THUNDERSTORM AT TULSA, OKLA., JUNE 6, 1919.

By J. A. REHLE.

[Date: Weather Bureau Aerological Station, Broken Arrow, Okla., June 21, 1919.]

During the afternoon of June 6, 1919, the genesis and growth of a cumulus cloud through cumulo-nimbus into an unusually destructive thunderstorm were watched by the men on this station. As this storm started and attained its greatest fury within a few miles of this station it will be interesting to note the free-air conditions recorded shortly before the storm, especially since free-air conditions cannot usually be obtained by kites for several hours previous to such a storm on account of low wind velocities.

During the morning the wind was too light to sustain a kite, and the temperature rose from 14.5° C. in the morning to 31° C. in the afternoon. At 1:50 p. m. a south breeze became strong enough to start a kite flight, and at 3:33 p. m. an altitude of 2,691 meters above sea-level was reached.

A summary of the free-air data, computed by the Aerological Division, is given in Table 1. A notable feature of this table is the steep temperature gradient up to 1,600 meters. This condition was favorable to strong local convection; in this case, however, the gradients were scarcely sufficient to carry the rising air aloft to a point where condensation would occur. This saturation level would have been reached by convection ascent at an altitude of approximately 1,750 meters above sea-level, under the surface conditions recorded at 3:33 p. m., with a temperature of 30.4° C. and a dewpoint of 18.8° C. $H_m = (T_a - T_d - 10) / 0.0077$. In the region where the cumulus clouds started these superadiabatic gradients must have extended upward sufficiently high for condensation to begin in the rising air. Then, once condensation had begun the gradients noted in Table 1 would have been sufficient for the continued upward movement of the saturated air, and the growth of the large cumulus clouds observed.

The wind, as determined by pilot-balloon ascensions at 3 p. m. on the 6th and at 7 a. m. on the 7th, is shown in Table 3.

<table>
<thead>
<tr>
<th>Time</th>
<th>Amount</th>
<th>Kind</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:50 p. m.</td>
<td>St. Cu.</td>
<td>SW.</td>
</tr>
<tr>
<td>2:31 p. m.</td>
<td>St. Cu.</td>
<td>W.</td>
</tr>
<tr>
<td>2:37 p. m.</td>
<td>1 Cu.</td>
<td>W.</td>
</tr>
<tr>
<td>3:28 p. m.</td>
<td>1 Cu.</td>
<td>W.</td>
</tr>
<tr>
<td>4:15 p. m.</td>
<td>Cu.</td>
<td>W.</td>
</tr>
<tr>
<td>4:46 p. m.</td>
<td>Cu.</td>
<td>SW.</td>
</tr>
</tbody>
</table>

At 3:28 p. m. the summits of a few cumulus clouds began to appear. One anvil shaped cumulus was seen to the northeast, and a row of three or four mountainous peaks stretched away to the west. At 4 p. m. an immense cumulus cloud estimated to be 40 or 50 kilometers away to the west-northwest, with a summit extending through the alto-cumulus layer and to a considerable distance above it, began to show signs of precipitation, and at 4:42 p. m. the first thunder was heard. At this time there was a well-marked area of precipitation in the center of the cloud and the whole mass was moving slowly eastward.

As the storm approached it increased rapidly in size and a veil of false cirrus overflowed eastward and southward. Underneath the anvil portion which extended forward the cloud took a well-developed mammatus-cumulus form. A continuous roar of thunder in the upper portion of the cloud was heard for perhaps half an hour before the arrival of the storm.

The storm moved from the west, i. e., with the wind at 2,500 meters altitude and higher, and covered Tulsa County and adjoining territory. The destructive violence was spread over several square miles, and extended from Collinsville on the north to Bixby on the south (see map). One child was killed at Bixby, several people were injured in various places by falling buildings, and damage to property and farm crops amounting to more than a million dollars was sustained. The damage resulted from a combination of wind, hail, and rain.

The anemometer at Broken Arrow recorded an extreme wind velocity from the north-northwest of 80 miles per hour (36 m. p. s.) and a maximum velocity for five minutes of 67 miles per hour (30 m. p. s.) at 6:28 p. m. Five or six miles farther west the wind appeared to have been more violent. A schoolhouse (fig. 1) and a large barn, just completed, were blown down, and several farmhouses and barns were unroofed. At
Fig. 1 (H. H. H.)—Southern Hemisphere circulation. (Lockyer.) (See p. 373.)

Fig. 1.—Union Schoolhouse, 5 miles west of Broken Arrow, blown down by the wind. Taken from the northwest. School library before the first window laid out to dry.

Fig. 2.—Map of Tulsa County, Okla., showing region of cloudburst of June 6, 1919. Arrow indicates region of destructive winds. Dotted area shows region of most violent hailstorm.

Fig. 3.—Home of E. L. Levin, 1602 South Boston Street. The flood swept this 6-room bungalow several yards from the foundation. The house was completely filled with water.
Bixby 20 houses were reported to have been demolished, and a number of oil tanks were damaged or blown away. This wind was not of tornadic character, but simply a straight blow with a front of 8 to 10 miles or more.

The heaviest rainfall, amounting in popular language to a cloudburst, fell in Tulsa, where 5.80 inches was recorded. At Broken Arrow 1.05 inches was recorded. These amounts are somewhat deficient on account of the high wind that accompanied the heaviest downpour.

Hailstones 1 inch in diameter fell in Broken Arrow; in Tulsa one hailstone was found to measure 8 by 64 inches in circumference, and another weighed 44 ounces. The heaviest fall of hail occurred between Broken Arrow and Tulsa, shown by the dotted area on the map (fig. 2).

**TORNADO AT FERGUS FALLS, MINN., JUNE 22, 1919.**

On the afternoon of Sunday, June 22, 1919, at 4:45 p.m., the town of Fergus Falls was struck by a tornado which, almost in a twinkling, razed 228 houses, killed 57 people, and injured many more.

From descriptions given by persons who saw the tornado as it approached the city, it appears that it was accompanied by all the phenomena which characterize such storms—a black, funnel-shaped, "twisting" cloud, or several of them, a heavy downpour of rain, and a terrific roar.

Mrs. Elsei Rathbun, who watched the storm from the Great Northern Railway Station, is quoted in the Minneapolis Tribune as saying that "the storm approached rapidly, with black clouds pushing up from the west toward the city. Just before it struck Fergus Falls there was a humming like a dozen factories all full of buzzsaws running at once, and then when the storm arrived there was a pandemonium of noise." Richard Krynen, according to the same paper, also watched the storm from the Great Northern station. He is quoted:

"For a considerable time before the tornado struck there was a rumbling sound, and then it started to rain and minded hard. We thought the rain was going to stop, but hailstones the size of marbles began to fall."

Quoting from the Minneapolis Journal of June 23, 1919:

The first storm, they say, struck the town from the northwest, and tore through the Lake Alice district. This was the one that wrecked the Grand Hotel. The second storm, which brought driving rain, approached from the southwest. A third, it is claimed, swept over the eastern portion of the town from the southeast, but did less damage.

Fergus Falls, with a population of 12,000, is situated in northwestern Minnesota. The town is divided into two sections, north and south of the Red River. It was the north portion that was demolished. See figures 1 and 2.

Telegraphing over hay-bale wire from Fergus Falls two days after the tornado occurred, Carlton W. Miles, of the Minneapolis Journal, said:

"Half the town looks like a vast acreage of kindling; the other half, save for trees split at the roots, is unharmed."

But while it is true that only half the town was demolished, the line of wreckage could be clearly traced for a distance of 10 miles to the east, and a bank check was picked up 60 miles away. The property loss was $3,500,000, of which $500,000 was in automobiles, many of which were caught by flying debris. In one instance the force of the wind split a huge tree, threw an automobile into the intersection; and then closed up the opening, holding the machine like a vise.

Here the hailstones said to have been the size of hens' eggs fell in large quantity. Over a wide area in this section the hail caused almost a total loss of what had promised to be an abundant crop of wheat and oats. Corn was torn to shreds, gardens obliterated, and fruit, particularly peaches, of which there were a number of commercial orchards, was nearly all knocked from the trees, while even the bark was seriously injured by the hail.

The flood in Tulsa resulting from the excessive rainfall caused property damage amounting to thousands of dollars. Houses were moved from their foundations (fig. 3), and garages and automobiles were washed away by a torrent several feet deep that raged through the lower sections of the city.

**Localization of damage.**—Three houses stand alone on Cleveland Avenue north. The top story of each is sliced off as clean as if with a cleaving knife.

In the Knoff residence a cut-glass vase was carried from its resting place on a buffet over a pile of dishes, around a corner into the living room and was found unbroken on the floor.

The Levorsen house on Lakeside drive was so badly damaged that it was deemed unsafe to enter. * * * All the furniture was in splinters except the buffet, which was moved 2 feet from the wall with not a dish broken.

In one house every stick of furniture was destroyed with the exception of the piano and a talking machine, which were not even scratched.—H. Lyman.