Evaluating the effects of changes in observatory position and surrounding urbanization on the historical temperature time series of the city of Trento in the Alps

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Introduction

Results from field measurements and numerical simulations are analyzed to gain information supporting the reconstruction of the temperature time series of the city of Trento in the Alps [1, 2, 3]. This project is challenging, mainly due to various relocations of the observational sites and the increasing effects of urbanization.

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.

Trento: the temperature series

The city of Trento (46°4'N, 11°7'E,) lies at 200 m MSL in the Adige Valley, in the Italian side of the Alps (Fig. 1). It has about 114 000 inhabitants. The historical time series of the city starts from the earliest available measurements in 1816 and is composed of observations performed at different sites. An overview of the observational sites composing the time series is given in Fig. 2.

Fig. 1 : Position of Trento in northern Italy.

Place	Altitude [m MSL]	Observer	Source	Years
Unknown	Unknown	Unknown	ZAMG Yearbook	1816-1832
Ex-Imperial Royal Gymnasium	200	Prof. F. Lunelli	Lunelli's manuscript and ZAMG Yearbooks	1820-1858 1864-1867
Unknown	Unknown	G. Garbari	Garbari's manuscript	1851-1871
Sericultural Institute (Laste)	330	F. Gerloni	ZAMG Yearbooks	1874-1875
Agricultural School at S. Giorgio	258	F. Gerloni	ZAMG Yearbooks	1876-1882
Casa Wolkenstein	210	A. Pernter et al.	ZAMG Yearbooks	1885-1915
Sericultural Institute (ECO)	200	Various	ZAMG Yearbooks	1898 1902-03 1908 1910-11
S. Bernardino Convent	244	Various	S. Bernardino Convent's documents	1919-1992
Laste weather station	312	Various	Autonomous Province of Trento	1920-2013

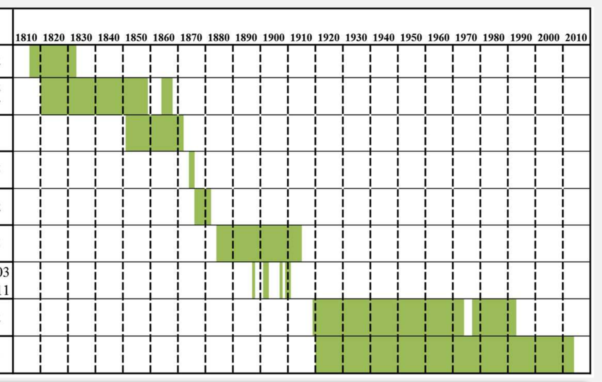

Fig. 2 : GANNT of the observations composing the temperature time series of Trento.

The city expansion

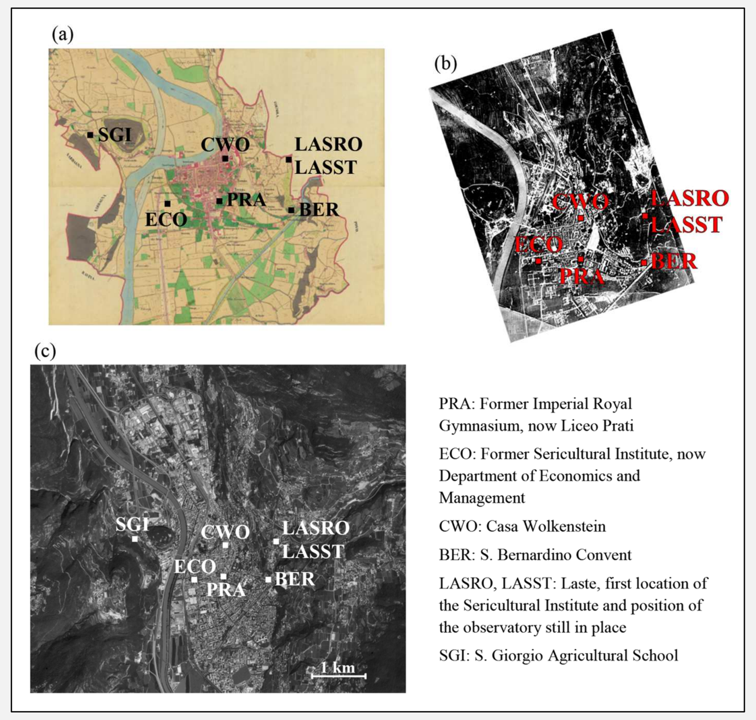

Fig. 3: The urban area of Trento in (a) mid 19th century (Austrian land register), (b) 1919, and (c) nowadays (aerial photo), along with location of historical observational sites in Trento and weather stations analyzed in this work.

The great expansion of the city from the mid-19th century to present can be appreciated in Fig. 3, showing the extension of the urban area of Trento in the mid-19th century, early 20th century and nowadays. From the mid-19th century to the early 20th century the city growth was limited to some sparse residential houses in the countryside south of the city. On the other hand great changes occurred in the last century.

Field campaign

A field campaign was carried out from August 2009 to November 2010 in the city of Trento with a twofold aim: (i) to evaluate temperature spatial variability in the urban area of Trento and (ii) to monitor systematic temperature differences between the sites where historical measurements were performed. Identical thermohygrometers (Onset Inc. Mod. HOBO H8 Pro) were placed in most of the historical observational sites in Trento (Figs. 3 and 4 and Table 1).

PLACE	HEIGHT (MSL)	λ_u	λ_p
PRA	200	~1	0.5
ECO	200	~1	0.5
BER	244	0.6	0.3-0.4
LASST	312	0.5	0.3
LASRO	312	0.5	0.3

Table 1: Height above mean sea level (MSL), urban fraction (λ_u), and building plan area fraction (λ_p) of the observational sites.

Data were divided into three weather classes for each season, based on global solar radiation measurements:

- Sunny days: $S > 2/3\, S_{max,m}$;
- Partly cloudy days: $1/3\, S_{max,m} < S \leq 2/3\, S_{max,m}$;
- Cloudy days: $S \leq 1/3\, S_{max,m}$;

where:
S: daily global solar radiation observed on each day;
$S_{max,m}$; maximum daily global solar radiation observed in that month.

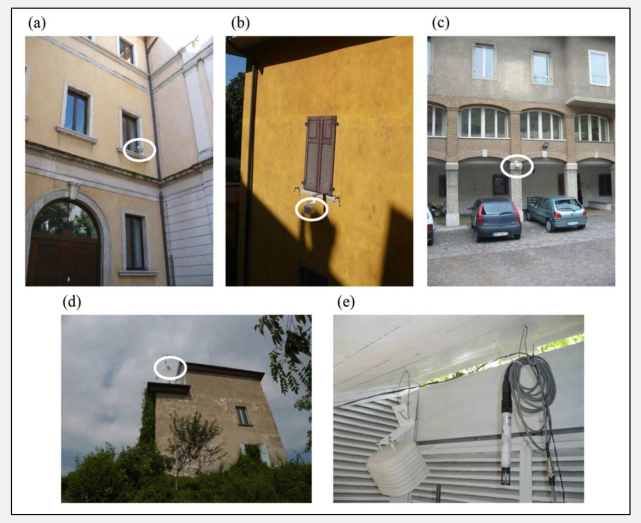

Fig. 4 : Pictures of the sensors installed during the field campaign at (a) ECO, (b) PRA, (c) BER, (d) LASRO, and (e) LASST.

Main results:

- similar temperatures at the two observational sites in the city center (PRA and ECO) and at the two sites on the slope (LASST and LASRO);
- temperature differences between the sites on the valley floor and on the slopes depend on weather conditions and season.

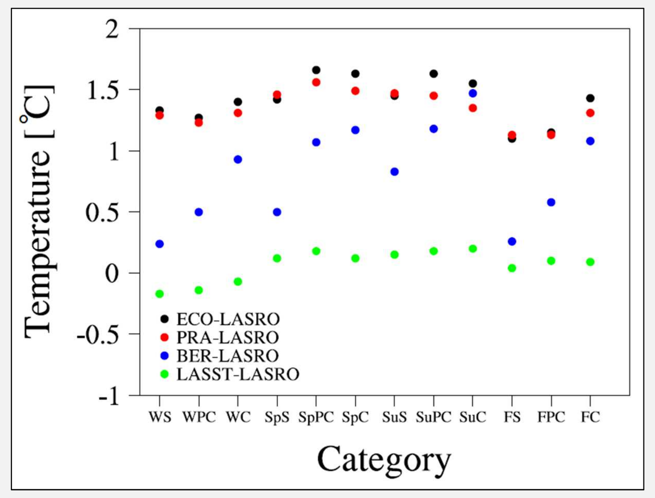

Fig: 5: Average temperature differences between the sites in the different categories: Winter Sunny (WS), Winter Partly Cloudy (WPC), Winter Cloudy (WC), Spring Sunny (SpS), Spring Partly Cloudy (SpPC), Spring Cloudy (SpC), Summer Sunny (SuS), Summer Partly Cloudy (SuPC), Summer Cloudy (SC), Fall Sunny (FS), Fall Partly Cloudy (FPC), Fall Cloudy (FC).

Numerical simulations: aims and set-up

Simulations reproducing the present situation were first validated against measurements from the field campaign to test the ability of the model to reproduce the thermal field in the urban area. Then, simulations were performed with identical initial and boundary meteorological conditions, but with historical land use and urban morphology, and no anthropogenic heat releases, to reproduce climatic conditions in Trento in the late 19th-early 20th century. The results from the "historical" simulations were analyzed with a twofold aim:

- get a clearer understanding of the effects of changes in the position of the observational sites;
- estimate the effect the of the increasing urbanization and the subsequent stronger intensity of the UHI on the time series, similarly to [5], comparing the "present" and the "historical" simulations.

One sunny day and one cloudy day for each season were simulated (Table 2).

Date	Category
15 Jan 2010	Winter Sunny (WS)
12 Jan 2010	Winter Cloudy (WC)
19 Apr 2010	Spring Sunny (SpS)
02 May 2010	Spring Cloudy (SpC)
25 Jun 2010	Summer Sunny (SuS)
03 Aug 2009	Summer Cloudy (SuC)
02 Oct 2009	Fall Sunny (FS)
16 Nov 2009	Fall Cloudy (FC)

Table 2: Simulated days.

Main model settings:

- 5 two-way nested domains with grid spacing of 40.5, 13.5, 4.5, 1.5, and 0.5 km (Fig. 6);
- 42 vertical levels, with higher resolutions near the ground (9 levels in the first 1000 m);
- Corine land cover dataset, modified for the historical land use (Fig. 7);
- BEP urban parameterization scheme, BouLac PBL scheme, Noah LSM;
- gridded datasets of anthropogenic heat (AH) flux from vehicular traffic and energy consumption and of urban morphology parameters for the present simulations (Figs. 8 and 9).

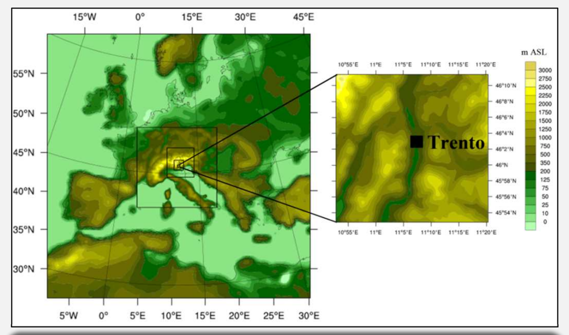

Fig. 6: The five nested domains.

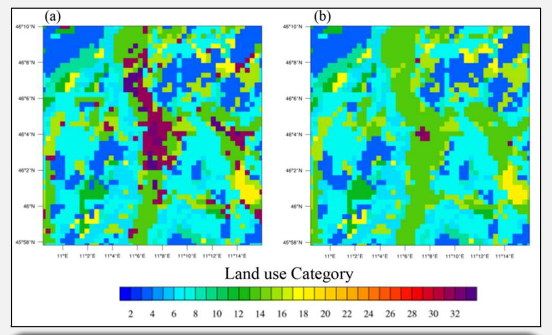

Fig 7: Land use for (a) present and (b) historical simulations.

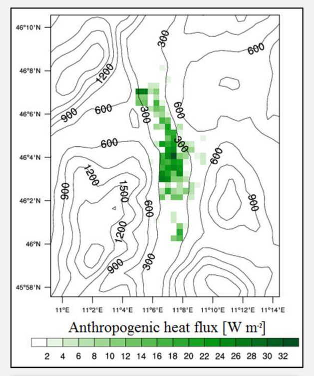

Fig 8: AH flux.

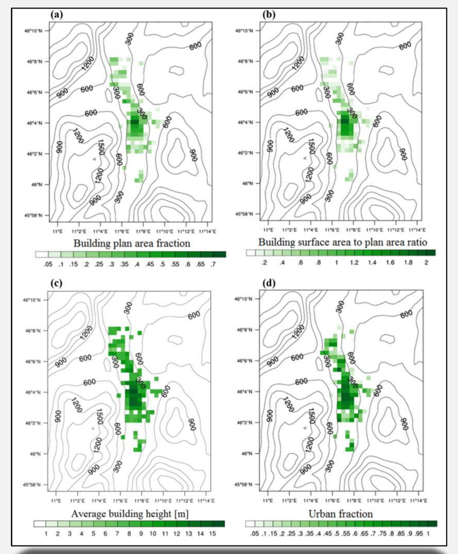

Fig 9: Urban morphology parameters used in input for the BEP scheme.

Numerical simulations: results

Validation of the present simulations:

Model results were validated against the measurements performed in the field campaign:

- good representation of the diurnal cycle of temperature in the urban area (Fig. 10);
- the main features of the temperature differences between the observational sites are well simulated. However the variability connected with seasonality and weather conditions is not captured (Fig. 11);
- the different behavior of the UHI intensity between sunny and cloudy days is captured. However the development of an urban cool island during daytime in sunny days is not seen by the model. Moreover the UHI is overestimated in winter (Fig. 12).

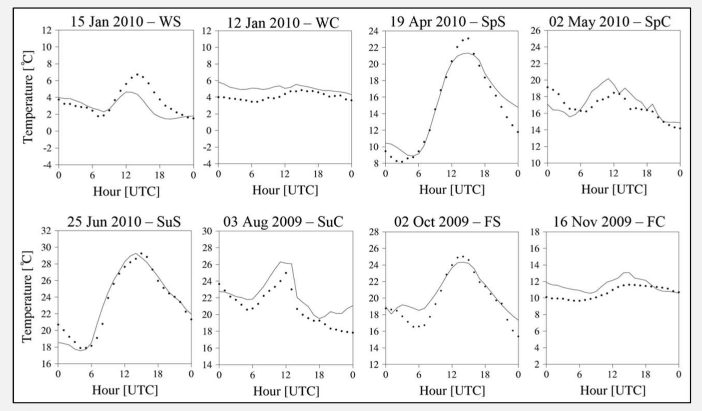

Fig 10: Diurnal cycles of temperature as observed (dots) and simulated by the present simulations (solid line) at PRA in the 8 days analyzed.

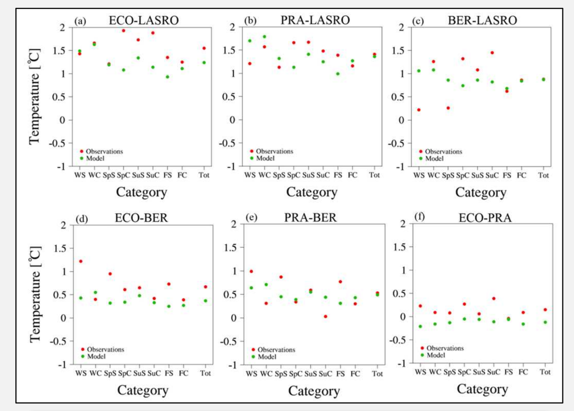

Fig 11: Average temperature differences between the observational sites observed and simulated by the present simulations.

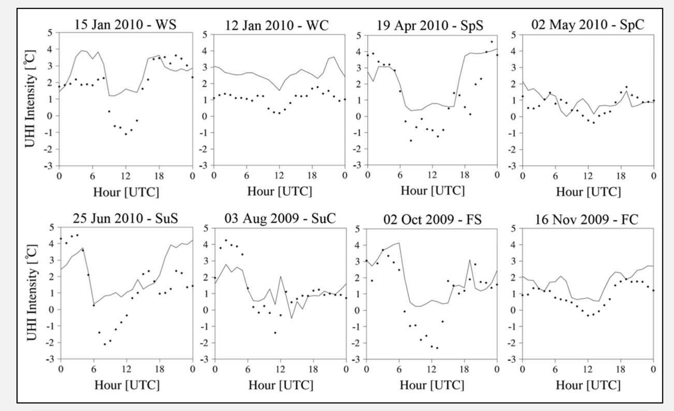

Fig 12: Diurnal cycles of UHI intensity, as observed (dots) and simulated by the present simulations (solid line) in the 8 days analyzed.

Historical simulations:

The average temperature differences between the sites more embedded in the urban area are not significantly different from the present runs, probably because urbanization grew similarly around them in the last century. On the other hand the temperature contrasts between LASRO, on the eastern slope, and the other sites were larger in the past, as the surroundings of this weather station have changed more (Fig. 13). Changes in urbanization effects at the two sites, LASRO and BER, where measurements were continuously performed in the last century, were estimated by comparing the results of present and historical simulations. Significant differences were found at both sites, but were larger at LASRO, where major urbanization changes occurred in the last century (Fig. 14). Differences between the two simulations are larger during sunny days and at night, when urbanization effects are stronger. Temperature differences follow the boundaries of the present urban land use. Smaller values occur only in the area close to the city center, where the urban land use was prescribed also in the historical runs, whereas during daytime the temperature differences between the two simulations become considerably smaller over the whole urban area (Fig. 15).

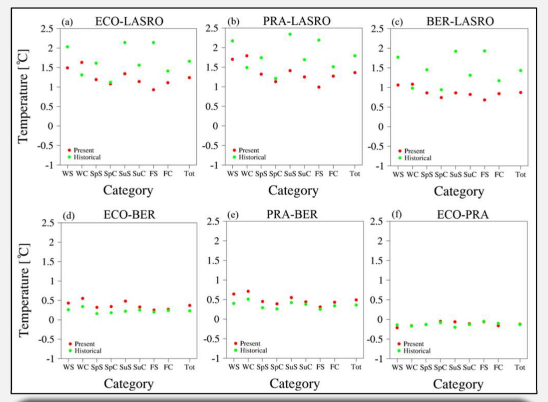

Fig 13: Average temperature differences between the observational sites simulated by the present and historical simulations.

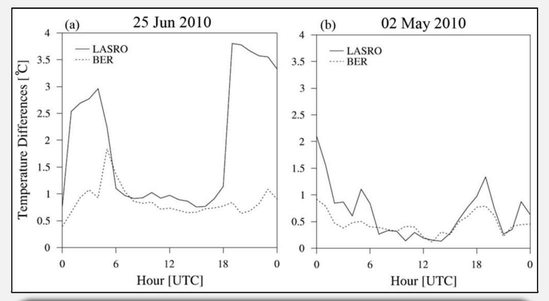

Fig 14: Diurnal cycles of the temperature differences between the present and historical simulations at BER and LASRO

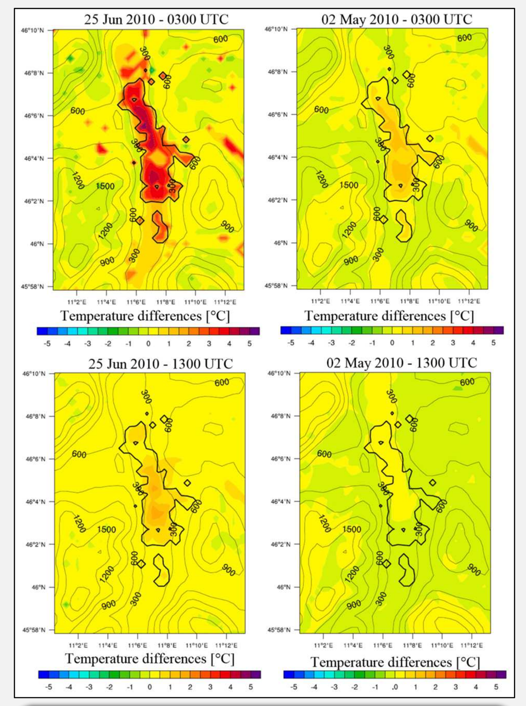

Fig 15: Temperature differences at 2 m AGL between the present and historical simulations.

Conclusions

Field campaign:

- No temperature differences between the two sensors in the city center.
- Temperature contrasts between the sensors on the valley floor and on the slope depend on weather conditions and season.

Numerical simulations:

- Rather good simulation of the thermal field in Trento.
- Temperature differences between the sites more embedded in the urban area are not significantly different between present and historical runs.
- Temperature contrasts between LASRO, on the slope, and the other sites were larger in the past, as the surroundings of this weather station have changed more.
- Significant differences between present and historical runs were found at the two sites, LASRO and BER, where measurements were continuously performed in the last century, but were larger at LASRO, where major urbanization changes occurred.

References

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