RECONSTRUCTION AND CLIMATOLOGICAL ANALYSIS OF THE TEMPERATURE SERIES OF VERONA (1741 – 2006)

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Abstract: Preliminary results from the reconstruction and climatological analysis of the long series of air temperature and precipitation measurements in Verona are presented. After careful search of both published and unpublished data from observations in various archives, libraries and academies, data covering the period 1741-2006 have been collected. A preliminary assessment about quality and reliability has been performed on the basis of metadata and historical information and complete series of monthly mean or extreme values have been obtained. Various gaps in the temperature series have been filled by means of correlation coefficients with respect to a reference series, evaluated on the basis of a weighted mean of correlation coefficients with the homogeneous series of Milano (1763-1998) and Padova (1725-1997). Outliers, detected by means of suitable test, have been removed and the Standard Normal Homogeneity Test allowed to detect discontinuities, which were corrected by application of suitable shifts, whose absolute values amount to a total of 1.21°C. After application of a low-pass filter, suitable trends were evaluated.

Keywords: *Verona, temperature series, precipitation series, homogenization, trend, climate.*

1. VERONA AND ITS CLIMATE

Verona is nowadays a middle sized city (about 260’000 inhabitants in 2001) at the foothills of the Alps, close to the inlet of the Adige Valley, where the Adige River flows out into the Po Plain, bending thereafter into various meanders, on a couple of which Verona developed (Figure 1). The city is at the junction of two major transport axes – one between central Europe and the Mediterranean basin, through the Brenner corridor and the Adige Valley, the other between east and west in northern Italy, across the Po Plain. Owing to this remarkable position, Verona has always been a major center for trade and manufacturing and a strategic fortified town.

Figure 1: Left: position of Verona in Northern Italy. Right: map of the city centre (as it is today) and positions where observations were made by the observers indicated in parentheses: (1) Maffei Palace, today renamed Lebrecht Palace (J. F. Séguier), (2) Castelvecchio castle (A. M. Lorgna and G. Maggi), (3) Cagnoli Palace (A. Cagnoli), (4) Botanical Garden of the Academy of Agriculture, Sciences and Letters, today Viviani square (G. Tomaselli, F. Mayer, M. Barbieri and G. Bertoncelli), (5) Spandri house (G. Spandri), (6) Botanical Garden as above (B. Bertoncelli), (7) Lebrecht Palace as above (B. Bertoncelli), (8) San Sebastiano church (G. Fracastoro), (9) Lyceum “A. Messedaglia” (G. Fracastoro, A. Cassandrini and P. Franchini), (10) Meteo4 observatory (E. Bellavite), (11) Meteo4 (E. Bellavite).

These particular conditions favoured the development of various activities in the fields of science and technology, especially in connection with economic activities (e.g. agriculture), among which the observations and analysis of weather and climate phenomena. As a consequence, starting in early ‘700, various scholars started, either independently or associated into academies or cultural circles, systematic observations of meteorological variables.

2. COLLECTED DATA

For the present work data covering almost completely the period 1741-2006 have been collected, after careful search of both published and unpublished data from observations in various archives, libraries and academies (Figure 2). In the first period (1741-1750) observations were made by Jean-François Séguier, followed (only for the year 1765) by Anton Maria Lorgna and (for 1768-1774) by Giuseppe Maggi in the castle of Castelvecchio. In 1788 the astronomer Antonio Cagnoli started collecting meteorological data for the Accademia di Agricoltura Scienze e Lettere di Verona (Academy of Agriculture, Sciences and Letters), a task which was later undertaken, on behalf of the Academy, by many observers without discontinuities until the end of XIX Century. The most remarkable observer was Bartolomeo Bertoncelli, who took continuously observations from 1854 to 1898 (45 years!). In 1900 Giovanni Fracastoro started again collecting meteorological data on request of the Ufficio Centrale di Meteorologia e Geodinamica (Central Office of Meteorology and Geodynamic). After him two other observers, Arturo Cassandrini and Pio Franchini, continued collecting data till 1947. In 1948 Emilio Bellavite started careful observations, which he still carries out.

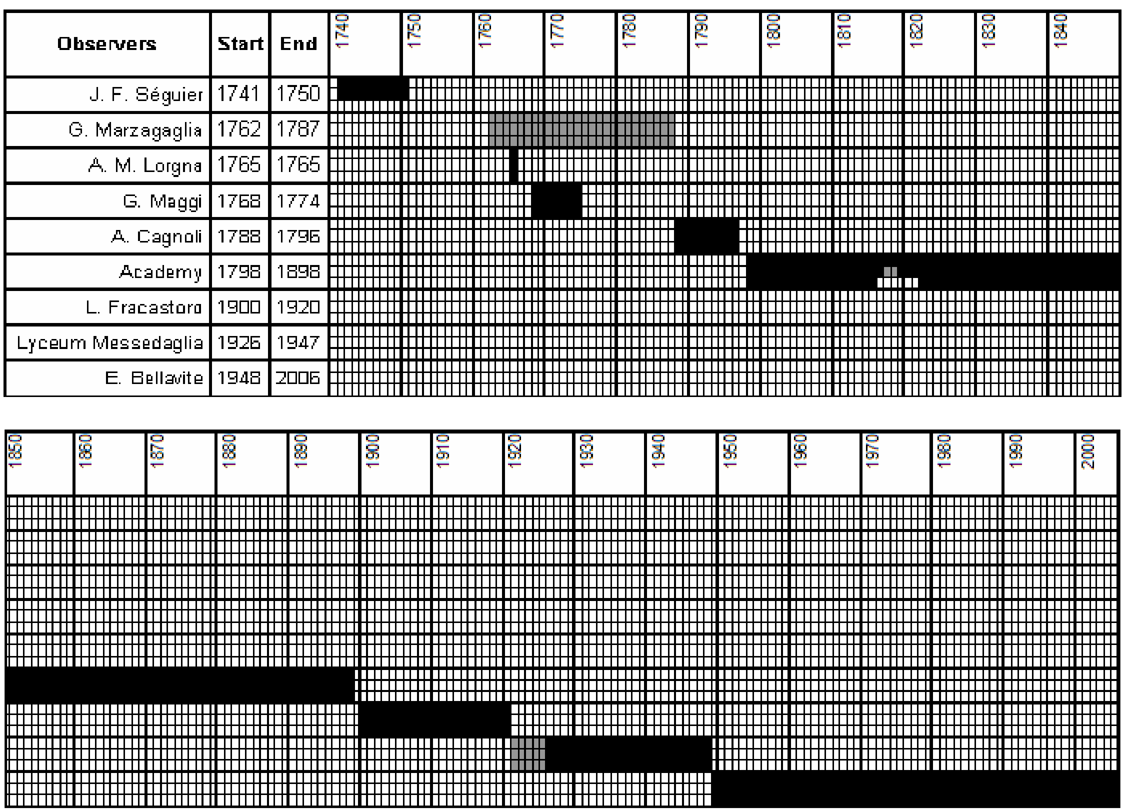

Figure 2: Gantt chart showing timing and duration of regular measurements made by various observers, as indicated in the first column. “Academy” includes most of the Observers that made observations on behalf of the Academy of Agriculture, Sciences and Letters, namely G. Tomaselli, F. Mayer, M. Barbieri, G. Bertoncelli and G. Spandri. “Lyceum Messedaglia” indicates the measurements taken at the Lyceum by A. Cassandrini and P. Franchini. For each observer, three horizontal lines indicate the variables he used to record: monthly mean temperature (upper line), monthly extreme of maximum and minimum daily temperature (middle line) and monthly total precipitation (lower line). Shaded cells indicate that the corresponding data are available, while those corresponding to empty cells are not available. Grey shaded cells denote data which, according to documental witnesses, were recorded, but have not yet been discovered.

3. DATA ANALYSIS

A preliminary assessment about quality and reliability has been performed on the basis of metadata and historical information. Temperature data prior to 1788 need particular care, due to some gaps and to possible ambiguities in the interpretation of the procedures adopted by the observers, which at that time were not yet fully standardized. Data analysis is still in progress. However complete series have been obtained for the period 1788-2006: the series of annual mean temperatures is shown in Figure 3. Gaps have been filled by means of correlation coefficients evaluated on the basis of a weighted mean of correlation coefficients of the homogeneous series of Milano (1763-1998) (Maugeri et al, 2002), and Padua (1725-1997) (Camuffo, 2002).

Then the series obtained has been normalized to the reference series in order to value and remove outliers. Values have been discarded when they were outside of an interval 3σ wide (where σ is the standard deviation) centred on the mean value. It has been found that the 90% of outliers were located before 1900, as it could have been imagined as a consequence of the better quality of recent instruments against older ones.

Finally the Standard Normal Homogeneity Test (Moberg and Alexandersson, 1997; Alexandersson and Moberg, 1997) has been applied to the series. This procedure allowed detection of various discontinuities, which were corrected by application of suitable shifts, whose absolute values amount to a total of 1.21°C.

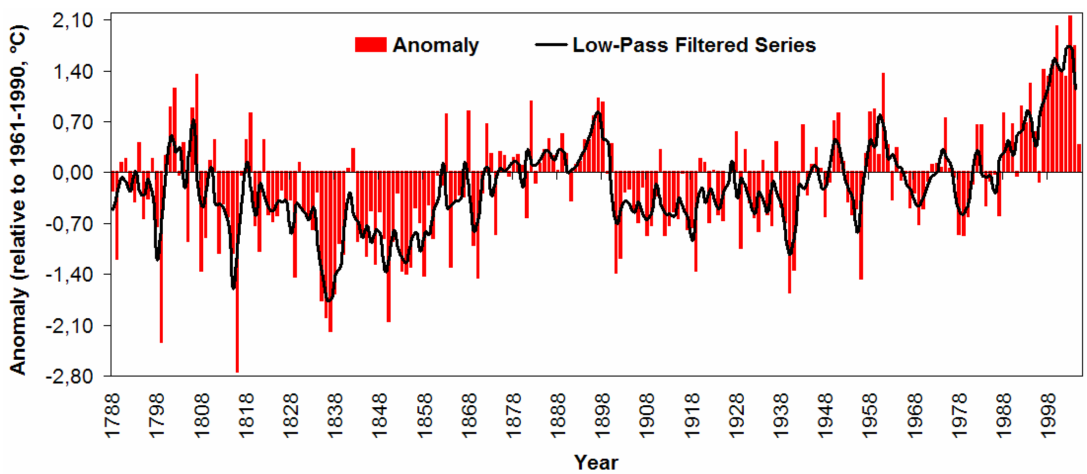

Figure 3: Red bars: anomalies of annual mean temperature in Verona (relative to the average value over the period 1961-1990) following the format introduced by IPCC (2001). Solid line: low-pass filtered series obtained by application of the digital recursive filter by de Franceschi and Zardi (2003).

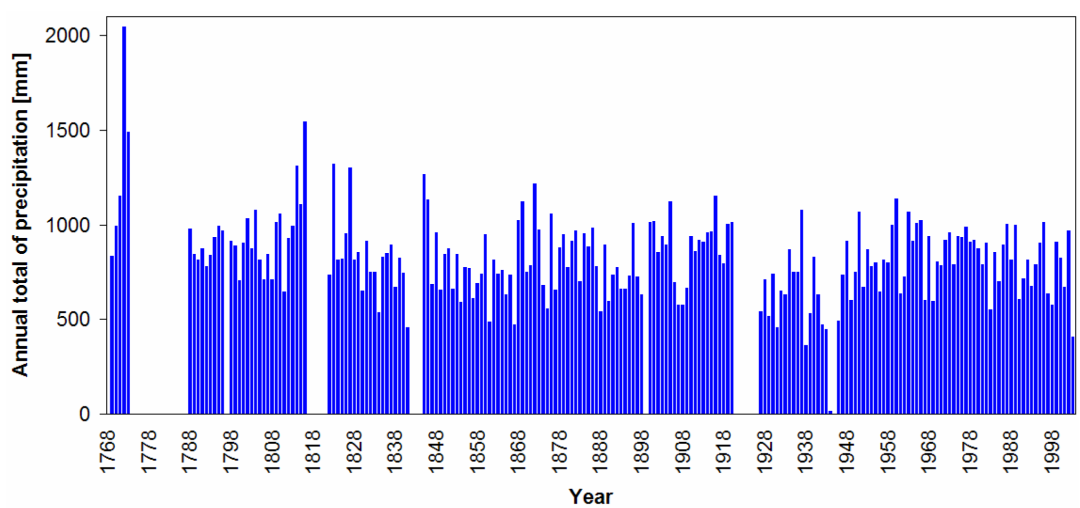

Figure 4: Annual total precipitation in Verona. The remarkable maximum in 1772 appears to be real, according to contemporary witness about incessant rains for five months in winter and early spring (Sormani Moretti, 1904).

A preliminary sample of annual total precipitation evaluated on the basis of data collected from 1768 are shown in Figure 4. Further analysis of precipitation data, including gap filling and homogenisation, is still in progress.

After application of a suitable digital recursive low-pass filter (de Franceschi and Zardi, 2003) to the homogeneous series of annual and seasonal mean temperatures, linear trends have been evaluated along with their uncertainties (Table 1). Finally the trends detected in the nonhomogenised series of total annual and seasonal precipitation are reported in Table 2.

Table 1: Temperature trends (°C century^{-1}) and related uncertainties.

Period	1788-2003	1974-2003
Winter (DJF)	0,79 ± 0,09	1,61 ± 1,36
Spring (MAM)	0,40 ± 0,08	10,25 ± 1,26
Summer (JJA)	0,14 ± 0,07	7,59 ± 0,98
Autumn (SON)	0,29 ± 0,07	4,39 ± 1,03
Year	**0,40 ± 0,06**	**5,99 ± 0,73**

Table 2: Precipitation trends (mm century^{-1}) and related uncertainties.

Period	Trend [mm century^{-1}]
Winter (DJF)	-10,10 ± 8,1
Spring (MAM)	-13,81 ± 9,2
Summer (JJA)	-13,96 ± 10,4
Autumn (SON)	-24,76 ± 10,3
Year	**-58,31 ± 20,7**

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