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The meteorological series from the Great St. Bernard, 1817-1863

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Abstract

The meteorological series from the Great St. Bernard, at 2479 m asl, reaches back to 1817 and is the longest high-altitude series in the world. Because of its location, the station is one of only two Swiss stations in the surface network of GCOS (Global Climate Observing System). The original data since 1819 were digitized in the framework of the DigiHom project, the data series for the first two years were recently found by MeteoSwiss and were also digitised. In this paper we describe the data series as well as the quality control procedures.

1. Introduction

High-altitude stations are particularly important for weather and climate monitoring. Already early in the history of meteorology, measurements were made at mountain stations (see Barry, 2008; Brönnimann, 2020). In Switzerland, measurements were made in the St. Gotthard Hospiz at 2093 m asl from 1728–1730 (pressure) and again 1781–1792. The latter data were digitized in the CHIMES project (Pfister et al., 2019; Brugnara et al., 2020b). In the same year, 1781, measurements started at Hohenpeissenberg in Germany at an altitude of 989 m asl. This series continues until today and is longest mountain top series (Winkler, 2009).

At the Great St. Bernard pass, 2479 m asl, monks started to make measurements in 1814. The series continues from 1817 to the present day and is the longest high-altitude series in the world. Together with the mountain top station Säntis (2502 m asl), which started in 1882, Great St. Bernard is one of two Swiss stations in the GCOS (Global Climate Observing System) surface network. The data from the Great St. Bernard have long been available in the form of daily and monthly means, expert-quality controlled by Schüepp (1991). The original

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data from Great St. Bernard since 1819 were more recently digitized in the framework of the Swiss DigiHom project (Füllemann et al., 2011). Recently, MeteoSwiss copied the data sheets from the first two years, so that now the complete original data are available.

This paper describes the data series as well as the quality control procedures of the Great St. Bernard. It is organized as follows. Section 2 provides information on the station history and instruments used. Section 3 describes the Quality Control procedure and shows the data as well as a brief example of data analysis. Conclusions are drawn in Sect. 4.

2. Instruments and location

Measurements started at Great St. Bernard (see Fig. 1 for location) already in March 1814 as part of the network of the Natural Sciences Society of Aargau (see Faden et al., 2020). Prior Abbé Murith, head of the monastery, was the observer. He delivered data to Aarau from March 1814 to September 1816 (the death of Murith), but they were not published. It seems that the data were sent to the London Meteorological Society (Zschokke, 1823; Custer, 1869), but our enquiries remained fruitless. Pictet (1817) mentions an even earlier attempt by the Academy of Torino to start measurements at the Great St. Bernard.

Measurements then started again in 1817 thanks to an initiative of Marc-Auguste Pictet (see Brönnimann et al., 2020), physicist and meteorologist in Geneva and at that time director of the Geneva Observatory. In the paper describing the station set-up, Pictet motivated the third attempt to start measurements at Great St. Bernard by Humboldt's work and the vision to collect global meteorological data. Humboldt's article on isothermal lines (Humboldt, 1817) is referenced and was summarized in the same issue of the journal. Another possible cause could have been the summer of 1816, which was cold and wet in Switzerland and which made the newly formed Swiss Natural Sciences Society formulate the price question: "Is it true that the climate of the high Alps in Switzerland has deteriorated?" The call explicitly excluded meteorological measurements, as the lack of suitable data was recognized (Bodenmann et al., 2012). Pictet was a member of the prize committee and had performed meteorological measurements in Geneva since the 1770s. However, he neither did mention the summer of 1816, nor the prize question in his article of 1817 (Pictet, 1817).

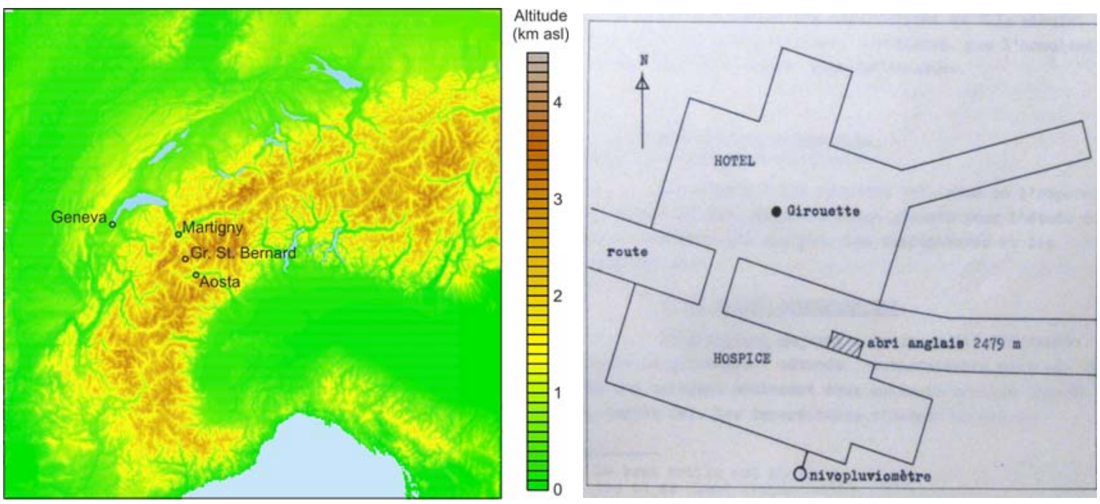

Figure 1. Left: Topographic map of the central Alps with the location of Great St. Bernard (source: etopo1). Right: Location of the weather station at the north-facing wall of the hospice (Janin, 1968).

Figure 2. Left: The station around 1935 (photo: Max Kettel, © Médiathèque Valais). Right: Location of the weather station in 2010 (Photo: Renate Auchmann).

Pictet arrived at Grand Saint Bernard on 14 September 1817 (measurements started on the same day), carrying with him a number of instruments. An article in “Bibliothèque universelle” describes the station set-up. The instruments were made by Mr. Gourdon (Rue des Corps-Saints) in Geneva and encompassed

1) a cistern barometer (ratio of tube versus cistern surface area of 1/100)

2) a Réaumur thermometer (mercury) attached to the barometer

3) a portable mercury thermometer

4) a portable hair hygrometer (Pictet exchanged the hair approximately every 2 years)

There was no pluviometer, hence the monks constructed one. The location of the pluviometer has changed several times (as is discussed below). Wind and clouds were also observed. The instruments were mounted outside a window on a north facing wall on the second floor of the building. The station is still mounted on the same wall today, at the third floor of the hospice, across the street from the hotel (see Figs. 1 and 2).

While there were replacements of thermometers (some documented in the correspondence stored at the Archive Great St. Bernard), there were no major changes to the meteorological station. Perhaps the most important change was the pavement of the street.

The observers were the monks of the monastery. They read the instruments at sunrise and at 2 in the afternoon and noted the results on data sheets. The data sheets were not to leave the monastery, only copies were sent to Geneva once per month with ordinary mail. The originals can still be seen at the monastery today. Observation times changed in 1827 to fixed hours.

As to precipitation measurements, there was no major change of location of the rain-gauges but small changes which affected the series. Schüepp (1991) distinguished six phases:

(1) 1818–1835: Snow height, not water equivalent was given. Schüepp (1991) used a temperature dependent conversion (1 cm of snow corresponds to 0.76 mm water at -15 °C but to 1.15 mm at 0 °C).

(2) 1836–1841: The transition to the metric system obviously brought some difficulties. Two extreme situation (an extreme snow fall as well as an avalanche) likely triggered slight relocations.

(3) 1842–1900: Rain-gauges were installed with 500 cm^2 collecting surface at a distance of 1.5 m from the southern wall of the building, 5 cm above the ground. Snow was often blown out of the rain gauge by strong winds and hence precipitation was often underestimated; from 1858 on there were very few days with precipitation totals <1.0 mm (small quantities were arguably neglected).

4) 1901–1917: No important loss of snow by strong winds occurred, arguably due to improved rain-gauge.

(5) 1918–1981: A new Hellmann-type rain-gauge with 200 cm^2 collecting surface was used, with a Nipher funnel to achieve horizontal flow over the instrument. The rain-gauge was now located 3.5 m from the south wall (see Fig. 1). There are 11 years with parallel measurements of both systems (Gautier, 1922, 1930). The new gauge indicates 60% more precipitation in winter and 25% in summer.

(6) 1982–1990: Start of automatic network with a balance system (collecting surface still 200 cm^2).

3. Data processing, quality control, and analysis

The data from the Great St. Bernard were copied by the monks and then sent to Pictet in Geneva, who published them in the “Bibliothèque universelle”. The original sheets (see Fig. 3) remained in Great St. Bernard. The data from the entire series were then again published by Cerutti (1987) and quality controlled and corrected by Schüepp (1991). However, only daily and monthly means were available, but not original data. In the framework of the project DigiHom (Füllemann et al., 2011), the original data from 1819 onward were digitized (only summary statistics were available for the first 2 years). Recently, the earlier sheets were provided by MeteoSwiss, such that now a complete record is available. Figure 3 shows an example data sheet from 1818.

The data from 1819 onward were digitized from the “Bibliothèque universelle” and quality-checked within DigiHom. The quality-checks were visual and included plotting against neighbouring stations as well as plotting morning against afternoon measurements. These data are described in Füllemann et al. (2011). The first two years were digitized from the original data sheets and are described here. These data were reprocessed as described in Brugnara et al. (2020a). The same diagnostic plots as described in that paper were produced, but for the entire segment 1817-1826, when observation times changed.

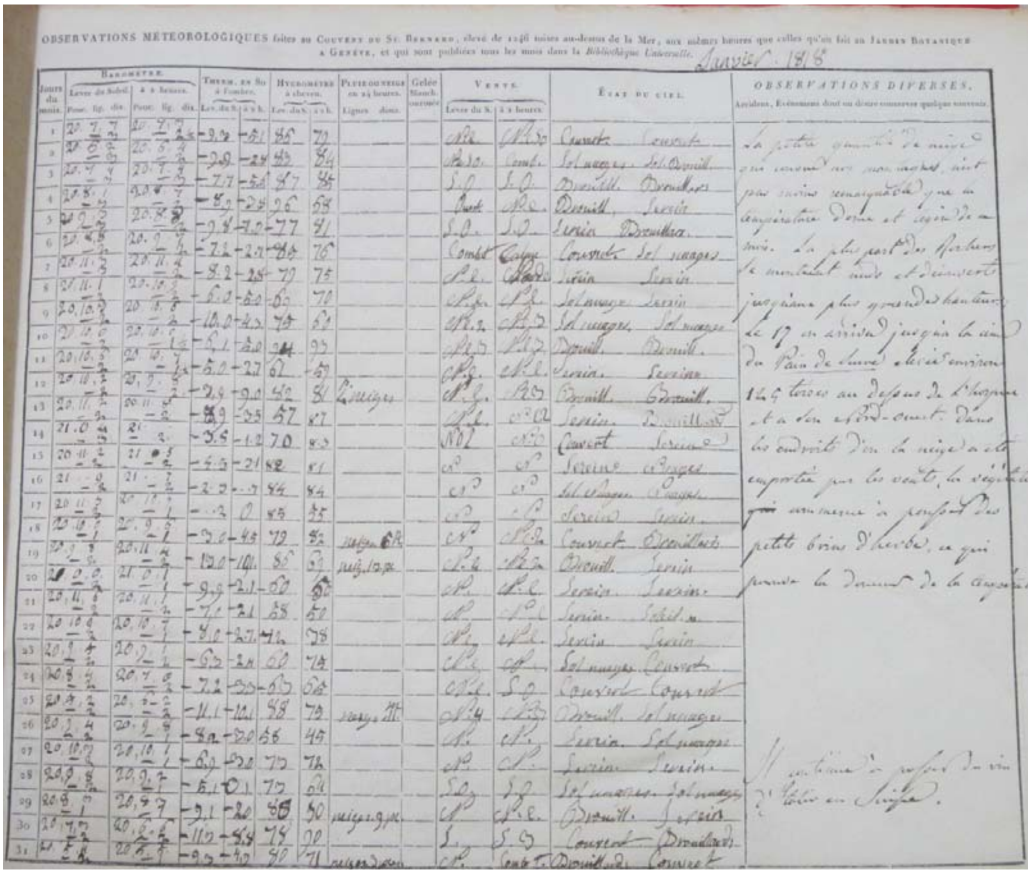

Figure 3. Original data sheet for January 1818 (from: Archives du Grand-Saint-Bernard).

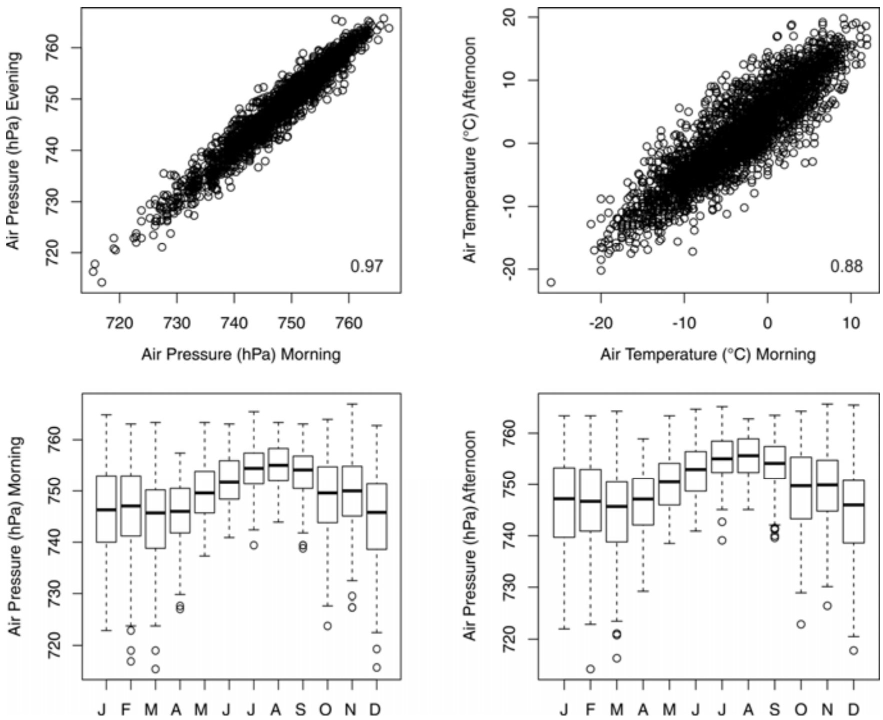

Figure 4. Analysis of pressure and temperature data from the Great St. Bernard, 1817-1826. The top row shows scatter plots of morning and afternoon series (the number in the lower right corner of the panel indicates the Pearson correlation coefficient). The bottom row shows box plots for pressure in the morning and in the afternoon as a function of calendar month (box indicates quartiles and median, whiskers extend to at most 1.5x the interquartile range from the box).

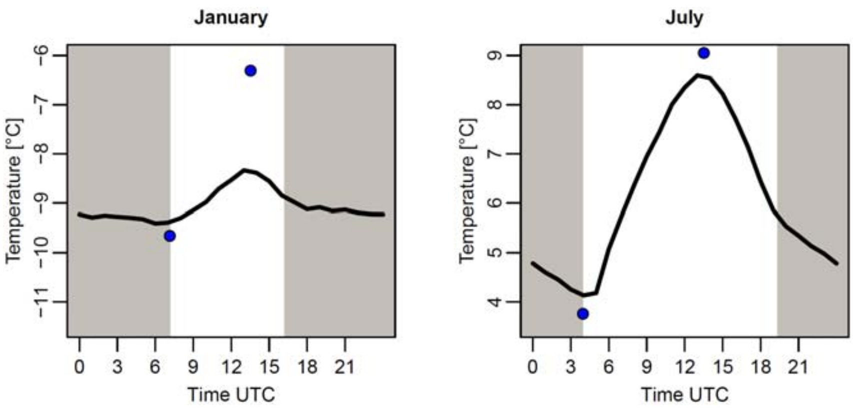

Figure 5. Diurnal temperature cycle in January (left) and July (right) in present-day (1984–2013, -2 °C to account for climate change) MeteoSwiss data (thick black line) as well as in the series from the Great St. Bernard. Grey shading indicates nighttime.

The quality control (see Brugnara et al., 2020a) was applied to the data from 1817 to 1826. In total 50 pressure values (out of 5995) and 9 temperature values (out of 5952) were flagged. This corresponds to 0.8% and 0.15%, respectively.

Comparing series of morning and afternoon with each other (Fig. 4, top row), we found a high correlation for pressure (0.97) and a lower correlation of 0.88 for temperature. These numbers are in the same range as those from other series for similar comparisons (morning versus afternoon or evening; see other papers in this volume). Also the annual cycle of air pressure shows no unusual features, except perhaps for the high pressure in November and low pressure in December (Fig. 4, bottom row).

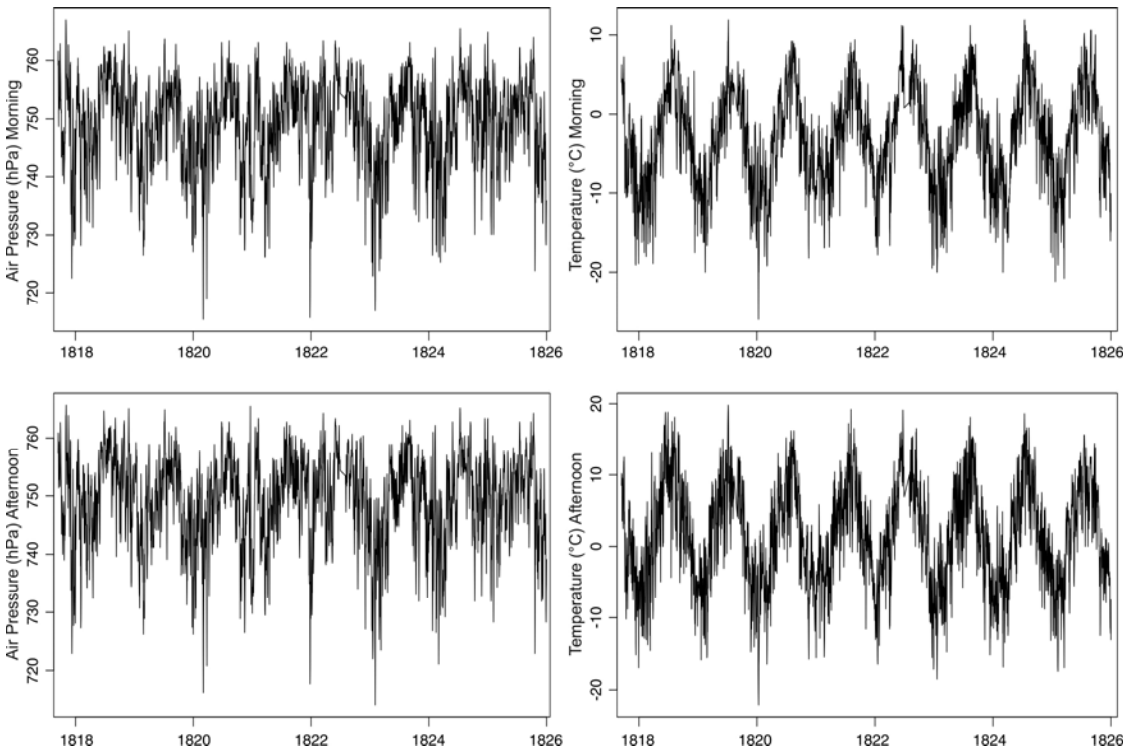

Figure 6. Time series of daily pressure (left) and temperature (right) from the Great St. Bernard, 1817-1826 from the morning (top) and evening (bottom) measurements.

A comparison of the diurnal cycle with present MeteoSwiss data (2 °C were subtracted to approximately account for climate change) shows a relatively good agreement in summer, when the amplitude of the diurnal cycle was only very slightly larger than today (Fig. 5). In contrast, during January, the historical data show much higher afternoon values, possibly because of radiation scattered by the snow affecting the measurements, while the sunrise observations are close to the expected value. In any case, the diurnal cycle in winter is much larger in the historical data than in present-day data, suggesting that adjustments are necessary before the historical data can be used for climatological purposes.

Time series plots for pressure and temperature over the 1817-1826 period are shown in Figure 6. Some individual outliers are seen in both variables. They appear both in morning and afternoon series (which however does not indicate their correctness). There is no indication for an inhomogeneity within the period displayed.

Finally, a brief analysis of data from the months of May and June 1818 from many stations in Switzerland (see Pfister et al., 2019) is shown in Figure 7 (Brönnimann, 2019). Note that the figure shows raw data; the series refer to different times of the day, and even the conversion of the scale (for the case of Schaffhausen) was preliminary. Despite this fact, high correlations and a good agreement of the absolute values are found. This shows that day-to-day weather is well captured and that already 200 years ago, the available data allow an overview of Swiss weather (except for Ticino and Grisons). Temperature at Grand St. Bernard correlates with a Pearson correlation coefficient of >0.8 with the series of Aarau, Bern and Geneva and 0.79 with that of Schaffhausen, despite the distance of 230 km and the different climatic setting. The figure shows the weather in the weeks prior to the collapse of an ice dam in the Val de Bagnes, only 20 km away from the Gr St. Bernard, on 16 June 1818. The dam was formed by the debris from the Giétro glacier. The subsequent flood killed 36 persons in the valley and in the Rhone valley in Martigny. A commemorative volume of the *Annales Valaisannes,* Dec. 2019, provides more details on the event.

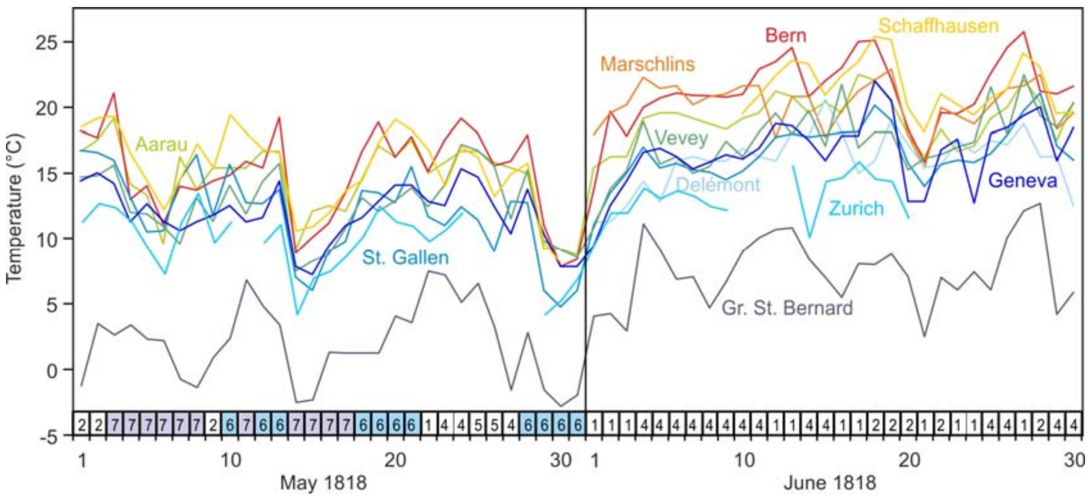

Figure 7. Daily temperature series from several sites in Switzerland digitized during the CHIMES project (note that the different series refer to different times of the day). The bottom part (numbers) indicate the daily weather types of the CAP7 classification according to Schwander et al. (2017). For the period May and June 1818. During this period, ice from the Gietro glacier blocked the Dranse, which formed a lake in the upper Val de Bagnes. During May, which fortunately was relatively cool, a tunnel was dug through the ice under the lead of Ignatz Venetz and the lake level could be lowered, although not sufficiently to prevent the subsequent catastrophe. The collapse of the ice dam on 16 June and the subsequent flooding killed 36 persons (from Brönnimann 2019).

4. Conlusions

There are only very few long, high-altitude meteorological series in the world. The series from Great St. Bernard, at 2479 m asl, might be considered the longest as it reaches back to 1817. It was famous in the early 19th century and used, *e.g.*, by Alexander von Humboldt. Today it contributes to the surface network of GCOS. In this paper we describe the digitization and quality control of the meteorological data. Data since 1819 were digitized in the framework of the DigiHom project, the earlier data in the framework of the GCOS Switzerland project “Long Swiss Meteorological Series”.

Here we analyse the first segment of the series from 1817 to 1826 (see Füllemann et al., 2011 and Schüepp, 1991 for further description of the later data). The series proves to be of good and consistent quality through the analysed time period, although the high afternoon values during winter months deserve further attention. A brief analysis of weather in 1818 also shows the consistency with other Swiss series. The homogeneity of the series remains to be assessed.

The metadata on the station are included in the inventory of Pfister et al. (2019). The data are provided via MeteoSwiss.

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Sources

Bibliothèque universelle (1816–1845), Geneva (successor title of Bibliothèque britannique), https://www.biodiversitylibrary.org/bibliography/10269#/summary

Archives des sciences physiques et naturelles (1846–1863), Geneva (successor title of Bibliothèque universelle), https://www.biodiversitylibrary.org/bibliography/5919#/summary

Archives du Grand-Saint-Bernard, Météo 01

References

Barry, R. G. (2008) *Mountain weather and climate.* 3rd Ed. Cambdrige University Press, Cambridge, UK.

Bodenmann, T., S. Brönnimann, G. Hirsch Hadorn, T. Krüger, and H. Weissert (2011) Perceiving, understanding, and observing climatic changes: An historical case study of the “year without summer” 1816, *Meteorol. Z.,* **20,** 577–587.

Brönnimann, S. (2019) Temps et climat en Suisse dans les années 1810. *Annales Valaisannes 2019,* 49-60.

Brönnimann, S. (2020) Climate of the free troposphere and of mountain peaks. *Oxford Encyclopedia of Climate Change,* doi:10.1093/acrefore/9780190228620.013.755.

Brönnimann, S., M. Bühler, and Y. Brugnara (2020) The Series from Geneva, 1798–1863. In: Brönnimann, S. (Ed.) *Swiss Early Instrumental Meteorological Series.* Geographica Bernensia G96, p. 47–59, doi: 10.4480/GB2020.G96.04.

Brugnara, Y., J. Flückiger, and S. Brönnimann (2020a) Instruments, Procedures, Processing, and Analyses. In: Brönnimann, S. (Ed.) *Swiss Early Instrumental Meteorological Series.* Geographica Bernensia G96, p. 17–32, doi: 10.4480/GB2020.G96.02.

Brugnara, Y., L. Pfister, L. Villiger, C. Rohr, F. A. Isotta, and S. Brönnimann (2020b) Early instrumental meteorological observations in Switzerland: 1708–1873. *Earth Syst. Sci. Data,* **12,** 1179–1190.

Cerutti, A. V. (1987) Raccolta di scritti di Umberto Monterin, Il Clima e le sue variazioni, Vol. II. Aosta, 205 pp.

Custer, H. (1869) Geschichte der aargauischen naturforschenden Gesellschaft während der ersten 50 Jahre ihres Bestandes, 1811–1861; erschienen in der Festschrift zur Feier der 500. Sitzung der ANG am 13. Juni 1869, 1-67.

Faden, M., L. Villiger, Y. Brugnara, and S. Brönnimann (2020) The Meteorological Series from Aarau, 1807–1865. In: Brönnimann, S. (Ed.) *Swiss Early Instrumental Meteorological Series*. Geographica Bernensia G96, p. 61–72, doi: 10.4480/GB2020.G96.05.

Füllemann, C., M. Begert, M. Croci-Maspoli, and S. Brönnimann (2011) Digitalisieren und Homogenisieren von historischen Klimadaten des Swiss NBCN – Resultate aus DigiHom. *Arbeitsb. MeteoSchweiz* **236**, 48 pp.

Gautier, R. (1922) Nouvelles mesures des chutes de pluie et neige au Great St. Bernard. *Archives des Se. Phys. et Nat.,* **4,** 343–353.

Gautier, R. (1930) Mesures des chutes de pluie et neige au Gr. St. Bernard. *Archives des Sc. Phys. et Nat.,* **12,** 216–223.

Humboldt, A. v. (1817) Des lignes isothermes et de la distribution de la chaleur sur le globe. *Annales de Chimie et de Physique,* **5,** 102–112.

Janin, B. (1968*) Le Col du Grand-Saint Bernard. Climat et Variations Climatiques.* Thèse, Univ. Grenoble.

Pfister, L., F. Hupfer, Y. Brugnara, L. Munz, L. Villiger, L. Meyer, M. Schwander, F. A. Isotta, C. Rohr, and S. Brönnimann (2019) Swiss Early Instrumental Meteorological Measurements. *Climate of the Past,* **15,** 1345–1361

Pictet, M.-A. (1817) Notice sur un établissement météorologique résemment dormé au couvent du Grand St. Bernard. *Bibliothèque Universelle des Sciences, Belles-Lettres et Arts,* **6,** 106–115.

Schüepp, M. (1991) The precipitation series of Gr. St. Bernard and Geneva since 1818. *Theor. Appl. Climatol.,* **44,** 139–142.

Schwander, M., S. Brönnimann, G. Delaygue, M. Rohrer, R. Auchmann, and Y. Brugnara (2017) Reconstruction of Central European daily weather types back to 1763. *Int. J. Climatol*., **37,** 30–44.

Winkler, P. (2009) Revision and necessary correction of the long-term temperature series of Hohenpeissenberg, 1781–2006. *Theor. Appl. Climatol.,* **98,** 259–268.

Zschokke, H. (1823) Zur Geschichte der Meteorologie und Atmosphäre. In: Zschokke, H. (Ed.) *Überlieferung zur Geschichte unserer Zeit.* Aarau, Sauerländer Verlag, p. 437–476.