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Two Meteorological Series from Bern from Trechsel, 1826–1849, and Benoit, 1837–1853

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Abstract

Friedrich Trechsel (1776–1849), university professor, and Daniel Gottlieb Benoit (1780–1853), doctor and amateur scientist conducted meteorological measurements in the city centre of Bern in the 1820s to 1850s. This paper describes the series. The 12-year overlap between the series allows a detailed comparison and a quality assessment. Overall we find a good agreement between the series, though several breaks are apparent. This paper accompanies the publication of the data.

1. Introduction

The compilation of Swiss early instrumental meteorological series in the framework of the CHIMES project revealed that, in Bern, observations have been made from 1760 until the start of the MeteoSwiss network in December 1863, albeit with some gaps (Pfister et al., 2019). The series are typically 10–30 years long and exhibit overlaps with each other. Although not all data have been found, a close-to-continuous record could possibly be obtained. Here we focus on two overlapping series from the early 19th century, namely a 24-year record from Friedrich Trechsel (1776–1849) and a 17-year record from Daniel Gottlieb Benoit (1780–1853). While Trechsel was a University professor, Benoit was an amateur scientist.

This paper describes the two series and provides detailed information on observers and locations. It accompanies the inventory of the Swiss early instrumental series (Pfister et al., 2019) and the publication of imaged data sheets (https://zenodo.org/record/3066836#.XVv-fGRS8-U) as well as of the data series (Brugnara et al., 2019, https://doi.pangaea.de/10.1594/

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PANGAEA.909141) which are also available from EURO-CLIMHIST (Pfister et al., 2017), Copernicus Climate Change Service (C3S) (Thorne et al., 2017) and MeteoSwiss.

The paper is to a considerable extent based on a Master thesis, which is available online (Flückiger, 2018; https://occrdata.unibe.ch/students/theses/msc/189.pdf). It is organised as follows. In Section 2 we introduce the series by Trechsel and Benoit, followed by a brief methodological chapter on their comparison. In Section 4 results of the comparison are presented. The paper ends with brief conclusions.

2. Measurements and instruments

2.1. The Trechsel series

Johann Friedrich Trechsel was born in 1776 in Burgdorf as the youngest child of a butcher. He grew up under rather poor circumstances and moved to Bern on his own at the age of 15 to study Theology and Mathematics. Before he founded the "Wissenschaftliche Lehranstalt" in Bern with Emanuel Zeender in 1800, he worked as a teacher at the boys' orphanage and as a pastor in Aubonne and Morges. With the reorganisation of the school system in 1805, the "Wissenschaftliche Lehranstallt" became redundant, but Trechsel became a professor for mathematics and from 1812 onwards for physics at the predecessor of the University of Bern, the "Akademie". He was involved in the triangulation of the Canton of Bern and in the planning of the Jura Waters correction. Furthermore, he was a member of both the Naturforschende Gesellschaft in Bern, in which he served as president during the years 1821, 1822 and 1829, and the Schweizerische Naturforschende Gesellschaft. In the latter, he served in the meteorological commission, where he organised and compiled the coordinated meteorological measurements in different locations across Switzerland. He retired in 1847 and died in November 1849. Trechsel was married from 1803 until his death and only survived by one of his six children (Trechsel, 1884; Graf, 1886; Zürcher, 2013).

Trechsel reported his data in French. He measured pressure, indoor and outdoor temperature, and humidity at 9 AM, 12 AM, 3 PM and 9 PM or 10 PM. Additionally, he observed wind direction and strength (1, 2, or 3) and weather using ten categories ("calme", "brouillard", "brume ou brouillard sec", "couvert", "clair", "nuages", "pluie", "neige", "grêle" and "orage").

Trechsel's weather measurements were carried out on Bern's Münsterplatz on the second floor of house number 317. This corresponds today to the address Herrengasse 1 (see Fig. 1). The measuring instruments were located 28.2 Parisian feet above the ground at 548.3 metres above sea level. Wind observations were based on the wind vane on the Zytglogge Tower. From 1848 to 1849, Trechsel measured the pressure in the second floor of Kramgasse 12 at an elevation of 542 metres above sea level.

We know that Trechsel used a fixed-cistern barometer, which was manufactured in Zurich in the year 1826 by Mechanicus Oeri, who had been a student of Fortin. Oeri had built all the barometers for the atmospheric pressure measurements of the Schweizerische Naturforschende Gesellschaft in 1826, so we can assume that it fulfilled contemporary scientific standards. Since its first use in 1826, the barometer remained at the same place until Trechsel

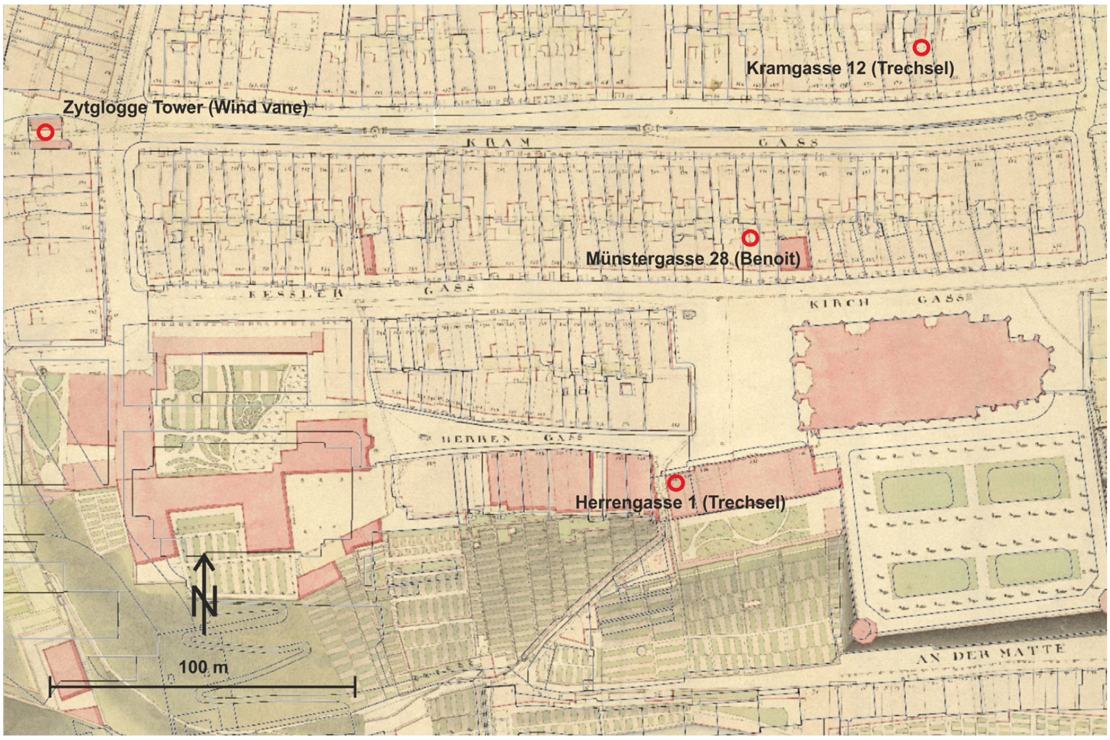

Figure 1. Map of the centre of Bern with the measurement locations (from: Oppikofer Atlas, Geodata: City of Bern).

relocated his measurements to Kramgasse 12 in January 1848. The barometer had been constantly observed since its installation in 1826. An indirect comparison (it is unknown when this took place) to the normal barometer stationed in the observatory in Paris showed a positive difference of 0.36 inches, which is accounted for in the published observations (Wolf, 1844a, 1848ab; D'Hombres-Firmas, 1841).

The tube of Trechsel's barometer had a width of 7.9 mm and one side of the quadratic cistern was 11.5 cm long. Therefore, the ratio between the surface in the tube and in the cistern was approximately 1 to 225, which was rather small for fixed-cistern barometers. It is not known whether Trechsel applied a correction for this. The noted values were already reduced to 0 °C, as is mentioned in the header of the data tables. However, it was not Trechsel himself who did the reduction to 0 °C, but Friedrich Henzi, a scholar of Rudolf Wolf responsible for the publication of the meteorological observations in the Mitteilungen der Naturforschenden Gesellschaft in Bern from 1844 to 1854 (Fig. 2). Trechsel explicitly indicates that the unit for measurements of the tube and the cistern of his barometer, as well as the derivation from the normal barometer, was Paris inches. We, therefore, conclude that he used the same unit for observations as well (Wolf, 1844a; Graf, 1886).

Possible errors of Trechsel's barometer include capillarity, inadequate correction for temperature (from 1844) due to the unknown thermometer used, and the dilatation of heat transfer. Trechsel's indoor temperature data, which were used for the correction of pressure, have been digitised only until 1843.

OBSERVATIONS MÉTÉOROLOGIQUES. JUILLET 1845.

Jours.	9 heures du matin. Barom. à 0°.	9 heures du matin. Therm extér.	9 heures du matin. Hygr.	Midi. Barom. à 0°.	Midi. Therm extér.	Midi. Hygr.	3 heures du soir. Barom. à 0°.	3 heures du soir. Therm extér.	3 heures du soir. Hygr.	9 heures du soir. Barom. à 0°.	9 heures du soir. Therm extér.	9 heures du soir. Hygr.	Thermomètre Max.	Thermomètre Min.	Etat du ciel à midi.	Vents à midi.
1	26· 6,39	+13,8	74,6	26· 6,08	+16,4	62,0	26· 5,82	+18,0	62,0	26· 5,69	+13,5			+ 4,5	Superbe	N. E.
2	6·11	+17,7	69,5	6,00	+21,5	64,0	5,77	+18,5	54,0	5,79	+14,0			+ 9,5	Superbe	N. E.
3	5,89	+19,6	73,5	5,62	+23,4	58,0	5 48	+23,8	57,5	6 15	+17,5			+10,0	Superbe	N. E.
4	6,40	+20,2	68,0	6,13	+23,6	62,0	5 96	+23,8	57,5	7,61	+10,1			+11,4	Superbe	N. E.
5	7,40	+18,0	80,0	7,14	+19,0	75,0	7,02	+22,0	71,0	6,79	+17,2			+11,3	Superbe	S. W.
6	7,35	+20,1	76,0	7,07	+23,7	70,0	6,86	+24,7	62,0	7,00	+18,8			+12,9	Superbe	E.
7	6,76	+21,4	73,0	6,56	+24,8	67,0	6,17	+26,1	50,0	6,20	+19,6			+14,0	Superbe	N. E.
8	5,03	+21,8	70,5	5,32	+25,4	61,0	4,91	+26,8	55,0	5,59	+18,8			+15,7	Superbe, orage à 4 h. du soir	E.
9	6,70	+16,0	88,0	6,55	+18,0	67,0	6,59	+16,2	60,0	6,59	+15,1			+12,2	Pluie	S. W.
10	5,10	+17,4	74,0	4,66	+19,1	72,0	4,06	+21,0	65,5	4,16	+16,7			+11,3	Soleil nuageux	N. E.
11	3,62	+16,6	81,0	3,24	+17,8		2,97	+17,1	76,0	3,51	+12,8			+ 8,8	Couvert	S. W.
12	4,51	+12,6	84,0	4,94	+17,7		5,09	+13,8	70,0	6,30	+10,6			+10,3	Soleil nuageux	S. W.
13	6,83	+12,8	76,0	6,68	+14,5		6,75	+13,8	74,0	6,89	+11,2			+ 9,2	Couvert	S. W.
14	5,67	+13,2	90,0	5,54	+14,7		5,10	+15,5	79,0	5,13	+11,7			+11,2	Ceuvert petite pluie	S. W.
15	4,98	+12,7	82,0	4,79	+10,8		4,78	+11,5	82,0	4,94	+10,0			+10,3	Pluie	S. W.
16	5,10	+11,3	76,0	5,27	+11,2		5,47	+ 9,9	91,0	6,24	+ 9,2			+ 7,5	Petite pluie, plus tard grésil	S. W.
17	6,31	+11,5	83,0	6,26	+13,7		6,15	+14,9	62,0	6,61	+10,3			+ 6,7	Bean	N. E.
18	6,73	+13,0	79,0	6·59	+15,4		6,53	+16,3	60,0	6,70	+11,4			+ 6,5	Superbe	N. E
19	5,11	+14,5	75,0	4,74	+18,0		4·21	+18,5	56,0	4,08	+14,4			+ 6,3	Superbe	N. E.
20	3,40	+15,5	81,0	3,25	+18,0		3,27	+17,8	67,0	3,80	+12,4			+11,4	Soleil nuageux	S. W.
21	4,11	+13,6	84,0	4,05	+18,5		3,94	+17,0	71,0	4,10	+13,8			+10,2	Soleil nuageux	S. W.
22	4,23	+10,6	82,0	4,09	+17,7		3,92	+19,5	73,0	4,16	+15,3			+10,2	Couvert	S. E.
23	4,57	+16,7	87,0	4,53	+17,8		4,12	+19,0	72,0	3,65	+16,0			+12,0	Petite pluie	S. W.
24	3,93	+17,0	78,0	4,02	+19,8		3,96	+20,3	62,0	4,49	+16,0			+12,7	Beau	S. W.
25	4,72	+18,3	74,0	4,70	+20,2		4,94	+16,5	88,0	5,28	+14,0			+12,6	Soleil nuageux	S. W.
26	5,49	+16,3	87,5	5,59	+15,2		5,53	+17,6	73,0	5,71	+13,2			+12,0	Petite pluie et tonnerre	S. W.
27	5,69	+14,2	74,0	5,47	+16,5		5,41	+17,0	60,0	4,31	+17,1			+11,0	Couvert apparence orag.	S. W.
28	4,54	+15,8	72,0	4,39	+16,8		4,00	+17,8	66,0	3,50	+12,2			+10,2	Couvert	S. W.
29	2,25	+12,7	95,0	2,23	+14,2		3,16	+10,2	89,0	4,37	+10,2			+10,0	Couvert, il a plu	S. W.
30	5,23	+12,4	86,0	5,26	+14,8		5,14	+15,0	79,0	3,60	+10,9			+ 8,6	Superbe	S. W.
31	4,28	+14,4	76,0	4,15	+17,6		3,42	+19,6	64,0	4·01	+15,4			+ 6,0	Nuageux	S. W.
1–10	26· 6,31	+18,6	74,7	26· 6,11	+21,5	65,8	26· 5,86	+22,1	59,4	26· 6,10	+16,1	91,0		+11,3	. . . Moy. du 1er au 10	
11–20	5,23	+13,4	80,7	5,14	+15,2	72,3	5,03	+14,9	71,7	5,42	+11,4	91,0		+ 8,8	. . . Moy. du 11 au 20	
21–31	4,46	+14,7	81,4	4,40	+17,2	74,7	4,32	+17,2	72,4	4,29	+14,0	89,5		+10,5	. . . Moy. du 21 au 31	
	26· 5,30	+15,5	79,0	26· 5,19	+17,9	71,1	26· 5,03	+18,0	68,0	26· 5,25	+13,9	90,5		+10,2	. . . Moy. du mois	

Figure 2. Trechsel's observations for July 1845 sheet as published in the "Mitteilungen der Naturforschenden Gesellschaft".

2.2. The Benoit series

Daniel Gottlieb Benoit was born in Bern in 1780. He grew up in Brandis, where his father Abraham Benoit was provincial governor from 1788 to 1794. Before he moved back to Bern, he received his education from a private tutor. In Bern he attended the Progymnasium and afterwards studied Theology. Nevertheless, the political circumstances around the Helvetic Republic made professional prospects of becoming a clergyman bleak and so Benoit decided to become a medic. He studied medicine in Bern, Jena, Bamberg, Würzburg and Paris and was conferred a doctorate in 1805. In 1806, he returned to Bern. In 1815, he became a doctor of medicine at the Inselspital, where he went as far as to become vice medical director. Despite his good reputation, the administration divested Benoit of his office in 1831. Henceforth, he left the medical profession and got involved in different councils, commissions and directions related to education, poverty reduction and public life. He lived with his parents, later with his older brother and was never married. From 1815 to 1832, he was a member of the Naturforschende Gesellschaft in Bern, where he served as the secretary in 1816 and 1817 and as the president in 1823 (Hugendubel, 1854; Wolf, 1854; Graf, 1886).

Benoit did not mention what type of instruments he used to measure air temperature and atmospheric pressure. Neither did he provide information on how exactly he conducted his measurements. The only information Benoit gave about his measurements, was that he carried them out twice a day at 6 AM and at 2 PM on the second floor of a house at the Kirchplatz in Bern (Benoit, 1853), which most likely corresponds with the Benoit house at the present-day address Münstergasse 28 (Weber, 2016).

Benoit did his measurements in an amateur capacity. At the time he started his measurements, he had already left the Naturforschende Gesellschaft Bern and therefore most likely did not have a mandate to collect meteorological data. Nevertheless, as a former member and highly qualified doctor, Benoit was used to scientific work and arguably was aware of measurement standards. Since Trechsel was Benoit's predecessor as president of the Naturforschende Gesellschaft in Bern, they almost certainly knew each other. Nevertheless, it is unclear whether Trechsel had direct influence on Benoit's measurements, or vice versa.

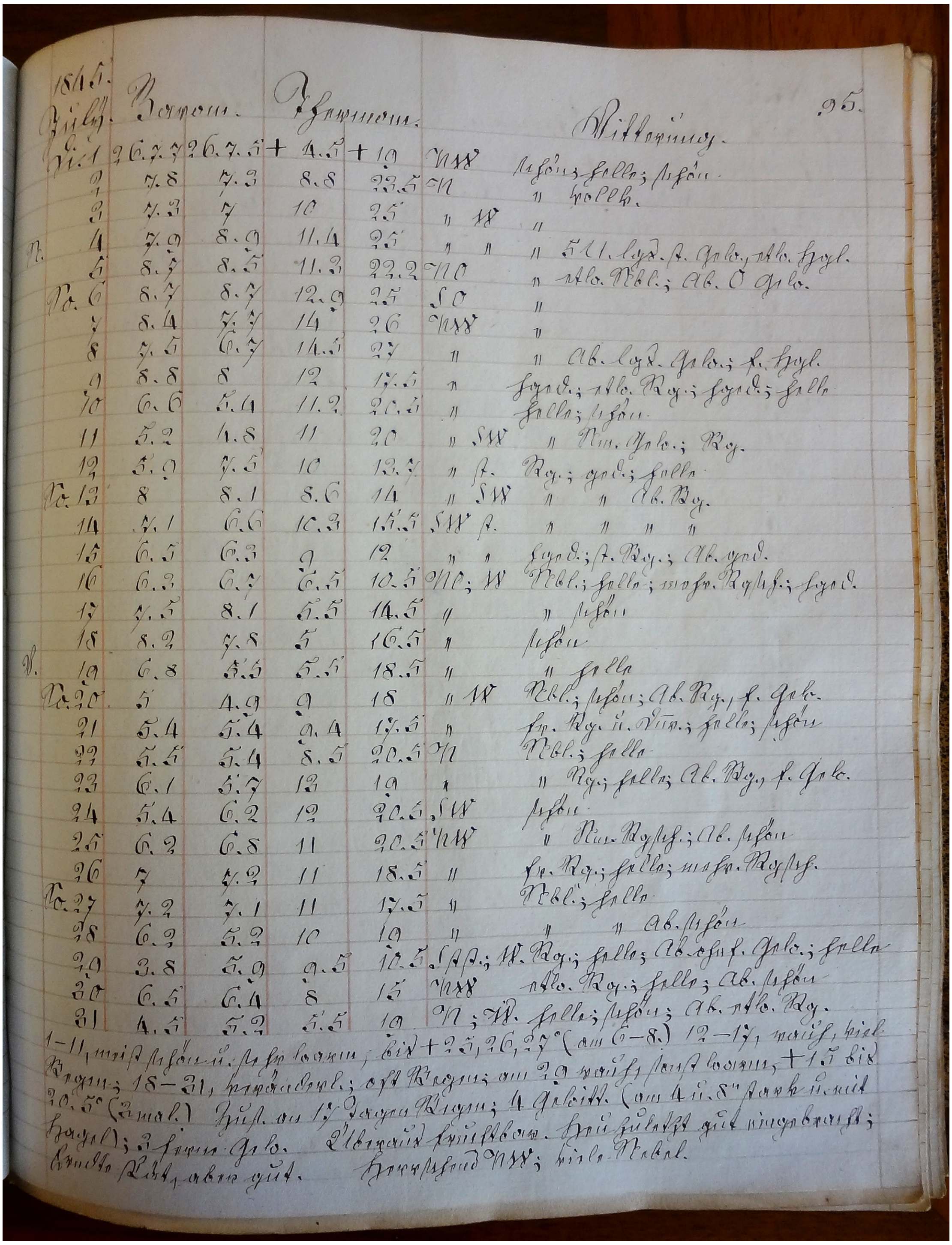

Figure 3. Observations for July 1845 sheet from Daniel Gottlieb Benoit (from Burgerbibliothek Bern, Mss.h.h.XXII.95, photo: Julian Flückiger).

Benoit's handwritten observation tables were imaged from the Burgerbibliothek Bern (Mss.h.h.XXII.95, Fig. 3). Daily data for the last period (1846–1854) were published in the Supplement Volumes (*Schweizerische Meteorologische Beobachtungen* **6** (1869), p.44–569). Each monthly sheet ends with a qualitative weather description including the number of rain days, first snow, start of harvest, quality of yields, etc.

3. Data processing and quality assurance

The data were processed as described in Brugnara et al. (2020). In the following, we present the results of the quality control procedure and some descriptive analyses of the data. In the subsequent Section we then compare the overlapping period of the two series. Far more detailed results and discussions are given in Flückiger (2018).

3.1. The Trechsel series

Applying quality control to the pressure series of Trechsel yielded 234 flagged values out of 31,218 (or 0.7%). Note that we reduced pressure to 0 °C between 1826–1843 using indoor temperature measurements, while from 1844 onwards we use the published data that were already reduced. As Trechsel observed four times per day, mutual comparisons were performed between morning and noon, noon and afternoon, and afternoon and evening. Results (Fig. 4) show an excellent correlation of morning and noon as well as noon and afternoon measurements (coefficients of 0.99). The correlation drops to slightly lower values for the comparison of afternoon versus evening values (which are further apart in time), but still reaches 0.94. The pressure climatology shows the expected seasonal cycle as well as the asymmetry of the tails of the distribution (*i.e.,* more negative extremes).

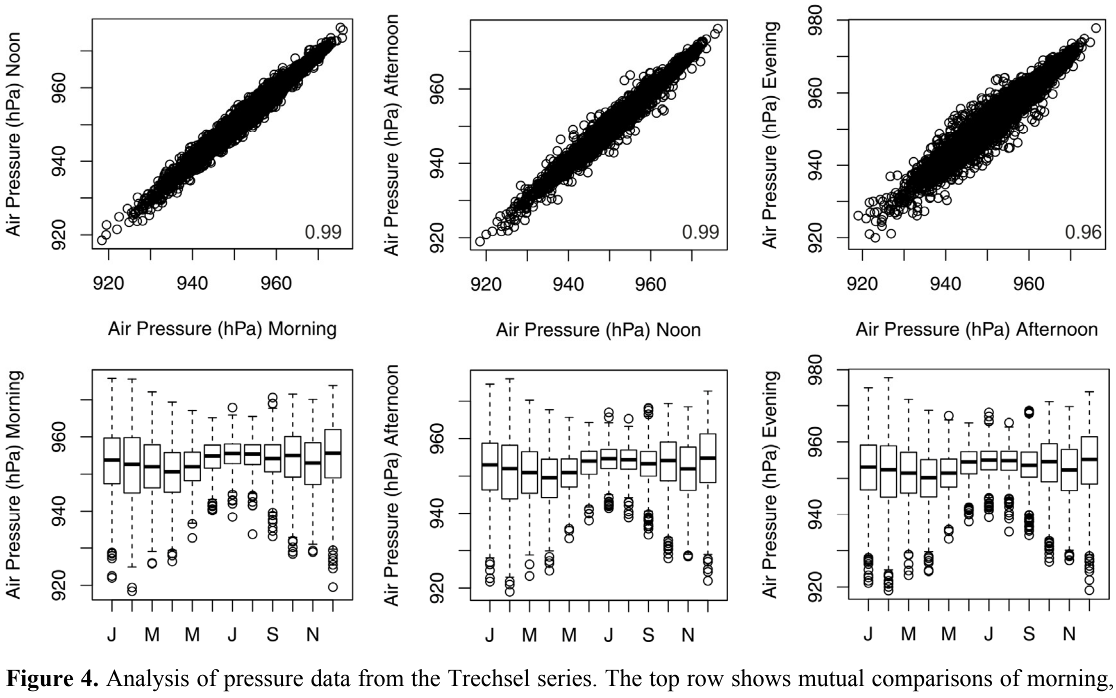

Figure 4. Analysis of pressure data from the Trechsel series. The top row shows mutual comparisons of morning, noon, and evening series (the number at the bottom right corner indicates the Pearson correlation coefficient), the bottom row shows box plots for morning, afternoon and evening as a function of calendar month (box indicates quartiles and median, whiskers extend to at most 1.5x the interquartile range from the box).

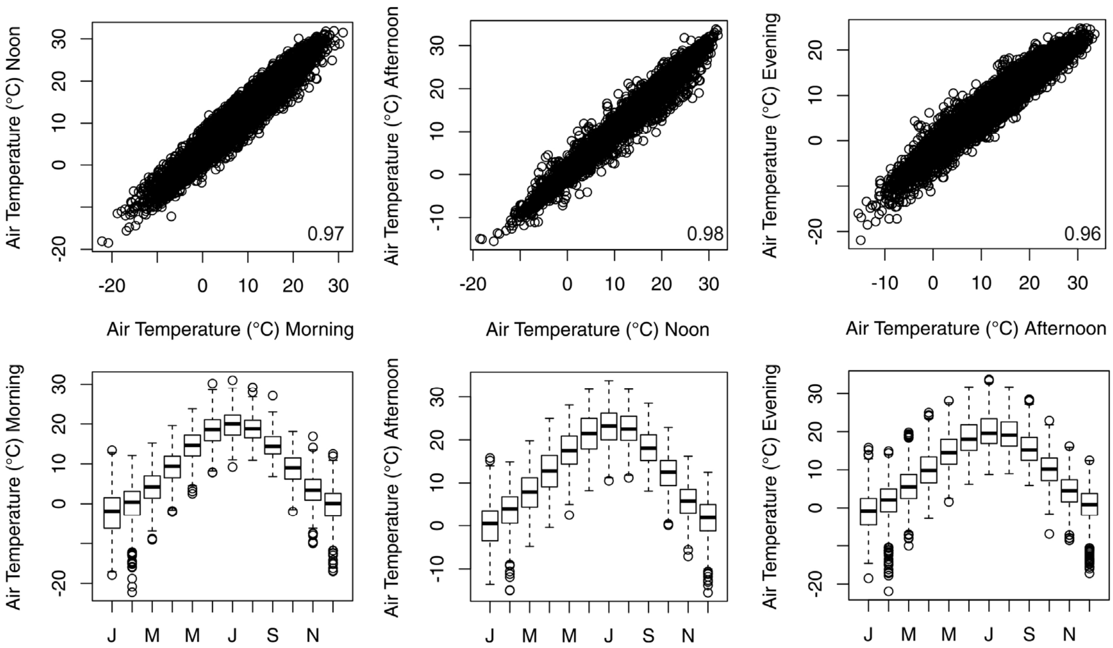

Figure 5. Analysis of temperature data from the Trechsel series. The top row shows mutual comparisons of morning, noon, and evening series (the number in the bottom right corner indicates the Pearson correlation coefficient), the bottom row shows box plots for morning, afternoon, and evening as a function of calendar month (box indicates quartiles and median, whiskers extend to at most 1.5x the interquartile range from the box).

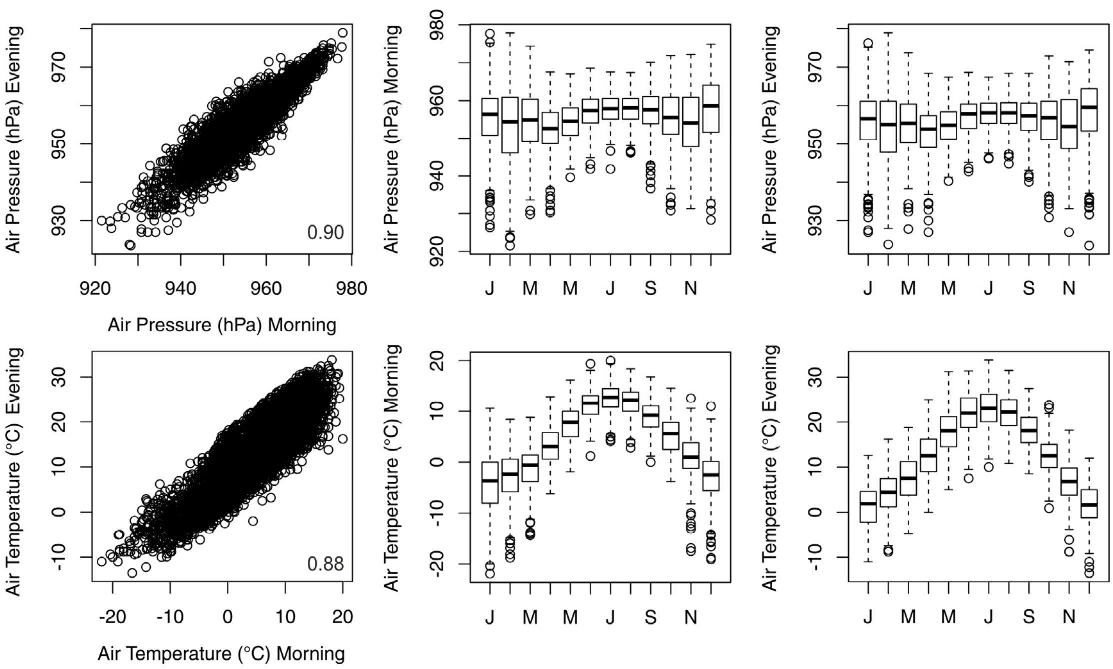

Figure 6. Analysis of pressure (top) temperature (bottom) and data from the Benoit series. The left row shows mutual comparisons of morning and evening series (the number in the bottom right corner indicates the Pearson correlation coefficient), the middle and right rows show box plots for morning and evening as a function of calendar month (box indicates quartiles and median, whiskers extend to at most 1.5x the interquartile range from the box).

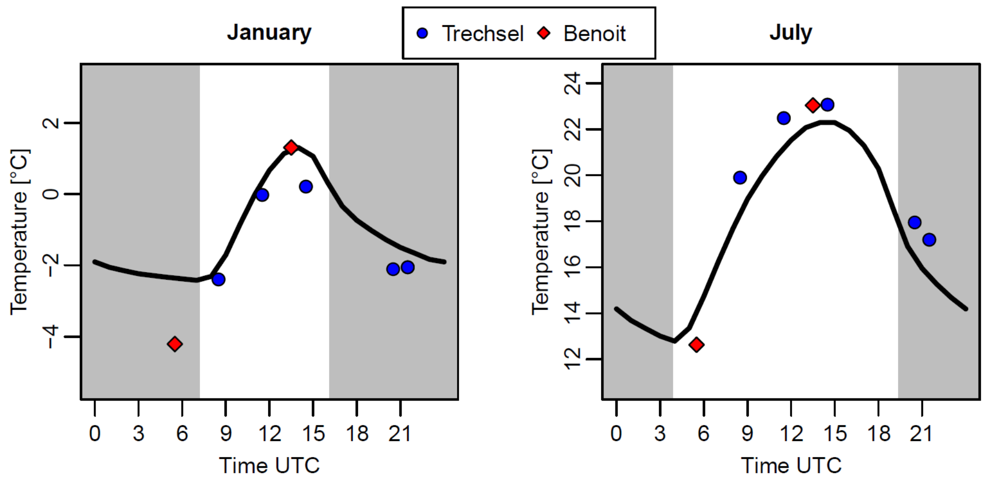

Figure 7. Diurnal cycle of temperature in January (left) and July (right) in present-day MeteoSwiss data (thick black line) as well as in the series from Trechsel and Benoit (grey shading indicates nighttime).

For the temperature series, we find 215 flagged values out of 31,178 (corresponding to 0.7%). The corresponding correlation analysis again reveals very high correlations between morning and noon as well as between noon and afternoon measurements, with coefficients of 0.97 and 0.98, respectively. The correlation between afternoon and evening measurements drops to 0.96, but since these two measurement times are further apart, this is expected.

3.2. The Benoit series

The Benoit series has twice daily measurements, in the morning and afternoon (here denoted evening, for consistence with the other series). Note that we do not know if Benoit reduced pressure. We assumed he reduced pressure to 10 °R, which was a common practice at that time. In the pressure series, only 26 out of 11274 measurements were flagged, corresponding to 0.2% of the values. For temperature, 98 out of 11285 values (or 0.9%) were flagged.

The comparison of the two pressure series per day (Fig. 6) shows a relatively large scatter. The correlation is 0.9. The lower left part of the scatter plot indicates possible shifts, which we will revisit in the next section. Note that Flückiger (2018) found additional problems in Benoit's pressure data prior to June 1840. The climatology (middle and right rows) shows the expected minimum in April.

The scatter plot for temperature (bottom left) shows an even larger scatter. In fact, the correlation (0.88) is among the lowest found in the CHIMES project based on corresponding analyses.

Figure 7 shows the comparison of the mean temperature values at the different observation times with the diurnal cycle of the modern MeteoSwiss station at Bern/Zollikofen, 1981–2010 (1 °C was subtracted to take global warming into account). The data from both records match the modern climatology quite well, with deviations mostly within 1 °C. The only exceptions are the morning temperatures of Benoit, which are too low especially in winter, pointing perhaps to an excessive radiative cooling of the thermometer. On the other hand, it is also evident how the choice of Trechsel for the morning observation time is not ideal in summer, when the temperature at 9 AM is closer to the daily maximum than to the minimum. A comparison of Trechsel's temperature measurements with present day data from Bern (Fig. 7) reveals a good correspondence of the diurnal cycle. In January Trechsel's measurements were slightly below, in July slightly above the present day data. Radiative effectes cannot be excluded.

4. Comparison of Trechsel's and Benoit's series

Since the two series from Trechsel and Benoit partly overlap, we compared the morning measurements (6:00 and 9:00 local time) as well as the afternoon measurement (14:00 and 15:00) directly. The comparison for pressure (Fig. 8, top) shows a good correlation, reaching 0.98 in the morning and slightly less (0.965) in the afternoon. Pressure measurements of the two series can therefore be considered precise. There are, however, differences. For instance, the differences between Benoit's morning and afternoon measurements is at odds with the diurnal pressure cycle as obtained from present (2004–2009) pressure measurements from the station Bern-Bollwerk, particularly in winter. On the other hand, Trechsel's data show the expected diurnal cycle (Flückiger, 2018). Hence, Benoit either measured too low morning values or too high afternoon values. Considering the offset from the one-to-one line (red line in Fig. 8), the latter is more likely as Trechsel consistently measured lower pressure values than Benoit. A possible explanation is that Benoit did not correct the pressure readings for temperature or did not correct them properly. The largest inhomogeneity on 1 January 1844 corresponds to the change of data source in Trechsel. The differences become smaller when Trechsel moved his measurements to Kramgasse 12, possibly due to the lower elevation of the latter location.

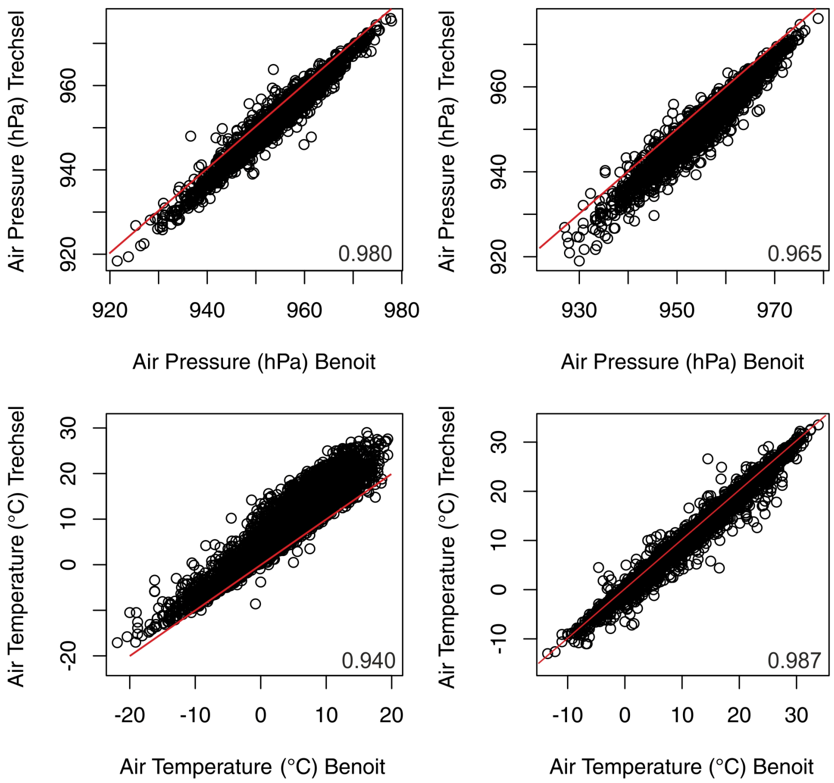

Figure 8. Mutual comparisons between the Trechsel and Benoit series in their overlapping period. Shown are (top) pressure and (bottom) temperature for (left) morning and (right) afternoon The numbers in the bottom right corners indicate the Pearson correlation coefficients.

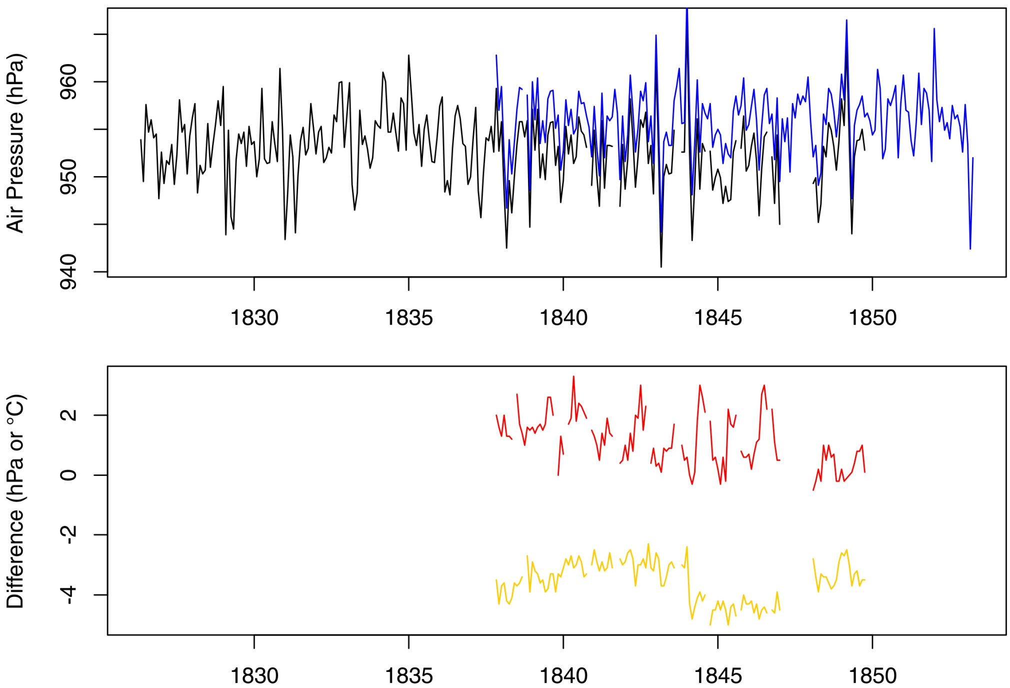

Figure 9. (top) Time series of monthly mean pressure from Trechsel (black) and Benoit (blue). (Bottom) difference series (Trechsel minus Benoit) of monthly mean temperature (red) and pressure (orange)

The comparison of temperature (Fig. 8, bottom) shows a worse agreement for morning as compared to afternoon measurements. This might at least partly be explained by the fact that the morning measurements were taken 3 hours apart during a time of day when temperature changes rapidly (see Fig. 7). In contrast, the afternoon measurements were taken only one hour apart during a time of day with slower temperature change. Particularly during summer, Trechsel (at 9:00) measured higher values than Benoit, as expected. The measurements in the afternoon follow the one-to-one line relatively closely.

Finally, we analysed time series of monthly mean temperature and pressure, derived from daily mean data as described in Brugnara et al. (2020). Results (Fig. 9 top) show again the higher pressure measured by Benoit as compared to Trechsel, but their course agrees very well. In fact, the correlation coefficient attains 0.987. The difference series (Fig. 8, bottom, red line) shows a large step change in 1844 which corresponds with a change in our source. A second step change appears in 1848, after Trechsel had relocated his measurements from Herrengasse 1 to Kramgasse 12. Further work will be necessary to produce a homogenised pressure time series.

The lower part of Figure 9 also shows the temperature difference. The difference series shows a pronounced annual cycle of ca. 2 °C and a change after 1848. It is difficult to assess possible error sources precisely. The measurements were always taken on the second floor of a building, arguably attached directly to a north-facing wall or to a suspension device several centimetres away from a north-facing wall. Hence, the thermometers were exposed to reflected or scattered radiation in each case, especially since at Herrengasse 1, Münstergasse 28 and Kramgasse 12 alike, there was a high, south-facing wall less than 10 metres away, possibly reflecting radiation, particularly during the months April to September around noon.

5. Conclusions

Meteorological measurements in Bern started in 1760. The CHIMES project has revealed that a close-to-continuous record, though with some gaps, could potentially be generated. Many of the series are however only 10–20 years long (Pfister et al., 2019). This paper describes two series by Friedrich Trechsel and Daniel Gottlieb Benoit which together cover the period 1826–1853 with a 12 year overlap, allowing for an analysis of their characteristics and possible errors. Trechsel was a trained scientist and served in the meteorological commission of the Schweizerische Naturforschende Gesellschaft, on whose behalf he organised and compiled coordinated meteorological measurements across Switzerland. He was thus well acquainted with the latest standards of meteorological measurements, and his instruments were funded by the Naturforschende Gesellschaft. Benoit was an amateur scientist, acting on his own behalf, though also well informed about measurement standards and with great dedication.

The analysis shows a generally good quality of the Trechsel series. The Benoit series also might be useful; differences between the two series can be explained by the time-of-day. In particular, the pressure series from Benoit compares well with the Trechsel series, such that it can be used to substitute the latter. The long term stability of the records yet remains to be analysed. There are still further segments of the 260 year long history of meteorological measurements made in Bern. Once these segments have been digitised and processed. The series will be homogenised and a long series will be constructed.

The data are further described in Brugnara et al. (2019, 2020) and made publicly available at https://doi.pangaea.de/10.1594/PANGAEA.909141, via MeteoSwiss and via the C3S Global Land and Marine Observations Database (Thorne et al., 2017) as well as EURO-CLIMHIST (Pfister et al., 2017). The images can be downloaded from https://zenodo.org/record/3066836#.XVv-fGRS8-U.

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