The Temperature Series of Trento: 1816-2002.

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ABSTRACT

A long temperature series of annual mean temperatures from the city of Trento (Central-Eastern Italian Alps: Fig. 1) has been composed on the basis of shorter records from different sources discovered in various archives. Applying the Standard Normal Homogeneity Test (SNHT: Alexandersson, 1986) some inhomogeneities have been detected (in connection with changes in the observing operators or institutions) and corrected by means of the procedure proposed by Alexandersson and Moberg (1997). The homogeneous series has been analized for regression, randomness and statistical significance, on annual basis, using Durbin-Watson, Mann-Kendall and Spearman's test (Yue et al., 2002). Regression analysis shows a significant increasing trend in the annual mean temperatures. This is particularly remarkable in the last 30 years, in agreement with the findings from other cases (IPCC, 2001, Auer et al., 2001).

1. Introduction

The early discovering and diffusion of instruments for meteorological measurements in the eighteenth century makes Italy a relatively rich area in instrumental records of meteorological variables. Temperature and precipitation series have been recently published from records starting in the eighteenth century in cities where ancient meteorological observatories were founded, such as Milano (1763), Padova (1725), Palermo (1791), Torino (1756), Bologna (1716), Roma (1782), and many other cities at the beginning of the nineteenth century: among them Mantova, Firenze, Genova, Aosta, Modena, Napoli, Parma, Pavia, Perugia, Udine, Trieste and Venezia (Buffoni et al., 1999). The historical temperature record of Trento presented here dates back to 1816. It is particularly significant as it displays remarkable length and continuity and is expected to be representative of climate evolution in the southern side of the Central-Eastern Alps, due to the geographic position of Trento. Furthermore, since the city remained relatively small during this time (Fig. 2), possible urban heat island effect should have negligibly affected the measurements.

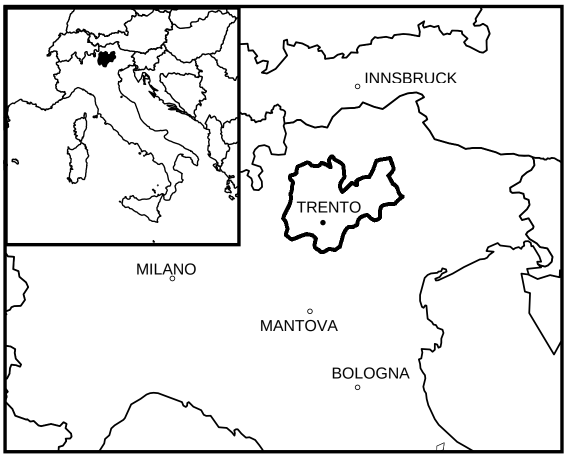

Figure 1: The position of Trento and other cities where historical stations exist, whose long series has been used for the homogenisation procedure in the present work (see Section 3).

In 1816 Trento and surroundings were part of the Austrian Empire and shared its establishment of a local meteorological and hydrological measurements network. As a consequence, in that region many other measurement stations were created, and various long series are now available, published in official yearbooks, such as in Arco (starting 1855), Riva del Garda (1869), San Michele all'Adige (1874) and Rovereto (1882). In addition measurements recorded by private observers helped to complete and strenghten the analysis based on official records. After 1918 routine meteorological measurements have been performed by the appointed Italian national Institutions.

This rich database over a relatively small area offers the opportunity for a detailed investigation of small-scale features of climatic change in alpine region, which was initiated with the work presented here starting from the most significant site.

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2. A short history of meteorological meauserements in Trento

The temperature record of Trento has been composed on the basis of shorter series from different sources. Earliest temperature measurements are reported in the first volume (1848-49) of the Meteorological Yearbooks of the Austrian Central Institute of Meteorology and Geodynamics (hereinafter ZAMG). This first volume included earlier data collected in Trento in 1816-1832 by an anonymous private observer and provided to the ZAMG by Joseph Wessely (1814-1898) in 1847. The volumes of the ZAMG yearbook published later (1856, 1864-1867, 1874-1882, and 1885-1915) report tables of temperature observations in Trento. The measurement site was at the former Sericultural Institute (*Istituto Bacologico*), close to the city center (Fig. 2, site B).

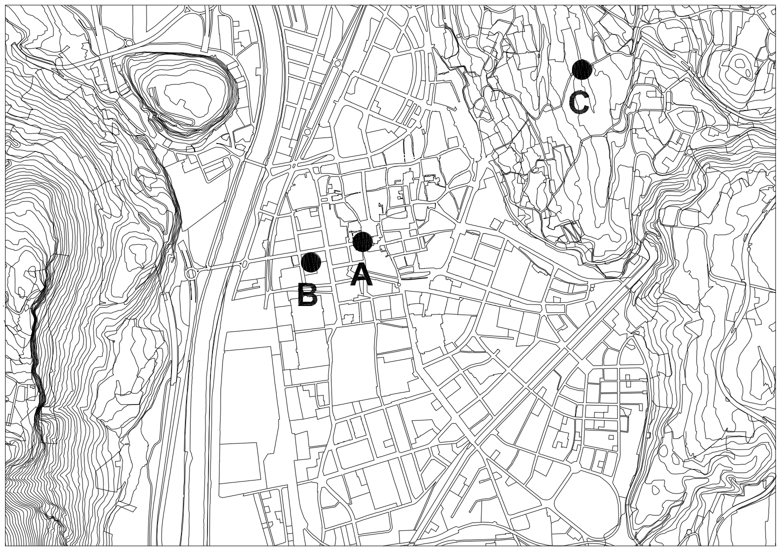

Figure 2: Map of the city of Trento and location of the meteorological stations used for the reconstruction of the series: (A) the Cathedral, (B) the Sericultural Institute and (C) Trento Laste.

Furthermore two unpublished manuscripts by private observers were found in the Municipal Library of Trento. The first was written by Francesco Lunelli (1792-1858), professor at the Imperial Royal Gymnasium in Trento. Lunelli used to collect daily temperature and pressure observations from 1828 to 1858 with instruments placed at 9.48 m above ground over the main door of the Cathedral (Fig. 2, site A). The instruments are still conserved at the Municipal Library. The second manuscript was written by Giuseppe Garbari (?-1871), who recorded daily temperature in Trento from 1851 to 1871.
In 1895-1913 another institution, the Imperial Royal Central Hydrographic Office in Vienna, used to have a station recording meteorological data in the city of Trento, close to the ZAMG's one .
After 1918 Trento became part of the Italian Kingdom and meteorological observations in Trento were regularly collected by the Royal Central Office of Meteorology in Roma starting in June 1919. The measurement site was on a hill near Trento, close to the still existing weather station of Trento Laste (Fig. 2, site C).
As a consequence, the overall record of Trento spans the period 1816-2002 with only few gaps (1871-72, 1883-84, 1915-19), the major one occurring during the first World War.

3. Homogeneity Test

The series of annual mean temperatures has been tested for homogeneity in order to find and correct changes due to non climatic factors. The resulting discontinuities can be cross-checked with metadata from the station history (e.g. change of the measurement location and/or instruments).
Standard Normal Homogeneity Test (Alexandersson, 1986) has been applied to perform this analysis. This procedure defines an indicator (T) in such a way that the occurrence of a maximum in T defines years where a disconuity is very likely to have occurred. To ascertain whether this discontinuity follows from climatic factors or not, a suitable treshold has to be set, whose value depends on the degree of reliability we want to achieve. In the present work we decided to require a 95% probability that the detected inhomogeneity is due to a non climatic change, and the associated threshold value (T95) resulted in a value of 9.51.
Furthermore the procedure requires that a reference series is created on the basis of some reliable series of data taken in the neighborhood of the candidate station. For the present analysis, the

long temperature records of Mantova, Bologna and Milano have been used along with Innsbruck temperature series from the ALP-CLIM database (Auer, 2001). The procedure suggested by Alexandersson and Moberg (1997) has been applied. The gaps in the candidate series have been filled using data from the reference series, after careful evaluation of the mean trends detected before and after the gaps. The series of the differences (Q) between temperatures of Trento and in the reference series have been evaluated. Once a discontinuity was detected in the Q series, a shift was applied to each temperature value in the candidate series before the date where the break occurred. The shift is evaluated on the basis of the average of the Q values in the sub-series before and after the break, respectively. This procedure can be iterated until all the maxima in the test parameter T are less than the treshold value.
The output of SNHT applied to the Trento series is shown in Fig. 3, where the value of the test variable T is reported at the beginning and at the end of the procedure, along with the series of Q. In the present case, a major inhomogeneity was found to occur in 1873 (where a shift of +2.0 K has been applied), a second one in 1828 (+1.13 K) and a third minor one in 1974 (-0.76 K).

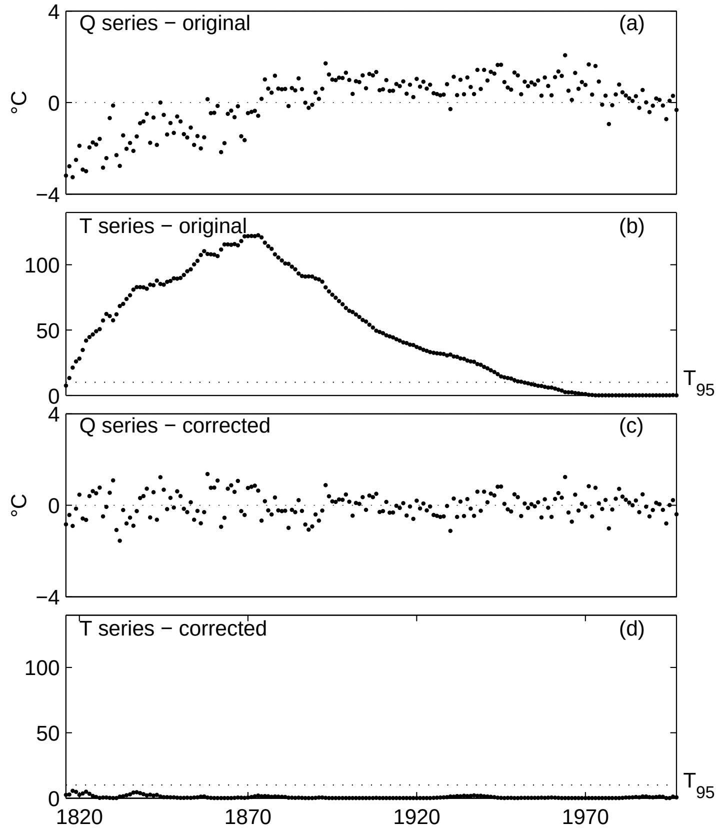

Figure 3: Output from homogeneity test on mean annual temperature in Trento (1816-2002). Q is the difference between temperatures of Trento and in the reference series, T is the test variable, T_{95} is the threshold.

The main evidence obtained from SNHT is that the inhomogeneities are mostly located in years when observations are known to have undergone a change. In fact the break in 1873 is due to the junction of Garbari's temperature record with the ZAMG data. The second break in 1828 is clearly associated which the transition between Lunelli's data and the first ZAMG records. On the contrary the disomogeneity occurring in 1974 could not be associated so far with recorded events of the station.

4. Results

After applying SNHT to the series, a trend analysis can be performed to evaluate climatic evolution of temperature in Trento. Before applying linear interpolation and trend estimation, the series has been averaged using a first order recursive filter with the same spectral characteristics as a decadal moving average with Gaussian weights and width equal to three time the variance (de Franceschi and Zardi, 2003) (Fig. 4).
Durbin-Watson (DW) Test for autocorrelation applied to the series resulted in a value of the test parameter V=1.63, which is greater than the critical value of the DW test. Therefore we conclude that serial correlation is not significant. This allows a correct and statistically significant linear regression evaluation.
Subsequently, both Mann-Kendall and Spearman Test (Yue et al., 2002) have been applied to evaluate the significance level of the estimated trend. The linear regression coefficient for the annual mean

series in the period 1816-2002 is (0.54 ± 0.08) K /100y with an associated linear correlation coefficient r=0.48.

The Mann-Kendall test value for this regression is Z_{MK}=6.27, and the associated probability p=0.5(1- erf(|Z|))=1.7 10^{-10}.

The Spearman test value for this regression is Z_S=-6.03, and the associated probability p=8 10^{-9}. Both tests give a clear indication of the statistical significance of the linear regression.

The linear regression coefficients evaluated for the last 50 and 30 years are (2.09 ± 0.5) K/100y and (3.37 ± 0.9) K/100y respectively.

Notice that they are higher than those calculated over the whole series. It is not clear at the moment whether this effect is amenable to global change or to other factors (possibly including urban heat island effect). This issue is the subject of ongoing research work.

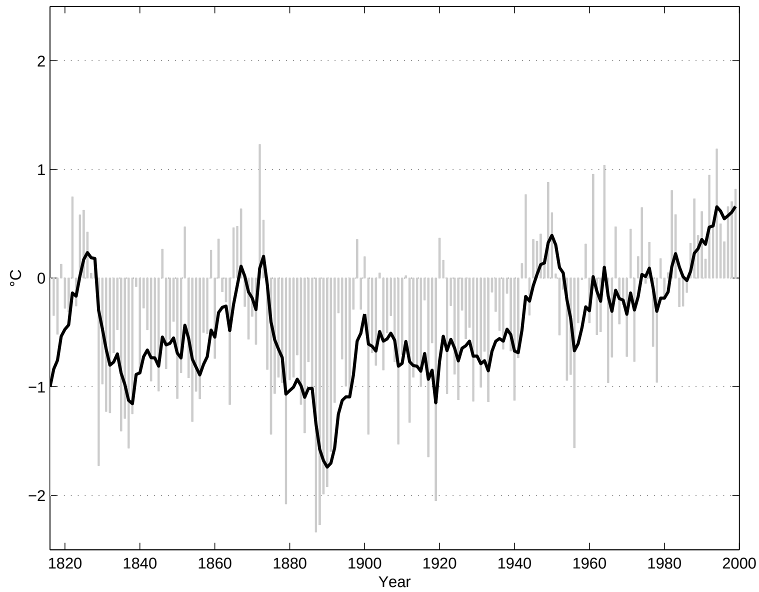

Figure 4: Bars: anomalies of Trento mean annual temperature according to IPCC (2001) plotting standard. Solid line: low-pass filtered series.

ACKNOWLEDGMENTS

This work was partly supported by the Provincia Autonoma di Trento under the project "Assessment of Climate Change effects in Trentino". The Authors acknowledge Dr. Remo Tomasetti for stimulating this work, as well as Prof. Lia de Finis and Prof. Herbert Killian for providing valuable historical information.

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