RECORD SNOWFALL OF APRIL 14–15, 1921, AT SILVER LAKE, COLORADO

J. L. H. PAULHUS

U. S. Weather Bureau, Washington, D. C.

[Manuscript received January 27, 1953]

ABSTRACT

A snowfall of 87 inches in 27½ hours on April 14–15, 1921, was reported at Silver Lake, Colo. This snowfall, if correctly measured, exceeds others generally accepted as being record values for the United States. Consequently it is important to determine the reliability of the observation. There is no evidence to indicate that the measurement was any less reliable than that of other heavy snowfalls, and it appears that a snowfall of this magnitude is meteorologically possible. The Silver Lake snowfall is therefore acceptable as the highest known recorded value for the United States.

INTRODUCTION

Although the meteorologist and hydrologist are generally interested in the water equivalent of a snowfall rather than in the snow depth, there are many, including the general public, highway and street maintenance engineers, etc., who are very much interested in the depth. Consequently, snowfalls of unusual depth receive a great deal of publicity in the press and in some meteorological publications.

While no large-scale survey of depths of snowfall throughout the United States has ever been made, several outstanding values printed in a few meteorological publications have been accepted, at least by inference, as record values. Thus, the 60-inch snowfall at Giant Forest, Calif., on January 18–19, 1933, has been accepted by many as being the maximum of record in the United States for a 24-hour period. Similarly, the Giant Forest snowfall of 87 inches on February 12–14, 1926, and the Vanceboro, Maine, snowfall of 96 inches on December 6–10, 1933, have been accepted as record values for 3 and 4 days, respectively.

Recently, attention was called to the reported snowfall of 87 inches in 27½ hours at Silver Lake, Colo., on April 14–15, 1921. In the same storm, Fry's Ranch, Colo., reported 62 inches in 22 hours. Both measurements exceed the Giant Forest record value for 24 hours. Prorated for 22- and 24-hour periods, the Silver Lake measurement yields 70 and 76 inches, respectively, indicating without doubt an outstanding snowfall rate for those durations. The 87-inch measurement actually equaled the amount generally accepted as being the record value for three days that was observed at Giant Forest on February 12–14, 1926.

The Silver Lake snowfall continued beyond the 27½-hour period to establish new records. During the 32½-hour period of more or less continuous snowfall from 1430 MST, April 14 to 2300 MST, April 15, 95 inches was reported. If the small snowfalls of April 12 and 13 are added to this amount, a record value of 100 inches in a total elapsed time (including breaks) of 85 hours is obtained. This value exceeds the generally accepted previous record of 96 inches in four days at Vanceboro, Maine, on December 6–10, 1933. The records established by the Silver Lake snowfall are as follows:

Duration (hours)	*Depth (inches)*	*Date*
24	[1] 76	Apr. 14–15, 1921
27½	87	Do.
[2] 32½	95	Do.
48	95	Apr. 13–15, 1921
72	98	Apr. 12–15, 1921
85	100	Do.

[1] Prorated.

[2] Longest period of apparently continuous snow.

EVALUATION OF RELIABILITY

Because of the new records established, the Silver Lake measurement was examined very thoroughly before being accepted. High winds on April 15 undoubtedly drifted the snow and made it difficult to choose a site having a representative depth. However, there is no evidence to indicate that the Silver Lake observer used less care in obtaining a representative snow depth than did the observers who measured the previous record snowfalls at Giant Forest and Vanceboro, which were also evidently accompanied by relatively high winds. Consequently, the Silver Lake measurement cannot be discarded on this basis.

The water equivalent of the major portion of the snowfall, the 87 inches which fell in the 27½ hours between 1430 MST, April 14, and 1800 MST, April 15, was reported as 5.60 inches, making the snow density (ratio of water equivalent to snow depth) 0.06. This low value of snow density is not unusual at the 10,000-ft. level (Silver Lake elevation 10,220 ft.), but does appear low for a snow layer more than 7 feet deep. However, of 16 stations above the 7,000-ft. level in the area reporting snowfall in the same storm, eleven reported snow densities under 0.10 and none over 0.13. Table 1, which lists the stations in decreasing order of elevation, shows that the water equivalent at Silver Lake compares favorably with that at other stations in the vicinity.

TABLE 1.—*Snow density at stations above the 7,000-ft. level in Apr. 14–15, 1921, Colorado storm*

Station	Elevation (ft.)	Snow depth (in.)	Water equiv. (in.)	Snow density
Lake Moraine	10,265	33	2.33	0.07
Silver Lake	10,220	95	6.40	.07
Victor	10,100	15	1.23	.08
La Veta Pass	9,242	48	1.87	.04
Longs Peak	9,000	50	4.93	.10
Hartsell	8,900	17	1.34	.08
Fremont Experiment Station	8,850	49	6.28	.13
Dillon	8,800	24	1.92	.08
Fraser	8,560	49	3.18	.06
Georgetown	8,550	52	3.77	.07
Elk Creek	8,440	37	2.52	.07
Grand Lake	8,380	48	3.00	.06
Estes Park	8,000	48	3.86	.08
Idaho Springs	7,543	48	4.90	.10
Fry's Ranch	7,500	62	7.65	.12
Monument	7,200	37	4.05	.11

Also, the Silver Lake storm precipitation is consistent with that of the stations in the region as shown by the total-storm isohyetal map of figure 1 for the 36-hour period from 1100 MST, April 14 to 2300 MST, April 15, which embraces practically all the heavy precipitation for the entire storm.

For further confirmation of the Silver Lake precipitation, the amounts shown on the map of figure 1 were expressed in terms of percentage of the mean annual precipitation at the respective stations and plotted on the map of figure 2. This map indicates that the water equivalent at Silver Lake could be higher and still agree with that of other stations.

There is little doubt as to the meteorological possibility of the prorated water equivalent of 4.90 inches in 24 hours. Denver, about 40 miles southeast of Silver Lake, reported the following air and dewpoint temperatures and winds on April 14 and 15:

	6 AM	*Noon*	*6 PM*
Apr. 14	41°–34°	52°–34°	44°–40°
	W2	N9	E15
Apr. 15	36°–35°	30°–29°	28°–26°
	NE20	N33	NW24

Taking 32° F. as a conservative estimate of the mean dewpoint from noon to noon at Denver (elev. 5,283 ft.) and assuming a pseudo-adiabatic saturated atmosphere with sea level at 1000 mb., a mean dewpoint of 15° F. is obtained for the 24-hour period at Silver Lake (elev. 10,220 ft.), which is only about 3 miles east of the Continental Divide. The mean east-west slope of the area in the vicinity of the station is about 2,500 ft. in 5 miles, or roughly 10 percent. The vertical component of a horizontal onslope wind of 30 m. p. h., another conservative estimate for the 10,000-ft. level in a storm situation, is 3 m. p. h., or 1.3 m. p. s.

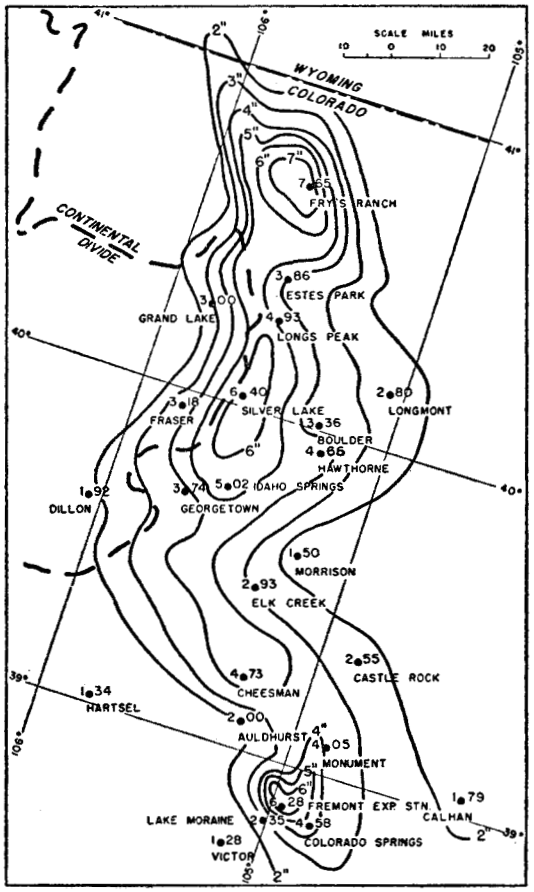

FIGURE 1.—Total-storm isohyetal map for 36 hours from 1100 MST, April 14 to 2300 MST, April 15, 1921.

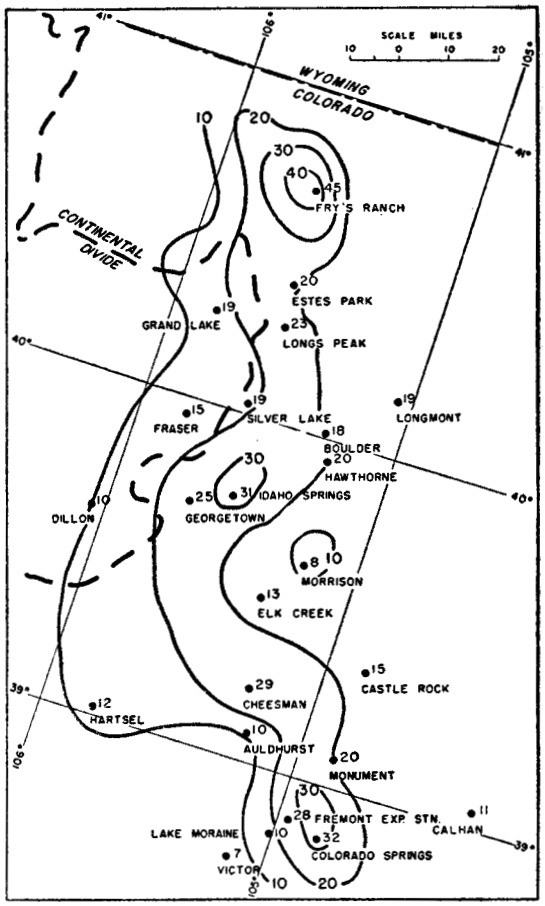

FIGURE 2.—Isopleths of total-storm precipitation of figure 1 expressed in percentage of mean annual precipitation.

Showalter's formula [1] for computing precipitation rates from a column of pseudo-adiabatically ascending air is

$$I=\frac{V_{z_0}\rho_0(x_0-x_1)}{7} \quad (1)$$

where I is the precipitation rate (in./hr.), V_z is the vertical speed (m./s.), ρ_0 is the air density (kg./m.^{3}), and x is the mixing ratio (g./kg.), the subscripts 0 and 1 referring to the base and top of the air column, respectively. For a column with base at 10,220 ft. and top at 20,000 ft. and the preceding assumed conditions of wind, temperature, and humidity, equation (1) yields

$$I=\frac{1.3\times 0.898(2.54-0.38)}{7}=0.36 \text{ in./hr.} \quad (2)$$

or 8.64 inches in 24 hours, which is about 176 percent of the amount estimated to have fallen. These computations indicate the 24-hour 76-inch snowfall is theoretically possible under the assumed conditions even if the snow density were as high as 0.11.

Also, it should be noted that Brooks [2] once roughly estimated that the maximum possible 24-hour fall of snow with density of 0.10 under normal packing conditions would be approximately 6 feet. Since the density of the snow at Silver Lake was appreciably less than 0.10, the prorated 76-inch 24-hour snowfall appears to be meteorologically possible.

The storm of April 14–16, 1921 was outstanding for the region. Thunder was reported at several widely scattered stations, indicating widespread convective activity. Fremont Experimental Station reported, "Heaviest snow of record on the 14th and 15th and only one ever recorded as breaking many trees." Referring to Denver, the Denver Post reported that, with a total snowfall of 11 inches and precipitation of 1.73 inches (part of which was rain), the April 14–15 storm was the second worst April blizzard since 1885. Snow drifted to a depth of 7 feet in many parts of the city. The Moffat road was tied up with drifting snow 8 feet deep just west of Corona. The storm was the worst in 5 years at Colorado Springs, where 19 inches of snow were reported. Splintered telephone and telegraph poles were strewn all the way from Denver to Colorado Springs.

CONCLUSION

The above considerations lead to the conclusion that the Silver Lake measurement is reasonable. There is no evidence to indicate that it was less accurate than the measurement of the snowfalls that until now have been accepted as record values, which, incidentally, have been exceeded several times if estimates by Weather Bureau personnel experienced in mountain snowfall are accepted as reliable. For these reasons, the Silver Lake snowfall is being accepted as providing the highest known rates in the United States for durations to 4 days.

ACKNOWLEDGMENTS

The assistance of L. H. Seamon, H. A. Scott, and V. S. Murino in collecting and analyzing portions of the data and preparing the maps is gratefully acknowledged. Credit for calling the attention of Central Office to the Silver Lake snowfall belongs to A. W. Cook, Meteorologist in Charge of the Weather Bureau Office at Denver. M. A. Kohler, A. L. Shands, C. K. Vestal, and W. T. Wilson reviewed the manuscript.

REFERENCES

1. A. K. Showalter, "Rates of Precipitation from Pseudo-Adiabatically Ascending Air," *Monthly Weather Review* vol. 72, No. 1, Jan. 1944, p. 1.
2. C. F. Brooks, "On Maximum Snowfalls," *Bulletin of the American Meteorological Society*, vol. 19, No. 2, February 1938, p. 87.

CORRESPONDENCE

REMARKS ON "ON THUNDERSTORM FORECASTING IN THE CENTRAL UNITED STATES"

ALBERT L. FORST

Short Range Forecast Development Section, U. S. Weather Bureau, Washington, D. C.

April 10, 1953

The technique for forecasting thunderstorms at Chicago described by Means (MONTHLY WEATHER REVIEW, vol. 80, No. 10, 1952, pp. 165–189) is not dependent upon a rigid geographical reference frame for the data determining the forecast, and therefore it is in order that an evaluation be made of its effectiveness at other stations in the central United States. For this purpose, forecasts for each day of June, July, and August, 1952 were made for the following nine stations in addition to Chicago itself: St. Cloud, Minn. (STC), North Platte, Nebr. (LBF), Dodge City, Kans. (DDC), Omaha, Nebr. (OMA), Columbia, Mo. (CBI), Dayton, Ohio (DAY), Oklahoma City, Okla. (OKC), Little Rock, Ark. (LIT), and Nashville, Tenn. (BNA). Results strongly suggest that local forecasters, particularly in the North Central States, may benefit from studying the article and putting the technique into