

Evaluation and verification of new UK air temperature extremes during the July 2022 heatwave: part 2, minimum temperatures

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Evaluation and verification of new UK air temperature extremes during the July 2022 heatwave.

Part 2: minimum temperatures

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The July 2022 heatwave in the United Kingdom

The World Meteorological Organization seeks to encourage the objective evaluation and publication of national and international weather and climate extremes (see, e.g. WMO, 2023a; Merlone *et al.*, 2024). With this in mind, this paper sets out an objective examination ‘for the record’ into the circumstances and validity of the two new UK air temperature records established on 19 July 2022 – namely, the maximum temperature (hereafter Tmax) 40.3°C recorded at Coningsby in Lincolnshire in Part 1, and the 24h minimum temperature (hereafter Tmin) 26.8°C at Shirburn Model Farm in Oxfordshire in Part 2.

Synoptic background

The circumstances leading up to the brief but intense heatwave that affected the British Isles during 18–20 July 2022 have already been set out in Part 1, including the synoptic situation and physical causes of the high temperatures. Of particular importance in this analysis is the conditions in the lowest few hundred metres of the atmosphere over England, and accordingly, two upper-air ascents are shown in Figure 1(a) from Herstmonceux, on the south coast of England, and Figure 1(b) from Nottingham, in the north Midlands, both for 0000 UTC on 19 July (the Herstmonceux ascent also appeared as Figure 4 in Part 1). The very pronounced subsidence inversion around the European anticyclone evident on both plots ensured extremely stable conditions. As discussed in more detail subsequently, this ‘subsidence cap’ (or ‘heat dome’ as it became known in the media) limited the depth of both convective and turbulent mixing within the near-surface boundary layer, and in doing so, exerted considerable influence on surface temperatures, both by day and by night.

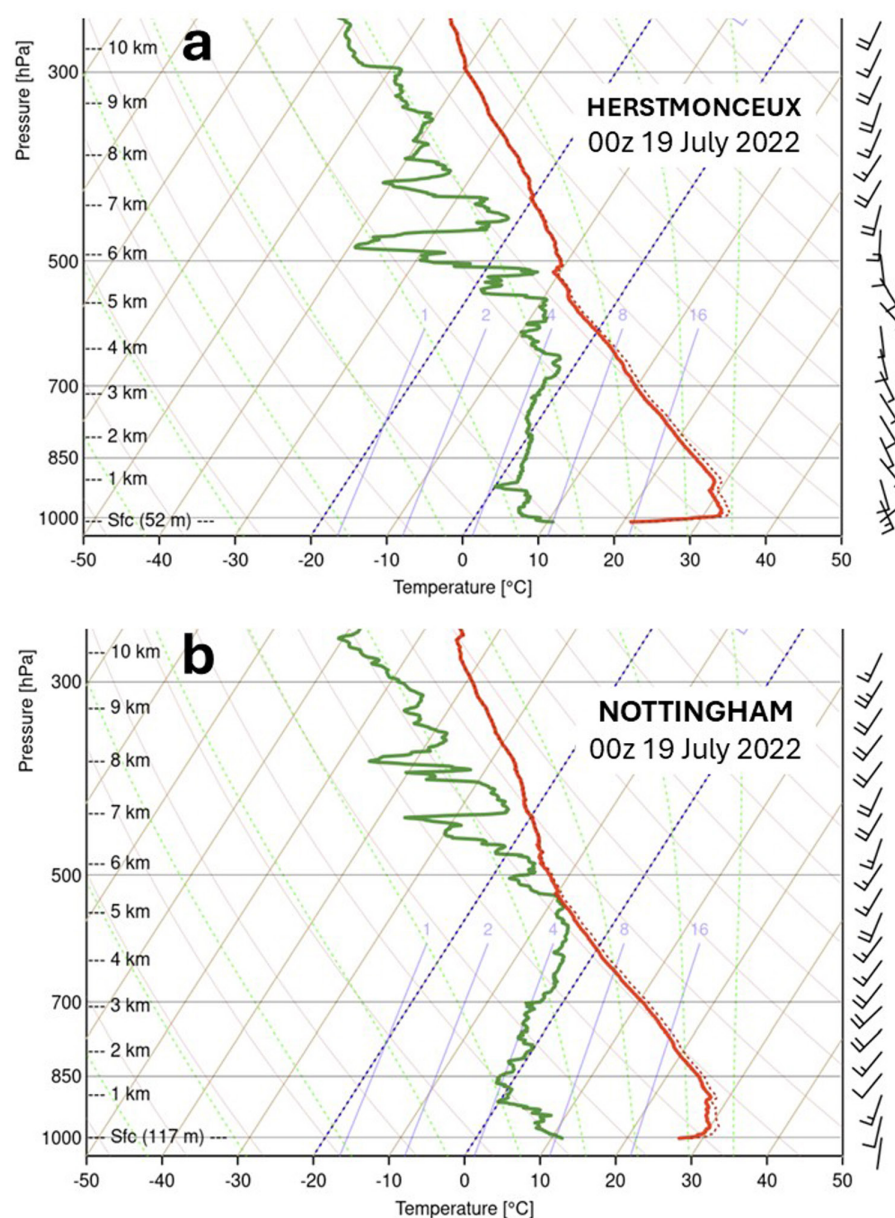


Figure 1. Upper-air ascents at 0000 UTC on 19 July 2022, to 10 km (300 hPa). The red line (to the right) shows the dry-bulb temperature; the green line (to the left) shows the dew point. Winds are shown in the right-hand margin in conventional notation. (a) Ascent from Herstmonceux (WMO no. 03882) on the south coast of England. The very sharp subsidence inversion evident between the surface and 300 m (980 hPa) was responsible for the very high minimum temperatures reported that morning from sites at even modest altitudes. The resulting very stable layer also inhibited the depth of convective mixing during daylight hours on 19 July, allowing surface temperatures to rise still further by limiting sensible heat exchange within the surface boundary layer. (b) As in Figure 1(a), but for Nottingham (03354) in the north Midlands. SkewT plots courtesy of www.rawinsonde.com/thunder_app/. (Figure 1a also appeared in Part 1, as Figure 4.)



Figure 2. Places referred to within the text.

Places referred to within the text are shown on Figure 2. Daytime temperatures, 18/19 July, have been covered in more detail in Part 1 and are not referred to further.

Overnight temperatures, 18/19 July 2022

Following the exceptional heat by day on 18 July, temperatures remained very high overnight in most places, with minimum temperatures of 18–20°C quite widely. Figure 3 shows reported minimum temperatures for the 24h ended 0900 UTC 19 July 2022.¹ The distribution is irregular, with sometimes very large variations between sites only a few kilometres apart, and this characteristic is examined more closely in this section. In particular, numerous high-altitude sites in England recorded extraordinarily high temperatures during the early hours on 19 July, and these are briefly commented on.

Figure 4 shows hourly temperatures 18/19 July at two sites in southeast England – Charlwood in Surrey (altitude 67m amsl) and Kenley Airfield in Greater London (altitude 170m). Kenley lies 19km northeast of Charlwood. The 24h 09–09h UTC Tmin at Charlwood was 14.9°C, but at Kenley it was 25.8°C. The reason for this extraordinary difference, and indeed the most unusual prevalence of high minimum temperatures at even modest altitudes, is evident from the midnight ascent from Herstmonceux on the south coast of England (Figure 1a). A very marked subsidence inversion saw temperatures rise from 21°C at the surface (52m

¹For comparison, except where stated otherwise all quoted values refer to the 24h period ending at 0900 UTC on 19 July; some values quoted during this spell referred instead to the overnight (21–09h UTC) Tmin – where the temperature at 0900 UTC on 18 July was somewhat lower, and thus remained as the 09–09h UTC Tmin.

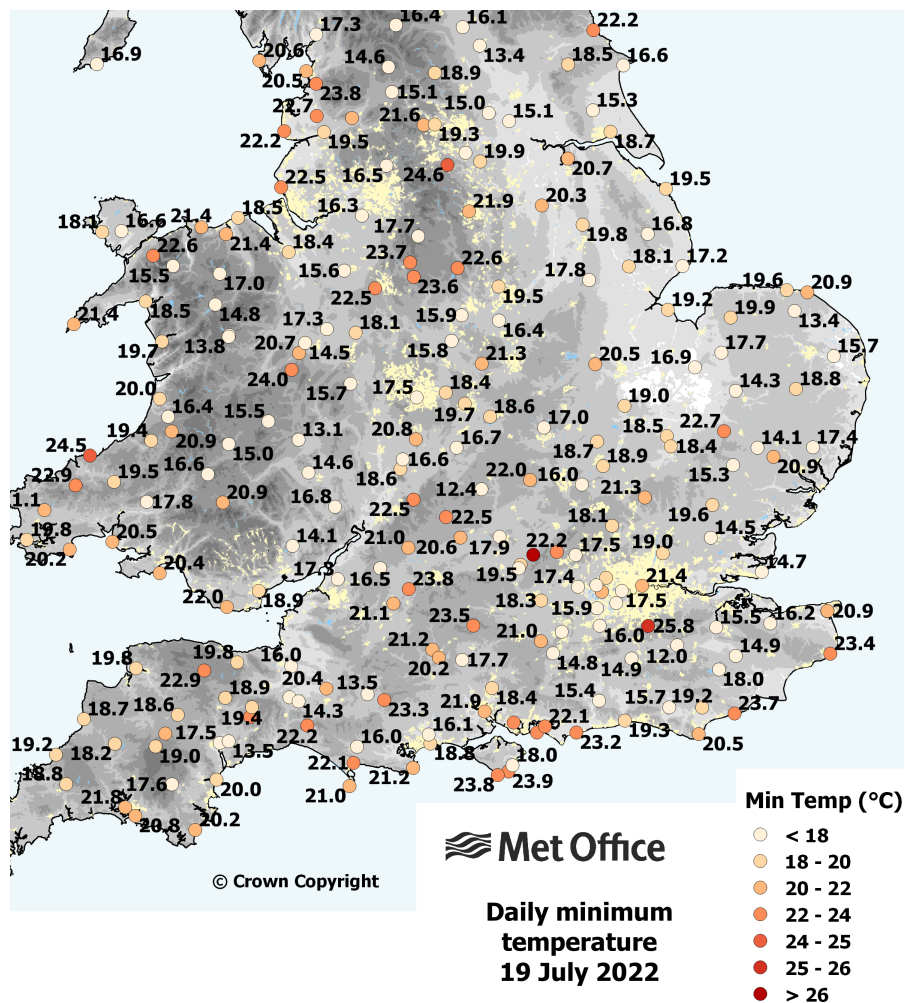


Figure 3. Map of 24h 0900–0900 UTC Tmin on 19 July 2022. (Source: UK Met Office National Climate Information Centre.) (©Crown.)

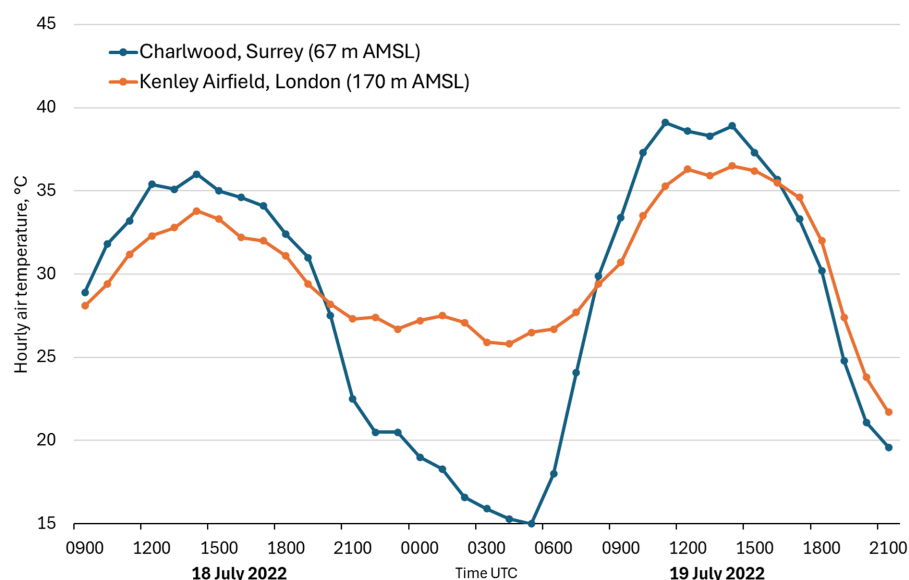


Figure 4. Hourly air temperatures, °C, at Charlwood, Surrey (WMO no 03769, 51.144°N, 0.229°W, altitude 67m amsl) and Kenley Airfield, Greater London (WMO no. 03781, 51.304°N, 0.091°W, altitude 170m), for the period 0900 UTC 18 July to 2100 UTC 19 July 2022. Tmin for the 24h ending 0900 UTC 19 July was 14.9°C at Charlwood, but 25.8°C at Kenley, less than 20km distant. (Source: synoptic messages.)

amsl) to 32°C just 140m above the launch site (195m amsl), remaining at this level for over 100m, declining only slowly to 29°C

at 1000m amsl. At the altitude of Kenley Airfield (170m), the ascent indicated a 'free air' temperature at this time of 32°C (com-

Table 1

The highest 24h (09–09h UTC) minimum temperatures observed in the UK during summer 2022, ranked, together with previous site records. All those from summer 2022 occurred on 19 July.

Station	Altitude (m)	First year of record	Highest Tmin summer 2022 (°C)	Previous highest Tmin ^a (°C)	Date of previous highest
Shirburn Model Farm (Oxfordshire)	108	1968	26.8	22.0	6 Aug 2003
Kenley Airfield (Greater London)	170	1989	25.8	21.6	2 Aug 1990
Emley Moor (West Yorkshire)	267	2011	24.7	18.6	1 Oct 2011
Aberporth (Dyfed)	133	1941	24.5	20.5	8 Sept 2021
Pennerley (Shropshire)	357	1988	24.0	19.1	20 July 2016
Ventnor Park (Isle of Wight)	60	1959	23.9	23.2	10 Aug 2003
Hazelrigg (Lancs)	95	1976	23.8	21.1	3 Aug 1990
Lyneham (Wiltshire)	145	1957	23.8	19.5	11 Aug 1997, 20 July 2016 and 12 Aug 2020
St Catherine's Point (Isle of Wight)	20	1924	23.8	22.4	3 Aug 1990
Leek, Thorncliffe (Staffs)	298	2002	23.7	20.0	20 July 2016
Hastings (East Sussex)	45	1930	23.7	23.5	4 Aug 1990

^aHighest Tmin prior to July 2022; Emley Moor also recorded 19.0°C on 12 July 2022.

Source: Met Office National Climate Information Centre.

pare Kenley Airfield's temperature at mid-night of 27°C, Figure 4). From Figure 1(a), it is evident that, for locations in southern and southeast England at least, the very pronounced increase in temperature with height would result in the highest temperatures being recorded at altitude. (Also notable on the Herstmonceux ascent, although not plotted on Figure 1(a), was a strong nocturnal jet at the level of the inversion – on the ascent shown, the wind at 992hPa, 170m above ground level, was 138°, 23kn – compared with 051°, 1kn at the surface.)

An even greater difference occurred between two sites in south Oxfordshire. At Benson (WMO no. 03658, 51.620°N, 1.098°W, 62m amsl) Tmin on 19 July was 19.5°C; just 9km distant to the northeast, on the slopes of the Chilterns, Tmin at Shirburn Model Farm (51.667°N, 0.983°W, 108m amsl) was 26.8°C, a new UK record; the circumstances of this latter value are examined in more detail subsequently. If it is assumed, from both the midnight Herstmonceux ascent and that from Larkhill at 0600 UTC 19 July (not shown), that overnight temperatures increased with height up to several hundred metres, then there is an intriguing possibility that overnight temperatures on the highest points in southeast England (for instance, Leith Hill in Surrey, 295m amsl or Walbury Hill in Berkshire, 297m) may not have fallen much below 28°C. Table 1 lists the highest 09–09h Tmin values recorded during summer 2022 – all occurred on 19 July. The predominance of stations at relatively high altitudes in this list is very noticeable – of the 11 locations listed,

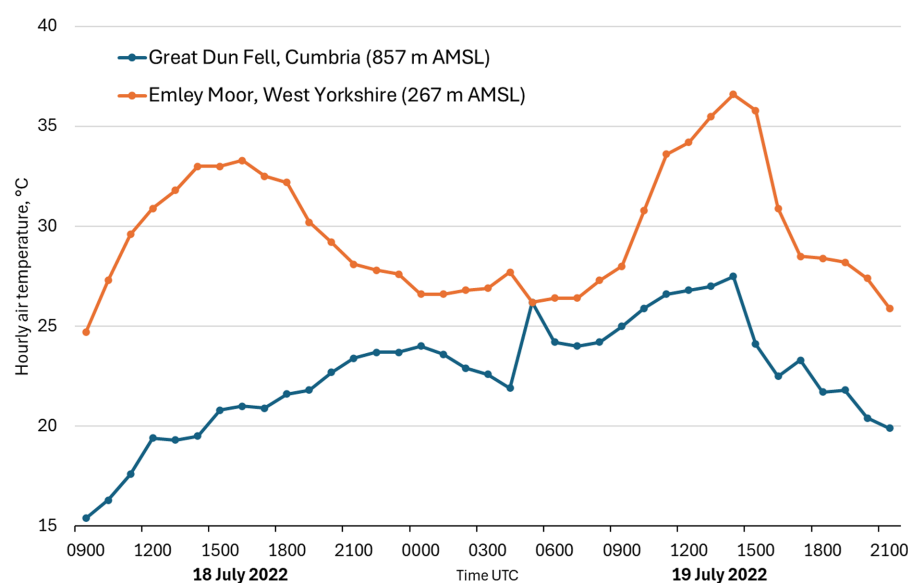


Figure 5. Hourly air temperatures, °C, at Great Dun Fell in Cumbria (WMO no. 03227, 54.684°N, 2.451°W, 847m amsl, the highest synoptic reporting station in England) and Emley Moor, West Yorkshire (WMO no. 03346, 53.670°N, 1.667°W, 267m amsl) for the period 0900 UTC 18 July to 2100 UTC 19 July 2022. Tmin for the 12h ending 0900 UTC 19 July was 21.4°C at Great Dun Fell and 25.9°C at Emley Moor (0900–0900 UTC values were 15.4 and 24.7°C respectively). (Source: synoptic messages.)

the average altitude is 154m, which is close to the 90th percentile of climatological station altitudes in England (164m). The ongoing maintenance of a good network of observing locations across the UK is vital to ensure that – as far as reasonably possible – representative observations continue to be available from all areas, including upland locations.

The Shirburn value surpassed the UK's previous highest 24h Tmin (23.9°C, at

Brighton in East Sussex on 3 August 1990 – Burt, 1992) by almost 3K, while numerous previous site records were also surpassed by margins of 3–5K (Table 1). The highest 24h Tmin during the prolonged August 2003 hot spell was 23.2°C at Ventnor on the Isle of Wight on 10 August (Burt, 2004). Both values were widely exceeded during July 2022, while a new national high Tmin record was established for Wales (24.5°C at Aberporth,

Table 2

Hourly observations from Great Dun Fell in Cumbria (WMO no. 03227, the highest synoptic reporting station in England) and Emley Moor, West Yorkshire (WMO no. 03346) for the period 2100 UTC 18 July to 0900 UTC 19 July 2022.

Date	Report time UTC	Wind direction (°)	Wind speed (kn)	Dry bulb (°C)	Dew point (°C)	Relative humidity (%)
Great Dun Fell 54.684°N, 2.451°W, 847m amsl						
18 July	2100	220	14	23.4	5.0	30
	2200	210	17	23.7	6.0	32
	2300	200	20	23.7	7.8	36
19 July	0000	210	17	24.0	8.9	38
	0100	210	17	23.6	9.4	41
	0200	200	16	22.9	8.1	39
	0300	210	21	22.6	9.6	43
	0400	210	21	21.9	10.0	47
	0500	200	17	26.2	2.9	22
	0600	200	20	24.2	5.2	29
	0700	210	16	24.0	4.8	29
	0800	190	17	24.2	7.4	34
	0900	190	19	25.0	6.7	31
			21–09h min	21.4°C		
Emley Moor 53.670°N, 1.667°W, 267m amsl						
18 July	2100	170	05	28.1	8.8	30
	2200	120	05	27.8	8.8	30
	2300	170	04	27.6	8.4	30
19 July	0000	210	06	26.6	9.7	34
	0100	190	10	26.6	10.5	36
	0200	200	09	26.8	9.9	34
	0300	230	07	26.9	8.4	31
	0400	230	09	27.7	5.5	24
	0500	130	06	26.2	6.0	27
	0600	100	05	26.4	8.2	32
	0700	160	03	26.4	9.8	35
	0800	120	04	27.3	11.4	37
	0900	110	06	28.0	13.4	41
			21–09h min	25.9°C		

Note: See also Figure 5.

Ceredigion) – see Figure 2 for site locations. The previous Welsh record had stood since 1948 (22.2°C at Victoria Park in Swansea, West Glamorgan on 29 July). The reported Tmin 21.3°C at Nunraw Abbey, East Lothian on 19 July, which would otherwise have established a new Scottish record, was not accepted as valid following an unsatisfactory Met Office inspection visit a few days after the event. The Scottish Tmin record remains 20.9°C at Achnagart, Highland on 26 July 2019.

The very sharp inversion shown on the Herstmonceux ascent for 0000 UTC on 19 July (Figure 1a) was also apparent further north. The Nottingham ascent for the same time (Figure 1b) showed an increase in temperature from 27°C at the surface (117m amsl)

to 30°C at 360m amsl, again with a marked low-level nocturnal jet (194° 20kn at 300m amsl, 188° 3kn at the surface). In northern England, overnight temperatures at altitude also remained extraordinarily high, at levels infrequently attained in daytime conditions. Figure 5 shows hourly temperatures at Great Dun Fell in Cumbria (847m amsl, the highest synoptic reporting station in England, Figure 2) and at Emley Moor, West Yorkshire (267m amsl); temperatures and wind direction and speed at both sites are given in Table 2. At Great Dun Fell, the overnight (21–09h UTC) minimum was an unprecedented 21.4°C – the 09–09h UTC Tmin was 15.4°C, being the temperature at 0900 on 18 July. At 0500 UTC, the temperature here stood at 26.2°C, dew point 2.9°C, relative humidity

just 22% – although there is a possibility the 0500 UTC values represent an artefact of Great Dun Fell's necessarily non-standard air temperature measurements. On a daily record (with some gaps) commencing in 1958, the previous highest overnight Tmin at this site was 17.2°C, on 12 July 2005. (Tmax at this site on 19 July 2022 was 27.5°C, some way below the highest on record, viz. 31.9°C on 5 August 2003). At Emley Moor, the 21–09h UTC Tmin on 19 July was 25.9°C, the 09–09h UTC value being 24.7°C at 0900 on 18 July. (Tmax at this site on 19 July was 36.8°C, well in excess of any previous recorded temperature on a record from 1971.) It is remarkable that even the 24h Tmin on this remote upland moor itself exceeded the previous all-time UK highest Tmin by almost a degree.

How reliable is the Shirburn Model Farm 24h Tmin of 26.8°C recorded on 19 July 2022?

The more formal internal review established by the Met Office to investigate and validate various categories of meteorological extremes, known as the Site Weather Assessment Team or SWAT process, has already been described in Part 1 (Burt, 2025). The sections that follow have been structured in the same manner as the Met Office internal SWAT report relating to the Tmin reported from Shirburn Model Farm, and relevant factual information has been extracted from that report where appropriate.

Stage 1: The synoptic situation – is the occurrence of the proposed record feasible given the season and synoptic situation?

The background to the event has previously been set out in Part 1, and is not repeated here, but it is clear that high minimum temperatures could be anticipated in the night following the almost unprecedented high daytime Tmax on 18 July. In addition, the strong subsidence inversion evident on the midnight Herstmonceux ascent (Figure 1a) suggests that overnight temperatures could be expected to increase with altitude in certain locations.

Stage 2: The station's geographical situation – given the synoptic situation, would a potential record be feasible from such a location?

As previously outlined, the distribution of 24h minimum temperatures to 0900 UTC that morning was highly variable (Figure 3), with sometimes very large variations between

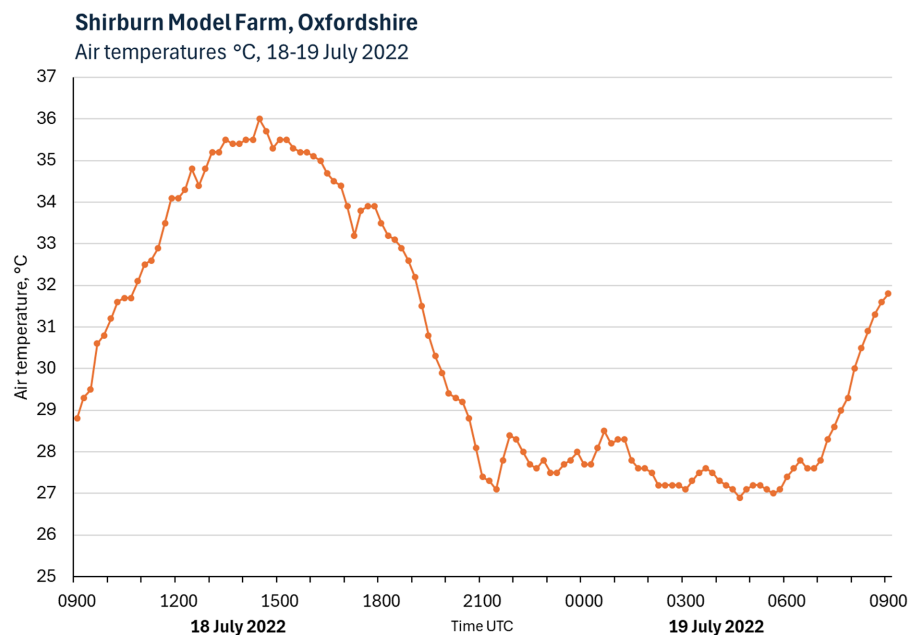


Figure 6. Air temperature record, 1min means logged at 12-min data intervals, from the Vaisala HMT333 logger installed in the screen at Shirburn Model Farm in Oxfordshire, for the 24h period commencing 0900 UTC 18 July 2022. The 09–09h Tmin recorded on this instrument, 26.8°C at 0440 UTC, agreed with that indicated on the alcohol minimum thermometer in the same screen. Just 9km to the southwest, Tmin that morning at Benson (only 9km distant, 67m amsl) was 19.5°C. See also Figure 7.

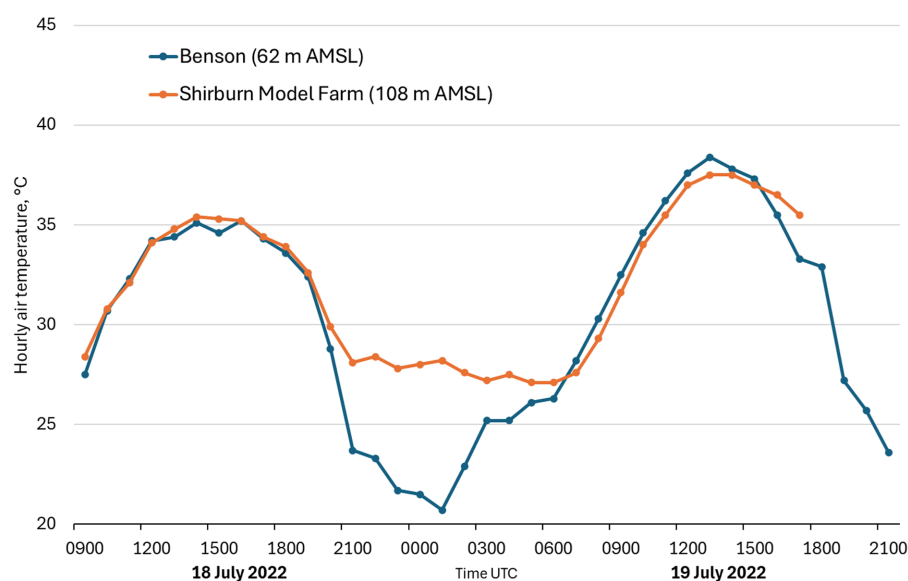


Figure 7. Hourly air temperatures, °C, at Benson in Oxfordshire (WMO no. 03658, 51.620°N, 1.098°W, 62 m amsl) and nearby Shirburn Model Farm (51.667°N, 0.983°W, 108m amsl) for the period 0900 UTC 18 July to 2100 UTC 19 July 2022. Tmin for the 24h ending 0900 UTC 19 July was 19.5°C at Benson, 26.8°C at Shirburn Model Farm. (Source: Benson data from synoptic messages, Shirburn Model Farm from in-screen Vaisala logger - see also Figure 6.)

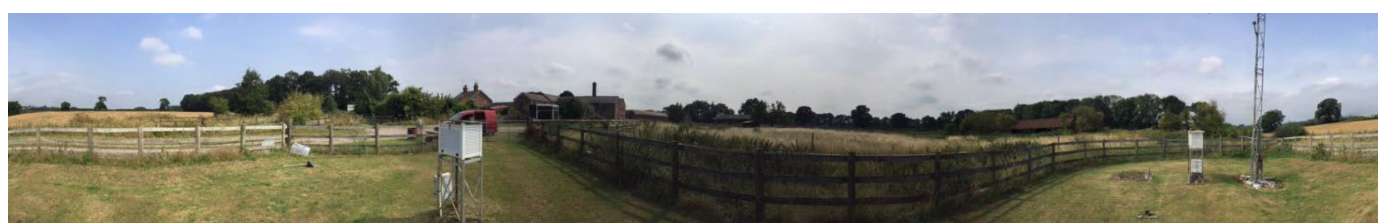


Figure 8. The site and instruments at Shirburn Model Farm, Oxfordshire, photograph taken in early August 2022. (©Crown.)

neighbouring sites that might normally have been expected to record broadly similar values. However, as previously outlined, the strong low-level inversion apparent on Figure 1(a) made it highly likely that temperatures would increase with altitude in some places. Despite the relatively minor difference in altitude between Benson and Shirburn (62m vs 108m), the latter lies less than 3km distant from Shirburn Hill (255m amsl) on the northern slope of the Chiltern Hills, and thus immediately downwind in the brisk south or southeasterly breeze evident at that level on the Herstmonceux midnight ascent (see Figure 1a). The upper slopes of the Chilterns, including Shirburn Hill, would have protruded well into the inversion, and turbulent mixing with warmer air at higher levels and entrainment to lower levels could be expected. Given its situation in such circumstances, a high Tmin at Shirburn Model Farm could not be ruled out.

Stage 3: Evidence of the occurrence/data

Tmin at the site was read manually from an alcohol-in-glass thermometer. The observer noted that the reading was very high but confirmed it had been carefully checked. The regional network inspector confirmed that the observer is both very competent and experienced. In addition, a Vaisala HMT333 logger housed in the same screen confirmed Tmin 26.8°C occurred just before 0440 UTC. Sunrise at the site was at 0408 UTC. Fortunately, the Vaisala logger also logged temperatures five times per hour (12-min data interval), and these are plotted for the 24h commencing 0900 UTC 18 July 2022 in Figure 6; the lowest logged temperature was 26.9°C at 0439 UTC. This record has not previously been published. Hourly temperatures extracted from this record are also plotted alongside those reported from Benson (9km distant, 40m lower in altitude) in Figure 7. The sharp cessation of evening cooling just after 2100 UTC is very pronounced, as is the remarkable 28.5°C logged at 0039 UTC.

Stage 4: Record quality considerations

The quality of the record – are the data from this site usually high quality and reliable? Have there been any quality flags placed on the data that would cause us to reconsider its use?



Figure 9. The interior of the thermometer screen at Shirburn Model Farm, Oxfordshire, showing the instruments: photograph taken in early August 2022. (©Crown.)

Records commenced at this site in 1969 and are of consistent high quality, with 99% of data in the previous 12 months unchanged.²

Stage 5: Risks of interference at the site?

The site is on private land, and interference would be unlikely – particularly in the early hours of the morning.

Stage 6: Details of the sensor(s) and exposure

As with the Coningsby record described in Part 1 (Burt, 2025), a Met Office regional inspector visited shortly afterwards (early August 2022) to review possible external influences on the site or exposure of the instruments that may have influenced the site's records. Figure 8 shows a view of the site at Shirburn Model Farm, while Figure 9 shows the screen interior; the back of both the alcohol thermometer and the Vaisala logger, together with (non-Met Office) dry and wet bulb PRTs, can be seen. The screen and thermometers were in good order and configured correctly.

At the inspector's visit, both the alcohol minimum thermometer and the Vaisala PRT were checked against a travelling standard, resulting in a <0.1K discrepancy in both instances. The alcohol minimum thermometer had been calibrated in the Met Office QA laboratory on 26 November 2019, the calibration remaining

²At the time of submission, the observations from this site were missing from the CEDA archive for the entirety of summer 2022 (June, July and August). This gap was queried with the Met Office QC team, but at the time of going to press (February 2025) no reason for the omission had been given.

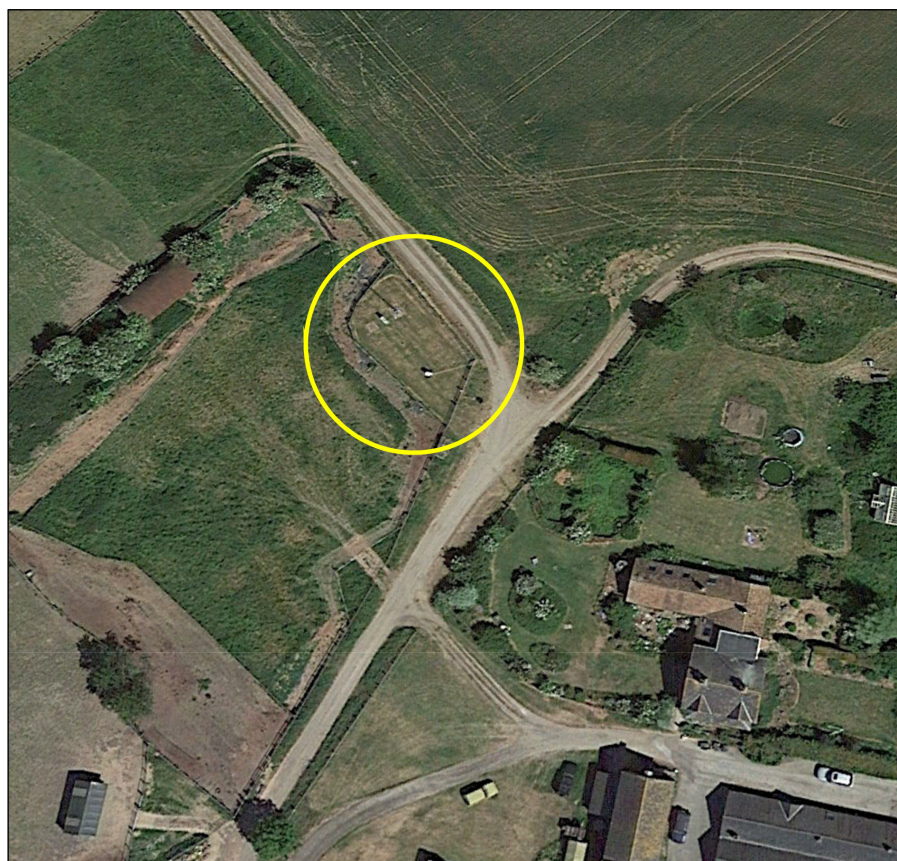


Figure 10. Google Earth image showing the location of the Shirburn Model Farm met enclosure (circled in yellow). North is at the top of the image.

valid for 5 years. Accordingly, there are no valid objections to the extreme on the grounds of incorrect sensor calibration.

The site itself is fairly open, but a line of trees to the northeast and a gravel track running past the enclosure act to increase the CIMO rating, and the site is rated as 'CIMO class 4' (WMO, 2023b: see table 3 in Part 1 for details of the CIMO scale). Figure 10 shows a Google Earth aerial view of the site, with the met enclosure circled in yellow. The CIMO site classification arises primarily from the proximity of non-natural surfaces around the site, primarily the nearby gravel track. These were assessed as 0% non-natural surfaces within 3 m of the screen, 5% within 10m, 12% within 30m and 6% within 100m; CIMO class 3 mandates <10% within 10m radius of the screen and no shade on the screen itself with solar altitudes >7°. While the nearby gravel track might be expected to retain some heat from the warmth of the previous day (Tmax at the site 36.0°C), it is unlikely that this would have significantly influenced the observed Tmin at the site.

Stage 7: Observer reliability and competence

As stated above, the observer's competence was not in question. The network inspector's final comment was 'I have no issues

with the exposure of this site and would be happy to accept the readings from there.' Together with the evidence from the Vaisala logger in the screen (Figure 6), there are no reasons to doubt the record.

Summary: SWAT evaluation

Following detailed consideration of each of the points in turn, the internal Met Office SWAT committee was satisfied that the observed record was genuine (although it is surprising that no reference was made in that report to the pronounced temperature inversion and its likely impact upon the site's overnight temperatures). The value was therefore formally accepted as a new UK Tmin record and duly announced in a Met Office press release on 22 August 2022 (Met Office, 2022a). The original (undated) SWAT report is available online (Met Office, 2022b, undated, and part redacted).

Climatological context of the highest minimum temperatures on 19 July 2022

The climatological context of the highest minimum temperatures recorded on 19 July 2022 (Table 1) has been outlined, including the establishment of many new site

records, together with new national records in England, Wales, and for the UK as a whole.

Summary and conclusions

The brief but very intense heatwave that affected the British Isles in July 2022 was of historical climatological significance, in which new UK extremes of daily maximum and minimum temperature were established; previous records were surpassed by very considerable margins, both at national and at individual site levels.

Acknowledgements

A considerable amount of source material for this analysis derives from work undertaken in the Met Office, specifically internal team members contributing to the SWAT reports seeking to evaluate and promptly verify the various extremes of temperature resulting from this event. Particular thanks are due to Mike Kendon from the National Climate Information Centre, who kindly provided Figure 3 and data from which Figures 6 and 7 were prepared. I am grateful for access to these materials, without which this paper would have been incomplete.

Conflict of interest statement

The author declares no conflict of interest.

Data availability statement

No new datasets were created during this analysis. Synoptic data were obtained through ogimet.com, and background climatology via the Natural Environment Research Council's CEDA archive at <https://archive.ceda.ac.uk/>.

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