Long-term Temperature Observations from Jena, Germany

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1 Introduction

Weather observations from Jena exist since at least the year 1770. However, searching the literature and climate data bases reveals several different time series from Jena with somewhat different data processing (averaging, adjustments etc.) even though the primary observations have been the same. This document summarises the history of the observations from Jena and the steps behind the compilation of the homogenised temperature record since 1770 shown on the main website.

2 Early measurements

The history of early weather observations in Jena has been described in detail by Grebe [1936] and summarised by Kluge and Müller-Westermeier [2000].

The first regular daily measurements were made by the clergyman I. G. Ch. Zeissing during 1770–1790 in Jena and later during 1791–1800 in Isserstedt close to Jena. A second set of regular measurements were performed 1782–1801 by the professor in mathematics and physics L. J. D. Suckow in Jena.

Unfortunately the original diaries of both these early observation time series are lost [Kluge and Müller-Westermeier, 2000]. Grebe [1936] had still access to the originals and recomputed 5-day, monthly and annual average temperatures from both time series. Thereby he also attempted to correct the data for station biases by comparing the observations from Jena with similar measurements from Erfurt, Coburg, Magdeburg and Berlin. The monthly temperatures from Zeissing (1770–1790) combined with the monthly temperatures from Suckow (1791–1800) and the monthly observations from the Sternwarte (see below) until the end of year 1935 were subsequently published in Grebe [1936]. They are digitally available in international climate databases, listed as "JENA E.GERMANY" (Id 61710555002 in the Global Historical Climatology Network, monthly v2 and v3; or Id 9499 in HADCRU).

3 Measurements after 1820 at the "Sternwarte"

In 1812 J.W. von Goethe founded the astronomical observatory "Sternwarte" in Jena and established regular meteorological observations both in Jena at the Sternwarte and also in several locations nearby within the former dukedom "Sachsen-Weimar-Eisenach". In the beginning the meteorological observations at the Sternwarte in Jena were somewhat irregular and of poor quality. However, from January 1821 on, regular measurements several times a day were taken,

first by Prof. Posselt and after 1823 by Prof. Heinrich Ludwig Schroen. The latter, with his helpers, diligently performed regular measurements over more than 50 years until his death in 1875. After some interruptions, measurements were taken up again in 1878. In 1881 the Sternwarte station was integrated into the Prussian Meteorological station network.

In the 20th century, the measurements were performed at the Sternwarte in the network of the "Reichswetterdienst, Wetteramt Weimar", after the second world war as part of the meteorological service of the GDR and, since 1989, the German Weather Service. All observations until 1999 were performed manually by staff of the Sternwarte, belonging to the Astrophysical Institute of the University of Jena. After October 31, 1999 the meteorological measurements became supervised by the faculty of Chemistry and Earth Sciences of the University of Jena. In August 2004 the station was converted to an automatic remote controlled weather station operated directly by the German Weather Service (DWD).

The logbooks with the still existing original manual measurements are archived in the Sternwarte. Before the transition to a remote controlled automatic weather station Prof. Kluge and his staff converted most of the recordings into a digital format. All instant recordings ("Terminwerte") were transferred to the DWD and compiled into daily, monthly and annual means using standard DWD routines with a limited quality control. All instant, daily, monthly and annual data are now automatically updated and are available at the Climate Data Center of the DWD in the OpenData section (Station Id: 02444). The daily values have also been included in the Global Historical Climatology Network daily data base, identified as "JENA STERNWARTE" (Id GM000004204).

Several earlier versions of daily, monthly and annual time series from the original instant Sternwarte observations have been compiled, analysed and published by several authors. Schroen published already early measurements in annual meteorological journals (e.g. Schroen [1835], containing the data of 1833) and a large fraction of the entire record obtained during his lifetime appeared in a statistical encyclopaedia on Thuringia [Hildebrandt, 1867]. A PhD thesis on the Jena record was published by Wagner [1915]. Grebe [1936] computed monthly averages and tried to eliminate potential station biases; the data set "JENA E.GERMANY" described above contains his values. More modern data collections and analyses of the Jena Sternwarte record can be found in Wustelt [1962], Kluge and Müller-Westermeier [2000], and Orlowsky [2002].

4 Station biases

Obviously, the weather observations from the Jena weather station are not homogenous. There exist several observation gaps, instrument changes and shifts of the actual observation position. Furthermore, instant measurements were not taken always at the same time of the day and the computation of daily means from the instant measurements therefore differs in parts of the record. Especially the observations in the 19th century are subject to such biases. Grebe [1936] noticed several of these and tried to manually correct them using concurrent measurements from nearby stations in Thuringia.

Objective ways to homogenise the temperature records from weather stations worldwide have been developed by several groups, e.g. the Climate Research Unit (CRU) in East Anglia, UK, the Goddard Institute for Space Studies (GISS) in New York or by Berkeley Earth (`https://berkeleyearth.org`). Such techniques use statistical comparisons of individual station records with the regional expectation in order to identify and flag implausible values, spurious jumps and offsets in the time series.

The impact of artefacts in the Jena temperature record is readily seen from the analysis performed by Berkeley Earth [Rohde et al., 2013]. Figures 1 and 2 show the difference between station and regional expected average monthly temperature for the Grebe and the Sternwarte data set. The red lines show the estimated station mean biases, exhibiting jumps at locations where systematic changes in instrumentation or observation procedures must have been made. It is interesting that the automatic procedure identifies the most of the jumps in the data, which were already found by Grebe in his manual analysis. Based on the local station diaries Grebe also was able to identify some of the reasons for the jumps. In particular the jump in 1833/34 can be explained by a change in the daily observation times and the calculation of the daily averages. And the jumps in 1904 and 1913 were caused by changes in the location of the station instrument box.

The magnitude of the bias-correction by the Berkeley Earth method is readily visible in Figure 3, which displays on annual basis the difference between the raw Sternwarte record from the DWD and the Berkeley Project corrected Grebe record. Accordingly, there are offsets on the order of -0.8 to +0.4C. After 1904 the offsets are much smaller and disappear.

In addition the growth of the city of Jena in the Saale valley during the last two centuries must have induced changes in the local microclimate. This might have lead to trends in some of the weather elements which might therefore not be representative for the larger region of eastern Thuringia. Such effects are difficult to detect and eliminate. It is for this reason that the DWD does not include the Jena station as part of its set of background reference climate stations. Still, being one of the longest weather records in central Germany, the Jena time series nevertheless constitutes a valuable documentation of local and to some extent also regional climate variability and change.

5 Compilation and display of annual temperature record

The record of annual mean temperatures displayed on the website and shown below (Figure 4) is compiled by merging the monthly mean temperatures from the Grebe data set prior to July 1904, bias-corrected by Berkeley Earth, and the monthly mean temperatures from the DWD archive from July 1904 on until today. From this time series annual means are computed and shown only for years with existing 12 months of observations. The fitted smooth trend curve is a Reinsch spline with a pass-through cutoff frequency of 50 years. The thin dashed gray line shows for comparison a similar trend curve fitted to the uncorrected annual values compiled from the DWD (STERNWARTE) record.

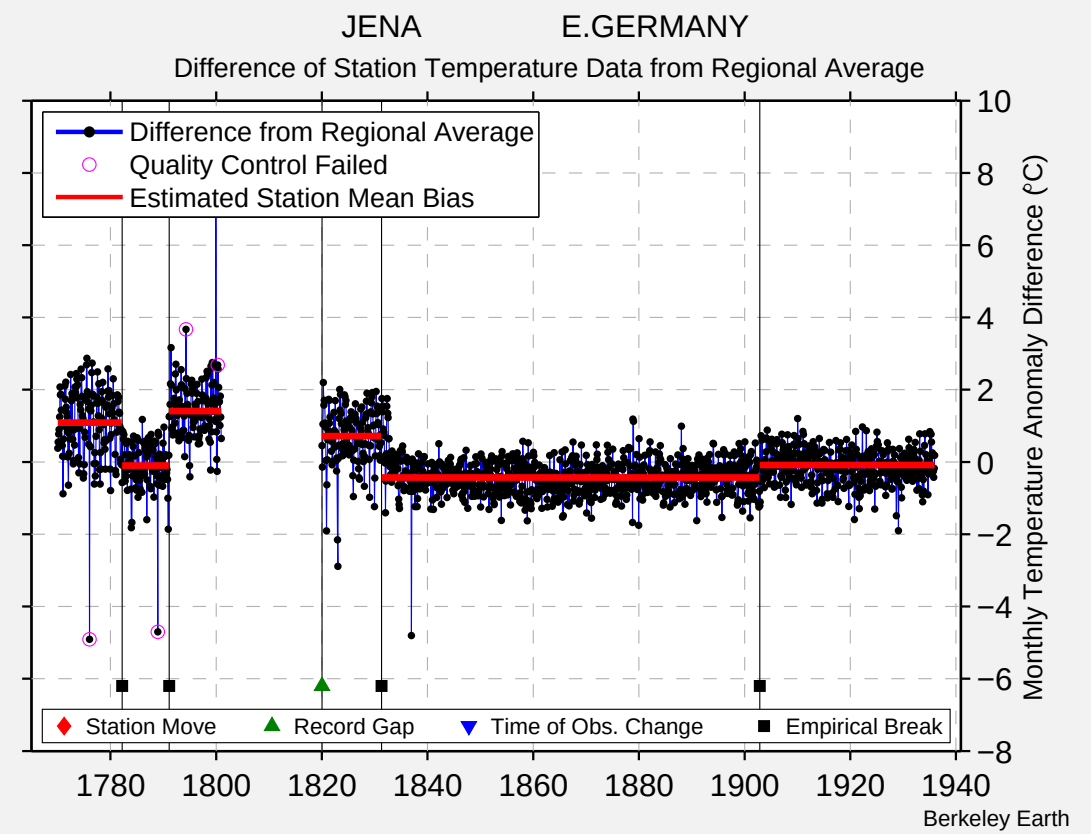

Figure 1: Difference between station and regional expected average monthly temperature. Grebe dataset (JENA E. GERMANY, Figure from https://berkeleyearth.org).

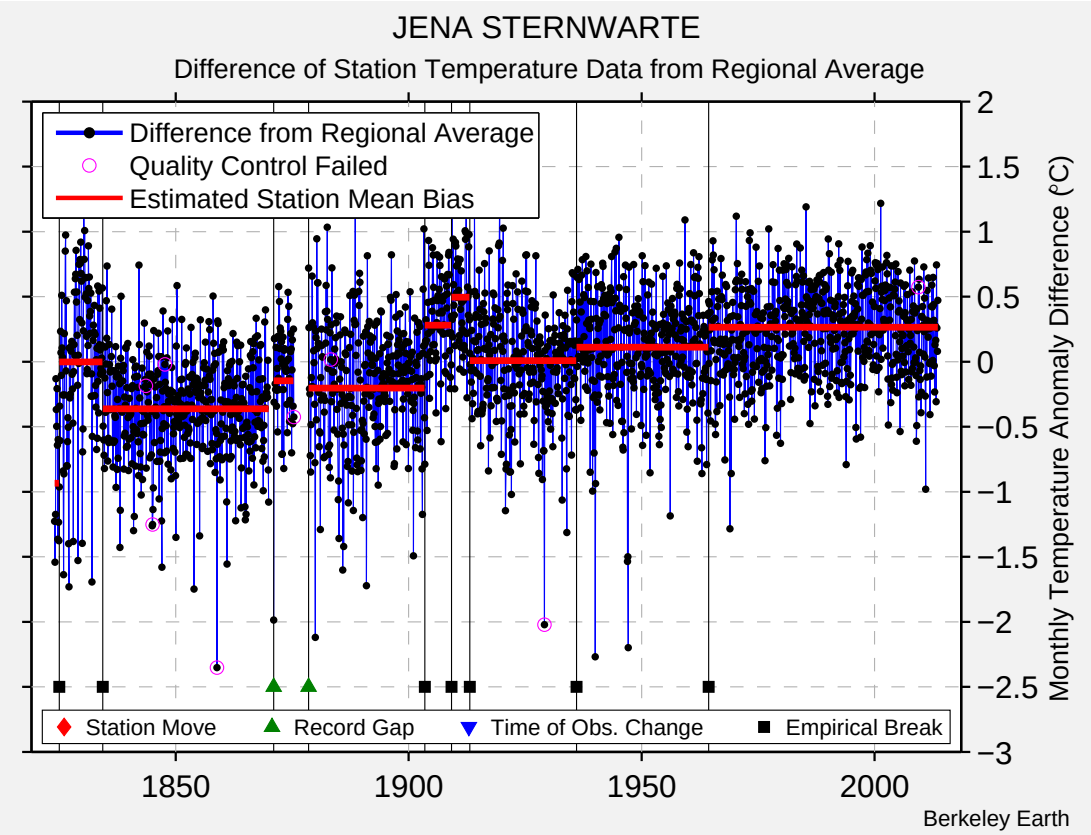

Figure 2: Difference between station and regional expected average monthly temperature. Sternwarte dataset (JENA STERNWARTE, Figure from https://berkeleyearth.org).

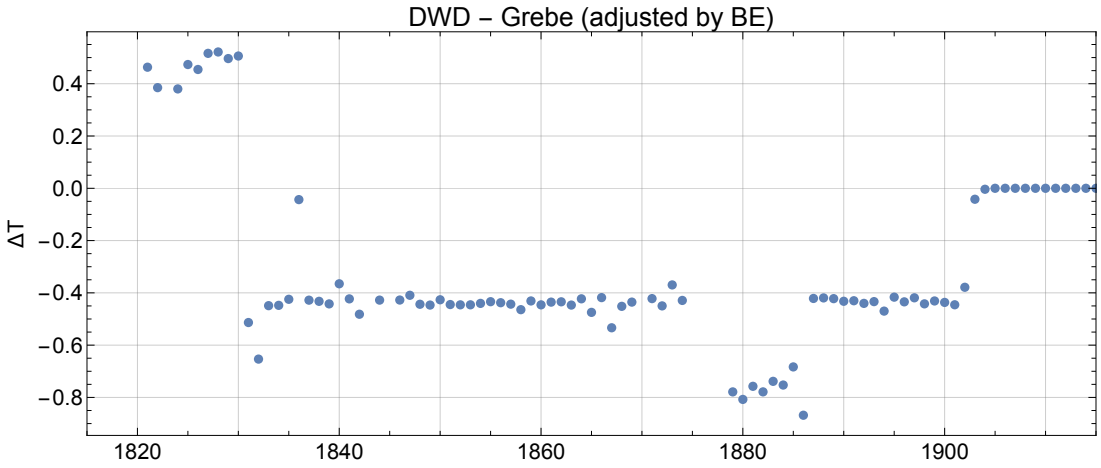

Figure 3: Difference between DWD Sternwarte record and the Grebe record corrected by Berkeley Earth (Data from https://berkeleyearth.org).

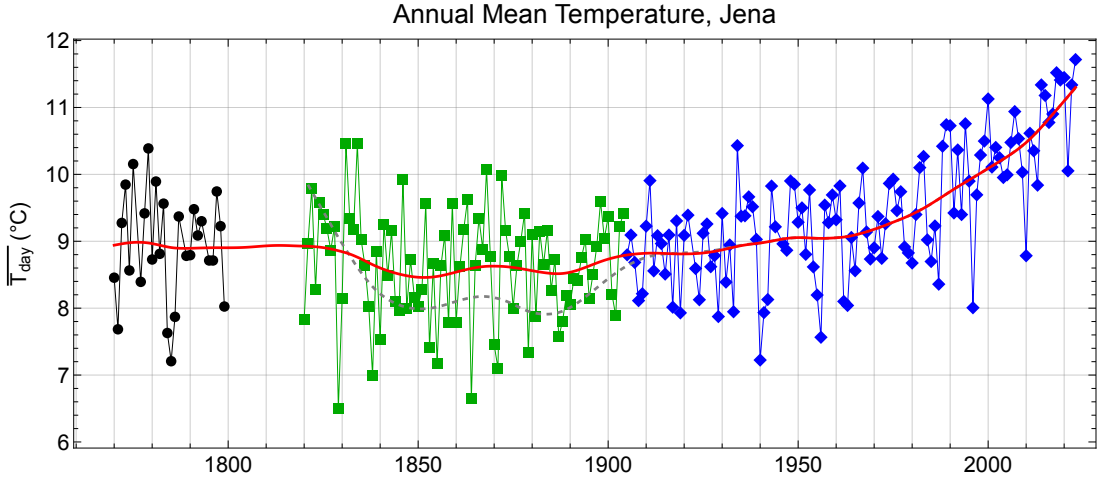

Figure 4: Annual mean temperature observed in Jena. Black: early observations by Zissing and Suckow compiled by Grebe. Green: Observations from the Sternwarte compiled by Grebe (up to 1904). Blue: Observations from the Sternwarte as archived by the DWD. Data prior to 1904 have been bias-corrected by the Berkeley Project (https://berkeleyearth.org).

6 Additional diagnostics

As seen in Figure 4, annual mean temperatures were relatively stable in the 19th and in the first half of the 20th century, but increased by about +2C since 1950. Figure 5 shows similar trend curves for the four seasons, revealing that the largest increase since 1950 happened during the summer months: in JJA the increase since 1950 is about +3C. This is also seen in Figure 6 which displays the average seasonal cycle for climatological reference periods 1841–1880, 1901–1939 and 1991–2020.

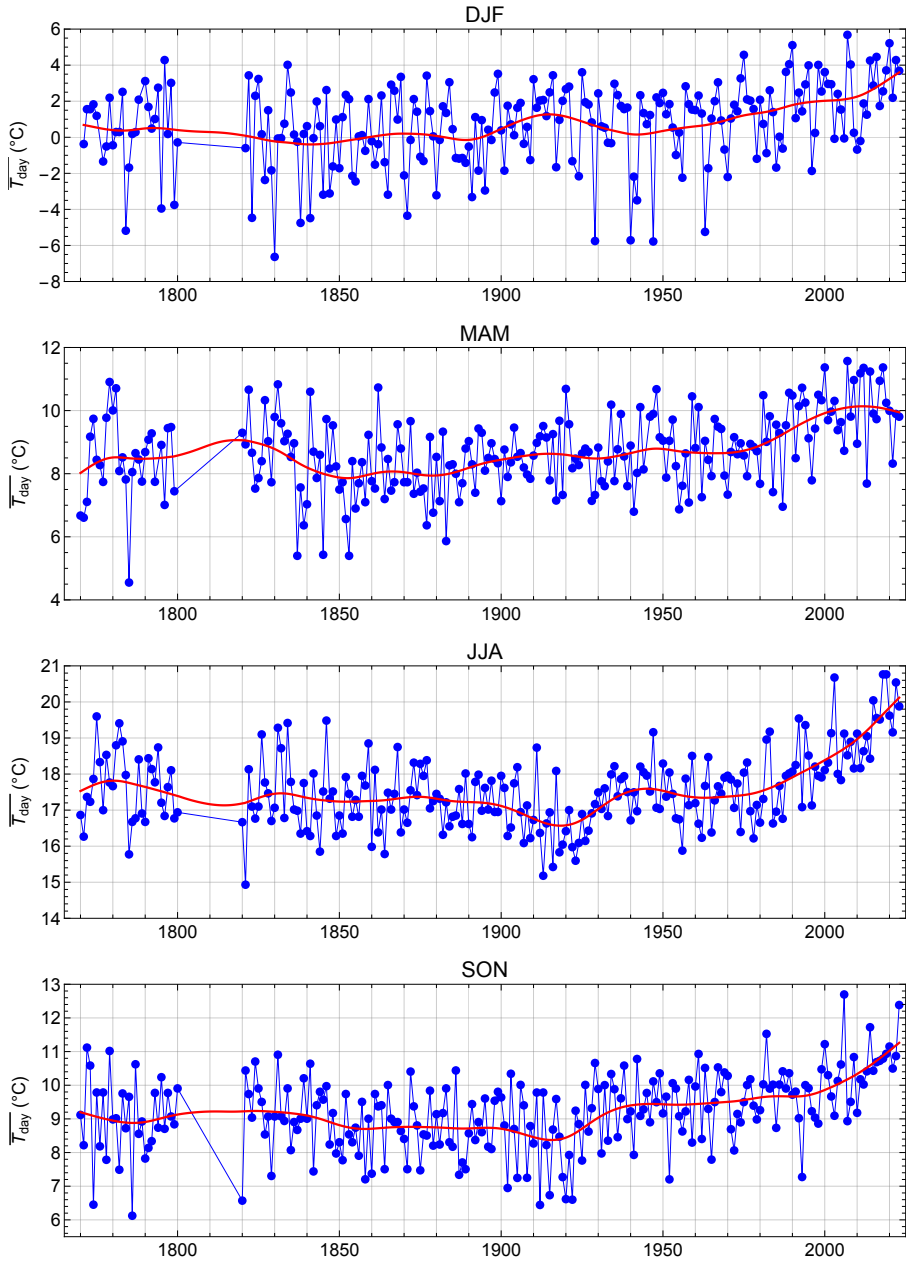

Figure 5: Mean temperature trends of the four seasons.

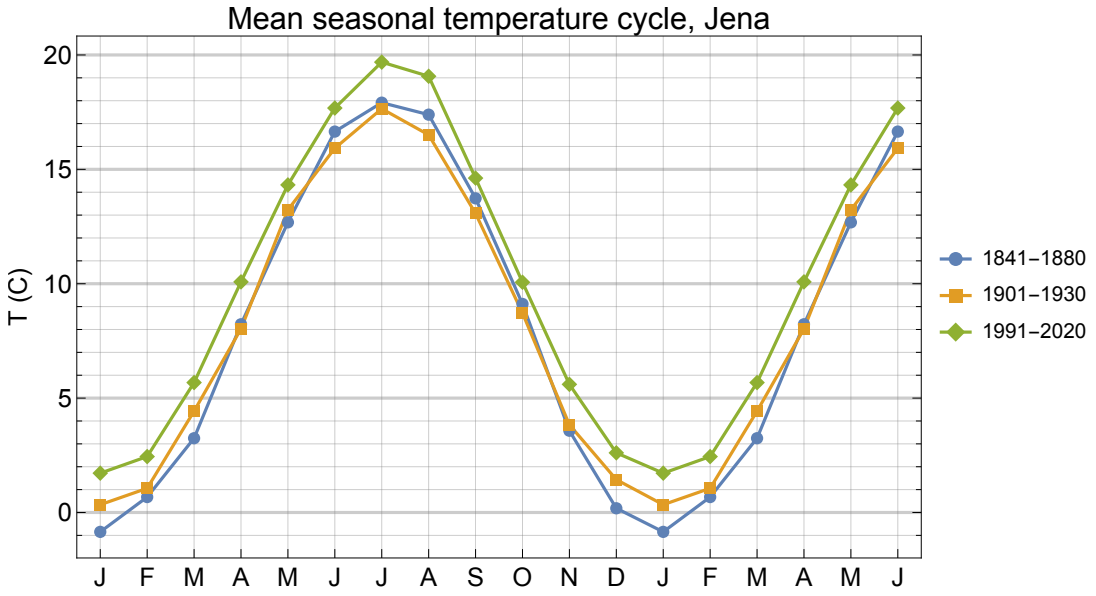

Figure 6: Mean seasonal temperature cycle for three different climatological reference periods. The first 6 months are repeated in order to show the seasonal cycle more clearly.

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