Homogenized historical climate series
Monthly minimum and maximum temperatures

User's guide, version 2024_01

Royal Meteorological Institute of Belgium, 2024

Introduction

In Belgium, the deployment of a climatological network dates back to the 1870s. Since 1880, regular observations of temperature and precipitation have been available at various locations across the country. These observation records are extremely valuable to analyse the climate evolution. However, climatological time series are often affected by non-climatic factors (WMO, 2020). The location and the environment of the measurement site, the instrumentation itself as well as the observation practices may change during the measurement period. Most series are composite, which means that several station records at nearby locations are concatenated to produce the final series. Each concatenation introduces an homogeneity break in the time series. In Belgium, the progressive replacement of open shelters by Stevenson closed shelters in the early 1950s is also a source of inhomogeneities in the historical series (Delvaux et al., 2019). These non-climatic factors affecting the meteorological records reduce the reliability of the time series for assessing actual climate variations. In order to evaluate climate trends, the homogenization of the long-term climate series is therefore required. This homogenization process aims at removing the non-climatic signal in these time series.

The homogenization of the Belgian historical temperature data by the Royal Meteorological Institute of Belgium is extensively decribed in Delvaux et al. (2019). The monthly means of the minimum and maximum daily air temperature at 1.5 m height above ground have been homogenized using the HOMER software (Mestre et al., 2013). The results were provided for 61 series over the period 1954–2015 (long series) and for 16 series starting before 1931 (historical series) including eight covering the full time period 1880–2015. The dataset presented here is the extension of the 16 longest series to 2023.

Method

The HOMER homogenization tool is a semi-automatic software which combines features from statistical methods, including PRODIGE (Caussinus and Mestre, 2004), ACMANT (Domonkos et al., 2011), and cghseg a joint segmentation method that was developed originally by biostatisticians in the context of DNA segmentation (Picard et al., 2011). These methods detect breakpoints by optimizing the segmentation of the time series into homogeneous subseries, using a dynamic programming approach to minimize internal variance (Caussinus and Lyazrhi, 1997). Based on the identified breakpoints, these methods apply a network-wide unified correction model (ANOVA, Caussinus and Mestre (2004)). It is worth pointing out that HOMER adjusts the data preceding a detected breakpoint to make them homogeneous with the data after that breakpoint. In this way, the most recent data (i.e., following the most recent breakpoint) are not modified. This offers a clear advantage for ongoing monitoring in that new data can be simply appended to the time series.

For this new homogenization phase, non-homogenized monthly data after 2015 are first appended to the homogenized series available until 2015. Monthly values are derived from valid daily values within a minimum threshold of 90 % available daily values within a month. If this criterion is not met, the monthly value is considered as missing. During the homogenization phase, new inhomogeneity breaks may appear in the extension period (after 2015) but also in the previously homogenized period. Indeed, appending new data could reveal additional breaks, which were not identified during the previous homogenization phase, particularly near the end of previously homogenized series (i.e., 2015).

It must be noticed that the homogenizations of the historical and long series have been performed separately in Delvaux et al. (2019). As a result, the positions and the amplitudes of the homogeneity breaks are not exactly the same in the historical series and the corresponding long series. The homogenization process of the historical series is based on a limited number of series which were all regrouped in one cluster extending over the whole country. In contrast, the number of long series was large enough to regroup them in 5 clusters with similar climatological conditions. Therefore, it is expected that the positions and the amplitudes of the breaks detected in the long series are more reliable. The minimum detectable amplitude (MDA) of break-points is generally smaller for the long series than for the historical series. In the present homogenization phase, we produce only one series merging the homogenized long series for the period where it is available with the historical series for the period preceding the start of the long series. The name and the code of this merged series are those of the historical series.

Results

Among the 16 historical series, 12 were extended and homogenized until december 2023. Two measurement stations were closed: Maredsous (code 220) in 2013 and Ezemaal (code 206) in 2017. The homogenization of two series, namely Oostende (code 212) and Deurne (code 201), is currently limited to 2020 due to data quality issues. Table 1 lists the available series, their location, altitude together with their start and end dates. The location of the last segment of the series is given as well. Six additional breaks have been introduced with respect to those already identified in the previous homogenization phase. The list of all homogeneity breaks in TX and TN series are given in Table 2 and 3, respectively. Next to the dates and amplitudes of the breaks, these tables also give the minimum detectable amplitude (MDA) which indicates the largest amplitude of the non-detected breaks. When clearly identified, the origin of the breaks is also mentioned. Many breaks are caused by changes affecting the instrument shelter, for example the change from open to closed shelter (Delvaux et al., 2019). In most cases, these changes are not well documented, hampering the attribution of the origin of many breaks.

Table 1: List of homogenized series with latitude and longitude (decimal degrees), altitude (m), start and end dates.

CODE_LS	NAME	LAT	LON	ALT	DATE_BEGIN	DATE_END
201	DEURNE	51.2250	4.4000	10	1880-02	2020-12
203	BRUXELLES-ZAVENTEM	50.8564	4.3664	35	1889-01	2023-12
206	EZEMAAL	50.7567	5.0825	50	1913-07	2016-12
208	JALHAY	50.5842	5.9717	298	1880-01	2023-12
210	LEUVEN	50.8633	4.6850	28	1930-05	2023-12
212	OOSTENDE	51.2233	2.9058	5	1880-01	2020-12
213	SINT-TRUIDEN	50.8161	5.1867	54	1880-01	2023-12
216	LEOPOLDSBURG	51.1078	5.2714	50	1881-01	2023-12
217	ROCHEFORT	50.1761	5.2244	193	1892-06	2018-12
218	CHIMAY	49.9819	4.3403	318	1910-09	2023-12
219	STAVELOT	50.3978	5.9356	320	1890-02	2023-12
220	MAREDSOUS	50.2867	4.7675	222	1893-01	2013-11
221	GEMBLOUX	50.5611	4.6597	160	1881-05	2023-12
222	MONT-RIGI	50.5186	6.0611	672	1928-01	2023-12
223	THIMISTER	50.6542	5.8633	280	1881-02	2023-12
224	UCCLE	50.7975	4.3592	100	1880-01	2023-12

Description of the data and metadata files

The datafiles can be found in the /DATA/CSV and /DATA/TXT directories and in 2 different formats:

- ho_monthly_series_<code>_<var>_<version>.<ext>, where
  <code> is the series code, <var> is the variable name, respectively tx and tn for maximum and minimum temperatures, <version> is the version (v2024_01), and <ext> is either csv or txt. Each row

contains the 12 monthly values of TN or TX for a given year.

- ho_monthly_series_<code>_tn_tx_<version>.<ext>, where
  <code> is the series code, <version> is the version (v2024_01), and <ext> is either csv or txt. Each row contains both TN and TX values for a given month.

The metadata files can be found in the /METADATA directory. It contains:

- series_metadata_<version>.csv, corresponding to the Table 1 above, the list of all series with code, name, latitude, longitude, altitude, start date and end date. Latitude and longitude are given in decimal degrees. Altitude (above mean sea level) is given in m.
- series_breaks_tx_<version>.csv and series_breaks_tn_<version>.csv, corresponding to resp. Table 2 and 3 below, the lists of all detected breaks in TX and TN series, respectively.

Documentation can be found in /INFO:

- homogenized_tt_series_users_guide_v2024_01.pdf, the present user's guide.
- series_history_breaks_<version>.pdf, a document containing for each series its history and the detected breaks.

References

Caussinus, H. and Lyazrhi, F.: Choosing a linear model with a random number of change-points and outliers, Annals of the Institute of Statistical Mathematics, 49, 761–775, 1997.

Caussinus, H. and Mestre, O.: Detection and correction of artificial shifts in climate series, Journal of the Royal Statistical Society Series C: Applied Statistics, 53, 405–425, 2004.

Delvaux, C., Ingels, R., Vrábeĺ, V., Journée, M., and Bertrand, C.: Quality control and homogenization of the Belgian historical temperature data, International Journal of Climatology, 39, 157–171, doi: https://doi.org/10.1002/joc.5792, 2019.

Domonkos, P. et al.: Adapted Caussinus-Mestre algorithm for networks of temperature series (ACMANT), International Journal of Geosciences, 2, 293, 2011.

Mestre, O., Domonkos, P., Picard, F., Auer, I., Robin, S., Lebarbier, E., Böhm, R., Aguilar, E., Guijarro Pastor, J. A., Vertacnik, G., et al.: HOMER: a homogenization software–methods and applications, Quarterly Journal of the Hungarian Meteorological Service, 117, 47–67, 2013.

Picard, F., Lebarbier, E., Hoebeke, M., Rigaill, G., Thiam, B., and Robin, S.: Joint segmentation, calling, and normalization of multiple CGH profiles, Biostatistics, 12, 413–428, 2011.

WMO: Guidelines on Homogenization, Tech. Rep. WMO-No. 1245., World Meteorological Organization, Geneva, 2020.

Table 2: Date, amplitude, minimum detectable amplitude (MDA) and origin of the TX series breaks.

LS code	LS name	Date	Amplitude in °C	MDA in °C	Origin
201	DEURNE	10/2002	-0.25	0.14	
201	DEURNE	4/1994	0.33	0.14	
201	DEURNE	12/1950	-1.29	0.17	observer change
201	DEURNE	1/1931	0.60	0.17	station catenation
203	BRUXELLES - ZAVENTEM	12/2005	-0.20	0.11	
203	BRUXELLES - ZAVENTEM	12/1980	-0.25	0.11	relocation
203	BRUXELLES - ZAVENTEM	12/1953	-2.12	0.18	station catenation
203	BRUXELLES - ZAVENTEM	12/1940	0.39	0.18	
203	BRUXELLES - ZAVENTEM	12/1932	-0.64	0.18	
203	BRUXELLES - ZAVENTEM	12/1908	0.94	0.18	
206	EZEMAAL	12/1988	-0.26	0.09	
206	EZEMAAL	12/1978	0.29	0.09	
206	EZEMAAL	8/1954	-1.49	0.15	station catenation
208	JALHAY	10/2015	0.64	0.16	
208	JALHAY	12/1970	-0.40	0.17	
208	JALHAY	12/1950	-0.72	0.23	observer change
208	JALHAY	12/1925	-0.68	0.23	
208	JALHAY	12/1887	0.62	0.23	
210	LEUVEN	12/1999	-0.27	0.09	
210	LEUVEN	12/1962	-0.24	0.09	
212	OOSTENDE	12/2006	-0.28	0.16	
212	OOSTENDE	4/1940	-0.96	0.20	station catenation
212	OOSTENDE	2/1936	0.27	0.20	station catenation
213	SINT-TRUIDEN	1/2008	-0.44	0.10	relocation
213	SINT-TRUIDEN	12/2001	-0.34	0.10	
213	SINT-TRUIDEN	12/1971	0.33	0.10	
213	SINT-TRUIDEN	12/1953	-0.55	0.17	station catenation
213	SINT-TRUIDEN	12/1915	0.57	0.17	
213	SINT-TRUIDEN	12/1913	-1.15	0.17	
216	LEOPOLDSBURG	12/2001	0.13	0.11	
216	LEOPOLDSBURG	12/1973	-0.24	0.11	
216	LEOPOLDSBURG	5/1940	-0.51	0.16	
217	ROCHEFORT	no breaks		0.11	
217	ROCHEFORT	12/1950	-0.60	0.15	observer change
217	ROCHEFORT	12/1927	-1.24	0.15	
217	ROCHEFORT	12/1919	0.61	0.15	
218	CHIMAY	12/1963	-0.34	0.13	
218	CHIMAY	12/1945	-0.45	0.16	
218	CHIMAY	12/1931	-0.91	0.16	
218	CHIMAY	12/1913	0.94	0.16	
219	STAVELOT	12/1959	0.67	0.13	
219	STAVELOT	12/1939	-1.64	0.15	
219	STAVELOT	12/1936	0.76	0.15	
219	STAVELOT	12/1917	-0.36	0.15	
219	STAVELOT	12/1908	-0.23	0.15	
220	MAREDSOUS	10/1991	-0.51	0.09	station catenation
220	MAREDSOUS	12/1966	0.26	0.09	
220	MAREDSOUS	12/1942	-0.57	0.16	
220	MAREDSOUS	12/1923	-0.38	0.16	
221	GEMBLOUX	12/2011	-0.24	0.10	
221	GEMBLOUX	12/1943	-0.77	0.15	
221	GEMBLOUX	12/1916	-0.43	0.15	
221	GEMBLOUX	12/1895	0.46	0.15	
221	GEMBLOUX	12/1890	-0.82	0.15	
222	MONT-RIGI	11/2014	-0.45	0.12	
222	MONT-RIGI	7/1989	0.57	0.16	station catenation
222	MONT-RIGI	11/1984	0.52	0.16	station catenation
222	MONT-RIGI	12/1977	-0.38	0.16	
222	MONT-RIGI	11/1953	-1.23	0.15	station catenation
222	MONT-RIGI	12/1935	0.49	0.15	
223	THIMISTER	12/2004	0.55	0.12	station catenation
223	THIMISTER	3/1989	-0.58	0.12	relocation
223	THIMISTER	12/1975	0.37	0.12	
223	THIMISTER	12/1956	-0.46	0.12	
223	THIMISTER	12/1947	-0.68	0.19	
223	THIMISTER	12/1936	-0.79	0.19	
223	THIMISTER	12/1932	-0.71	0.19	
223	THIMISTER	12/1927	0.28	0.19	
223	THIMISTER	12/1923	1.57	0.19	
224	UCCLE	6/1983	-0.91	0.15	station catenation
224	UCCLE	12/1899	0.51	0.15	
224	UCCLE	12/1890	-0.51	0.15	

Table 3: Date, amplitude, minimum detectable amplitude (MDA) and origin of the TN series breaks.

LS code	LS name	Date	Amplitude in °C	MDA in °C	Origin
201	DEURNE	12/1950	-1.29	0.17	observer change
201	DEURNE	1/1931	0.60	0.17	station catenation
203	BRUXELLES - ZAVENTEM	12/2005	-0.28	0.15	
203	BRUXELLES - ZAVENTEM	12/1980	-0.26	0.15	relocation
203	BRUXELLES - ZAVENTEM	12/1953	-0.81	0.16	station catenation
203	BRUXELLES - ZAVENTEM	12/1911	-0.31	0.16	
206	EZEMAAL	12/1996	0.19	0.13	observer change
206	EZEMAAL	12/1971	0.29	0.13	
206	EZEMAAL	2/1959	-0.75	0.13	
206	EZEMAAL	12/1949	0.29	0.17	
208	JALHAY	3/1996	1.02	0.15	station catenation
208	JALHAY	12/1983	-0.42	0.15	
208	JALHAY	12/1971	0.97	0.15	
208	JALHAY	12/1950	-0.52	0.22	observer change
208	JALHAY	12/1916	0.23	0.22	
210	LEUVEN	12/1984	0.30	0.13	station catenation
210	LEUVEN	12/1972	0.37	0.13	
210	LEUVEN	12/1953	0.86	0.16	
210	LEUVEN	12/1945	-0.89	0.16	
210	LEUVEN	12/1938	1.37	0.16	
210	LEUVEN	12/1933	-0.74	0.16	
212	OOSTENDE	12/2006	-0.42	0.14	
212	OOSTENDE	12/1991	0.48	0.14	
212	OOSTENDE	12/1988	-0.52	0.14	
212	OOSTENDE	12/1970	-0.32	0.14	
212	OOSTENDE	4/1940	-0.36	0.17	station catenation
212	OOSTENDE	12/1919	-0.26	0.17	
213	SINT-TRUIDEN	12/1983	0.69	0.13	
213	SINT-TRUIDEN	12/1970	-0.19	0.13	
213	SINT-TRUIDEN	12/1944	0.73	0.19	
213	SINT-TRUIDEN	6/1938	-1.88	0.19	station catenation
213	SINT-TRUIDEN	12/1892	0.36	0.19	
216	LEOPOLDSBURG	12/1981	-0.32	0.15	station catenation
216	LEOPOLDSBURG	5/1940	-0.20	0.19	
216	LEOPOLDSBURG	12/1914	0.55	0.19	
217	ROCHEFORT	12/2008	-0.52	0.17	
217	ROCHEFORT	12/1991	0.60	0.17	
217	ROCHEFORT	12/1966	-0.45	0.17	
218	CHIMAY	12/1947	-0.66	0.17	
218	CHIMAY	12/1927	0.32	0.17	
218	CHIMAY	12/1919	0.58	0.17	
219	STAVELOT	3/2018	-0.33	0.20	
219	STAVELOT	12/1984	-0.58	0.17	relocation
219	STAVELOT	12/1965	0.58	0.17	
219	STAVELOT	12/1959	0.66	0.17	
219	STAVELOT	12/1938	-0.32	0.20	
219	STAVELOT	12/1919	-0.39	0.20	
220	MAREDSOUS	12/1949	0.37	0.18	
220	MAREDSOUS	12/1936	-0.42	0.18	
221	GEMBLOUX	12/1980	-0.24	0.17	
221	GEMBLOUX	12/1943	0.71	0.20	
221	GEMBLOUX	12/1941	-0.98	0.20	
221	GEMBLOUX	12/1915	0.28	0.20	
222	MONT-RIGI	12/1960	-0.19	0.12	
222	MONT-RIGI	12/1937	-0.33	0.17	
223	THIMISTER	11/2013	0.38	0.14	
223	THIMISTER	12/2004	-0.66	0.19	station catenation
223	THIMISTER	12/1971	-0.64	0.19	
223	THIMISTER	12/1968	0.66	0.19	
223	THIMISTER	12/1945	0.35	0.22	
223	THIMISTER	12/1934	0.58	0.22	
223	THIMISTER	12/1921	-1.01	0.22	
223	THIMISTER	12/1899	0.48	0.22	station catenation
224	UCCLE	6/1983	0.15	0.17	station catenation
224	UCCLE	6/1886	-0.59	0.17	station catenation