Actuarial Weather Extremes Series: Record-Setting Heat Across Three Continents in July 2023

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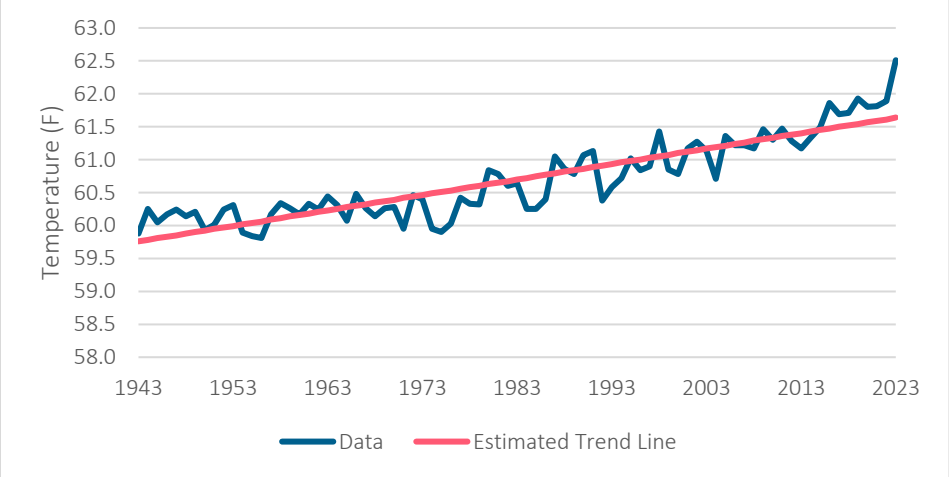
For the Earth as a Whole, July 2023 Was the Hottest July on Record

July 2023 was the hottest July on record according to data produced by the European Center for Medium-Range Weather Forecasts (ECMWF). Based on this data, the average worldwide temperature[1] across the earth's surface was 62.5F, which is 3.1 standard deviations above the historical average of 60.7F for the month of July computed across the period from 1940 to 2022:

Figure 1

AVERAGE WORLDWIDE TEMPERATURE COMPUTED ACROSS THE MONTH OF JULY



Data source: ERA5 dataset produced by ECMWF. Note that the data for July 2023 is preliminary and could potentially be revised.

[1] Please refer to the final section of this report for a description of the methodology used to calculate the worldwide average temperature.

Temperature Maps for July 2023

The ERA5[2] dataset produced by ECMWF is "gridded", meaning that data is available for geographic locations at regularly spaced intervals of latitude and longitude. The grid spacing for ERA5 is 0.25 degrees which translates into over one million grid points across the entire surface of the earth. The data is available both in hourly time units and in monthly averages. This report uses the monthly ERA5 data. Each observation in the monthly dataset is equal to the average hourly temperature (for a specific grid point) computed across an entire month. Note that the data for July 2023 is preliminary and could potentially be revised.

Using the gridded data, maps were created to illustrate which parts of the earth were most severely affected by unusually high temperatures in July 2023. These maps are available online:

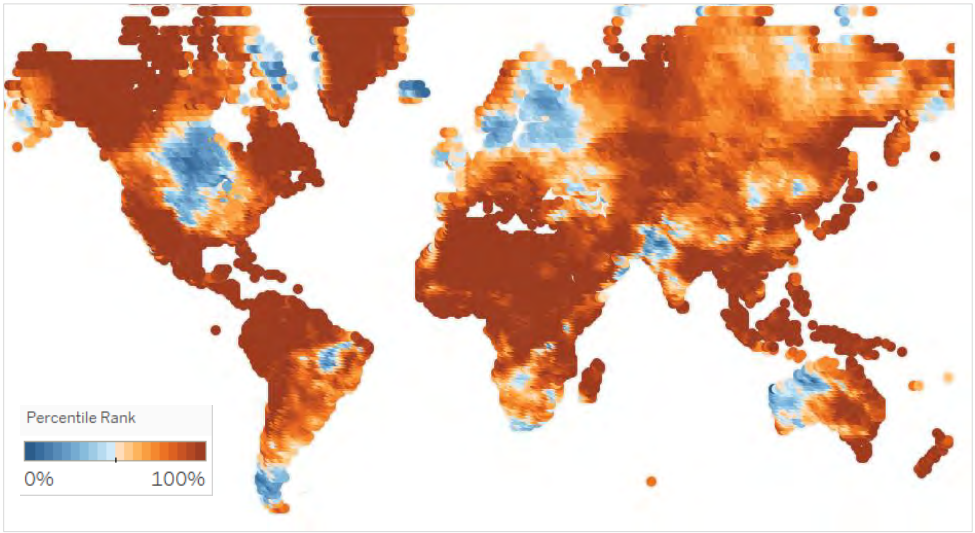
https://tableau.soa.org/#/site/soa-public/views/ERA5July2023TemperatureRanking_v2021_2/1PctRank?:iid=1

The upper lefthand corner of this Tableau visualization contains four tabs, providing access to four different color-coded maps of the temperature data, as follows:

1. A map that shows, separately for each grid point, the percentile ranking of the July 2023 temperature observation. This map is displayed below in Figure 2. A ranking of 100% indicates that the July 2023 temperature was a record-high relative to data for each July from 1940 through 2022. Conversely, a ranking of 0% indicates a record low. A ranking of "N" percent indicates that the July 2023 temperature falls at the Nth percentile of the 1940 to 2022 temperature observations.
2. A map that shows, separately for each grid point, the July 2023 temperature expressed in units of standard deviations above the 1940-2022 average temperature. A value of 2.5, for example, means that the July 2023 temperature was 2.5 standard deviations above the 1940-2022 average for July.
3. A map that shows, separately for each grid point, the July 2023 temperature minus the 1940-2022 average for July.
4. A map that shows, separately for each grid point, the July 2023 temperature.

Figure 2

PERCENTILE RANKINGS OF JULY 2023 MONTHLY AVERAGE TEMPERATURES

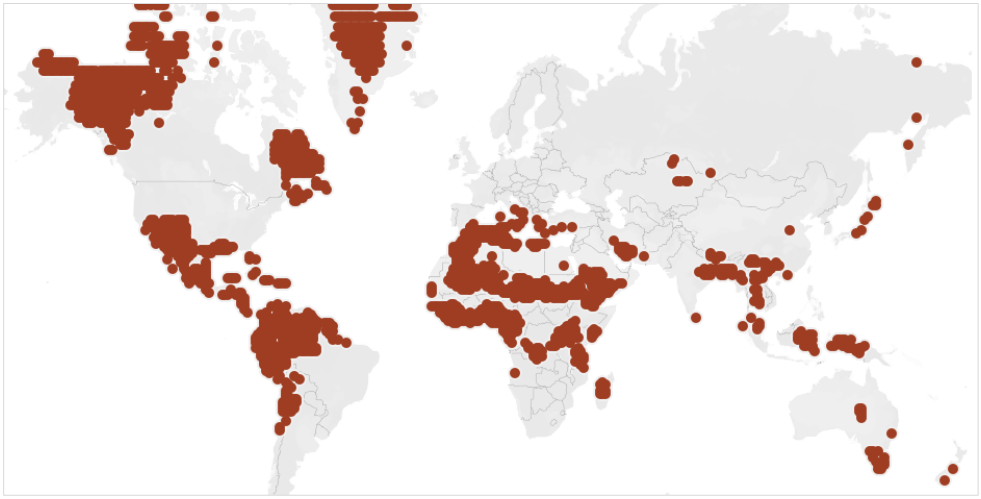


[2] https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels-monthly-means?tab=overview

Figure 2 reveals that large sections of North America, South America, and Africa experienced near-record or record-high temperatures in July 2023.

To focus on those locations with unusually high temperatures, each map is outfitted with a user-controlled filter. For example, map 1 has a filter that restricts the range of percentiles that are displayed. Figure 3 was generated by setting this filter such that only those grid points with record-high temperatures are displayed:

Figure 3
LOCATIONS FOR WHICH THE JULY 2023 MEAN TEMPERATURE WAS A RECORD-HIGH



Methodology for Computing the Worldwide Average Temperature

Figure 1 displays a time series of worldwide average temperatures for the month of July. Each data point in the time series was computed as a weighted average across all grid points in the ERA5 dataset (over both land and sea), using the cosine of each grid point's latitude as the weight.

ERA5 grid points are evenly spaced with respect to degrees latitude and longitude, but they are not evenly spaced when measured in miles or kilometers. As one approaches the poles, lines of longitude converge, reducing the distance between grid points. Consequently, an unweighted average across grid points would result in the overweighting of data near the north and south poles. The standard remedy used by climate scientists is to weight each data point by the cosine of its latitude. At the equator, the resulting weight is 1.0; at 45 degrees north or south, the weight is 0.71; at 60 degrees north or south, the weight is 0.50, declining rapidly to zero as one approaches either pole. Using cosine of latitude as the weights, the resulting weighted average correctly reflects the area between grid points.

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