



The Series from Geneva, 1799–1863

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Abstract

This paper describes the series from Geneva from 1799 onward as they were digitised and published in the DigiHom 3 project. During the first 23 years of the period considered, the meteorological measurements in Geneva were performed at the same place – the old botanical garden – by the same observer – Marc-Auguste Pictet. These data have previously been used to study the “Year Without a Summer” of 1816. In addition to the standard meteorological variables, we also describe wind and cloud observations of this segment. In 1822 the observations were moved to the new botanical garden. Two further changes in location took place until 1863. This paper briefly describes the observations in Geneva after 1799.

1. Introduction

As many long meteorological time series, the series from Geneva, reaching back to 1760, is composed of several shorter segments. This is particularly the case in the 18th century. Several papers in this volume describe individual segments; an overview of all segments is given in Häderli et al. (2020). In this paper we describe the data from 1799 to 1863 with a focus on the period December 1798 to December 1821 (see Bider and Schüepp, 1961, for an overview). The measurements from this period were published by Marc-Auguste Pictet in the journal “Bibliothèque Britannique” until 1815, then in “Bibliothèque universelle des sciences, belles-lettres, et arts”.

Because of its climatic relevance – it contains a particularly warm, dry period in the early 1800s, followed by the “Year without a Summer” of 1816 – the series has been studied in

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many publications (e.g., Auchmann et al., 2012, 2013; Brönnimann, 2015; Brugnara et al., 2015; Brönnimann and Krämer, 2016), but only a brief description was given in these papers. Here we provide further information on the series and instruments. This paper is largely based on a Master thesis at ETH Zurich by Leïla Breda (Breda, 2010) and a Bachelor thesis at University of Bern by Marcel Bühler (Bühler, 2011). We briefly also cover the latter part of the series, from 1822 to 1863, which was digitised and processed in the DigiHom project (Fülle- mann et al., 2011). A description of all series can be found in Schüepp (1961).

The paper is organised as follows. Section 2 describes the location of the first segment, *i.e.*, the old botanical garden. In Section 3 the instruments are discussed. Section 4 describes data processing and quality control and presents the data. The Section also describes the cloud classification. Conclusions are drawn in Section 5. The metadata are incorporated in a registry (Pfister et al., 2019), images are publicly available (<https://zenodo.org/record/3066836#.XVv-fGRS8-U>) and the data can be obtained from MeteoSwiss.

2. Locations and observers

From December 1798 to December 1821 observations were taken at the same location, the old botanical garden situated on the Bastion St-Léger, and with the same instruments. Figure 1 shows the location on a contemporary map and a contemporary view of the city (Auchmann et al., 2012); Table 1 gives an overview of the segments until 1863. The old botanical garden was well protected from the influence of buildings, according to Pictet (1822b). This botanical garden was constructed in 1793 by the Société de Physique et d’Histoire naturelle and had an effective area of 1800 m² (Sigrist and Bungener, 2008).

Temperature, pressure, wind direction, and humidity were measured twice a day at sunrise and at 14:00 (during the first 13 months also at sunset). These measurements time were chosen because they correspond approximately to the minimum (sunrise) and maximum (14:00) daily temperature (Pictet, 1796, 1822a,b). Precipitation was measured once a day. A qualitative description of the sky was given at sunrise and 14:00 as well as the presence of dew or frost at sunrise in addition to the measurements.

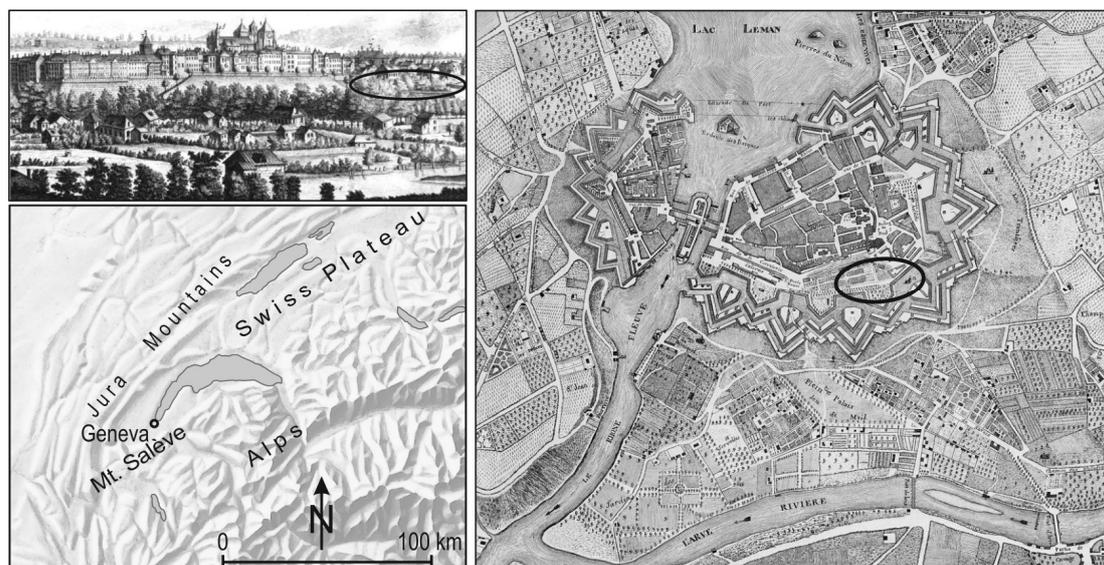


Figure 1. Location of the old botanical garden in Geneva (from Auchmann et al., 2012).

Table 1. Overview table of historical meteorological measurements in Geneva, 1798–1863 (data from Pfister et al., 2019; for earlier series see Häderli et al., 2020)

Location	Lat	Lon	Alt	Observer	Start	End
Jardin Botanique	46.199	6.151	395.6	Marc-Auguste Pictet	1798	1821
Nouveau Jardin Botanique	46.20011	6.14523	380	not known	1822	1825
Pont des Tranchées (Passerelle de Saint-Antoine)	46.19797	6.15238	394	not known	1826	1835
Observatoire de Genève	46.19961	6.15211	401	not known	1836	1863

By the end of 1821, the station was moved to the new botanical garden (Nouveau Jardin Botanique). The observation times remained the same. After only 3 years, the station was moved again to Pont des Tranchées (Passerelle de Saint-Antoine) in 1825. Measurements times changed to 9:00 and 15:00 local time. After 10 further years, in 1835, observations were re-located to the Observatoire de Genève. There, temperature observations were performed 6 times daily (8:00, 9:00, 12:00, 15:00, 20:00, 21:00) during 10 years and then, from 1846 onward, four times daily (9:00, 12:00, 15:00, 21:00); pressure was observed four times daily during the entire period. Observations continued to the start of the Swiss Meteorological network in 1863, although from 1860 to 1863 only daily means are available (a full overview of all segments is given in Häderli et al., 2020).

During the period from December 1798 to December 1821, Marc-Auguste Pictet was the observer. Pictet was a scientist, journalist and publisher from Geneva. He was born on 23 July 1752 and studied at the Geneva Academy. One of his mentors was Horace Benedict de Saussure. From 1776 onward he assisted Jacques-André Mallet at the Geneva Observatory, who had started to make meteorological observations only a few years earlier. Pictet was one of the observers. In 1786 he became professor of natural philosophy at the Academy, thus succeeding de Saussure. From 1796 onward Pictet co-published the “Bibliothèque Britannique”, which later became the “Bibliothèque universelle”. He published the meteorological measurements in this journal. In addition to the measurements at the Geneva Observatory, Pictet also made meteorological measurements at his apartment and later in the botanical garden. From 1790 to 1819, Pictet was director of the Geneva Observatory. He initiated the erection of a meteorological station at Great St. Bernard in 1817.

Pictet had a large scientific network, was co-founder of the Geneva and later the Swiss Natural Sciences Society and member of various other science societies. He also was politically active (see Sigrist, 2011). Pictet died on 19 April 1825.

After the move of the observatory to the new botanical garden and then to Pont des Tranchées, different observers from the observatory took care of the station. From 1836 on, according to Grenon (2010), observations were made on the northern terrace of the new observatory of 1830, financed by the city and the canton of Geneva. The observatory had the status of a Cantonal Astronomical Observatory and its directors were professors at the academy (later at the University) of Geneva. The observations, which became more and more complex (up to 9 observations per day), were made by the staff of the observatory (see Pfister et al., 2019).

3. Instruments

In this section, which is mainly taken from Breda (2010), we provide information on the instruments in the first part of the series, 1798 to 1821.

3.1 Temperature measurements

The temperature was measured by a mercury thermometer with an isolated bulb. It was divided in 80 parts and subdivided to the 100th (Pictet, 1819b, 1822b) in unit of °Réaumur (°R). Temperatures were reported at 0.1 °R (corresponding to 0.125 °C). The instrument was installed 1.30 m above the ground (Pictet, 1822b). The thermometer was orientated towards the north behind a small house (Pictet, 1796, 1819b, 1822b).

We have little information on the manufacture and reading conditions. It is therefore difficult to estimate the temperature data uncertainty. We have however information on an error detected in the thermometer. Pictet (1822b) wrote that the thermometer was tested on the occasion of a site change. It was 0.5 °R higher than other thermometers that mutually agreed. In melting ice, it was also 0.5 °R higher (Pictet, 1822b).

The rising of the zero point of old thermometers is a well-known problem (see Winkler, 2009) and is caused by the glass composition of early instruments (potassium and sodium oxides). We applied a correction following Winkler (2009). Since the thermometer was used from January 1796 onward, we applied a stepwise correction of 0.1 °C/year from 1796 to 1801; from 1802 to 1821 the correction was kept constant at −0.6 °C. This can probably correct some of the errors coming from the elasticity of the glass and changes in the volume of the bulb.

3.2 Pressure measurements

Two barometers were used to measure the pressure. However, we have only little information on the instruments and their manufacturers. The first one was a fixed cistern barometer with a float. The inside diameter was 9.02 mm wide. Hence, errors due to capillarity should be small. Observation was performed with a ring and vernier, dividing the line in 32^{nds}. Its precision was given to the 16th of a line (Pictet, 1796, 1821). The second barometer was a syphon barometer with a mobile ruler. The observation was made by looking at the apparent contact of the mercury convexity with the inferior section of a ring that had a vernier, dividing the line in 16th (Pictet, 1819a, 1822b). The precision of a 16th of a line corresponds to a precision of 0.19 hPa.

The two instruments were placed side-by-side and had the same absolute height (Pictet, 1821, 1822b). The barometers were fixed on a wall in a window frame (Pictet, 1822a,b). This installation was made to compare the two instruments measurements. All observations were reduced to 10 °R (Pictet, 1796). This was done using a mercury thermometer fixed to the barometer (Pictet, 1822b). Pressure units are inches, lines and 16th of a line.

From the information on the instrument, we found no clear error in the manufacture and the reading of the barometer. The procedure to read the barometer is well described (not shown) and made us think that the manufacture of the barometers and the observations were

done with great care. Besides, two barometers controlled each other which can avoid some errors and demonstrates the aim to be precise.

3.3. Precipitation measurements

Precipitation was observed with an udometer with a surface of 1055.2 cm². It had the form of a hollow, upside down pyramid. A cylindric container made of glass was placed under it. It enables to measure with the precision of the 12th of a line (0.19 mm) (Pictet, 1796). The height in the container was 4 times the height of the fallen rain. The measured height was reduced to the 1/4 of the apparent depth (Pictet, 1822b). Evaporation might have been a problem of this rain gauge (limited shielding from solar radiation), but we have no information on the gauge material.

It seems that the snow was mostly measured at the ground because the unit is different: precipitation was measured in units of lines and 12th of line and the snow was mainly measured in inches. As the udometer had no inches graduation, one can conclude that the snow was measured as height from the ground. We transformed the snow as water equivalent to be able to analyse precipitation in its liquid or solid form equally. Having no information about the snow density, we divided the snow height by 10 to have a water quantity because the measured snow height was always new snow with usually low density. According to the WMO (2008), the water equivalent of fresh snow can be evaluated by dividing it by 10 as a long-term average value.

Faites au JARDIN BOTANIQUE de GENÈVE: 395,6 mètres (203 toises) au-dessus du niveau de la Mer: Latitude 46°, 12'. Longitude 15°. 14". (de Tems) à l'Orient de l'Observatoire de PARIS.

OBSERVATIONS ATMOSPHÉRIQUES. AVRIL 1818.

Jours du Mois.	Phases de la Lune.	ВЛОМЕТР. réduit à la température de 10° R.				THERM. à l'ombre à 4 pieds de terre, divisé en 80 parties.		HYGROMÈT. à cheveu.		Pluie ou neige en 24 heures.		Gelée blanche ou rosée.	Vents.		Etat du ciel.	OBSERVATIONS DIVERSES.
		Lev. du Sol. à 2 heures.		L. du S. à 2 h.		L. du S. à 2 h.		Lig. d'ontz.		L. du S. à 2 h.						
		Pouc. lig. seiz.	pouc. lig. seiz.	Dix. d.	Dix. d.	Degr.	Degr.	Lig. d'ontz.	L. du S.	à 2 h.						
1		26. 11. 13	26. 11. 6	- 1. 0	+ 5. 7	92	71	—	—	—	—	cal.	NE	cl., id.	<p>La température a été singulièrement favorable à la végétation. Les blés sont très beaux partout; les orges sont bien levés ainsi que les petits trèfles. Les prés sont bien garnis, et la campagne, sans être très-avancée, promet généralement une belle récolte.</p> <p>On trouvera dans un article particulier de ce Cahier, page 243, des remarques générales sur la constitution atmosphérique orageuse de la première moitié de Mars.</p> <p>Déclinaison de l'aiguille aimantée, à l'Observatoire de Genève, le 30 Avril 20° 14'.</p> <p>Température d'un Puits de 34 pieds, le 30 Avril + 9. 8.</p>	
2		11. 14	27. 0. 1	0. 0	8. 0	90	72	—	—	—	—	G.B.	cal.	NE		cl., id.
3		7. 0. 9	0. 5	1. 3	8. 8	92	68	—	—	—	—	G.B.	cal.	NE		nua., cl.
4		0. 5	0. 7	+ 1. 2	8. 0	86	69	—	—	—	—	—	NE	NE		cou., cl.
5		0. 10	0. 7	- 1. 0	9. 9	98	59	—	—	—	—	G.B.	NE	NE		cl., id.
6	●	26. 11. 8	26. 10. 15	+ 1. 3	13. 3	88	58	—	—	—	—	—	NO	SO		cl., id.
7		11. 0	11. 10	7. 6	8. 3	91	97	3. 0	—	—	—	—	SO	cal.		plu., id.
8		11. 9	11. 6	2. 5	15. 2	99	61	—	—	—	—	—	cal.	o		nua., id.
9		10. 5	11. 2	6. 0	13. 0	83	78	—	—	—	—	—	o	SO		cou., id.
10		11. 10	10. 6	2. 5	9. 2	98	71	0. 9	—	—	—	—	cal.	cal.		nua., cou.
11		7. 8	9. 1	6. 0	6. 2	82	90	0. 6	—	—	—	—	SO	SO		nua., pl.
12		9. 3	10. 8	3. 5	4. 9	92	78	—	—	—	—	—	SO	NO		plu., cou.
13	☾	27. 0. 11	11. 15	- 1. 2	5. 8	95	60	—	—	—	—	G.B.	NE	NE		nua., cl.
14		26. 10. 0	9. 4	+ 0. 1	5. 6	91	58	—	—	—	—	—	NO	SO		nua., cou.
15		9. 12	9. 2	3. 0	6. 0	96	86	—	—	—	—	—	cal.	NE		cou., id.
16		7. 2	6. 7	2. 5	7. 0	92	92	1. 6	—	—	—	—	cal.	cal.		nua., pl.
17		4. 10	3. 5	4. 3	10. 0	96	77	3. 9	—	—	—	—	cal.	NE		cou., cl.
18		3. 12	4. 7	5. 0	7. 0	98	82	1. 6	—	—	—	—	cal.	NE		plu., nua.
19		6. 1	7. 0	4. 5	10. 8	98	71	0. 9	—	—	—	—	cal.	cal.		nua., id.
20		8. 14	9. 3	4. 7	12. 0	97	64	—	—	—	—	—	SO	NE		nua., id.
21	☺	9. 9	9. 7	7. 0	14. 0	92	65	—	—	—	—	—	cal.	SO		cou., cl.
22		9. 15	9. 5	5. 0	16. 0	90	59	—	—	—	—	—	cal.	SO		cl., id.
23		8. 5	7. 2	4. 5	14. 3	95	64	—	—	—	—	—	SO	cal.		nua., id.
24		7. 3	6. 3	8. 0	17. 0	90	59	—	—	—	—	—	SO	SO		cl., id.
25		5. 5	6. 0	8. 0	11. 8	91	85	0. 6	—	—	—	—	cal.	cal.		cou., id.
26		6. 14	8. 4	7. 0	13. 0	96	68	3. 6	—	—	—	—	NE	NE		cl., cou.
27	☾	8. 11	9. 1	9. 0	15. 0	87	64	—	—	—	—	—	SO	cal.		plu., nua.
28		9. 10	10. 3	9. 5	14. 2	95	79	0. 6	—	—	—	—	S	SO		cou., id.
29		10. 1	9. 10	9. 6	15. 2	98	76	—	—	—	—	—	NE	NE		cou., nua.
30		9. 1	8. 10	9. 0	14. 2	98	67	—	—	—	—	—	SE	cal.		nua. pl., grêl t.
Moyennes.		26. 9. 0,73	26. 9. 5,40	+ 4. 23	+ 10. 65	92,87	72,27	16. 3	—	—	—	—	—	—	—	

Figure 2. Data sheet from the “Bibliothèque universelle” for April 1818.

OBSERVATIONS	BAROMÈTRE réduit à 0°.				TEMPÉRATURE EN DEGRÉS CENTIGRADES.						FRACTION DE SATURATION.				EAU dans les 24 h	VENT dominant.	Clarté moy. du Ciel.	
	8 h. du m.	Midi.	4 h. du soir	8 h. du soir	8 h. m.	Midi.	4 h. d. s.	8 h. d. s.	Minim.	Maxim.	8 h. m.	Midi.	4 h. s.	8 h. s.				
1	721,68	722,56	722,81	724,15	+9,2	+13,1	+12,9	+10,4	+6,9	+14,6	0,91	0,75	0,77	0,89	4,0	N.	1	0,85
2	725,98	724,91	725,97	724,35	+12,7	+16,5	+16,7	+15,7	+5,2	+17,8	0,85	0,61	0,65	0,37	"	N.	1	0,65
3	725,48	725,05	722,88	722,62	-10,8	+15,5	+15,6	+15,2	+10,6	+14,5	1,00	0,85	0,89	0,92	0,7	N.	1	0,90
4	720,82	720,04	719,97	720,65	+14,1	+16,2	+14,5	+15,4	+10,6	+18,2	0,89	0,82	0,78	0,92	3,1	N.	1	0,91
5	721,24	721,12	720,95	721,84	+14,4	+17,6	+17,9	+15,0	+11,6	+19,9	0,87	0,72	0,62	0,82	"	N.	1	0,88
6	721,85	721,99	721,28	722,59	+16,1	+21,5	+20,6	+15,5	+12,7	+22,9	0,78	0,62	0,44	0,70	"	S.	1	0,48
7	725,18	725,22	725,64	724,56	+16,6	+16,0	+15,6	+15,0	+11,1	+18,5	0,76	0,77	0,95	0,98	4,4	SO.	1	0,97
8	725,59	725,45	725,82	727,55	+14,5	+17,2	+17,9	+16,6	+11,8	+18,8	0,90	0,69	0,74	0,74	1,9	N.	1	0,86
9	727,76	727,56	726,04	725,94	+16,7	+19,7	+21,6	+19,4	+14,7	+21,7	0,80	0,67	0,57	0,69	"	N.	1	0,46
10	725,51	724,25	722,55	721,86	+18,2	+21,6	+25,9	+19,4	+12,4	+26,6	0,85	0,67	0,45	0,75	"	N.	1	0,18
11	721,69	720,57	718,64	719,07	+20,6	+21,4	+25,7	+15,9	+15,5	+24,0	0,77	0,70	0,57	0,92	5,5	variab.	0,68	
12	719,58	719,71	719,74	720,65	+11,7	+14,0	+13,1	+12,4	+10,6	+13,8	0,98	0,86	0,95	0,98	21,9	variab.	1,00	
15	722,71	723,35	725,97	725,92	+15,0	+14,5	+15,5	+11,1	+10,4	+13,6	0,78	0,67	0,66	0,87	0,5	SSO.	1	1,00
14	724,79	724,76	724,06	724,55	+12,2	+14,5	+14,9	+11,5	+9,9	+16,0	0,77	0,68	0,61	0,77	0,2	NNE.	2	0,87
13	726,05	726,96	727,69	728,97	+15,0	+15,8	+16,5	+14,7	+11,0	+16,4	0,76	0,59	0,60	0,77	"	NNE.	2	0,91
16	729,10	728,26	727,54	727,40	+15,2	+17,0	+18,1	+15,4	+12,0	+18,6	0,75	0,57	0,51	0,67	"	N.	1	0,65
17	728,51	728,55	727,99	728,57	+15,8	+19,2	+19,2	+17,5	+8,6	+20,5	0,72	0,59	0,62	0,71	"	N.	1	0,59
18	728,55	726,99	725,70	725,72	+13,7	+19,5	+19,9	+18,1	+11,0	+21,0	0,80	0,60	0,59	0,67	"	N.	1	0,06
19	724,51	725,04	721,07	721,05	+17,2	+20,4	+20,8	+19,2	+11,2	+25,5	0,75	0,65	0,68	0,69	"	N.	1	0,55
20	719,44	721,49	720,05	720,35	+15,8	+14,5	+15,7	+9,5	+9,5	+17,6	0,96	0,82	0,82	0,95	22,2	SSO.	1	0,91
21	719,61	718,80	717,45	718,59	+12,5	+16,2	+16,2	+11,5	+9,0	+18,7	0,58	0,41	0,45	0,66	"	SSO.	1	0,67
22	718,95	718,02	717,64	717,82	+11,5	+14,7	+16,8	+12,8	+6,2	+18,1	0,76	0,59	0,43	0,75	1,0	variab.	0,78	
23	718,59	719,32	720,12	721,59	+10,8	+14,9	+14,9	+15,4	+10,0	+16,5	0,85	0,57	0,60	0,59	2,6	S.	1	1,00
24	725,97	724,70	724,47	725,69	+12,2	+17,1	+15,5	+14,6	+11,1	+20,0	0,94	0,75	0,80	0,78	1,0	N.	1	0,75
25	727,65	726,95	726,10	726,70	+17,4	+21,7	+20,5	+18,7	+10,8	+25,5	0,80	0,51	0,56	0,70	5,4	SSO.	1	0,85
26	726,46	726,14	726,82	727,35	+15,7	+18,6	+19,5	+17,4	+12,8	+26,5	0,95	0,68	0,69	0,88	4,5	SSO.	2	1,00
27	728,82	728,02	727,02	726,97	+20,5	+24,8	+26,7	+22,4	+15,9	+26,7	0,54	0,52	0,59	0,76	"	S.	1	0,18
28	728,56	727,57	726,50	726,20	+18,1	+21,4	+25,2	+24,4	+12,9	+27,5	0,81	0,70	0,65	0,64	"	N.	1	0,00
29	727,54	726,82	725,98	725,64	+24,7	+50,0	+50,2	+25,4	+18,0	+51,4	0,55	0,58	0,45	0,67	"	SSO.	1	0,04
30	725,50	724,58	723,99	725,58	+25,9	+50,0	+26,9	+22,8	+20,0	+52,0	0,65	0,41	0,62	0,65	"	variab.	0,79	

Figure 3. Data sheet from the “Archives des sciences physiques et naturelles” for June 1853.

3.4 Wind measurements and cloud observations

The wind direction was observed with a gears and dial weathercock fixed on the roof of a building (Pictet, 1796). There were nine possible wind directions: north, northeast, east, southeast, south, southwest, west, northwest and calm.

We have no information on the type of wind vane used for the measurements nor on the way to read the wind direction. The wind direction precision being much less accurate than nowadays standards, the other requirements are of little importance. In some cases, there were two wind directions indicated instead of one, the wind direction was given between two classes or there was an undefined character. These cases were simply removed, as there are in total only 20 of these cases. The wind strength was indicated nine times as “light”, “strong”, “very strong” or “violent”. These indications were not taken into account, because this information was not given systematically. Cloud information was taken from the column “Etat du ciel”, where often several terms were used for one observation time. The processing of cloud information is discussed in Section 4.4.

4. Processing

4.1. Digitising, processing, and quality control

The data from Geneva were digitised from the printed sheet in the “Bibliothèque universelle” (see Fig. 2 with twice daily measurements for April 1818). This work was performed within

the framework of the DigiHom project funded by MeteoSwiss (Fülle­mann et al., 2011). Temperatures were first converted from °R to °C by multiplication with 1.25. Pressure and precipitation which were measured in French inches were converted to present day units as described in Brugnara et al. (2019, 2020) and pressure was subsequently reduced to 0° C.

While the station underwent changes in location and measurement frequency, the data publication did not. Data were published in the “Bibliothèque universelle” and from 1846 in the “Archives des sciences physiques et naturelles”, which was the continuation of the science part of “Bibliothèque universelle”. Figure 3 shows a sample data sheet from 1853, now with four times daily measurements.

Visual Quality Control as well as comparisons with neighbouring stations were performed mainly to find digitisation errors. The DigiHom data were then delivered to MeteoSwiss, where they are available for download (see Fülle­mann et al., 2011). In the following we present the same standard analyses as performed for the other stations in this volume (Sect. 4.2).

Only instrumental observations were delivered in DigiHom. Wind and cloud cover were also digitised. While wind is straight forward (and was used, *e.g.*, in Auchmann et al., 2012) cloud cover is not. In this paper we therefore describe the processing of cloud cover and how quantitative information can be retrieved (Sect. 4.3).

4.2. Data analysis

As a first check of the quality of the series we compared the measurements made at different times of the day with each other. For the first two periods (1798–1821 and 1822–1825) we compared the twice daily series (sunrise and noon). For the third period (1826–1835, three times daily series) we compare morning and noon, morning and afternoon as well as noon and afternoon measurements. Finally, for pressure data during the fourth period (1836–1859), we compare morning to noon, noon to afternoon and afternoon to evening measurements. The same comparison is done for temperature, 1846–1859. For those years where temperature is available 6 times daily, we compare 8:00 to 9:00, 12:00 to 15:00 and 20:00 to 21:00.

Pressure shows in general very good results (Fig. 4). None of the correlations is lower than 0.96. Already in the first segment of the series, we find a very good correspondence. During the last 25 years of the series, correlation coefficients reach very high values and almost no outliers occur. Only during the period 1826 to 1835, remaining outliers might be the cause of the somewhat lower values.

For temperature, a more nuanced discussion is necessary (Fig. 5). During the first period, correlations are relatively low. Morning and noon correlations in temperature are only 0.86 in the first period and even less, 0.84 during the (short) second period. After the move to Pont des Tranchées in 1826 (and perhaps new instruments), correlations clearly increase. As expected, highest correlations are found between the series that were taken at the same location one hour apart. Coefficients exceed 0.99. This demonstrates a very high reproducibility of the measurements. Correlations then decrease again during the last 15 years, when only four times daily measurements could be compared. The observation hours were thus further apart.

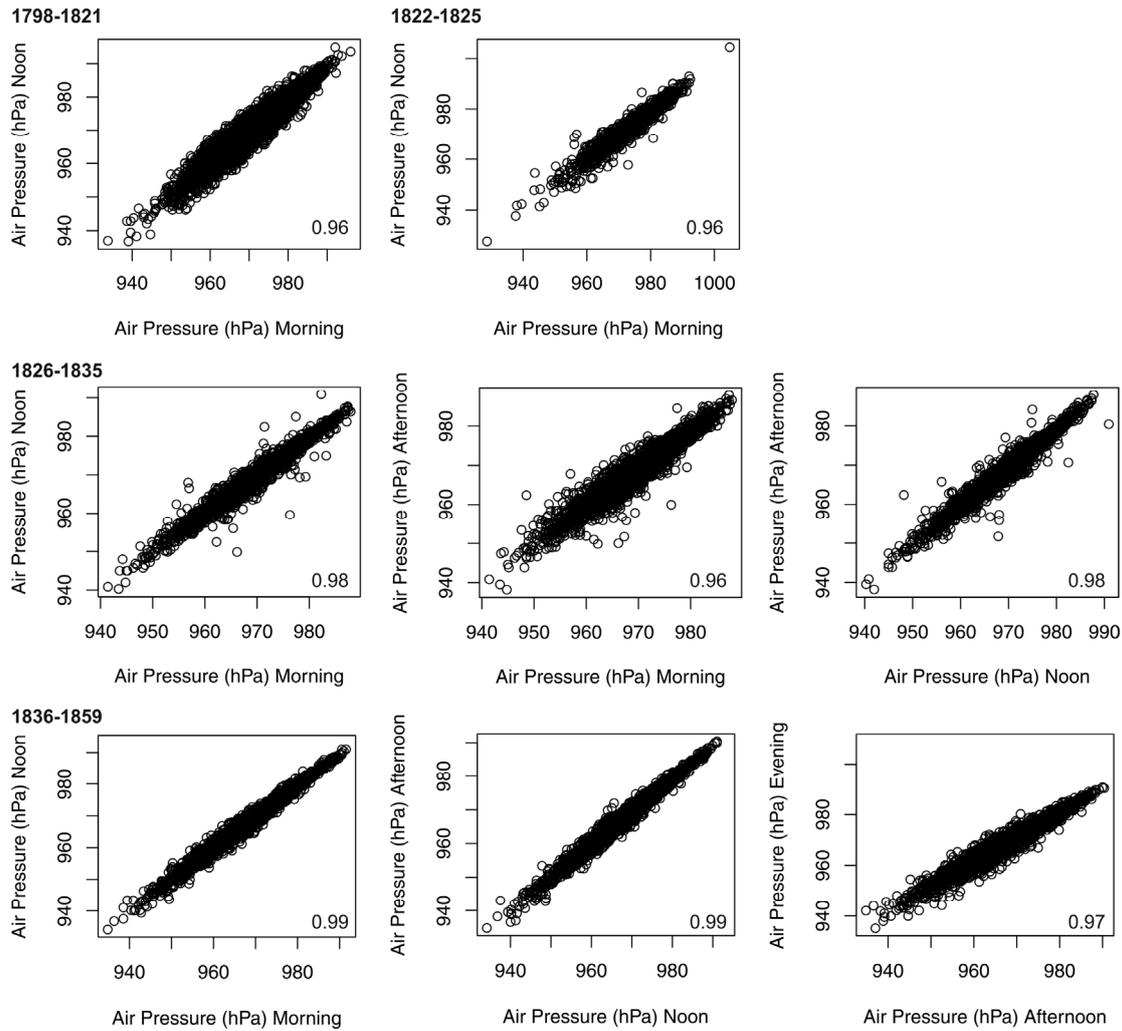


Figure 4. Analysis of pressure data from Geneva. The panels show comparisons of series from different times of day for different observation periods (see Table 1; the number indicates the Pearson correlation coefficient).

Figure 6 shows the comparison of the mean temperature values at the two observation times of Pictet’s record with the diurnal cycle of the modern MeteoSwiss station at Geneva-Cointrin, 1981–2010 (1 °C was subtracted to take global warming into account). The measurements of Pictet appear of good quality in terms of the amplitude of the diurnal cycle, both in winter and in summer.

In all, this analysis reveals a high quality of the temperature series after 1826 and, for pressure, all the way back to 1798 (except perhaps for some outliers). We have not analysed the stability of the series. Further segments of the series will be digitised (see also Häderli et al., 2020), and the homogenisation of the series will then be attempted when all segments are available and can be combined.

4.3. Cloud classification

Based on the digitised cloud observations, a classification was attempted. The documents from 1799 to 1821 use mainly nine different terms (given in abbreviations), but these terms were used in 190 different combinations. These nine terms were the following (in brackets: number of use):

- couvert (overcast) (5970)
- nuageux/nuage (cloudy) (4425)
- clair (clear) (3111)
- pluie (raining) (2187)
- serein (fair) (1911)
- brouillard (fog) (1139)
- brume (mist) (485)
- neige (snow) (352)
- soleil (sunshine) (333)

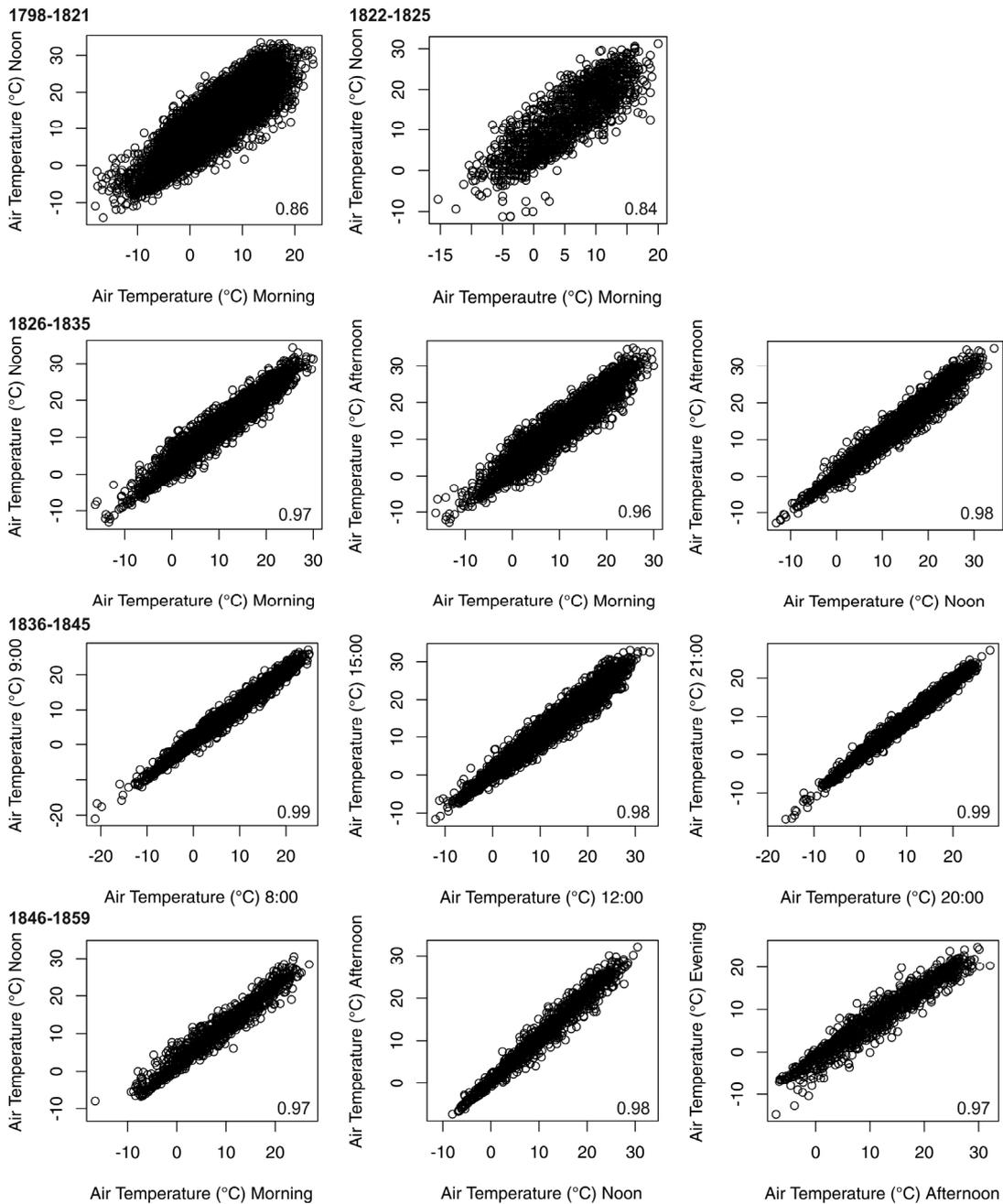


Figure 5. Analysis of temperature data from Geneva. The panels show comparisons of series from different times of day for different observation periods (see Table 1; the numbers indicate the Pearson correlation coefficients).

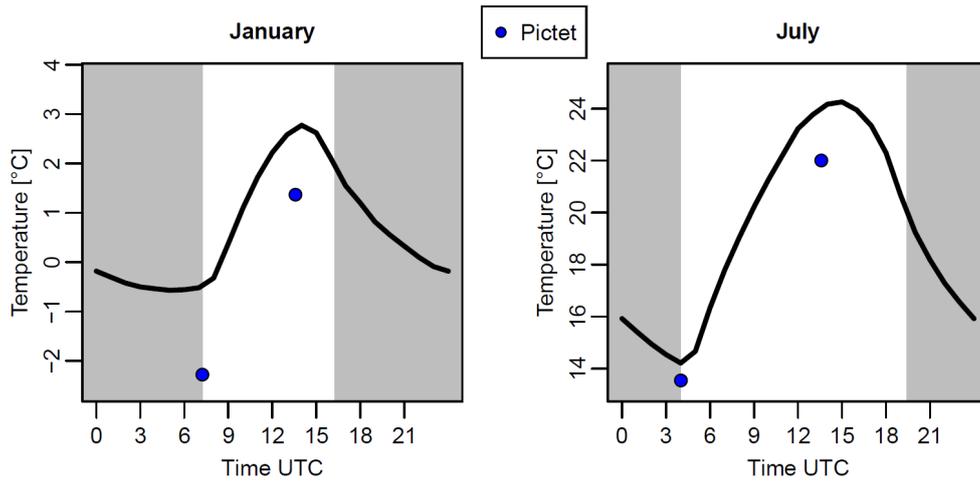


Figure 6. Diurnal cycle of temperature in January (left) and July (right) in present-day MeteoSwiss data (thick black line) as well as in the Geneva series from Pictet (grey shading indicates nighttime).

To obtain a classification that is more comparable to today’s classification, we aggregated the 190 classes. This was made difficult by the fact that the terms used at that time were not explained, and at times different abbreviations were used. A specific problem was fog. Two of the terms *brouillard* (fog) or *brume* (mist) can be used for fog, often the abbreviation “br” is used, which in this case is ambiguous. We therefore combined the two categories into one. Still, combinations such as “*brume serein*” (fog, clear) are difficult to interpret. Likewise “*soleil*” does not necessarily mean no clouds. A further complication was that the use of terms was obviously inhomogeneous within the 1799–1821 period.

We first classified individual observations into six categories (clear, fog/clear, sun/clouds, overcast/clear, clouds, overcast) and then reduced this classification to three categories – clear, partly cloudy, and overcast – by classifying entire days. If two of the three observations fell into the former category “clear” or “overcast”, then the days were classified as “clear and overcast”, respectively. All other days were classified as partly cloudy. In this way we could find a stable classification. Following are the classes:

- clear (cl, cl serein, cl sol, serein, serein sol, sol, tres-cl, un peu cl)
- fog/clear (brouil cl, brouil serein, brouil serein ton, brouil sol, brume cl, brume serein, brume sol pâ, cl pom, cl qq brouil, pâ, pâ serein, pâ serein sol, pâ sol, pom, pom sol, serein vap, sol faible, sol vap, vap)
- sun/clouds (brouil cl nua, brume cl nua, brume nua serein, cl nua, cl nua serein, cl nua sol, cl nua ton, cl qq nua, éclaircis, nua serein, nua serein sol, nua sol, nua sol ton, qq nua)
- overcast/fair (brouil, brouil épars, brouil faible, brouil givre, brouil léger, brouil neige pluie serein, brouil pluie serein, brume, brume pluie serein, cl couv, cl couv nua, cl pluie, cl pluie neige sur Sal, couv nua sol, couv serein, couv sol, éclaircis, neige pluie serein, neige serein, pluie serein, pluie serein ton, pluie sol)
- clouds (brouil nua, brume nua, cl nua pluie, couv léger, couv nua pluie sol, couv pet pluie sol, nua, nua pâ, nua roul, nua, nua pâ, nua ton, nua vap)

- overcast (brouil couv, brouil couv gresil, brouil couv neige, brouil couv nua, brouil couv pluie, brouil couv pluie ton, brouil neige nua pluie, brouil nua pluie, brouil nua pluie ton, brouil pluie, brume couv, brume couv neige, brume couv pluie, brume couv serein, brume neige nua, cl neige nua, cl neige sur Jura, couv, couv dégel, couv éclair pluie ton, couv givre, couv grêle, couv grêle pluie ton, couv gresil, couv gresil pluie, couv neige, couv neige pluie, couv nua, couv nua pluie, couv nua pluie ton)

Results of the classification into three categories are shown in Figure 7. The series is clearly not homogeneous prior to ca. 1811. However, the data for the later period clearly reveal, for instance, the increase in cloud cover in the 1816 “Year Without a Summer” (e.g., Auchmann et al., 2012).

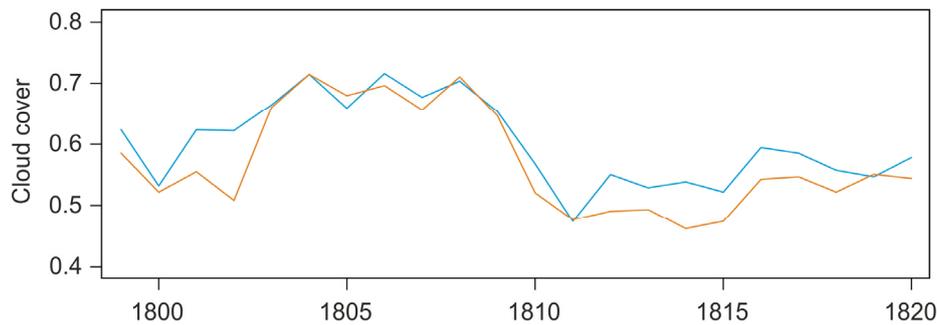


Figure 7. Annual mean time series of cloud cover in Geneva based on the three categories “clear” (0%), “overcast” (100%) and “partly cloudy” (50%) for morning (blue) and noon (orange).

5. Conclusions

The series from Geneva is one of the prime series in Switzerland. It has been used in numerous studies and, together with the series from Basel, serves as a reference for estimates of long-term climate change in Switzerland. Moreover, the data from 1798 to 1821 have been used in several studies, in particular for studying the “Year Without a Summer” of 1816 (Auchmann et al., 2012). This paper describes the series in more detail, including a description of instruments, locations, and procedures. In addition to the standard meteorological variables, we also describe the wind and cloud observations. Cloud cover was described by combinations of several terms. As a step towards quantification, we classified cloud cover into six classes and further into three classes.

We show that particularly from 1826 onward, the data are of high quality. The 1798 to 1821 data are internally homogeneous and of also of good quality. Precipitation, however, shows a clear inhomogeneity in the 1820s. Cloud cover, despite the fact that the observer did not change, shows an inhomogeneity around 1811. The digitised data described in this paper are available from MeteoSwiss.

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