Met Office
Hadley Centre

HadCET v2.1.0.0

Release Notes, July 2024

Overview

This document summarises the recent improvements to the CET dataset as part of this minor release.

This includes an improvement to the production process to allow for an annual refresh of the previous year's daily and monthly series values using quality-controlled station data – see link.

The V2.1.0.0 release also corrects daily and monthly values for minor clipping errors erroneously applied to station mean temperature values up to the end of 2020. Due to the way in which the CET series is constructed, these erroneous values had an impact on the full mean temperature series as well as the maximum and minimum temperature series.

As part of the new release, the source CET station temperature data will also be made available via the data download page. These files containing mean/minimum/maximum temperature observations will be updated daily alongside the series with provisional data and refreshed annually with quality controlled data as part of the new annual release cycle.

Furthermore, the CET seasonal and annual averaged temperature values will be returned to a higher level of precision, with averaged values to hundredths of a degree instead of tenths of a degree as is the case currently. This allows for more granularity in the ranked series. For example, 2022, the warmest year on record in CET, can now be distinguished from the second warmest year whereas previously these were both tied on 11.1C.

Finally, the tables on the CET data download page containing the monthly/seasonal/annual rankings will be updated to rank the periods from warmest to coldest as opposed to coldest to warmest.

The magnitude of these changes on the CET daily and monthly series is small and well within the uncertainty range for the series as described by David Parker and Briony Horton in their 2005 paper.

Met Office
Hadley Centre

1. Summary of changes

Following recent development work, the CET daily series between 1853 and 2020 was found to have been calculated using station mean temperature values with the second decimal place digit truncated. This rounding error also occurred on the rural station mean temperatures used as part of the urban adjustment calculations.

In most cases, the issue was due to a truncation of the second decimal place digit as opposed to a rounding error, which resulted in the mean temperature values used being below the observed value. In the remaining cases, the issue was due to the mean temperature being rounded to one decimal place.

Due to the way in which the CET temperature series are generated, with minimum and maximum temperature series adjusted back to the mean temperature series, this correction resulted in many daily and monthly values being changed in this latest release (v1.2.0.0).

However, the magnitude of the correction was minor across the daily and monthly series, as is summarised below:

Daily

- Mean CET: 50,246 (54%) changes to the series up to and including the end of 2023 (92,041 values)
    - 99% of value changes within 0.1C, with the remaining 1% within 0.2C
    - 60% of the changes resulted in an increase in the daily temperature.

- Min CET: 41,698 (78%) changes to the series up to and including the end of 2023 (53,325 values)
    - 94% of value changes within 0.1C, with the remaining 6% within 0.2C
    - 65% of the changes resulted in an increase in the daily temperature.

- Max CET: 41,201 (77%) changes to the series up to and including the end of 2023 (53,325 values)
    - Over 99% of value changes within 0.1C, with the remaining 1% within 0.2C
    - 56% of the changes resulted in an increase in the daily temperature.

Monthly

- Mean CET: 569 (13%) changes to the series up to and including the end of 2023 (4,380 values)
    - 97% of value changes within 0.1C, with the remaining 3% within 0.2C
    - 85% of the changes resulted in an increase in the monthly temperature.

- Min CET: 586 (33%) changes to the series up to and including the end of 2023 (1,752 values)
    - 89% of value changes within 0.1C, with the remaining 11% within 0.2C
    - 90% of the changes resulted in an increase in the monthly temperature.

- Max CET: 587 (33%) changes to the series up to and including the end of 2023 (1,752 values)
    - 100% of value changes within 0.1C
    - 66% of the changes resulted in an increase in the monthly temperature.

Met Office
Hadley Centre

2. Station Mean Temperature correction

The correction to the source CET station mean temperature values was applied to all records between 1853 and 2020 and to rural CET station values for the period for which these stations are used to calculate the urban adjustments between 1959 and 1989.

However, since some adjustments are calculated for different periods and applied to all recent values, these changes impacted all series values after 1853 when the CET V2 series temperatures were derived directly from the station temperatures.

In most cases, the 0.05C error in station temperatures was caused by the truncation of the second decimal point digit after the mean temperature was calculated from minimum and maximum temperatures. For example, a mean temperature calculated from a minimum temperature of 3.0C and a maximum temperature of 10.5C would yield a mean temperature of 6.75C but be truncated to 6.7C in the series value calculation.

This led to the mean temperature series developing a systematic cool bias with the correction leading to temperatures more often being adjusted upwards.

CET Station Corrections 1853-2023:

# Differences between V2.1.0.0 and V2.0.1.0 mean temperatures								
Difference	**Radcliffe**	**Rothamsted**	**Ross-on-Wye**	**Stonyhurst**	**Malvern**	**Squires Gate**	**Ringway**	**Pershore College**
+0.05C	26,138	13,806	23,365	20,863	18,698	10,996	9,813	10,676
0C	32,050	27,301	11,386	23,140	19,258	12,684	14,853	12,405
-0.05C	4,041	12,193	800	763	542	278	308	295
Total	**62,229**	**53,300**	**35,551**	**44,766**	**38,498**	**23,958**	**24,974**	**23,376**

% of values for each magnitude of correction between V2.1.0.0 and V2.0.1.0 mean temperatures								
Difference	**Radcliffe**	**Rothamsted**	**Ross-on-Wye**	**Stonyhurst**	**Malvern**	**Squires Gate**	**Ringway**	**Pershore College**
+0.05C	42.0%	25.9%	65.7%	46.6%	48.6%	45.9%	39.3%	45.7%
0C	51.5%	51.2%	32.0%	51.7%	50.0%	52.9%	59.5%	53.1%
-0.05C	6.5%	22.9%	2.3%	1.7%	1.4%	1.2%	1.2%	1.3%

CET Rural Station Corrections 1959-1989:

# Differences between V2.1.0.0 and V2.0.1.0 mean temperatures					
Difference	**Rothamsted**	**Luddington**	**Preston Wynne**	**Squires Gate**	**Macclesfield**
+0.05C	2,711	3,804	5,302	5,473	5,086
0C	5,636	3,953	5,633	5,662	5,802
-0.05C	2,976	136	227	185	227
Total	**11,323**	**7,893**	**11,162**	**11,320**	**11,115**

% of values for each magnitude of correction between V2.1.0.0 and V2.0.1.0 mean temperatures					
Difference	**Rothamsted**	**Luddington**	**Preston Wynne**	**Squires Gate**	**Macclesfield**
+0.05C	23.9%	48.2%	47.5%	48.3%	45.8%
0C	49.8%	50.1%	50.5%	50.0%	52.2%
-0.05C	26.3%	1.7%	2.0%	1.6%	2.0%

3. CET Daily series

Following the correction of the source station mean temperature values, 33% of the derived daily mean temperature values were adjusted upwards by at most 0.2C, with the largest shift in temperatures occurring after 1974. This is because urbanisation adjustments are applied to the CET temperature series after 1974 which have been calculated on already adjusted daily values.

As the CET minimum and maximum temperatures are adjusted back to the derived mean temperatures, these series have also been adjusted following the correction in station mean temperatures. 51% of daily minimum temperatures were adjusted upwards by at most 0.2C as were 43% of daily maximum temperatures.

The CET daily mean series was only corrected after 1853 when the series values were calculated directly from the station temperatures.

As Figure 1 and 2 show, up until 1974 the temperature changes had a much smaller impact on the series values, particularly when averaged across the year. After 1974, there is more variability between the values due to the urban adjustments being calculated using corrected rural station mean temperature data as well as already adjusted series data.

Since corrections to the station observations were only applied up until the end of 2020 when the values were truncated, the difference in the CET series after this period has reduced. However, as urbanisation adjustments are applied to all recent series values, and these adjustments have also changed, there is still a slight difference in all series after 2020.

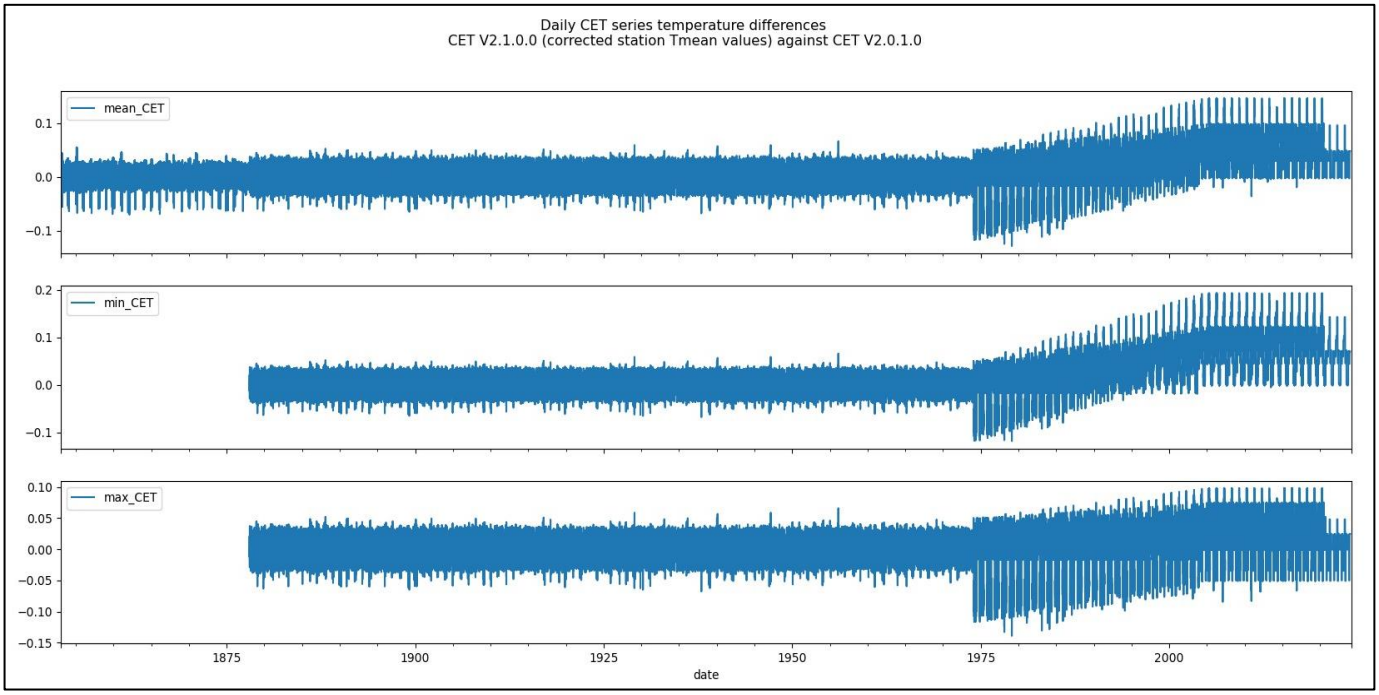


Figure 1 – Daily CET series differences between V2.1.0.0 and V2.0.1.0 (1853-2023)

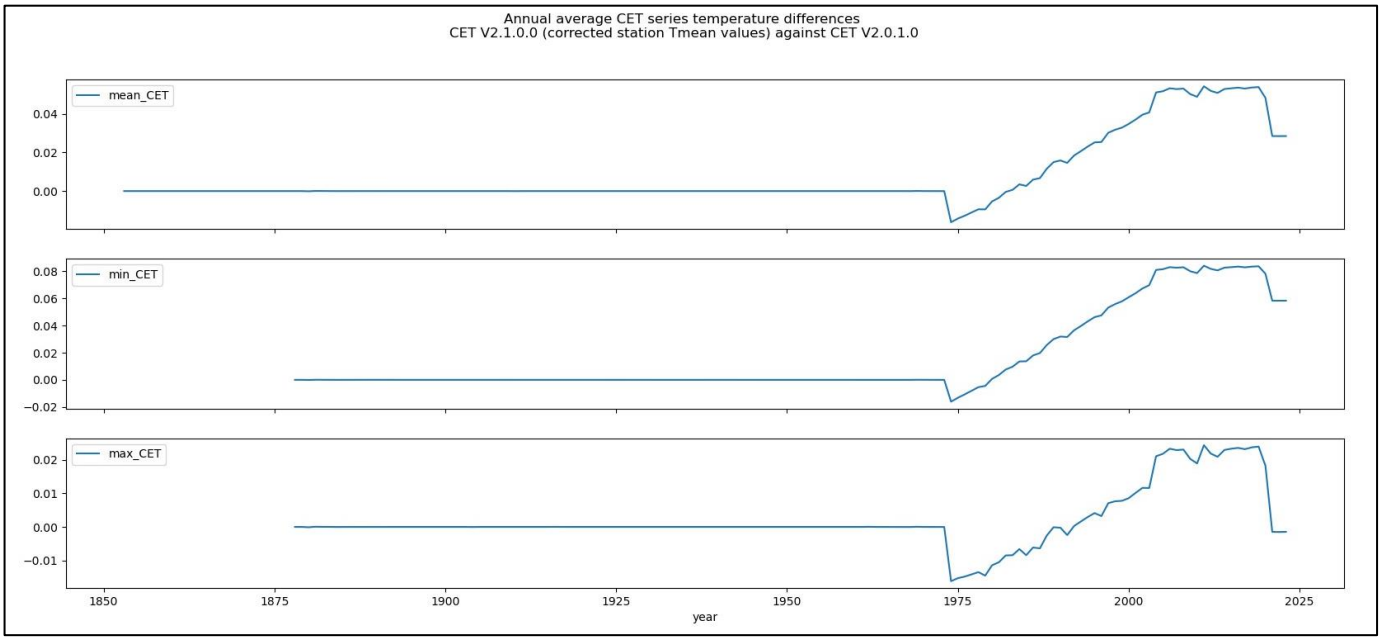


Figure 2 - Daily CET series differences between V2.1.0.0 and V2.0.1.0 averaged by year (1853-2023)

	Average differences between daily values in V2.1.0.0 and V2.0.1.0		
Period	**Mean CET**	**Min CET**	**Max CET**
1878-1973	0C	0C	0C
1974-2004	0.01C	0.03C	-0.002C
2005-2023	0.05C	0.08C	0.02C

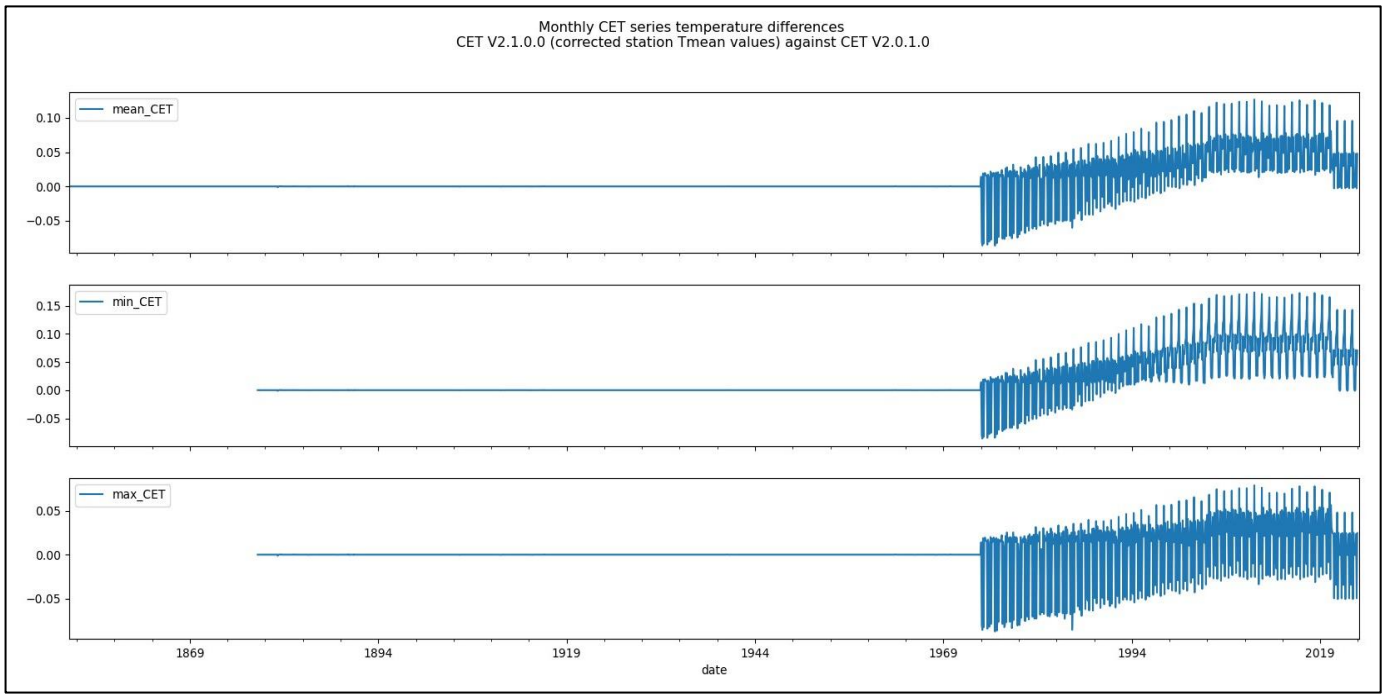
4. CET Monthly series

There is a similar trend in the adjustment of the monthly CET series values following the correction of the station mean temperature values. The monthly series, derived directly from the daily series, are also impacted by the station mean temperature corrections. 11% of the CET monthly mean temperature values were adjusted upwards by at most 0.2C, with all adjustments occurring after 1973.

Similarly for monthly minimum and maximum temperature averages, the impact of the changes on the daily series only affected months after 1973 with the 30% of monthly minimum temperature and 22% of monthly maximum temperature increases all occurring in this period.

This is because the change in daily CET series values prior to 1973 were not only much smaller but were also more variable, with a similar number of days being adjusted upwards as downwards. After 1973, the daily series values were more consistently being adjusted upwards following the correction.

However, as with the daily series, all corrections were minor and within the range of uncertainty expected for the CET series.



Met Office
Hadley Centre

5. CET Long Term Averages

Mean CET

The correction to the source mean temperature values had a small impact on the mean temperature monthly long-term averages (LTAs), with all except April 1991-2020 average being within 0.1C of the previous version.

The correction in the monthly LTAs shows a distinct warming trend, with the 1991-2020 monthly averages increasing more than the earlier periods. Since the urban adjustments are calculated at a monthly level, certain months show a larger change in average mean temperatures. The largest change in monthly average temperatures was April 1991-2020 which, following the correction, was 0.11C warmer than in V2.0.1.

February, March, May and November LTAs for 1961-1990 and 1971-2000 were actually being slightly overestimated in V2.0.1 but the remaining months were all underestimated for these periods.

Mean CET	Monthly LTA differences between V2.1.0.0 and V2.0.1.0			
Month	1961-1990	1971-2000	1981-2010	1991-2020
Jan	0.01C	0.02C	0.05C	0.06C
Feb	-0.03C	-0.03C	0.01C	0.03C
Mar	-0.03C	-0.02C	0.01C	0.04C
Apr	0.03C	0.05C	0.08C	0.11C
May	-0.03C	-0.04C	-0.02C	0.01C
Jun	0.02C	0.04C	0.05C	0.06C
Jul	0.01C	0.02C	0.02C	0.02C
Aug	0.01C	0.01C	0.02C	0.02C
Sep	0.01C	0.01C	0.02C	0.02C
Oct	0.02C	0.03C	0.05C	0.06C
Nov	-0.03C	-0.03C	-0.01C	0C
Dec	0.01C	0.03C	0.04C	0.06C

Met Office
Hadley Centre

Min CET

The correction to the source mean temperature values also had an impact on the minimum temperature monthly long-term averages (LTAs), with all except April 1991-2020 average being within 0.1C of the previous version. The April 1991-2020 average was previously underestimated in V2.0.1.0 by 0.15C.

As with the mean temperature LTAs, the minimum temperature LTAs were underestimated for the most recent climatological period. February, March, May and November were slightly overestimated for the 1961-1990 period and were all reduced by 0.02C following the correction.

Min CET	Monthly LTA differences between V2.1.0.0 and V2.0.1.0			
Month	1961-1990	1971-2000	1981-2010	1991-2020
Jan	0.02C	0.04C	0.05C	0.08C
Feb	-0.02C	-0.01C	0.05C	0.09C
Mar	-0.02C	0C	0.05C	0.1C
Apr	0.03C	0.07C	0.12C	0.15C
May	-0.02C	-0.01C	0.02C	0.05C
Jun	0.02C	0.05C	0.06C	0.09C
Jul	0.01C	0.01C	0.02C	0.03C
Aug	0.01C	0.01C	0.02C	0.02C
Sep	0.01C	0.01C	0.01C	0.02C
Oct	0.02C	0.04C	0.06C	0.08C
Nov	-0.02C	-0.02C	0.02C	0.05C
Dec	0.02C	0.04C	0.06C	0.08C

Met Office Hadley Centre

Max CET

The correction to the source mean temperature values had a slightly smaller impact on the maximum temperature monthly long-term averages (LTAs), with all monthly averages within 0.1C of the previous version.

The April 1991-2020 average was again the most underestimated in V2.0.1.0, this time by 0.06C. The May 1971-2000 average was the most overestimated prior to the correction being made and was adjusted down by 0.06C.

As with minimum and mean temperature, as more daily values in more recent years were being underestimated than between 1961 and 1990, the later LTA periods were adjusted to be warmer than the 1961-1990 period.

Min CET	Monthly LTA differences between V2.1.0.0 and V2.0.1.0			
Month	1961-1990	1971-2000	1981-2010	1991-2020
Jan	0.02C	0.04C	0.05C	0.08C
Feb	-0.02C	-0.01C	0.05C	0.09C
Mar	-0.02C	0C	0.05C	0.1C
Apr	0.03C	0.07C	0.12C	0.15C
May	-0.02C	-0.01C	0.02C	0.05C
Jun	0.02C	0.05C	0.06C	0.09C
Jul	0.01C	0.01C	0.02C	0.03C
Aug	0.01C	0.01C	0.02C	0.02C
Sep	0.01C	0.01C	0.01C	0.02C
Oct	0.02C	0.04C	0.06C	0.08C
Nov	-0.02C	-0.02C	0.02C	0.05C
Dec	0.02C	0.04C	0.06C	0.08C

Met Office
Hadley Centre

6. Increased series precision

In HadCET v2.0.1.0 the CET averages in the series and ranked table files are displayed to 1 decimal place. Some of the CET daily and monthly mean temperatures are only available to this level of precision since these series are anchored directly to Gordon Manley's temperature series which is itself only available to this level of precision.

However, from v2.1.0.0 onwards, where additional precision is available for averaged values this will be made available in the series files, with values returned to 2 decimal places. This will specifically apply to the seasonal and annual averages.

This allows for greater transparency, particularly with regards the ranked series values which are sorted using the higher precision values but were only displayed to 1 decimal place. With this additional information, certain years that were "tied" on temperature averages in the ranked tables can now be shown with more granularity.

The tables below show the v2.0.1.0 top 10 warmest and coolest years on record in the monthly mean temperature series alongside the equivalent rankings in the V2.1.0.0 series. For each, the values are shown here to 1 decimal place and to 2 decimal places. The V2.1.0.0 rankings to 2 decimal places will be made available in the new version of the dataset.

Top 10 warmest years from monthly mean temperature series								
Rank	V2.0.1.0 (1d.p.)	V2.0.1.0 (2d.p.)	Year		V2.1.0.0 (1d.p.)	V2.1.0.0 (2d.p.)	Year	Rank change
1	11.1C	11.15C	2022		11.2C	11.18C	2022	0
2	11.1C	11.10C	2023		11.1C	11.13C	2023	0
3	11.0C	10.98C	2014		11.0C	11.04C	2014	0
4	10.9C	10.90C	2006		11.0C	10.95C	2006	0
5	10.8C	10.79C	2020		10.8C	10.84C	2020	0
6	10.7C	10.75C	2011		10.8C	10.80C	2011	0
7	10.7C	10.72C	2018		10.8C	10.77C	2018	0
8	10.6C	10.64C	1949		10.7C	10.67C	2017	-1
9	10.6C	10.62C	2017		10.6C	10.64C	1949	+1
10	10.6C	10.58C	1999		10.6C	10.61C	1999	0

Top 10 coolest years from CET monthly mean temperature series								
Rank	V2.0.1.0 (1d.p.)	V2.0.1.0 (2d.p.)	Year		V2.1.0.0 (1d.p.)	V2.1.0.0 (2d.p.)	Year	Rank change
1	6.9C	6.86C	1740		6.9C	6.86C	1740	0
2	7.3C	7.29C	1695		7.3C	7.29C	1695	0
3	7.4C	7.44C	1879		7.4C	7.44C	1879	0
4	7.7C	7.67C	1698		7.7C	7.67C	1698	0
5	7.7C	7.67C	1694		7.7C	7.67C	1694	0
6	7.7C	7.73C	1692		7.7C	7.73C	1692	0
7	7.8C	7.78C	1814		7.8C	7.78C	1814	0
8	7.8C	7.82C	1784		7.8C	7.82C	1784	0
9	7.9C	7.86C	1688		7.9C	7.86C	1688	0
10	7.9C	7.88C	1675		7.9C	7.88C	1675	0

7. Updating ranked tables

Currently, the ranked tables on the data download page are ordered from the coldest month/season/year to the warmest, with “Rank 1” being the coldest period. From the new release onwards, these ranked files will be updated to reverse the current ordering and instead rank from the warmest month/season/year to the coldest. This will make it easier for user to identify the warmest months/seasons/years on record in HadCET.