

Australia.—In Queensland * * * the month was one of drought.¹

Guam.—AGANA, March 30.—A typhoon of moderate intensity struck the island of Guam last Saturday, raged four days and receded without causing loss of life, but leaving property damage estimated at \$200,000.—*New York World, March 31, 1923.*

Argentina.—In Buenos Aires the unusually high March temperature of 94° F. recorded on the 12th, was fol-

lowed by a fall of 36° F. in 12 hours. Pressure rose 5 mb. almost instantly.¹

Brazil.—* * * In the north the rainfall averaged 53 mm. below normal. In the center the distribution was irregular; in the south the fall averaged 100 mm. above normal, the excess being greatest in the extreme south. * * * There is still an absence of intense anticyclones and the general circulation presents no unusual features.¹

DETAILS OF THE WEATHER IN THE UNITED STATES.

GENERAL CONDITIONS.

ALFRED J. HENRY.

The single outstanding feature of the month was the steady march of anticyclonic areas from the Pacific, some of which entered the continent north of the mouth of the Columbia and others as far south as the middle California coast.

As a direct result of this movement, drought prevailed in the Pacific Coast States, also in the Plateau region, the northern Rocky Mountains, and the upper portions of the Missouri and Mississippi Valleys; the most striking result, however, was the unseasonable temperatures recorded in many parts of the country due to the transportation of cold air from higher latitudes. Details appear in subsequent pages.

CYCLONES AND ANTICYCLONES.

By W. P. DAY.

March, in contrast to the preceding month, showed greatly increased barometric activity, a rapid succession of cyclones and anticyclones passing within the range of observation. Twenty low-pressure areas were noted and tracked, nine of which were of the Alberta type (Alaskan or North Pacific cyclones coming into the field of observation from Alberta), but the more important storms began as secondary developments over the south or southwest and several attained major intensity.

Thirteen high-pressure areas—anticyclones—were observed and these incursions of denser air were quite important as cold waves in several instances. The cold-wave types are usually masses of cold air loosed from the cold polar cap which advance southward over Canada when pressure conditions in the United States are favorable. Anticyclones moving in from the Pacific do not bring marked changes to colder.

FREE-AIR SUMMARY.

By L. T. SAMUELS, Meteorologist.

The general characteristics of the average free-air conditions for the month as a whole showed remarkably close agreement with those for February, 1923, with respect to departures from normal. Thus it will be observed in Table 1 that the temperature departures were all negative except in the upper levels at Groesbeck, a condition identical with that found last month. The persistence of large departures with increase in altitude was likewise most pronounced at the northern stations.

The vapor pressure departures conformed regularly with those for temperature and the relative humidity averaged in general somewhat less than the normal in the

lower levels and above in the upper levels, although practically all the departures were less than 10 per cent.

At each of the six kite stations minimum March temperature records were exceeded at various upper levels. These low temperatures were observed as a rule during the prevalence of severe cold wave conditions, a number of which occurred during the month.

In Table 2 are shown the resultant wind velocities and directions for the month and their normal values. A striking feature observed in the table is the high resultant velocities for the month at all stations except Broken Arrow and Groesbeck. The usual connection found between the resultant wind direction and the temperature departures is especially well illustrated. At Drexel and Ellendale where negative temperature departures were greatest the north component is found to exceed the normal by an appreciable amount. At Royal Center, Broken Arrow, and Due West the south component is decidedly less than normal while at Groesbeck, where negative temperature departures occurred in the lower levels and positive departures in the upper levels, the south component was less than normal in the former but exceeded it in the latter.

High winds were frequent during the month, there being more than twice as many observed velocities of 40 meters per second or more as occurred during March, 1922. These were observed by means of pilot balloons and are given in the following table:

Station.	Date.	Velocity.	Direction.	Altitude.
		<i>m. p. s.</i>		<i>m.</i>
Camp Alfred Vail, N. J.	16	47	wsw.	500
Camp Benning, Ga.	7	42	w.	5,000
Do.	9	41	wnw.	6,500
Do.	14	46	w.	7,200
Rolling Field, D. C.	10	41	sw.	1,400
Fort Bragg, N. C.	7	50	w.	3,500
Broken Arrow, Okla.	7	61	w.	6,500
Fort Curtis, Va.	14	42	nw.	3,200
Drexel, Nebr.	5	40	wsw.	1,400
Ellendale, N. Dak.	27	54	wnw.	4,600
Groesbeck, Tex.	13	46	w.	4,400
Do.	24	46	wsw.	9,500
Kelly Field, Tex.	11	40	w.	1,400
Lansing, Mich.	27	42	wnw.	2,250
Camp Lewis, Wash.	19	60	wsw.	2,000
Fort Riley, Kan.	26	45	w.	6,700

In order to verify the high velocities recorded at Ellendale on the 27th and at Groesbeck on the 13th, a second observation was made immediately after the first at both of these stations and the results found were substantially the same, thereby adding to the confidence which may generally be placed in single theodolite observations even in high winds.

The observation at Camp Alfred Vail on the 16th is cited because of the abnormally rapid increase in the wind speed at a comparatively short distance above the surface. The recorded velocities indicated a surface wind of but 9 meters per second overrun by a gale of 47

¹ *Meteorological Magazine*, April 1923, pp. 68-69.

¹ *Meteorological Magazine*, April 1923, pp. 68-69.

meters per second just 500 meters above. A strong substantiation of this rather unusual condition was found in the observations at several near-by stations although the extreme velocity and the rate of increase with altitude were somewhat less than at Camp Vail. A similar occurrence was found at Kelly Field, Tex., on the 11th when the velocity increased from 13 meters per second at the ground to 40 at 600 meters above. Pressure conditions in the two cases were quite similar. Camp Vail was at the time in the southeast quadrant of a strong barometric depression which subsequently moved very rapidly northeastward; Kelly Field was in the southwestern quadrant of a low which later moved rapidly northeastward and increased greatly in intensity.

The hurricane velocity of 60 meters per second (133 m. p. h.) observed at Camp Lewis, Wash., on the 19th at 2,000 meters elevation was an accompaniment of a disturbance of wide extent moving in over the Canadian Northwest following the intense cold wave over the country at this time.

Winds of 40 meters per second or more reported on the 7th over Oklahoma, Georgia, and North Carolina at elevations above 4,000 meters appear significant in view of the rapid east-northeastward movement of the severe cyclonic depression central on that morning south of the southern New England coast. In this same connection the great velocities recorded at Groesbeck on the 24th may be mentioned and seem very likely to be directly associated with the unexpectedly rapid movement of the pressure areas over the western and central sections of the country at and immediately following this time.

Both a. m. and p. m. pilot balloon observations at Groesbeck on the 8th showed a backing of the wind with increase in altitude as follows: South at surface, east at 2,000 meters, north at 2,500 meters, and west above 3,000 meters. This turning is more characteristic of the summer season than of spring since the percentage of counterclockwise turning with altitude for south surface winds at this station is normally less than 5 per cent for spring whereas for summer it is 25 per cent.

A diurnal series consisting of 9 kite flights was obtained at Groesbeck, extending from 7:25 a. m. of the 17th to 9:50 a. m. of the 18th, during which time a severe cold wave arrived over this region. The average maximum altitude reached for the series was 3,165 meters, the highest flight being 3,939 meters at 8:58 a. m. on the 17th and the lowest 2,707 meters at 4:54 a. m. on the 18th. The wind at the surface remained southerly during the first 7 flights of the series, veering with increase in altitude to WSW. above 2,000 meters elevation. The first evidence of a northerly component appeared at the surface at 4:15 a. m. of the 18th. This had reached the 1,000 meter level by 6 a. m. but had not extended above 1,300 meters by 9:21 a. m. when the series was ended. The pilot-balloon observation taken at 2 p. m. indicated surface north-northwesterly winds backing to WNW. at 1,500 meters, when the balloon was lost in stratus clouds. The presence of 10/10 stratus clouds at this time and the fact that they were moving from the WSW. seems to indicate that the wedge of northerly air did not extend above 1,500 meters altitude at this place. This fact is

further borne out by the 7 p. m. cloud observation at Palestine, Tex., which was 10/10 strato-cumulus from the south, there being no 7 p. m. observation available from Groesbeck. The temperature distribution shows an abundance of interesting characteristics, one of the more striking of which was the gradual elevation of an inversion layer extending first from 1,000 meters to 1,400 meters until it was found during the last flight to lie between 1,800 meters and 2,200 meters. Its average lapse rate was roughly -2° per 100 meters. During the eighth flight a second inversion made its appearance, extending from the surface to 700 meters above, and the ninth and last flight showed this to have risen so that it reached from 700 to 1,200 meters with an average lapse rate of -2° per 100 meters.

TABLE 1.—Free-air temperatures, relative humidities and vapor pressures during March, 1923.

TEMPERATURE ($^{\circ}$ C.).												
Altitude.	Broken Arrow, Okla. (233 m.)		Drexel, Nebr. (396 m.)		Due West, S. C. (217 m.)		Ellendale, N. Dak. (441 m.)		Groesbeck, Tex. (141 m.)		Royal Center, Ind. (225 m.)	
	m. s. l.	Mean.	De- parture from 3-year mean.	Mean.	De- parture from 3-year mean.	Mean.	De- parture from 3-year mean.	Mean.	De- parture from 6-year mean.	Mean.	De- parture from 5-year mean.	Mean.	De- parture from 5-year mean.
Surface..	8.8	-1.9	-1.8	-5.3	12.7	-1.9	-6.7	-3.7	11.9	-1.8	6.8	-4.2
250.....	8.7	-1.9	.....	.....	12.5	-1.8	.....	.....	11.2	-1.9	0.6	-4.2
500.....	6.6	-2.1	-2.2	-5.1	11.0	-1.1	-7.0	-3.9	10.0	-1.8	-1.4	-4.3
750.....	4.9	-2.5	-2.8	-4.7	9.6	-1.0	-8.0	-4.5	9.2	-1.6	-2.5	-4.4
1,000.....	4.0	-2.6	-3.1	-4.6	8.5	-1.0	-8.7	-5.2	9.0	-1.0	-3.1	-4.3
1,250.....	3.4	-2.6	-2.9	-4.4	7.2	-1.1	-9.2	-5.4	8.2	-1.1	-4.0	-4.6
1,500.....	2.6	-2.7	-3.2	-4.4	5.9	-1.2	-9.4	-5.2	7.7	-1.0	-4.7	-4.6
2,000.....	1.0	-2.9	-4.7	-4.1	3.7	-1.0	-10.0	-4.4	6.8	-0.6	-5.9	-4.3
2,500.....	-1.4	-2.6	-7.0	-3.9	1.9	-0.9	-12.4	-4.6	5.8	+0.5	-8.0	-4.2
3,000.....	-3.8	-2.5	-9.1	-3.4	0.0	-0.9	-14.9	-4.6	4.4	+1.4	-10.4	-4.3
3,500.....	-6.0	-2.3	-11.8	-3.4	-2.1	-0.8	-17.2	-4.5	1.8	+1.7	-10.0	-1.8
4,000.....	-8.0	-1.5	-14.1	-3.1	-4.5	-1.6	-20.2	-4.9	-1.1	+1.7	.....	.....
4,500.....	-10.8	-0.9	-17.3	-2.7	-7.7	-1.6	-23.8	-5.1	-4.4	+1.0	.....	.....
5,000.....	.....	.....	.....	.....	.....	.....	-27.5	-5.5	-7.7	+0.3	.....	.....

RELATIVE HUMIDITY (%).												
Surface..	59	-6	74	+6	63	-1	76	00	66	-4	68	-2
250.....	59	-6	.....	.....	63	-1	.....	.....	66	-3	68	-2
500.....	59	-5	72	+5	61	-3	75	+1	64	-2	65	-3
750.....	58	-5	68	+3	59	-5	70	+3	64	0	60	-5
1,000.....	56	-5	62	+1	58	-7	67	+5	60	-1	56	-6
1,250.....	51	-6	58	+3	57	-8	65	+7	59	+2	52	-7
1,500.....	47	-6	56	+5	57	-8	63	+7	59	+6	47	-10
2,000.....	40	-5	59	+10	50	-9	58	+4	49	+8	40	-14
2,500.....	39	-4	63	+14	46	-4	57	+3	43	+7	38	-15
3,000.....	46	+5	60	+10	43	00	55	+2	42	+10	42	-12
3,500.....	54	+11	59	+10	39	+2	52	-1	43	+11	.....	.....
4,000.....	50	+10	55	+7	38	+2	46	-7	44	+11	.....	.....
4,500.....	49	+10	53	-1	36	+2	50	-5	44	+9	.....	.....
5,000.....	.....	.....	.....	.....	.....	.....	52	-5	44	+11	.....	.....

VAPOR PRESSURE (mb.).												
Surface..	6.79	-2.11	3.96	-1.39	9.83	-1.44	2.91	-1.02	10.16	-1.64	4.57	-2.02
250.....	6.72	-2.10	.....	.....	9.68	-1.42	.....	.....	9.79	-1.49	4.48	-1.98
500.....	5.83	-1.99	3.71	-1.34	8.59	-1.30	2.81	-1.00	8.91	-1.13	3.67	-1.84
750.....	5.11	-1.82	3.29	-1.23	7.67	-1.37	2.43	-0.88	8.51	-0.64	3.11	-1.81
1,000.....	4.63	-1.77	2.91	-1.14	7.06	-1.39	2.13	-0.90	7.94	-0.28	2.71	-1.71
1,250.....	4.10	-1.70	2.74	-0.90	6.43	-1.45	1.96	-0.87	7.40	+0.12	2.37	-1.65
1,500.....	3.58	-1.55	2.57	-0.72	5.70	-1.40	1.88	-0.77	7.02	+0.67	2.07	-1.64
2,000.....	2.68	-1.26	2.29	-0.49	4.10	-1.35	1.63	-0.64	5.46	+1.06	1.69	-1.44
2,500.....	2.22	-1.02	2.05	-0.32	3.04	-0.89	1.28	-0.62	4.64	+1.37	1.50	-1.20
3,000.....	2.11	-0.54	1.67	-0.34	2.25	-0.49	0.94	-0.56	4.28	+1.70	1.28	-1.14
3,500.....	2.00	-0.40	1.34	-0.31	1.43	-0.43	0.68	-0.53	3.90	+1.63	.....	.....
4,000.....	1.73	-0.34	1.02	-0.40	0.77	-0.53	0.45	-0.51	3.38	+1.30	.....	.....
4,500.....	1.56	-0.29	0.88	-0.41	0.07	-0.53	0.37	-0.38	3.23	+1.24	.....	.....
5,000.....	.....	.....	.....	.....	.....	.....	0.27	-0.31	3.11	+1.29	.....	.....

TABLE 2.—Free-air resultant winds, m. p. s., during March, 1923.

Altitude. m. s. l. (m.)	Broken Arrow, Okla. (233m.)				Drexel, Nebr. (396m.)				Due West, S. C. (217m.)				Ellendale, N. Dak. (444m.)				Grossbeck, Tex. (141m.)				Royal Center, Ind. (225m.)				
	Mean.		5-year mean.		Mean.		5-year mean.		Mean.		3-year mean.		Mean.		6-year mean.		Mean.		5-year mean.		Mean.		5-year mean.		
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	
	Surface.....	S. 36°W.	2.0	S. 4°W.	2.9	N. 73°W.	0.6	S. 43°W.	0.8	S. 42°W.	1.7	S. 49°W.	2.0	N. 45°W.	4.5	N. 17°W.	2.0	S. 35°E.	1.0	S.	1.5	S. 57°W.	3.2	S. 33°W.	2.1
250.....	S. 35°W.	2.0	S. 4°W.	3.1	.....	.....	.....	.....	S. 47°W.	2.5	S. 50°W.	2.2	.....	.....	.....	.....	S. 30°E.	1.3	S. 2°E.	2.2	S. 56°W.	3.4	S. 32°W.	2.4
500.....	S. 28°W.	2.7	S. 8°W.	4.7	N. 82°W.	1.4	S. 46°W.	1.1	S. 55°W.	3.4	S. 53°W.	3.1	N. 40°W.	4.6	N. 55°W.	1.8	S. 3°E.	1.9	S. 9°W.	4.0	S. 56°W.	6.5	S. 42°W.	5.1	
750.....	S. 28°W.	3.2	S. 11°W.	5.9	N. 70°W.	3.7	S. 72°W.	2.3	S. 68°W.	4.3	S. 58°W.	4.2	N. 62°W.	4.9	N. 81°W.	2.4	S. 11°W.	3.2	S. 21°W.	4.9	S. 70°W.	8.0	S. 40°W.	6.5	
1,000.....	S. 35°W.	4.5	S. 23°W.	6.8	N. 63°W.	5.2	S. 83°W.	3.1	S. 71°W.	6.2	S. 60°W.	5.5	N. 70°W.	5.7	S. 85°W.	3.1	S. 31°W.	3.6	S. 33°W.	5.6	S. 75°W.	11.4	S. 50°W.	7.4	
1,250.....	S. 40°W.	5.1	S. 32°W.	7.5	N. 62°W.	6.7	N. 87°W.	4.1	S. 69°W.	7.7	S. 60°W.	7.2	N. 68°W.	6.9	N. 85°W.	4.1	S. 37°W.	3.9	S. 40°W.	5.9	S. 80°W.	12.5	S. 65°W.	8.4	
1,500.....	S. 47°W.	6.0	S. 48°W.	6.9	N. 62°W.	7.1	N. 88°W.	5.2	S. 70°W.	10.4	S. 60°W.	9.1	N. 66°W.	8.3	N. 84°W.	5.5	S. 31°W.	3.4	S. 44°W.	5.8	N. 88°W.	13.5	S. 69°W.	9.1	
2,000.....	S. 63°W.	8.5	S. 62°W.	7.4	N. 67°W.	9.8	N. 83°W.	6.9	S. 76°W.	13.7	S. 71°W.	11.7	N. 64°W.	10.7	N. 82°W.	7.9	S. 47°W.	3.7	S. 58°W.	6.8	N. 81°W.	14.7	S. 75°W.	10.7	
2,500.....	N. 82°W.	7.2	S. 74°W.	7.6	N. 74°W.	12.8	W.	8.8	S. 81°W.	14.5	S. 81°W.	13.2	N. 67°W.	13.9	N. 78°W.	10.7	S. 68°W.	5.9	S. 64°W.	8.7	S. 87°W.	17.0	S. 78°W.	11.7	
3,000.....	S. 86°W.	9.3	S. 81°W.	8.8	N. 77°W.	16.2	W.	11.4	S. 76°W.	15.9	S. 81°W.	13.5	N. 77°W.	16.5	N. 79°W.	11.9	S. 73°W.	7.8	S. 68°W.	9.0	N. 76°W.	21.2	S. 86°W.	14.0	
3,500.....	S. 89°W.	8.6	S. 74°W.	10.3	N. 76°W.	17.8	N. 84°W.	14.8	S. 78°W.	18.6	S. 80°W.	13.3	N. 76°W.	17.3	N. 83°W.	13.7	S. 54°W.	14.5	S. 72°W.	12.0	N. 79°W.	28.6	S. 82°W.	16.5	
4,000.....	S. 85°W.	8.4	S. 81°W.	10.4	N. 71°W.	21.9	N. 76°W.	17.8	N. 86°W.	17.9	S. 84°W.	14.5	N. 87°W.	14.1	S. 89°W.	15.0	S. 60°W.	14.8	S. 67°W.	13.7
4,500.....	N. 68°W.	11.6	S. 83°W.	10.9	N. 77°W.	19.3	N. 81°W.	17.5	N. 68°W.	18.8	N. 89°W.	12.6	S. 85°W.	17.3	S. 89°W.	16.3	S. 68°W.	15.3	S. 83°W.	13.3
5,000.....	N. 68°W.	11.0	S. 83°W.	11.3	W.	18.1	N. 80°W.	15.7	W.	19.6	N. 88°W.	17.8	S. 68°W.	15.3	S. 81°W.	15.9

THE WEATHER ELEMENTS.

By P. C. DAY, Meteorologist in Charge of Division.

PRESSURE AND WINDS.

The rapid changes in the atmospheric circulation during the several months of the past winter, referred to previously, which showed some signs of abating in February, were renewed during March, and the month as a whole more than maintained its reputation for unpleasant weather, and, in some portions at least, ran true to tradition concerning lamb-like entrance and lion-like exit.

The pressure for the month as compared with the normal was, as during the preceding month, high over nearly all districts of the United States and Canada, the only exceptions being the Great Lakes and St. Lawrence Valley regions, where, unlike February, the averages were slightly less than normal. Pressure was distinctly above normal over the far Northwest, due to the presence of a well-developed anticyclonic condition that persisted during much of the month over that region.

The pressure for March, 1923; as compared with the preceding month, showed diminution in all parts of the country, as might be expected, though the changes were unusually large over all districts and particularly in the central and northwestern districts, due mainly to the abnormally high pressure of February.

Among the more important anticyclones of the month were the following:

On the morning of the 17th high pressure appeared in the far Canadian Northwest, attended by a sharp fall in temperature, which during the following two days overspread the Great Plains, central valleys and West Gulf States, bringing below-zero temperatures into the upper Mississippi Valley and adjacent regions, and freezing weather almost to the lower Rio Grande Valley. During the following 24 hours it moved rapidly to the South Atlantic coast, losing somewhat in severity of the attending cold, but still giving temperatures in numerous instances lower than ever before reported so late in the month. Again, on the morning of the 27th, high pressure moved into the Northwestern States and during the following 48 hours overspread the northern and central districts to the eastward of the Rocky Mountains, with attending low temperatures, again breaking the record for low temperatures so late in the season at a number of points in the central and northern districts. Before this anticyclone had passed off the Atlantic coast another

had appeared in the British Northwest, and by the morning of the 30th had entered the United States with great strength between the Rocky Mountains and the Great Lakes, and penetrated into the central valleys during the last day of March and into the more eastern districts by the first of April. This, too, was attended by severe cold for the season, and many points in central and eastern districts again had the lowest temperatures ever observed so late in spring.

Cyclones were numerous, and frequently well-defined during the first half of the month, particularly over the Great Lakes and to the eastward. The outstanding storm of the month, however, moved from its position in central Texas on the morning of the 11th, to the southern end of Lake Michigan by the morning of the 12th, developing great force as it moved over the middle Mississippi Valley and adjacent territory. After leaving the Great Lakes, however, it lost energy rapidly, and was central over northern New England 24 hours later as a storm of only moderate intensity. This storm was attended by high winds, rain and snow over wide areas adjacent to its path, and local storms of great severity occurred, attended by loss of life and large damage to property, the details of which appear in other parts of this Review.

Aside from the storms of the 11th and 12th, other severe windstorms occurred locally during the first week of the month, and again on the 15th and 16th. The latter half of the month was comparatively free from storms of this character.

The usual notes concerning damaging storms appear in a table at the end of this section.

The frequent changes in pressure distribution during the month greatly complicated the wind systems, and the prevailing directions were not from common points over extensive areas, as shown on Chart VI.

TEMPERATURE.

March was a month of frequent and sharp temperature changes, and on many occasions the weather bore the earmarks of winter more prominently than those of spring. This was particularly the case in portions of New England, where, on account of the long, cold winter, and the frequent lack of proper fuel or of even any at times, the hopes undoubtedly nurtured that March would bring relief were cruelly disappointing.

The first two weeks were moderately warm over the districts from the Rocky Mountains eastward, save during the second week when it was distinctly cold over the