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THE REMARKABLE TEMPERATURE FLUCTUATIONS IN THE BLACK HILLS REGION, JANUARY 1943*

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[U. S. Weather Bureau, Rapid City, S. Dak., March 1943]

On January 22, 1943, temperature fluctuations of incredible magnitude and rapidity occurred on the slopes of the Black Hills in South Dakota. Some of the changes observed at Rapid City attracted Nation-wide attention.

This region is habitually subject to surprising temperature changes. Indeed, the chinook is so prevalent that it may be considered a prominent climatological factor. Some of the outstanding temperature changes contained in the Rapid City record are as follows: The greatest daily range at Rapid City was observed on January 13, 1913, when the temperature rose from -17° at 8 a.m. to 47° above zero at 10 p.m., a rise of 64° in 14 hours. The greatest 24-hour rise in temperature occurred on December 28-29, 1933; on this occasion the mercury climbed from zero at 8 p.m. on December 28 to 67° above zero at 1:45 p.m. on December 29. On January 10, 1911, the temperature dropped from 55° at 7 a.m. to 8° above zero at 7:15 a.m.; cold weather continued until January 12, when the temperature rose from 13° to 43° within 10 minutes, between 1:30 and 1:40 a.m.; at 6 a.m. the temperature stood at 49° , but fell to 13° below zero by 8 a.m., a drop of 62° in two hours.

Because of such temperature variations this region has achieved some measure of fame, or notoriety, but even these precedents were inadequate preparation for the occurrences of January 22, 1943.

The phenomenon first became manifest at Spearfish, S. Dak., at 7:32 a. m. when a rise of 49° was recorded within 2 minutes. (-4° to 45° .) After many sharp variations, the mercury plunged from 54° at 9 a. m. to -4° at 9:27 a. m. Sturgis, S. Dak., experienced a similar sequence of slightly less marked changes beginning 52 minutes later. As the phenomenon progressed southward, Rapid City came under its influence. Beginning at 10:29 a. m. a sudden warming of 32° occurred within 4 minutes, which was succeeded at 10:36 a. m. by a drop of 22° within 3 minutes, only to rise immediately from 20° to 56° within 5 minutes. And so it continued with such changes as from 60° at 11:57 a. m. to 13° at 12:02 p. m.; from 15° at 12:35 p. m. to 50° at 12:46 p. m.; and from 58° at 5:22 p. m. to 17° at 5:26 p. m. Little wonder the oldest settlers could recall no parallel.

The changes experienced chronologically by a stationary observer were startling enough, but to the motorist and pedestrian were even more so. At 11 a.m. on the east side of the Alex Johnson Hotel in Rapid City, winter was in all its glory, while around the corner on the south side, not 50 feet away, spring held sway, only to be swept away in a flash by the sting of winter, and then to return. Motorists were forced to park, unable to immediately

remove a thick frost that appeared almost instantly on windshields, so sudden and warm was the wind. Streets were coated instantly with a peculiar light frost. Similar reports came from all over the region, and in practically all cases the sharpest differences were coincident with changes in elevation.

The Black Hills are an anticlinal or elongated dome-shaped mass, culminating in peaks over 7,200 feet above sea level and sloping down abruptly to 3,000 feet on the east, and gradually on the west to 4,200 feet. Actually, they are the highest mountains between the Atlantic Ocean and the Rocky Mountains. Five major ranges traverse the region from north to south. The most westerly of these is an infacing, limestone escarpment at a mean elevation of 6,800 feet. The region lies principally within parallels 43° to 45° north latitude, and meridians 103° to $104^{\circ}30'$ west longitude; it is largely in South Dakota, partly in Wyoming; and is about 125 miles long in a north-northwesterly and southerly direction, and about 65 miles in width. (See fig. 1.)

While the more sensational and newsworthy variations occurred on January 22, the situation had been developing for several days previously.

On January 15 an outbreak of extremely cold Continental Arctic air invaded the Great Plains region and thereafter became stagnant, with the Black Hills near the western edge of the air mass. This produced the lowest temperatures observed for several years at many stations in the Great Plains and the Black Hills. By January 19 the extreme western edge of the air mass had moderated somewhat and was now classified Continental Polar warm air, but the Black Hills remained in the subzero air behind a cold front about 200 miles to the south and west. The front moved near the Hills on January 20 and had become quite stationary. Dynamically heated Maritime Polar air, under the influence of a strong depression over the Pacific Northwest, began overrunning the wedge of cold air in Montana and northeastern Wyoming early on January 20. The early morning sounding at Great Falls, Mont., indicated a strong upper inversion from 7,400 feet to 8,800 feet.

The surface position of the front on January 20 was about 150 miles west and south of the Black Hills on a northwest-southeast line; and though the front was later indicated in a position nearer the Black Hills, data available to the analyst did not justify placing the front east of the Black Hills at any time during the period under consideration. Yet, warm air did appear at all elevations above 4,500 feet.

While towns and villages at lower elevations were still in the grip of this winter's severest weather, Lead, Custer,

*Unless otherwise noted, all temperatures in this paper are in the Fahrenheit scale.—Ed.

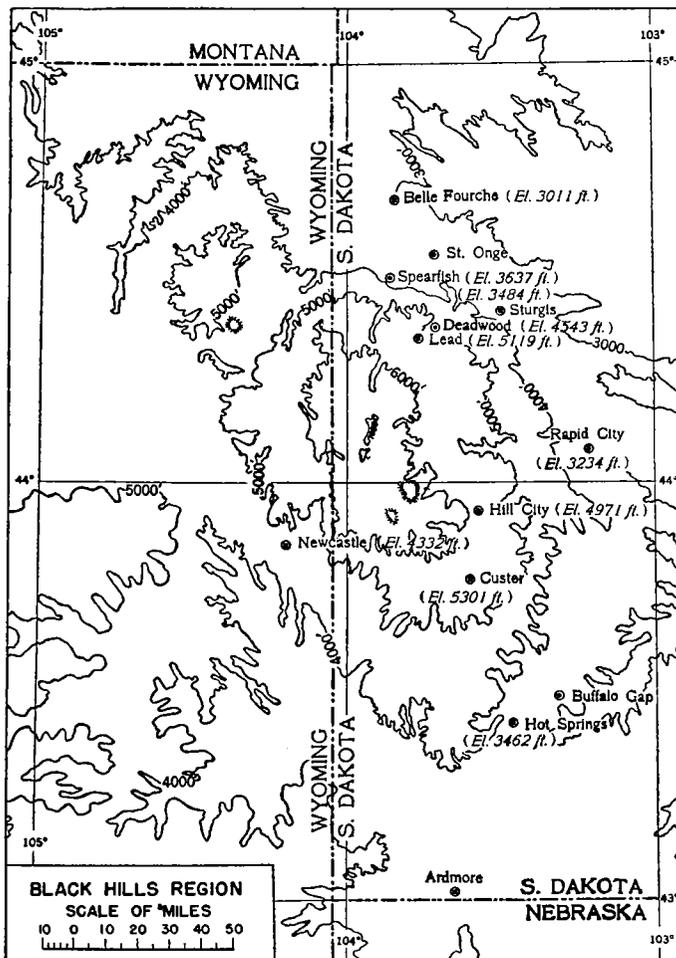


FIGURE 1.—Sketch of the Black Hills region.

Mount Rushmore, Hill City, and all inhabited higher elevations reported "chinooks" and other "mysterious" temperature rises on January 20. This warm air gradually progressed to lower elevations until January 22. Of course, minor recessions occurred, but the higher stations, such as Lead, Hill City, and Custer, were constantly in the warm air after January 20.

The warm air which arrived at Lead before noon was not felt at Deadwood until evening. Deadwood is 3 miles northeast of Lead and 600 feet lower. The elevation at Lead is 5,119 feet.

In the northern Hills, warm air was not in evidence below 4,500 feet until January 22. The Black Hills airport, about 10 miles north of Deadwood at an elevation of 3,913 feet, remained severely cold until January 22. However, relatively lower elevations in the southern Hills received temporary relief during the early morning hours of January 21. Hot Springs, 3,442 feet, was up 60° at 6 a. m., January 21, from the lowest temperature of January 20, but at 7:30 a. m. temperatures again had fallen to -2° from a peak of 40° at 6 a. m. This recession also was noted at Deadwood; here it occurred at 4:30 a. m. with a fall of 48° within a few minutes.

As the front approached on January 21 and 22, its orientation relative to the Hills remained the same, but the southern portion of the Black Hills was nearer the surface position of the front. As this situation developed, warm air began to appear at lower elevations. This fact and all available data strongly suggest a penetration of the frontal surface, with the line of temperature discontinuity determined by the slope of the frontal surface.

Indeed, this seems the only logical assumption. For in no other manner is it possible to account for the astonishing temperature differences of January 22, recorded on the eastern (steep) side of the Black Hills.

If we attempt to explain these discontinuities on the basis of horizontal motions of a surface front, the wave-like pattern of the fluctuations observed on the Spearfish-Sturgis-Rapid City-line would necessarily have been due to a disturbance of the front which would have been propagated laterally from north to south in the manner of a standing wave. Examination of the temperature traces shows wave lengths too small and amplitudes too large to attribute to motions of a surface front, considering the energy involved; also, the disturbances ceased suddenly and systematically from north to south, whereas a standing wave would be expected to diminish gradually in amplitude along the entire line.

The phenomenon is more easily explained if we look to possible causes in the cold air beneath the frontal surface. On January 21 an upper inversion had developed at Bismarck, N. Dak., with its base at 3,400 feet. Twenty-four hours later the base of this inversion had moved upward to 4,600 feet. The position of the surface front south of the Black Hills had not changed greatly.

Therefore we may assume that a fresh outbreak of cold air had steepened the frontal slope. Upon reaching the rough terrain of the Black Hills the resulting turbulence in this accelerating cold air easily could have disturbed the configuration of the frontal slope in the manner required to produce the observed results. The definite southerly motion of the surface front observed in the Missouri Valley on the following day seems to justify the assumption of a fresh outbreak of cold air. By the evening of January 23 the entire Black Hills region was submerged by the cold air under the frontal surface. Though complete data are not available, our information is sufficient to place the line of temperature discontinuity, for practically the entire period, between Lead and Spearfish, elevations 5,119 feet and 3,637 feet, respectively, in the northern hills; between Lead and Sturgis, 3,452 feet, and Hill City, 4,976 feet, and Rapid City, 3,219 feet, on the eastern slope; and between Custer, 5,301 feet, and Hot Springs, 3,443 feet, in the southern hills. Spearfish, Sturgis, Rapid City, and Buffalo Gap reported low temperatures throughout the period, except on the 22d when the warm air reached its lowest elevations. Data for the western slope are scanty, but it is believed the recessions and propagations at Lead and Deadwood may be assumed to have occurred over the entire region, though at higher levels to the north.

Perhaps a better analogy may be obtained if we consider the Black Hills region to be, in this instance, an island engulfed by a sea of cold air, shallow to the south (near the surface position of the front) and deeper to the north. As the tide moves northward, lower elevations on the island become exposed to the warm air above the sloping surface of the sea of cold air; but waves on the surface of this cold fluid continue to cause extremely sharp variations on the shore line. Finally at low ebb, the shore line recedes and almost the entire island emerges from the cold fluid. Soon thereafter the tide is reversed and the cold air becomes progressively deeper, with some irregularities due to the rugged conformation of the bottom, until the entire island is submerged.

While this phenomenon was popularly believed to be due to a chinook, it is doubtful whether any considerable dynamic heating took place over the Black Hills. Undoubtedly, the overrunning Maritime Polar air had been already modified by dynamic heating in its passage over

the Rocky and Big Horn Mountains. Large temperature discontinuities already existed across the surface front in Wyoming when this airmass appeared on January 20.

Pilot-balloon observations and pilot reports from aircraft at Rapid City indicated a strong current of over-running warm air within a few thousand feet of the surface as early as January 20. At levels above the highest elevations in the Black Hills, velocities generally exceeded 70 m. p. h. Such vigorous overrunning of the stationary cold mass to the east accounts for the large body of Superior air over the central and southern Great Plains noted on the surface charts of January 22 and 23. This subsidence air was returned to eastern Wyoming by southeasterly surface winds—further intensifying the temperature discontinuity. A difference of 70° was noted between Sheridan, Wyo., and Lewistown, Mont., on January 22; while on January 21, passage of the front contributed to a range of 75° at Box Butte, Nebr. Daily ranges exceeding 50° were numerous at stations in Wyoming and Nebraska which were near the front from January 19 to 23. In addition to the unprecedented temperature range reported at Box Butte, Nebr., outstanding changes include a range of 66° at Torrington, Wyo., on January 19; 65° at Harrison, Nebr., on January 21; and 61° at Clearmont, Wyo., on January 22.

Local chinook effects possibly contributed to conditions observed in the Black Hills, but it is evident that the phenomenon was essentially the result of the wavering motion of a pronounced quasi-stationary front separating Continental Arctic air from Maritime Polar air. The position of the front at 6-hour intervals is shown in figure 2.

Among many interesting and informative letters received is the following from Cedric A. Barnes, Chief Air way Communicator, Black Hills Airport, Spearfish, S. Dak.

JANUARY 22, 1943.

I live at St. Onge, about 5 miles north and 3 miles east of the station. When I left, the temperature was between 5° and 10° below zero F., which was expected. About half way south, the windshield on the car frosted so suddenly and so heavily that I was well toward the ditch before I could get stopped. When I got out to clean the windshield of the car, it felt like a warm spring day with about 15 miles of wind from the SW. When I reached the station, about 8:15 a. m. the temperature was 45° F., with WSW 44-mile wind, and rain showers. Having no extra thermometer at the station, I took the operator who had just gone off watch, and returned to St. Onge, where I had a glass, centigrade, chemical thermometer,

which I knew was reasonably accurate. We left St. Onge about 9:15 a. m. The indicated temperature was then -18.0° C. In the next 2 miles the temperature rose to -16.1° C. In the next ¼ mile it raised to -13.0° C. This distance is in a creek bottom from 20 to 50 feet below the surrounding land. In the next 200 to 300 feet, the windshield frosted as it had before. We got out to clean it. From tracks in the snow we found that *we were only 10 feet from where I had stopped an hour before!* The thermometer read plus 9.8 C.° We had come up about 20 feet out of the creek bottom. A little further south and a little higher up we looked back. There was a line of white, thick stratus following the creek, the tops from 100 to 150 feet above the surface, with heavy snow blowing from the northeast. The wind was about 30 mile SW where we were, ¼ mile away.

L. M. Jones, Weather Bureau inspector traveling in the vicinity at the time, writes:

On my way to Rapid City a day or two later I overheard discussions and comments about this strange phenomenon at nearly every stop I made. The changes took place over a rather wide area, but were much more pronounced at some places than at others. While some of the most pronounced and rapid changes were experienced at Rapid City, there was perhaps greater contrast in temperature at Lead and Deadwood. There is such a short distance between these two towns (2 to 3 miles between business sections) that they seem like one town, except that Deadwood lies in the canyon and Lead is built at a higher elevation. At one time it was reported that the temperature at Lead was 52° while at the same time it was -16° at Deadwood. Several plateglass windows were cracked in the downtown section of Lead because of the rapid rise in temperature.

The official in charge at Rapid City, Harley N. Johnson, has furnished the Central Office with a photostatic copy of an unofficial Bristol-type thermograph record made at Rapid City during the week ending Monday, January 25, 1943, and considered to be entirely reliable (see figure 2). The record includes the phenomenal temperature fluctuations which took place in that area on Friday, January 22, 1943.

Following are readings taken from the record, together with temperatures observed at the regular 6-hourly observations at the airport:

The city area is much more favorably situated at the very foot of the Black Hills to receive blasts of descending air from the west or southwest. From the reproduced thermograph record it can be seen that sudden puffs of warm air reached the city at frequent intervals during the morning. After 12:30 p. m., the warm air completely enveloped the city area and continued throughout the afternoon.

Time (MWT)	Bristol recorder (city)		Time (MWT)	Rapid City Airport (8 miles northeast of the city)	
	Temperature	Remarks and change		Temperature	Remarks
5:30 a. m.-----	°F. -5	Slow rise for 4 hours.			
9:20 a. m.-----	5	+10°.	6:30 a. m.-----	°F. -8	Airport continued in the cold air until afternoon. Some time during the afternoon, the temperature reached 50°.
9:40 a. m.-----	54	+49°.	12:30 p. m.-----	3	
10:30 a. m.-----	11	-43°.	6:30 p. m.-----	6	
10:45 a. m.-----	55	+44°.			
11:30 a. m.-----	10	-45°.			
11:50 a. m.-----	34	+24°.			
12:15 p. m.-----	16	-18°.			
12:40 p. m.-----	56	+40°, stationary all afternoon.			
4:00 p. m.-----	56				
5:00 p. m.-----	12	-42°, slow, steady fall.			
7:30 p. m.-----	5	-7.			

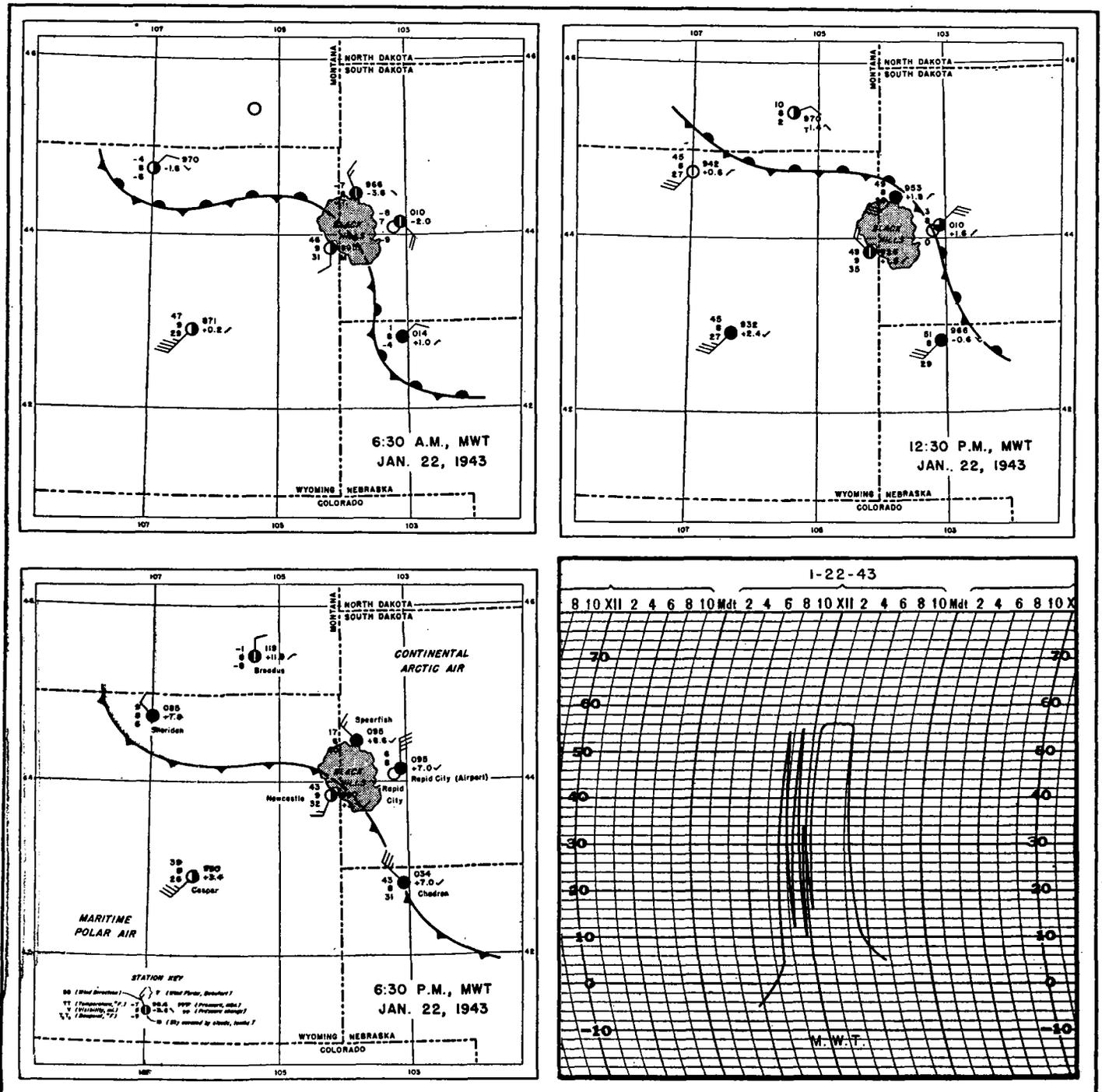


FIGURE 2.—Upper left, upper right, and lower left, position of the front on January 22, 1943, at 8-hour intervals; lower right, Bristol-type thermogram at Rapid City during the week of January 19-25, inclusive, showing the phenomenal fluctuations on January 22.