who are able to appreciate the nature and value of the work of that band of British scientific heroes, without whose efforts, the result of long years of patient training in research, the war would inevitably have been lost, on the land, on the sea, and in the air. If the lay press would descend from its wooden pedestal and inculcate in the public mind that knowledge and love of science through which "our men of science"—unexcelled in the whole world—acquired their equipment for winning the war, instead of perpetuating the silly and antiquated notion that they are habitually immersed in useless hobbies of no practical utility, it would do real service to the country.—The London *Electrical Review*.

NOTES ON METEOROLOGY AND CLIMATOLOGY

TORNADOES

A FEW weeks ago an official of the Weather Bureau was asked this question: How many tornadoes will a healthy cyclone hatch in a day? This, naturally, was a difficult question to answer; but it must be admitted that the tornadoes of March 28, in the middle western and southern states, and those of April 20 in Mississippi, Alabama and Tennessee, afford striking examples of the fecundity of barometric depressions when other conditions are favorable. The *Monthly Weather Review*[1] for April, 1920, contains about 18 papers, discussions, and notes concerning these very destructive tornadoes, as well as those which occurred in North Carolina and Oklahoma on April 12 and May 2, respectively.

Eleven of the thirteen tornadoes of March 28 occurred in the region surrounding lower Lake Michigan and two occurred in western Alabama and eastern Georgia. It appears that they were associated with the passage of the squall front or line of wind-convergence which marked the barrier, in the southeastern quadrant of the deep "low," between southeasterly and southwesterly winds. The "low" which gave rise to this wind-shift line moved from east-central Nebraska to northern Wisconsin in the course of the day. In the region of lower Lake Michigan, it was possible to trace the hourly progress of the line as it advanced on a slightly curved front in a general east-northeasterly direction. It appeared at 6 A.M. in northeastern Missouri and southeastern Iowa; at noon, it extended along the eastern line of Illinois northward to the lake, thence curving northwestward into Wisconsin; at 9 P.M., it had almost reached Lake Huron, and was over the western end of lake Erie. As its northern end reached Lake Michigan, there was a perceptible forward bulge which may be attributed to the decreased friction as the wind advanced over the smooth water surface.

Regarding the circumstances under which these tornadoes were formed, Dr. Charles F. Brooks, in his discussion, says:

> Why did these 13 tornadoes occur on the afternoon of March 28? Let us review the facts as brought out by the weather observations:
>
> 1. There were strong, unusually warm winds from the southeast and south-southeast over a large area from the Gulf of Mexico to the Great Lakes.
>
> 2. A well-marked line . . . separated these winds from still stronger, but slightly cooler southwest or south-southwest winds in a belt immediately to the west.
>
> 3. Heavy thunderstorms, some with tornadoes and hail, occurred along this line of converging winds.
>
> 4. Immediately to the west of the northern portion of this line was a belt of diverging winds, characterized by brilliantly clear skies and exceedingly dry air, the driest on record at some stations. . . .
>
> 5. Kite observations indicated the presence of a cold southwest-west wind at a moderate height overrunning the warm surface wind.
>
> 6. The northeasterly movement of the tornados and lower clouds and the fall of hail on or to the east of the tornado paths indicated a southwest to, at least, west-southwest wind not far aloft.
>
> Surely this was an unusual set of conditions. With winds meeting at an angle of about 60° and at a rate of about 30 miles an hour, large volumes of air were sent upward and given a counterclockwise rotary motion by the thrusts of the southwest squalls routing under the rear portions of the

[1] Papers on tornadoes, pp. 191–213. Reprints of these papers may be obtained upon application to the Chief, United States Weather Bureau, Washington, D. C.

slower north-northwestward-moving masses of warmer air. At a moderate height condensation took place in the moist, upthrust air, and as it ascended at a lesser rate of cooling, due to the liberation of the latent heat of condensation, it probably was squeezed aloft at an increased rate by the cold wind it was probably encountering. Under such conditions intense vertical movement accompanied by a rotary motion of small dimensions makes a tornado.

The circumstances surrounding the formation of the tornadoes of April 20 were somewhat different. In this case, there was a long, oval-shaped low pressure area over the southern part of the Mississippi valley. The storms occurred in the morning at a time when the line of wind-convergence was a considerable distance to the west of the line of tornado formation. Therefore, it can not be said, as in the previous case, that the mechanical effect of the wind-shift line was operative. There is another striking feature: All of these whirls were formed along a north-south line which lay about 30 miles west of the Mississippi-Alabama line. The first occurred at Ingomar at 7:30 and followed a northeasterly course into Tennessee where it continued by a series of dips almost to the center of the state. The second began about 40 miles south of the first, near Bradley at 8:00 A.M. and moved northeastward, disappearing in northcentral Alabama. The third began near New Deemer, at 8:30 A.M. and ended near Brownsboro, Alabama. (This was the longest of the four paths, and was marked by an almost continuous swath of destruction for 150 miles.) The fourth appeared at Bay Springs at 9:55 and ended near the state line east of Meridian, having passed within a mile of the Weather Bureau office at that place. The significant facts are, (1) that these tornadoes formed on a nearly north-south line, and (2) that they formed at almost equal intervals of time and distance. The probable explanation is that these formations resulted when an overrunning layer of cold air arrived over a given place, where other conditions were favorable, increasing the vertical temperature gradient to such a degree that there was immediate and intense convection. That this advancing front was probably coming from the northwest is shown by joining the positions of the tornadoes at any given time. The resulting line is normal to the wind direction supposed to exist aloft.

According to Mr. J. H. Jaqua, the Weather Bureau meteorologist at Meridian, Mississippi, the passage of the tornado at that place was accompanied by almost total darkness. He says:

> . . . The darkness between 10:30 and 10:39 A.M. was as intense as would be common for a cloudy moonless night at 9:30 or later, and though lights were on in the business houses (but no street lights were in operation), pedestrians could distinguish each other only with great difficulty. . . . The pall of darkness was so unnatural that it was extremely weird. . . .

No account of tornadoes is complete without the recital of some of the many "freaks" which such storms are wont to perform. The removal of feathers from chickens, the complete destruction of houses, the clean sweeping through deep forests, and the carrying of objects great distances, are examples frequently recounted. Of the many curious pranks of these storms, however, there are some which are worthy of mention. Here are some excerpts from the numerous accounts in the article cited above:

> An automobile locked in a garage was undamaged, although the garage was blown to splinters.
>
> Half a dozen glass jars of fruit were carried 100 yards by the winds and not damaged. (*Bay Springs, Miss.*)
>
> A car load of stone was whipped about like a feather, and trees, one especially large oak, were twisted from the roots as if they had been bits of wire. (*Florence, Ala.*)
>
> There seemed to be two puffs of wind; one carried things toward the west. In about a quarter of a minute everything came back. I tried to keep my family down on the floor. One of my boys blew out of the house; then blew back. . . . (*From report of J. P. Sanderson, Newburg, Ala.*)
>
> [The tornado] swept rapidly across the cove, . . . as it neared the mountain range and went over it, leaving a path clear of any standing timber, houses, or fences. In going over the path of

the storm the next day . . . cedar trees, with trunks 16 inches through [were found] lying on the upper benches of the mountain, that had been torn up by the roots down in the valley and brought up bodily and deposited among the big timber on top of the range. . . . (*Postmaster Okal, Huntsville, Ala.*)

. . . A mule was hurled 100 feet against a tree stump, its body pierced by a 2 by 4 scantling; a horse was carried several hundred feet into a patch of wood where it was found the following morning apparently unhurt; a steel range from the Preston home was found 3 miles away in a wheat-field; harrows, plows and other agricultural implements were scattered over the fields for miles around; a sewing machine was found hanging from a tree limb. . . . (*Occurred in the tornado of April 12, in Union County, N. C., according to Mr. G. S. Lindgren.*)

This list could be continued indefinitely, and it is presumed that each locality visited could yield a number of remarkable "freaks."

The series of articles in the *Review* is concluded by a reprint from the "Physics of the Air,"[2] by Dr. W. J. Humphreys on the "Tornado and its cause," and a bibliography prepared by Professor C. F. Talman, which gives the principal publications containing statistics of tornadoes in the United States.

It is needless to say that the twenty-one or more tornadoes which have been experienced in the United States this spring, have been terribly destructive of life and property. It is estimated that in the tornadoes of March 28 killed 163, injured several hundred and destroyed ten million dollars worth of property. Those of April 20 were even more destructive of life, there being 229 deaths reported and over 700 injured, with a property loss also extending into the millions. This most destructive of storms is so extremely local that even though there may be a wind speed of between two and five hundred miles per hour in the funnel-cloud, this speed falls off so rapidly with distance from the center that the wind may not even be of destructive violence within a few hundred yards. Owing to this extreme localization, the tornado can not be accurately forecast; and if it could, it is so violent that no precautions could be taken except these already observed in localities where it frequently occurs—namely, keeping in readiness the storm-cave.

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[2] *Journal of the Franklin Institute*, January, 1918, pp. 114–116.

SPECIAL ARTICLES

THE SOUNDS OF SPLASHES

UNDER the above title an interesting note has just been published by Professor C. V. Raman and Mr. Ashutosh Dey.[1] The authors call attention in a footnote to the fact "that the splash of a liquid drop is practically soundless unless the height of fall exceeds a certain minimum." In connection with this remark it seems perhaps worth while to publish a note on a preliminary study of a similar problem which I made in 1915. I have been intending to return to the work, but have been giving my attention to other matters.

My observations were confined to drops of water falling into water, and were made by ear. They indicate not only a single minimum height of fall within which the drops strike the water silently, but also other greater heights of fall for which the drops enter the water without sound. The boundary between a region in which a drop makes a sound when it strikes and a region in which it does not make a sound when it strikes is very sharp, a fraction of a millimeter difference in the height of fall being sufficient to pass from a drop which falls silently to one which makes a sharp click when it strikes.

In the figure the results of five experiments are shown. The numbers at the left give the distances in centimeters from the orifice from which the drop fell to the surface of the water below. Each vertical line indicates a range throughout which the drops click when they strike the water. The maximum heights of fall tried are indicated by the horizontal dotted lines.

It will be seen that in most cases a drop strikes silently if it falls less than about 5.5 cm., if it falls more than about 7 cm. but less

[1] *Phil. Mag.* (6), 39, p. 145, January, 1920.