S. Weather Bureau. Press report. Press report.
22	9 19	Canton.....	44 36	75 10	3	1			Shook furniture.	U. S. Weather Bureau.
VERMONT.										
22	8 59	Ferrisburg..... Montpelier.....	44 13 44 16	73 15 72 34	3-4 3	1 1			Windows rattled..... People awakened.....	Rev. J. H. Long. Press report.

TABLE 2.—Instrumental reports, May, 1917.

[Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.]

[For significance of symbols see REVIEW for January, 1917, p. 26.]

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _N		
Alaska. Sitka. Magnetic Observatory. U. S. Coast and Geodetic Survey. J. W. Green.								
Lat., 57° 03' 00" N.; long., 135° 30' 06" W. Elevation, 15.2 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
					$V \quad T_0$			
Instrumental constants...					E	10	16.7	
					N	10	15.4	
1917.			H. m. s.	Sec.	μ	μ	km.	S and L uncertain. It may be that two earthquakes overlap.
May 1.								
	eP _N		18 38 32					
	eP _N		18 39 46					
	S _N		18 50 16	10				
	S _N		18 51 24	10				
	eL _N		18 57 38					
	L _N		19 06 57	28				
	L _N		19 09 16	28				
	M _N		19 09 48	28		160		
	M _N		19 11 16	20	160			
	C _N		19 18 —	15				
	F _N		21 19 —					
	F _N		21 24 —					
9	P _N		16 16 18	11				
	L _N		16 24 31	22				
	M _N		16 30 30	13		30		
	C _N		16 42 —	14				
	F _N		17 04 —					
31	eP _N		8 50 54	3				
	eL _N		8 53 39	20				
	eL _N		8 54 28	20				
	M _N		8 55 25	16		520		
	M _N		8 57 20	17	1,620			
	C _N		9 06 —	12				
	F _N		10 23 —					
	F _N		11 12 —					

Arizona. Tucson. Magnetic Observatory. U. S. Coast and Geodetic Survey. F. P. Ulrich.

Lat., 32° 14' 48" N.; long., 110° 50' 06" W. Elevation, 769.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

$V \quad T_0$
 Instrumental constants... $\begin{pmatrix} E & 10 & 13.9 \\ N & 10 & 18.9 \end{pmatrix}$

1917.			H. m. s.	Sec.	μ	μ	km.	
May	1	P _N	18 39 36	4				S and L doubtful.
		P _N	18 39 40	4	.....	.....	.....	
		S _N	18 50 01	11	.....	.....	.....	
		S _N	18 50 08	14	.....	.....	.....	
		L _N	19 02 41	14	.....	.....	.....	
		L _N	19 03 01	16	.....	.....	.....	
		M _N	19 08 43	21	.....	170	.....	
		M _N	19 29 52	16	280	.....	.....	
		C _N	19 42 —	16	.....	.....	.....	
		F _N	22 46 —	.....	.....	.....	.....	
25		eP _N	14 42 33	2	.....	.....	.....	
		eP _N	14 42 45	4	.....	.....	.....	
		M _N	14 43 50	6	.....	100	.....	
		M _N	14 44 05	12	140	.....	.....	
		F _N	14 57 —	.....	.....	.....	.....	
		F _N	15 02 —	.....	.....	.....	.....	
28		eP _N	6 06 42	4	.....	.....	.....	
		eP _N	6 06 44	2	.....	.....	.....	
		M _N	6 08 05	5	10	.....	.....	
		M _N	6 08 10	6	.....	20	.....	
		F _N	6 13 —	.....	.....	.....	.....	
		F _N	6 15 —	.....	.....	.....	.....	
31		P _N	8 55 24	4	.....	.....	.....	
		eP _N	8 55 39	8	.....	.....	.....	
		eS _N	9 01 41	10	.....	.....	.....	
		eS _N	9 01 41	4	.....	.....	.....	
		L _N	9 04 40	22	.....	.....	.....	
		M _N	9 08 26	12	20	.....	.....	
		M _N	9 09 57	22	.....	90	.....	
		F _N	10 52 —	.....	.....	.....	.....	
		F _N	10 56 —	.....	.....	.....	.....	

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _N		

California. Berkeley. University of California.

Lat., 37° 52' 16" N.; long., 122° 15' 37" W. Elevation, 85.4 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. Mount Hamilton. Lick Observatory.

Lat., 37° 20' 24" N.; long., 121° 38' 34" W. Elevation, 1,281.7 meters.

(See Bulletin of the Seismographic Stations, University of California.)

California. Point Loma. Raja Yoga Academy. F. J. Dick.

Lat., 32° 43' 03" N.; long., 117° 15' 10" W. Elevation, 91.4 meters.

Instrument: Two-component, C. D. West seismoscope.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _N		
1917.			H. m. s.	Sec.	μ	μ	km.	Tremors recorded during 24 hours ending 15 ^h on dates given, except the record of a local shock on the 28th.
May 2					*100	*100		
3					*100	*100		
6					*100	*100		
10					*500	*100		
16					*100	*100		
22					*100	*100		
24					*100	*200		
26					*50	*100		
28			14 —		*400	*400		2 to 3 seconds duration.
30					*50	*50		

* Amplitude on instrument.

California. Santa Clara. University of Santa Clara. J. S. Ricard, S. J.

Lat., 37° 26' 36" N.; long., 121° 57' 03" W. Elevation, 27.43 meters.

(See record of the Seismographic Station, University of Santa Clara.)

Colorado. Denver. Sacred Heart College. Earthquake Station.
A. W. Forstall, S. J.

Lat., 39° 40' 36" N.; long., 104° 56' 54" W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg.; astatic, horizontal pendulum.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _N		
1917.			H. m. s.	Sec.	μ	μ	km.	P and S somewhat obscured. Three sets of waves appear on record. Waves appear in sharp, well-defined groups with periods of calm between. Another maximum at 19 ^h 15 ^m .
May 1	P		18 49					
	S		19 04					
	L _N		19 09	30-32		*2,300		
	L _N		19 09	28-30	*2,700			
	M _N		19 10	32		*2,800		
	M _N		19 10		30	*2,800		
	C		19 51		20	*1,000		
	F		19 55					
9	L _N		16 38					Very regular sinusoidal waves. Three well-defined groups. No preliminaries visible.
	L _N		16 41					
	M _N		16 48		20	*750		
	M _N		16 50		20	*750		
	F _N		16 50					
	F _N		16 51					
17								Wavelets at intervals from 3 ^h to 13 ^h of long period and small amplitude.
31	L _N		8 43					Very distinct and regular sinusoidal waves. Time doubtful; clock stopped. No record on E-W.
	F _N		8 50					

* Trace amplitude.

TABLE 2.—Instrumental reports, May, 1917—Continued.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _n		

District of Columbia. Washington. U. S. Weather Bureau.

Lat., 38° 54' 12" N.; long., 77° 03' 03" W. Elevation, 21 meters.

Instrument: Marvin vertical pendulum, undamped. Mechanical registration.

Instrumental constants. $V = 110$ $T_0 = 6.4$

1917.			H. m. s.	Sec.	μ	μ	km.	
May 1	II _u	P	18 36 30				8,700	
		S	18 46 28					
		SR	18 52 16					
		L	18 57 08	24				
		L	19 29 30	19				
		L	19 50 00	16				
		L	20 33 00	15				
		L	20 44 00	20				
		F	23 00 00					
4		eL	1 46 00					
		F	2 35 00					
9		eL	16 18 20					
		L	16 48 00	20				
		F	17 40 00					
14*		e	21 57 30					
		L	22 02 00	20				
		F	22 35 00					
25		i	14 58 03					Phases uncertain.
		F	15 08 00					
25		e	6 21 46					In California.
		F	6 24 00					Phases indistin-
29*		eL	6 56 00					guishable.
		F	7 40 00					
31	II _u	P	8 56 56				6,140	
		S	9 04 40					
		L	9 13 00					
		F	10 35 00					L waves very irreg-
31		eL	19 54 17					ular.
		F	20 05 00					

* Occurrence and times based on experimental records of Marvin's new 2-component vertical pendulum, not yet described.

District of Columbia. Washington. Georgetown University.

F. A. Tondorf, S. J.

Lat., 38° 54' 25" N.; long., 77° 04' 24" W. Elevation, 42.4 meters. Subsoil: decayed diorite.

Instruments: Wiechert 200 kg. astatic horizontal pendulums, 80 kg. vertical.

Instrumental constants. $V = 165$ $T_0 = 5.4$ $\epsilon = 0$
 $N = 143$ 5.2 0
 $Z = 80$ 5.0 0

1917.			H. m. s.	Sec.	μ	μ	km.	
May 1		eP	18 46 06					Microseisms present.
		S _m	18 56 10					
		S _n	18 56 26					
		eL _m	19 02 11					
		eL _n	19 02 17					
		M _m	19 29 47		16			
		M _n	19 34 17			13		
		F	21 40 ..					
3		F	13 48 00					Microseisms present.
								Sheet put on at 12h
								58m; at 12h 59m long
								waves show.
4		e	1 40 55					Microseisms present.
		L _n	1 46 10	20				
		L _m	1 47 18	15				
		F	2 23 00					
9		e _m	16 36 20					Very heavy micro-
		e _n	16 36 30					seisms present. No
		eL _n	16 47 42					distinct maximum.
		eL _m	16 47 43					
		L _n	16 57 07	20				
		L _m	16 57 40	20				
		F	17 30 00					
25		e?	14 52 19					All phases doubtful.
		S _n	14 57 49					
		S _m	14 57 56					
		F	15 11 00					
31		P	8 57 05					Vertical shows P at
		S _n	9 04 42					8h 57m 9s. Other
		S _m	9 04 43					phases indistinct.
		L	9 15 38	18				
		M _m	9 20 02		21			
		M _n	9 22 38			11		
		F	11 05 ..					
31		eL	19 54 02					Microseisms present.
		F	20 10 ..					

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis-tance.	Remarks.
					A _m	A _n		

Hawaii. Honolulu. Magnetic Observatory. U. S. Coast and Geodetic Survey. Frank Neumann.

Lat., 21° 19' 12" N.; long., 158° 03' 48" W. Elevation, 15.2 meters.

Instrument: Milne seismograph of the Seismological Committee of the British Association.

Instrumental constant. $T_0 = 18.6$

1917.			H. m. s.	Sec.	μ	μ	km.	
May 1		P	18 35 54					
		L	18 44 00	21				
		M	18 58 48		*17,000			
		C	20 05 00					
		F	23 37 00					
2		P	1 38 12					
		L	1 48 00	18				
		M	1 52 18		*400			
		C	1 58 42					
2		e	3 21 30					
		M	3 37 00	18		*500		
		C	3 30 00					
		F	4 24 00					
2		eP	4 39 00					
		eL	4 49 48					
		M	4 53 06	21		*200		
		C	4 56 00					
		F	5 28 00					
2		L	14 27 12	20		*200		
		M	14 39 18					
		F	15 34 00					
3		L	13 17 30					
		M	13 29 54	19		*200		
		F	13 27 00					
4		P	0 52 54					
		L	0 59 24					
		M	1 14 00	19		*600		
		C	1 26 00					
		F	2 35 00					
6		P	23 14 00					
		L	23 23 54	21		*600		
		M	23 25 00					
		C	23 32 00					
		F	24 14 00					
7		e	8 28 00					
		M	8 28 48	19		*100		
		F	8 47 00					
9		eP	16 05 24					
		eS	16 13 54					
		L	16 21 18					
		M	16 25 00	20		*3500		
		C	16 49 00					
9		eP	19 50 06					
		L	20 00 06	20		*400		
		M	20 03 48					
		C	20 06 00					
		F	21 57 00					
10		eP	22 54 18					
		M	23 05 18	20		*200		
		C	23 09 00					
		F	23 18 00					
14		L	0 40 24					
		M	0 42 12			*100		
		F	0 57 00					
14		eP	22 17 54					
		eL	22 25 36	20		*1000		
		M	22 30 42					
		C	22 33 00					
		F	23 28 00					
18		P	19 12 12					
		L	19 21 54					
		M	19 30 00	21		*500		
		C	19 34 00					
		F	20 14 00					
21		L	9 41 00					
		M	9 43 48	15		*100		
		C	9 46 00					
		F	9 54 00					
23		L	21 53 06					
		M	21 57 06	21		*200		
		F	22 13 00					
24		eP	19 37 00					
		eS	19 43 00					
		L	19 49 18					
		M	19 52 18	19		*400		
		C	19 57 00					
		F	20 43 00					

* Trace amplitude.

Time of P doubtful. Observer entered room at time of maximum.

TABLE 2.—Instrumental reports, May, 1917—Continued.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _E	A _N		
Hawaii. Honolulu. Magnetic Observatory—Continued.								
1917.			<i>H. m. s.</i>	<i>Sec.</i>	<i>μ</i>	<i>μ</i>	<i>km.</i>	
May 24	eL		23 50 30					
	M		23 56 12	20	*100			
25	F		0 05 00					
26	eL		4 29 00					
	M		4 36 00	20	*100			
	F		4 41 00					
29	P		6 19 24					
	S		6 24 12					
	L		6 26 54	22				
	M		6 31 06		*1000			
	F		7 09 00					
31	eP		8 54 42					
	L		9 00 12					
	M		9 09 48	21	*6000			
	C		9 12 00					
	F		12 18 00					

* Trace amplitude.

Kansas. Lawrence. University of Kansas. Department of Physics and Astronomy. F. E. Kester.

Lat., 38° 57' 30" N.; long., 95° 14' 58" W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants.. $\begin{matrix} V & T_0 & \epsilon \\ \{E & 177 & 3.4 & 4:1 \\ \{N & 205 & 3.4 & 4:1 \end{matrix}$

1917.		H. m. s.	Sec.	μ	μ	km.	
May 1	eP _N	18 40 51					Very faint record. P _N not discernible.
	S	18 51 20					
	L	19 09 27	55-60				
	L _T	19 11 07	30				
	M _N	19 26 17	18	17			
	M _N	19 27 23	17		14		
	F	22 09 ..					
9	eP _N	16 13 04					Record on E-W very illegible. iP _N may be building shock.
	iP _N	16 14 00			1		
	eS _N	16 19 14					
	L _N	16 27 33					
	M _N	16 48 50	23		1		
	F	17 37 ..					
31	eP _N	8 55 46					N-S not recording properly.
	iP _N	8 55 54					
	S _N	9 02 17					
	S _N	9 06 08					
	iL _N	9 09 25					
	L _N	9 10 15	20-25				
	M _N	9 13 25		8			
	F _N	10 00 ..					

Maryland. Cheltenham. Magnetic Observatory. U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44' 00" N.; long., 76° 50' 30" W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. $\begin{matrix} V & T_0 \\ \{E & 10 & 33 \\ \{N & 10 & 25 \end{matrix}$

1917.		H. m. s.	Sec.	μ	μ	km.	
May 1	eP _N	18 45 24	2				S and L doubtful; it may be that there are two earthquakes overlapping.
	S _N	18 56 03					
	S _N	18 56 28					
	L _N	19 02 30					
	L _N	19 02 32					
	L _N	19 22 34	20				
	L _N	19 24 12	22				
	M _N	19 25 37	24	*1100			
	M _N	19 34 20	17		*450		
	C	19 47 ..	17				
	F	20 33 ..					
31	P _N	8 57 03	4				
	P _N	8 57 06	4				
	S _N	9 04 46	8				
	S _N	9 04 49	8				
	eL _N	9 13 24	19				
	eL _N	9 13 35	19				
	M _N	9 20 27	21	*500			
	M _N	9 22 46	21		*300		
	C _N	9 39 ..	14				
	C _N	9 46 ..	14				
	F _N	10 21 ..	12				
	F _N	10 26 ..					

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _E	A _N		

Massachusetts. Cambridge. Harvard University Seismographic Station, J. B. Woodworth.

Lat., 42° 22' 36" N.; long., 71° 08' 59" W. Elevation, 5.4 meters. Foundation: Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration).

Instrumental constants.. $\begin{matrix} V & T_0 & \epsilon \\ \{E & 80 & 23 & 0 \\ \{N & 50 & 25 & 4:1 \end{matrix}$

(Report for May, 1917, not received.)

Missouri. Saint Louis. St. Louis University. Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38' 15" N.; long., 90° 13' 58" W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instrument: Wiechert 80 kg. astatic, horizontal pendulum.

Instrumental constants.. $\begin{matrix} V & T_0 & \epsilon \\ \{E & 80 & 7 & 5:1 \end{matrix}$

1917.		H. m. s.	Sec.	μ	μ	km.	
May 1	III _u	eP	18 45 01				Times uncertain; wireless time service suspended.
		eS	19 ..				
		eL	19 16 ..				
		F	22 17 ..				
4	I _u	eP	1 20 ..				
		F	2 ..				
9	I _u	e _g	16 50 ..				
		F	17 40 ..				
25	I _u	e	14 52 ..				
		F	15 02 ..				
31	II _u	eP	8 56 ..			5,100	
		S?	9 02 04				
		L	9 08 ..				
		M	10 10 03	20	5		
		F	10 20 ..				

New York. Buffalo. Canisius College. John A. Curtin, S. J.

Lat., 42° 53' 02" N.; long., 78° 52' 40" W. Elevation, 190.5 meters.

Instrument: Wiechert, 80 kg., horizontal.

Instrumental constants.. $\begin{matrix} V & T_0 & \epsilon \\ \{E & 80 & 7 & 5:1 \end{matrix}$

(Report for May, 1917, not received.)

New York. Fordham. Fordham University. Daniel H. Sullivan, S. J.

Lat., 40° 51' 47" N.; long., 73° 53' 06" W. Elevation, 23.9 meters.

Instrument: Wiechert, 80 kg.

Instrumental constants.. $\begin{matrix} V & T_0 & \epsilon \\ \{E & 72 & 7.2 & 1.5:1 \\ \{N & 72 & 7.2 & 3.8:1 \end{matrix}$

(Report for May, 1917, not received.)

TABLE 2.—Instrumental reports, May, 1917—Continued.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _N	A _S		

New York. Ithaca. Cornell University. Heinrich Ries.

Lat., 42° 26' 58" N.; long., 76° 29' 09" W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kg., horizontal pendulums (mechanical registration).

Instrumental constants. $\begin{matrix} V & T_0 & e \\ \{E & 13 & 22 & 4:1 \\ & N & 14 & 25 & 4:1 \end{matrix}$

1917. May 1	eP _N	H. m. s.	Sec.	μ	μ	km.	Instrument out of order during later part of April.
	eP _N	18 45 54	6				
	P _N	18 46 10	6				
	S _N	18 51 58	7				
	S _N	18 55 57	20				
	eS _N	18 56 08	20				
	eS _N	19 02 18	22				
	eS _N	19 02 26	17				
	L _N	19 14 50	56				
	M _N	19 35 02	18		340		
	M _N	19 38 42	17	250			
	F _N	22 16 ..					
	F _N	22 57 ..					
2	eL _N	2 25 38	16				
	F _N	2 53 ..					
2	eL _N	4 01 15	16				
	F _N	4 44 ..					
2	eL _N	5 34 24	17				
	F _N	5 55 ..					
4	eL _N	1 34 15	20				
	F _N	2 23 ..					
9	e _N	16 40 35	24				
	F _N	17 46 ..					
9	e _N	20 36 05	17				
	F _N	20 49 ..					
25	e _N	14 57 57	3-9				
	F _N	15 09 ..					
31	P _N	8 56 34	4				
	P _N	8 56 40	4				
	S _N	9 04 02	7				
	S _N	9 04 05	6				
	eL _N	9 13 07	7-20				
	eL _N	9 13 10	7-18				
	F _N	10 58 ..					
	F _N	11 13 ..					

Panama Canal Zone. Balboa Heights. Isthmian Canal Commission.

Lat., 8° 57' 29" N.; long., 79° 33' 29" W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants. $\begin{matrix} V & T_0 \\ \{E & 10 & 20 \\ & N & 10 & 20 \end{matrix}$

(Report for May, 1917, not received.)

Porto Rico. Vieques. Magnetic Observatory. U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 09' N.; long., 65° 27' W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants. $\begin{matrix} V & T_0 \\ \{E & 10 & 17.5 \\ & N & 10 & 18.0 \end{matrix}$

1917. May 1	eP _N	H. m. s.	Sec.	μ	μ	km.	S and L uncertain. It may be that two earthquakes over- lap.
	eP _N	18 37 35	7				
	eP _N	18 46 43	7				
	S _N	18 56 25	12				
	S _N	18 56 27	18				
	L _N	19 21 50	30				
	L _N	19 22 27	20				
	M _N	19 22 55	27	*130			
	M _N	19 25 27	23		*270		
	M _N	19 40 07	18		*270		
	M _N	19 40 15	17	*130			
	C _N	20 00 ..	16				
	C _N	20 04 ..	15				
	F _N	21 05 ..					
	F _N	21 27 ..					
9	eP _N	16 35 00					
	M _N	17 12 30	26		*30		
	F _N	18 08 00					
31	P _N	9 09 10					
	M _N	9 33 40	20	*30			
	M _N	9 33 45	18		*180		
	C _N	9 39 ..	16				
	C _N	9 42 ..	16				
	F _N	10 25 ..					
	F _N	10 30 ..					

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _N	A _S		

Vermont. Northfield. U. S. Weather Bureau. Wm. A. Shaw.

Lat., 44° 10' N.; long., 72° 41' W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants. $\begin{matrix} V & T_0 \\ \{E & 10 & 15 \\ & N & 10 & 16 \end{matrix}$

1917. May 1	II _N	P	H. m. s.	Sec.	μ	μ	km.	
		P	18 37 28				8,380	
		S	18 47 04					
		L	18 57 00	20				
		L	19 23 20	34				
		L	19 27 20	20				
		F	22 40 00					
9		e	16 18 13					
		L	16 46 45	34				
		F	17 25 00					
25		e	14 59 23					
		F	15 10 00					
31	II _N	P	8 56 57				5,680	
		S	9 04 16					
		L	9 13 26	20				
		F	11 00 00					
31		e	19 57 00					
		F	20 00 00					

Canada. Ottawa. Dominion Astronomical Observatory. Earthquake Station. Otto Klotz.

Lat., 45° 23' 38" N.; long., 75° 42' 57" W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants. $\begin{matrix} V & T_0 \\ \{E & 120 & 26 \end{matrix}$

1917. May 1	O	H. m. s.	Sec.	μ	μ	km.	O and distance ap- proximate.
	eP _N	18 27 ..				12,900	
	eP _N	18 42 00					
	iS _N	18 54 58					
	e _N	18 56 28	20				
	i _N	18 56 54					
	e _N	19 15 ..	56-48				
	e _N	19 21 ..	40-26				
	eL _N	19 23 36	30				
	eL _N	19 24 00	24				
	M _N	19 35 00	18		180		
	L _N	19 40 00	16				
	L _N	19 47 00	16				
	L _N	20 00 00	16				
	L _N	20 19 00	15				
	LR1 _N	20 25 00	40				
	LR1 _N	20 26 00	24				
	L _N	20 31 00	25				
	L _N	20 42 00	20				
	F _N	21 40 00					
2	eL _N	2 28 00					
	L _N	2 40 ..	16				
	L _N	2 50 ..					
2	eL _N	4 01 ..					
	L _N	4 01 ..	20-16				
	L _N	4 15 ..					
2	eL _N	15 08 18					
	L _N	15 17 ..	20				
	L _N	15 30 ..					
3	eL _N	12 56 00					
	L _N	13 08 00	18				
	F _N	13 35 00					
4	eP _N	1 33 23				5,000?	
	eP _N	1 33 26					
	S _N	1 40 06					
	S _N	1 40 10					
	eL _N	1 47 36	18				
	eL _N	1 48 24	18				
	L _N	1 56 ..	18-15				
	L _N	2 22 ..					
	F _N	2 45 ..					
9	O	16 02 45				8,380	
	eP _N	16 14 25					
	eP _N	16 14 26					
	S _N	16 24 02					
	S _N	16 24 05					
	eL _N	16 39 00	20				
	L _N	16 44 24	40				
	L _N	16 56 00	20				
	L _N	17 10 00	11				
	F _N	17 45 ..					

TABLE 2.—Instrumental reports, May, 1917—Continued.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					Δ_N	Δ_S		

Canada. Ottawa. Dominion Astronomical Observatory—Continued.

1917.			<i>H. m. s.</i>	<i>Sec.</i>	μ	μ	<i>km.</i>	
May 22	eP		9 00 34				30	Local shock. A few people were awak- ened.
	S		9 00 37					
	F		9 00 42					
25	eP?		14 50 10				950?	
	eL?		15 01 14	8				
	F		15 15 —					
28	eP?		6 22 40					
	eP?		6 23 09					
	eL		6 24 30	7				
	eL		6 25 36	8				
	F		6 32 —					
31	O		8 47 23				5,580	
	iP		8 56 28					
	eP		8 56 29					
	SRL		9 07 36					
	eL		9 12 00	10				
	L		9 16 00	20				
	M		9 17 30	20	35	165		
	L		9 33 00	16-14				
	L		9 44 —	14-12				
	L		9 55 —	13-12				
	L		10 02 —	11				
	LR1?		11 16 30	10				
	F		11 45 00					
31	eL		{ 19 56 — 20 08 — }	20				

Canada. Toronto. Dominion Meteorological Service.

Lat., 43° 40' 01" N.; long., 79° 23' 54" W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrumental constant... 18. Pillar deviation: 1 mm. swing of boom=0.50".

1917.			H. m. s.	Sec.	μ	μ	km.	
May 1	P		18 42 06					Vibrations large and clearly de- fined. S waves of large ampli- tude.
	iP		18 46 24					
	eS		18 53 24					
	iS		18 54 48					
	iS		18 56 30	12-18	*5000			
	iL		19 03 06					
	L		19 21 30					
	iL		19 25 36					
	iL		19 27 36					
	M		19 31 48		*27000+			
	M		19 37 18					
	M		19 40 00					
	iL		19 45 12					
	iL		19 47 12					
	iL		19 49 18					
	L		19 50 18					May be part of pre- ceding quake.
	L		21 52 42					
	L		22 51 18					
	L		23 42 06					
2	F		0 51 54					
2	L		2 21 36					
	eL		2 25 42					
	M		2 27 54		*400			
	F		3 13 12					
2	L?		3 31 54					
	eL		3 59 42					
	M		4 12 24		*400			
	F		5 06 24					
2	e?		5 15 24					
	eL		5 26 30					
	M		5 29 18		*300			
	F?		7 19 12					
2	e		8 14 18		*50			
	F		8 18 00					
2	e?		14 39 30					
	L		15 02 06					
	e		15 11 36					
	eL		15 15 24					
	M		15 17 24		*300			
	F		15 30 36					
3	e		13 01 36					
	L		13 05 00					
	M		13 06 18		*200			
	F		13 30 24					

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _N	A _S		
Canada. Toronto. Dominion Meteorological Service—Continued.								
1917.			H. m. s.	Sec.	μ	μ	km.	
May 4	e		0 49 36					
	e		1 13 12					
	e		1 35 54					
	eL		1 44 18					
	M		1 50 06		*700			
	eL		1 54 12					
	M		1 56 12		*700			
	e		3 13 54					
	F		3 35 06					
6	e		23 41 06					
	L		23 52 00					
7	L		0 00 48					
	eL		0 03 48					
	M		0 06 48		*300			
	F		0 42 00					
7	e		9 19 06		*50			
	F		9 24 30					
9	e		16 18 30					Marked distur- ance.
	S?		16 28 30					
	e		16 32 42					
	L		16 41 06					
	L		16 45 12					
	iL		17 00 00	18				
	iL		17 03 00					
	M		17 06 00		*1600			
	M		17 09 00		*1600			
	L		18 14 18					
	L?		18 39 18					
	F		18 53 48					
9	L		20 34 00					Possibly a dual earthquake.
	eL		20 36 00					
	M		20 37 30		*500			
	L		21 40 12					
	L		21 41 18					
	M		21 49 24		*800			F in air currents
14	L?		22 35 18					Phases masked air currents.
	L?		22 49 30					
	L?		23 19 54					F lost in air rents.
24	eL		20 25 06					
	M		20 27 42		*200			F?
25	L		14 58 30					
	M		15 01 12		*100			
	F		15 05 12					
29	L		6 59 48					Marked gradual creasing and creasing thick- ing.
	eL		7 04 12					
	M		7 12 30		*300			
	F		7 48 12					
31	P		8 56 30				5,500	In Alaska. Mark record.
	S		9 03 42					
	eS		9 06 48					
	iS		9 07 48					
	L		9 13 06					
	L		9 14 00	18-24				
	iL		9 21 30		*4000			
	M		9 21 30					
	eL		10 02 42					
	L _{rep}		12 05 24					
	F		12 29 12					
31	L		19 53 36		*50			

Canada. Victoria, B. C. Dominion Meteorological Service.

Lat., 48° 24' N.; long., 123° 19' W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant... 18. Pillar deviation, 1 mm., swing of boom=0.54".

1917.			H. m. s.	Sec.	μ	μ	km.	
May 1	P		18 31 32				6,370	Kamchatka.
	S		18 39 28	12-18				
	L		18 49 54					
	M		19 15 01					
	F		19 18 09		*17,000+			
			23 35 01					
	VERTICAL.				Δ_z			Time unreliable for L, M, and F.
	P		18 32 00	4-5				
	S		18 40 20	8-10				
	L?		18 50 00	24				
	M		19 00 00	20				

* Trace amplitude.

TABLE 2.—Instrumental reports, May, 1917—Continued.

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _m	A _n		
Canada. Victoria, B. C. Dominion Meteorological Service—Contd.								
1917. May	2	P or S. M. F.	H. m. s. 1 51 22 2 10 43 2 31 32	Sec.	μ	μ	km.	‡
	2	L. F.	3 41 27 4 04 44					M at cut-off.‡
	2	M.	5 12 12		*200			‡
	2	L? M.	14 54 52 15 02 49					‡
	3	M. F.	13 18 09 13 22 32		*400			
	4	P? M. F.	1 06 45 1 41 27 2 28 34			*700		
	6	P or L. M. F.	23 33 31 23 44 26 23 58 49			*600		
	7	P? M. F.	8 58 49 9 02 17 9 04 44			*100		
	9	P. S. L. M. eL.	15 59 49 16 07 45 16 17 32 16 44 27 18 28 00				6,370	May be Kam- chatka.
						*3,500		F?
			VERTICAL.		A _z			
		P. S. M.	15 59 00 16 06 00 16 39 30	2-4 6 18			5,320	L?
	9	M.	21 30 34		*200			May be part o above.
	14	P? L. M. F.	22 41 59 22 44 28 22 52 24 23 16 42			*200		
	24	P? L? M.	20 03 00 20 10 30 20 12 00			*200		F?

Date.	Char-acter.	Phase.	Time.	Period. T.	Amplitude.		Dis- tance.	Remarks.
					A _m	A _n		
Canada. Victoria, B. C. Dominion Meteorological Service—Contd.								
1917. May 25	-----	P.....	H. m. s.	Sec.	μ	μ	km.	
		L.....	14 52 02					
		M.....	14 53 31					
		F?.....	14 55 01		*200			
			15 00 58					
29	-----	P?.....	6 44 35					
		L.....	6 47 02					
		M.....	6 51 57		*500			
		F.....	7 02 48					
31	-----	P.....	8 53 54				2,290	Alaskan Peninsula.
		iP.....	8 55 53					S waves of large
		iS.....	8 57 42					amplitude.
		L.....	8 58 22					
		M.....	9 01 20		*14,500			
		F.....	12 25 38					
			VERTICAL.		A _z			
		P.....	8 53 54	3-4			1,680	
		S.....	8 56 48	4				
		L.....	8 58 12	18				
		M.....	9 01 00	21	67			
31	-----	L.....	19 53 42	18-24	*100			
		F?.....	19 59 00					

* Trace amplitude.

‡ Probably after-shocks.

SEISMOLOGICAL DISPATCHES.¹

Rome, May 9, 1917.

Violent earthquakes in Calabria created a panic among the populace there to-day. Inhabitants of towns and villages fled to the open fields. No fatalities have been reported. (United Press.)

Ogdensburg, N. Y., May 22, 1917.

Three distinct earth shocks were felt in this vicinity at 4 a. m. to-day. Persons were roused from sleep by the shaking of their houses, but no damage has been reported. (Assoc. Press.)

¹ Reported by the organizations indicated and collected by the seismological station at Georgetown University, Washington, D. C.

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological work and studies:

Aitken, John.

1. On dust, fogs, and clouds. 2. On dew. Edinburgh, London. 1917. 28½cm. (Reprinted from the Transactions of the Royal Society of Edinburgh, v. 30, p. 337-368; v. 33, p. 9-64.)

Annuaire astronomique et météorologique pour 1917 par Camille Flammarion. . . Paris [1917.] [4] 436 p. front. illus. figures. tables. 18cm. At head of title: 53e année. [Climatologie de l'année, 1915, p. [387]-409 with charts.]

Brazil. Directoria de meteorologia e astronomia. Seção de meteorologia e physica do globo.

Boletim meteorológico. Anno de 1910. Observações meteorológicas feitas no Observatorio nacional do Rio de Janeiro e nas estações da rede nacional. Bruxelles, n. d. ix, 173 p. tables. figures. fold. diagram. 3 fold. maps. 34½cm. At head of title: Ministerio da agricultura, industria e commercio. Preface in Spanish and French.

Brazil. Observatorio nacional do Rio de Janeiro.

Anuario para o anno de 1917. v. 33. Rio de Janeiro. 1917. vii, 480 p. tables. fold. diagram. 18½cm. At head of title: Ministerio da agricultura, industria e commercio. [Includes meteorological observations 1911-1915 at 27 stations.]

Briggs, Lyman James.

Comparison of the hourly evaporation rate of atmometers and free water surfaces with the transpiration rate of *Medicago sativa*, by L. J. Briggs and H. L. Shantz. Washington. 1917. plates. graphs. 26cm. (Reprinted from Journal of agricultural research, v. 9, no. 9.)

Chemulpo, Korea. Meteorological observatory.

Annual report for the year 1915. Jinsen. 1917. ii, 175 p. [1] tables. maps. diagrams. 30cm. (Last leaf in Japanese.)

Conseil permanent international pour l'exploration de la mer.

Bulletin hydrographique pour l'année juillet, 1914-juin, 1915. . . Copenhagen. 1917. ix, 28, 8 p. tables. 2 maps. diagram. 32½cm.

Cox, George Walter.

Intensity of rainfall in the Transvaal. 6 figures, 24½cm. (Excerpted from the South African journal of science, v. 12, July, 1916, p. [686]-693.) [Six rainfall charts.]

Denmark. Meteorologiske institut.

Nautisk meteorologisk aarboeg: Nautical meteorological annual, 1916. Kjøbenhavn. 1917. lxxviii, 153 p. tables. maps. 31cm. Text in Danish and English.

Diem, K.

Regenwaarnemingen op Sumatra's oostkust en de oostkust en de oostkust van Atjeh in 1916. Medan. 1917. 19 p. tables. 25cm. (Mededeelingen van het Deli proefstation te Medan, Sumatra.)

Duchêne, Émile Auguste.

Flight without formulæ; simple discussions on the mechanics of the aeroplane. . . tr. from the French by John H. Ledeboer; 2d ed. London, New York, [etc.] 1916. vii, 211 p. diagrams. 23cm.

Eredia, Filippo.

Il clima di Derna. Roma. 1916. 55 p. (incl. title-page) tables. 23½cm. At head of title: Ministero delle colonie. (Estratto dal Bollettino d'informazioni, anno 4, n. 7-9.)

Fergusson, Sterling Price.

Relation of snow to irrigation and forestry. The great importance of snow conservation and the methods used for determining the amount and value of snowfall. 25½cm. (Excerpted from Science conspectus, v. 3, no. 5. April, 1913, p. 152-157.)

Giorgi, Cosimo de.

Distribuzione delle piogge nella provincia di Lecce (Terra d'Ottranto) col. map. 24cm. (Excerpted from La geografia, v. 5, May-June, 1917, p. 210-212.)

Grenfell, Wilfred Thomason, and others.

Labrador: the country and the people; new ed. with additional chapters. New York. 1913. xii, 529 p. front. (port.) plates. figures. map. 20cm. Bibliography, p. 519. [Climate, p. 69-80.]

Hamel, Gustav.

Flying; some practical experiences, by Gustav Hamel and C. C. Turner. London. 1914. xii, 341 p. front. plates. figures. tables. 23½cm. [Chapters 8-9. Winds and weather.]

Italy. R. Esercito italiano. Sezione meteorologica.

Bollettino N. 34. Sabato, 3 Febbraio, 1917. . . Notizie meteoriche della zona di guerra. 1 sheet. table. 25½ x 35½cm.

Bollettino meteorico della zona di guerra. . . [Giorno 3 Febbraio, 1917. Ore 8.] 3 p. (incl. title-page.) table. 23 x 48cm.

Cartina meteorica della zona di guerra. Giorno 3 Febbraio, 1917-ore 8. 1 sheet. 49½ x 71cm.

Clima della conca di Gorizia. . . Roma. 1916. 23 p. (incl. title-page). fold. table. 17cm. Pubbl. N. 10.

Clima e acque dell' Altipiano dei sette comuni. [Roma. 1916.] 54 p. (incl. title-page). fold. tables. 17cm. Pubbl. N. 8.

Clima e acque dell' Altipiano di Báinsizza S. Spirito o di Laschek. . . Roma. 1916. 15 p. (incl. title-page.) fold. table. 17cm. Pubbl. N. 9.

Indicazione di alcuni punti soggetti a valanghe. Pubbl. 12. [Parts] 1-15. Roma. 1916. [4] p. 14cm. [each.]

Neve nelle Alpi venete od orientali; valori annui medii dell' altezza, frequenza e durata. Roma. 1916. [4] p. 14cm. Pubbl. N. 13.

Notizie sul clima del Carso e delle coste triestine. Roma. 1916. 43 p. (incl. title-page.) tables. (partly fold.) 17cm. Pubbl. N. 6.

Notizie sulla bora friulana e triestina. Roma. 1917. 29 p. (incl. title-page). tables. 17cm. Pubbl. N. 14.

Pioggia, acqua e fango su terreni impermeabili; trincee e camminamenti scavati in tali terreni. (Edizione 2a.) Roma. 1917. 17 p. (incl. title page). 17cm. Pubbl. No. 16.

Primo anno di osservazioni meteorologiche nell'alto Isonzo (M. Nero) Giugno 1915-Giugno 1916. [Roma. 1916.] [4] p. table. 18cm. Pubbl. N. 7.

Valanghe nelle Alpi venete od orientali. Nozioni pratiche sopra i pericoli, le precauzioni, il salvataggio. Roma. 1916. 24 p. (incl. title-page). 17cm. Pubbl. N. 11.

Valanghe nelle Alpi venete od orientali. . . (Edizione 3a.) Roma. 1917. 30 p. (incl. title-page). 17cm. Pubbl. N. 15.

Osaka (Japan) Meteorological observatory.

Annual report. Pt. 2. Seismological observations in Osaka, 1916. Osaka. 1917. cover title, 27 [33] p. 3 fold. plates. tables. 25½cm. In English and Japanese. Running title: Seismological bulletin. [Twelve diagrams of earthquakes.]

Rodés, Luis.

Organización meteorológica en los Estados Unidos; su desarrollo progresivo en orden a la navegación y a los intereses agrícolas. Tortosa. 1917. 31 p. (incl. title-page). plates. 22cm.

Shreve, Forrest.

Rôle of winter temperatures in determining the distribution of plants. 25½cm. (Reprinted from American journal of botany, vol. 1, no. 4, April, 1914, p. [194]-202.)

Southern railway company.

Floods of July, 1916: How the Southern railway organization met an emergency; [ed. by J. C. Williams]. [Washington, D. C.] 1917. 131 p. (incl. title-page). illus. plates. fold. map] 31cm.

Spain. Observatorio central meteorológico.

Anuario del observatorio central meteorológico. Suplemento al tomo 1. Madrid. [1917]. [21] 155 p. [1] plate. tables. 4 fold. diagrams. 32cm. At head of title: Dirección general del Instituto geográfico y estadístico. Director general: Marques de Teverga.

Anuario . . . 2. Madrid. [1917]. vii, 259, [1], [2] p. tables. diagrams. (partly fold.) maps (partly fold.) 32cm.

Stonyhurst college observatory.

Results of meteorological, magnetical, and seismological observations, 1916. . . Blackburn, 1917. xiv, 50 p. tables. 18½cm.

Theophrastus.

Enquiry into plants and minor works on odours and weather signs, with an Eng. tr. by Sir Arthur Hort. London, New York. 1916. 2 v. front. 17cm. (Loeb classical library.) Text in Greek and English. [Concerning weather signs, v. 2, p. 390-433.]

Upsala. Universitét. Observatoire météorologique.

Bulletin mensual. v. 48. Année 1916. . . Upsala, 1916-17. 74 p. tables. 34½cm.

X, pseud.

Um estudo meteorológico de Angola. charts. 25½cm. [Excerpted from the Boletim of the Sociedade de geographia de Lisboa, 35a. Série, nos. 1-3, Janeiro a Março, 1917, p. 25-40.]

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following titles have been selected from the contents of the periodicals and serials recently received in the library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

Aeronautics. London. v. 12. May 9, 1917.

Cave, C. J. P. Some meteorological conditions which increase the danger of flying. p. 336-340.

American philosophical society. Proceedings. Philadelphia. v. 56. no. 1. 1917.

Marvin, Charles Frederick. Cleveland Abbe. p. ix-xix.

Engineering news-record. New York. v. 78. 1917.

Newton, C. G. South American rainfall reverse of northern Pacific. Chilean records show precipitation increases from north to south and from coast to mountain. p. 410-411. (May 24.)

Horton, Robert E. Failure of hydraulic projects from lack of water prevented by better hydrology. p. 490-492. (June 7.)

London, Edinburgh, and Dublin philosophical magazine. London. 6 ser. v. 33. June, 1917.

Whipple, F. J. W. The motion of a particle on the surface of a smooth rotating globe. p. 457-471.

Arctowski, Henryk. Normal anomalies of the mean annual temperature variation. p. 487-495.

Meteorological society of Japan. Journal. Tokyo. 36th year. May, 1917.

Okada, T. Some researches in the far eastern seasonal correlations. (Third note.) p. 55-63. [See this issue, p. 238. for the second note; June for the 3d note.]

Nature. London. v. 99. 1917.

Walkden, S. L. Aeroplanes and atmospheric gustiness. p. 225-226. (May 17.)

Harding, Charles. The past winter. p. 294-295. (June 7.)

Royal meteorological society. Quarterly journal. v. 43. January, 1917.

Brooks, C. E. P. A meteorologist in China. p. 1-14. [Includes meteorological summaries from Wuhu, Chinghsiang and Amoy.]

Geddes, A. E. M. The storm of 11th to 13th November, 1915, in its passage over the British Isles. p. 15-27.

Bonacina, L. C. W. Readjustment of pressure differences: a reply to Sir Napier Shaw's criticism. p. 27-28.

Salter, Carle. The measurement of rainfall duration. p. 29-41.

Turner, H. H. Discontinuities in meteorological phenomena. Third note. p. 43-60.

Gold, Ernest. Formula for obtaining differences of pressure corresponding with given differences of height. p. 60.

Cave, C. J. P. The forms of clouds. p. 61-82.

Shaw, Napier. Meteorology for schools and colleges. p. 83-89.

Hall, Maxwell. West Indian cyclones and the local wind. Second note. p. 92-95.

Mr. James J. Hicks. p. 99. [Obituary.]

Marriott, William. Mr. Edward Mawley. p. 99-101. [Obituary.]

Lempfert, B. G. K. Prof. Henrik Mohn, D. Sc. p. 101-102. [Obituary.]

Royal meteorological society. Quarterly journal. v. 43. April, 1917.

Lyons, Henry George. The distribution of pressure and the air circulation over northern Africa. p. 116-150. [Includes charts of isobars and winds at the surface and at 3,000 m. altitude.]

Royal meteorological society—Continued.

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SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF MAY, 1917.

P. C. DAY, Climatologist and Chief of Division.

PRESSURE AND WINDS.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII (XLV—48) while the average values for May, 1917, at the several stations, with departures from the normal, are shown on Tables I and III.

At the beginning of the month low pressure obtained over the Lakes region, the upper Ohio Valley, and Middle Atlantic States; elsewhere it was generally above the average. Low pressure overspread most southern districts on the 3d and 4th, and continued for several days, after which pressure above the normal prevailed over that portion of the country and continued at intervals until the last week of the month, when it was generally below the average. In the central valleys and to the northward relatively high pressure obtained throughout the greater part of the first half of the month. During the latter half several rather extensive low areas moved from the West and Southwest over the central and northeastern districts causing pressures below the normal to predominate in those sections.

In the Pacific Coast States the pressure averaged near or slightly above the normal during much of the month.

The month closed with pressure below the normal from the upper Lakes to western Texas and New Mexico, but relatively high pressure prevailed over the Atlantic coast districts and in the far Northwest; elsewhere it was generally near the normal.

For May, as a whole, the barometric pressure averaged well below the normal over most districts east of the Mississippi River, the departures being quite pronounced in the region from the Ohio Valley to the Canadian Maritime Provinces. Pressure was also below the average for the month, but to a less degree, over much of the Plateau region. In the Great Plains, western Gulf States, upper Lakes Region, Pacific coast and British Northwest Provinces, the pressure for the month was above normal, particularly so in the northern Plains region.

The distribution of the HIGHS and LOWS was generally favorable for northerly winds in most sections from the Great Plains States eastward, except near the Gulf and South Atlantic coasts, where they were southerly. In the Rocky Mountains region and to the westward variable winds prevailed, but mostly from some northerly quadrant.

TEMPERATURE.

For May as a whole the temperature everywhere averaged below the normal, except in the extreme northwestern portion of Montana.

A more detailed record of the unseasonably cold weather during the month will be found in the June issue of the REVIEW.

PRECIPITATION.

During the early part of the first half of May the rainfall was rather liberal in most portions of the cotton region, especially in Florida and adjacent States, while

during the latter part of this period it was markedly scanty in those districts. In the spring-wheat belt, from the upper Lakes Region westward to the Rocky Mountains divide, little or no precipitation occurred during this half of the month, and similarly in the southern portions of California and Arizona no rain fell. However, light to fair amounts occurred in the far Northwest and the Middle Plateau region, and large amounts for the region fell in northeastern New Mexico, in the Texas Panhandle and northwestward to southern Montana, while moderate amounts fell in portions of New York and New England.

From the 16th to 22d practically no rain fell in the South Atlantic and Gulf States, in extreme western Texas and southeastern New Mexico, the south New England States, and portions of North Dakota, Minnesota, and Montana. Elsewhere the rainfall was rather evenly distributed and fairly heavy in many sections. During the remainder of the month ample precipitation fell over the greater part of the country, with excessive amounts in much of the Ohio Valley and in parts of Nebraska, South Dakota, and West Virginia; heavy falls occurred in portions of Missouri, Kansas, Pennsylvania, New York, and the New England States; and fairly good amounts were received in the northern portions of the Cotton States from South Carolina to Mississippi. However, little or no rain fell in southern Georgia, and the coastal portion of the Gulf States, the Rio Grande Valley, and in northern Minnesota and North Dakota.

For the month as a whole the precipitation was heavy in portions of the Ohio, lower Missouri, and central Mississippi Valleys. It was light in the southern Appalachian region, much of Florida and Louisiana, southern Mississippi, the Rio Grande Valley, the northern portions of Michigan, Wisconsin, and Minnesota, most of North Dakota, and over northeastern Montana. Over the cotton belt as a whole the precipitation for May was less than normal, especially in the central portion, though several important areas received amounts near the average. On the other hand in the great corn States the month was nearly everywhere wetter than normal.

RELATIVE HUMIDITY.

The relative humidity for May as a whole was generally below the normal from the eastern portions of the Great Plains to the Atlantic coast, except in the lower Lakes region and portions of adjacent States, the eastern New England coast, and the central portions of Illinois and Missouri. Elsewhere there was relatively more moisture in the atmosphere than the average for May, the excess in portions of the Plateau and Middle Rocky Mountains regions being unusually large.

GENERAL SUMMARY.

The weather was generally favorable for practically all small grain crops, although during the first and last weeks of the month unseasonably low temperatures retarded their growth in most sections.

Winter wheat made good progress generally, except during the early part of the month, when the cold weather delayed its growth. Spring wheat, as a rule, likewise progressed favorably throughout the month, and

rye, oats, and barley also made good progress after the first few days.

The weather was generally dry and cold in the cotton belt, with the result that cotton was late and its condition unsatisfactory. In some sections the poorest cotton stands were plowed up and the land planted to food crops.

In many sections the month was too cold for corn, and therefore its germination and growth were much retarded. The planting of potatoes and other truck crops, while somewhat delayed, made good progress, and there are many reports of increased acreage of these crops.

The weather was favorable for meadows and pastures and the condition of live stock improved. The general outlook for most fruits was promising, although some were damaged by frosts and unseasonably low temperatures.

SEVERE LOCAL STORMS.

The following notes of severe storms have been extracted from reports by officials of the Weather Bureau. The weather conditions will be discussed in detail by Prof. H. C. Frankenfield in a later issue.

Arkansas.—Two tornadoes occurred in Mississippi County on May 27. One was near Manila, where 6 persons were killed, 5 injured, and property valued at \$12,500 destroyed. Another passed near Archilleon, Clear Lake, and Cottonwood Point, resulting in 12 persons being killed, 55 injured, and property valued at \$43,000 being destroyed. On the same date a "straight blow" caused some damage to fruit and property in the western portion of the State.

Hailstorms occurred on the 3d at nearly all reporting localities in central, western, and northern portions of the State. Hailstones of unusual size fell at Arkadelphia, some measuring 9 inches in circumference and weighing 7 ounces. Unusually large stones were also reported near Ozark.

Georgia.—Several severe hailstorms occurred during May. On the 1st in Tift and Brooks Counties the hail was very large, drifted to a depth of several inches, and greatly damaged crops. On the 4th at Americus, Covington County, the stones were over an inch in diameter and covered the ground. Crops were greatly damaged. On the 22d at Atlanta and Carlton a number of residences and roofs were damaged and many hogs and chickens killed. Damage to crops was about \$15,000.

Illinois.—On May 9 at Macomb a windstorm caused minor damages to buildings and trees, and one person was killed by lightning. On the 21st in Hamilton and White Counties, a storm with a funnel-shaped cloud caused property damage of \$10,000 to \$15,000. One person was injured and one reported killed.

Severe tornadic storms occurred in this State on the 26th and 27th, causing 105 deaths and injuring 680 persons, and estimated property losses amounted to three and one-third million dollars. On the 30th-31st a number of local storms, believed to have been straight blows, caused the death of five persons in Alexander and Pulaski Counties and destroyed property to the value of at least \$200,000.

Kansas.—A severe hailstorm occurred in the northwestern part of Logan County on May 29; at places hail was 3 inches deep on the level and drifted to a depth of 12 inches.

At least six tornadoes are known to have occurred in widely scattered localities in Kansas during the latter

part of the month. These resulted in the death of 24 persons, the injury of many more, and the destruction of property valued at approximately \$728,000.

Kentucky.—On the 9th a windstorm at Louisville and a heavy hailstorm in Fayette County caused considerable damage. On the 22d, heavy hailstorms caused much damage in Lee and Fayette Counties, a damaging windstorm occurred in New Castle, and a barn was burned by lightning in Jefferson County.

Severe storms occurred in many places in the State on the 27th, being most damaging in the extreme western counties and in the blue-grass region. The reported results of these storms are 68 persons killed, about 350 injured, and a million and a half to two million dollars worth of property destroyed.

Tennessee.—On May 21 a windstorm passed over Bolivar, uprooting trees and damaging a number of buildings. In Sweetwater Valley a windstorm on the 22d demolished several dwellings and many barns and caused the death of one man and serious injuries to others.

Severe hailstorms are reported to have occurred in Hickman County on the 1st, Roane and Sequatchie Counties on the 22d, Davidson County on the 26th, and Maury County on the 30th. Heavy rains caused serious local floods in Haywood County on the 25th and Hickman County on the 26th.

Four severe local storms crossed the western half of the State between 4 and 9 p. m. on the 27th, traveling in nearly parallel lines in an east-northeast direction, and causing a total loss of 25 lives, 248 injured, and property loss of nearly \$400,000.

Texas.—A tornado of small dimensions is reported to have occurred 12 miles southwest of Kaufman on the 21st.

Average accumulated departures for May, 1917.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	° F.	° F.	° F.	In.	In.	In.	0-10		P. ct.	
New England.....	48.2	-6.2	-10.9	3.16	-0.30	-1.90	6.8	+1.2	74	-2
Middle Atlantic.....	56.3	-5.4	-4.0	2.82	-0.70	-2.40	6.0	+0.9	63	-8
South Atlantic.....	66.5	-3.3	+5.7	2.33	-1.50	-4.90	4.2	-0.4	65	-8
Florida Peninsula....	76.0	-1.7	+3.1	2.62	-1.60	-5.20	3.5	-0.8	72	-2
East Gulf.....	67.5	-4.7	+4.4	2.58	-0.90	+0.20	4.0	-0.8	63	-9
West Gulf.....	67.9	-5.0	+1.5	3.15	-1.00	-5.90	4.9	0.0	70	-5
Ohio Valley and Tennessee.....	58.2	-6.7	-6.4	3.67	0.00	+2.20	5.8	+0.7	66	-2
Lower Lakes.....	49.8	-7.7	-13.6	3.58	+0.40	+0.10	6.7	+1.3	72	+2
Upper Lakes.....	47.9	-4.8	-16.5	2.50	-0.90	-1.90	5.6	+0.5	68	-4
North Dakota.....	52.3	-2.0	-12.1	0.18	-2.30	-2.90	3.2	-2.2	50	-15
Upper Mississippi Valley.....	56.6	-5.3	-12.4	3.38	-0.80	-1.00	5.1	-0.2	66	-2
Missouri Valley.....	56.5	-5.3	-5.7	4.17	0.00	+0.30	4.9	-0.5	64	-1
Northern slope.....	48.8	-4.2	-17.5	3.10	+0.70	+1.00	5.8	+0.3	64	+3
Middle slope.....	56.2	-6.6	-6.0	3.08	-0.70	-1.70	5.8	+0.9	64	+2
Southern slope.....	65.7	-4.9	-0.1	2.08	-0.60	-2.70	3.6	-0.7	51	+3
Southern Plateau.....	60.0	-5.7	-11.6	0.36	0.00	-0.60	2.4	-0.2	42	+11
Middle Plateau.....	51.5	-5.0	-32.0	1.87	+0.70	-0.50	5.7	+1.6	56	+10
Northern Plateau.....	54.0	-3.0	-20.1	1.96	+0.20	0.00	6.1	+1.0	59	+3
North Pacific.....	51.9	-1.9	-12.2	1.51	-0.90	-4.50	7.0	+0.6	78	+1
Middle Pacific.....	54.4	-3.2	-10.5	0.62	-0.70	-5.80	3.9	0.0	69	+1
South Pacific.....	58.6	-3.0	-6.9	0.30	-0.30	-2.20	4.4	+0.4	70	+1

WEATHER CONDITIONS ON THE NORTH ATLANTIC DURING
MAY, 1916.

The data presented are for May, 1916, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month. Chart IX (XLV-50) shows for May, 1916, the averages of pressure, temperature, and the prevailing direction of the wind at 7 a. m., 75th meridian time (Greenwich mean noon), together with notes on the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of the average monthly pressure as shown on Chart IX differed but slightly from the normal, although the circulation of the air was somewhat more sluggish and the barometric gradients weaker than usual in May. The North Atlantic or Azores HIGH, with a crest of 30.15 inches, was central about 10 degrees east of its usual position, while over the western division of the ocean the average pressure for the month was near the normal. An area of low pressure surrounded by an isobar of 29.8 inches covered a large part of the area between the 45th and 55th parallels and the 30th and 55th meridians. The lowest average pressure for any 5-degree square was 29.75 inches and occurred in the square between latitudes 50°-55° and longitudes 45°-50°, where the lowest individual pressure was 29.36 inches on the 13th and the highest 30.32 inches on the 23d. The highest average pressure reading was 30.18 inches in each of the two squares between latitudes 30°-35° and longitude 20°-30°, the lowest reading being 29.79 inches on the 1st and the highest 30.39 inches on the 26th. Over some portions of the northern waters there was a marked variation in the pressure from day to day, and the averages for the three decades of the month differed considerably in some squares while in others the pressure was comparatively uniform. In the square between latitudes 60°-65° and longitudes 20°-25° the average for the first decade was 30.12 inches; the second, 29.82 inches, and for the last 11 days, 29.77 inches. In the square between latitudes 60°-65° and longitudes 5°-10° west the figures were as follows: First decade, 29.87 inches; second, 29.96 inches; and last 11 days, 29.91 inches. In the square between 60°-65° and longitude 0°-5° east they were: First decade, 29.80 inches; second, 29.97 inches; and last 11 days, 29.99 inches. In the vicinity of the Azores HIGH the pressure during the last decade was considerably higher than during the first two, while in the waters adjacent to the American coast and in the Gulf of Mexico there was comparatively little variation during the month.

GALES.

The number of gales reported during the month was considerably less than usual with the exception of a limited area between the 35th and 40th parallels, and the 50th and 65th meridians, where they occurred on two days, a percentage of 6 which is practically normal. While there were a number of cyclonic disturbances during the month, most of them were of light intensity, not well developed, and irregular in movement. In consequence of this condition only one storm track is shown on the chart.

On April 30 a LOW (I in Chart IX) was central near latitude 34°-longitude 70°, while northerly and northeasterly gales of from 40 to 65 miles an hour prevailed along the American coast between the 32d and 36th parallels, the storm area extending as far east as the 69th

meridian. This disturbance moved rapidly in a northeasterly direction, and May 1 the center was near latitude 40°, longitude 57°; in the western quadrants northeasterly gales of 55 miles an hour were encountered, while in the region between the 67th meridian and the American coast light variable winds prevailed. This LOW then curved sharply toward the north, and on the 2d the center was near St. Johns, N. F., where the barometric reading was 29.36 inches. The force of the wind had increased slightly from that of the previous day, and fog occurred at a number of widely separated localities between the 45th and 60th meridians. From the 3d to the 5th a fairly well developed LOW covered the waters adjacent to the European coast between Gibraltar and the English Channel, while two vessels between the 45th and 50th parallels and the 14th and 17th meridians reported moderate to strong northerly gales. On the 6th this area was central on the west coast of England and covered a large portion of the North Sea, extending nearly to the Scandinavian Peninsula. This LOW was of slight intensity and remained practically stationary until the 10th, when the center was apparently somewhere over northern Europe, not shown within the limits of the chart. During this period light to moderate winds were the general rule over this area of low pressure, although a few reports of moderate gales were received.

Between May 6 and 12 a second shallow depression occupied the area in the vicinity of St. Johns, N. F., its movement between these dates being slight and irregular. In this period light to moderate winds prevailed over the entire western division of the ocean, while fog occurred off the Banks of Newfoundland and along the American coast as far south as the 38th parallel. On the 13th this LOW covered a large area in mid-ocean north of the 50th parallel, while westerly gales were reported from a limited area between the 40th and 45th parallels. From the 14th to the 16th the barometric conditions remained practically unchanged, and light to moderate winds prevailed over the entire ocean. On the 16th a second LOW of slight intensity was central near Wilmington, N. C.; the force of the wind remained moderate and fog occurred off the New Jersey coast. This LOW moved rapidly in a northerly direction, and on the 17th the center was about 100 miles east of New York. The wind had increased somewhat in force since the previous day, although no specially high velocities were reported. The storm continued slowly in its northerly movement, weakening in intensity as it progressed, and on the 18th the center was apparently somewhere over eastern Canada, although it was impossible to locate it accurately on account of lack of observations.

From the 18th to the 26th there was no well-defined movement of any high or low areas; the atmospheric conditions were exceptionally stagnant with weak gradients and light to moderate winds, while fog was reported from a number of scattered localities. On the 27th a LOW was central near latitude 44° and longitude 57°; the winds were moderate in force and fog covered a limited area near the center. This disturbance moved slowly in a northeasterly direction, and on the 28th the center was near St. Johns, N. F., where the barometer reading was 29.48 inches. The conditions of wind and weather were practically the same as on the previous day, and fog continued along the American coast between Hatteras and the Delaware. During the next 24 hours the easterly movement of this LOW was slight, as on the 29th the center was only about 250 miles east of its position on the previous day. It then curved sharply toward the northeast, and on the 30th the center was near latitude 52°,

longitude 41°. On both the 29th and 30th the winds were for the most part of little force, although on the latter date one vessel near latitude 46°, longitude 34°, encountered a southerly gale of 50 miles an hour.

TEMPERATURE.

The average temperature of the air over the greater part of the ocean during May, 1916, was somewhat above the normal. The greatest positive departure, 4 degrees, occurred over a limited area in the northwestern division and in the Gulf of Mexico, while between latitudes 25°-30° and longitudes 45°-70° the departures were slightly negative. The temperature departures at a number of Canadian and United States Weather Bureau stations on the Atlantic and Gulf coasts were as follows:

°F.	°F.
St. Johns, N. F. +1.3	Norfolk, Va. +3.0
Sydney, C. B. I. +0.8	Hatteras, N. C. +2.3
Halifax, N. S. 0.0	Charleston, S. C. +2.0
Eastport, Me. +0.7	Key West, Fla. -0.1
Portland, Me. -1.1	Tampa, Fla. +1.2
Boston, Mass. +2.0	New Orleans, La. +2.6
Nantucket, Mass. -1.0	Galveston, Tex. -0.4
Block Island, R. I. 0.0	Corpus Christi, Tex. 0.0
New York, N. Y. +0.5	

The lowest individual temperature reading reported during the month was 42° F., which occurred on three different days in the 5-degree square that includes the east coast of Labrador, and also in the square between latitudes 55°-60° and longitudes 40°-45°. The highest temperature for the same squares was 48°, which was reported on two days.

FOG.

Off the Banks of Newfoundland, where the maximum amount of fog usually occurs, the number of days on which it was observed during the month was somewhat below the normal, and the same conditions held true over the middle and eastern sections of the steamer lanes. In the 5-degree square immediately east of Nantucket

Island fog was observed on 12 days, a percentage of 39, the normal for that region being 30 per cent. Along the American coast between the 35th and 40th parallels it also occurred somewhat oftener than usual.

HAIL AND SNOW.

Hail was reported by one vessel on May 25 near latitude 52°, longitude 8° west, and again on the 26th about 8° west of that position. No reports of snow during the month were received.

Winds of 50 miles per hour (22.4 m./sec.) or over during May, 1917.

Station.	Date.	Velocity.	Direction.	Station.	Date.	Velocity.	Direction.
		Mis./hr.				Mis./hr.	
Block Island, R. I.	5	56	ne.	Mt. Tamalpais, Cal.	24	62	nw.
Buffalo, N. Y.	1	56	sw.	Do.	25	72	nw.
Do.	19	54	w.	Nantucket, Mass.	5	60	ne.
Do.	22	52	sw.	New York, N. Y.	2	50	nw.
Do.	23	66	sw.	Do.	10	58	nw.
Do.	24	64	sw.	Do.	11	56	nw.
Chattanooga, Tenn.	22	53	sw.	Norfolk, Va.	28	62	s.
Columbus, Ohio.	24	51	w.	Pierre, S. Dak.	20	53	ne.
Detroit, Mich.	1	55	w.	Pittsburgh, Pa.	22	52	sw.
Do.	19	54	w.	Point Reyes			
Drexel, Nebr.	25	51	e.	Light, Cal.	14	53	nw.
El Paso, Tex.	26	53	w.	Do.	6	60	nw.
Do.	29	60	sw.	Do.	7	74	nw.
Fort Smith, Ark.	27	50	sw.	Do.	8	50	nw.
Grand Haven,				Do.	9	61	nw.
Mich.	1	53	w.	Do.	16	50	nw.
Helena, Mont.	15	55	sw.	Do.	19	55	nw.
Indianapolis, Ind.	23	50	w.	Do.	20	57	nw.
Lexington, Ky.	22	56	sw.	Do.	21	63	nw.
Louisville, Ky.	9	59	nw.	Do.	22	61	nw.
Do.	22	54	w.	Do.	23	59	nw.
Do.	27	61	s.	Do.	24	72	nw.
Minneapolis, Minn.	18	53	sw.	Do.	25	56	nw.
Modena, Utah.	15	50	sw.	Do.	30	50	nw.
Mt. Tamalpais, Cal.	4	52	nw.	Portland, Me.	14	(*)	nw.
Do.	5	78	nw.	Do.	20	(*)	nw.
Do.	6	92	nw.	Do.	26	(*)	nw.
Do.	7	76	nw.	Do.	29	(*)	ne.
Do.	9	68	nw.	Providence, R. I.	10	50	nw.
Do.	14	54	nw.	Do.	25	55	nw.
Do.	15	61	nw.	St. Louis, Mo.	30	50	s.
Do.	17	50	nw.	Sand Key, Fla.	6	54	n.
Do.	18	60	nw.	Do.	7	68	sw.
Do.	19	64	nw.	Sioux City, Iowa.	13	54	w.
Do.	21	72	nw.	Toledo, Ohio.	1	58	sw.

* Wind velocities at Baltimore, Md., and at Portland, Me., have been in error for some time past. A table of correct values is in preparation.—EDITOR.

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and

lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by section, May, 1917.

Section.	Temperature.								Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.						Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest.	Date.			Station.	Amount.	Station.	Amount.
Alabama.....	66.2	-5.2	3 stations.....	97	26†	3 stations.....	33	9†	2.37	-1.73	Robertsdale.....	5.76	Livingston.....	0.47
Arizona.....	61.5	-4.3	Maricopa.....	106	14	Alpine.....	14	6	0.97	+0.52	Grand Canyon No. 1.	2.79	Parker.....	0.00
Arkansas.....	63.5	-5.6	2 stations.....	97	26†	Dutton.....	31	1†	3.15	-1.93	Alicia.....	8.52	Arkadelphia.....	0.33
California.....	57.2	-4.9	Greenland Ranch.....	106	14	Tamarack.....	10	16	0.75	-0.47	Inskip.....	4.83	12 stations.....	0.00
Colorado.....	45.9	-6.3	Lamar.....	90	17†	Dillon.....	-8	6	3.25	+1.46	Limon.....	7.63	Gunnison.....	0.65
Florida.....	73.4	-2.7	Fort Meade.....	100	27	3 stations.....	40	9†	2.64	-1.18	Miami.....	6.05	Gainesville.....	0.88
Georgia.....	67.0	-4.9	Statesboro.....	100	27	Blue Ridge.....	30	9	2.71	-0.46	Carlton.....	5.27	Blakely.....	0.65
Hawaii (April report).....	70.7	+0.4	Mahukona.....	94	28	Volcano Observatory	47	7	6.55	-0.21	Hakalau.....	24.80	Launiopoko, Maui.....	0.50
Idaho.....	49.7	-1.7	Glenns Ferry.....	92	13	3 stations.....	12	2†	2.20	+0.26	Pocatello Nursery.....	6.95	Silver City.....	0.37
Illinois.....	56.6	-6.2	Ottawa.....	92	18†	2 stations.....	27	10	4.23	+0.16	Paris.....	7.96	Dwight.....	1.59
Indiana.....	55.5	-7.0	Collegeville.....	92	20	3 stations.....	24	10	4.83	+0.78	Butlerville.....	9.51	Connersville.....	1.35
Iowa.....	55.1	-5.4	Tipton.....	95	18	Chariton.....	25	5	3.87	-0.70	Iowa City.....	7.33	Rockwell City.....	1.69
Kansas.....	57.5	-6.3	La Crosse.....	100	18	Tribune.....	20	4	3.65	-0.47	Centralia.....	8.82	Wakeeney.....	0.97
Kentucky.....	58.9	-6.8	2 stations.....	92	18†	Beattyville.....	30	14	3.43	-0.49	Carrollton.....	7.62	Manchester.....	1.34
Louisiana.....	69.6	-4.5	Liberty Hill.....	98	26	Kelly (near).....	34	8	1.50	-2.68	Logansport.....	4.05	Angola.....	0.06
Maryland-Delaware.....	57.2	-5.7	2 stations.....	93	20	Oakland, Md.....	27	26	3.03	-0.36	Oakland, Md.....	5.20	Delaware City, Md.....	1.81
Michigan.....	48.0	-6.1	Cassopolis.....	80	19	Ewen.....	17	28	2.79	-0.65	Mount Clemens.....	5.88	Humboldt.....	0.40
Minnesota.....	52.0	-2.5	Beardsley.....	94	18	Cloquet.....	16	6	1.94	-1.35	Fairmont.....	7.90	2 stations.....	0.00
Mississippi.....	66.9	-5.2	Shubuta.....	98	31	Duck Hill.....	34	9	1.92	-2.72	Okolona.....	4.95	Fayette.....	0.13
Missouri.....	58.7	-6.2	Steffenville.....	91	17†	Dean.....	30	1†	4.33	-0.47	Lockwood.....	7.12	Paifton (near).....	2.06
Montana.....	48.9	-2.0	3 stations.....	96	15	Brenner.....	0	5	2.33	-0.13	Pine Grove.....	7.15	White Water.....	0.03
Nebraska.....	53.2	-5.8	O'Neill.....	98	16	3 stations.....	21	5	4.85	+1.23	Butte.....	8.42	Culbertson.....	1.96
Nevada.....	50.3	-3.8	Logan.....	97	14	Mahoney Ranger Sta	11	1	2.05	+1.34	Lamoille.....	5.79	Oasis Ranch.....	0.05
New England.....	47.8	-7.3	Bridgeport, Conn.....	86	20	2 stations in Vermont	20	4†	3.41	+0.03	Blue Hill, Mass.....	5.86	2 stations.....	1.62
New Jersey.....	54.0	-6.3	2 stations.....	90	20	Culvers Lake.....	22	4	3.83	-0.15	Long Branch.....	6.83	Vineland.....	2.08
New Mexico.....	51.9	-5.7	Artesia.....	97	16	2 stations.....	9	6†	1.40	+0.29	Anchor Mine.....	5.38	Newman.....	0.00
New York.....	48.2	-8.0	Roslyn.....	85	20†	Raquette Lake.....	20	3	3.81	+0.17	Liberty.....	6.20	Chazy.....	1.86
North Carolina.....	61.9	-4.8	Goldsboro.....	98	21	Highlands.....	28	13	2.80	-1.23	Goldsboro.....	4.67	Hatteras.....	0.85
North Dakota.....	51.2	-1.4	2 stations.....	98	16	Marstonmoor.....	15	2	0.30	-2.25	Bierman.....	2.08	4 stations.....	0.00
Ohio.....	54.1	-7.0	Green.....	93	17	2 stations.....	26	3†	4.18	+0.45	Wickliffe.....	6.51	Somerset.....	1.61
Oklahoma.....	62.5	-2.5	Cherokee.....	102	18	Kenton.....	27	7	2.32	-3.12	Vinita.....	5.52	Hammon.....	0.33
Oregon.....	51.6	-5.2	Vale.....	89	14	Crescent.....	10	4	2.01	-0.33	Headworks.....	5.32	Big Eddy.....	0.31
Pennsylvania.....	53.3	-6.6	Chambersburg.....	90	18	Mount Pocomo.....	20	4	3.39	-0.45	Corry.....	8.09	Sunbury.....	1.65
Porto Rico.....	77.0	-0.2	Canovanas.....	98	18	Aibonito.....	54	20	6.69	-0.63	Rio Piedras.....	16.41	Potomac.....	0.00
South Carolina.....	66.3	-5.1	Walterboro.....	98	27	Mountain Rest.....	31	13†	3.09	-0.37	Cheraw.....	5.16	Orangeburg.....	1.50
South Dakota.....	51.9	-3.7	Alexandria.....	95	18	2 stations.....	20	2	3.16	+0.39	Fairfax.....	9.31	Britton.....	0.04
Tennessee.....	61.0	-6.2	2 stations.....	92	20†	Erasmus.....	29	14	3.36	-0.63	Hohenwald.....	6.95	Union City.....	1.68
Texas.....	69.1	-4.4	Fowlerton.....	108	22	Dalhart.....	26	7	2.76	-0.83	San Marcos.....	7.06	Barstow.....	T.
Utah.....	49.5	-4.6	Lemay.....	95	14†	Blacks Fork.....	2	3†	2.60	+1.25	Utah Expt. Sta.....	5.63	Bluff.....	0.45
Virginia.....	59.1	-5.4	Hopewell.....	96	20	Rocky Mount.....	30	12	3.02	-0.88	Richmond.....	4.59	Ivanhoe.....	1.78
Washington.....	53.2	-1.6	Granger.....	92	9	Paradise Inn.....	18	4	1.43	-0.77	Touchet Ridge.....	4.44	Ellensburg.....	0.18
West Virginia.....	55.5	-6.7	Moorefield.....	95	18	Lost Creek.....	25	14	4.88	+1.05	Camden-on-Gauley.....	8.45	Wheeling.....	2.45
Wisconsin.....	50.4	-4.3	Muscoda.....	90	18	Deerskin Dam.....	13	6	2.42	-1.54	Brodhead.....	5.01	Antigo.....	0.41
Wyoming.....	43.8	-4.9	Hyattville.....	92	15	Foxpark.....	-7	6	3.39	+1.43	Lagrange.....	6.84	Hyattville.....	0.35

† Other dates also.

DESCRIPTION OF CHARTS AND TABLES.

(See the REVIEW for January, 1917, p. 40.)

TABLE I.—Climatological data for Weather Bureau stations, May, 1917.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.						Snow on ground at end of month.						
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Maximum.	Date.	Mean minimum.	Date.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.			Clear days.	Partly cloudy days.		Cloudy days.	Average cloudiness, tenths.	Total snowfall.			
																					Miles per hour.	Direction.	Date.									
New England.	Fl.	Fl.	Fl.	In.	In.	In.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	°F.	%	In.	In.	Miles	Miles													
Eastport.....	76	67	85	29.68	29.77	-0.19	43.2	-3.7	65	19	50	29	1	37	18	40	37	82	1.62	-2.2	13	9,182	nw.	44	e.	29	6	10	15	6.9	1.2	.....
Greenville.....	1,070	6	117	29.70	29.82	-0.15	47.3	-6.2	79	20	55	32	6	40	29	42	36	68	3.19	-0.5	15	5,120	nw.	31	nw.	26	8	16	6.6	2.6	.....	
Portland, Me.....	103	82	117	29.70	29.82	-0.15	47.3	-6.2	79	20	55	32	6	40	29	42	36	68	3.19	-0.5	15	5,120	nw.	31	nw.	26	8	16	6.6	2.6	.....	
Concord.....	288	70	79	29.49	29.80	-0.18	47.6	-8.1	79	20	57	32	4	39	40	45	36	68	2.92	-0.3	13	7,889	n.	34	s.	19	4	9	18	7.4	1.0	.....
Burlington.....	404	11	48	29.39	29.83	-0.14	47.0	-6.9	75	31	55	32	16	39	36	40	45	36	2.00	-0.8	13	7,889	n.	34	s.	19	4	9	18	7.4	1.0	.....
Northfield.....	876	12	60	29.84	29.84	-0.13	44.2	-9.3	75	31	53	26	16	35	40	45	36	68	2.80	-0.6	18	6,081	s.	32	ne.	12	3	9	19	7.8	2.6	.....
Boston.....	125	115	188	29.68	29.81	-0.17	50.7	-5.9	80	20	58	36	6	44	28	47	43	77	4.45	+0.9	14	8,303	nw.	31	e.	5	9	5	17	6.3	T.	.....
Nantucket.....	12	14	90	29.78	29.79	-0.20	48.1	-5.9	68	20	54	34	1	42	21	45	42	85	4.22	+1.6	12	13,031	w.	60	ne.	5	9	5	17	6.3	T.	.....
Block Island.....	26	11	46	29.78	29.81	-0.18	49.2	-3.7	71	20	57	38	6	44	23	45	43	85	3.01	-0.7	12	12,949	w.	56	ne.	5	9	5	17	6.3	T.	.....
Narragansett Pier.....	9	9	9	29.78	29.81	-0.18	49.2	-3.7	71	20	57	38	6	44	23	45	43	85	3.01	-0.7	12	12,949	w.	56	ne.	5	9	5	17	6.3	T.	.....
Providence.....	160	215	251	29.64	29.81	-0.17	50.6	-7.9	81	20	59	34	5	43	30	44	37	66	3.95	-0.1	13	10,600	nw.	55	nw.	25	5	10	16	6.8	T.	.....
Hartford.....	159	122	140	29.65	29.82	-0.16	51.0	-6.5	80	20	59	34	5	43	30	44	37	66	3.66	-0.1	13	6,214	nw.	36	nw.	25	5	10	16	6.8	T.	.....
New Haven.....	106	117	155	29.72	29.83	-0.16	52.2	-5.4	82	20	60	34	4	44	30	45	38	64	3.45	+0.2	16	7,025	nw.	35	s.	24	5	11	15	6.4	T.	.....
Middle Atlantic States.							56.3	-5.4								63	2.82	-0.7														
Albany.....	97	102	115	29.72	29.83	-0.15	51.0	-7.9	77	19	58	38	15	44	29	45	38	66	2.83	-0.2	15	6,159	nw.	29	s.	19	8	11	12	6.3	T.	.....
Binghamton.....	871	10	69	28.90	29.83	-0.15	48.8	-8.2	80	19	56	31	4	41	37	46	39	64	3.29	+0.1	17	5,187	nw.	26	se.	1	4	6	21	7.6	T.	.....
New York.....	314	414	454	29.50	29.83	-0.16	53.2	-6.1	82	20	61	38	6	46	29	46	39	64	3.29	+0.1	17	5,187	nw.	26	se.	1	4	6	21	7.6	T.	.....
Harrisburg.....	374	94	104	29.47	29.87	-0.11	56.6	-5.1	86	18	64	39	4	49	38	48	39	57	1.95	-1.7	8	6,249	nw.	33	n.	10	4	10	17	7.4	0.0	.....
Philadelphia.....	117	123	190	29.74	29.86	-0.13	57.2	-5.0	86	20	65	41	6	49	38	48	39	57	1.95	-1.7	8	6,249	nw.	33	n.	10	4	10	17	7.4	0.0	.....
Reading.....	325	81	98	29.51	29.86	-0.13	57.2	-5.0	86	20	65	41	6	49	38	48	39	57	1.95	-1.7	8	6,249	nw.	33	n.	10	4	10	17	7.4	0.0	.....
Scranton.....	805	111	119	29.00	29.86	-0.12	51.6	-7.2	82	19	59	35	6	47	38	47	39	58	3.01	-0.4	10	6,382	nw.	30	e.	12	5	14	12	6.5	0.0	.....
Atlantic City.....	52	37	48	29.80	29.85	-0.13	54.8	-2.7	87	20	62	38	9	48	33	49	43	70	3.32	+0.3	9	6,495	sw.	32	sw.	24	6	7	18	7.0	T.	.....
Cape May.....	18	13	49	29.86	29.87	-0.12	56.3	-2.3	88	20	64	38	9	48	33	49	43	70	3.32	+0.3	9	6,495	sw.	32	sw.	24	6	7	18	7.0	T.	.....
Sandy Hook.....	22	10	57	29.81	29.83	-0.12	56.3	-2.3	88	20	64	38	9	48	33	49	43	70	3.32	+0.3	9	6,495	sw.	32	sw.	24	6	7	18	7.0	T.	.....
Trenton.....	190	159	183	29.64	29.84	-0.15	54.6	-7.2	82	19	59	35	6	47	38	47	39	58	3.01	-0.4	10	6,382	nw.	30	e.	12	5	14	12	6.5	0.0	.....
Baltimore.....	123	100	113	29.74	29.87	-0.12	59.2	-5.0	86	20	63	38	4	46	31	47	40	65	2.90	-0.6	12	9,843	nw.	48	nw.	10	7	13	11	6.3	0.0	.....
Washington.....	112	62	85	29.74	29.86	-0.14	59.6	-4.6	89	20	67	42	6	51	32	50	42	57	3.24	-0.3	9	6,183	nw.	45	nw.	2	6	10	15	6.8	0.0	.....
Lynchburg.....	681	153	188	29.16	29.90	-0.10	60.7	-5.2	90	20	72	38	9	50	37	52	46	61	2.21	-1.8	10	6,689	nw.	30	nw.	1	8	14	9	5.2	0.0	.....
Norfolk.....	91	170	205	29.79	29.89	-0.11	62.4	-3.8	91	20	72	43	9	50	35	53	46	61	1.98	-2.1	10	6,495	nw.	37	sw.	28	17	9	5	4.6	0.0	.....
Richmond.....	144	11	52	29.73	29.88	-0.11	61.2	-6.1	91	20	72	41	9	50	35	53	47	63	2.59	+0.7	10	6,713	sw.	38	nw.	27	11	10	10	5.4	0.0	.....
Wytheville.....	2,293	49	55	27.56	29.91	-0.08	55.2	-6.2	83	21	64	37	8	46	33	48	43	66	2.18	-1.7	10	6,064	w.	37	w.	28	16	7	8	4.4	0.0	.....
South Atlantic States.							66.5	-3.3								65	2.33	-1.5														
Asheville.....	2,255	70	84	27.61	29.94	-0.05	57.0	-5.6	85	19	67	35	9	47	35	49	44	65	1.30	-2.5	10	6,955	nw.	30	se.	22	10	14	7	4.7	0.0	.....
Charlotte.....	773	153	161	29.09	29.92	-0.07	63.6	-2.8	89	20	74	41	14	53	29	55	49	63	2.45	-1.5	6	8,584	sw.	50	sw.	28	11	9	11	5.2	0.0	.....
Hatteras.....	11	12	50	29.88	29.90	-0.11	64.6	-4.5	90	18	70	47	9	59	21	58	55	75	0.85	-3.3	4	11,307	sw.	44	n.	8	14	12	5	4.4	0.0	.....
Manteo.....	12	4	46	29.88	29.90	-0.11	64.6	-4.5	90	18	70	47	9	59	21	58	55	75	0.85	-3.3	4	11,307	sw.	44	n.	8	14	12	5	4.4	0.0	.....
Raleigh.....	376	103	110	29.50	29.90	-0.09	64.2	-3.9	92	20	72	44	10	55	28	55	47	58	2.23	-1.8	3	6,549	sw.	38	w.	22	15	6	10	4.7	0.0	.....
Wilmington.....	78	81	91	29.84	29.92	-0.09	66.6	-2.5	92	19	76	44	14	57	29	58	53	68	2.94	-2.0	9	6,549	sw.	38	w.	22	15	6	10	4.7	0.0	.....
Charleston.....	48	11	92	29.90	29.95	-0.06	70.2	-2.2	91	19	76	44	14	57	29	58	53	68	2.94	-2.0	9	6,549	sw.	38	w.	22	15	6	10	4.7	0.0	.....
Columbia, S. C.....	351	41	57	29.56	29.93	-0.07	67.0	-4.8	92	21	77	44	14	57	30	56	48	55	2.72	-0.5	7	5,882	sw.	38	w.	22	15	6	10	4.7	0.0	.....
Augusta.....	180	62	77	29.75	29.94	-0.05	67.8	-4.4	93	27	79	45	14	56	34	61	56	67	2.09	-1.1	5	4,987	nw.	33	nw.	4	16	7	8	3.7	0.0	.....
Savannah.....	65	150																														

TABLE I.—Climatological data for Weather Bureau stations, May, 1917—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.		
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Maximum.	Date.	Mean minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of dew point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity.								
																							Miles per hour.							Direction.	Date.
Ohio Valley and Tennessee.	Ft.	Ft.	Ft.	In.	In.	In.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	%	In.	In.	In.	Miles							0-10	In.	In.	
							58.2	-6.7										66	3.67	0.0								5.8			
Chattanooga	762	189	213	29.18	29.98	-0.01	62.6	-6.0	86	21	73	42	9	52	32	53	45	57	2.95	-0.7	9	7,414	sw.	53	sw.	22	8	16	7	5.0	0.0
Knoxville	906	93	100	28.91	29.96	+0.03	60.9	-5.6	86	21	71	39	14	50	34	52	45	60	2.52	-1.2	8	4,440	sw.	36	s.	22	10	11	10	5.2	0.0
Memphis	399	76	97	29.59	30.01	+0.05	64.2	-6.5	87	26	73	43	5	56	24	56	49	62	2.91	-1.4	7	6,955	sw.	46	w.	21	14	12	5	4.0	0.0
Nashville	546	168	191	29.40	29.99	+0.01	61.8	-7.0	86	31	72	41	14	51	30	54	47	62	4.75	+1.2	7	8,153	nw.	46	nw.	27	14	7	10	4.7	0.0
Lexington	989	193	230	28.88	29.95	+0.04	56.9	-7.4	84	19	66	35	5	48	32	51	44	61	3.51	0.0	10	10,894	sw.	56	sw.	22	8	11	12	5.8	0.0
Louisville	525	219	255	29.38	29.97	+0.01	59.6	-7.1	87	19	69	38	4	50	30	51	44	61	4.39	+0.8	14	10,231	sw.	61	s.	27	6	12	13	6.3	0.0
Evansville	431	139	175	29.49	29.96	+0.01	60.4	-6.7	85	19	70	40	4	51	28	53	46	62	3.68	+0.2	13	9,269	nw.	48	sw.	22	9	15	7	5.0	0.0
Indianapolis	822	194	230	29.05	29.94	+0.03	56.0	-7.3	85	19	65	33	4	47	31	49	42	64	3.36	-0.6	10	10,303	w.	50	w.	23	6	8	17	6.4	T.
Terre Haute	575	96	129	29.31	29.93	+0.03	57.4	-6.6	86	19	67	35	5	48	28	51	46	70	6.29	0.0	14	8,086	nw.	36	nw.	8	4	13	14	6.5	T.
Cincinnati	628	11	51	29.26	29.94	+0.05	56.6	-6.5	86	19	66	35	10	47	35	49	42	63	4.62	+1.1	13	6,663	sw.	37	sw.	1	10	10	11	5.8	0.0
Columbus	824	173	222	29.04	29.91	+0.07	55.2	-7.1	86	19	64	36	9	46	34	50	46	76	2.80	-0.9	11	10,275	nw.	51	w.	24	6	12	13	6.1	0.0
Dayton	899	181	216	28.95	29.90	+0.05	55.0	-7.9	84	19	64	35	10	46	34	50	47	78	3.81	-0.1	15	9,360	w.	46	sw.	22	8	11	12	6.2	T.
Pittsburgh	842	353	410	28.99	29.89	+0.10	54.6	-8.0	83	19	63	36	3	46	32	49	45	75	2.65	-0.6	16	9,685	nw.	54	sw.	22	4	9	23	7.7	0.0
Elkins	1,940	41	50	27.87	29.91	+0.09	53.6	-5.5	84	19	64	32	26	43	41	46	41	68	4.35	+0.4	16	4,252	w.	34	w.	22	5	9	17	7.2	T.
Parkersburg	638	77	84	29.27	29.93	+0.06	57.6	-5.7	86	19	67	34	10	48	30	50	45	69	5.06	+1.6	11	5,267	nw.	30	nw.	26	9	13	13	5.8	0.0
Lower Lake Region.							49.8	-7.7										72	3.55	+0.4								6.7			
Buffalo	767	247	280	29.03	29.86	-0.11	47.4	-7.1	77	31	54	34	3	40	31	43	39	76	2.88	-0.2	15	13,614	sw.	66	sw.	23	4	12	15	6.8	T.
Canton	448	10	61	29.35	29.83	+0.12	46.8	-6.4	81	31	55	31	15	38	39	43	38	76	2.28	-0.6	12	8,160	e.	36	ne.	5	7	9	15	6.5	T.
Oswego	335	79	91	29.48	29.85	+0.12	46.4	-6.3	80	19	53	33	3	40	37	42	38	76	3.20	+0.4	16	7,833	n.	40	nw.	19	5	6	20	7.1	T.
Rochester	523	97	113	29.30	29.88	+0.09	49.2	-7.5	84	19	57	34	3	41	36	43	37	68	3.16	+0.2	17	7,344	w.	38	nw.	19	5	12	14	6.6	T.
Syracuse	597	97	113	29.21	29.86	+0.12	48.0	-7.7	79	19	55	32	3	41	32	43	38	69	3.65	+0.3	17	9,082	nw.	48	nw.	19	4	9	18	7.3	T.
Erie	714	130	166	29.10	29.87	+0.11	49.6	-7.7	83	19	57	35	5	43	32	45	41	75	6.74	+3.3	20	10,685	ne.	48	sw.	1	6	15	10	6.3	0.1
Cleveland	762	190	201	29.07	29.89	+0.09	51.2	-7.3	83	19	58	37	23	45	29	46	43	76	2.89	-0.3	16	10,620	ne.	48	w.	1	6	13	12	6.7	0.0
Sandusky	629	62	103	29.21	29.89	+0.09	52.0	-7.2	87	19	59	38	5	45	33	47	42	72	3.13	-0.1	15	11,143	ne.	48	sw.	1	2	14	15	7.1	0.0
Toledo	628	208	243	29.22	29.90	+0.07	52.6	-7.1	85	19	61	34	5	44	33	47	41	70	4.58	+1.3	15	12,003	nw.	58	sw.	1	6	13	12	6.3	T.
Fort Wayne	856	113	124	29.00	29.93	+0.07	53.2	-7.0	85	18	62	33	9	44	32	47	41	68	4.00	0.0	12	8,305	nw.	46	sw.	1	8	10	13	6.1	0.0
Detroit	730	218	245	29.11	29.90	+0.07	51.4	-6.5	83	19	59	33	3	43	29	45	40	69	3.32	0.0	15	9,667	n.	55	w.	1	5	8	18	7.0	T.
Upper Lake Region.							47.9	-4.8										68	2.50	-0.9								5.6			
Alpena	609	13	92	29.25	29.92	-0.05	45.6	-3.9	79	16	54	31	3	38	33	41	35	67	3.04	-0.3	7	10,178	nw.	41	w.	2	9	11	11	5.8	5.7
Escanaba	612	54	60	29.31	29.98	+0.01	46.3	-3.7	81	16	54	30	9	38	33	40	34	65	1.04	-2.4	4	9,103	ne.	40	ne.	22	11	8	12	5.4	T.
Grand Haven	632	54	92	29.25	29.93	+0.03	48.4	-6.4	76	17	56	34	22	41	27	44	39	72	4.23	+0.9	11	9,456	w.	53	w.	1	15	7	9	4.8	T.
Grand Rapids	707	70	87	29.16	29.93	+0.04	51.7	-6.3	83	18	61	33	3	42	31	45	38	63	4.48	+1.1	9	5,696	ne.	34	w.	1	6	14	11	5.8	T.
Houghton	684	62	99	29.28	30.01	+0.04	45.8	-3.9	79	16	55	30	4	36	41	40	38	63	1.04	-2.2	5	7,672	w.	36	s.	19	13	9	9	4.9	2.7
Lansing	878	11	62	29.97	29.92	+0.05	50.2	-7.7	83	19	60	30	3	44	45	40	42	72	3.37	-0.2	12	6,097	nw.	29	sw.	1	4	7	20	7.6	T.
Ludington	637	60	66	29.24	29.95	+0.06	46.6	-4.2	81	17	54	32	22	39	29	42	37	72	2.74	0.0	9	7,543	n.	34	w.	1	17	4	10	4.3	1.2
Marquette	734	77	111	29.21	30.02	+0.05	44.8	-4.2	81	16	53	27	4	37	38	39	33	66	1.45	-1.9	5	7,711	nw.	40	sw.	19	8	7	16	6.4	6.3
Port Huron	638	70	120	29.19	29.89	+0.08	47.0	-6.7	82	19	54	31	3	40	34	43	39	75	1.63	-1.6	14	10,014	ne.	40	sw.	1	8	10	13	6.1	T.
Saginaw	641	48	82	29.21	29.91	+0.08	50.0	-6.7	80	18	59	32	3	41	37	44	39	69	3.97	-0.2	12	8,700	nw.	38	w.	1	2	9	20	7.9	T.
Sault Sainte Marie	614	11	61	29.25	29.95	+0.00	44.0	-3.7	71	29	53	27	4	35	36	39	33	68	1.87	-1.4	7	7,937	nw.	38	nw.	23	7	9	15	6.3	3.7
Chicago	823	140	310	29.06	29.95	+0.01	52.6	-4.9	88	19	60	37	23	46	27	45	38	61	3.41	0.0	11	10,101	n.	38	nw.	19	12	7	12	5.2	T.
Green Bay	617	109	144	29.29	29.95	+0.00	50.2	-4.3	82	17	59	30	23	41	3																

TABLE I.—Climatological data for Weather Bureau stations, May, 1917—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	Barometer above sealevel.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sealevel, reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.	Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.							Maximum velocity.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																
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Billings.....	3,140	5						48.8	-4.2									64	3.10	+0.7		Miles																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.			Depths of precipitation (in inches) during periods of time indicated.												
		From—	To—		Began—	Ended—	Amount before excessive rate began.	5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.
Ablene, Tex.	19	6:35 p.m.	D. N. p.m.	1.10	6:53 p.m.	7:18 p.m.	0.03	0.17	0.28	0.34	0.45	0.51								
Albany, N. Y.	29			0.82																
Alpena, Mich.	1			1.21																
Amarillo, Tex.	13			0.41																
Anniston, Ala.	28			0.54																
Asheville, N. C.	4			0.42																
Atlanta, Ga.	4	5:40 a.m.	7:42 p.m.	0.97	6:16 a.m.	6:45 a.m.	0.03	0.05	0.11	0.23	0.44	0.61	0.64							
Atlantic City, N. J.	1	12:20 p.m.	1:35 p.m.	0.81	12:44 p.m.	1:11 p.m.	0.16	0.18	0.30	0.40	0.51	0.60	0.63							
Augusta, Ga.	7			0.53																
Baker, Oreg.	6			1.08																
Baltimore, Md.	1	1:30 p.m.	1:50 p.m.	0.49	1:32 p.m.	1:43 p.m.	0.02	0.20	0.45	0.47										
	28	3:13 p.m.	3:50 p.m.	0.40	3:13 p.m.	3:24 p.m.	0.00	0.12	0.39	0.40										
	3	4:15 a.m.	6:55 a.m.	1.06	5:04 a.m.	5:44 a.m.	0.09	0.14	0.18	0.19	0.26	0.45	0.72	0.84	0.91					
Bentonville, Ark.	3	4:05 p.m.	9:20 p.m.	1.51	4:04 p.m.	4:27 p.m.	0.01	0.14	0.50	0.52										
	21	9:05 a.m.	1:15 p.m.	1.06	11:34 a.m.	11:52 a.m.	0.42	0.12	0.28	0.45	0.52									
Binghamton, N. Y.	29			0.82																
	3	9:52 a.m.	12:05 p.m.	0.79	11:34 a.m.	11:52 a.m.	0.15	0.14	0.33	0.55	0.63									
Birmingham, Ala.	27-28	5:10 p.m.	7:40 p.m.	1.67	5:45 p.m.	7:05 p.m.	0.03	0.11	0.19	0.35	0.54	0.75	0.91	1.13	1.18	1.21	1.25	1.37	1.55	
	29	10:15 p.m.	D. N. a.m.	0.58	10:54 p.m.	11:20 p.m.	0.03	0.13	0.16	0.20	0.32	0.49	0.51							
Bismarck, N. Dak.	29			0.25																
Block Island, R. I.	1			0.65																
Boise, Idaho.	24			0.71																
Boston, Mass.	29			0.49																
Buffalo, N. Y.	19			0.66																
Burlington, Vt.	29			0.67																
Cairo, Ill.	21			0.73																
Canton, N. Y.	19-20			0.37																
Charles City, Iowa.	18	9:42 p.m.	11:30 p.m.	0.84	10:00 p.m.	10:15 p.m.	0.03	0.13	0.34	0.54										
Charleston, S. C.	4	1:05 p.m.	3:00 p.m.	0.95	1:27 p.m.	1:53 p.m.	0.03	0.23	0.47	0.59	0.62	0.82	0.80							
	31	5:25 p.m.	9:10 p.m.	0.78	6:25 p.m.	6:39 p.m.	0.03	0.29	0.48	0.54										

‡ No precipitation occurred during month.

inch in

0	120
n.	min.

† No precipitation occurred during month.

TABLE II.—Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during May, 1917, at all stations furnished with self-registering gages—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Valentine, Nebr.	20			1.30														0.53			
Vicksburg, Miss.	3	D. N. a. m.	D. N. a. m.	0.82	2:36 a. m.	2:54 a. m.	0.10	0.25	0.43	0.49	0.54										
Walla Walla, Wash.	21-22	D. N. p. m.	D. N. a. m.	0.81	11:42 p. m.	12 midn't.	0.03	0.09	0.31	0.60	0.74										
Washington, D. C.	1			0.33														0.21			
Wichita, Kans.	28			0.38														0.24			
Williston, N. Dak.	27			2.22														0.65			
Wilmington, N. C.	30-31			0.07														0.01			
Winnemucca, Nev.	23	12:53 p. m.	1:50 p. m.	0.69	12:59 p. m.	1:31 p. m.	0.03	0.20	0.37	0.39	0.39	0.40	0.63	0.64							
Wytheville, Va.	23			1.13														0.15			
Yankton, S. Dak.	22			0.61														0.46			
Yellowstone Park, Wyo.	20			0.52														0.35			
	22-23			0.56														*			

* Self-register not in use.

† Record partly estimated.

‡ No precipitation occurred during month.

TABLE III.—Data furnished by the Canadian Meteorological Service, May, 1917.

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max. + mean min. +2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Fed.	Inches.	Inches.	Inches.	° F.	° F.	° F.	° F.	° F.	° F.	Inches.	Inches.	Inches.
St. Johns, N. F.	125	29.50	29.64	-0.34	40.7	-2.2	47.3	34.2	63	30	3.36	-0.30	0.0
Sydney, C. B. I.	48	29.72	29.76	- .21	41.6	-3.6	49.3	33.9	65	26	4.45	+0.68	1.5
Halifax, N. S.	88	29.63	29.74	- .24	44.5	-3.9	52.3	36.6	66	29	4.86	+0.60	2.2
Yarmouth, N. S.	65	29.67	29.74	- .24	42.9	-4.7	48.8	37.0	58	28	4.56	+0.76	5.7
Charlottetown, P. E. I.	38	29.70	29.74	- .22	41.6	-5.3	47.5	35.7	61	30	3.18	+0.27	0.2
Chatham, N. B.	28	29.78	29.80	-0.15	42.2	-6.3	48.9	35.5	68	26	5.42	+2.21	3.6
Father Point, Que.	20	29.82	29.84	- .09	39.8	-4.2	45.3	34.3	53	24	3.30	+0.72	0.7
Quebec, Que.	206	29.51	29.82	- .12	46.2	-3.7	54.9	37.5	80	30	2.52	-0.56	5.2
Montreal, Que.	187	29.61	29.82	- .12	48.3	-6.4	57.0	39.7	77	32	3.35	+0.40	T.
Stonecliffe, Ont.	489	29.25	29.86	- .07	50.2	-2.1	58.2	42.3	82	31	1.23	-1.28	0.0
Ottawa, Ont.	236	29.57	29.83	-0.11	48.9	-6.0	58.1	39.6	80	32	2.14	-0.45	T.
Kingston, Ont.	285	29.54	29.85	- .11	48.2	-4.7	56.4	40.0	73	33	2.59	-0.09	T.
Toronto, Ont.	379	29.45	29.86	- .12	49.3	-3.9	57.9	40.7	78	34	2.35	-0.69	T.
White River, Ont.	1,244	28.65	29.98	+ .03	41.5	-4.2	54.8	28.1	74	12	1.53	-0.42	6.6
Port Stanley, Ont.	592	29.24	29.88	- .09	47.7	-5.4	56.5	38.9	74	30	4.47	+1.29	0.0
Southampton, Ont.	656	29.16			44.1	-6.6	51.9	36.4	74	26	2.85	+0.41	0.5
Parry Sound, Ont.	688	29.18	29.88	- .07	48.1	-3.0	58.5	37.8	74	29	2.92	-0.01	1.2
Port Arthur, Ont.	644	29.32	30.03	+ .07	47.0	+1.1	58.0	36.0	84	28	1.42	-0.73	0.0
Winnipeg, Man.	760	29.23	30.07	+ .11	51.1	-0.5	67.0	35.2	88	25	0.03	-2.25	0.0
Minneapolis, Man.	1,690	28.24	30.06	+ .10	49.1	+0.7	64.3	33.9	92	21	0.04	-1.41	0.0
Qu'Appelle, Sask.	2,115	27.74	29.98	+0.04	51.1	+1.3	64.3	38.0	86	24	0.23	-1.42	T.
Medicine Hat, Alberta.	2,144	27.62	29.88	- .01	57.4	+3.3	72.8	42.0	94	25	0.17	-1.14	0.0
Swift Current, Sask.	2,392	27.38	29.94	+ .02	52.3	+1.6	67.7	37.0	92	20	0.04	-1.72	0.0
Calgary, Alberta.	3,428	26.40	29.92	+ .04	49.0	0.0	63.4	34.6	82	22	1.58	-0.19	0.4
Banff, Alberta.	4,521	25.34	29.91	+ .03	44.5	-2.5	57.6	31.4	71	17	3.28	+1.24	9.9
Edmonton, Alberta.	2,150												
Prince Albert, Sask.	1,450	28.45	30.01	+ .06	52.6	+5.0	67.0	38.3	85	24	0.77	-0.49	3.0
Battleford, Sask.	1,592	28.22	29.95	+ .03	54.6	+3.6	68.4	40.9	93	25	0.36	-1.26	0.2
Kamloops, B. C.	1,262	28.69	29.97	+ .08	57.2	-1.9	68.9	45.6	82	33	1.64	+0.40	0.0
Victoria, B. C.	230	29.79	30.05	+ .05	49.9	-2.6	55.9	43.9	62	40	0.56	-0.92	0.0
Barkerville, B. C.	4,180	25.66	29.97	+0.13	42.4	-3.1	53.5	31.3	67	20	1.62	-0.90	0.0
Hamilton, Bermuda.	151	29.85	30.01	- .05	67.3	-2.1	72.1	62.5	78	55	4.18	-0.48	0.0

* See Explanation of Tables in this REVIEW for January, 1917, p. 40.

Chart I. Hydrographs of Several Principal Rivers, May, 1917.

XLV-42.

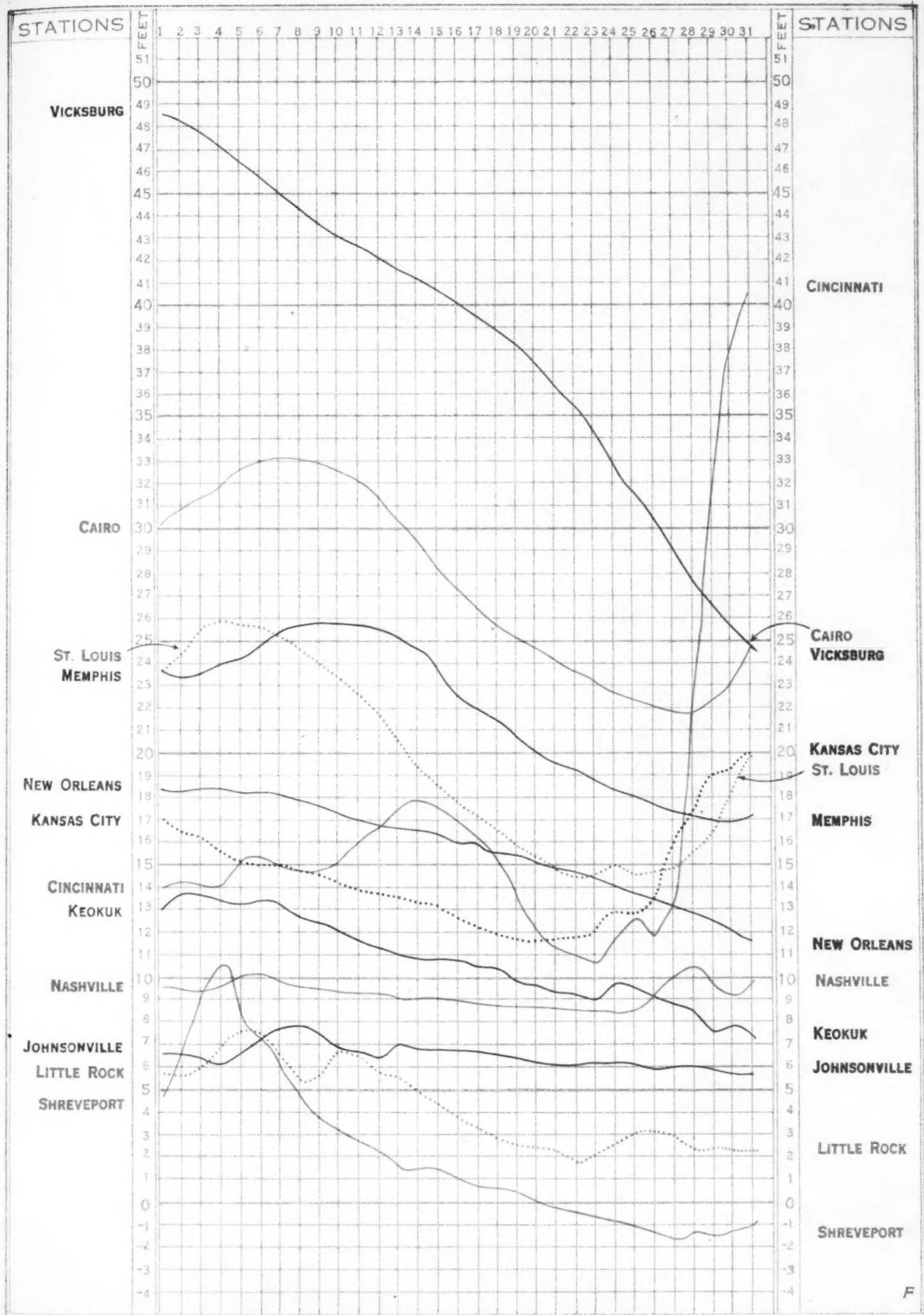


Chart II. Tracks of Centers of High Areas, May, 1917.
(Plotted by Charles A. Donnel.)

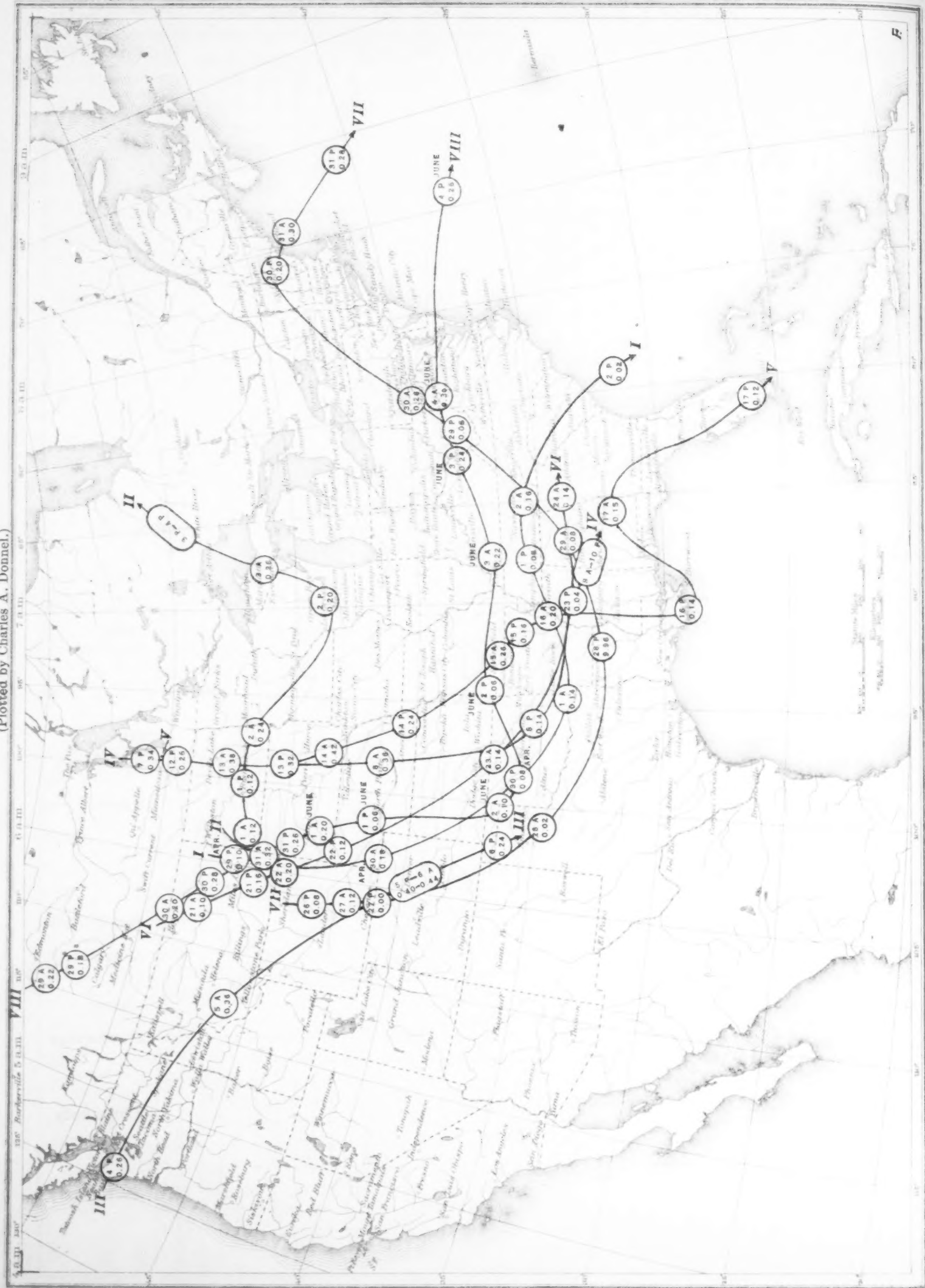


Chart III. Tracks of Centers of Low Areas, May, 1917.
(Plotted by Charles A. Donnell.)

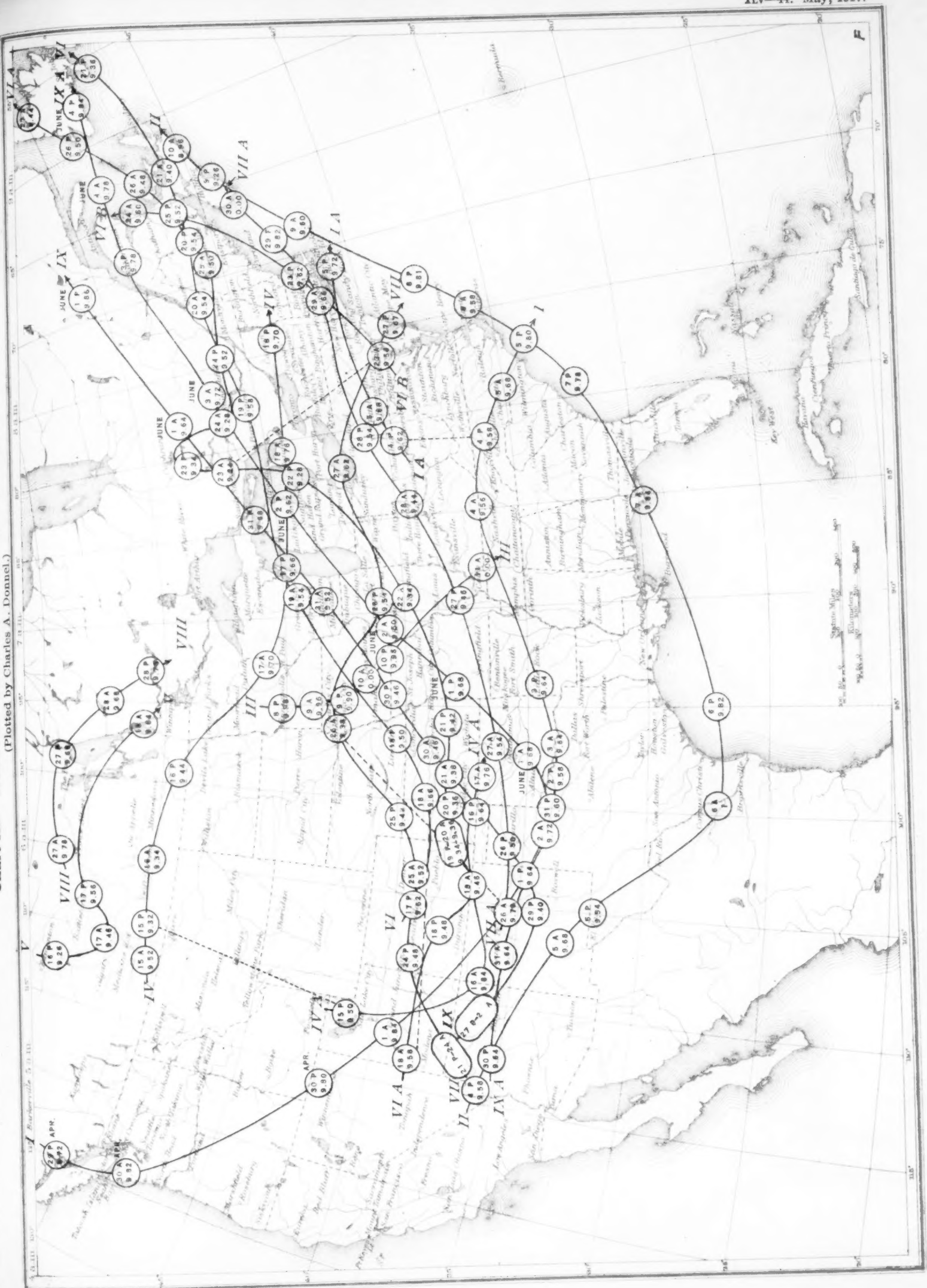


Chart IV. Departure (°F.) of the Mean Temperature from the Normal, May, 1917.

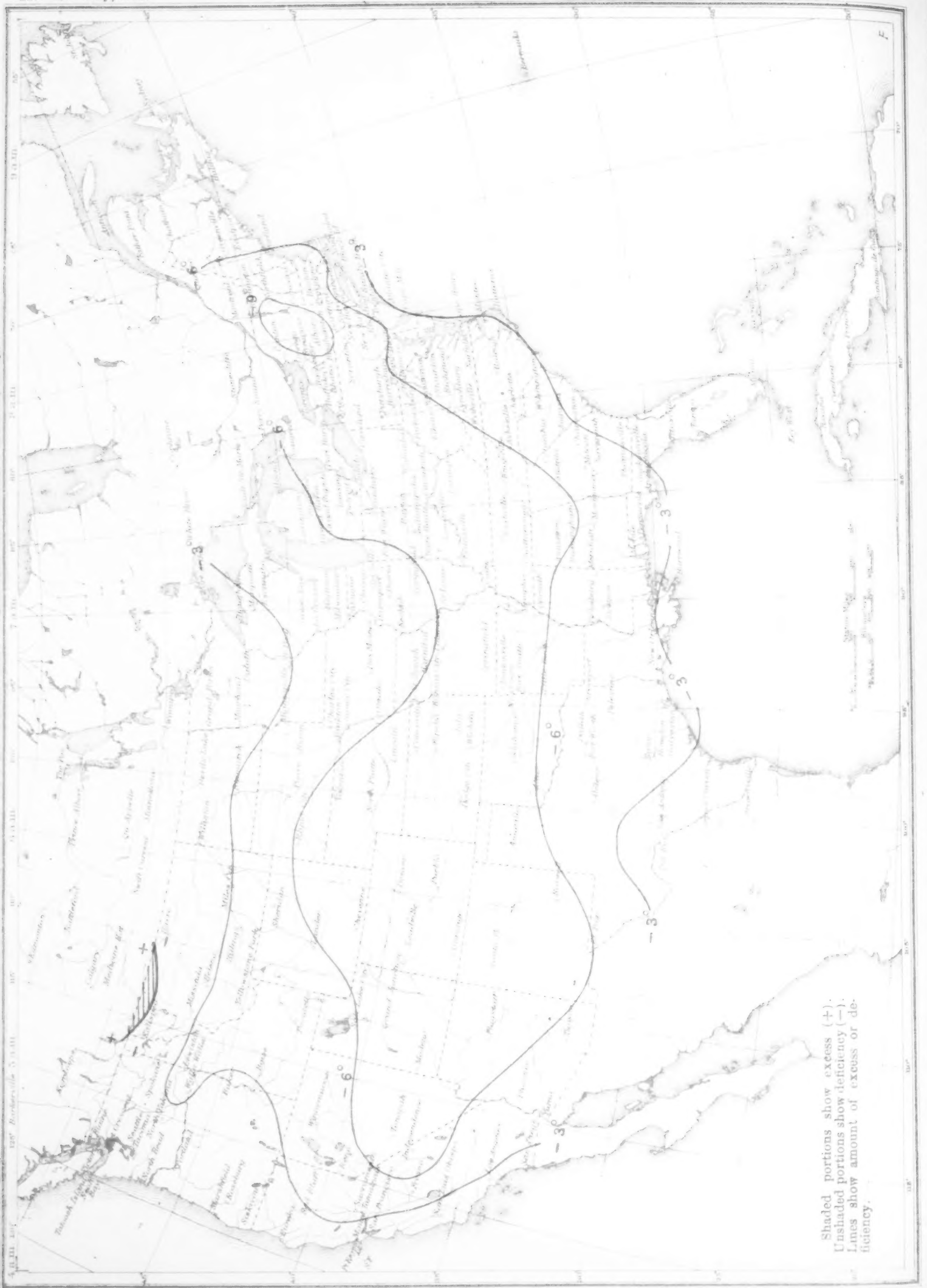


Chart V. Total Precipitation, May, 1917.

Chart V. Total Precipitation, May, 1917.



Chart VI. Percentage of Clear Sky between Sunrise and Sunset, May, 1917.

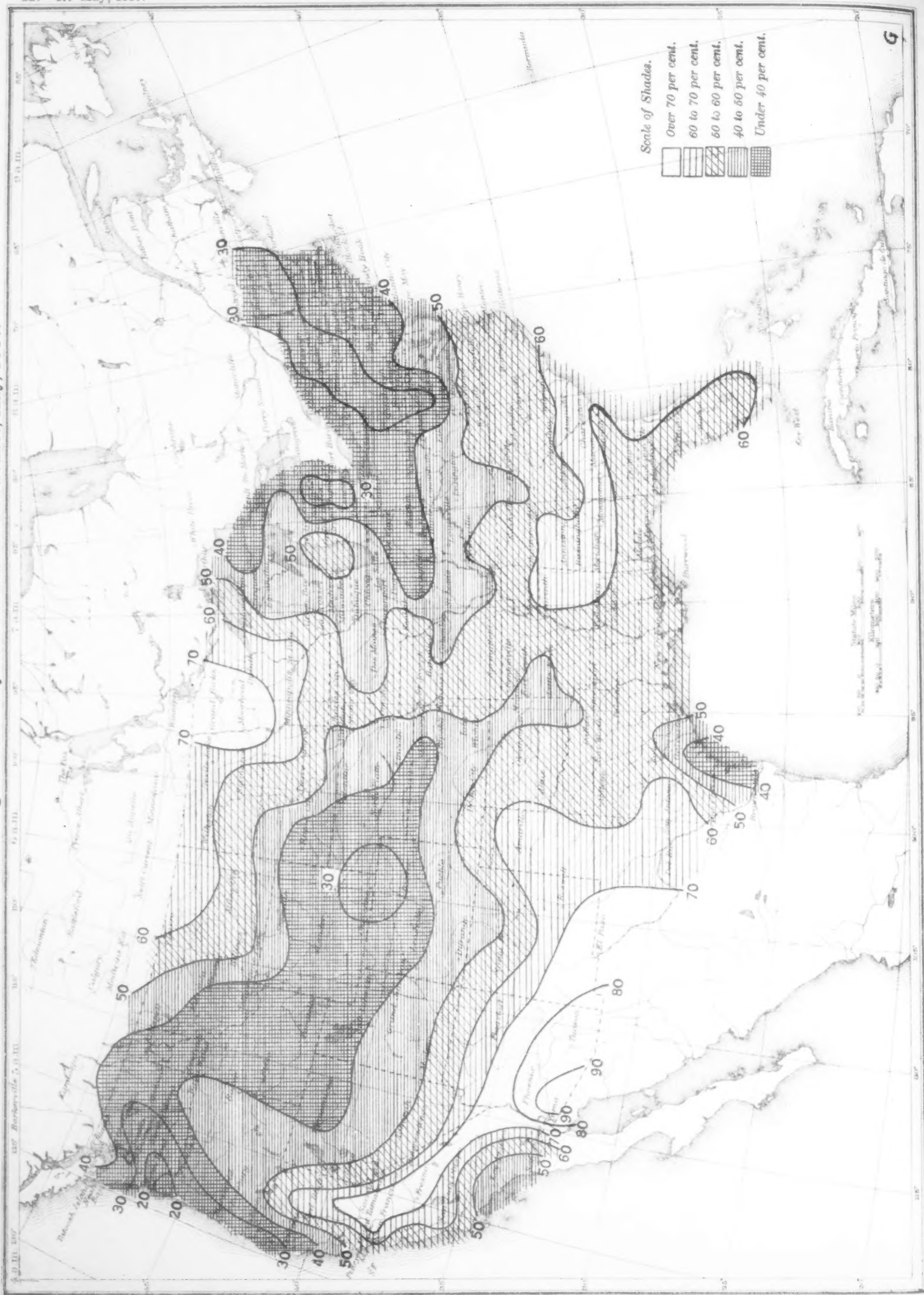
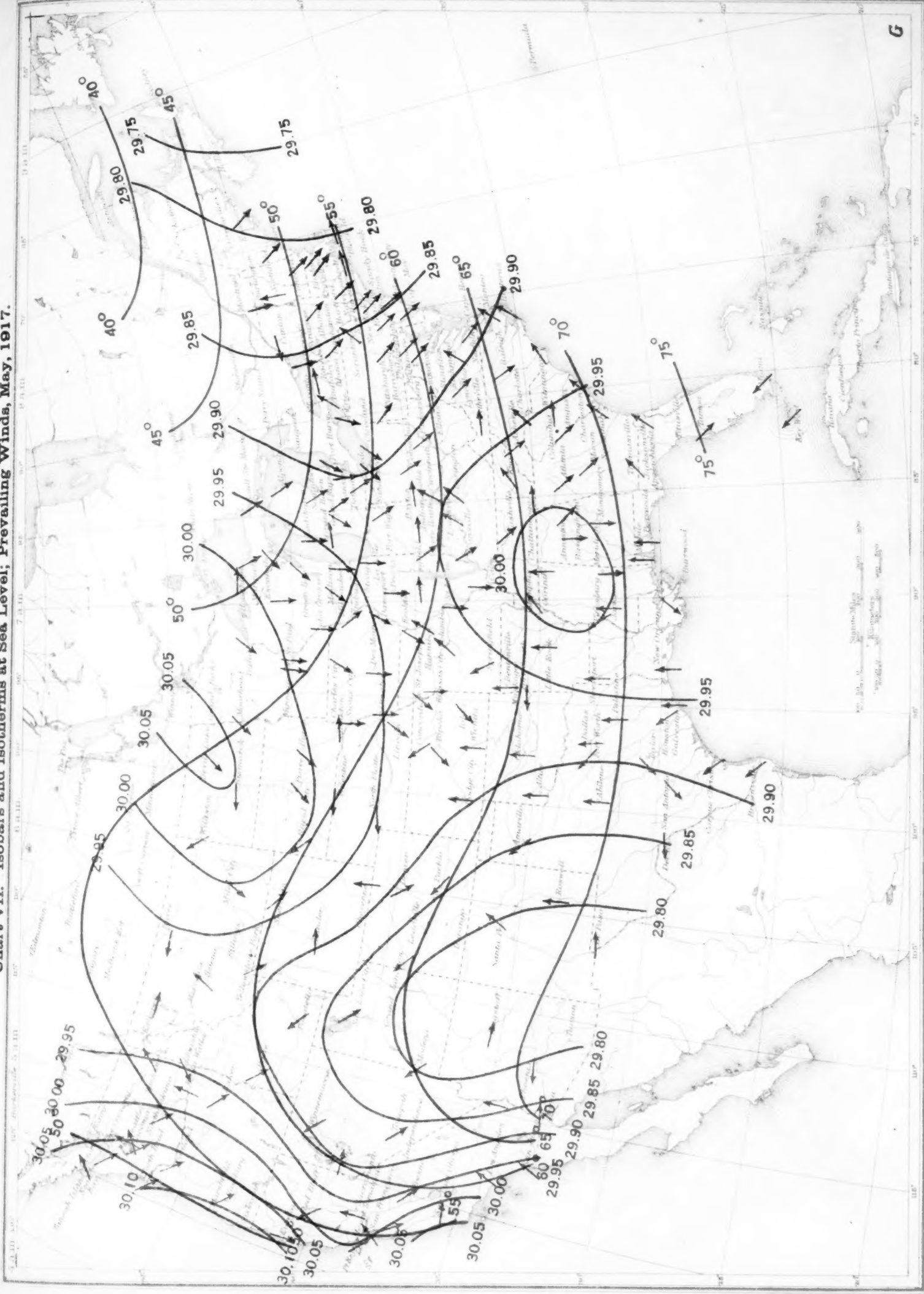


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, May, 1917.

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Chart VIII. Total Snowfall, Inches, May, 1917.



Chart IX. Means of Meteorological Data for North Atlantic Ocean, May, 1916.

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(Plotted by F. A. Young.)

