Death Valley: world-beating temperatures, no sweat

Dear Sir, Madam

Death Valley: world-beating temperatures, no sweat.

On the 16th Aug, 2020 the weather station at the Furnace Creek Visitor Centre (California, USA) reached a scorching 54.4°C, the second highest annual maximum recorded at that site according to the Global Historic Climate Network (Menne et al., 2012; Figure 1). If this preliminary reading is confirmed, it will also be the highest reliably recorded air temperature on Earth since 1913 (Merlone et al., 2019). By adding to the narrative of increasingly dangerous heat as the planet warms, such extremes understandably capture the attention of the scientific (Aridi, 2020) and popular media (BBC, 2020). Indeed, Figure 1 highlights how annual maxima at Death Valley have risen with global mean air temperature since the 1970s.

However, air temperature is not necessarily the best indicator of our changing climate and human health implications; *total heat* is better. This is the sum of sensible and latent heat components. Air temperature is directly proportional to the former whereas the latter also depends on the amount of water vapour in the air. Humans *perceive total* heat because cooling via sweating becomes less efficient as latent heat rises (Matthews, 2018). Total heat can be converted to an *equivalent temperature*: the regular (dry bulb) temperature, plus the amount the air would warm if all the water vapour content condensed. By this measure, the values recorded at Furnace Creek on 16th August (maximum = 68.6°C) were *not* at all exceptional. In fact, on the same day, 304 stations in the Integrated Surface Database (ISD; Smith et al., 2011) reached a higher equivalent temperature (Figure 2).

The UK also endured an episode of prolonged hot weather in August 2020, but the maximum of 36.4 °C was considerably lower than the Death Valley peak (Figure 3). However, the gulf closes substantially if we consider *total* heat instead. Although only three ISD UK stations had published data at the time of writing, an equivalent temperature of 60.8°C occurred at Tibenham Airfield on the August 11, when the ERA5 reanalysis (Hersbach et al., 2020) suggests values climbed as high 65.1°C slightly further west (Figure 3). These values are, respectively, only 7.8 and 3.5°C lower than the peak equivalent temperature at Death Valley on the 16 August. The UK value narrows the gap because of much higher humidity, with a maximum dewpoint of 17.9°C at Tibenham on 11 August, compared to a peak value of 9.9°C in Death Valley on 16 August according to the ISD. The dryness of Death Valley is one of the

reasons that air temperatures at the site can rise so high: with no surface water to evaporate, all the available energy at the surface is converted into sensible heat.

Unfortunately, readers will not hear about equivalent temperature on the news, nor is the world record value well known. This should change because as greenhouse gas concentrations rise, the energy accumulating in the atmosphere comprises mainly sensible and latent heat (Peterson et al., 2011), and human modifications or natural changes to land surfaces can affect how that heat is divided. Reliance upon air temperatures may therefore overlook this build-up of energy (Pielke et al., 2004). For instance, irrigating a landscape can lower the near surface temperature, even if *total* heat content rises (Im et al., 2013)! Equivalent temperature is related linearly to total heat content, so provides a straightforward and complete way of tracking energy accumulation in the atmosphere as the climate changes.

Another benefit of equivalent temperature is that it helps reveal those communities at risk from heat stress because it relates to how human physiology keeps us cool. At high values (when we need to sweat), it behaves very similarly to measures used to communicate "how hot it feels", that are perhaps already familiar to readers -- like the Heat Index and Wet Bulb Globe Temperature (Matthews, 2018). The equivalent temperature reveals that the most extreme (total) heat is not found in the deserts of North America, but rather in the more humid climates of the Persian Gulf and Indo Gangetic Plain, with the highest value in ERA5 (113.6°C; Jan 1979-Aug 2020) found in Pakistan (Figure 4). In such locations, conditions can already exceed the theoretical upper limit of human heat tolerance (Raymond et al., 2020). To reflect this rising threat to human health, the almanac of weather extremes should include entries for equivalent temperature. Our attention should also be directed eastwards – out of the frying pan of Death Valley and into the fires of South and West Asia. These are the true frontlines in the battle against deadly heat.

Tom Matthews, Loughborough University, UK

Email: t.matthews@lboro.ac.uk
Contact number: 00441509222788

References

Aridi, R., 2020. Death Valley hits highest temperature since 1931 [WWW Document]. Science | AAAS. URL https://www.sciencemag.org/news/2020/08/death-valley-hits-highest-temperature-1931 (accessed 8.25.20).

BBC, 2020. “Highest temperature on Earth” recorded in US [WWW Document]. BBC News. URL https://www.bbc.com/news/world-us-canada-53788018 (accessed 8.25.20).

GISTEMP Team, 2020. GISS Surface Temperature Analysis (GISTEMP), version 4 [WWW Document]. NASA Goddard Institute for Space Studies. URL https://data.giss.nasa.gov/gistemp/ (accessed 8.25.20).

Hersbach, H., Bell, B., Berrisford, P., Hirahara, S., Horányi, A., Muñoz-Sabater, J., Nicolas, J., Peubey, C., Radu, R., Schepers, D., Simmons, A., Soci, C., Abdalla, S., Abellan, X., Balsamo, G., Bechtold, P., Biavati, G., Bidlot, J., Bonavita, M., Chiara, G.D., Dahlgren, P., Dee, D., Diamantakis, M., Dragani, R., Flemming, J., Forbes, R., Fuentes, M., Geer, A., Haimberger, L., Healy, S., Hogan, R.J., Hólm, E., Janisková, M., Keeley, S., Laloyaux, P., Lopez, P., Lupu, C., Radnoti, G., Rosnay, P. de, Rozum, I., Vamborg, F., Villaume, S., Thépaut, J.-N., 2020. The ERA5 Global Reanalysis. Quarterly Journal of the Royal Meteorological Society n/a. https://doi.org/10.1002/qj.3803

Im, E.-S., Marcella, M.P., Eltahir, E.A.B., 2013. Impact of Potential Large-Scale Irrigation on the West African Monsoon and Its Dependence on Location of Irrigated Area. J. Climate 27, 994–1009. https://doi.org/10.1175/JCLI-D-13-00290.1

Lenssen, N.J.L., Schmidt, G.A., Hansen, J.E., Menne, M.J., Persin, A., Ruedy, R., Zyss, D., 2019. Improvements in the GISTEMP Uncertainty Model. Journal of Geophysical Research: Atmospheres 124, 6307–6326. https://doi.org/10.1029/2018JD029522

Matthews, T., 2018. Humid heat and climate change. Progress in Physical Geography: Earth and Environment 42, 391–405. https://doi.org/10.1177/0309133318776490

Menne, M.J., Durre, I., Vose, R.S., Gleason, B.E., Houston, T.G., 2012. An Overview of the Global Historical Climatology Network-Daily Database. J. Atmos. Oceanic Technol. 29, 897–910. https://doi.org/10.1175/JTECH-D-11-00103.1

Merlone, A., Al-Dashti, H., Faisal, N., Cerveny, R.S., AlSarmi, S., Bessemoulin, P., Brunet, M., Driouech, F., Khalatyan, Y., Peterson, T.C., Rahimzadeh, F., Trewin, B., Wahab, M.M.A., Yagan, S., Coppa, G., Smorgon, D., Musacchio, C., Krahenbuhl, D., 2019. Temperature extreme records: World Meteorological Organization metrological and meteorological evaluation of the 54.0°C observations in Mitribah, Kuwait and Turbat, Pakistan in 2016/2017. International Journal of Climatology 39, 5154–5169. https://doi.org/10.1002/joc.6132

Peterson, T.C., Willett, K.M., Thorne, P.W., 2011. Observed changes in surface atmospheric energy over land. Geophys. Res. Lett. 38, L16707. https://doi.org/10.1029/2011GL048442

Pielke, R.A., Davey, C., Morgan, J., 2004. Assessing “global warming” with surface heat content. Eos Trans. AGU 85, 210–211. https://doi.org/10.1029/2004EO210004

Raymond, C., Matthews, T., Horton, R., 2020. The Emergence of Heat and Humidity Too Severe for Human Tolerance. Science Advances In press.

Smith, A., Lott, N., Vose, R., 2011. The Integrated Surface Database: Recent Developments and Partnerships. Bull. Amer. Meteor. Soc. 92, 704–708. https://doi.org/10.1175/2011BAMS3015.1

Figures

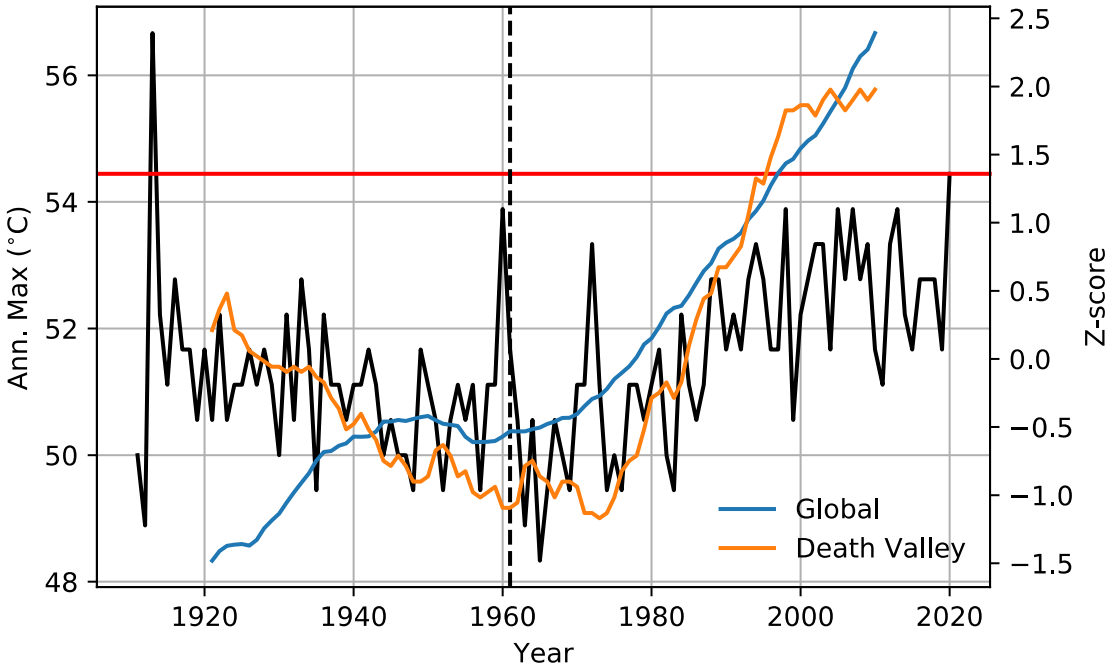

Figure 1. Annual maximum temperatures at the Furnace Creek, Death Valley (-116.877 °E, 36.462 °N) as taken from the ISD. Note that the station changed location slightly in 1961 (marked by the dotted line). The "global" temperature series is given as a smoothed with a 30-year average (GISTEMP Team, 2020; Lenssen et al., 2019). For comparability, both smoothed series were converted to z-scores by subtracting the (whole) period mean and dividing by the standard deviation.

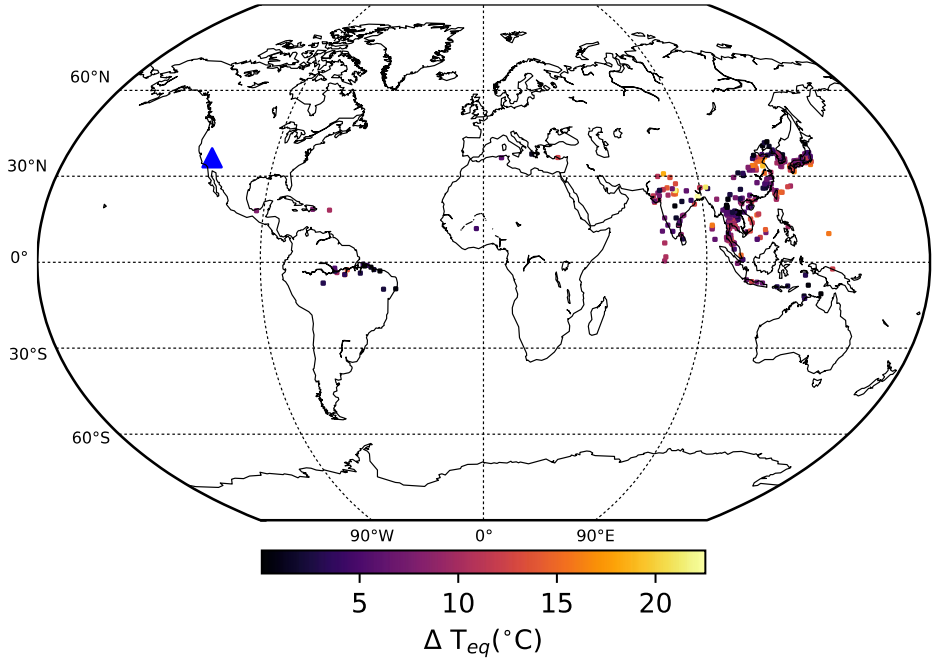

Figure 2. The difference between maximum equivalent temperature recorded at ISD weather stations and peak equivalent temperature at Furnace Creek, Death Valley on 16 August 2020 (blue triangle). Only stations with equivalent temperature exceeding those at Death Valley are plotted.

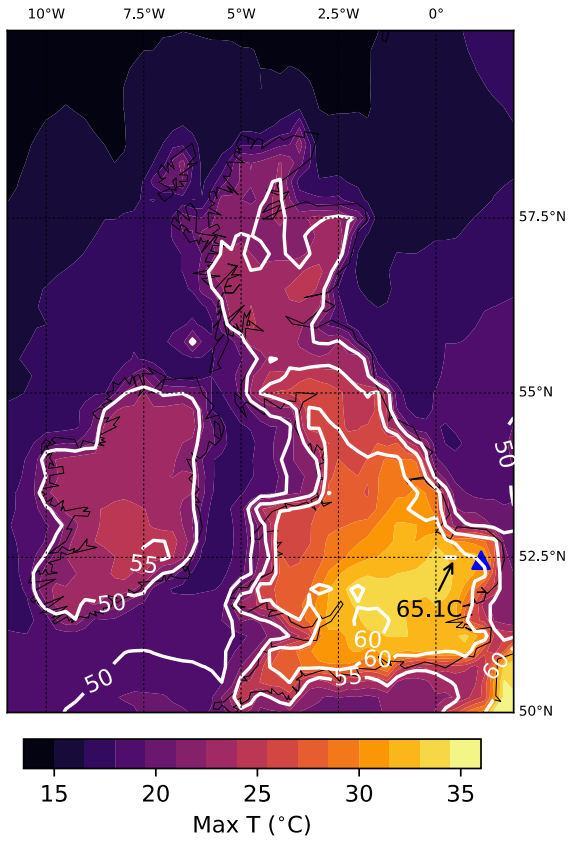

Figure 3. Maximum (2 m) air temperatures from the ERA5 reanalysis over 01-19 August, 2020. White contours show the maximum equivalent temperature over the same period, with the arrow and annotation highlighting the peak value. Note that only contours above 50°C are shown. The location of Tibenham Airfield (see text) is marked by the blue triangle.

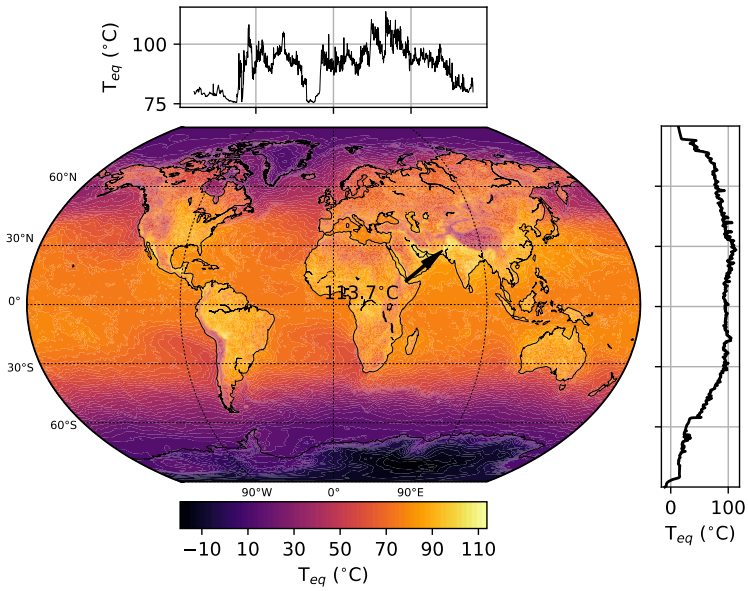

Figure 4. All-time maximum (Jan 1979-Aug 2020) equivalent temperature at each grid point in ERA5. The location (28.25°N,67.5°E) of the highest value worldwide (113.6°C; 7 July 2007) is annotated with the arrow. Inset plots show the maximum values as a function of longitude (top) and latitude (right).