

## DEATH VALLEY—THE HOTTEST KNOWN REGION.

By ANDREW H. PALMER, Meteorologist.

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## SYNOPSIS.

Ten years of record obtained at the United States Weather Bureau's substation at Greenland Ranch, in Death Valley, Calif., indicate that this is the hottest region in the United States, and, so far as extreme maximum temperatures are concerned, the hottest known region on earth. The temperature of 134° F., recorded on July 10, 1913, is believed by meteorologists to be the highest natural air temperature ever recorded with a tested standard thermometer exposed in the shade under approved conditions. High temperatures are common throughout the year, but the highest occur during midsummer. Precipitation is extremely light, the normal annual precipitation being less than 2 inches. Evaporation is excessive, as the relative humidity is extremely low most of the time, and especially during the hot spells of summer. White people find the midsummer heat most trying; even the Indians go up to the Panamint Range during July and August. The weather station maintained at Greenland Ranch in cooperation with the Pacific Coast Borax Co. is unique in many ways.

*Desert regions of the United States.*—Textbooks in geography used in the public schools a generation ago contained maps on which the legend "Great American Desert" covered all the region between the Missouri River and the Sierra Nevada-Cascade Mountain Range. As a matter of fact, the only true and extensive desert regions of the United States lie in southeastern California, southern Nevada, and western Arizona. They embrace an area of about 570,000 square miles. Among the most conspicuous and typical wastes are the Colorado Desert, the Mojave Desert, and Death Valley, all of which are in California.

Contrary to a very general impression, the desert regions of the United States are not all level wastes of sand. Included within these regions are lofty mountain ranges, deep and gloomy canyons, sand hills, pinnacles, "needles," level plains stretching to the horizon, and depressions many feet below sea level. Throughout these regions the characteristic feature is little or no rainfall. Consequently there are no streams, except a few like the Colorado River, which has its origin in mountain snows hundreds of miles away. There are no lakes, except one or two like Owens Lake, a shallow body of salt water which is rapidly evaporating. Dry lake beds indicate that water may once have been more abundant in these regions than it is now.

*Death Valley.*—Death Valley is situated in southeastern California, near the Nevada boundary. It extends from north to south through a distance of about 100 miles, and lies between high mountain ranges. The width varies from 2 to 8 miles. It is the deepest depression in the United States, though only about 100 miles southeast of Mount Whitney, elevation 14,501 feet, the highest point in the United States. The lowest point of Death Valley is not definitely known—one estimate places it at 280 feet, and another at 337 feet below sea level. Its sides rise precipitously from the valley floor, which is generally level. The center of the valley is about 260 miles by road from Los Angeles.

Historically, Death Valley has been intimately related to the pioneer events of the West. This is due to the fact that adventurous pioneers sometimes used it as a means of entry into California when they came overland from the East, before the days of the railroads. But these early adventurers were unacquainted with such regions, and disasters were frequent as a result.

*Greenland Ranch.*—Until recently the only permanent inhabitants of Death Valley were a few of the Pinte, Shoshone, and Mojave Indian tribes, whose day of total

extermination is near. The first permanent white settlement was established about 40 years ago by the Pacific Coast Borax Co., of 20-mule team fame. A tract of about 65 acres situated on the eastern edge of Death Valley was placed under irrigation. The water supply was a difficult problem to solve, in view of the fact that the normal annual precipitation is less than 2 inches. Not infrequently less than 1 inch of rain falls in a year. Successful agriculture can not be maintained on less than 15 or 20 inches of precipitation annually without the aid of irrigation. A group of springs known as Warm Springs was found in the Funeral Mountains near by, and these serve as the source of irrigation water supply;

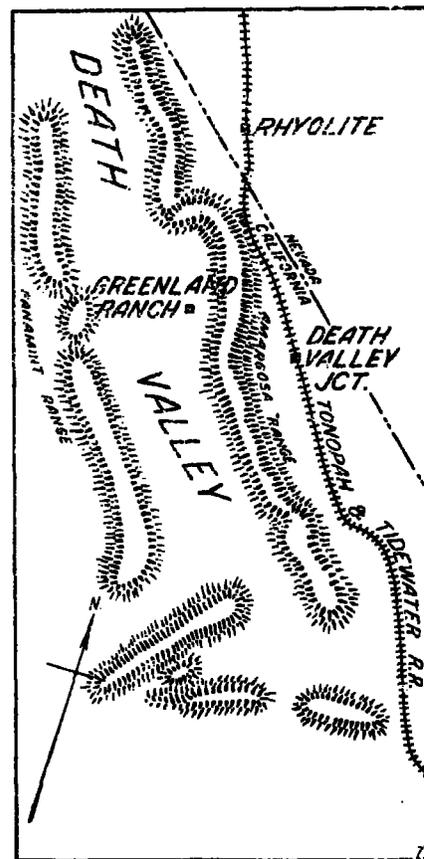


FIG. 3.—Map of Death Valley, Calif.

the temperature of the water issuing from these springs is about 100° F.

This ranch was originally called Furnace Creek Ranch, because it was situated near a depression where the air suggested a blast from a heated furnace. In the latter depression water may be found throughout the year in what is known as Furnace Creek, which is fed by about 100 springs. The flow of water is about 80 miner's inches (2 c. f. s.), a quantity sufficient to irrigate 70 acres.

After the ranch was successfully established its name was changed to Greenland Ranch because of the marked contrast between the green alfalfa fields and the eternally brown desert surrounding. Four crops of alfalfa are gathered each year. The principal product of the ranch is dressed meat; however, experiments are being made in

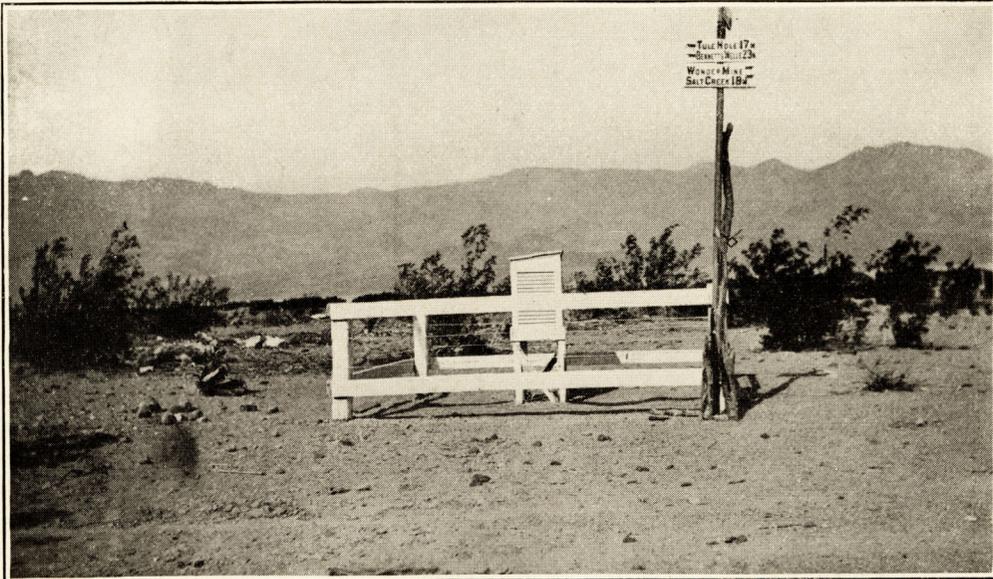


FIG. 1.—U. S. Weather Bureau instrument shelter at Greenland Ranch, Death Valley, Calif., 178 feet below sea level.

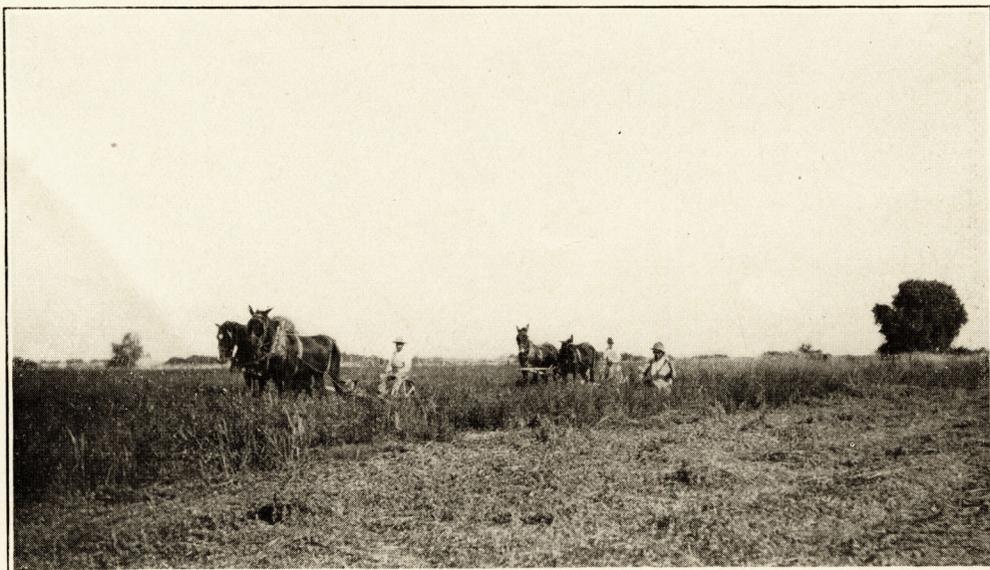


FIG. 2.—Cutting alfalfa on Greenland Ranch in April.

raising poultry, and in growing vegetables, dates, citrus and deciduous fruits. The ranch was established and is maintained for the purpose of serving as the source of food supply to miners at work in the adjacent mountains.

Death Valley is perhaps the most maligned natural attraction in North America. For the winter automobile tourist its scenic possibilities are vast. This famous or infamous valley is almost as brilliantly colored as is the Grand Canyon of the Colorado.

The Automobile Club of southern California is erecting 1,200 metal-enameled signs on the desert roads and 250 signs of waterholes. The California State legislature recently appropriated \$5,000 for the installation of signs indicating the positions of springs and waterholes in the desert portions of the State. In 1916 Congress authorized the Secretary of the Interior "to discover, develop, protect and render more accessible for the benefit of the general public, springs, streams and waterholes on desert and public lands of the United

*High temperatures.*—Nearly every summer during the past few years the highest natural air temperatures recorded in the United States by means of tested thermometers under approved methods of exposure have been those for Greenland Ranch. The following is a list of the extreme maximum temperatures recorded at this station during the past 11 summers:

TABLE 1.—Extreme maximum temperatures recorded at Greenland Ranch.

	° F.		° F.
1911.....	122	1917.....	125
1912.....	120	1918.....	125
1913.....	134	1919.....	123
1914.....	126	1920.....	125
1915.....	124	1921.....	123
1916.....	127		

The extreme maximum temperature of 134° recorded on July 10, 1913, is the highest natural-air temperature ever recorded on the earth's surface by means of a

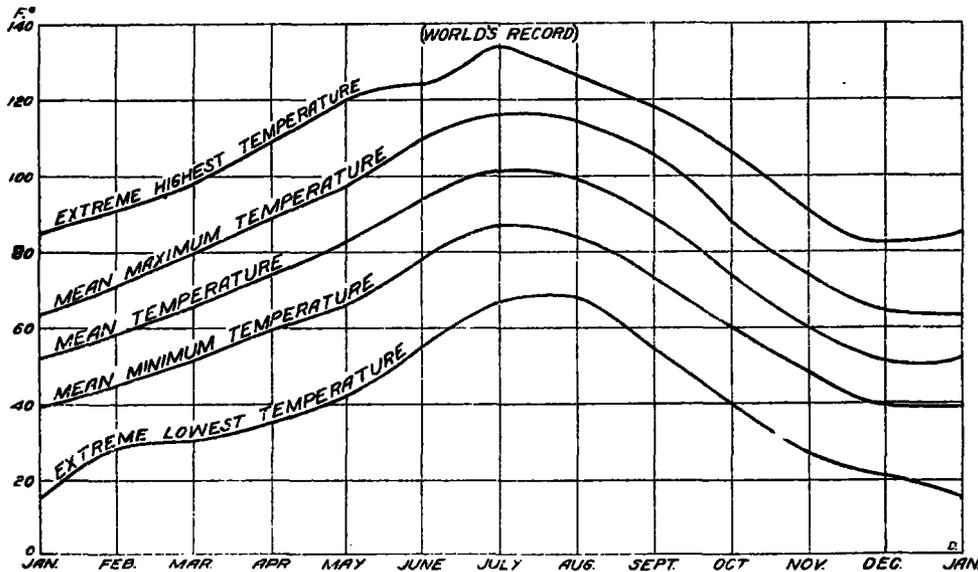


FIG. 4.—Average and extreme temperatures recorded at Greenland Ranch.

States and in connection therewith to erect and maintain suitable and durable monuments and signboards at proper places and intervals along and near the accustomed lines of travel and over the general area of said desert lands, containing information and directions as to the location and nature of said springs, streams and waterholes, to the end that the same may be readily traced and found; also to provide convenient and ready means, apparatus and appliances by which water may be brought to the earth's surface at said waterholes for the use of such persons; also to prepare and distribute suitable maps, reports and general information relative to said springs and waterholes and their specific location."

In 1911 the United States Weather Bureau established a weather station on Greenland Ranch in cooperation with the company which operates the ranch. Carefully tested maximum and minimum thermometers together with a standard 8-inch rain-gage and a regulation instrument shelter were lent by the Weather Bureau and were installed under approved conditions. The white foreman of the ranch was appointed cooperative observer.

More than 10 years of unbroken weather records at this unique station are now on file. They are among the most interesting weather records in existence. The following are some of the noteworthy features:

tested standard thermometer exposed in a standard ventilated instrument shelter. By way of explanation it should be stated that the instrument shelter used at this station is the same as those used at several thousand other weather stations maintained by the Weather Bureau throughout the United States. It has louvered sides, a double roof, tight floor, is painted white, faces north, and its floor is about 4 feet from the ground. It is about 50 feet distant from the nearest high object. There is a free circulation of the air through the louvered sides, the double roof cuts off the heating effect of the sunshine, and the tight floor shuts out reflected and radiated heat from the ground.

There is no authoritative and reliable weather record in existence which contains a higher natural-air temperature than the one here recorded on July 10, 1913, namely, 134°. In the *Encyclopedia Britannica* (9th ed., vol. 30, p. 810) it is stated that a temperature of 167° was recorded in the Desert of Gobi, in Mongolia. This unbelievable temperature has never been accepted by meteorologists as a trustworthy record, however.

At Greenland Ranch, temperatures of 100° or higher occur almost daily during June, July, and August. The hottest month on record is that of July, 1917, when the mean temperature was 107.2°.

TABLE 2.—Temperature data, Greenland Ranch, Death Valley, California, 1911–1921.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Mean temperature.....	52.5	58.1	65.4	71.2	81.7	94.2	101.2	99.0	89.2	74.1	60.3	51.5	75.0
Mean maximum temperature.....	63.8	71.1	79.6	89.0	97.1	110.5	115.7	114.0	105.2	87.9	74.2	61.3	89.4
Mean minimum temperature.....	39.6	45.0	51.2	59.3	66.3	78.0	86.6	84.0	73.3	60.3	48.2	39.6	61.0
Extreme highest temperature.....	85	91	98	109	120	124	134	126	118	106	91	82	134
Extreme lowest temperature.....	15	28	30	35	42	55	67	68	54	40	27	21	15

A hot spell which has perhaps not been equaled anywhere else on the earth's surface, so far as reliable weather records are available, is the following, as recorded at Greenland Ranch:

TABLE 3.—Temperatures at Greenland Ranch during hot spell of July, 1913.

	1913	Maximum temperature.	Minimum temperature.
July 8.....		128	90
9.....		129	93
10.....		134	85
11.....		129	85
12.....		130	85
13.....		131	85
14.....		127	86

The excessive heat of Death Valley is easily explained. Situated well to the south of the summer storm tracks, there are no alternating weather conditions such as characterize the passage of HIGHS and LOWS. It is a typical solar climate, solar insolation being the chief control. During the long summer days the air is excessively heated by the high sun, as there is too little moisture in the air to permit the formation of clouds. Excessive heating causes ascending currents, and air slips down the sides of the adjacent mountains to take the place of air rising over the valley floor. The air which slips down the mountain slopes is heated dynamically as it descends. The winds are local and convectional. The desert sand, gravel, rocks, and salt are so highly heated during the long days that they do not have opportunity to cool through radiation during the short nights. The cumulative effects of these various agencies result in the temperatures quoted.

*Rainfall and humidity.*—The precipitation record during the past 10 years at Greenland Ranch is not less interesting than the temperature record. Not infrequently six consecutive months have passed without measurable rain. During 1917 the total rainfall was less than one-half inch. During 1919 it was slightly over one-half inch. The average annual precipitation is less than 2 inches. However, "it never rains but it pours." Rainfall is usually of short duration, but it rains hard when it rains. Snowfall of measurable depth is unknown. Gales and dust storms are of frequent occurrence. There are few days when the sun does not shine. In fact, there is some sunshine practically every day in the year.

TABLE 4.—Precipitation at Greenland Ranch, Death Valley, 1911–1921 (inches).

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1911.....						0	0	0	1.40	0	0	0	.....
1912.....	0		1.10	T	T	0	0.10	0	0	0.20	0	0	1.40
1913.....	0.01	1.90	.10	0	0.01	0	.60	0.01	.30	0	1.61	0	4.54
1914.....	.87	.21	0	.12	0	0.05	0	0	0	0	0	0.60	1.65
1915.....	1.10	.02	.02	.08	.02	0	.07	0	0	0	0	0	1.81
1916.....	1.51	.20	.02	0	.40	0	0	0	0	.10	0	0	2.23
1917.....	.01	0	0	.01	.30	0	.06	0	.01	0	0	0	0.43
1918.....	0	.30	.75	0	T	0	0	.01	0	.01	0	0	1.12
1919.....	0	0	.01	0	0	0	.01	0	0	0	.20	.80	0.52
1920.....	.60	1.00	.30	0	.10	.60	0	.10	0	.20	0	0	2.90
1921.....	.40	0	0	0	0	0	0	0	0	0	0	0	.....
Mean.....	.43	.36	.23	.03	.08	.06	.08	.01	.16	.06	.18	.09	1.79

T. means trace.

Though no long-continued records of humidity have been kept, occasional determinations show that during the hot summer months the relative humidity may fall as low as 5 per cent. Many curious facts result from this low relative humidity. A large portion of the irrigation water is lost through evaporation before it reaches the alfalfa fields. A 4-inch iron pipe 1 mile long was installed between Texas Springs and the ranch in order to provide clean drinking water. While passing through the pipe this water is highly heated during the daytime, but its temperature is subsequently reduced to about 70° even in the hottest weather by being confined in the common desert canteen which is covered with burlap, which is kept moist. The rapid evaporation of water from the burlap covering is sufficient to cool the water contained in the canteen.

*Life in the desert.*—Because of extreme climatic conditions, the native flora and fauna of Death Valley are scanty. The former include innumerable varieties of the cactus family, such as prickly-pear, cholla, Spanish dagger, sagebrush, mesquite, greasewood, and other plants indigenous to arid surroundings where a water supply is meager. A catalogue of the fauna is almost as brief, and includes only the jack-rabbit, horned toad, scorpion, lizard, rattlesnake, kangaroo cat, desert turtle, fox, mountain sheep, badger, lynx, and other wildcats. Birds of many varieties are numerous, as migrating flocks often stop at the ranch for food and drink, as well as to rest. The common insects are abundant. The dry desert has been an impenetrable barrier to the natural migration of various plants. However, within the past few years Bermuda grass, "devil grass," and Johnson grass have secured an entry, and now give trouble as in other regions.

Not being accustomed to persistent high temperatures and moistureless air, white men do not remain long in Death Valley. While sunstroke is unknown there, several people have perished from heat, thirst, or exhaustion. During summer most of the work is done at dawn or shortly after sunset, as the blazing sun renders work in the middle of the day impracticable, and even dangerous. Mr. O. A. Denton, the white foreman who remained longest, namely, eight years, was a mechanical genius in providing a semblance of comfort in hot weather. During the summer he made his bed in front of a revolving fan, after wetting his blanket and after sprinkling the floor with water. The fan was driven by an overshot water wheel.

Like the St. Bernard hospice in the high Alps of Switzerland, Greenland Ranch also serves as a traveler's relief station. The immense barren tracts of the Southwest have no natural oases similar to those of the Great Sahara of Africa. However, they contain, separated by long distances one from the other, small springs and waterholes which lie concealed by surrounding scant bushgrowth, reedy vegetation, and quiete or desert grass. The chief evidences of human occupation are the long, long roads which lead from one watering place to another. Greenland Ranch has saved the life of many a lost traveler or prospector who has staggered within its borders with parched throat and speechless swollen tongue. At the rear of the ranch there are four mounds—graves of those who have perished of thirst or heat before they were able to reach the ranch.

Blessed with abundant precipitation, residents of the eastern United States little appreciate the value of water. Until one has seen the desert portions of the Southwest he can not fully understand the significance of generous rainfall. In the West water is wealth. With the aid of irrigation, desert portions of Arizona and California have

been made "to blossom as the rose." Marvellous transformations have been enacted in the Imperial Valley of California, and in the Salt River Valley of Arizona. But because of excessive heat and the salt and alkali in the soil it would be a much greater miracle to transform Death Valley into an agricultural region.

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BIBLIOGRAPHY.

"Notes on the Climate and Meteorology of Death Valley, California," by Mark Harrington; Washington; 1892; 50 pp; *Weather Bureau Bulletin 1*.  
 "The Hottest Region in the United States," by G. H. Willson; *Mo. WEATHER REV.*, 43: June, 1915; pp. 278-280, and 341.  
 "The Great Deserts of California and Nevada," by H. O. Collins; *Bulletin of the Southern California Academy of Sciences*, vol. 18, p. 1, pp. 29-36, 1919.  
 "Routes to Desert Watering Places in the Salton Sea Region, California," *Water-Supply Paper 490-A, U. S. Geological Survey*, by J. S. Brown; 86 pp.; 7 plates; 1919.  
 "Routes to Desert Watering Places in the Mojave Desert Region, California," *Water-Supply Paper 490-B, U. S. Geological Survey*, by David G. Thompson; 183 pp.; 15 plates; 1921.

WEATHER RECORDS AT LOOKOUT STATIONS IN NORTHERN IDAHO.

By J. A. LARSEN, Forest Examiner.

[Priest River Forest Experiment Station, 1920.]

Records which furnish information regarding weather conditions on mountains have always been of interest to the public and to scientists. To the United States Forest Service these are of great use in constructing the ground work for better forest fire protection. Students of climate, botany, ecology, and animal life are always eager for such data.

The tables given below have been prepared from records of air temperature, relative humidity, and air movement at Forest Service fire lookouts in northern Idaho during the summer of 1919. The instruments used are standard maximum and minimum thermometers of the United States Weather Bureau pattern, the Robinson anemometers and sling psychrometers. The thermometer shelters were improvised from wooden boxes placed at regular height above the ground and oriented so that the instruments were shaded from the sun at all times. The instruments at the Experiment Station lookout were housed in a regular Weather Bureau shelter. The data for the lower stations with which the mountain records are compared are supplied by the United States Weather Bureau cooperative stations at Wallace, Kooskia, Spokane, and Priest River Forest Experiment Station.

The lookout points at which these records were taken are as follows:

Lookout.	National forest.	Elevation (feet above sea).	Observer.
Coolwater.....	Selway.....	6,930	Gerald Gill.
Monumental Buttes.....	St. Joe.....	6,979	Eugene Harpole.
Sunset.....	Coeur d'Alene.....	6,424	Paul Wiekward.
Mount Slicox.....	Cabinet.....	6,840	Louis F. Rosenthal.
Experiment Station.....	Kaniksu.....	6,000	G. W. Simmons.

The figures in Tables 1 and 2 represent fairly well the average air temperature conditions in northern Idaho during the warm and clear days which usually occur from the beginning of July until the middle of September.

TABLE 1.—Air temperature on lookouts and at low stations, summer, 1919 (° F.).

Lookouts and cooperative stations.	July.			August.			September.			Dates missing.
	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	Maximum.	Minimum.	Mean.	
Coolwater, elevation 6,930.	71.1	51.1	61.0	69.4	51.8	60.8	62.1	42.2	52.1	Sept. 21-30.
Kooskia, elevation 1,261.	92.8	50.1	71.4	86.2	51.3	68.8	71.9	40.8	56.4	
Monumental Buttes, elevation 6,979.	71.3	47.2	59.2	72.6	49.1	60.8	59.9	39.5	49.7	Sept. 18-30.
Wallace, elevation 2,770.	85.9	48.5	67.2	83.3	42.5	66.3	71.1	35.6	53.4	
Priest River Experiment Station lookout, elevation 6,000.	69.3	51.9	60.6	68.6	51.0	59.8	57.3	41.6	49.9	Aug. 5-12.
Priest River Experiment Station, elevation 2,300.	86.1	42.3	64.2	84.8	47.8	62.9	72.0	41.1	56.5	Sept. 20-30.

TABLE 2.—Diurnal march of air temperature on the mountain and at the valley station, August, 1919 (° F.).

Location and elevation.	A. M.						P. M.					
	2	4	6	8	10	Noon 12	2	4	6	8	10	12
Valley, 2,300.....	42.7	40.4	39.5	50.4	64.5	76.7	82.4	83.3	78.5	61.2	51.0	46.1
Mountain, 6,000.....	54.4	52.8	54.6	59.2	61.3	64.3	67.2	65.7	61.2	57.7	56.5	55.3

The data in Table 1 show that the maximum air temperatures are in every instance higher at the low than at the high stations; the differences vary from 10° to 17° and in one case is as great as 21°. The minimum temperatures are in every case lower in the valleys than on the mountains, but the differences are not as pronounced as in case of the maxima; they vary in most cases 2, 3 and 4° and are not above 10°. These inversions are no doubt due to the rise of the heated air from the valley land at night to higher levels and a simultaneous downward flow of cold air along the