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SOME ADDITIONAL FACTS ABOUT THE CLIMATE OF DEATH VALLEY, CALIF.

By ERNEST E. EKLUND

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Since the days of the pioneers when emigrants braved the heat and the parched and trackless wastes of Death Valley in their efforts to reach the Pacific coast, this spot has held romantic and historical interest and has furnished the background for many tales based upon the hardships of these pioneers and upon the many tragic scenes that have been enacted there.

Death Valley, one of the typical desert regions in the United States, is located in southeastern California near the Nevada boundary. It extends between high mountain ranges in a generally north-south direction a distance of some 100 miles and averages about 10 miles in width. More than 400 square miles are below sea level. The deepest depression in the United States, 276 feet below sea level, is found in Death Valley, although Mount Whitney, the highest point in the United States, 14,496 feet, is only 86 miles to the west-northwest.

A first-order station of the Weather Bureau was established in Death Valley on April 30, 1891, and continuous observations were made during the next 5 months. No further records were made there until June 1911, when a climatological station of the Weather Bureau was established through the cooperation of the Pacific Coast Borax Co. The station was established at Greenland Ranch, probably better known as Furnace Creek Ranch, a tract of about 70 acres under irrigation, situated on the eastern side of the valley, in latitude $36^{\circ}27'$ N. and longitude $116^{\circ}50'$ W., not far from the location of the former station. The elevation of the station is 178 feet below sea level, 98 feet higher than the lowest part of the valley. Observations have been continued since June 1911, so records for 20 years are available. Harrington (1) and others have discussed the climate of Death Valley, the later discussions being based on the records made at Greenland Ranch. The purpose of the present paper is to review these records and point out such salient facts as may be gleaned from the longer record now available.

Discussions of the climate of Death Valley have stressed the high temperatures recorded there, and without doubt temperature is the outstanding climatic feature. Maximum temperatures ranging from 125° F. to 130° F. have been recorded at a number of stations in the desert regions of southeastern California, but on July 10, 1913, an extreme maximum temperature of 134° F. was recorded at Greenland Ranch. This is the highest natural-air shade temperature ever recorded officially in California. The record has been investigated and has been accepted as reliable, and in this connection Mr. F. W. Corkill, mill superintendent of the Pacific Coast Borax Co., stated, "Regarding the temperature of 134° F., which was recorded (at Greenland Ranch) on July 10, 1913, I will state that this record should be considered correct." (2) He goes on to state that a man perished

that day and his chauffeur almost lost his life; a high wind prevailed but he did not recall whether it was from the north or south. This temperature of 134° F. was recognized as the highest authentic natural-air temperature that, to that time, had ever been recorded anywhere under approved conditions of equipment and exposure. Higher temperatures had been reported but were never accepted as trustworthy. Greenland Ranch thus had the distinction of holding the world's record for extreme high temperature, and this record stood until September 13, 1922, when a temperature of 136° F. was recorded at Azizia, Tripoli. This, according to the Meteorological Glossary of the British Meteorological Office, is the world's absolute extreme high temperature.

High temperatures are by no means rare in Death Valley, judging from the records of Greenland Ranch, and it seems probable that even higher temperatures occur on the floor of the Valley, 98 feet lower than Greenland Ranch, considering the probable cooling effect of irrigated land and green vegetation at Greenland Ranch and the greater effect of insolation at the lower elevation. Extreme maximum temperatures of 120° F. or higher have occurred at Greenland Ranch in every month from May to September, inclusive, and such temperatures have occurred there each year since the record began. In July 1929 the mean maximum temperature was 119.5° F.

Temperatures of 100° F. or higher have occurred each month from March to October, inclusive, and temperatures of 85° F. or higher have occurred during every month of the year. The average number of days with maximum temperature of 120° F. or higher in June is 4, in July, 10, and in August, 5. In July and August 1917 maximum temperatures of 120° F. or higher were recorded on 43 consecutive days and during the same summer maximum temperatures of 100° F. or higher were recorded on 113 consecutive days. This record was exceeded in 1916, however, when 126 consecutive days fell within this classification. Records of this sort are comprehensible when one considers the fact that maximum temperatures of 100° F. or higher are of almost daily occurrence in June, July, and August and that a monthly mean temperature of 106.8° F. occurred in July 1922.

High temperatures at Greenland Ranch have been emphasized so often that one might be led to believe that the weather is never cool there. This is by no means true. Temperatures of 32° F. or lower have been recorded from October to March, inclusive; and in December, January, and February 1928-29 there were 72 consecutive days on which the temperature fell to the freezing point or lower. The absolute extreme low temperature at Greenland Ranch, 15° F., occurred on January 8, 1913, and the minimum temperature on the following day was 16° F. When the observer made on his record sheet the

notation, "Unusually cold for Death Valley" he could not realize that he was writing about the absolute extreme minimum temperature in a record covering 20 years. The significance of his notation is supported by the fact that extreme low temperatures occurred at many places in California during that cold spell. In this connection, it is interesting to note that the highest temperature and the lowest temperature ever recorded at Greenland Ranch occurred in the same year and nearly 6 months apart. The lowest monthly mean minimum temperature ever recorded there was 24.5° F. in January 1929, and in January 1919 the monthly mean temperature was only 43.0° F. Thus Death Valley has a winter season when freezing weather frequently occurs.

The nights are comfortably cool as a rule from October to April, inclusive, when the minimum temperatures average less than 60° F. Minimum temperatures during midsummer are quite different. The mean minimum temperature in July is 87.6° F. Minimum temperatures of 90° F. or higher are not unusual in June, July, and August, and have been recorded occasionally in April, May, and September. Minimum temperatures of 100° F. or higher are not unknown. In August 1924 there were 12 consecutive nights (19th to 30th) when the temperature did not go lower than 100° F. The maximum temperature during this period was 124° F. In July and August 1929 there were 46 consecutive nights when the temperature did not go lower than 90° F.

In general, then, the summer months are uncomfortably hot and the winter months are comfortably cool, the hottest month being July with a mean temperature of 102.0° F. and the coolest January with a mean temperature of 51.4° F. The mean daily range in temperature varies from 27.6° F. in December to 33.2° F. in September. During the hottest months, July and August, the mean daily range in temperature is not quite so large as in the months immediately preceding and following, due no doubt to the inability of the ground to radiate during the night the store of heat that accumulates during the daytime. Daily ranges in temperature of 40° F. or more may be expected from March to November, inclusive, 38° F. in January and February, and 33° F. in December; but daily ranges of 50° F. or more have been recorded in practically all months, while on September 28, 1924, an extreme daily range of 67° F. was recorded, from 112° F. to 45° F.

In the foregoing a number of periods have been mentioned during which unusual temperatures were recorded at Greenland Ranch and it may be of interest to note the outstanding features of the temperatures during some of those periods, as follows:

HOT SPELL WITH EXTREME MAXIMUM TEMPERATURE 134° F.

Date	Maximum	Minimum	Mean	Range
1913				
July 4.....	119	77	98	42
July 5.....	126	73	100	53
July 6.....	125	89	107	36
July 7.....	127	89	108	38
July 8.....	128	90	109	38
July 9.....	129	93	111	36
July 10.....	134	85	110	49
July 11.....	129	85	107	44
July 12.....	130	85	108	45
July 13.....	131	85	108	46
July 14.....	127	86	106	41
July 15.....	119	86	102	33

43 CONSECUTIVE DAYS WITH MAXIMUM TEMPERATURE 120° F. OR HIGHER

Period	Temperature	Date
July 6 to Aug. 17, 1917.....	(Highest, 125..... (Lowest, 76.....)	July 12. Aug. 13 and 14.

72 CONSECUTIVE DAYS WITH MINIMUM TEMPERATURE 32° F. OR LOWER

Period	Temperature	Date
Dec. 2, 1928, to Feb 11, 1929.....	(Highest, 74..... (Lowest, 20.....)	Dec. 7. Jan. 22.

COLD SPELL WITH EXTREME MINIMUM TEMPERATURE 15° F.

Date	Maximum	Minimum	Mean	Range
1913				
Jan. 7.....	50	20	35	30
Jan. 8.....	50	15	32	35
Jan. 9.....	58	16	37	42

Comparative temperature data, as well as other data, based on the records made at Greenland Ranch from 1911 to 1930, inclusive, are presented in table 1, and some of the data are shown in graphic form in figure 1.

Although many persons have died, no doubt, on account of the heat in Death Valley, it is probable that by far the greater number of tragic deaths have been from thirst. Drinkable water is not obtained readily and to the unfortunate travelers in Death Valley rain would have been a godsend, but the records indicate that it would sometimes be a long while between drinks if dependence were placed upon the occurrence of rain in sufficient quantity to allay thirst. Recently the statement was made by one who should have been better informed that rain never falls in Death Valley because the water evaporates before it reaches the ground. To be sure the average precipitation is light but the situation is hardly as bad as this statement indicates. Several times in the last 20 years one could have visited Death Valley for 6 months or more at a time and, based on his own observations, could have said truthfully that no rain falls there. He could have spent the whole year of 1929 there without seeing even a drop of rain and had this stay included part of December 1928, and part of January 1930 the visitor would have witnessed 401 consecutive days on which no measurable precipitation occurred. This record for consecutive days without measurable precipitation has been exceeded at other stations in the deserts of southeastern California but nevertheless the average annual rainfall at Greenland Ranch, 1.38 inches, is less than that of any other California station. Rain is liable to fall at Greenland Ranch in any month of the year and there is no well-defined rainy season such as characterizes the climate of the Pacific coast in general. Rainfall of 0.01 inch or more in 24 hours occurs on the average only seven times a year and the frequency of rainfall is not much greater if immeasurable amounts, or traces, are also included. In January, February, and March, measurable rainfall occurs on the average 1 day each month while in practically all other months the average number of rainy days is considerably less than one half. The greatest number of rainy days in 1 year was in 1913 when measurable rainfall occurred on 16 days and the least in 1929 when no rain, not even a trace, was recorded. The greatest number of rainy days in any 1 month was 5 in March 1918, but the total monthly precipitation was only 0.75 inch. A daily rainfall of 1 inch or more has been recorded at Greenland Ranch only four times in nearly 20 years and the greatest amount ever recorded in 24 hours is 1.40 inches. This amount fell between 3 p.m. September 29 and 1 p.m. September 30, 1911, and the observer made the notation "Heaviest rain for several years." On November 9, 1923, however, precipitation of 1.40 inches was recorded when the observation was taken at 5 p.m. and the next

day the precipitation was recorded as 0.30 inch but the hours of beginning and ending are not given so it is possible that the total of 1.70 inches occurred within 24 hours. At any rate, this is the heaviest rain that ever occurred at Greenland Ranch on 2 consecutive days and it is also the greatest monthly precipitation of record with one exception. The heaviest monthly rainfall, 1.90 inches, occurred in February 1913. The wettest year was 1913 when 4.54 inches of rain fell and the driest was 1929 which was rainless. Comparative precipitation data are included in table 1.

Although rainfall is scanty in Death Valley, heavy precipitation occurs in the mountains on each side. These rains are frequently very local and, especially in summer, occur as the result of thunderstorms, but they produce torrents in the canyons that discharge into Death Valley. These torrents cause the combed appearance of

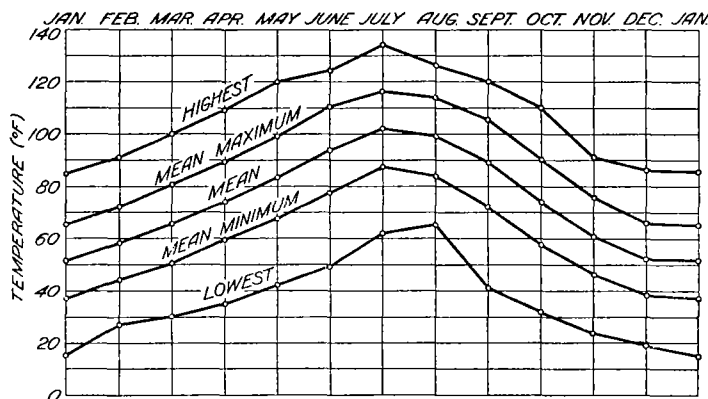


FIGURE 1.—Temperature graph of Greenland Ranch, Calif., for the period 1911-30, inclusive.

the surfaces over which they flow, and sometimes do considerable damage to roads. While thunderstorms are no doubt frequent in the mountains which rise on each side of Death Valley, they occur much less frequently within the valley. Clouds occur frequently, however, and cloudy days are by no means uncommon, although by far the larger number of days are recorded clear. Few partly cloudy days appear in the record, but the average number of clear days and the average number of cloudy days each month are included in the comparative data in table 1.

No systematic records of relative humidity have been made in Death Valley over any considerable period, but McAdie (3) states that hygrographic records covering one year indicate that while the relative humidity is low there are periods when a high percentage of saturation prevails and that apparently the relative humidity in Death Valley is not much lower than that of the Great Valley of California. Palmer (4) states that occasional determinations of relative humidity indicate values as low as 5 percent in summer. Lower relative humidities have been determined in connection with the fire-weather

observations in California and it therefore appears logical to assume that in Death Valley the relative humidity is sometimes considerably less than 5 percent on summer days. No doubt considerable variations in relative humidity would be found within the valley, depending upon the place of observation in relation to wind direction and source of moisture. Contrary perhaps to general belief, numerous sources of water such as springs, rivers and marshes, usually highly mineralized, exist in or adjacent to Death Valley (5).

Records of wind direction in Death Valley are not complete but they indicate that the prevailing winds are from the south and southeast, with northerly winds having the next greatest frequency. This is to be expected, considering that high mountain ranges lie to the east and west, but topographical influences such as canyons and ridges no doubt produce local deviations from the general north-south circulation of the valley. Available records indicate that the air in Death Valley is not stagnant but that it is in active motion usually and that high winds, sometimes accompanied by sandstorms, are not infrequent.

TABLE 1.—Comparative data, Greenland Ranch, Calif. (1911-30)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Mean temperature.....	51.4	58.1	65.5	74.6	83.4	94.0	102.0	98.9	88.9	74.0	60.6	52.0	75.3
Mean maximum temperature.....	64.9	72.3	80.4	89.6	99.1	110.4	116.4	113.7	105.5	90.3	75.6	65.8	90.3
Mean minimum temperature.....	36.9	43.9	50.6	59.5	67.7	77.6	87.6	84.0	72.3	57.7	46.3	38.2	60.2
Mean daily range.....	28.0	28.4	29.8	30.1	31.4	32.8	28.8	29.7	33.2	32.6	29.3	27.6	30.1
Greatest daily range.....	50	53	49	52	52	53	56	50	67	57	51	46	67
Highest temperature.....	85	91	100	109	120	124	134	126	120	110	91	86	134
Lowest temperature.....	15	27	30	35	42	49	62	65	41	32	24	19	15
Maximum 120° F. or higher.....	0	0	0	0	1	10	29	17	0	0	0	0	52
Maximum 100° F. or higher.....	0	0	0	8	29	30	31	31	30	16	0	0	159
Minimum not less than 100° F.....	0	0	0	0	1	10	12	16	3	0	0	0	17
Minimum not less than 90° F.....	0	0	0	4	4	15	31	28	9	0	0	0	81
Minimum 32° F. or lower.....	31	12	1	0	0	0	0	0	0	3	6	30	57
Average precipitation.....	0.31	0.27	0.15	0.01	0.05	0.03	0.06	0.04	0.09	0.08	0.18	0.08	1.38
Greatest total precipitation.....	1.51	1.90	1.10	0.28	0.40	0.60	0.60	0.40	1.40	0.35	1.70	0.60	4.54
Greatest amount in 24 hours.....	1.00	1.00	0.70	0.28	0.40	0.60	0.31	0.30	1.40	0.50	1.40	0.35	1.40
Greatest number of rainy days.....	4	4	5	2	1	1	3	3	2	1	4	2	16
Average number of clear days.....	23	20	25	24	24	26	25	27	27	26	24	23	204
Average number of cloudy days.....	8	8	6	6	7	4	6	4	3	5	6	8	71

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