the time of the shower, however, (and this may be said to mark the passage of the squall line,) there was a very sudden drop from 65° to 56° and a somewhat slower rise to 63° by 5.15, followed by an irregular drop to 56° at 8 p. m.

Figure 6, giving the copies of the original records from Springfield and Grand Rapids, shows the progress of meteorological phenomena during the day. It appears from the examination of many records, even from those much closer to the paths of the tornadoes than these, that there is very little disturbance to the diurnal march of the elements upon the passage of these very violent disturbances up to within a very short distance from the whirl. This simply emphasizes the extremely local character of the tornado, and is borne out by the seemingly capricious conduct of the whirling cloud as it passes along. As is seen from the figure there was little or no barometric disturbance at the time of tornado passage, although severe tornadoes passed only a few miles from the station.—*C. LeRoy Meisinger.*

A KITE FLIGHT IN THE CENTER OF A DEEP AREA OF LOW PRESSURE.

By VINCENT E. JAKL, Meteorologist.

[Weather Bureau Aerological Station, Drexel, Nebr., May 24, 1920.]

Kite flights are not ordinarily possible near the centers of intense LOWS on account of the kites being unable to withstand the attendant stormy weather or winds of gale to hurricane force. On March 28, 1920, Drexel was evidently in or near the very center of a well-defined LOW of the circular or oval type. Light winds in this region of the LOW made a flight possible, but also limited the flight to a comparatively low altitude. Notwithstanding the low height attained by the kites on that day, the rather unusual circumstance of the flight invites a discussion of the free-air conditions that prevailed, especially in view of the fact that tornadoes occurred on the same day over middle eastern and southern States. The deductions arrived at, suggesting an explanation of tornado conditions, are principally from the results of this flight and a comparison of them with the conditions shown by the flights of the previous and following days. Related conditions on other dates or at other stations are also discussed or referred to.

The weather map for 7 a. m., 90th meridian time, on March 28, 1920, shows a deep area of low pressure over the Missouri Valley, the innermost isobar, 29 inches (sea-level), encircling Omaha, Nebr., as an approximate center. Drexel, Nebr., being only 18 miles west-northwest of Omaha, can be given equal prominence as the center of the low-pressure trough. In point of fact, the pressure at this hour of observation, reduced to sea level by the usual method of computation, was 28.94 inches at Drexel, or 0.04 inch lower than at Omaha.

A kite flight, begun almost simultaneously with the general 7 a. m. surface observations represented on the weather map of this date, was finished two hours later. The surface pressure reached its lowest level about the time the flight was begun, and remained practically stationary till about an hour after the flight was ended. The upper-air observations recorded during the flight can therefore be properly referred to the position of Drexel in the LOW indicated on the 7 a. m. weather map.

Light haze prevailed during the flight and until 11 a. m., or throughout the time the pressure remained low and stationary. Following the abrupt rise in pressure that began at 11 a. m., the haze gave place to stratocumulus clouds that quickly overcast the sky, and brought a fall of light rain, turning to snow. The surface wind, that had been light southerly during the flight, became a northwest gale shortly after the rise in pressure set in.

The significant facts that it is intended to bring out are the veering diminishing winds aloft during the progress of the flight, the apparent progressive veering of the winds from the highest altitude down to the ground, and the progressive fall in temperature at certain altitudes from the 27th to the end of the flight on the 28th.

The generally light diminishing winds encountered during the flight are undoubtedly a feature of the central area of a LOW, and can probably be explained as due to the gradual readjustment of the air masses to an almost opposite direction of movement. Some interesting conclusions, however, may be inferred from the apparent circumstance of the progressive veering of the wind downward toward the ground and the fall in temperature that attended and preceded the veering in direction. If the inference that the fall in temperature attending and preceding the veering in direction is carried farther, and an earlier fall in temperature in the higher altitudes assumed, some of the observed characteristics of the front of LOWS might be more easily explained.

A question that suggests itself from the records of the 27th and 28th is: Was the rapidly rising temperature in the strong southerly winds noted at and near the ground on the 27th, coincident with falling temperature at higher altitudes; and if so, was a similar but more pronounced condition a day later over sections farther to the east responsible for the tornadoes that were reported from middle eastern and southern States?

The first part of this question can be answered in the affirmative if the evidence is sufficient that the fall in temperature (with presumably no change in surface-wind direction, but with a change of 2 or 3 points at 1,500 meters) noted in the lower strata on the 28th began in the higher strata on the 27th. While it will be noted from Table 1 that much lower temperatures were recorded at all altitudes on the 28th as compared with corresponding altitudes on the 27th, there seems no reason to doubt, from the circumstance of pressure distribution, that the wind at these altitudes was blowing continuously from a southerly or southwesterly direction from the morning of the 27th to the morning of the 28th.

Owing to the strength of the winds aloft on the 27th, the flight on that day did not reach an altitude high enough nor cover a period of time long enough to show any marked changes in temperatures in the higher strata. A more complete kite flight was made on the same day at Royal Center, Ind., a record of which is given in Table 2. This record shows a small but distinct fall in temperature and increase in the lapse rate in the higher levels. However, more definite evidence of a simultaneous fall in temperature aloft and rising or sustained high temperature near the ground in the front quadrants of a LOW may be deduced from the records of some diurnal series of flights. Reference is made to the records of the diurnal series of October 16–17 and November 8–9, 1917 (1), both of which are good illustrations of progressive temperatures aloft preceding thunderstorm conditions. While these records apply to the autumn season, they are fairly typical of the conditions in the front of a LOW leading to unstable equilibrium, and have been selected as the most descriptive of the records available.

Upper-air observations show conclusively that in the extratropical cyclone the isobars open up and become

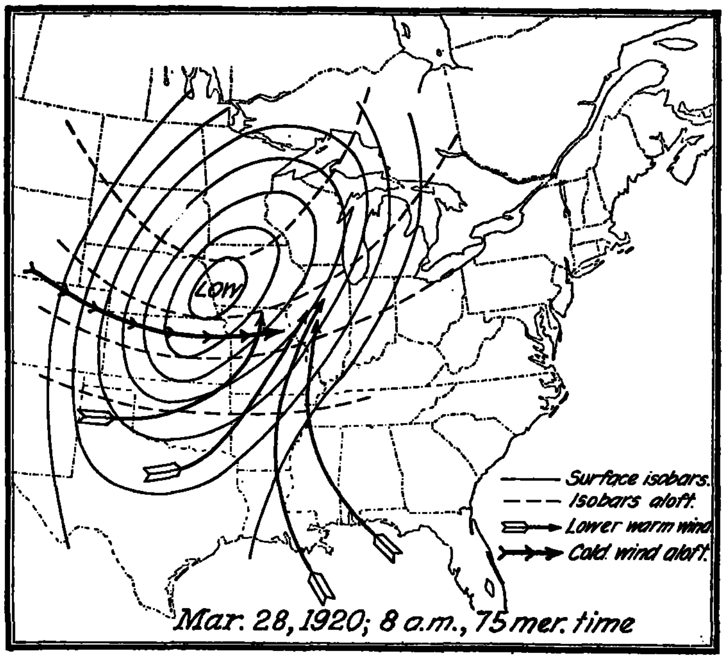

Fig. 7.—Wind flow in upper and lower levels of the LOW of March 28, 1920.

more or less V-shaped in the upper regions, and that the change from closed to open isobars varies in altitude according to the intensity, temperature distribution, and other characteristics of the storm. Assuming a circulation as depicted in figure 7, steep vertical temperature gradients and unstable equilibrium can be accounted for over the area receiving strong drainage of warm moist air from the Gulf. That colder air in the upper strata actually followed in the wake of the storm of March 28, is attested by the record of the kite flight of March 29. In this flight, the temperature recorded at 4,250 meters above sea level was as low as the midwinter mean for that altitude. (**2**) It is of further interest to note that this low temperature aloft occurred in an area of relative, not absolute, high pressure.

It is quite reasonable to suppose that the position of the V-shaped isobars aloft with reference to the center of low pressure on the surface varies with individual storms, and probably with the season for any average type of storm. A seasonal variation might account for the peculiarity of tornadoes to the spring and early summer months and the related fact of lag in the recovery of temperature aloft in spring. This lag is well shown for March and April over Drexel in figure 2, page 3, MONTHLY WEATHER REVIEW, January, 1920. (**2**)

In contrast to this sustained low temperature aloft is the occasional warm wave in strata near the ground, an example of which is shown in the temperature record of the flight of March 27. It is apparent from this record and from the subsequent further heating of the surface layers that in these lower strata temperatures finally occurred that were equal to or slightly exceeded the June averages. (**2**) The extreme contrast in temperature that occurred within less than 48 hours between the surface layers and those aloft was therefore nearly equal to the extreme annual range in their respective monthly averages.

Further statistical study of upper air observations in LOWS will probably show some average annual variation in the position of the isobars aloft with reference to those on the surface. A possible seasonal change that suggests itself from a cursory examination of kite flight records is that the apex or lower extremity of the isobars aloft may on the average be displaced eastward as the warm season advances. When flights are possible in the rear of pronounced circular or oval LOWS of the type of

TABLE 1.—*Free-air data from kite flights at Drexel, Nebr.*

Mar. 27, 1920.

Time.	Surface temperature.	At different heights above sea. Altitude.	Temperature.	Δt/100 m.	Wind. Direction.	Wind. Velocity.
A. M.	°C.	m.	°C.			m. p. s.
6:51	8.0	396	8.0	....	sse.	8.0
		500	8.6	....	sse.	9.9
		750	10.2	....	s.	14.5
		1,000	11.8	....	ssw.	19.0
7:03	8.0	1,088	12.3	−0.62	ssw.	20.6
		1,250	12.7	....	ssw.	20.4
		1,500	13.3	....	ssw.	20.0
7:17	8.4	1,602	13.6	−0.25	ssw.	19.9
		2,000	10.3	....	ssw.	19.0
7:31	9.0	2,292	7.8	0.84	ssw.	18.4
		2,500	4.9	....	sw.	18.2
7:42	9.4	2,841	2.8	0.85	sw.	17.9
		2,500	5.5	....	sw.	19.8
		2,000	9.4	....	sw.	22.6
7:55	10.1	1,602	12.6	0.80	sw.	24.9
		1,500	13.4	....	sw.	23.8
		1,250	15.4	....	sw.	21.0
		1,000	17.4	....	sw.	18.3
9:37	15.4	974	17.6	−3.48	sw.	18.0
9.46	15.7	793	11.3	1.21	ssw.	9.3
		750	11.8	....	ssw.	9.5
		500	14.8	....	ssw.	10.3
9:51	16.1	396	16.1	....	ssw.	10.7

Mar. 28, 1920.

Time.	Surface temperature.	At different heights above sea. Altitude.	Temperature.	Δt/100 m.	Wind. Direction.	Wind. Velocity.
A. M.	°C.	m.	°C.			m. p. s.
7:38	6.6	396	6.6	....	sse.	5.4
		500	6.1	....	sse.	7.4
		750	4.9	....	s.	12.2
7:46	6.6	825	4.5	0.49	s.	13.7
		1,000	3.3	....	s.	12.0
		1,250	1.7	....	ssw.	9.5
		1,500	0.0	....	sw.	7.1
8:30	7.6	1,581	−0.5	0.71	sw.	6.3
		1,500	0.1	....	sw.	6.2
		1,250	2.0	....	w.	6.1
9:19	9.0	1,171	2.6	0.08	w.	6.0
		1,000	2.7	....	wsw.	6.0
9:27	9.0	805	2.9	1.64	ssw.	6.1
		750	3.7	....	ssw.	6.0
		500	7.6	....	sw.	5.6
9:31	9.2	396	9.2	....	sw.	5.4

Mar. 29, 1920.

Time.	Surface temperature.	At different heights above sea. Altitude.	Temperature.	Δt/100 m.	Wind. Direction.	Wind. Velocity.
A. M.	°C.	m.	°C.			m. p. s.
9:17	4.0	396	4.0	....	ssw.	5.4
		500	3.7	....	ssw.	5.0
10:02	5.3	714	3.1	0.28	sw.	4.3
		750	2.9	....	sw.	4.7
		1,000	1.6	....	wsw.	7.5
		1,250	0.3	....	w.	10.2
10:31	6.8	1,375	− 0.3	0.51	w.	11.6
		1,500	− 1.3	....	w.	12.6
		2,000	− 5.4	....	w.	14.6
10:46	7.3	2,069	− 6.0	0.82	w.	14.9
		2,500	− 7.7	....	w.	15.0
10:58	8.3	2,782	− 8.8	0.39	w.	15.1
		3,000	− 9.7	....	w.	15.1
11:11	8.0	3,364	−11.2	0.41	wnw.	15.2
		3,500	−12.0	....	wnw.	15.7
		4,000	−15.1	....	w.	17.5
11:34	9.4	4,117	−15.8	0.61	w.	17.9
11:44	9.6	4,252	−16.3	0.28	w.	17.9
P. M.		4,000	−15.8	....	w.	17.6
12:15	10.6	3,965	−15.6	0.41	w.	17.4
		3,500	−13.7	....	w.	18.8
1:12	13.0	3,285	−12.8	0.63	w.	19.5
		3,000	−11.0	....	w.	18.0
		2,500	− 7.9	....	wsw.	15.5
1:34	13.7	2,427	− 7.4	0.96	wsw.	15.1
		2,000	− 3.3	....	wsw.	12.6
1:45	13.8	1,874	− 2.1	0.92	wsw.	11.9
		1,500	1.4	....	wsw.	12.0
2:03	13.2	1,247	3.7	1.05	wsw.	12.0
		1,000	6.3	....	wsw.	11.5
2:18	13.1	830	8.1	1.29	wsw.	11.1
		750	9.1	....	wsw.	11.0
		500	12.4	....	wnw.	10.5
2:25	13.7	396	13.7	....	wnw.	10.3

March 28, they show a deep northerly or northwesterly wind, sometimes backing to westerly at still higher altitudes. On the other hand, flights in the rear of LOWS that seem more common to the winter season frequently show a strong, cold, more or less shallow northerly wind, surmounted by a wind from some southerly direction.

Thunderstorms occurred in the vicinity of Drexel on the night of the 27th–28th. The LOW had evidently been insufficiently developed to cause tornadoes in this section on the 27th, while by the 28th the conditions of temperature conducive to strong vertical circulation had passed by.

It is possible that when tornadoes occur near the center of a deep depression their cause is often largely mechanical and arises from a wind shift line much more abrupt than that apparent in the LOW of March 28.

REFERENCES.

(1) MONTHLY WEATHER REVIEW, SUPPLEMENT No. 11, Aerology No. 6, pages 63–66 and 76–80. See also MONTHLY WEATHER REVIEW, June, 1919, 47: fig. 5, p. 371.

(2) **W. R. Gregg.** Average free-air conditions as observed by means of kites at Drexel Aerological Station, Nebr., during the period November, 1915, to December, 1918, inclusive. MONTHLY WEATHER REVIEW, January, 1920, 48: 1–11.

DISCUSSION.

While there is no direct proof that there was a cold wind above the line where the tornadoes formed, it is reasonable to surmise its presence to account for the shift in surface wind. One other bit of evidence as to the presence of the cold wind above the warm is found in the occurrence of the tornado near Lincoln, Ill., late in the afternoon, about six hours after the passage of the wind-shift line that carried the other tornadoes. At Springfield, Ill., there was at this time a gradual change of wind to west, but it would not appear to have been sudden enough to account for a tornado without the aid of a strong vertical movement induced by a considerable contrast between the temperature of the wind near the surface, and that at a moderate elevation. In any event, the presence of a cold wind aloft may not be indispensable to the formation of tornadoes, where winds converge violently.—*Charles F. Brooks.*

TABLE 2.—*Free-air data from kite flights at Royal Center, Ind., Mar. 27, 1920.*

Time.	Surface temperature.	At different heights above sea.				
		Altitude.	Temperature.	$\frac{\Delta t}{100\text{ m.}}$	Wind.	
					Direction.	Velocity.
A. M.	°C.	m.	°C.			m. p. s.
10:36	11.4	225	11.4	....	se.	6.3
		250	11.1	....	se.	6.2
		500	8.6	....	se.	5.3
11:03	12.3	636	7.2	1.04	se.	5.0
		750	7.6	....	se.	5.8
		1,000	8.6	....	s.	7.4
		1,250	9.5	....	ssw.	9.1
11:53	14.8	1,314	9.8	−0.38	ssw.	9.5
		1,500	8.7	....	ssw.	10.8
		2,000	5.8	....	sw.	14.5
P. M.						
12:09	14.9	2,419	3.3	0.59	wsw.	17.5
		2,500	2.6	....	wsw.	17.4
		3,000	−1.5	....	wsw.	16.6
		3,500	−5.7	....	sw.	15.8
12:40	16.0	3,708	−7.4	0.73	sw.	15.5
		3,500	−6.1	....	sw.	15.3
		3,000	−3.0	....	sw.	14.7
1:05	16.5	2,537	−0.1	0.92	sw.	14.2
		2,500	0.3	....	sw.	14.3
		2,000	4.9	....	sw.	15.4
		1,500	9.5	....	ssw.	16.4
1:34	17.4	1,383	10.6	0.15	ssw.	16.7
		1,250	10.8	....	ssw.	15.8
		1,000	11.2	....	s.	14.0
		750	11.6	....	sse.	12.2
1:54	17.5	605	11.8	1.53	se.	11.2
		500	13.4	....	se.	10.7
		250	17.2	....	se.	9.5
2:00	17.6	225	17.6	....	se.	9.4

THE TORNADOES OF MARCH 28, 1920, IN EAST-CENTRAL ALABAMA.

By P. H. SMYTH, Meteorologist.

[Weather Bureau, Montgomery, Ala., Apr. 24, 1920.]

The principal tornado first appeared at Deatesville, 18 miles north of Montgomery, and another at Cedar Springs, farther north. Unseasonably high temperatures prevailed during all the morning and afternoon of the 28th; at Montgomery the maximum was 77° F. at 11:45 a. m.; and at Wetumpka and Auburn the highest were 77° and 76°, respectively. The absolute humidity, as shown by the records at Montgomery, was likewise unseasonably high; the relative humidity at 7 a. m. was 91 per cent, at noon 74 per cent, and at 7 p. m. 79 per cent. Thunderstorms were reported from 10 stations in Alabama, most of these being in the east-central portion of the State. At Montgomery the average hourly wind velocity during the day was 14 miles, the directions varying from southeast to southwest.

THE DEATESVILLE-AGRICOLA-WEST POINT TORNADO.

This, the principal tornado in Alabama on the 28th, first appeared about 1 mile north of Deatesville, western Elmore County, near the Autauga-Elmore County line, at about 2:30 p. m. From Deatesville it moved east-northeastward over northern Elmore County, through south-central Tallapoosa County, wiping out the little village of Agricola, thence across southern Chambers County, crossing the Georgia-Alabama line at West Point, Ga., at about 3:37 p. m. The length of the track in Alabama, from Deatesville, Ala., to West Point, Ga., is about 65 miles on a straight line. Assuming the times as given above as correct, the speed of translation was about 60 miles per hour. As shown by a number of reports received, the tornado was well defined, from 100 yards to a quarter of a mile in diameter, marked by the usual funnel-shaped cloud, and accompanied by winds of very destructive violence.

Evidence of rotation was slight, amounting to the directions of felled trees at West Point, Ga., as reported by Conductor Hal Cline, of the Atlanta & West Point Railroad. He states that trees on the north side of the storm's path lay to the left; in the center, straight ahead; on the south side, to the right. Mr. Cline, while he did not see the funnel-shaped cloud, describes the clouds at West Point, Ga., just before the tornado struck, as follows:

> Coming to West Point about 3:30 p. m., I noticed awfully black, greenish-looking clouds; stood there about five minutes loading passengers. As we pulled out it began to rain a little; in about two minutes the storm hit us. We had to stop the train until it passed; came very near moving the train from the track. Of course, we were not directly in the path of the tornado, but on its edge. Being inside the cars and the rain so terrific, we did not look to notice the clouds.