Urban Climate 10 (2014) 509–529

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

Effects of changes in observational sites position and surrounding urbanisation on the temperature time series of the city of Trento

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ARTICLE INFO

Article history:
Received 12 September 2013
Revised 19 February 2014
Accepted 11 April 2014

Keywords:
Valley city
Temperature time series
Urbanisation effects
WRF model
Urban parameterisations

ABSTRACT

The paper presents a combined analysis of results from field measurements and numerical simulations aimed at supporting the reconstruction of the temperature time series of the city of Trento in the Alps. This project is challenging, due to various relocations of the observational sites and the increasing effects of urbanisation.

Identical temperature sensors were placed at the historical observational sites of the city, to detect systematic differences between these places under various seasonal patterns and weather conditions. However, since differences measured nowadays may not be representative of those occurring in the past, numerical simulations were also run with the WRF model, using a historical land use. Furthermore simulations with the present land use were performed and validated against the observations carried out during the field campaign.

The comparison between "present" and "historical" simulations suggests that temperature differences between the sites more embedded in the urban area have not changed significantly from the past, whereas greater modifications have occurred at a location on the valley slope, progressively incorporated into the city. Moreover it is shown that the progressive urbanisation has played a significant role in Trento's temperature record, the effect being more significant under sunny conditions, when the UHI is stronger.

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http://dx.doi.org/10.1016/j.uclim.2014.04.003
2212-0955/

1. Introduction

Many historical meteorological observational sites are located in major urban areas. As a consequence, their records are prone to be influenced by local climatic modifications induced by the rapid growth of cities in the last two centuries. It is in fact well known that urban areas display modified climatic conditions with respect to the surrounding countryside. In particular they are affected by the so-called Urban Heat Island (UHI), i.e. they display higher temperatures compared to the adjacent rural areas, especially during nighttime. The detection of urbanisation effects on climatological records, and the subsequent attribution of observed temperature trends to local effects rather than to global warming, is not an easy task, especially for the earliest time series, covering time periods for which urban records cannot always be compared with rural temperature time series, and metadata are scarce. Many studies have addressed this problem with different methods. However general conclusions cannot be drawn, as situations differ from case to case. Jones et al. (2008) stated that urbanisation did not contribute to the temperature trends observed in the last century in Vienna and London, while contrasting results were found for some Chinese cities. Huang et al. (2009) compared trends recorded by rural and urban weather stations in the metropolitan area of Osaka (Japan), concluding that urbanisation is responsible for at least half of the observed warming trend. Recent investigations of the effects of urbanisation on local warming trends have adopted an approach based on numerical model simulations. Van Weverberg et al. (2008) and Hamdi et al. (2009) took advantage of historical maps of land use to estimate urbanisation effects on the temperature record in Brussels, using two different modelling approaches. One estimated the magnitude of urbanisation effects under selected weather conditions with a mesoscale model, whereas the second examined the impact of land cover change using an urban parameterization scheme in a stand-alone mode, coupled with downscaled reanalysis data for a 40-year period.

Further complications in the reconstruction of urban historical time series arise when observations have been performed at different locations throughout the years, leading to discontinuities in the time series (Andrighetti et al., 2009). In fact temperatures taken at different points within a city may display significantly different values depending on the local urban morphology and on the degree of urbanisation (Oke, 1987; Stewart and Oke, 2012). Furthermore the estimation of the temperature shifts between time series recorded at different places may be not straightforward, as it may strongly depend on seasonal and weather conditions.

All the above problems connected with the reconstruction of an urban historical time series were encountered in the present investigation of Trento, a medium-sized city on the Adige Valley floor, in the Italian part of the Alps (Fig. 1). Regular observations of air temperature in Trento date back to 1816. However measurements were collected at different sites from that time, as shown in more detail in Section 2 (Rampanelli and Zardi, 2008). Furthermore inhomogeneities in the time series were introduced not only by the different degree of urbanisation between the sites, but also by topographic effects, since observations were collected at different altitudes on the slopes of the valley. Moreover Trento is characterised by peculiar local atmospheric phenomena. As it is typical of mountain valleys, on clear-sky days during summer and spring daily-periodic valley and slope winds occur (Rampanelli et al., 2004; Serafin and Zardi, 2010a,b; Serafin and Zardi, 2011; Rotach and Zardi, 2007). A particular feature typical for Trento is the arrival of a lake breeze blowing from a nearby valley (de Franceschi et al., 2002, 2003; Laiti et al., 2013a,b). During wintertime ground-based temperature inversions frequently occur (de Franceschi and Zardi, 2009), as a consequence of the weaker solar radiation input and the reduced sky-view factor (Grigiante et al., 2010). All the above processes may significantly affect the spatial distribution of temperature in the urban area of Trento, adding additional complexity to the reconstruction of the time series. Therefore, in order to obtain reliable information supporting the reconstruction of the historical time series, a field campaign was carried out aiming at evaluating temperature differences between the principal sites where observations were performed. Of course it is clear that temperature differences detected nowadays may be different from those occurring in the past. Nevertheless the analysis of the results of the field measurements provides important information about typical microclimatic differences between parts of the city with different degrees of