DAILY MILAN TEMPERATURE AND PRESSURE SERIES (1763–1998): HISTORY OF THE OBSERVATIONS AND DATA AND METADATA RECOVERY

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Abstract. Daily meteorological observations have been made at the Brera astronomical observatory in Milan since 1763. Initially they concerned air temperature, air pressure, wind direction and state of the sky; other measurements such as precipitation, relative humidity and wind speed were gradually included in the following years. In terms of homogeneity the series can be divided into two main periods, due to the great reorganisation of the observations that Francesco Carlini performed in 1835. As a consequence of other minor changes, each of these periods can then be divided into some other sub-periods, the most problematic years being the first (1763–1804) and the last (1963–today) ones. Within this context the purpose of the paper is to present the history of Milan's temperature and pressure series, giving particular emphasis to all the information that can be useful for the evaluation of the reliability and of the homogeneity of the data. Moreover the data recovery is discussed and the quality and the availability of both hand-written (observatory registers) and published (ephemeridis, bulletins, year-books) data and metadata sources are analysed.

1. Introduction

Instrumental records are the ultimate indicators of the climate of the past. The highest spatial density of long instrumental records is available in Europe, some areas having often near-continuous observations that go back to the early 18th century.

As a consequence of local, national and international projects carried out in the last few decades, many of these series now exist in digital format. However they often have at least two flaws: time resolution is too low (generally monthly) and no procedures for the critical evaluation, correction and homogenisation of the data have been applied.

The Milan series gives a good example of this situation: monthly data collections began to be compiled in the first part of the 19th century (Cesaris, 1817), then they have often been updated and published. These data, sometimes completed with the Milan Linate airport observations, are included in the principal international climatic data sets, even if they include a number of inhomogeneities due to changes both in instrument location and observation methods.

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In this context the purpose of our research was to:

1. reconstruct daily temperature and pressure series for Milan (1763–1998);
2. recover and study all the information on the quality and on the homogeneity of the data;
3. homogenise the data both on the basis of this information and by comparison with other series;
4. perform some climate analysis.

This paper will deal with points 1 and 2. Data homogenisation is discussed in Maugeri et al. (2002), where also changes in the environment around the Milan station during the long time of the series are described. Climate analysis and comparison with some other series is presented in Moberg et al. (2000) and in Yan et al. (2002).

A similar research performed a few years ago allowed for a recovery of Milan daily precipitation too; data and methods are presented in Buffoni and Chlistovsky (1992) and in Maugeri et al. (1995a), whereas some analysis is reported in Chlistovsky et al. (1999).

2. History of Temperature and Pressure Observations

2.1. FROM THE EARLY OBSERVATIONS TO CARLINI'S REORGANISATION

The meteorological observations in Milan began on the first of January, 1763 at the Brera Astronomical Observatory thanks to Jesuit Father Louis La Grange, who was the Observatory Director from its foundation in 1762 until 1766.

The early data recorded from 1763 to 1777 were first published in 1778 in the Brera Observatory Ephemeridis (Figure 1), from whose preface interesting information on La Grange's thermometer can be obtained (Osservatorio Astronomico di Brera, 1778): It was a Réamur one with a metallic scale divided into degrees and quarters of degree, each degree corresponding to 1.19 French lines (2.26 mm). According to Capelli (1861), La Grange's thermometer was one of the most precise thermometers for that period. It soon got lost and was replaced by another one carrying the incision '1785' on its back. Both Capelli (1862) and Celoria (1874) state that the last one was identical to the description of the old one and that only the date on its back allowed them to distinguish it from the thermometer used by Father La Grange.

Besides air temperature, the first meteorological measurements concerned air pressure, wind direction and the state of the sky.

The first barometer for which some information is available was an Adams one that was introduced around 1800 (Cesaris, 1817). It had a mahogany case and a brass scale. The tube diameter was around 3 French lines (6.8 mm) (Osservatorio Astronomico di Brera, 1841). According to Carlini (1855a) this instrument

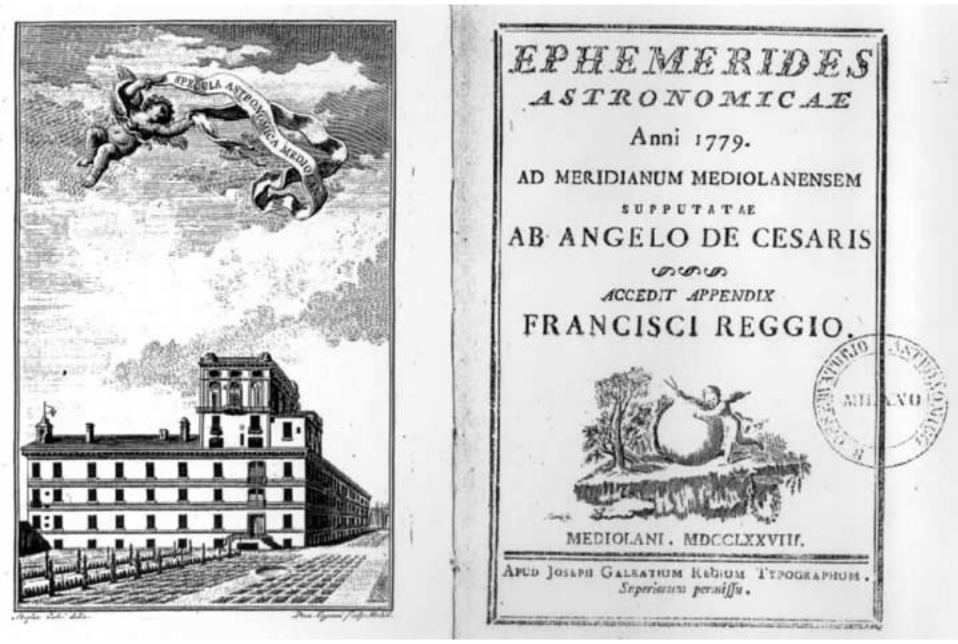


Figure 1. Front cover of Milan Astronomical Ephemeridis for the year 1779. On the left view of the Brera Observatory (Osservatorio Astronomico di Brera, 1778).

allowed, by means of a float, for a regulation of the height of the top level of the mercury in the cistern permitting compensation of the effect of air pressure variations. Barometers with floats seem to have been especially popular in Italy, even well into the 19th century (Middleton, 1964).

Both the thermometer and the barometer were located on the Astronomer's home floor (Buzzetti, 1844; Capelli, 1862). The thermometer was hung on a wall, outside a north-facing window, over a small courtyard; it was protected against solar direct and reflected radiation by a screen (Cesaris, 1819). The barometer was located in the southern part of the Astronomer's home. The height of its cistern was 131.52 metres above sea-level (Carlini, 1837; Capelli, 1861; 1862).

As far as observation times are concerned, at the beginning two different observations were taken each day: the first was made at '*mane*' i.e. at sunrise both for temperature and pressure, the other one was made at '*vespere*' that is about three hours 'post meridiem' for temperature (Osservatorio Astronomico di Brera, 1778; Reggio, 1798) and approximately twelve hours after sunrise for pressure (Carlini, 1837; Osservatorio Astronomico di Brera, 1841). These observation times were selected in order to have estimates of daily extreme temperatures (Osservatorio Astronomico di Brera, 1778; Reggio, 1798; Buzzetti, 1844) and to record air pressure with a regular time resolution. The early observation times were adopted until 1835. Later on, the number of daily observations reached seven and then decreased

Table I

Location of the instruments and observation times. Hours are expressed in local time until February 1924; later on they are expressed in Central Europe Mean Time.

Period	Position of the instruments	Observation times
1763–1834	Thermometer: northern side of the Astronomers' home, out of a window Barometer: inside one of the Astronomers' rooms at 131.52 meters above sea-level	Thermometer: sunrise, about 15 hrs Barometer: sunrise; 12 hrs later
1835–June 1963	Thermometer: northern side of a building close to the tower, in a meteorological box out of a window Since 1835 daily maximum and minimum temperatures were measured too Barometer: corridor next to Starke's Meridian circle room at 147.11 metres	1835/1838: 6-9-12-15-18-21-24 1839/1843: 5-8-11-14-17-20-23 1844/1859: 6-9-12-15-18-21-24 1860/1863: (Feb.): 6-9-12-15 1863 (March)/1877: 6-9-12-15-18-21 1878/1880: 9-13.20-15-21 1881/1884: 9-12.45-15-21 1885/1897: 9-12.37-15-21 1898/1924 (May): 9-12-15-21 1898/1924 (june)/1932 (Nov.): 9-15-21 1932 (dec.)/1963 (June): 8-14-19
July 1963–July 1987	Thermometer: from July 1963 to July 1968 in the botanical garden; then the same position as in 1835–1963 Barometer: entrance of the observatory at 133.05 metres	8-14-19
August 1987–June 1993	Thermometer and barometer: on a terrace next to the 'cupola a fiore' Height of the barometer: about 144.5 metres	Hourly data
June 1993– →	Thermometer and barometer: on a terrace overhanging the old window Height of the barometer: about 145.5 metres	Hourly data

again according to Table I where the instrument displacements that have occurred till now are shown as well.

With the exclusion of the barometer substitution around 1800, only minor changes were made in the period 1763–1830. The most interesting information in relation to temperature data concerns the courtyard walls that in 1818 were smoothed and made white. This event might correspond to the introduction of an inhomogeneity that Angelo Cesaris, in charge of the meteorological observations from 1804 to 1832, pointed out in 1819, because of the higher reflectivity of the white polished surface (Cesaris, 1819). It is worth noticing that Cesaris was very interested in studying the bias caused by uncorrected thermometer location and therefore he also performed measures in other sites of the Brera building. These additional records were taken on the Specola tower and outside the normal meteorological window, but further from the wall and without any screen in order to evaluate the influence of the building on nocturnal minimum temperature (Cesaris, 1819).

Another important change made in Cesaris's period was the introduction of a small thermometer that was annexed to the barometer (November, 1817) in order to allow the pressure observations to be corrected for temperature. At the beginning of 1817 a new vessel for precipitation collection was introduced too.

All this information gives evidence of an attempt to improve the quality of the observations performed by Cesaris in the period 1816–1818.

After 1830 and especially after Cesaris's death (1832), a troublesome period involved the Brera Observatory until 1834, also because the building was subject to restoration work. During that not-so-well documented period the meteorological instruments must have been moved at least once (Carlini, 1837), but no precise news has been found about that.

2.2. 1835 CARLINI'S REORGANISATION

The changes caused by the 1832–1834 restoration work, together with the realisation that more accurate methodologies should have been employed in meteorological measurements, induced Francesco Carlini, Director of the Observatory from 1833 until 1862, to make a great reorganisation of the Milan observations (Carlini, 1837; Capelli 1861; 1862). So, starting from 1835 the equipment type and site, the operational procedures and the observation times were radically improved. The main changes concerning temperature and pressure measurements can be outlined as follows:

- the thermometer was moved next to the top of the highest tower of the Brera building (Figure 2) outside a north-facing window at 145/146 meters above sea level (Figure 3). The thermometer was shielded against reflected solar radiation by means of a screen with three moving grids, two vertical at both sides and a horizontal one on the top. Moreover it was kept in a constantly airy place, since the window was always left open and was also communicating with the winding staircase leading to the top of the tower (Carlini, 1837);
- a maximum and minimum thermometer was introduced. This Six type thermometer, improved by Bellani, was used only for three years; afterwards, in 1838, it was replaced by a maximum and by a minimum Rutherford-type thermometer pair because of the high frequency of errors the Six-type was subjected to (Osservatorio Astronomico di Brera, 1841; Carlini, 1855b);
- the barometer was moved to a corridor communicating with the Starke's meridian circle room. After this displacement the elevation of the barometer changed from 131.52 metres above sea level to 147.11 metres above sea-level (75.48 French Toise);
- the number of daily observations was increased from two to seven;

Figure 2. View of the Brera observatory around 1870 (Zagar, 1963). The picture shows the highest tower of the Brera building where Starke's meridian circle was located.

- the old thermometer was replaced by another one, called '*a bolla nuda*' which probably means 'with naked bulb'. Moreover a reference thermometer was placed beside the first one in order to compare and correct the measurements (Osservatorio Astronomico di Brera, 1841);
- the tube of the old Adams barometer was replaced by a new one with a diameter of 10.27 millimetres (4.55 French lines). The barometer was also checked and an error (0.29 lines) in the device that allowed the zero of the scale to coincide with the top level of the mercury in the cistern was corrected (Carlini, 1835). Moreover an error of 0.078 lines in the length of the brass scale was identified and a first estimate of the capillary depression was given (0.137 lines) (Carlini, 1835). As the two errors had opposite signs, the effect was quite small (0.059 lines), and therefore it was not considered (Carlini, 1855 a; Capelli, 1864).

Even if Carlini's reorganisation undoubtedly did improve meteorological equipment and data acquisition procedures, it also introduced a great discontinuity in the series in such a way that the earlier data cannot be compared with the ones recorded from 1835, unless corrections are made (Buzzetti, 1844; Carlini, 1855b; Capelli, 1862; Celoria, 1874). Actually Carlini's reorganisation did probably not only coincide with a very sharp inhomogeneity on the first of January, 1835, but may have been characterised by some problems in the following 2–3 years as well.

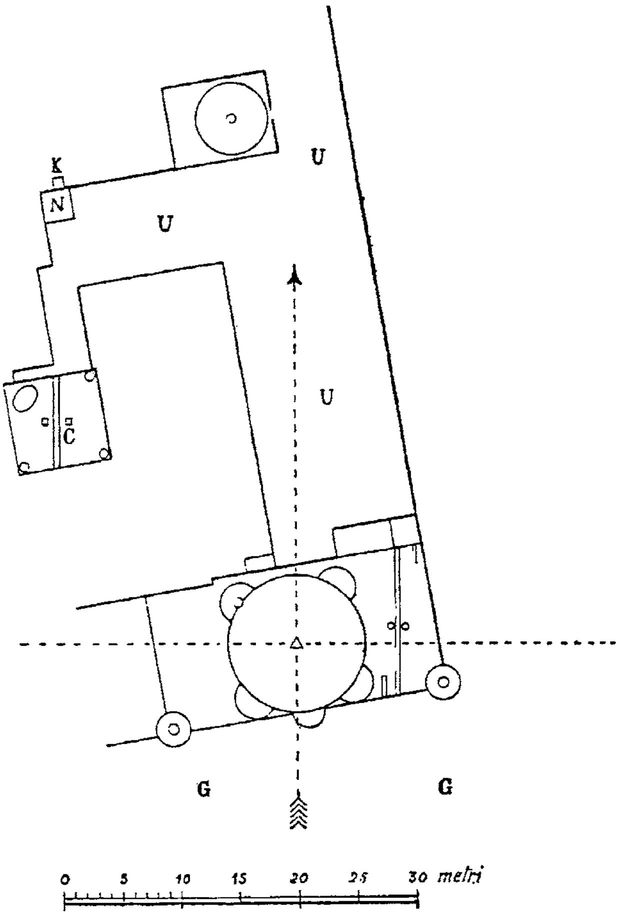


Figure 3. Map of the Brera observatory top floor published in 1889 (Rajna, 1889). C = Starke's meridian circle room; G = Botanical garden; K = Carlini's screen; N = Terrace of the anemometer and of the rain gauge; U = Astronomers' rooms (on the lower floors).

2.3. FROM CARLINI'S REORGANISATION TO THE DEVELOPMENT OF THE ITALIAN METEOROLOGICAL NETWORK

After the great 1835 reorganisation, Carlini continued to improve the Milan observations especially working on the quality and on the accuracy of the instruments. Within this context he set up a project for the construction of a reference barometer that was finished in 1854. The comparison with the Brera Adams barometer showed a difference of 0.24 lines, corresponding to 0.54 mm (Carlini, 1855a).

As far as the acquisition of new instruments is concerned, the principal ones were an August psychrometer in 1843 (Capelli, 1862) and a Fortin barometer in 1860 (Capelli, 1864). The barometer, constructed by Grindel, had a tube diameter of 12 millimetres and a brass case with a scale in millimetres. It was compared with the reference one by more than 20 comparisons in order to detect its instrumental error (0.87 mm) (Capelli, 1864). In 1860, at the same time air pressure began to be expressed in millimetres of mercury, temperature began to be measured in °C.

In 1862 Giovanni Virginio Schiaparelli succeeded Carlini in the direction of the Observatory: Since he was aware of the importance of long homogeneous data series, no meteorological instruments were moved under his management (Schiaparelli, 1867, 1875). However some other changes were probably made under his direction too. In fact, after Italian political unity (1860), the national meteorological network grew rapidly leading to a strong standardisation (Camuffo, 2002). The process required about 15 years and took place in a context where standardisation grew fast also outside Italy. It started in 1865 with the Navy; then the Ministry of Agriculture, Industry and Trade began to collect data for the whole Italian territory and it was completed in 1879 when the Central Bureau for Meteorology (*Ufficio Centrale di Meteorologia*) was founded (Maugeri et al., 1995b, 1998). Even if no detailed information is available, we suppose that this standardisation caused some inhomogeneities in the series as changes were probably made to match the new requirements of national and international organisations. An example is the management of the meteorological window that in Carlini's period was always open in order to keep the thermometers in a constantly airy place. No information is given about that, but in the frame of the standardisation of the period 1865–1880 it probably was closed. Another example is the calibration of the barometer: even if the Milan reference barometer was considered a good one, it resulted affected by a significant error during an intercomparison campaign carried out by Father Francesco Denza in the period 1870–1875 (Denza, 1876, Grassi, 1879). As in the previous case no sufficient information is available to clearly identify an inhomogeneity, however it is possible to suppose that a new instrumental error was adopted around 1875 (Maugeri et al., 1998).

2.4. FROM 1880 TO THE RELOCATION TO THE BOTANICAL GARDEN

After 1880 the amount of information decreases, as a consequence of standardisation of instruments and methodologies. The last detailed notes are the ones of Edoardo Pini who was in charge of the meteorological observations from June, 1881 (Pini, 1882, 1884). However the interest of this information is low as after 1880 instrumental problems were more or less solved and so starting from 1885 instrument changes were no longer reported.

In 1920 the screen which had been used since Carlini's reorganisation was subjected to restoration. The new repaired screen (Figure 4) was made of oak wood and was provided with louvred walls at its top and sides. Moreover, a louvred wooden wall with a 45°inclination was placed below the screen in order to better shield the thermometers from reflected radiation (Gabba, 1921, 1922).

In the difficult period after the First World War, characterised by deficiency in staff and funding, the Observatory director, E. Bianchi, thought that meteorol-

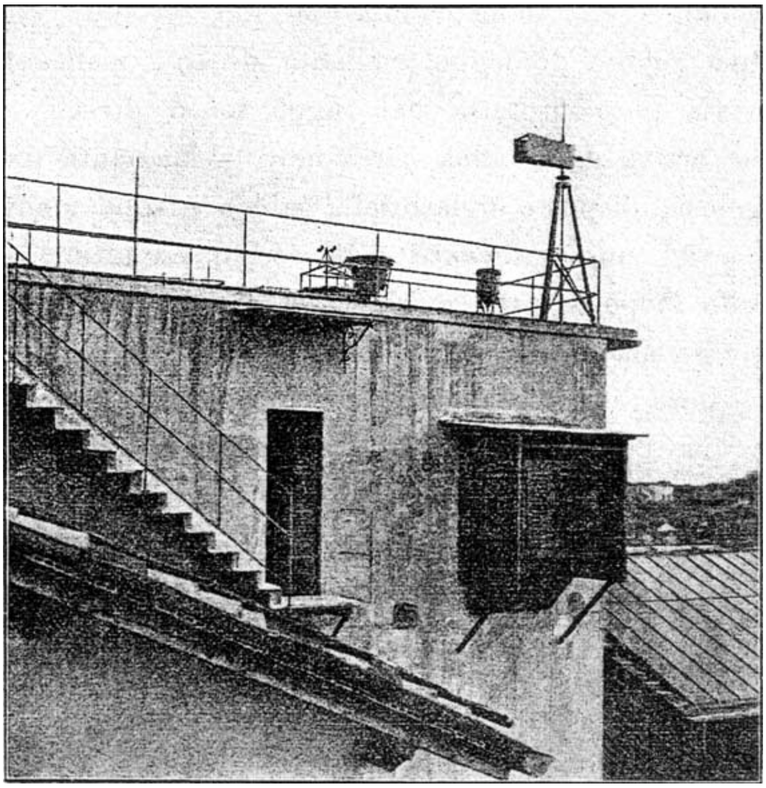


Figure 4. The screen after the 1920 restoration (Gabba, 1921).

ogy could disturb astronomy, the main purpose of the Specola, and therefore it is mainly thanks to L. Gabba that the meteorological activity at Brera was carried out. Fortunately under the following directors, L. Volta and F. Zagar, this activity was enhanced again and in the years after the Second World War new meteorological and climatological studies were made (Campa, 1947; Santomauro, 1957) and research on the history of the series was performed as well (Santomauro, 1963).

2.5. THE RECENT YEARS

On 30th June 1963 the thermometers were relocated from the former place to a Stevenson screen in the Botanical Garden (Osservatorio Astronomico di Brera, 1964). The relocation, however, was not successful since the data turned out to be less representative than in the old location. Thus, on the 24th of July 1968 Carlini's window was restored again (Osservatorio Astronomico di Brera, 1969). In 1963, at the same time when the thermometers were moved to the Botanical garden, the old Fortin barometer was substituted with an aneroid one that was located at a height of 133.05 metres above sea level (Osservatorio Astronomico di Brera, 1964).

In 1972 the Observatory Director A. Kranjc decided to abandon meteorological observations. Nevertheless this activity went on in the same location under the management of the Atmospheric Dynamics Department that had become independent from the Observatory. Later on (1987) the current Observatory Director G. Chincarini countermanded this decision and took again charge of the meteorological activity. Therefore, in August, a new meteorological station was installed in such a way that meteorological parameters could be automatically acquired, recorded and filed. The automatic station (Lastem, Anadata Clima ADA/40) has been uninterruptedly operating since then. Initially the instruments were located far from Carlini's site. Then, in June 1993, they were moved to a terrace overhanging the old window so that still nowadays the instruments are located at a short distance from the place where data have been taken since 1835 (Figure 5). Some comparison between the data collected by the automatic station and the ones collected within the old screen is discussed in Maugeri et al. (2002).

3. Data and Metadata Recovery

The research program for the digitisation of the daily minimum and maximum temperatures was set up at the beginning of the 1990s with the aim of improving both data quality and time resolution. Before this program only monthly series were available. They were published in a number of monographic studies on Milan climate (Cesaris, 1817; Osservatorio Astronomico di Brera, 1841; Carlini, 1858; Celoria; 1874; De Marchi, 1879; Pini, 1891; Gabba and Bottino-Barzizza, 1923; Campa, 1947; Santomauro, 1957; Behrens, 1965) and were generally constructed using the data regularly issued by Milan observatory on the publications listed below:

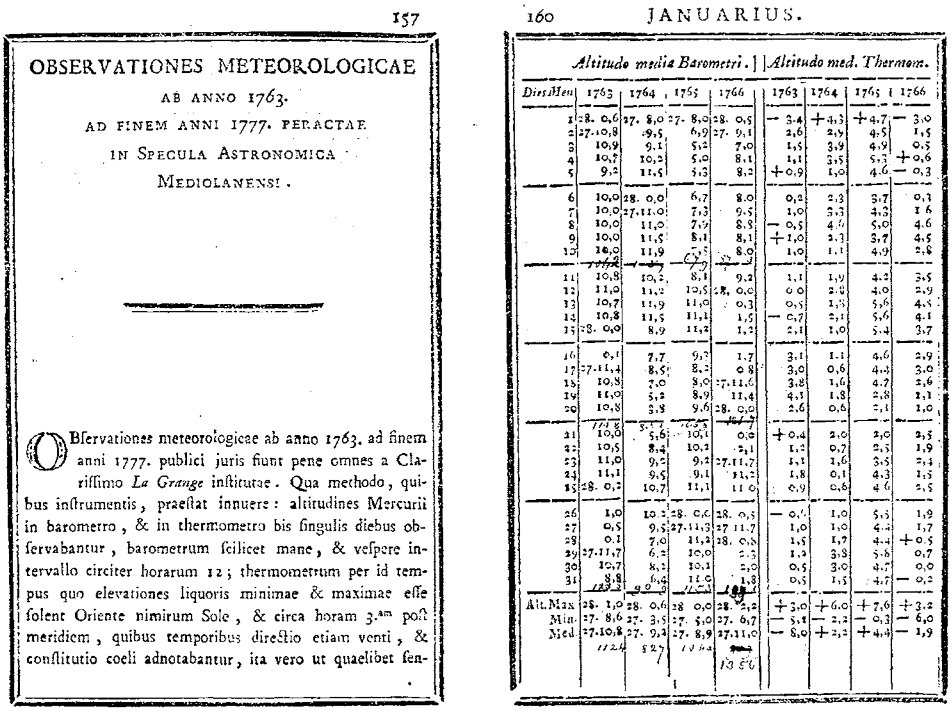
- *Effemeridi Astronomiche di Milano*, from 1775 to 1874 (Figure 6);
- *Giornale del Regio Istituto Lombardo di Scienze, Lettere ed Arti*, from 1841 to 1857;
- *Atti del Regio Istituto Lombardo di Scienze, Lettere ed Arti*, from 1858 to 1863;
- *Rendiconti dell'Istituto Lombardo di Scienze e Lettere*, from 1864 to 1987;
- *Pubblicazioni delle Osservazioni Meteorologiche a cura dell'Osservatorio di Brera*, from 1880 to 1971 and from 1988 until today.

Within this context the aim of the program was to recover daily temperature data using as much as possible the original hand-written observatory registers.

Except for the manuscripts relative to the first period spanning from 1763 to 1780 which have been lost, all the hand-written registers containing the meteorological observations are still preserved at the Archives of the Brera Astronomical Observatory. Unfortunately, the earliest available records are very difficult to decipher and only from May 1798 can they be correctly recovered. Later on the

Figure 5. The modern automatic station. It is located a few metres above Carlini's window.

manuscripts kept improving till 1880 when they finally attained a very good level (Figure 7). So, with the exception of some short periods, daily minimum and maximum temperatures could be recovered from the original sources. A detailed discussion of this activity is reported in Buffoni et al. (1996) and a summary of the data sources and of the digitised series is shown in Table II. Actually daily extreme temperatures were recovered only starting from 1838, whereas for the initial period



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OBSERVATIONES METEOROLOGICAE
AB ANNO 1763.
AD FINEM ANNI 1777. PERACTAE
IN SPECULA ASTRONOMICA
MEDIOLANENSI.

Observationes meteorologicae ab anno 1763. ad finem anni 1777. publici juris fiunt pene omnes a Clarissimo *La Grange* institutae. Qua methodo, quibus instrumentis, praestat innuere: altitudines Mercurii in barometro, & in thermometro bis singulis diebus observabantur, barometrum scilicet mane, & vespere intervallo circiter horarum 12; thermometrum per id tempus quo elevationes liquoris minimae & maximae esse solent Oriente nimirum Sole, & circa horam 3.am post meridiem, quibus temporibus directio etiam venti, & constitutio coeli adnotabantur, ita vero ut quaelibet sen-

160 JANUARIUS.

Dies Men.	Altitudo media Barometri. 1763	1764	1765	1766	Altitudo med. Thermom. 1763	1764	1765	1766
1	28. 0,6	27. 8,0	27. 8,0	28. 0,5	− 3,4	+ 4,3	+ 4,7	− 3,0
2	27.10,8	9,5	6,9	27. 9,1	2,6	2,9	4,5	1,5
3	10,9	9,1	5,2	7,0	1,5	3,9	4,9	0,5
4	10,7	10,2	5,0	8,1	1,1	3,5	5,3	+ 0,6
5	9,2	11,5	5,3	8,2	+ 0,9	1,0	4,6	− 0,3
6	10,0	28. 0,0	6,7	8,0	0,2	2,3	3,7	0,3
7	10,0	27.11,0	7,3	9,5	1,0	3,3	4,3	1,6
8	10,0	11,0	7,9	8,8	− 0,5	4,6	5,0	4,6
9	10,0	11,5	8,1	8,1	+ 1,0	2,3	3,7	4,5
10	10,0	11,9	7,5	8,0	1,0	1,1	4,9	2,8
11	10,8	10,2	8,1	9,2	1,1	1,9	4,2	3,5
12	11,0	11,2	10,5	28. 0,0	0,0	2,8	4,0	2,9
13	10,7	11,9	11,0	0,3	0,5	1,3	5,6	4,5
14	10,8	11,5	11,1	1,5	− 0,7	2,1	5,6	4,1
15	28. 0,0	8,9	11,2	1,2	2,1	1,0	5,4	3,7
16	0,1	7,7	9,7	1,7	3,1	1,1	4,6	2,9
17	27.11,4	8,5	8,2	0,8	3,0	0,6	4,4	3,0
18	10,8	7,0	8,0	27.11,6	3,8	1,6	4,7	2,6
19	11,0	5,2	8,9	11,4	4,1	1,8	2,8	1,1
20	10,8	3,8	9,6	28. 0,0	2,6	0,6	2,1	1,0
21	10,0	5,6	10,1	0,0	+ 0,4	2,0	2,0	2,5
22	10,5	8,4	10,2	2,1	1,2	0,7	2,5	1,9
23	11,0	9,2	9,2	27.11,7	1,1	1,6	3,5	2,4
24	11,1	9,5	9,1	11,2	1,8	0,1	4,3	1,5
25	28. 0,2	10,7	11,1	11,0	0,9	0,6	4,6	2,5
26	1,0	10,2	28. 0,0	28. 0,5	− 0,6	1,0	5,5	1,9
27	0,5	9,5	27.11,3	27.11,7	1,0	1,0	4,4	1,7
28	0,1	7,0	11,2	28. 0,8	1,5	1,7	4,4	+ 0,5
29	27.11,7	6,2	10,0	2,3	1,2	3,8	5,6	0,7
30	10,7	8,2	10,1	2,0	0,5	3,0	4,7	0,0
31	8,8	6,4	11,0	1,8	0,5	1,5	4,7	− 0,2
Alt. Max	28. 1,0	28. 0,6	28. 0,0	28. 2,2	+ 3,0	+ 6,0	+ 7,6	+ 3,2
Min.	27. 8,6	27. 3,5	27. 5,0	27. 6,7	− 5,4	− 2,2	− 0,3	− 6,0
Med.	27.10,8	27. 9,2	27. 8,9	27.11,0	− 8,0	+ 2,2	+ 4,4	− 1,9

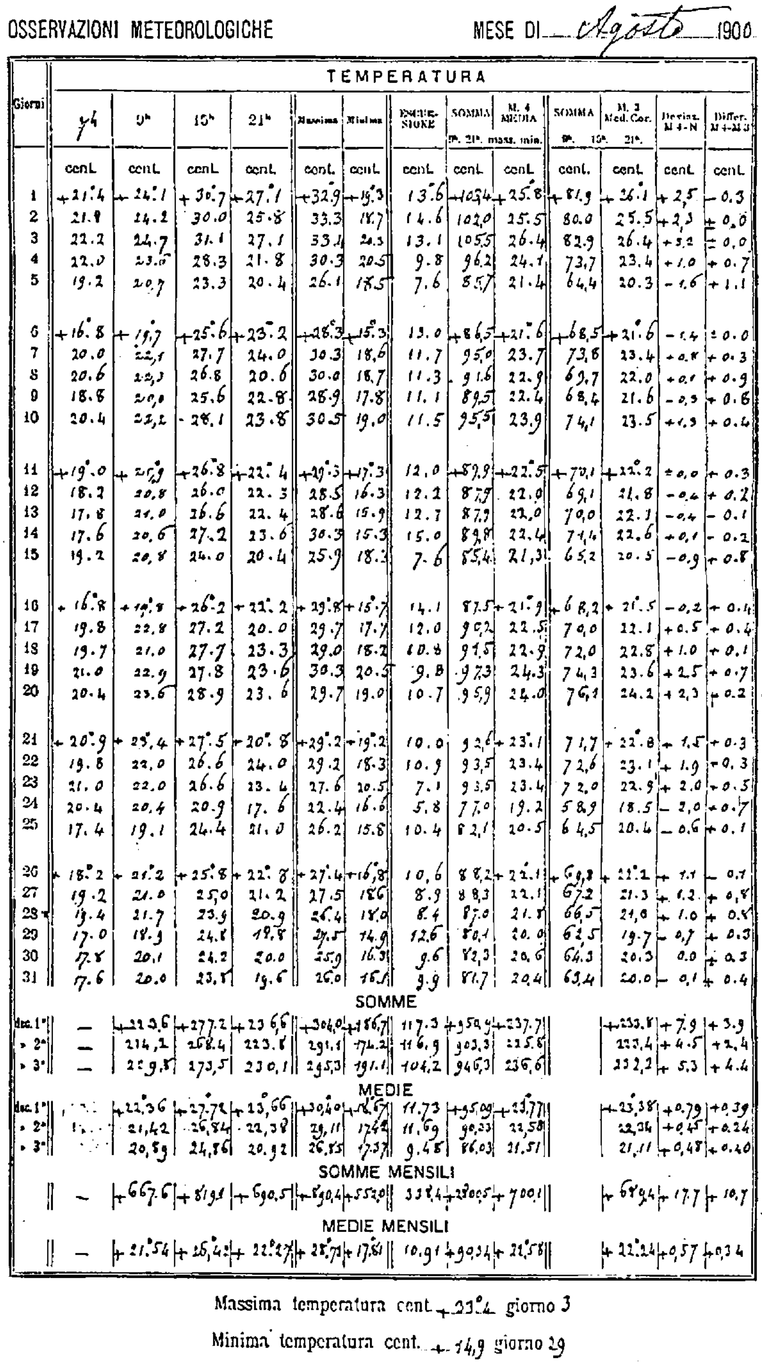
Figure 6. Until 1874 Milan meteorological data were published on Milan Astronomical Ephemeridis. The earliest ones were included in the Ephemeridis for the year 1779 (Osservatorio Astronomico di Brera, 1778) which also report information on instruments and measurement methods.

only estimates of them are available. They are '*mane*' and 'vespere' observations for 1763–1834 period and 6 a.m. and 3 p.m. ones for 1835–1837 period.

At the same time temperature data were recovered from the hand-written registers, all the notes on the observations were recovered too (Buffoni et al., 1996). The collection of these notes is a very important part of the station metadata file. Beside the ones contained in the hand-written observatory registers other important notes on the history of the observations were recovered from the data issues listed previously and from about 20 monographic studies on Milan data. All these notes constitute the station metadata file.

After the daily temperature data had been recovered from the hand-written registers a detailed comparison with the published data was made. It allowed a number of errors to be identified in the published data, but also showed that, with the exception of a few periods, their effect on monthly means is generally negligible. A list of the principal differences between the hand-written and the published versions of Milan temperature data is reported in Buffoni et al. (1996).

As the analysis of the differences between hand-written and published Milan temperature data verified that the quality of Milan published data is generally good, air pressure data have mainly been recovered from these sources (Table II) and the



OSSERVAZIONI METEOROLOGICHE — MESE DI Agosto 1900

TEMPERATURA

Giorni	7h	9h	15h	21h	Massima	Minima	Escursione	Somma (9h, 21h, mass. min.)	M. 4 Media	Somma (9h, 15h, 21h)	M. 3 Med. Cor.	Deviaz. M 4-N	Differ. M 4-M 3
	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.	cent.
1	+21.4	+24.1	+30.7	+27.1	+32.9	+19.3	13.6	+103.4	+25.8	+81.9	+26.1	+2.5	−0.3
2	21.9	24.2	30.0	25.8	33.3	18.7	14.6	102.0	25.5	80.0	25.5	+2.3	±0.0
3	22.2	24.7	31.1	27.1	33.1	20.3	13.1	105.5	26.4	82.9	26.4	+3.2	±0.0
4	22.0	23.0	28.3	21.8	30.3	20.5	9.8	96.2	24.1	73.7	23.4	+1.0	+0.7
5	19.2	20.7	23.3	20.4	26.1	18.5	7.6	85.7	21.4	64.4	20.3	−1.6	+1.1
6	+16.8	+19.7	+25.6	+23.2	+28.3	+15.3	13.0	+86.5	+21.6	+68.5	+21.6	−1.4	±0.0
7	20.0	22.1	27.7	24.0	30.3	18.6	11.7	95.0	23.7	73.8	23.4	+0.8	+0.3
8	20.6	22.3	26.8	20.6	30.0	18.7	11.3	91.6	22.9	69.7	22.0	+0.1	+0.9
9	18.8	20.0	25.6	22.8	28.9	17.8	11.1	89.5	22.4	68.4	21.6	−0.3	+0.8
10	20.4	22.2	28.1	23.8	30.5	19.0	11.5	95.5	23.9	74.1	23.5	+1.3	+0.4
11	+19.0	+20.9	+26.8	+22.4	+29.3	+17.3	12.0	+89.9	+22.5	+70.1	+22.2	±0.0	+0.3
12	18.2	20.8	26.0	22.3	28.5	16.3	12.2	87.9	22.0	69.1	21.8	−0.4	+0.2
13	17.8	21.0	26.6	22.4	28.6	15.9	12.7	87.9	22.0	70.0	22.1	−0.4	−0.1
14	17.6	20.6	27.2	23.6	30.3	15.3	15.0	89.8	22.4	71.4	22.6	+0.1	−0.2
15	19.2	20.8	24.0	20.4	25.9	18.3	7.6	85.4	21.3	65.2	20.5	−0.9	+0.8
16	+16.8	+19.8	+26.2	+22.2	+29.8	+15.7	14.1	87.5	+21.9	+68.2	+21.5	−0.2	+0.4
17	19.8	22.8	27.2	20.0	29.7	17.7	12.0	90.2	22.5	70.0	22.1	+0.5	+0.4
18	19.7	21.0	27.7	23.3	29.0	18.2	10.8	91.5	22.9	72.0	22.8	+1.0	+0.1
19	21.0	22.9	27.8	23.6	30.3	20.5	9.8	97.3	24.3	74.3	23.6	+2.5	+0.7
20	20.4	23.6	28.9	23.6	29.7	19.0	10.7	95.9	24.0	76.1	24.2	+2.3	+0.2
21	+20.9	+23.4	+27.5	+20.8	+29.2	+19.2	10.0	92.6	+23.1	71.7	+22.8	+1.5	+0.3
22	19.8	22.0	26.6	24.0	29.2	18.3	10.9	93.5	23.4	72.6	23.1	+1.9	+0.3
23	21.0	22.0	26.6	23.4	27.6	20.5	7.1	93.5	23.4	72.0	22.9	+2.0	+0.5
24	20.4	20.4	20.9	17.6	22.4	16.6	5.8	77.0	19.2	58.9	18.5	−2.0	+0.7
25	17.4	19.1	24.4	21.0	26.2	15.8	10.4	82.1	20.5	64.5	20.4	−0.6	+0.1
26	+18.2	+21.2	+25.8	+22.7	+27.4	+16.8	10.6	88.2	+22.1	+69.7	+22.1	+1.1	−0.1
27	19.2	21.0	25.0	21.2	27.5	18.6	8.9	88.3	22.1	67.2	21.3	+1.2	+0.8
28	19.4	21.7	23.9	20.9	26.4	18.0	8.4	87.0	21.8	66.5	21.0	+1.0	+0.8
29	17.0	18.9	24.8	19.8	27.5	14.9	12.6	80.1	20.0	63.5	19.7	−0.7	+0.3
30	17.8	20.1	24.2	20.0	25.9	16.3	9.6	82.3	20.6	64.3	20.3	0.0	+0.3
31	17.6	20.0	23.8	19.6	26.0	16.1	9.9	81.7	20.4	63.4	20.0	−0.1	+0.4
SOMME													
dec. 1°	—	+223.6	+277.2	+236.6	+304.0	+186.7	117.3	+950.9	+237.7		+233.8	+7.9	+3.9
» 2°	—	214.2	268.4	223.8	291.1	174.2	116.9	903.3	225.8		223.4	+4.5	+2.4
» 3°	—	229.8	273.5	230.1	295.3	191.1	104.2	946.3	236.6		232.2	+5.3	+4.4
MEDIE													
dec. 1°		+22.36	+27.72	+23.66	+30.40	+18.67	11.73	+95.09	+23.77		+23.38	+0.79	+0.39
» 2°		21.42	26.84	22.38	29.11	17.42	11.69	90.33	22.58		22.34	+0.45	+0.24
» 3°		20.89	24.86	20.92	26.85	17.37	9.48	86.03	21.51		21.11	+0.48	+0.40
SOMME MENSILI													
	—	+667.6	+819.1	+690.5	+890.4	+552.0	338.4	+2800.5	+700.1		+689.4	+17.7	+10.7
MEDIE MENSILI													
	—	+21.54	+26.42	+22.27	+28.72	+17.81	10.91	+90.34	+22.58		+22.24	+0.57	+0.34

Massima temperatura cent. +33.4 giorno 3

Minima temperatura cent. +14.9 giorno 29

Figure 7. Example of the Brera observatory hand-written registers. This high quality level was reached around 1880, then no important changes were made until 1972, when the Observatory abandoned meteorological measures.

Table II

Sources used to reconstruct Milan temperature and pressure series and data that were moved to computer readable form

Period	Data sources		Data transferred to digital form
	Thermometer	Barometer	
1763–1777	Emphemeridis	Ephemiridis	Mean values between '*mane*' and '*vespere*' observations
1778–1834	Ephemeridis (1778–1797); then handwritten registers 1818–1830	Ephemeridis; handwritten registers for the period	'*Mane*' and '*vespere*' observations
1835–1972	Handwritten registers	Ephemeridis and other published sources (Buffoni et al., 1996)	Temperature: daily maximum and minimum values; 3 p.m. and 6 a.m. for the period 1835–1837 Pressure: 3 to 7 daily observations
1973–1987	Bulletins of the Istitudo Lombardo di Scienze e Lettere		
1988– →	Automatic station		Hourly observations and daily minimum and maximum values

hand-written registers have been used only if homogeneity tests showed that errors could be present. Moreover, they have been used for the period 1818–1830 as it was necessary to digit the internal temperatures, i.e. the temperatures of the barometer, that are not reported on the Ephemeridis.

Daily Milan temperature and pressure data is available on CD-ROM as a result of EC-project *'Improved understanding of past climate variability from early daily European instrumental sources'* (IMPROVE). The CD is enclosed with a hardbound print of this special issue. The CD-ROM includes the original data, i.e. the ones that were recovered from the original sources and completed and homogenized versions of them (Maugeri et al., 2002) as well as other series arisen from the same project.

4. Conclusions

The recovery of Milan daily temperature and pressure series has been presented and all the information that can be useful in order to evaluate the quality and the homogeneity of the data has been discussed.

The principal results are as follows:

- Metadata give evidence of a number of events that could cause inhomogeneities in Milan temperature and pressure series.
- The most important event is Carlini's reorganisation. Even if it undoubtedly did improve meteorological equipment and data acquisition procedures, it also

introduced a great discontinuity in the series in such a way that the earlier data cannot be compared with the ones recorded from 1835 unless corrections are made.

- Besides Carlini's reorganisation, the most critical years in relation to data homogeneity are the first (1763–1804) and the last (1963 – today) ones.
- Some problems in the Milan data were probably caused by the development of the national meteorological network that began a few years after Italian political Unity (1860). Even if no detailed information is available, metadata seem to show that the standardisation introduced by this network caused some inhomogeneities in the series as changes were probably made to match the new requirements of national and international organisations.
- The comparison with the hand-written temperature data gave evidence that the published sources (ephemeridis, bulletins, etc . . .) contain a number of errors, but also showed that their effect on climate analysis is generally negligible. So, at least for Milan, the data issues regularly published by the Milan Observatory can be properly used to recover the original daily data.

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