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THE CLIMATE OF DEATH VALLEY

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Death Valley is world–famous for extremes in climate, particularly for its very high summer temperatures and overall lack of precipitation. While it is true that Death Valley may become excessively hot in the summer, the winters are frequently quite cool. Although annual average rainfall is less than 50mm at Furnace Creek on the valley floor (all data are from National Park Service records unless otherwise stated), there are places within a very short distance that receive far more rain and even frequent snow.

Since Death Valley is one of the hottest and driest places on earth, one would think that its climate is well–documented. Such is not the case. There are several brief published accounts of narrow aspects of Death Valley's climate (Court 1954; Ecklund 1933; Felton 1965; Geiger 1965; Harrington 1892; Hunt 1975). However, none of these represent a detailed summary of the climate and they are often buried in more general works. It is hoped that this work is a step in filling this void. Climatic data for Death Valley are incomplete both in terms of area and of time. Precipitation data have been collected from many parts of the region but at different times for different places and often only for certain months of the year. Only Furnace Creek (the National Park Service Visitor Center) has a complete record of any length (from 1911 to the present) and there are certain problems even with this record. Most of the data for Furnace Creek consist only of temperature and precipitation records. Evaporation data are incomplete and data on wind, humidity, sunlight and clouds are minimal. The temperature and precipitation records were collected at Furnace Creek (Greenland Ranch) and then the nearby Visitor Center from 1911 to 1934 and from 1961 to the present. From 1935 to 1960, the information was collected at Cow Creek, the ranger residence several kilometers northeast. In 1959 Furnace Creek re-

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ceived 47mm of precipitation while Cow Creek received 44mm. While such minor discrepancies will certainly not have much of an effect on the vegetation, landscape or human activities, it is a small but significant difference.

Variation in data between this paper and other publications is due to the length of time over which data were collected. The numbers averaged over the period of 1911 to 1965 will vary from the numbers averaged over the period from 1911 to 1992 because the first set of data does not include the figures derived from 1966 to 1992 which may have been either higher or lower than the average thus changing the overall mean. Ideally, all the numbers should represent averages from the first day records were kept until today. Obviously, this is not always possible.

Temperature

Temperature data of any reliability are available only for Furnace Creek. Daily ranges in January, the coldest month, are 3–18°C. July is the hottest month and the average daily range is 31–47°C. This makes Death Valley, in the summer, one of the world's most consistently hot places (see Table 1).

The lowest temperature ever recorded was –9°C and the highest ever was 57°C. Both of these records were set in 1913! That same year, Death Valley received a record rainfall (also matched in 1983)! A strange year indeed. Although the 57°C was a world record at the time, it was later surpassed, (but only once) by a temperature of 58°C in Libya in 1922 (Griffiths & Driscoll 1982). The highest ground temperature of 94°C was set in 1972 when the air temperature was 53°C.

The very high temperatures in Death Valley have been the subject of brief discussion in the literature. Just after the record temperature in 1913, several authors wrote about its possible causes (Wilson 1915; Palmer 1922). Others have been suspicious of the 57°C reading ascribing it to faulty equipment (Court 1949; Ludlum 1963). Since the air temperature regularly tops 50°C, the additional few degrees are certainly within the realm of possibility. However, in more recent years, with improved equipment, no similar temperatures have occurred.

While these are the records at Furnace Creek, there are undoubtedly similar or greater extremes in the immediate area. Furnace Creek is about 30m higher than Badwater. Thus Badwater could at times be expected to be about one degree warmer due to adiabatic warming.

TEMPERATURE RECORDS AT FURNACE CREEK

Month	Average	Average Maximum	Average Minimum	Record High	Record Low	Average Diurnal
Jan.	11	18	4	31	-9**	14
Feb.	16	23	8	33	-3	15
Mar.	19	27	12	38	-1	15
Apr.	24	31	17	44	2	14
May	29	38	22	49	6	16
June	36	43	27	52	9	16
July	39	47	31	57*	11	16
Aug.	39	45	30	52	18	15
Sept.	33	41	27	49	5	14
Oct.	25	33	17	45	0	16
Nov.	17	24	9	36	-4	15
Dec.	12	19	4	30	-7	15
Means	25	32	17			15

Figures are in °C

*Record High **Record Low

Table 1.Temperature Records at Furnace Creek
This is a month–by–month summary taken from National Park Service Records from 1911–1983

Likewise, Telescope Peak, a very few kilometers southwest could be as much as 34°C cooler.

There are many factors contributing to Death Valley's high temperatures. Death Valley is at a latitude of about 36 degrees north of the equator. This is far enough south so that the sun spends a significant amount of time high in the sky during daytime hours.

Locations at the same latitude such as Tulsa, Nashville and southern Europe are not nearly so hot so there are obviously other factors to consider.

At Badwater, Death Valley is about 87m below sea level. This is the lowest elevation in the western hemisphere. All the air moving to Badwater must sink and therefore heats adiabatically. In addition to angle of incidence and altitude, albedo plays an important role in determining temperature. The albedo of Death Valley is probably about average. Most of the rocks are dark colored and have a dark coating of desert varnish. However, the playa on the floor of Death Valley is a high-albedo surface. However, Death Valley ends up with a higher than average absorption due to its lack of cloud cover. Because Death Valley is clear and cloudless much of the year, more energy reaches the surface and it becomes hotter.

To the west of Death Valley lie a formidable series of mountain ranges which effectively block the moderating flow of moist Pacific air. Cool summer Pacific air (and relatively warmer winter air) does not reach Death Valley without modification as it crosses the the north-south oriented mountains to the west. Dry air heats and cools more readily than humid air. Thus Death Valley becomes hotter in summer and cooler in winter than the lands directly on the coast to the west.

In summary, Death Valley is hot because it is fairly far south, very low, very clear, blocked from moist air by mountains and its surface materials are not overly reflective.

Rainfall

There are more precipitation data available for Death Valley than other climatic data. Precipitation measurements have been taken in many different places throughout the area but they are not always from comparable time periods. Furthermore, information may have been lost at the more remote stations due to high evaporation rates, infrequent checking of rain gauges and vandalism.

Death Valley's rainfall distribution is bimodal with most precipitation coming in the winter months and a smaller amount occasionally in late summer. The winter rainfall comes from large Pacific middle latitude wave cyclonic storms passing over the region. Precipitation from such storms is usually in the form of light rain on the valley floor and heavier rain and snow in the upper elevations. This general pattern may vary somewhat as snow may fall on the floor of the valley and past winter storms have caused numerous wash-outs destroying roads and buildings. Summer rainfall is more localized and usually more intense. It is the result of moisture-bearing tropical air from the south being forced over the local mountains as the air moves toward the interior. The total amount of precipitation is highly variable. The amount received in the wettest year can be seven to eight times that received in the driest year.

At Furnace Creek, annual rainfall has varied from 0–115 mm. There are many months that usually receive no rainfall but during most years, at least a little rain falls from December through March. Table 2 shows the total annual rainfall at Furnace Creek from 1911 to 1991. Only once did it not rain at all in a year's time: 1929. Twice, in 1913 and again in 1983 it rained a record 115 mm. From these data, 1911 to 1991, the average annual precipitation at Furnace Creek is 48.5mm/yr. Other places in the Monument receive different amounts of precipitation. Although data from these remote stations is sparse, generally the valley floor to the south of Furnace Creek receives less precipitation and the mountains and valley floor to the north receive more precipitation (see Appendix A and Figure 1).

Many factors affect the amount and type of precipitation that falls in the Death Valley area. Although the winds do generally blow from the Pacific Ocean towards Death Valley, the cold ocean hinders evaporation which in turn produces a generally drier climate throughout central and southern California. Secondly, and more importantly, high mountain barriers to the west isolate Death Valley from its Pacific moisture source. Even though it is only 290km from the sea, moisture from winter storms must cross over the coastal ranges (1,700m in altitude). Then the winds must cross the Sierra Nevada Range (4,400m)—the highest in the contiguous 48 States. After that, the winds must also cross the Inyo Mountains (3,200m) and finally the Panamint Range (3,000m) before they reach Death Valley. By that time, there is very little moisture left in the air mass. Death Valley is a rain shadow desert produced by the Sierras and other high mountains to the west.

After a cold front passes, high pressure frequently builds to the northeast of Death Valley and this tends to block or divert subsequent storms. Thus due to mountain barriers, general wind circulation patterns and the fact that air moving into Death Valley must flow downhill and thereby warm up and dry out, the floor of Death Valley is a very

Yea r	mm	Year	mm	Year	mm
1911	36 (a)	1938	87	1965	84
1912	36	1939	87	1966	20
1913	115 (b)	1940	61	1967	35
1914	42	1941	107	1968	41
1915	33	1942	24	1969	87
1916	57	1943	64	1970	58
1917	11	1944	52	1971	24
1918	28	1945	49	1972	57
1919	13	1946	71	1973	58
1920	74	1947	22	1974	88
1921	15	1948	8	1975	38
1922	45	1949	88	1976	107
1923	60	1950	25	1977	71
1924	11	1951	18	1978	102
1925	15	1952	98	1979	45
1926	21	1953	2	1980	81
1927	45	1954	66	1981	44
1928	22	1955	13	1982	56
1929	0 (c)	1956	20	1983	115 (b)
1030	37	1957	59	1984	103
1931	20	1958	52	1985	24
1932	4	1959	44	1986	32
1933	7	1960	47 (d)	1987	95
1934	39	1961	37 (e)	1988	98
1935	36	1962	20	1989	11
1936	67	1963	61	1990	33
1937	27	1964	27	1991	39
				ANN. MEAN:	49

(a) 1911 data incomplete, not included in averages
(b) wettest years, 1913 and 1983
(c) driest year
(d) possible error in station records
(e) due to station move from Cow Creek to Furnace Creek, both averaged together

Table 2. Furnace Creek Precipitation 1911–1991

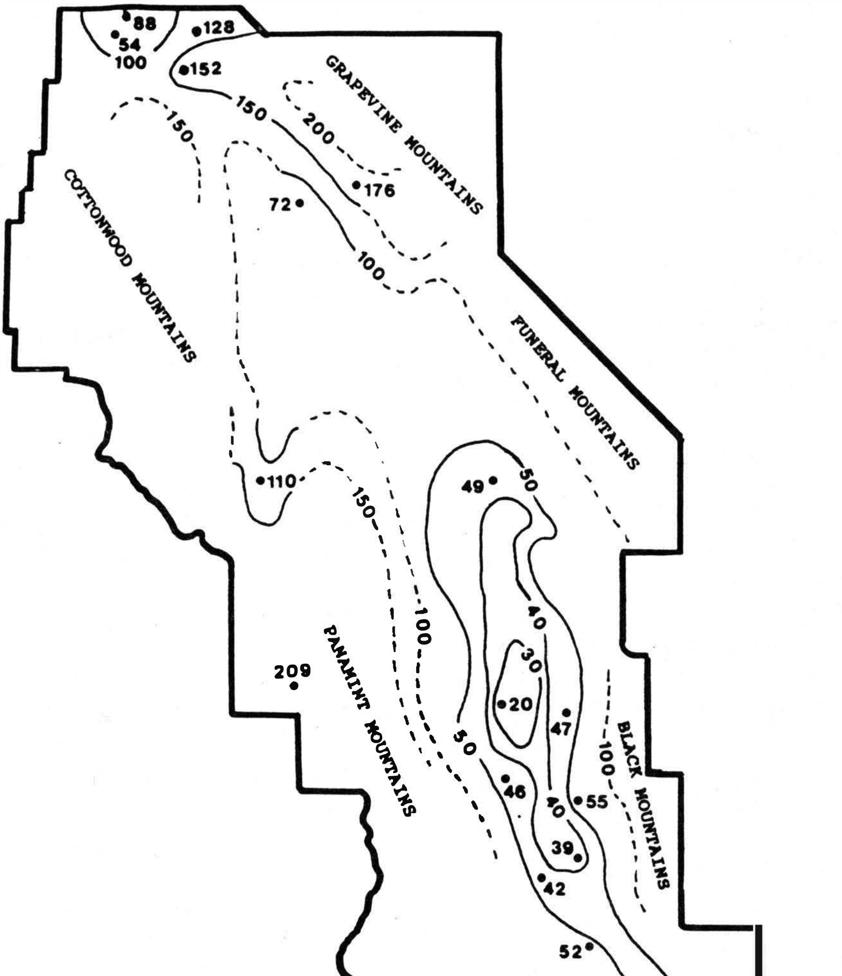

Figure 1. Average Annual Rainfall in Death Valley National Monument
(Figures are in mm)

arid place. However, the rainfall around the edges of the Death Valley region is far more variable.

In Death Valley, it is not uncommon to find orographic conditions combined with either cyclonic or convection conditions because of the many high mountains. Each front that passes in the winter must rise over the ranges thus producing such a combination. In summer, moist tropical air occasionally finds its way as far north as Death Valley. This air is heated by Death Valley's extreme heat and it rises as it moves against the mountains. The air rising orographically in the winter frequently rises against the western slopes while in the summer the air often rises against southern or eastern slopes. Since the less frequent summer moist air is heated more severely, it rises faster producing more intense rain but of shorter duration than the winter storms.

Other Moisture Elements

Evaporation. By any precipitation standards, Death Valley is dry. When one considers evaporation in addition to the scant rainfall, Death Valley becomes hyper–arid. Although information is available only from Furnace Creek and for only a few years, evaporation rates can easily exceed 3,300mm per year. The main cause of this high evaporation rate is, of course, the high temperatures. But clear weather, high angle of incidence of incoming sunlight, high absorption rates and wind in most seasons are also contributing factors. Table 3 is a monthly summary of evaporation for Furnace Creek (For comparison, the precipitation is also included).

Humidity, Clouds, Haze. While records for these three elements of atmospheric moisture are virtually nonexistent, some generalizations can be made. Humidity is usually higher than one might imagine. Although data are only available for the year 1983, the relative humidity in January ranged from 8–75 per cent and the relative humidity for July ranged from 3–28 per cent. In the summer, a desert haze is quite common. Most of the year Death Valley is essentially cloud–free. Alto–stratus clouds with nearly complete sky coverage occur at times in winter with the passage of the large cyclonic storms. In the summer, cumulo–nimbus clouds may occur in association with thunderstorms. Generally, Death Valley has about 300 cloud–free days each year.

MONTH	EVAPORATION (mm)	PRECIPITATION (mm)	DEFICIT (E–P) (mm)
Jan.	115	5	110
Feb.	155	8	147
Mar.	247	6	241
Apr.	317	3	314
May	401	1	400
June	504	1	503
July	520	3	517
Aug.	426	2	424
Sept.	348	3	345
Oct.	253	3	250
Nov.	141	5	136
Dec.	64	5	59
TOTAL:	**3,491**	**45**	**3,446**

Table 3. Evaporation at Furnace Creek

The degree of aridity at any location is best determined by noticing the difference between precipitation and evaporation which are both measured in similar units. In Death Valley, evaporation exceeds precipitation by a factor of 77 times.

Wind

Death Valley lies within the general westerly wind belt of North America. This flow from west to east is accentuated in the summer by the development of a strong high pressure area off the Pacific Coast and by a thermal low pressure area in the southwestern Great Basin area of southern Nevada, eastern California and northwest Arizona. Death Valley lies in the northwest corner of this thermal low. The strong west to east wind in summer is distorted by this low pressure zone and the surrounding mountains. In winter, the winds are less controlled by the high pressure zone in the Pacific than by the passage of the large cyclonic storms. After the passage of these storms there is often residual high pressure over central Nevada to the northeast of Death Valley. Most of the strong winds that occur in Death Valley are thus north to south or less commonly south to north. Obviously, the orientation of the mountains plays a significant role in controlling the wind's direction. Detailed velocity measurements are only available for 1983 and are not available in summarized form but in both January and July, the wind velocity, taken on an hourly basis, ranged from 1–48 kph.

How Does Death Valley Compare with Other Deserts?

Many geographers over the years have attempted to devise climate classification schemes whereby areas of similar climate can be grouped together according to temperature, rainfall and other characteristics (see for example, Thornthwaite 1948). There is no place quite like Death Valley either in terms of the specifics of its climate or the reasons for it. Locations exhibiting the greatest similarity include the deserts of Arabia, Australia, northern Africa (Sahara) and northwestern Mexico. Death Valley differs from these in several respects. First, Death Valley is noticeably cooler in the winter than most of these areas. Secondly, Death Valley is dry primarily because of the rainshadow effect of the mountains while the other deserts mentioned are dry mostly due to descending tropical air masses.

In general, when compared to the world's other deserts, Death Valley is hotter in summer and cooler in winter than deserts found in tropical areas. But Death Valley is hotter in summer *and* winter than most middle–latitude deserts such as the Gobi in Asia. Overall, Death Valley is about equal in aridity with other deserts except on the valley floor where it is distinctly drier.

Appendix A

Precipitation Summary of Death Valley.

Station	Elevation (meters)	Data Base (years)	Average Annual Precip.	Range
Furnace Creek*	–58	1911–1991	49	0–115
Wildrose**	1,341	1967–70, 72-76	209	81–279
Grapevine Ranger Sta.	701	1974, 76–78 80, 82, 83	152	69–266
Grapevine Canyon	914	1979, 82, 83	128	66–224
Klare Spg.	975	1978–80, 82, 83	176	26–115
Titus Cyn. Mouth	244	1974, 76–80	72	26–115
Ubehebe Crater	792	1979–80	54	52–57
Big Pine Road	805	1977–80, 82, 83	88	22–163
Emigrant Ranger Sta.	658	1977–80 82, 83	110	72–179
Ashford Jct.	0	1973–76, 81	43	10–67
Bennett's Well	–76	1973–76	46	12–68
Copper Cyn.	–73	1976, 81	55	40–70
Mormon Pt.	–15	1973–76, 81	39	8–69
Salt Tanks	–73	1973–76, 81	42	3–78
Tule Spg.	–79	1981	20	20
Warm Spgs. Jct.	–61	1973, 75, 81	52	35–72
Badwater	–85	1974–76	47	11–78

*Measured at Greenland Ranch 1911–1934 and 1961–present. Measured at Cow Creek 1935–1960.

**Snow measured separately, not melted.

The mean figures are mapped in Figure 1.

Acknowledgement

Unless otherwise cited, all of the data presented herein was obtained from the National Park Service archives in the Research Library at Furnace Creek. The personnel at the Visitor Center were very cooperative in letting me pour through their records.

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