Death Valley Illusion: Evidence Against the 134 °F World Record

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ABSTRACT

The world record hottest near-surface air temperature of 134 °F recorded at Greenland Ranch, Death Valley, California on 10 July 1913 is demonstrated to be approximately 14 °F hotter than what likely occurred on that date. Using July data from non-Death Valley stations during 1923 to 2024 we compute a range of temperature lapse rates diagnosed from the differences between Greenland Ranch station and the average of higher-elevation stations' maximum temperatures (T_{MAX}) and elevation. The range of lapse rates from those 102 years of July data are then used to estimate Greenland Ranch temperatures during the early years (1911-1922). The first two weeks of July 1913 are shown to be spuriously hot, and other years at Greenland Ranch exhibit anomalous July temperature behavior as well. Despite the establishment of a U.S. Weather Bureau instrumented shelter at Greenland Ranch in 1911, based upon historical accounts we believe some of the shelter readings in the early years were replaced with hotter values, possibly taken from the veranda of the ranch house using a thermometer of unknown provenance. As a result of these findings, we recommend that the 134 °F world record status be rescinded, and that many of the Greenland Ranch temperature reports during the early years be more closely evaluated for data quality.

SIGNIFICANCE STATEMENT

Climate monitoring depends upon long-term stability of historical data records. We analyze the world record hottest temperature of 134 °F on 10 July 1913 in Death Valley as an example of misreported temperature data. Using data from surrounding stations, this measurement is shown to be approximately 14 (+/-2) °F hotter than what likely occurred (120 °F) on that date.

CAPSULE

The world record hottest temperature of 134°F from Death Valley on 10 July 1913 is shown to be approximately 14 °F hotter than what likely occurred (120 °F).

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Introduction

The world record hottest near-surface air temperature reading of 134 °F[1] at Greenland Ranch (also called Furnace Creek Ranch) in Death Valley on 10 July 1913 is legendary, and has not been equaled since. But is it authentic? Even as the global climate system has warmed, the highest temperatures recorded at Death Valley in the years since 1913 have struggled to reach 130 °F (in both 2020 and 2021). Previous authors have noted its meteorologically unusual nature (Willson, 1915; Court, 1949; Court, 1953) and at least one has challenged its validity (Reid, 1987). Using the first 37 years of data from Greenland Ranch, Court (1949) estimated from a probability distribution argument that such an event would occur only once every 650 years.

Death Valley is likely the hottest summer locale in the Western Hemisphere. The hot summertime desert conditions there are a combined result of strong solar heating due to low latitude (36 °N), clear skies and low humidity from summertime tropospheric high pressure and associated sinking air (subsidence), protection from moisture intrusions by surrounding mountain ranges and plateaus, mostly bare ground, and especially elevations below sea level (Roof and Callagan, 2003; Hunt et al., 1966). Precipitation is rare on the floor of Death Valley in summer, with a July average total rainfall of 0.11 inches (Roof and Callagan, 2003). Natural vegetation such as creosote bush and mesquite is sparse and mostly exists where watered by subsurface streams that flow down from the surrounding mountains. As a result, cooling from evapotranspiration is negligible.

The first non-native Americans to reach Death Valley were the gold-seekers of 1849 (Manly, 1929). Exaggerations and misrepresentations led to “illusions” of great mineral wealth that were seldom realized. (Lingenfelter, 1986, hereafter L86). Dehydration took the lives of many of these emigrants on their treks across the desert floor, and by the late 1800s, the reputation of Death Valley as a dangerous and foreboding corner of rural America was

[1] For historical continuity, we will use English units for temperature (°F), precipitation (inches), and elevation (feet).

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widely known. Even an esteemed academic journal sounded tabloid in its description of Death Valley; from L86:

> *"Even so enlightened a journal as the Scientific American succumbed to the deadly illusion, branding the valley the Puit d'enfer — the pit of hell into which "very few persons have ever gone…who returned to tell the tale." And its editor sadly lamented that the valley's awful "climatic violence" would never be known because "no man could survive there long enough to secure continuous observations of any extent."* (*Scientific American*, 19 September 1885)

As early as 1915 the peculiar nature of the 134 °F reading was discussed by Willson (1915):

> *"The daily weather maps have been carefully studied for some peculiarity that would explain the extremely hot weather in Death Valley in July, 1913, but it is doubtful if a sufficient cause was found. The weather type was that which always causes high temperatures over the south Pacific coast district, it was not unusually pronounced, and did not give record temperatures in any other portion of California."*

Willson speculated that the light northerly wind flow over the mountains would have descended into the valley, heated by compression, and might have become "stagnant" in Death Valley where it was "heated rapidly by the reflected heat from the rocks and desert floor." But it could be argued that all air reaching the floor of Death Valley on dry summer days is subject to these effects, and as recounted by Willson, July of 1913 was not substantially different from any other July in this regard.

In *Death Valley — The Hottest Known Region*, Palmer (1922) described the first ten years of data collected from Greenland Ranch station, taking the temperature measurements at face value, and described the unique geography of the region. Also in 1922, a Popular Science Monthly article proclaimed "*Welcome to the Hottest Spot on Earth!*" (Hogg, 1922) and included a photo of ranch foreman Oscar A. Denton circa 1918-1920 indicating the almost celebrity status of the cooperative observer at the time.

While it is not well established just how hot shelter-height air temperatures can get under conditions experienced on the floor of Death Valley in summer, Zhang and Boos (2023) argued that maximum temperatures are limited by convective mixing combined with how warm the mid-troposphere is, as measured by the 500 hPa (~20,000 ft altitude) temperature. Court (1949) examined the statistically unlikely nature of the 134 °F measurement and noted that air over a desert surface in the summer has been measured to be 160 °F or hotter as one

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approaches to within inches of the solar-heated surface. This is supported by the 159 °F surface skin temperature estimated by satellite in Lut Desert, Iran (Mildrexler et al., 2011). Such extreme surface skin temperatures are why near-surface air temperature measurements are made at standardized heights, usually in the range of 4 to 6 ft. above ground level. Measurements made too close to the surface will produce excessively hot daytime values, as well as excessively cold nighttime temperatures under clear skies and light wind conditions when the skin temperature usually falls below the shelter-height temperature (Sparks, 1972).

The world record 134 °F report has been largely accepted at face value (Willson, 1915; Palmer, 1922; Court, 1949) in large part because a U.S. Weather Bureau (USWB) instrumented shelter was installed at Greenland Ranch in 1911, in cooperation with the ranch owner, Pacific Coast Borax Company. It has simply been assumed that the reported temperature came from that shelter and was dutifully recorded by the ranch foreman at that time.

But while good instrumentation and exposure are necessary conditions for weather measurements, they are not sufficient conditions. We will provide evidence from surrounding non-Death Valley stations that such a high temperature as 134 °F is implausible. It will be shown that July daily maximum temperatures (T_{MAX}) at Greenland Ranch in years exhibiting no significant measurement issues are closely approximated with an average of the surrounding stations' daily T_{MAX} after average differences in elevation are accounted for. Furthermore, it will be demonstrated that positive biases in maximum temperatures were not restricted to 10 July 1913.

Finally, we will address the interesting historical and cultural setting of Greenland Ranch (called Death Valley National Park station after 1960) which might have contributed to the misreported temperatures. Arguably, there has never been a more challenging environment and time in history to make weather observations than Death Valley in summer before air conditioning and other modern conveniences arrived. While there were limited but dedicated high-quality summertime temperature measurements made in Death Valley in the late 1800s (which came at personal peril and produced unremarkable results), it might come as no surprise that temperature measurements made by a ranch foreman tasked with being a cooperative observer in such an extreme environment in the early 1900s might prove problematic. Even as recently as the 1950s a series of cooperative observers at Greenland Ranch had trouble making routine measurements due to poor eyesight, unapproved changes

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in the time of day for taking observations, lack of observing time due to demands of multiple jobs, and even abandonment of the task due to lack of interest (Stachelski, 2013).

Death Valley Temperatures Estimated from Surrounding Stations

There are now many decades of temperature measurements in Death Valley and at higher-elevation stations in the region surrounding the basin. The Greenland Ranch station, operating from 1911 to 1961, was located 178 ft below sea level, which contrasts with the surrounding, non-Death Valley stations which since 1913 averaged from 3,000 to 3,700 ft above sea level. Death Valley T_{MAX} can be reasonably well estimated using the higher-elevation stations with a simple elevation-based adjustment to their temperatures, especially in the summertime when the airmass over the desert southwest U.S. is dominated by tropospheric high pressure, slowly sinking air, weak winds, and spatial uniformity at any given altitude. Daytime mixing of the lower tropospheric air is provided by the strong solar heating of the surface, which we will show results in a rather constant decrease in temperature with height (the lapse rate).

To quantitatively estimate Greenland Ranch temperature, we will use the daily Global Historical Climate Network Version 3 (Menne et al., 2012) reported values of daily T_{MAX}. Only stations within 155 mi (250 km) of Greenland Ranch were included, and those were required to be east of the Sierra Nevada mountains to avoid occasional exposure to cooler Pacific maritime air masses (see Fig. 1).

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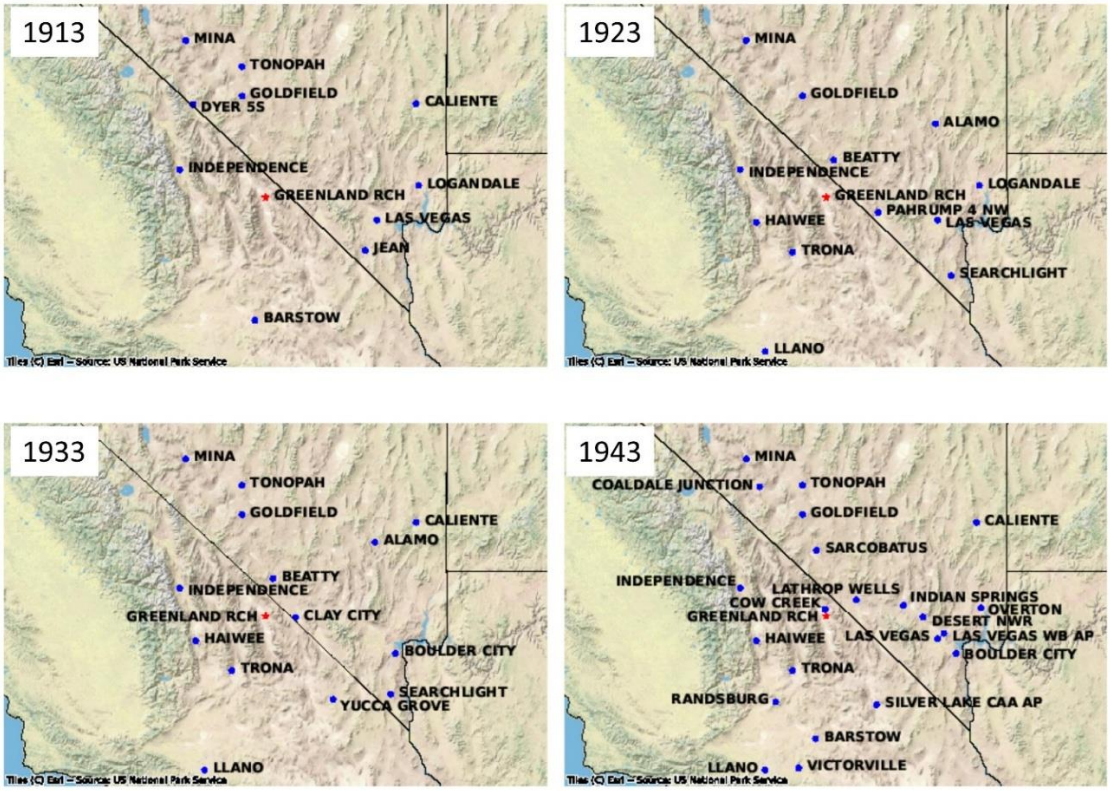

Fig. 1. Example station locations used in the analysis for July in the years 1913, 1923, 1933, and 1943.

To be included in analysis, at least 23 of 31 days had to have reported data, and no more than two consecutive days could have missing data. Those 1-to-2-day periods of missing data were replaced with linearly interpolated temperatures from the bounding days. As a result, every station included in the analysis had 31 days of data.

Quantitative estimates of Death Valley July daily T_{MAX} in 1913 will be made from the higher-elevation stations by using a range of lapse rates Γ (temperature decrease with elevation) diagnosed from the 102 individual years of July T_{MAX} data from 1923 to 2024. Those yearly lapse rate estimates are made by simply removing the July-average daily T_{MAX} difference between Death Valley and the surrounding (non-Death Valley) stations, and then dividing that temperature difference by the corresponding difference in elevation. In equation form, the diagnosed lapse rate in July of any given year is

$$\Gamma = -\left[T_{DV} - \overline{T}_{NDV}\right]/\left[h_{DV} - \overline{h}_{NDV}\right], \qquad (1)$$

and the estimate of the Death Valley station temperature is then

$$T^{*}_{DV} = \overline{T}_{NDV} - \Gamma\left[h_{DV} - \overline{h}_{NDV}\right], \qquad (2)$$

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where the overbar denotes a 31-day average over all non-Death Valley stations in a particular July, and h is the station elevation. Evaluating Eq. 1 in each of the 102 years from 1923 to 2024 will provide a range of estimated lapse rates for years with presumably good data to apply to the year of the world record measurement, 1913, and thus provide a range of estimated errors for the day of the record measurement, July 10.

Example July time series of Greenland Ranch measured and estimated daily T_{MAX} are shown in Fig. 2 for the years 1931-34. In this case, we have simply removed the July-average temperature difference between Greenland Ranch and surrounding stations (the numerator in Eq. 1) to produce estimates of Greenland Ranch T_{MAX} (gray time series) which can be compared to the observations (red time series).

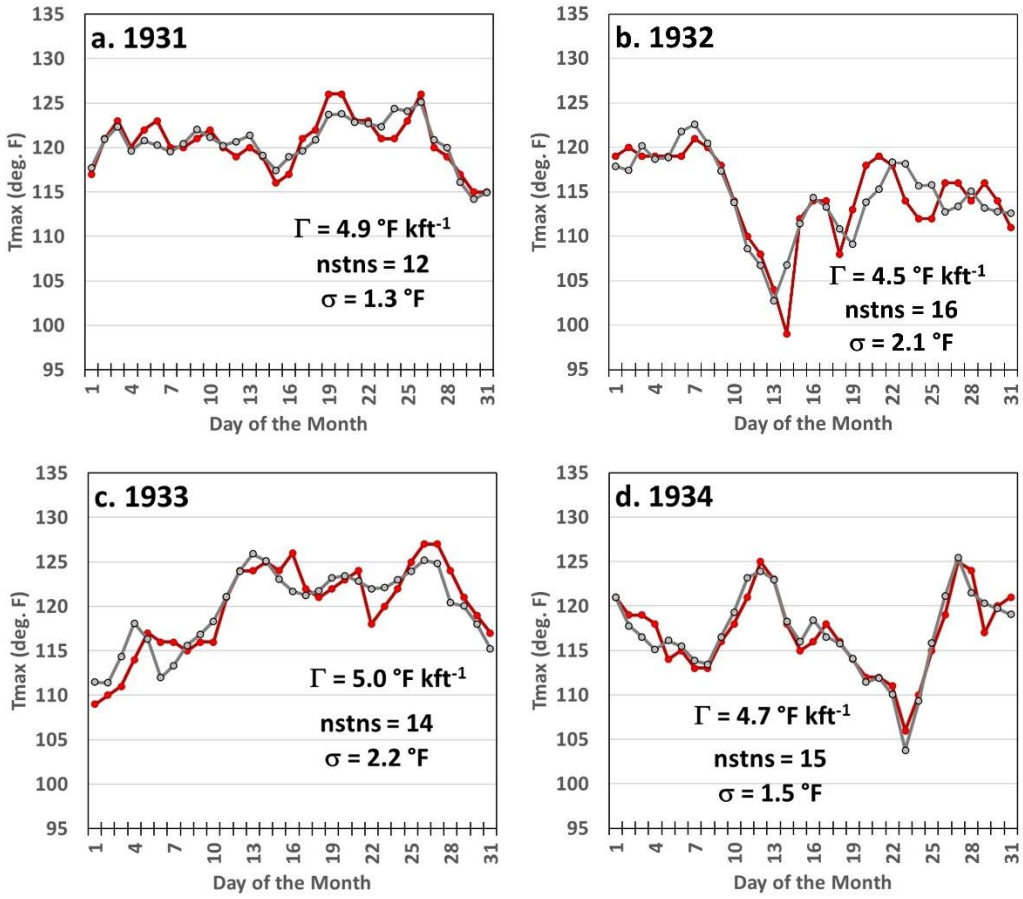

Fig. 2. July daily estimates and measurements of Greenland Ranch T_{MAX} for the years 1931 through 1934, using a July-average temperature offset computed in each year separately. That temperature offset divided by the average elevation difference between Greenland Ranch and the non-DV stations gives the indicated diagnosed lapse rates, Γ (see Eq. 1) The number of non-DV stations used is also shown, as is the daily standard deviation (σ) of the difference between observed and estimated T_{MAX}.

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Also shown in Fig. 2 are the diagnosed July-average lapse rates, which range from 4.5 to 5.0 °F kft^{-1}. The standard deviation of the daily difference between measured and estimated Greenland Ranch T_{MAX} in these four years ranges from 1.3 to 2.2 °F, which gives some idea of the noise in the estimates of daily Greenland Ranch temperatures from the surrounding stations.

To obtain a more comprehensive estimate of diagnosed lapse rates we expand the time frame to all available years, from 1911 to 2024. The resulting lapse rates are shown in Fig. 3a, along with the number of higher-elevation stations used in those estimates in Fig. 3b.

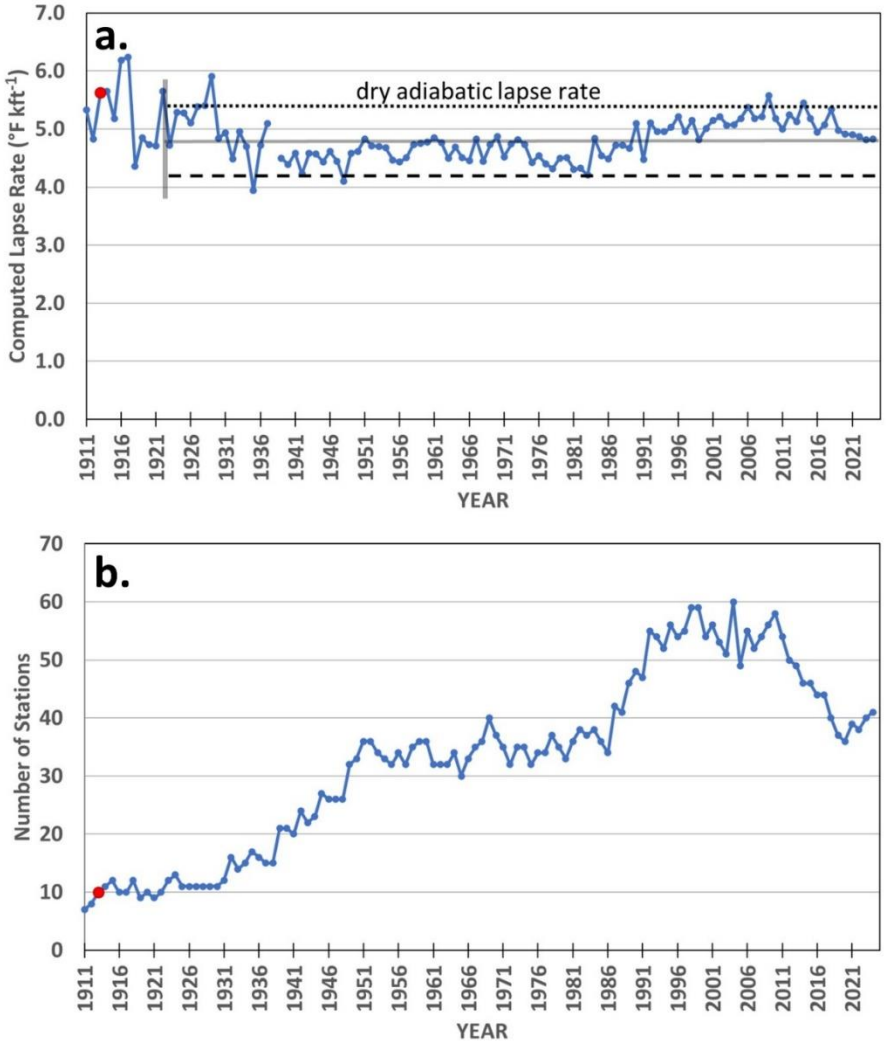

Fig. 3. (a) Computed July lapse rates necessary to match Greenland Ranch July-average T_{MAX} with surrounding stations' average T_{MAX} in each year from 1911 to 2024, and (b) the number of available surrounding stations used. The lapse rates then used to estimate July 1913 Greenland Ranch temperatures range from 4.2 °F kft^{-1} (dashed line) to the dry adiabatic value of 5.4 °F kft^{-1} (dotted line), with a central estimate of 4.8 °F kft^{-1} (thick gray line), based upon lapse rates diagnosed from 1923 onward.

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Note the early years have more variability in the diagnosed lapse rates, the result of both occasional warm biases in a few of the years (evaluated below) and noisier T_{MAX} estimates due to fewer available non-Death Valley stations.

To evaluate the 1913 world record T_{MAX} we assumed a central estimate of 4.8 °F kft^{-1} average lapse rate from 1923-2024 (gray line in Fig. 3a), with a range from 4.2 °F kft^{-1} to the dry adiabatic value of 5.4 °F kft^{-1}(dashed and dotted lines in Fig. 3a, respectively). It is this range of values we will use in the earliest years of the Greenland Ranch record to evaluate biases and errors in the Greenland Ranch T_{MAX} observations, especially the 134 °F world record value.

If we use the 102-year average lapse rate and apply it to the individual Julys in each year from 1911 to 1922, we obtain the daily time series shown in Fig. 4.

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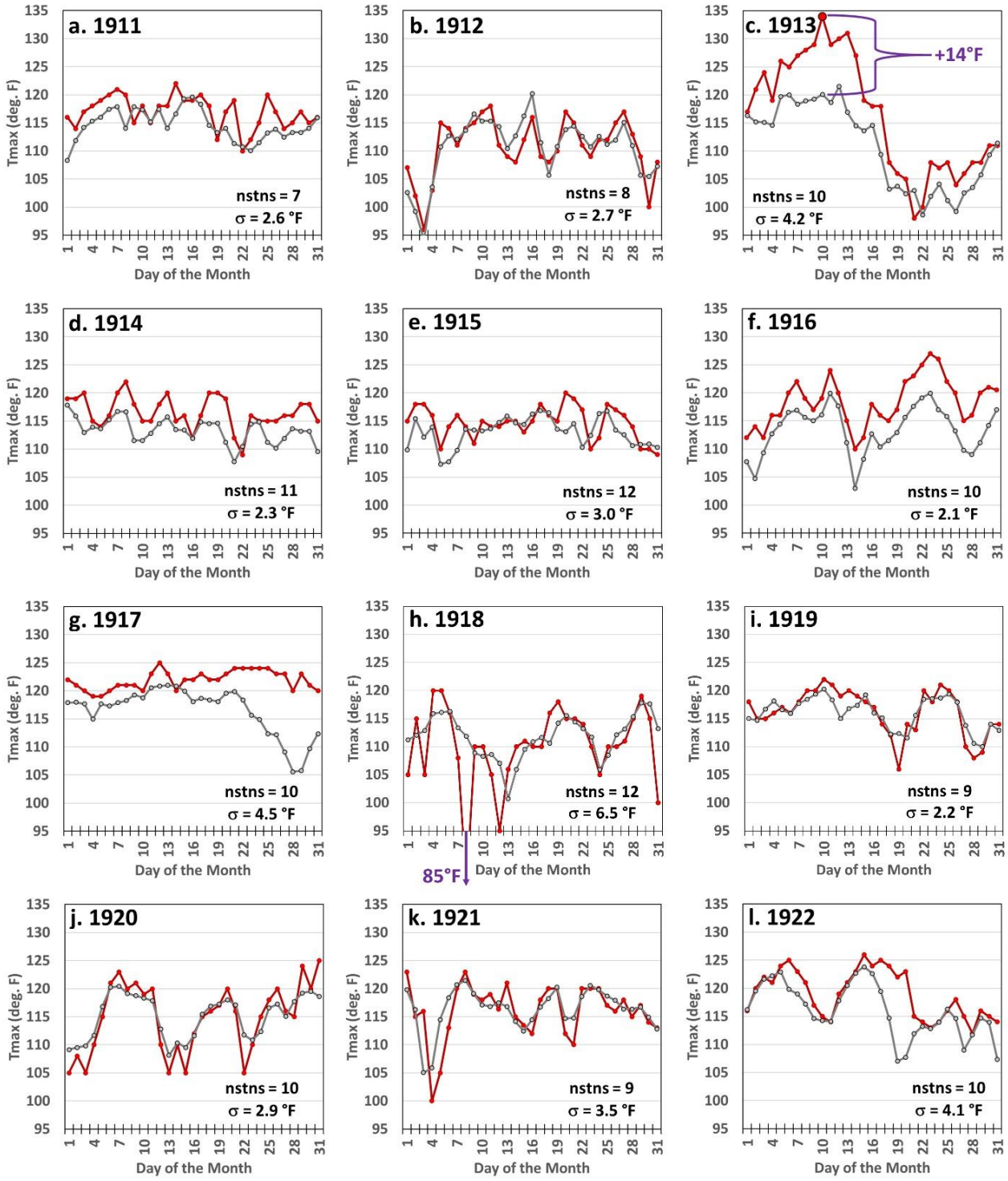

Fig. 4. Measured (red) and estimated (gray) daily T_{MAX} for July in the years (a) 1911 through (l) 1922 at Greenland Ranch, Death Valley, California, using a 102-year average lapse rate value of 4.8 °F kft^{-1} from the period 1923-2024. Also shown is the standard deviation of the daily differences between measured and estimated T_{MAX}.

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Of special note is the +14 °F difference on 10 July 1913 (Fig. 4c), which gives our central estimate of the true T_{MAX} on that date of 120 °F, a stark departure from the reported (world record) value of 134 °F. Using the assumed lapse rate range mentioned above results in our estimated range of true 10 July 1913 T_{MAX} as 118 °F to 122 °F, corresponding to a measurement bias of +12 °F to +16 °F — again with a central estimate of T_{MAX} = 120 °F.

There were other days in addition to 10 July 1913 with rather large warm biases. The 17-day period from 2 to 18 July 1913 had an average estimated bias of +8.2 (+/-2) °F (see Fig. 5), with a second +14 °F warm bias on 13 July when a maximum temperature of 131 °F was recorded.

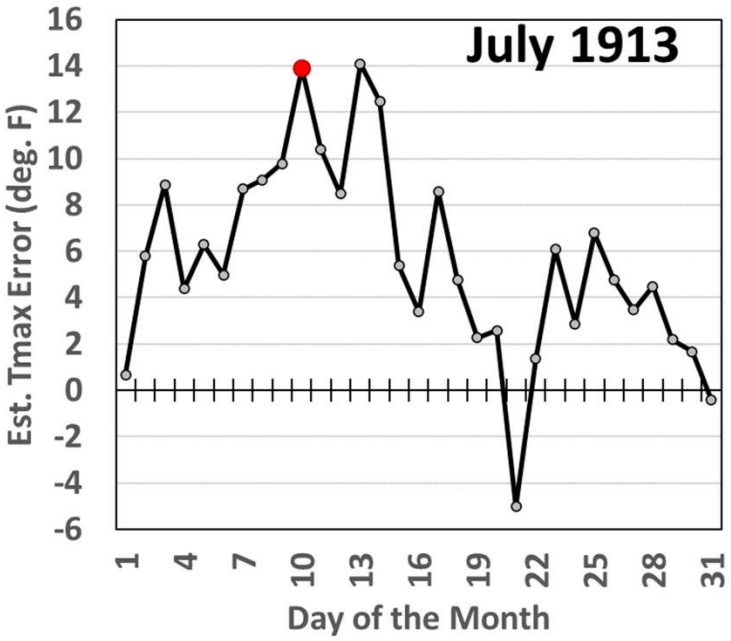

Fig. 5. Estimated daily errors in Greenland Ranch reported T_{MAX} during July 1913. The date of the world record measurement is indicated in red.

Other years with a large number of warm biases in Fig. 4 were 1914, 1916, 1917, and 1922. Additionally, in 1918 there were an implausibly large number of temperatures (22 of 31 days) that were integer multiples of 5 (e.g. 105, 110, 115, etc.), while 1920 had 19 days, suggesting the observer was simply estimating those temperatures rather than reading them from the thermometer. These compare with a 102-year (1923-2024) average of 6.7 days per July being integer multiples of 5. The largest July standard deviation of the daily differences between measured and estimated T_{MAX} was in 1918 (σ = 6.5 °F) and the world record year of 1913 (σ = 4.2 °F). These are considerably larger than the 102-year (1923 to 2024) average σ

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= 2.0 °F. Taken together, these comparisons suggest that the early years at Greenland Ranch included many anomalous July temperatures.

To put the early years of Death Valley temperatures into historical context we next examine some of the earliest temperature measurements made there.

Earliest Measurements of Death Valley Temperatures Depended Upon Thermometer Exposure

Before the arrival of the USWB instrument shelter in 1911, hot summertime temperature measurements for Death Valley were noted by several sources. According to L86 (page 5),

> "*The first actual measurements of summer temperatures in Death Valley, made by the Wheeler survey in the 1870s, showed a maximum of 121 °F, which the Army Signal Corps proclaimed the highest temperature ever recorded in the United States*."

These measurements would have been made during the Wheeler expedition in 1875 (Roof & Callagan, 2003).

In John Spear's 1892 book *Sketches of Death Valley and Other Borax Deserts of the Pacific Coast* (Spears, 1892) there is an extreme account of temperature measurements made by James J. McGillivray, a mineral surveyor:

> *"The heat there is intense. A man cannot go an hour without water without becoming insane. While we were surveying there we had the same wooden-case thermometer that is used by the Signal Service* (predecessor to the USWB). *It was hung in the shade on the side of our shed, with the only stream in the country flowing directly under it, and it repeatedly registered 130 (degrees), and for forty-eight hours in 1883, when I was surveying there, the thermometer never once went below 104 (degrees)."*

In *Chronology of the Death Valley Region in California and Nevada, 1849-1949* by T.S. Palmer (1989) it was stated that on 3 July 1890, the air temperature reached 136 °F "according to observations by James W. Dayton." Dayton was the Greenland Ranch caretaker from approximately 1884 until his death on 24 July 1899.

As a more scientific example, a temporary weather station was established in Death Valley for five months in 1891, from May through September, providing the most complete early record of detailed summer meteorological conditions in the basin. Mark Harrington, the chief of the newly-formed USWB, set up a first-order station "at the foot of the Funeral

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Mountains, about two miles northwest of the mouth of Furnace Creek" (Harrington, 1892). This location was at Harmony, site of the borax mining works supported by Greenland Ranch. The maximum thermometer was housed in a standard cotton region shelter, presumably like the one installed at Greenland Ranch in 1911. The manufacturer of the thermometer was the Henry J. Green Company of Brooklyn, New York, which provided meteorological instrumentation for the USWB and other government institutions in the U.S. and abroad (H. J. Green, 1892). H. J. Green was thus the likely provider of the Greenland Ranch USWB shelter thermometer. Hourly wind, temperature, humidity, pressure, sky condition, and general weather observations were taken by observer John H. Clery. The maximum temperature that summer was a rather unremarkable 122 °F on three consecutive days, from 30 June to 2 July 1891. As just one example of the extreme heat there, the assistant observer, R.H. Williams, "succumbed to the heat soon after his arrival" and required medical treatment in Keeler, California. Maximums of 122 °F were also recorded on 24 and 25 August 1891 at this temporary station.

In order to potentially explain the anomalous warmth of the early-July 1913 reports, we are especially interested in the anecdotal reports of excessive temperatures taken from the veranda of the Greenland Ranch living quarters. In contrast to the rather modest 121 °F Wheeler Survey measurement in 1875 and the 122 °F measurements made by Harrington in 1891, Spears (1892) recounted that,

> "*A thermometer hanging under the wide veranda on the north side of the adobe house on the Death Valley ranch, has registered 137 degrees*"

It is not known whether this is a retelling of the 136 °F measurement made by James Dayton on 3 July 1890. Also, it is not known what kind of thermometer was used for these measurements on the ranch building veranda.

Taking air temperature measurements from the veranda of the ranch living quarters presents problems. Even if placed on the north side of the ranch building, during the summer it would be necessary to protect the thermometer from the direct rays of the late afternoon sun which would have been north of west by 4 p.m. local solar time until sunset. This could heat the north wall of the building, if not the thermometer itself. According to Spears (1892) and Coolidge (1937), both of whom visited Greenland Ranch, the ranch living quarters building was of adobe construction with 4 ft thick walls and a double roof to help protect the interior from daytime heating by the sun. We speculate that the double roof might have contributed to

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the excessively hot temperature readings from the veranda. A single roof would produce hot air at the top surface, which would have been carried upward and away from the building by convective air currents. But a double roof would have also produced hot air in between the two roof layers, which could only be vented out the edge of the roof overhanging the veranda. Since the prevailing wind direction there in the summer is from the south, it is possible that the north side of the veranda experienced hot air intrusions from between the roof layers.

A common theme from these historical accounts is that the hottest temperatures measured in Death Valley (over 130 °F) were obtained with non-standard exposure of the thermometers. Before the arrival of the USWB instrumented shelter in 1911, ranch employees claimed evidence of air temperatures at Greenland Ranch that sometimes reached, and even exceeded, 130 °F. And, indeed, temperatures might well have been that high on the ranch house veranda. Yet, in over a century of additional summers of official records in a warming climate, a reading of 130 °F from instrumented shelters would not be reached again until 2020 and again in 2021.

Next, we examine the written and photographic evidence that supports our contention that many of the summer temperatures recorded at Greenland Ranch during the tenure of ranch foreman and cooperative observer Oscar Denton did not come from the USWB shelter.

History and Cultural Setting of Greenland Ranch

It is doubtful that the modern meteorologist, climatologist, or weather observer has adequate appreciation of the difficult conditions endured daily by cooperative observers in Death Valley 100+ years ago. Even as late as the early 1900s Death Valley maintained a Wild West character. As recounted by Coolidge (1937) based upon his travels there in 1916,

"*There was absolutely no law of any kind until a very few years ago*…"

L86 provides extensive documentation of the difficulties in travelling to Death Valley before 1900. The first motorcar to visit Death Valley arrived in 1905. Railroads were extended close to Death Valley in 1907 to allow easier access for miners and tourists. By about 1915 a motorist from Los Angeles could drive their automobile into the basin via Death Valley Junction. Prior to these developments, a visit to an area as remote and harsh as Death Valley was rife with hardship and peril and took many days of travel by foot, horseback, or mule-drawn wagons.

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Even today, a summertime visit to Death Valley is potentially dangerous requiring sensible preparation and planning. Running out of gas can have deadly consequences. On average, one person dies in DVNP each year due to hyperthermia (National Park Service, undated). It is against this backdrop that we begin to understand the difficulties in measuring daily weather in Death Valley in summer.

Greenland Ranch History

A detailed history of Greenland Ranch was provided by Greene (1981). Greenland Ranch was developed by William T. Coleman to support borax mining operations at nearby Harmony. During the 1880s borax was scraped from the land surface by workers, processed, and hauled in wagons to the railhead at Mojave by the famous twenty-mule teams. The ranch was a green oasis amidst very bleak surroundings. Thanks to water diverted from Furnace Creek Wash flowing down from the Funeral Mountains, alfalfa, hay, fruits and vegetables thrived on several tens of acres of cultivated land. Livestock and chickens were raised to provide meat and eggs for the workmen. The ranch was an isolated but welcome outpost where workers and mule teamsters could cool off, relax and recharge.

Francis M. ("Borax King") Smith purchased Coleman's holdings in 1890 and formed the Pacific Coast Borax Company. Smith continued to support Greenland Ranch even as the borax operations ended at Harmony, the closest mining operation supported by the ranch. The ranch's focus gradually shifted from alfalfa and livestock to date groves and tourism in the 1930s. Death Valley National Monument was created in 1933, roads to Greenland Ranch were soon paved, and electricity came to Furnace Creek. The Furnace Creek Inn and Furnace Creek Ranch resorts were built, converting the basin to a more tourist-friendly destination.

Greenland Ranch Conditions 1911-1920, and Observer Oscar Denton

Life during the summer as a Greenland Ranch caretaker from the late 1800s to the early 1900s meant coping with lonely days and enduring dangerously hot weather. Manual labor was not possible during most of the daylight hours of midsummer when high temperatures averaged close to 115 °F, so farm work was accomplished close to sunrise and sunset. All ranch workers and miners, except for the ranch foreman, left the valley during the summer months and returned in the fall, so the ranch foreman was alone during most of the summer. Midday hours were typically spent lounging in a hammock in the shade in a wet, grassy area, or sometimes in front of a large fan powered by water flowing through the irrigation ditch

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dug from Furnace Creek Wash. Simply surviving the heat of summer afternoons must have been the main concern of the earliest caretakers.

Despite the harsh summer conditions, a lone foreman at Greenland Ranch, Oscar A. Denton (Fig. 6), minded the ranch during the summers of 1913-1920 and made the daily weather observations.

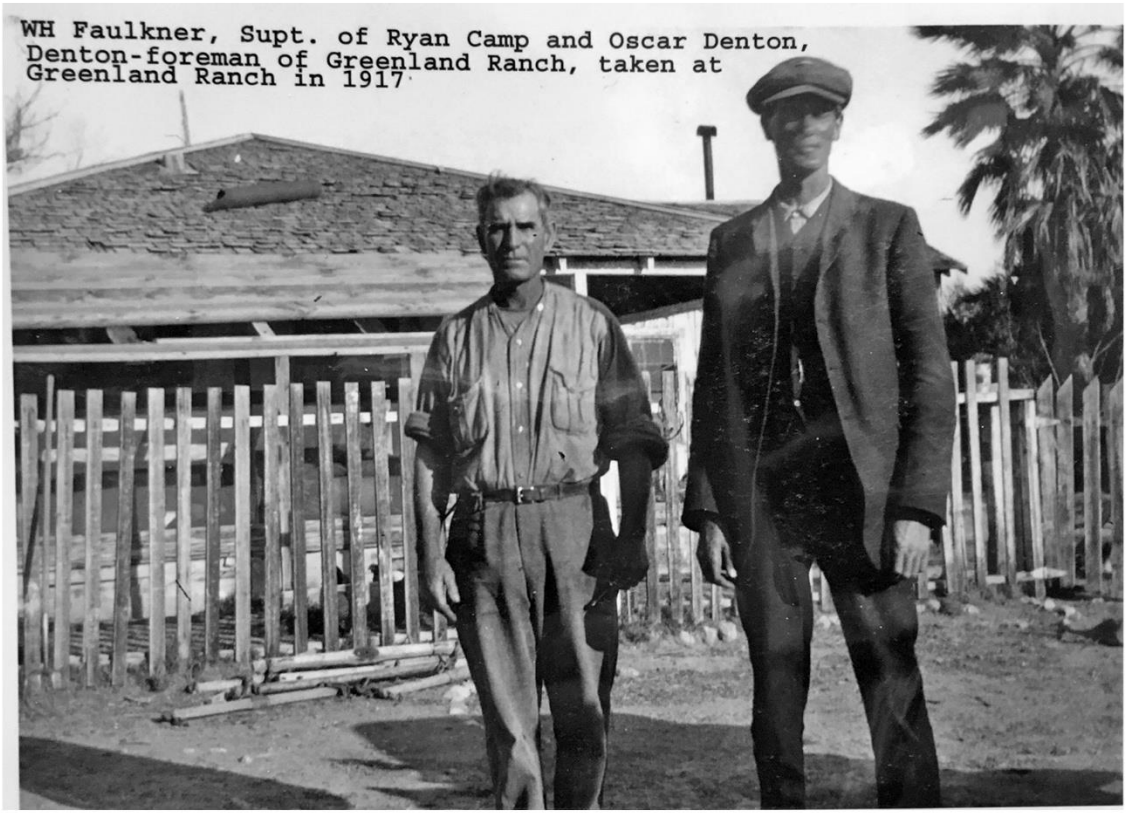

Fig. 6. Greenland Ranch foreman and cooperative weather observer Oscar Denton (left) around 1917 (photo archived at Eastern California Museum, Independence, California)

As recounted by Coolidge (1937), Denton was a loner, suspicious of any visitors to the ranch who did not carry proof of being associated with the Pacific Coast Borax Company. While it was normal to be on the lookout for any outlaws who might want to steal property in such a remote location, Denton's wariness is reported to be the result of his prior experiences in northern Mexico, which is where he was born and resided when young. As related by Coolidge (1937) based upon his visit to Greenland Ranch around 1917 and his conversations with Mr. Denton,

> *"…Oscar had an unpleasant experience during the Mexican Revolution and he had a special reason for being suspicious of strangers, since there were men who had sworn to kill him. He had retreated, in fact, to the most isolated place in North America, and they*

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could not say they were just going by. If they came to Furnace Creek they intended to kill him, and he was ready to act accordingly".

These historical events suggest that Oscar Denton's daily life in Death Valley during summer involved distractions and discomforts that might help explain some of the measurement issues we have documented.

The USWB Instrument Shelter at Greenland Ranch

Before the USWB station equipment arrived in 1911, Denton and his foreman predecessor Thomas Osborn, ranch superintendent Fred Corkill, as well as James Dayton in the late 1880s and early 1890s had access to one or more thermometers at Greenland Ranch. As previously mentioned, a reading of 136 °F or 137 °F was reportedly made by Dayton prior to 1892 from the veranda of the ranch living quarters. The type of thermometer that was used, its accuracy, and its exposure all remain unknown.

In contrast, the USWB equipment provided to the ranch in 1911 was state-of-the-art for that time period. The instrument shelter was installed by ranch superintendent Fred Corkill, who had previous experience as a cooperative observer at Candelaria, Nevada. But it quickly became apparent that the USWB equipment was not producing temperatures as high as the ranch employees were expecting. As Willson (1915) stated,

"The maximum thermometer in use during the hot weather of July, 1913 was graduated up to 135 F only, and in a note accompanying his report at the close of the month, the observer stated that he doubted if the record was sufficiently high because other ordinary thermometers at the ranch showed a much higher temperature."

As previously noted, most if not all thermometers used by U.S. Government agencies at the time were procured from H. J. Green. An H. J. Green instrument catalog circa 1910-1915 states "Our barometers and thermometers will be found in use on every station of the U.S. Weather Bureau". While most thermometers in that catalog were graduated to only 120 °F (H.J. Green catalog, 1892), a fine example of a USWB maximum thermometer from the time with the mercury-in-glass stem graduated in °C extending to 57 °C (135 °F) is provided by the Smithsonian (undated photo). Since the H. J. Green catalog also states "thermometers made to order", we therefore assume that the Greenland Ranch station had a specially made thermometer, graduated in °F and extending up to 135 °F.

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Ironically, the siting of the USWB instrument shelter might have contributed to the implausible world record that still stands today. The expectation by ranch workers that temperatures at Greenland Ranch sometimes exceed 130 °F ended up conflicting with the measurements made in the USWB instrumented shelter which was installed next to an irrigated field of alfalfa. The unexpectedly cool shelter temperatures led to correspondence[2] between the ranch superintendent (Mr. Corkill) and Pacific Coast Borax Company executives containing an expression of disappointment that the official temperature measurements were considerably lower than expected. We speculate this conflict might have prompted Denton to inappropriately replace the official maximum temperatures with measurements taken from the poorly-exposed thermometer on the veranda.

George Willson, USWB forecaster at San Francisco was aware of the cooler readings made next to the irrigated field (Willson, 1915):

> *"The location for the instruments was carefully selected, the shelter being placed over an alfalfa sod, the floor about 4 feet above the ground, the shelter door facing north and about 50 feet from the nearest high object. The location is such that the shelter is not exposed to the reflected heat from the desert. Evaporation is excessive in this section and liberal irrigation is necessary to maintain plant life; hence, the cooling by evaporation from surrounding damp ground and live vegetation is probably sufficient to lower the readings of the instruments several degrees. Undoubtedly the temperature down in the desert bottom of the valley is much higher than it is at Greenland ranch."*

Willson's comments make it clear that the USWB shelter measurements were not representative of the natural desert conditions in Death Valley.

In the beginning of the USWB shelter measurements, it was ranch caretaker Thomas Osborn who was tasked with the daily observations. But the monthly climate forms indicate

[2] Much historical evidence of ranch correspondence and Denton's background and possible motivations not presented here has been compiled by co-author W.T.R.: https://stormbruiser.com/chase/2017/11/30/unravelling-death-valleys-134f-temperature-record-part-6-observer-oscar-a-denton/

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that Osborn only lasted for about twelve months, maybe through May of 1912 after which he contracted typhoid and died later that year. Tom Meston and Fred Corkill signed the forms "for Thomas Osborn" in June, July, and August of 1912. The highest temperature in 1912 at Greenland Ranch was a rather typical 120 °F. The form for September 1912 was signed by Oscar Denton. Thus, Denton served as caretaker, foreman, and weather observer at Greenland Ranch from September 1912 until February 1921, surviving eight summers there.

The anomalous behavior of the Greenland Ranch maximum temperatures culminated during the first two weeks of July 1913 when the excessively hot reports from 127 to 134 °F were recorded by Denton (see Figs. 4 and 5). The inconsistent and problematic nature of the early Greenland Ranch climate record suggests to us that Denton recorded some temperature data which did not come about through proper observing procedures. One of the authors (W.T.R.) has reviewed the original USWB monthly reporting forms in detail and found that many of the recorded "set max" temperatures during 1913 to 1915 were higher than the next day's T_{MAX}, unrealistic behavior which started upon Denton's arrival in October 1912. This suggests Denton was resetting the maximum thermometer more than once per day (against protocol), perhaps to make sure that the day's T_{MAX} did not reflect the conditions on the day before.

Alternatively, Denton could have been simply making up some of the entries. This was clearly the case in July of 1918 and July of 1920, when an unrealistically large number of temperatures were reported that were integer multiples of five: 22 of 31 days in July 1918 and 19 days of 31 days in 1920. These are by far the greatest number of such cases in any of the years from 1911 to 2024; the average for 102 years from July 1923 to July of 2024 was only 6.7 days out of 31 being multiples of five.

As further evidence of attempts to obtain temperatures less influenced by the irrigated alfalfa field, there are photographs (Fig. 7 a,b) suggesting the instrumented shelter was moved away from the irrigated field for an unknown period of time. The top two photos in Fig. 7 (circa 1920) obviously have natural vegetation to the west of the station rather than irrigated field. The station was then moved back next to the alfalfa field as evidenced by the March 1924 photo (Fig. 7c) and another photo from the mid-1920s (Fig. 7d). We surmise that Denton was seeking to obtain temperatures more in line with what ranch employees were accustomed to measuring on the living quarters veranda. Note that the rain gage does not appear in Fig. 7a, is to the east of the shelter in Fig 7b, but is to the west of the shelter in Fig. 7c and 7d. The apparent instrumentation moves are not reflected in the metadata for the

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Greenland Ranch site, nor were they mentioned in previous studies of Greenland Ranch measurements (e.g. Stacheski, 2013). There is no evidence that USWB representatives visited Greenland Ranch from the initial station installation in 1911 until a first visit in March 1924, so such station moves could have been done without their knowledge.

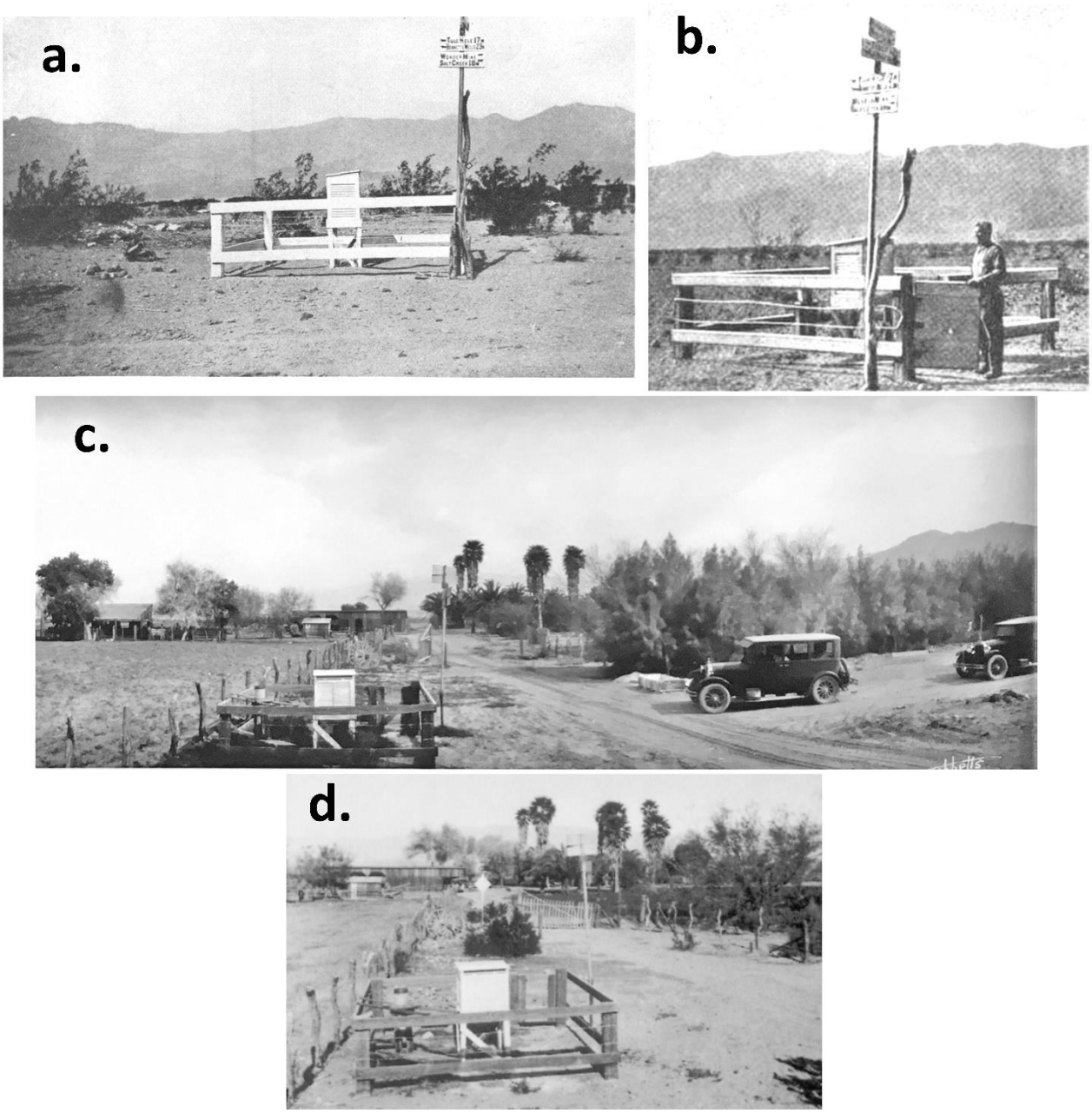

Fig. 7. Greenland Ranch instrumented shelter with unfenced natural vegetation to the west [(a) circa 1920 from Palmer (1922), and (b) looking southwest, with Oscar Denton, circa 1920-21 from Hogg (1922)], then returned to the original site next to a fenced and irrigated alfalfa field [looking north, (c) circa 1926-28 based upon the Dodge 126 sedans, and (d) 1926 photo from Bancroft Library, University of California, BANC PIC 1978.027-ALB].

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While we will likely never have a full explanation for the excessively hot summer temperatures recorded in the early years at Greenland Ranch, given the available evidence we surmise those temperatures did not originate from the USWB instrumented shelter, and instead might have been made on the living quarters veranda. We estimate from surrounding stations that the most likely temperature on 10 July 1913, if taken from a properly sheltered desert environment, would have been approximately 120 (+/- 2) °F, which is well below the 134 °F world record value. Furthermore, for a two-week period in early July 1913 temperatures likely averaged 8 °F cooler than those reported.

Summary and Conclusions

The meteorological setting of Death Valley in the summer allows temperatures there to be rather accurately estimated from surrounding stations which are exclusively at higher elevations. The unusually hot temperatures measured at Greenland Ranch in early July 1913 are shown to be inconsistent with temperatures at surrounding stations. Specifically, the 134 °F record temperature from 10 July 1913 was likely 12 °F to 16 °F hotter than what occurred, and temperatures during 2-18 July 1913 averaged 8 °F hotter than those estimated from surrounding stations.

Additionally, the fact that Death Valley temperatures have only recently attained 130 °F (in 2020 and 2021), and the early recognition (Willson, 1915) that there were not anomalous synoptic weather conditions in the region on 10 July 1913, support our conclusion of a large warm bias in the world record value. While it is the World Meteorological Organization (WMO, 2023) which officially establishes records for weather and climate extremes, we recommend that the world record status of the 134 °F temperature report be rescinded. We also recommend that many of the recorded temperatures from Greenland Ranch prior to 1930 be reviewed by NOAA and some flagged for poor data quality.

Why would such excessively hot temperatures be recorded? The ranch employees had expectations of hotter temperatures based upon widely circulated claims of 135 °F (or higher) temperatures as early as 1890 taken from the living quarters veranda. But the initial 1911 siting of the USWB instrument shelter in a location that was more oasis than desert produced substantially cooler daytime temperatures than the ranch caretakers were used to measuring, leading to correspondence regarding the unexpected (and even “disappointing”) cool temperatures in June and July of 1911.

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USWB shelter photographs at Greenland Ranch taken while Oscar Denton was the observer show the thermometer shelter at two different places: at the original USWB-chosen site along the eastern edge of an irrigated (and thus cooler) alfalfa field; and at a likely hotter site above bare ground with no indication of nearby farmland. Denton's apparent station move — undocumented in station metadata — and his note on the monthly climate form suggest to us that he was attempting to obtain hotter temperatures more in line with those measured by a thermometer (with unknown manufacture, calibration, or siting) on the ranch quarters veranda.

While the station move away from the irrigated field would not explain the excessively hot temperature measurements, especially those in the first two weeks of July 1913, they support a pattern of straying from proper observing protocol. Indeed, there might not have been well established protocols since there is no record of USWB personnel visiting Greenland Ranch either to install the USWB shelter or to train ranch employees. Their first documented visit there was not until 1924, at least 13 years after the shelter was installed. It is possible Denton simply moved the USWB thermometers from the shelter to the veranda for periods of time. Given the lack of documentary evidence, all of these explanations must be considered speculative. While the quantitative evidence we have provided should be sufficient to establish that many of the hottest temperatures at Greenland Ranch in the early years there are misreported, more evidence supporting our claims are from written correspondence and other data analysis not presented here, available at footnote 2, above.

The scenario we have outlined is consistent with the "illusory" nature (as it was characterized by L86) of much of the information coming out of Death Valley in the late 1800s and early 1900s, which maintained Death Valley's mystique in the minds of the public who were increasingly visiting Death Valley to experience the dangers there for themselves. We suggest that Greenland Ranch's early temperature record, despite the best intentions of the USWB, fell victim to Death Valley lore and illusion. We believe that Denton recording hotter temperatures than those indicated from the USWB instrument shelter helped give Death Valley the notoriety which he felt it deserved as hottest spot in the United States, if not the world.

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Data Availability Statement.

All data analyzed here are contained in a spreadsheet at https://github.com/roywspencer-nsstc/Death-Valley, including original GHCN daily (GHCNd) data publicly available from NOAA/NCEI and all calculations made from those data.

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