HOT SPELL OF AUGUST, 1918.

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The high temperatures of the first decade of August, 1918, came seemingly as a climax to a year of remarkable weather.

Beginning in October, 1917, a series of cold waves of unusual severity for the season swept far south over the Plains States, causing frost and freezing temperature in that month nearly to the Gulf coast. The winter of 1917–18 was marked by severe cold,[1] heavy snow, and ice.[2] Finally in August, 1918, the temperature rose to heights not hitherto attained in almost half a century of observations.

The writer of this paper made the official forecasts for the Washington district for August. While the hot spell was in progress it was a matter of continual surprise to him that, considering the pressure distribution, such abnormally high temperatures should persist day after day in some portions of the country. Records of maximum temperature that had stood for nearly half a century were not only broken, but the new record itself was in some cases exceeded on the following day. A retrospective view of the conditions preceding and during the prevalence of the high temperatures is helpful to a better understanding of the phenomenon than could be gained by the necessarily brief examination of the daily weather maps that was possible at the time; hence the preparation of this paper.

The use of summer time by the Weather Bureau has its disadvantages. The morning observation, coming an hour earlier than hitherto, gives current temperatures that are nearer the daily minimum in the greater portion of the country than formerly. Similarly, moving the evening observation forward an hour brings it that much nearer the hour of maximum temperature, so that in the Plains States there are but a few degrees separating the temperature at 7 p. m. 75th Meridian Time (5 p. m. to 6 p. m. Sun time) from the daily maximum. As a result the temperatures charted on the daily maps have been somewhat higher than have hitherto been charted under the same pressure conditions, and it has been more or less difficult, at times, to distinguish between abnormal heating due to cyclonic influences, and the apparent increase in temperature due to reading thermometers at an earlier hour in the afternoon.

Contributing causes.—In my judgment the high temperatures were the result of several influences acting in conjunction, viz: (1) The pressure distribution; (2) insolation, probably not exceptional in any respect, but unchecked by clouds for several consecutive days; (3) the topography of the Plains States, which is favorable to a transfer of heated air from lower to higher latitudes in the region where the hot spell developed; and (4) possibly dynamic heating (over Montana) where there was a descent of warm dry air from high to low levels. Just to what degree No. 4 contributed to the rise in temperature over Montana on the 1st and 2d is a matter of speculation, but it seems quite clear that dynamic heating was at least a factor. The pressure distribution, however, is believed to be the controlling and, indeed, the principal factor in the causation of the phenomena.

The cumulative effect of above-normal temperature over the Plains States, especially south of Kansas, for at least two months previous to August 1, must have contributed to the warming of the air layers next to the surface. Kite flights at Drexel, Nebr., directly in the heated area, show that the air up to at least one kilometer above the surface was at a relatively high temperature as late as the 7th, when the crest of the hot weather was over the Atlantic Coast States.

Some idea of the probable magnitude of the changes involved by the transfer of air from one region to another by the circulation induced by cyclonic systems may be had from the excerpt (Table 1) from the Kite Flight, made at Drexel, Nebr., August 5, 1918.

TABLE 1.—*Temperature and wind in the air layers next to the surface at Drexel, Nebr., 10 p. m., Aug. 5, 1918.*

[Courtesy Aerological Division.]

Summer (75th mer.) time. P. M.	Altitude above surface.	Temperature.	Wind.	
			Dir.	Vel. (m. p. s.)
h. m.	*m.*	*°C.*		
10 9	0	33.0	SSW.	9.8.
10 12	104	32.6	SSW.	14.4.
10 13	354	31.8	SSW.	26.0.
10 15	399	31.6	SSW.	28.1.
10 20	604	29.7	SSW.	28.2.
10 25	854	27.5	SSW.	28.3.
Mean		31.0 C. 87.8 F.	SSW.	22.4 meters per second. 50.1 miles per hour.

An inspection of this table shows that the layers of the atmosphere up to 854 meters (2,802 feet) above the surface were abnormally warm, and that the air was moving from the SSW. at a speed of more than 60 miles an hour in the stratum between 400 and 850 meters above the surface. How are these data to be analyzed? Was there an actual physical transfer of air from one point to another at the speed indicated? If so, the result must be an excess of air in one region and a deficiency in another, a condition that obviously could not exist without making itself visible in the surface pressure distribution.

The pressure distribution on August 1 at the evening observation was characteristic of the hot-weather type for the Plains States and the Mississippi and Missouri Valleys—viz, a trough of low pressure extending from the mouth of the St. Lawrence, west-southwest via the Upper Lakes, the Missouri Valley, the Central Plains States, and the southern Rocky Mountain region, to the summer low in the lower Colorado basin. This trough of low pressure was flanked on its southern side by an area of relatively high pressure, which covered the Southeastern States and the adjacent portion of the North Atlantic Ocean. At no time on the evening maps during the hot spell did the pressure in the southeastern High reach the level of 30.10 inches, although it was always relatively higher than in the northwestern trough. The latter changed from day to day in its minor details, but the essential features were practically unchanged. The method by which it retained its geographic position throughout the 10-day period was somewhat as follows: Pressure over the Canadian Northwest and, indeed, over the Pacific near the coast of Alaska being low, there was no tendency for areas of high pressure to develop in the rear of LOWS. That is to say, there was no reaction to high pressure in the rear of a LOW such as takes place in normal weather conditions. Consequently, along the northern storm path in the United States there was a procession of shallow disturbances, moving slowly and, frequently, in a halting manner, instead of the usual sequence LOW-HIGH-LOW-HIGH, etc.

The southeastern HIGH was a contributing cause, but can scarcely be considered as other than one link in the

[1] See *Brooks, Chas. F.*, Geographical Review. 5: 405–414.
[2] See this REVIEW, February, 1918.

chain of events which produced the hot weather in the great interior valleys and the Plains States.

The pressure distribution on the evening of August 1 (evening maps are considered in all cases) is shown on figure 1 (Chart No. XLVI-72), which is a reduced copy of the weather map for that date. Only the weather maps of the 1st and 8th (8th see fig. 2) have been reproduced, since the intermediate maps are but slight variations on the general type illustrated by the maps of these two dates. Considering now the map of the 1st, it will be noticed that in addition to the general trough of low pressure, there is a cyclonic depression with central pressure 29.65 inches just north of Montana, and that this depression is separated from the trough of low pressure by a shallow HIGH with central pressure of barely 30 inches over Manitoba. In passing, I may say that the only interruption to the procession of LOWS across the Lake region was on the 2d, when this shallow HIGH had moved to the Upper Lake region with an increase of a tenth of an inch in pressure. It caused onshore winds over Wisconsin from both Superior and Michigan, and a temporary cooling of 10 to 15 degrees.

Returning now to a consideration of the LOW north of Montana, it may be remarked that this LOW and its subsequent movement was the immediate circumstance leading to the abnormally high temperatures over the Missouri Valley and districts farther eastward. It is probable that the center of this LOW moved rapidly to the northeast, and that the depression noted over Manitoba on the evening of the 3d was a secondary which formed in its southwest quadrant. In any event, the arrival of this secondary LOW north of Lake Superior on the 4th, and its subsequent drift eastward, was the direct visible cause of the high temperatures in the Lake region on the 4th, 5th, and 6th.

I have prepared temperature charts, of which two are reproduced as figures 3 and 4 (Charts XLVI-74 and XLVI-75), showing the rise and progress of the hot spell. The heavy lines on these charts are lines of zero change in the temperature; the inclosed areas are regions where the temperature at the observation made daily at 7 p. m., 75th Meridian Time, was 10 degrees or more above the normal. Figure 3 (Chart XLVI-74) shows the inception of the hot spell on August 1, with two separate areas of temperature more than 10 degrees above the normal. On the 2d there were still two separate areas, but these had merged into a single area on the 3d, with the peak of the high temperature over eastern Kansas and western Missouri, where the positive departure was 20 to 25 degrees.

The movement of a shallow HIGH across the upper lakes on the 2d, as already mentioned, seemed to intensify the heat over Kansas, southeastern Nebraska, western Missouri, Arkansas, Oklahoma, and extreme northern Texas. Just how this was accomplished is largely a matter of speculation. The apparent effect of this HIGH on the surface pressure distribution was to make a dent in the barometric trough where it crossed the Lake region. In other words, on the evening of the 2d this trough had become crescent-shaped, with low pressure in the two horns of the crescent. The eastern horn hung over the mouth of the St. Lawrence, and the western horn over Missouri and eastern Kansas. The surface wind over the Plains States and the interior valleys was not controlled by this HIGH. Consequently, southerly winds continued and there was no moderation in the temperature due to the presence of the Lake region HIGH. It is clearly apparent that during the 2d and 3d, when the HIGH of August 2 occupied the Upper Lake region, there was practically no eastward advance of the surface heating; but on the 4th, when the HIGH had passed eastward and off to sea over New England, and the secondary LOW, before mentioned, had moved into the Lake Superior region, the trough formation shown in figure 1 (Chart XLVI-72) was restored and there was a decided eastward spread of the high temperatures, the eastern limit at the evening observation of the 4th extending from Erie, Pa., southward into the extreme western part of Virginia.

The high temperature spread eastward more rapidly than the low pressure, a fact which immediately suggests the inquiry, which is cause and which effect? Or are both effects of a common cause?

By the evening of the 5th the eastward limit of the warm weather was found over western New England, with two centers of departure from the normal of 20 degrees or more, one in western Pennsylvania and southeastern Ohio, the other extending from southwestern lower Michigan to northeastern Kansas. A notable feature of the hot weather in the Lake region was the fact that places on the lee shore of the Lake suffered almost as much from the heat as places on the windward side. Thus, Chicago on the windward side experienced a temperature of 26 degrees above the normal on the afternoon of the 5th, while Grand Haven on the opposite or leeward side of the Lake experienced a temperature of 20 degrees above the normal, or only 6 degrees less than on the windward side of the Lake.

The peak of the hot spell was reached in Kansas on the 3d; in Indiana, Ohio, Kentucky, Tennessee, and northern Alabama on the 5th; in the middle Atlantic coast States on the 6th and 7th; and in the Carolinas on the 6th. The hot spell did not extend into Georgia and Florida or into Maine.

The greatest excess of temperature was 26 degrees above the normal at Chicago, Ill., at the evening observation of the 5th. The temperature at the observation was 100°. The temperature was between 20 and 25 degrees above the normal in eastern Kansas and western Missouri on the 3d and 4th. On the 5th the region of greatest departure extended from northeastern Kansas to southern Michigan, and a second area covered the upper Ohio Valley. On this date the temperature was 10 degrees or more above normal over an area of more than a million square miles. On the 6th the high temperatures had overspread the Middle Atlantic States, the greatest positive departures being in Pennsylvania. The hot weather continued in the East over the 7th and 8th, but did not spread into eastern New England.

The hot spell was broken by thundershowers that were irregularly distributed, but were nevertheless effective in reducing the extremely high temperatures, especially in the great eastern cities. A curious anomaly is to be noted however, viz, an interruption of nearly two days in the sequence of thunderstorms in the different parts of the heated territory. On the afternoon of the 4th thunderstorms were fairly general in the upper Lake region and along Lake Erie, and a few isolated storms occurred in the East Gulf and the northern portion of the Middle Atlantic States. Thunderstorm activity was not renewed the next day in the eastern districts, although the LOW, which had become V-shaped with the apex of the V extending southwestward over New England and the Middle Atlantic States, was favorable to thunderstorm development. The next day, the 6th, was equally devoid of thunderstorms except for sporadic cases in the southern Appalachian region. But on the 7th, after the original LOW had passed off to sea, a shallow depression appeared over New England. Almost coincidentally, thunderstorms occurred over the Middle Atlantic States, apparently beginning over the Appalachians of Virginia, West Virginia, and North Carolina, and spreading thence east-northeast. On the following day there were thunderstorms over a much wider area, principally in the lower Lake region, and although high temperatures still prevailed locally, the strength of the hot spell was broken, and a general lowering of temperatures, beginning in New England, set in and continued for some days. High temperatures continued in western districts until the 14th.

In Washington, D. C., while the atmosphere was extremely hot on the afternoons of the 6th and 7th, the air was dry, and but few serious cases of heat prostration occurred.

The conspicuous features of the hot spell were: (1) Its short duration both in the extreme Northwest and in the East; (2) the general dryness of the air; and, finally, the manner in which it broke up—viz, through local thunderstorms during the night of the 7th–8th.

The duration in the Canadian Northwest and also in Eastern States hardly exceeded two days, although locally in the East there were some high maxima on the 8th.

The dryness of the air was a characteristic feature of the hot weather. In the small table below will be found the mean of the maximum temperatures for the three days on which the highest maxima were registered, and the three-day mean relative humidity for the same days computed from observations made uniformly at noon at each of the points named. The stations have been selected to represent points in a west-east line from Kansas City, Mo., to the Atlantic coast:

Stations.	Mean maximum, 3 days.	Mean noon relative humidity, 3 days.
	°F.	Per cent.
Kansas City, Mo	106	19
Springfield, Ill.	104	28
Columbus, Ohio	101	41
Philadelphia, Pa	101	49
Washington, D. C	103	46
New York, N. Y	96	45
Hartford, Conn	94	53

The break-up of the hot spell.—The peak of the hot spell in the East was reached on the 6th, but there were also high maxima on the 7th and 8th. It was not until the 15th, however, that the maximum temperature at Washington failed to register above 85°. After the local thunderstorms on the afternoon of the 7th in the upper Ohio Valley, southwestern Pennsylvania, the northern portion of the Appalachian region, the District of Columbia, and Maryland, the day temperatures did not reach the high figures of the 5th and 6th, but the night temperature of the 8th–9th, in portions of the Middle Atlantic States from Philadelphia, Pa., south, was exceptionally high.

The thunderstorm which occurred at Washington, D. C., on the evening of the 7th was of rather exceptional character. The day was cloudless up to 4 p. m. At 5 minutes after 4 the sun was obscured by a high sheet cloud, probably in the alto-cumulus level. A well-defined type of mammato-cumulus cloud was observed in the north and northwest just prior to the beginning of the thunderstorm. The first thunder was heard at 5:12 p. m. For the next four hours there was a constant display of electrical activity, although rain did not begin until 7:20 p. m. The surface wind which before the storm had been very light from northeast shifted first to southeast and then at 5:35 p. m. to northwest, with a gust velocity of 28 miles per hour, and continued from the northwest, increasing to a maximum velocity of 38 miles at 7:10 p. m. Soon thereafter it diminished in velocity, and by 9:30 p. m. the movement was close to zero. The temperature, which at 5 p. m. was 102°, fell to 73° by 8:30 p. m.

The exceptional character of the storm was the absence of cumulo-nimbus and scud clouds, and the apparent development of the storm at a high level immediately over the District of Columbia. The storm moved to the eastward, and was reported at Baltimore, Md., later in the evening, but did not reach Philadelphia or other stations to the northeast.

On the morning of the 12th high pressure appeared off the coast of British Columbia, and on the 13th and 14th advanced across the northern Rocky Mountain region and the Missouri Valley, thus terminating the period of abnormally high temperature which had prevailed since the 1st.

I have attempted to correlate the movement of the higher currents as indicated by the upper clouds with the weather conditions on the surface.

The proposition has been advanced in some quarters that cirrus clouds moving from east to west are an incident of hot weather in the Plains States. In order to test this proposition I have charted the upper clouds observed not only in the heated area but for all parts of the country for the first decade of August.

On the days when very high temperatures prevailed there was a marked absence of clouds within the heated area, thus indicating that vertical convection was not active. In the few cases of upper clouds observed the movement was closely in accord with the normal expectation, viz, from west to east. The only movement of upper clouds out of the ordinary during the first decade of August was a well-marked advance of cirro-stratus from the southeast, first observed on the middle Gulf coast in the evening of the 5th, continuing on the 6th, and extending inland to Arkansas. Doubtless these high clouds were formed in the outflow from the tropical disturbance that struck the Louisiana coast on the afternoon of the 6th. The movement evidently had no bearing upon the hot weather. A further examination of the upper cloud motion at representative stations in the Middle West for the six months, January to June, 1918, showed especially in March and April a rather large number of westerly motions considering that the normal proportion of westerly to easterly motion is about as 1 to 20. Nevertheless it does not seem probable that the westerly motions observed in March and April can be definitely related to the hot weather experienced in August.

An examination of the record of kite flights at the three aerological stations of the Weather Bureau discloses the following very interesting fact, viz, that on the 5th and 6th, when the lower air strata up to 3 and 4 kilometers were moving from the southwest, as shown by the kites, the upper clouds showed an apparently unbroken movement from the same direction up to the base of the stratosphere. The significance of this movement can not now be discussed, but if it should turn out, as it probably will, that warm southerly winds of great depth are characteristic features of the eastern front of cyclones, and that cold northwest winds are equally a feature of the western side or the rear of cyclonic systems, then it would appear that any hypothesis framed to account for the origin and maintenance of cyclones and anticyclones which does not take account of these two great wind currents is incomplete.

In conclusion, it would seem that the explanation of the abnormally high temperatures of August, 1918, is to be found in the fact that for some time, as a result of the unhindered insolation that had been received at the earth's surface in the Plains States, not only the surface of the earth but the air layers in contact therewith and upward, probably to at least a kilometer above the surface, had become unusually warm; the development of a barometric gradient for fresh southerly winds on the 1st and 2d and again on the 4th, 5th, and 6th, was the concluding step in the phenomenon.

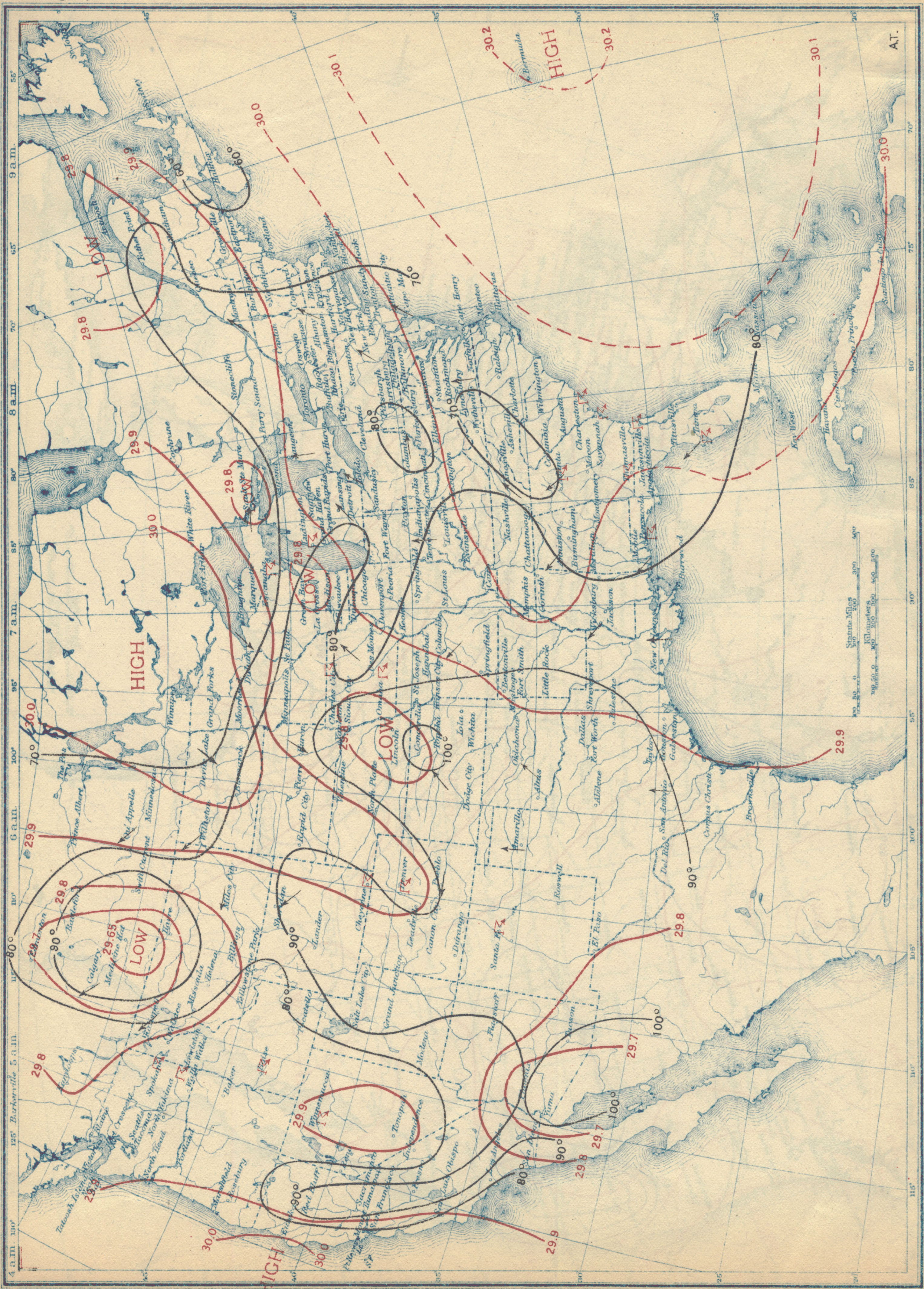

Fig. 1. Weather Map, 7 p. m., 75th meridian time, August 1, 1918.

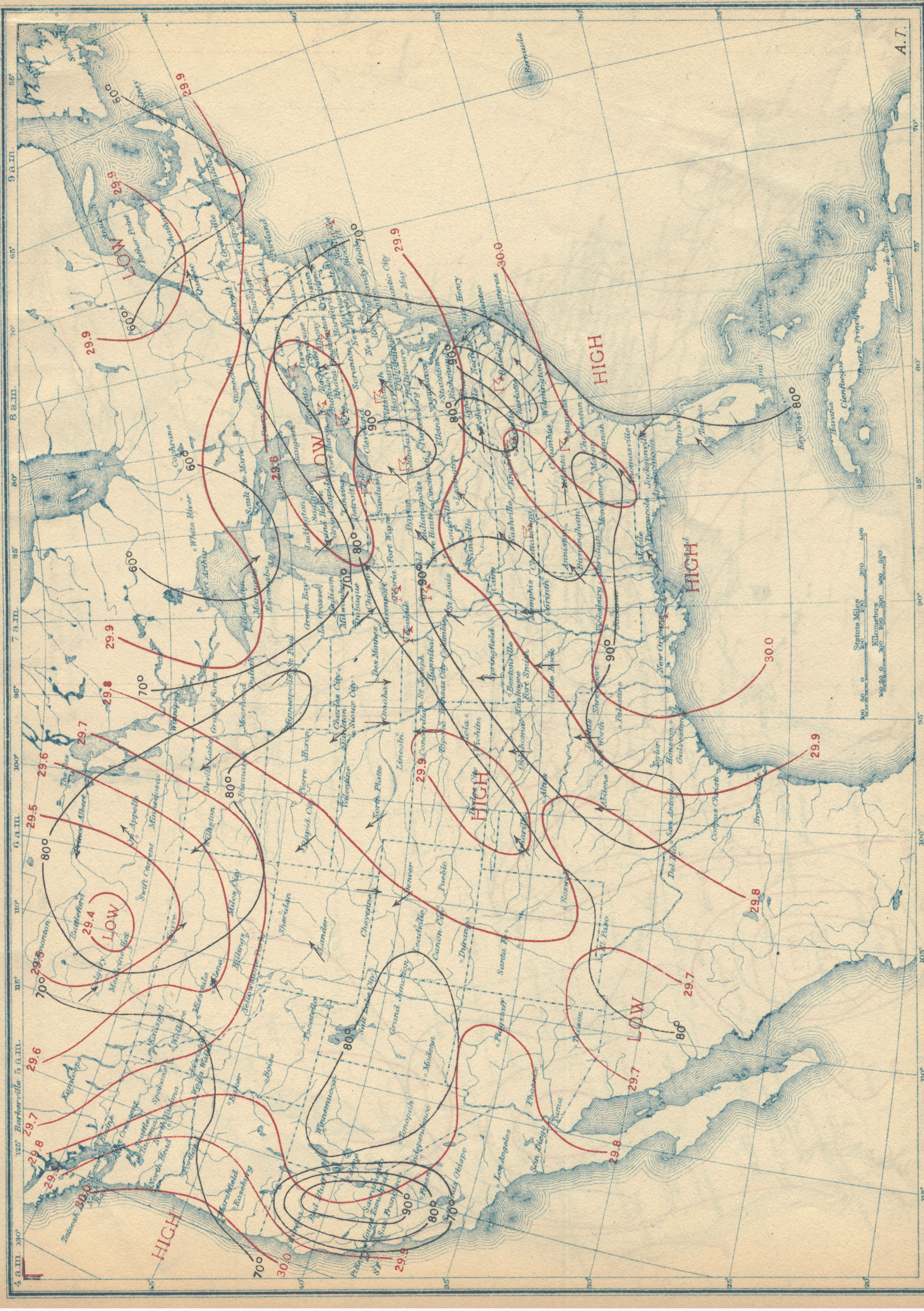

Fig. 2. Weather Map, 7 p. m., 75th meridian time, August 8, 1918.

Fig. 3. Departures from Normal Temperature, 7 p. m., 75th meridian time, August 1, 1918.

Fig. 4. Departures from Normal Temperature, 7 p. m., 75th meridian time, August 8, 1918.