Meteorological Series from Basel 1825-1863

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Abstract

The meteorological series from Basel is one of the two existing long Swiss series and reaches back to 1755. It has been re-evaluated by Bider et al. (1958) and Bider and Schuepp (1961) based on daily values. We have digitised the underlying original data. Here we describe the data from 1825 to 1863, most of which were measured by Peter Merian (his data cover 1828-1863). Additional observers were Burckhardt (1825-1827), Fürstenberger (1826-1830), Schneider (1836-1846), and Kaufmann (1862-1863). We provide information on the locations, observers, and instruments (where available), as well as the quality control procedures. The data is available from MeteoSwiss.

1. Introduction

Basel is one of only two long Swiss meteorological series available until now (the second is Geneva; both reach back to 1755) and consequently often used in climatology. The individual segments that make up this series have been described in detail by Riggenbach (1892). Bider et al. (1958) and Bider and Schüepp (1961) then undertook the work to concatenate the individual segments to a long, homogeneous series. In the framework of the MeteoSwiss project DIGIHOM III (Füllemann et al., 2011) and the Swiss GCOS project "Long instrumental series", the individual segments are re-digitised and re-assessed and complemented with further segments (e.g., covering the long gap from 1804-1826 during which the Basel series up to now was filled in with data from Mulhouse and Delémont). Several important segments covering the years 1755 to 1829 are discussed in other papers in this volume (e.g., Brönnimann and Brugnara, 2020). In this paper we focus on five series from 1825 to 1863 (the start of the national meteorological network today run by MeteoSwiss).

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During this period, at least five different observation series are available, partly or even fully overlapping. The corresponding observers were J. Rudolf Burckhardt, Johann Jakob Fürstenberger, Peter Merian, Andreas Schneider, and Fritz Kaufmann. By far most the most observations are from Peter Merian. This paper describes the metadata on these series. On the one hand, observers, locations, and instruments are described (Section 2), on the other hand, processing and quality control of the data series. Section 3 presents results and some analyses. Conclusions are drawn in Section 4. Metadata on the stations are incorporated in the inventory of Pfister et al. (2019); the data can be obtained from the MeteoSwiss website.

2. The five series

This section summarizes the metadata for each of the five series, three of which consist themselves of series taken at different locations. In addition to archival material, we rely strongly on the information given in Riggenbach (1892), Bider et al. (1958) and Bider and Schüepp (1961). Table 1 gives an overview of the five series (including the sub-series); Figure 1 gives an overview of the locations on a contemporary map). Note that over summer, Merian often measured in other locations close to Basel. Although digitized, these data are not further considered in this paper.

Table 1. Meteorological observations in Basel, 1825-1863 (see Section Sources for a complete list of the data and metadata sources). # refers to Fig. 1. GF = ground floor, 1F…3F = first…third floor, MZ = mezzanine; p = pressure, T = temperature, w = wind speed, wdir = wind direction, wn = weather notes, o = other observations, h = humidity, R = precipitation. Diff. M1 indicates altitude or pressure differences to M1 (St. Johannvorstadt). Sources: Riggenbach (1892), Pfister et al. (2019).

Period	#	Location	Diff. M1	Observer	Variables	Instruments/notes
1825-27		unknown		J. Rudolf Burckhardt	p, T, wn irregular, early morning, late evening	unknown
1826-33	M1	St. Johannvorstadt/ Spitalstrasse 14, 2F	0	Peter Merian	p, T, h, w, wdir, o, wn 3x daily (only data after 1828 available)	Dumotiez barometer, then Loos and then (1828) Oeri barometer (mercury, reduced) Loos thermometer Oechsle thermometer Bellani minimum-maximum thermometer (1828/1829) Apel thermograph Geriner thermometrograph
1833-35	M2	Freie Strasse 23, 3F	-0.36 hPa			
1835-37	M2	Freie Strasse 23, 2F	+0.09 hPa			
1837-63	M3	Domhof/Münsterplatz 12, 2F	+13.77 m -1.83 hPa			
1835-63	MR	Alter Botanischer Garten			R	
1827		Marchmatt (summer)			p, T, h, w, wdir, wn 3-15x daily	
1828		Arlesheim (summer)			p, T, h, w, wdir, wn 3-16x daily	
1829		Binningen (summer)			p, T, h, w, wdir, wn 4x daily	
1830		Binningen (summer)				
1832		Badenweiler (summer)				
1836	M4	Stückelberger Gut (summer)				
1837		Höllstein				
1826-27	F1	Hebelstrasse 22, GF		Johann Jakob Fürstenberger	p, T, w, wdir, h, wn mostly 8, 11, 14, 21	Loos barometer Bellani thermometer Oechsle thermograph
1828	F2	Schlüsselberg 13. 1F				
1828-32	F3	Nadelberg 37 1F				
1838-49	S1	Falkensteinerhof, 2F		Andreas Schneider	p, T, w, wdir, Wn 3x daily	(only 1838-46 available)
1849-56	S2	Augustinergasse/ Museum, MZ				(unavailable)
1856-63	K	Augustinergasse/ Museum, MZ		Franz Kaufmann	p, T, wdir 3x daily	(only 1862-63 available)

Figure 1. Locations of meteorological observations in Basel, 1825-1863, on a contemporary map. Shown are locations of Fürstenberger (F1 to F3), Merian (M1 to M4, MR), Schneider (S1 and S2), and Kaufmann. Map: Löffelplan, produced 1857-1859, published 1862 (source: Geoportal Kanton Basel Stadt). Not shown are the locations of Burckhardt's observations as well as those performed in the vicinity of Basel (Marchmatt, Arlesheim, and Binningen).

2.1. The series by J. Rudolph Burckhardt

Not much is known about the series by J. Rudolf Burckhardt, which was found at the University library of Basel. Possibly the observer was Johann Rudolf Burckhardt, 1802-1869, a lawyer from Basel. The series is not mentioned in Riggenbach (1892), Bider et al. (1958) or other compilations. The observations consist of 2-4 times daily measurements (at varying hours) of temperature, indicated in Réaumur, and pressure as well as weather descriptions. Unfortunately, we do not know the location of the measurements. The series spans the years 1825-1827 and thus might be important to concatenate earlier (Daniel Huber) and later segments (Peter Merian) of the Basel series.

Figure 2. Data sheet from J. Rudolf Burckhardt for September 1825, University Library of Basel (L III 25).

The series are hand written in a note book; the hand writing is at times hard to read, pages are sometimes stained, and there are many strike throughs. An example sheet is shown in Figure 2.

2.2. The series by Peter Merian

The longest and most comprehensive series from Basel from the 19th century is that from Peter Merian which started in 1826 (although we only have the data from 1828 onward). Peter Merian (1795-1883) was a scientist and politician of Basel. He was professor of Physics and Chemistry at University of Basel, from 1835 onward also professor of Geology. Three times he served the University as rector and had several political positions.

His grandfather Abel Socin already made measurements from 1783 to 1805 (Pfister et al., 2019). The barometric measurements in Basel in 1826 were originally performed in the context of altimetric measurements, but then continued by Merian. Together with his friends Friedrich Trechsel from Bern (see Flückiger et al., 2020) and Daniel Meyer from St. Gall (see Hürzeler et al., 2020), Merian tried to establish a meteorological network with the help of the

Swiss Natural Sciences Society, but did not find support. However, the three stations continued and the data were collected and published by the society.

Peter Merian measured all his life. As of 1864, the station transited into one of the new Swiss meteorological network that was run by the Swiss Natural Sciences Society (later by MeteoSwiss); the period from 1864 onward is not discussed in this paper. Prior to 1864, Peter Merian measured mainly at three locations: St. Johannvorstadt, Freie Strasse, and Münsterplatz. From 1835 onward, his thermometric, barometric and hygrometric measurements were supplemented by precipitation measurements in the old botanical garden (read daily by the gardener). During some of the summers, Merian measured at other locations. Some of these locations were at the outskirts of the city, but some also were 10 km or further away, such as Marchmatt or Arlesheim. The latter two series were already digitsed within DIGIHOM (Füllemann et al., 2011). An extensive discussion is found in Riggenbach (1892).

Merian's first barometer in April 1826 was a Dumotiez barometer (divided in inches and 1/12th inches), form Jun 1826 onward he used a Loos barometer (Darmstadt), in inches and tenths, with an attached Réaumur thermometer. However, the pressure data in Merian's original data tables for 1826 and 1827 (note that our sources start only 1828) were taken from Fürstenberger. In 1828 Merian obtained three Oeri mercury barometers form the Swiss Natural Sciences Society (the same type of instruments was also used in Bern by Trechsel), with attached Réaumur thermometer. Merian reduced the pressure values. The diameter of the Oeri barometer was 4 lines, the quadratic cistern measured 4 inches, which yields a ratio of 1/200. A vernier allowed reading with an accuracy of 0.05 inch. Comparisons with other barometers showed good results, but Merian suspected that a change in the wood as well as leaking mercury might have affected the measurements. The barometer was calibrated upon arrival, but with an error (and some loss of mercury during a transport to Fürstenberger; for details see Riggenbach, 1892). From 8 September 1828, the Oeri barometer replaced the Loos barometer for the observations. The Loos barometer was henceforth used at the summer observation sites (see Table 1). At many later occasions, comparisons with other instruments were performed, some of which served as travelling standards and allowed tracing the barometer standard to that of the Paris observatory (see Riggenbach, 1892)

Peter Merian used several Loos mercury thermometers over the course of his measurements. He also acquired two Bellani minimum-maximum thermometers. They were in operation during the cold winter 1829/30 but broke soon thereafter. Later he acquired a Bellani thermograph. One of the Loos thermometers was later used as wet bulb thermometer. Details on the instruments are given in Riggenbach (1892). Not much is known, however, about the thermometers used after the 1830s.

As to the precipitation measurements, the pluviometer in the botanical garden had an area of 131.5 square inches; 0.01 inches of rain correspond to 26.0849 g of water. This number was used for the conversion by Riggenbach (1892).

The data sheets from Peter Merian can today be found in the Basel University library. An example sheet is shown in Figure 3. The sheets are well organized and well legible. Merian often copied measurements from other observers, presumably to complement his own record (Pfister et al., 2019).

Figure 3. Data sheet from Peter Merian at Freie Strasse, January 1837, University Library of Basel (NL 307 : 6), http://doi.org/10.7891/e-manuscripta-14531.

2.3. The series by Johann Jakob Fürstenberger

Peter Merian organised parallel measurements to check his own measurements. During the entire time period from 1826 to 1863, there were several control stations, and comparisons were also made at several other occasions. During the first years, from 1826 to 1832, such measurements were performed by Johann Jakob Fürstenberger. He was the step brother of Peter Merian. Later, control measurements in Basel were performed by Andreas Schneider and Franz Kaufmann (Sect. 2.4.). These measurements were not consulted by Bider et al. (1958) when constructing the long Basel temperature series. However, the series are relatively short.

Figure 4. Data sheet from J. J. Fürstenberger, April 1826. University Library of Basel (NL 307 : 4), http://doi.org/10.7891/e-manuscripta-14519.

Fürstenberger measured at three locations (see Table 1). The data from the first two years are particularly important as they may help to complement Merian's measurement backward (*i.e.,* Merian's tabulated pressure data for these year were actually Fürstenberger's data). Fürstenberger used a Loos barometer. He had a Bellani thermometer, an Oechsle thermometer and later an Oechsle thermograph. The instruments were partly the same as those of Merian as they frequently exchanged instruments. Riggenbach (1892) gives some further details. Fürstenberger's data sheet can also be found in the University Library of Basel. An example sheet is shown in Fig. 4.

2.4. The series by Andreas Schneider and Franz Kaufmann

A further control series was performed at the Museum Augustinergasse (today Natural History Museum). Observations were first taken by Andreas Schneider, bookbinder and later preparatory of the museum (Häner, 2017). Schneider probably observed in 1832 and from 1838 to 1856 (Riggenbach, 1892). Our data span the period 1838-1846 and are rather episodic, with frequent measurements during some months followed by long gaps.

From 1856, measurements at the Museum were continued by Franz Kaufmann. Our data from Kaufmann however only cover the period 1862-1863. Note that both the Schneider and the Kaufmann series do not fill gaps or complement the Merian series, but they are nevertheless important for comparison.

3. Processing and Quality Assessment

For Basel, many overlapping series are available. We therefore extend our quality control procedures. Rather than only comparing records from different times-of-day form the same record with each other and flagging outliers (residuals outside 4 standard deviations from a least-squares regression, see Brugnara et al., 2020), we also compared records from different stations with each other as well as thermometer and thermograph records form the same location. This results in a higher number of flagged values. Note that we always flag both of the compared values. Having more information as in this case would often allow to decide which of the two compared values is likely wrong. However, this cannot easily be done in an automatic way and therefore this decision is deferred to the user. We use two different flags for the internal QC (comparing different times-of-day from the same location) and the multi-station QC.

Because several of the series have many measurements per day, we divided the day into 6 intervals (divided by 7, 11, 13, 15, and 19 UTC) for the QC. For the plotting and correlations shown in the following, we use fewer intervals, namely three for Burckhardt, Schneider, and Kaufmann, four for the Fürstenberger series, and six for the Merian series.

The series from Burckhardt overlaps only partly with other series. In total 19 (out of 1589) and 17 (out of 1843) values were flagged for pressure and temperature, respectively. The correlation plots (Fig. 5) reveal rather low correlations, although it should be mentioned that the time of observation varied. Nevertheless, the series may be useful to fill gaps in particular during the transition period from the Huber measurements to the Merian series; a period during which the existing Basel series is supplemented with data from Delémont. However, the quality seems lower than that of other series.

Results for the Fürstenberger series (Fig. 6) include the comparison between thermometer and thermograph as well as the barometric measurements. The flagging identified 55 (out of 3426) outliers for the thermometer, 40 (out of 2630) for the thermograph and 64 (out of 3426) for the barometer. Comparing only the neighbouring times of day (Fig. 6), we find very good agreement between the series from different times of the day. Correlations are distinctively higher than those for the Burckhardt series. For temperature, the comparison between thermometer and thermograph also shows a very good agreement. Only for the pressure comparison between afternoon and evening we find a somewhat lower correlation, which however may be explained by the larger time difference between these two measurements.
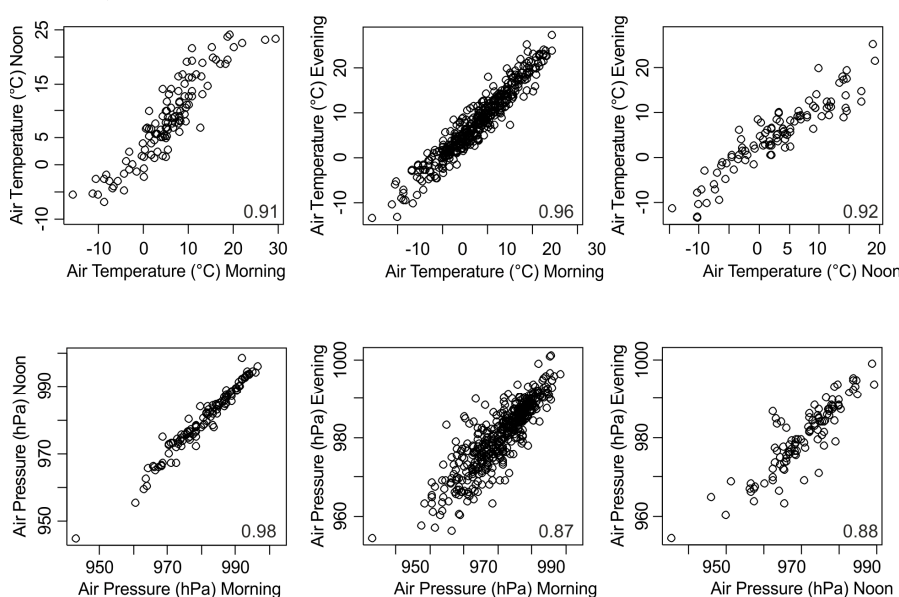
Figure 5. Mutual comparisons of morning, noon, and evening series of temperature (top) and pressure (bottom) from J. Rudolf Burckhardt. The number in the lower right corners of the panels indicates the Pearson correlation coefficients.
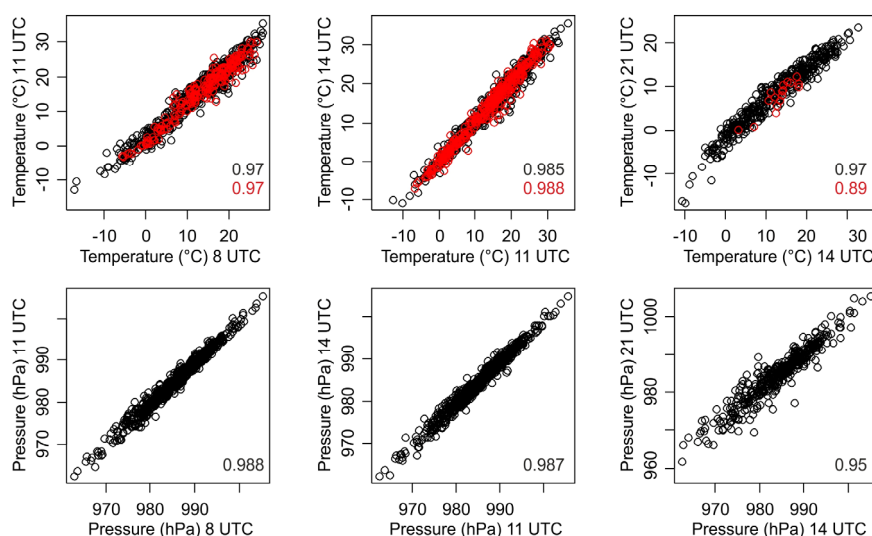
Figure 6. Mutual comparisons of four times daily series of temperature (top) and pressure (bottom) from Fürstenberger. In the top row, red circles indicate temperature from the thermograph, black circles those from the thermometer. The numbers in the lower right corners of the panels indicate the Pearson correlation coefficients.
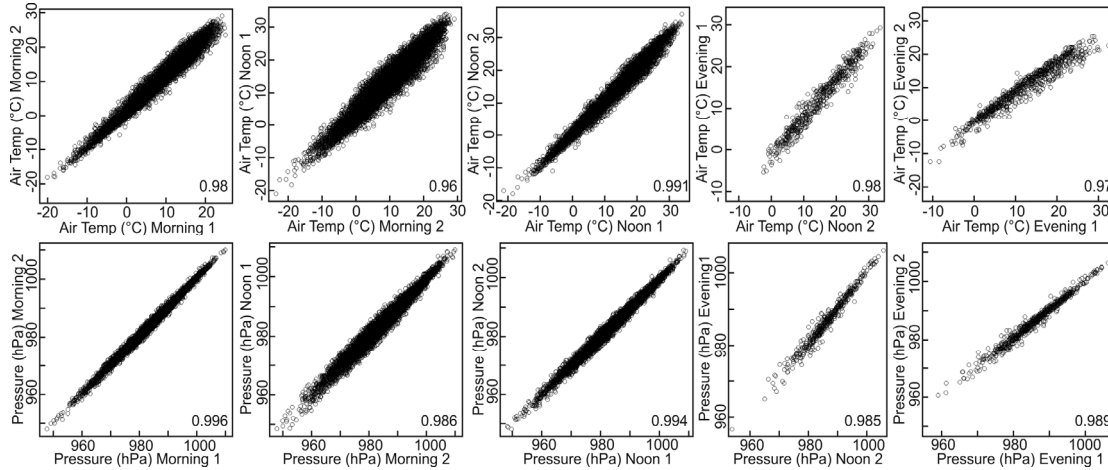
Figure 7. Comparisons of six times daily series of temperature (top) and pressure (bottom) from Merian. Only plots for neighbouring observations are shown. The number in the lower right corners of the panels indicates the Pearson correlation coefficients.

The Merian series is the longest and most used series. The up to six times daily observations provide a large amount of data. Out of 68304 measurements, 495 temperature measurements and 801 pressure measurements were flagged during our procedure. In terms of correlations (Fig. 7), temperature measurement performed during neighbouring times of the day correlate very well, between 0.97 and 0.99. Likewise, for pressure we find excellent correlations, exceeding 0.99.

The corresponding analyses for the Schneider series (Fig. 8) shows a generally good correlation for both, temperature and pressure. Both variables show nearly identical values, for some periods in the morning and evening. It is possible that some of the measurements were copied. This is clearly not the case for the noon measurements. In the comparison for pressure, we see a distinctive shift which occurs after a measurement gap from 7 May to 22 June 1840. This could indicate a change in the instrument, or also indicate copied data. This fact certainly merits further attention when the data series are concatenated to a single series.
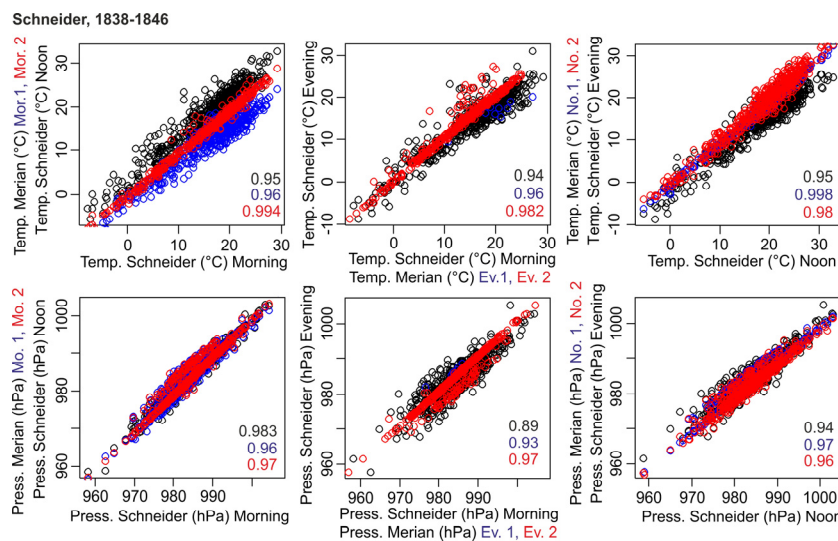
Figure 8. Mutual comparisons of three times daily series of temperature (top) and pressure (bottom) from the Schneider series. Also shown are comparisons with overlapping series from Merian (red and blue circles). The numbers in the lower right corners of the panels indicate the Pearson correlation coefficients for the scatter plots in the corresponding colours.
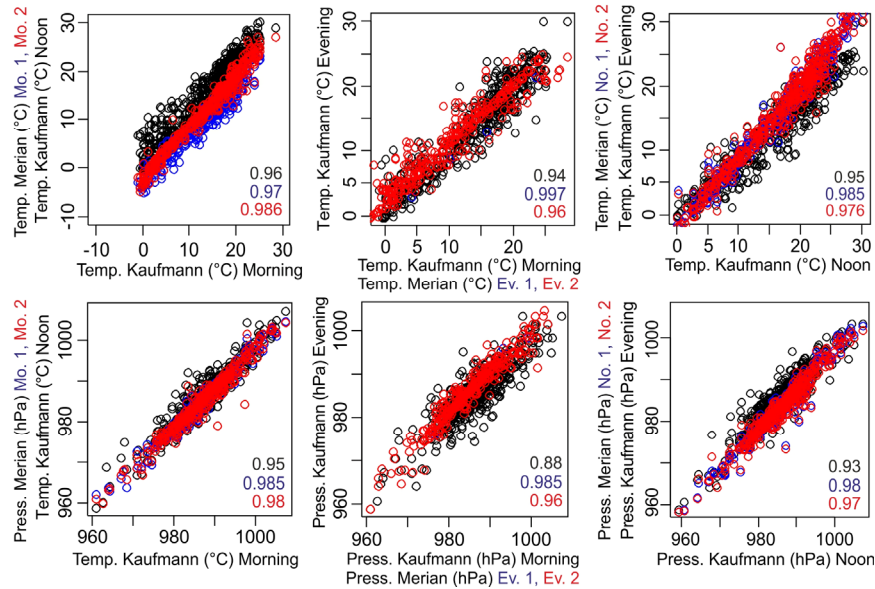
Figure 9. Mutual comparisons of three times daily series of temperature (top) and pressure (bottom) from the Kaufmann series. Also shown are comparisons with overlapping series from Merian (red and blue circles). The numbers in the lower right corners of the panels indicate the Pearson correlation coefficients for the scatter plots in the corresponding colours.

Corresponding plots for the Kaufmann series (Fig. 9) shows a very good agreement both mutually between different times of day as well as with the overlapping Merian series. However, in the Kaufmann series temperatures hardly ever drops below -1.2 °C. The reason for this remains unknown, but casts some doubts.

Further we analysed the diurnal cycle in the data (Fig. 10). Only the Merian series has sufficiently stable observing times to plot them together with a current diurnal cycle from the MeteoSwiss station (1 °C was subtracted to take global warming into account). The agreement is excellent for all partial series in summer. During winter, the diurnal cycle also agrees well, but the data during the first observation period are considerably lower than the other series.

Finally, we formed daily means and monthly means for all series. The results are plotted in Figure 11. The Merian series is very long and seems to be long term stable. It has been worked on exhaustively by Riggenbach (1892), Strub (1910), and Bider et al. (1958).
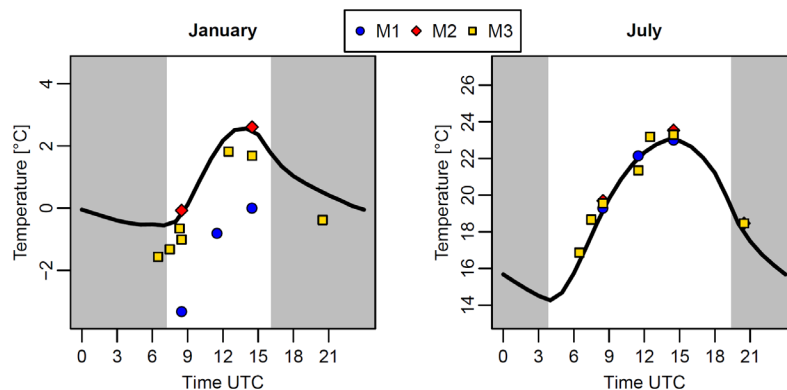
Figure 10. Diurnal cycle of temperature in January (left) and July (right) in present-day MeteoSwiss data (thick black line) as well as in the Basel series from Merian (grey shading indicates nighttime).

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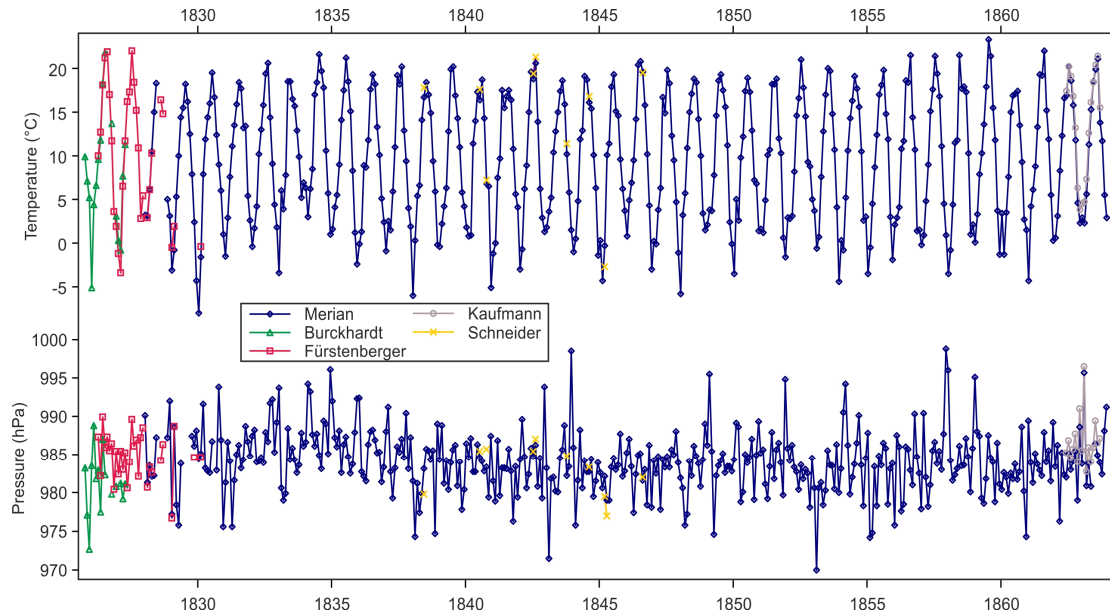
Figure 11. Time series of (top) monthly temperature and (bottom) monthly mean pressure in Basel from all five series.

Corrections can be taken from these works. The Burckhardt and Fürstenberger series could extend Peter Merian's series back and connect to Huber's series and therefore are particularly valuable, albeit short. They show a good mutual agreement in terms of temperature, but an offset in pressure (which in the case of Burckhardt might be due to the unknown location). The mutual overlap and the overlap of Fürstenberger with Merian may make it possible, although challenging, to combine the series.

The scarce data from Schneider show a good agreement with Merian. The same is true for Kaufmann's data, although a temperature difference to Merian is found in winter. Pressure seems to be higher in the Kaufmann series than in the Merian series. Riggenbach (1892) compiled all information on barometer altitudes and offsets determined form barometer intercomparisons, such that corrections could be taken from there (see Table 1).

4. Conclusions

The meteorological series from Basel is currently the longest evaluated meteorological series from Switzerland (together with that from Geneva). In this paper we analyse several segments covering the period 1826 to the start of the Swiss national network in 1864. The series were taken by five observes. The most prominent and most comprehensive series is that from Merian, but the other four series by Burckhardt, Fürstenberger, Schneider and Kaufmann are valuable to fill gaps and to better assess the transition from earlier series to this series. Overall the quality of the Merian data is excellent, and its measurement frequency is high. The overlap of the series allows a better quality control (as intended by Merian). In addition, the series from Burckhardt (despite the lack of metadata) and Fürstenberger are valuable in extending the series further back and, together with the Huber series, perhaps helping to fill the "interregnum", which is how Bider et al. (1958) termed the period 1805 to 1825.

The data are made publicly available by MeteoSwiss. They will also be available from the C3S data Global Land and Marine Observations Database (Thorne et al., 2017) and

EURO-CLIMHIST (Pfister et al., 2017). Together, the different series from Basel may allow the construction of a new "Basel series", which, unlike its precedent, is not filled in with data from Mulhouse and Delémont. However, this paper also shows that inconsistencies still need to be resolved.

Acknowledgements

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