Preliminary activity with COSMO-1 over Torino including TERRA-URB parameterisation

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1 Introduction

The modeling of urban environment has gained much attention in the last years; in fact, multiple parameterisations for the land use type have been developed. The bulk schemes take into account the overall radiative, thermal, turbulent-transfer properties, and water-storage capacity of the urban canopy with a set of bulk parameters. These model parameters are estimated from model sensitivity experiments. The bulk schemes are suitable for capturing the general characteristics of the urban climate in regional climate modeling in an efficient way. However, they do not explicitly resolve the complex processes depending on the local characteristics of the urban canopy, which further modulate the urban climate. The explicit canyon schemes explicitly capture the complex physical processes depending on the local characteristics of the urban canopy, which further modulate the urban climate. Yet, the applicability of these explicit-canyon schemes for atmospheric modeling is sometimes limited by either the lack of detailed urban canopy information, computational cost and their model complexity.

In COSMO model, cities are represented by natural land surfaces with an increased surface roughness length and a reduced vegetation cover (modification of soil and vegetation parameters of the TERRA model). However, in this representation, urban areas are still treated as water-permeable soil with aerodynamic, radiative and thermal parameters similar to the surrounding natural land. Therefore, this basic representation could not reliably capture the urban physics and associated urban-climatic effects including urban heat islands. For this reason, further developments of the parameterisation of the urban land have been carried out. In particular, the TERRA-URB bulk parameterisation scheme with a prescribed anthropogenic heat flux has been used in this work (see [1] and [2] for details). The simple bulk-model TERRA-URB includes the effects of buildings on the air flow without resolving the energy budgets of the buildings themselves, but using the externally calculated anthropogenic heat flux. This approach allows representing effects of multiple cities on the atmosphere without requiring additional data on the building structure. The use of the previously estimated anthropogenic heat flux, modified thermal and radiative parameters and a modified surface-layer transfer scheme, provides the urban heat island with the correct diurnal phase. The magnitude of this flux can potentially be revised to fit the mean measured signal. TERRA-URB uses a pre-calculated anthropogenic heat flux (Q_F), which accounts for country-specific data of energy consumption, calculated on the base of the population density and the latitude dependent diurnal and seasonal distribution. Due to this simple representation of the urban land as a bulk, TERRA-URB is computationally inexpensive. The latest version of TERRA-URB implements the Semi-empirical Urban canopy parameterization (SURY). It translates urban-canopy parameters (containing 3D information) into bulk parameters. TERRA-URB takes additional surface parameter input fields: ISA (Impervious Surface Area) and AHF (Annual-mean anthropogenic Heat Flux), generated with EXTPAR via the WebPEP interface. By default, TERRA-URB takes fixed values for the urban canopy parameters: variation of urban-canopy parameters is optional.

2 Test case and model setup

In the period 1-16 July 2015, Piemonte region and Torino in particular experienced extreme temperature values and uncomfortable conditions for the population. In particular July 2015 has been the hottest July since 1958 (Fig. 1). For more information regarding the climatological analysis and the methodology, see [4] (in Italian). It comes out that July 2015 is ranked first in all the measurements. In Torino, the maximum temperature reached 38.5°C during that period and ground stations data pointed out the presence of a clear UHI effect. This is the reason why this area and this period represent a suitable benchmark to test the capabilities of COSMO, and in particular of the urban parameterization. The analysis follows the study published in the COSMO Newsletter 16 ([3]) so the same stations have been considered: Torino Consolata (urban), Torino Giardini Reali (urban park) and Moncalieri Bauducchi (rural) (see Fig. 2 and Tab. 1).

The model setup is the following:

- COSMO resolution: 0.009° (about 1 km);

name	lat	lon
Moncalieri/Bauducchi (rural)	44.961111°	7.709227°
Giardini Reali (urban park)	45.073699°	7.688576°
Consolata (urban)	45.076667°	7.679444°

Table 1: List of stations used.

	AHF (W/m^2)	ISA	URBAN	H (m)	Soil Type
Bauducchi	3	0.061	0	225	6
Consolata	23.6	0.91	1	232	6
Giardini Reali	15.3	0.825	1	230	6

Table 2: Values of some variable in the selected points.

- computational domain: 100 x 100 points, 60 vertical levels, time step 3 s (see Fig. 3);
- time period: from 1 to 7 July 2015;
- forcing data: IFS analysis (resolution of 0.075°).

The simulations have been performed according to the following prospect:

- NON-URB: simulation with TERRA-URB off;
- URB: simulation with TERRA-URB on.

The maps of few important parameters are shown in Fig. 4 and the single values correspondent to the single point are listed in the Tab. 2. The model considers Moncalieri Bauducchi a rural station and the other two urban stations (correctly).

3 Results

The time series of observed T2m in the three stations are plotted in Fig. 5 with the model output (URB and NON-URB). A general overview confirms that in Consolata the daily maxima are slightly overestimated by URB, while the minima are better than the operational (NON-URB). In Giardini Reali the maxima are nicely simulated by URB while the minima are overestimated (NON-URB is better). As expected there are no significant differences between URB and NON-URB simulations in rural areas, that is both underestimate the maxima and overestimate the minima.

Tab. 3 shows the average observed T2m value and the average bias (model minus observation) related to the basic simulations. URB allows a reduction of the average bias compared with NON-URB in Consolata and in Moncalieri, while in Giardini Reali the trend is opposite.

In Fig. 6 the soil surface temperature time series are shown. While there is basically no change in rural areas (Moncalieri), there is a large modification in the city with a general increase, especially in the maxima values.

	Obs	Bias Urb	Bias Non-urb
Consolata	29.4	0.68	-1.22
Moncalieri	28.2	-0.55	-0.74
Giardini Reali	28.7	1.37	-0.59

Table 3: Mean observed T2m values and mean model bias.

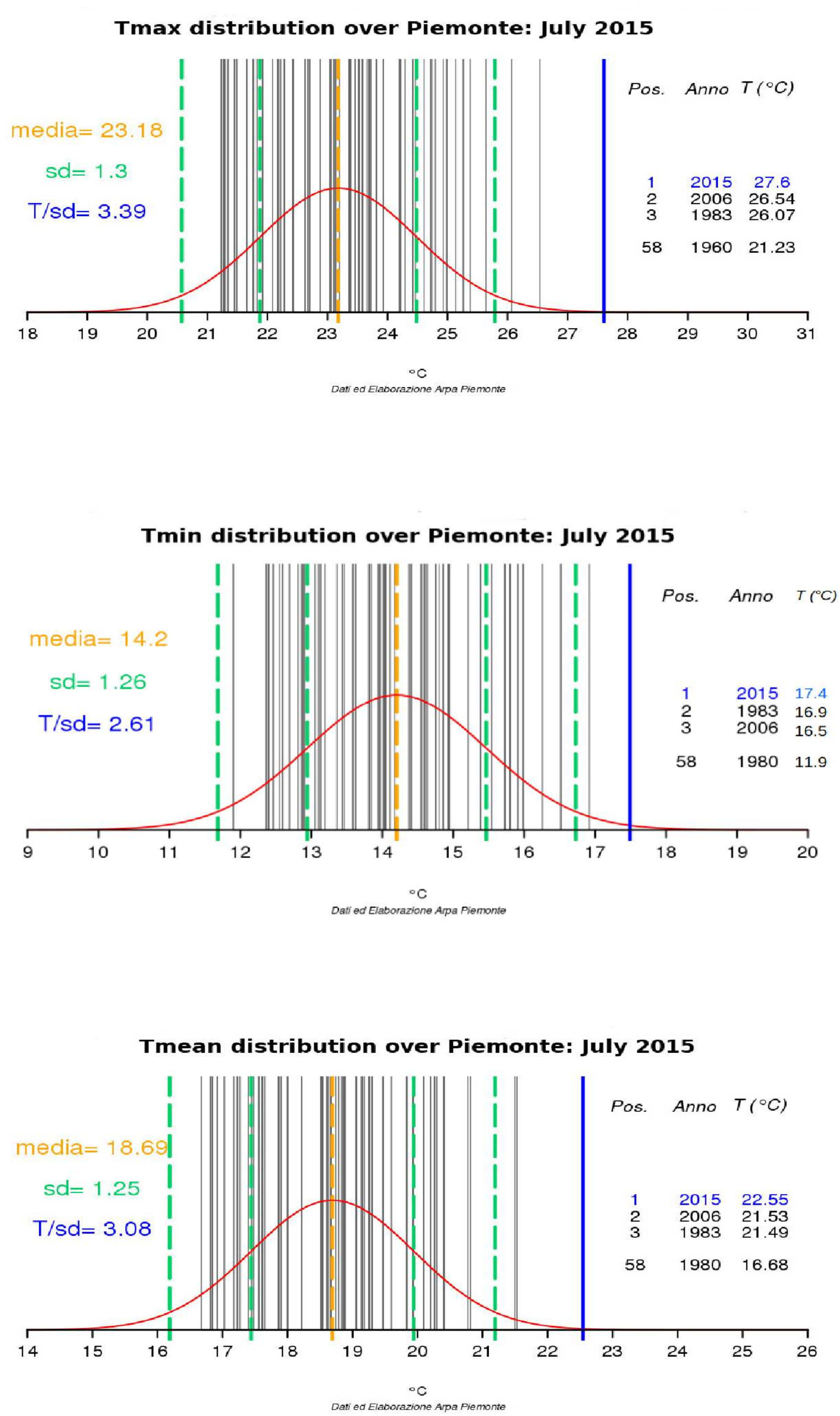

Figure 1: Distribution of T2m max (top), min (middle) and mean (bottom) in July 2015 over Piemonte.

Figure 2: Location of the three observation stations considered in the Torino area (1, 2 and 9).

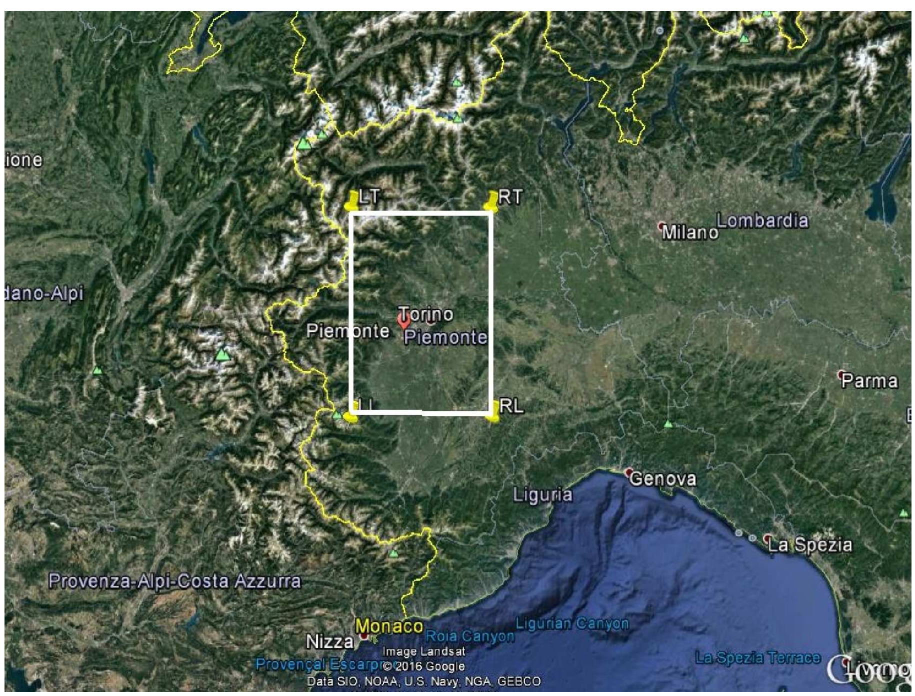

Figure 3: The computational domain.

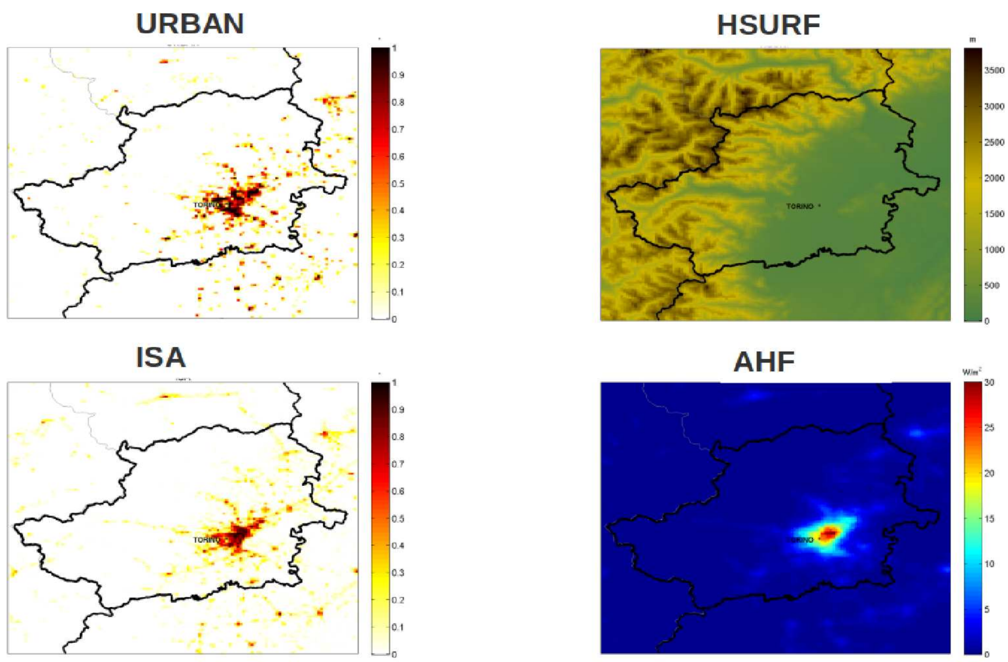

Figure 4: Distribution of the additional parameters over the area.

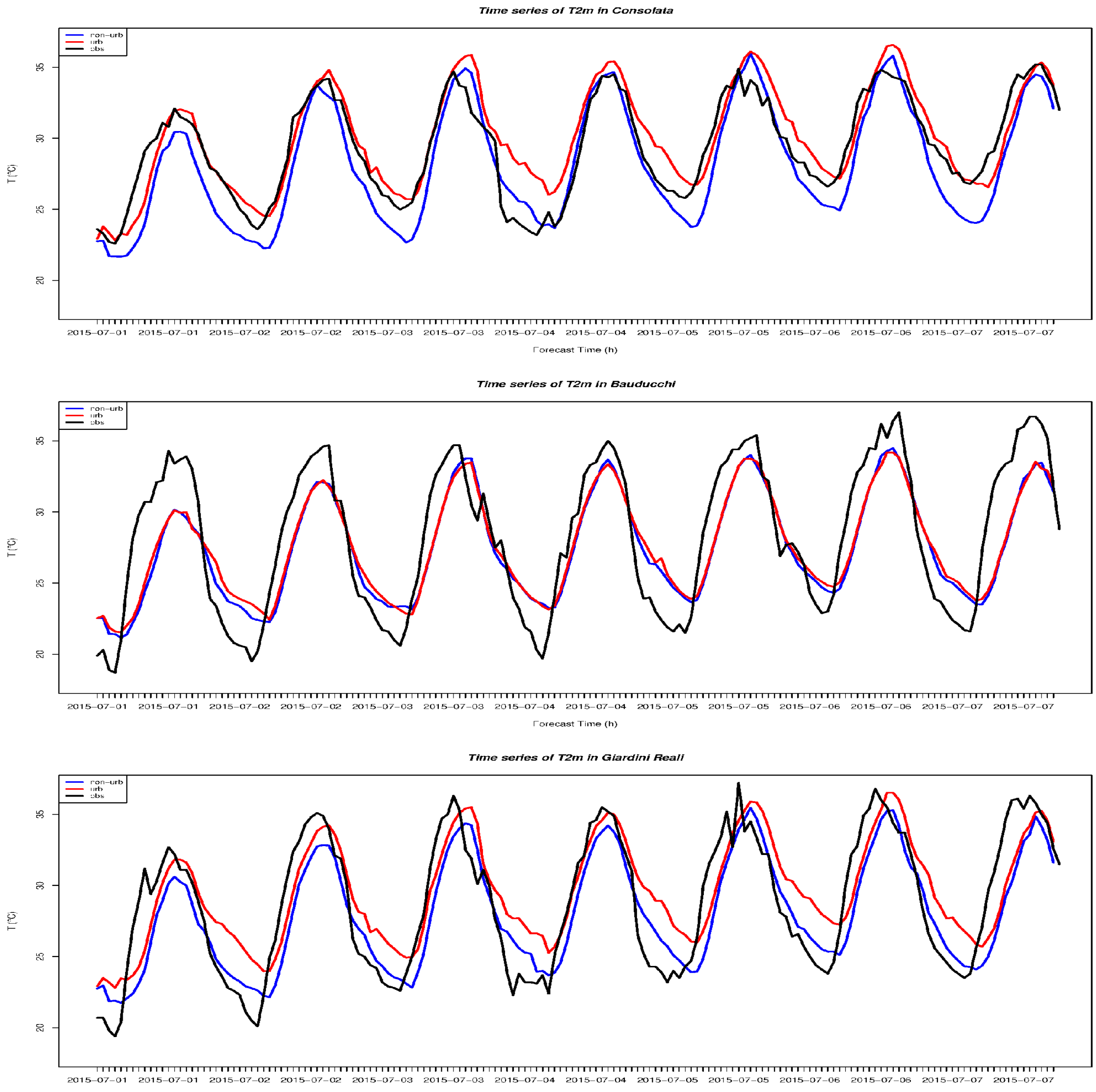

Figure 5: Time series T2m for Consolata station (urban cell, top), Moncalieri Bauducchi (rural, middle) and Torino Giardini Reali (urban, bottom) with the different simulations and observed data.

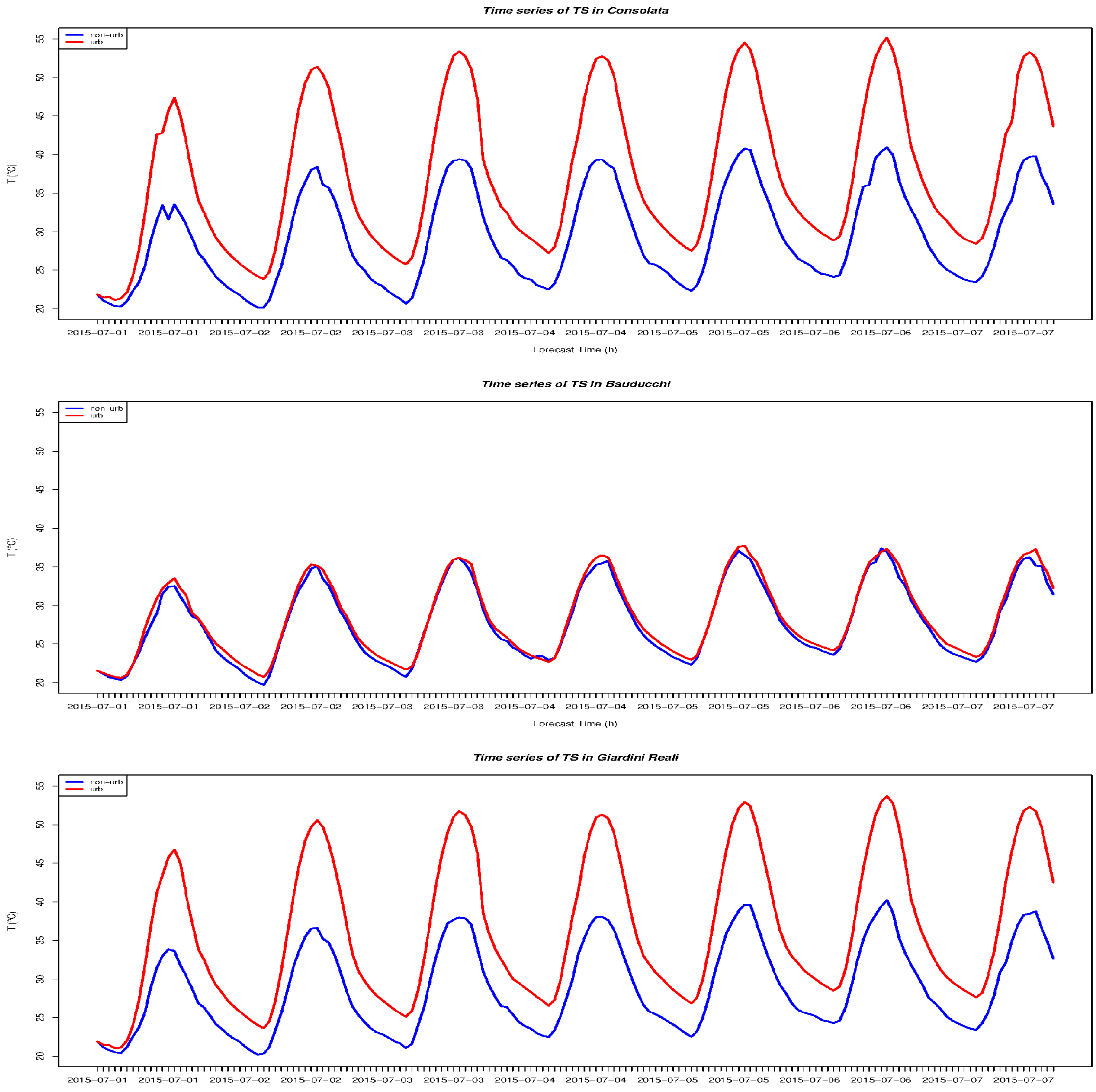

Figure 6: Time series of T_S (soil surface T) for Consolata station (top), and Moncalieri (middle) and Giardini Reali (bottom) with the different simulations.

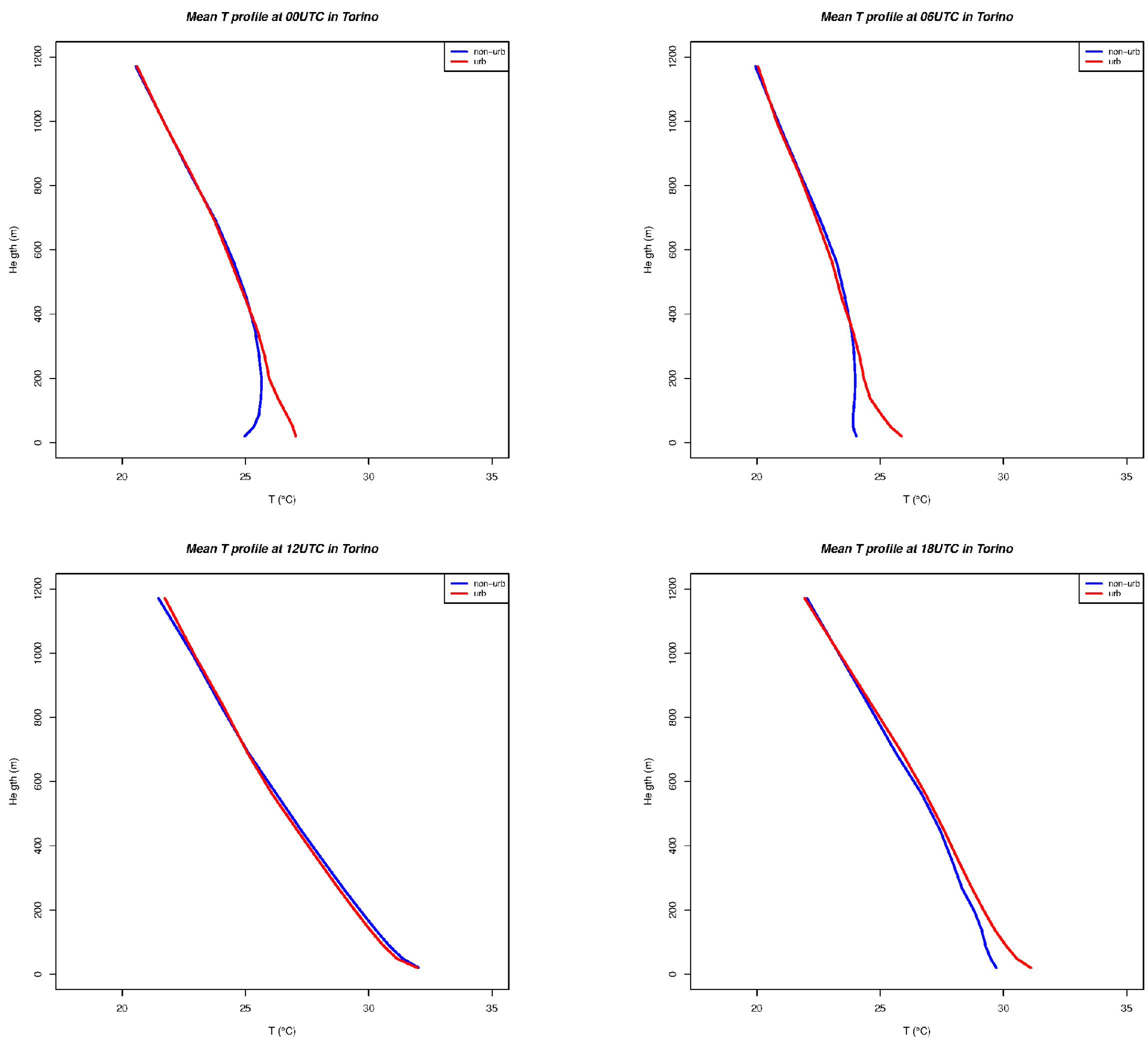

Figure 7: Mean vertical profile of T over Torino Consolata at different hours.

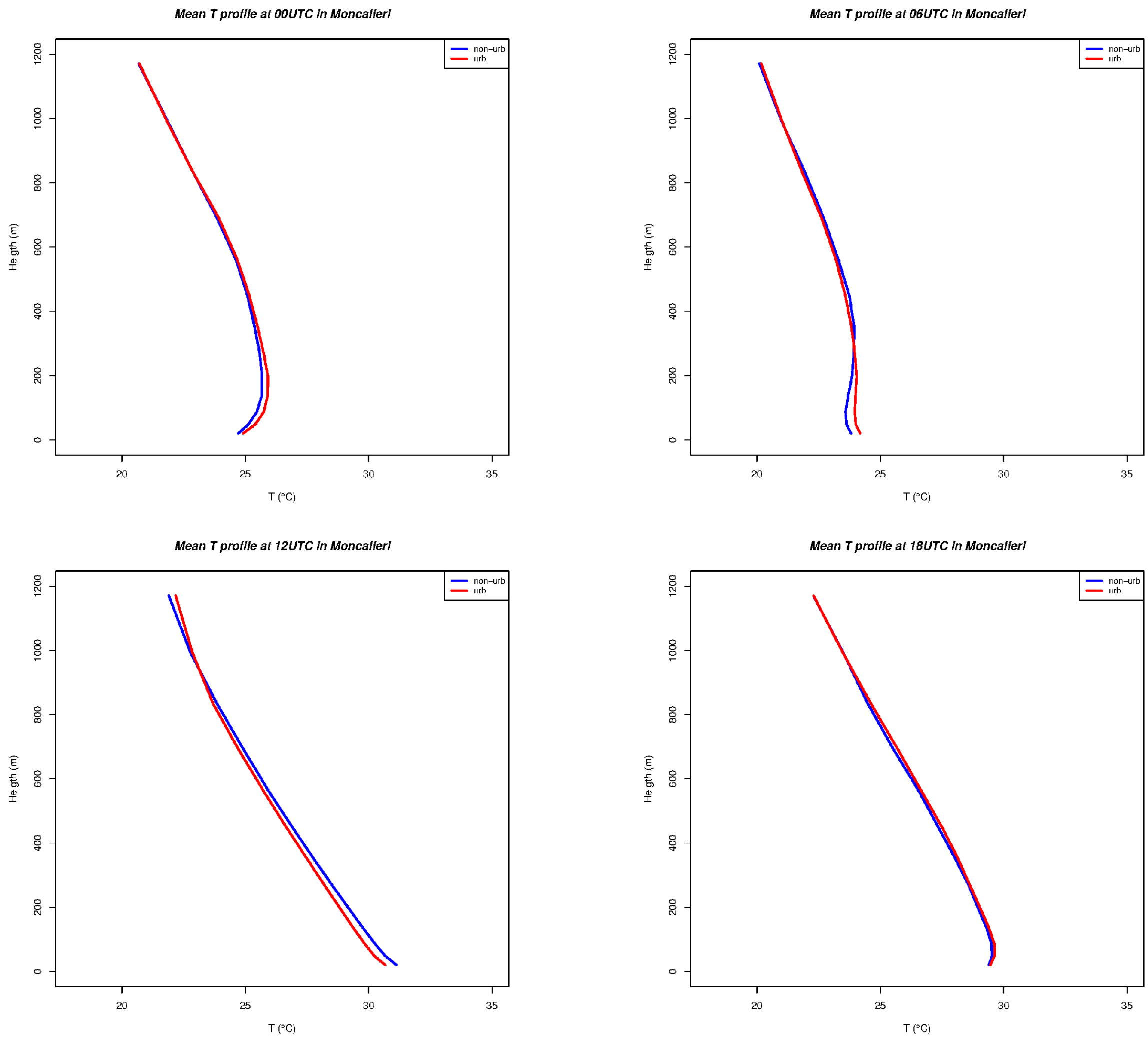

Figure 8: Mean vertical profile of T over Moncalieri Bauducchi at different hours.

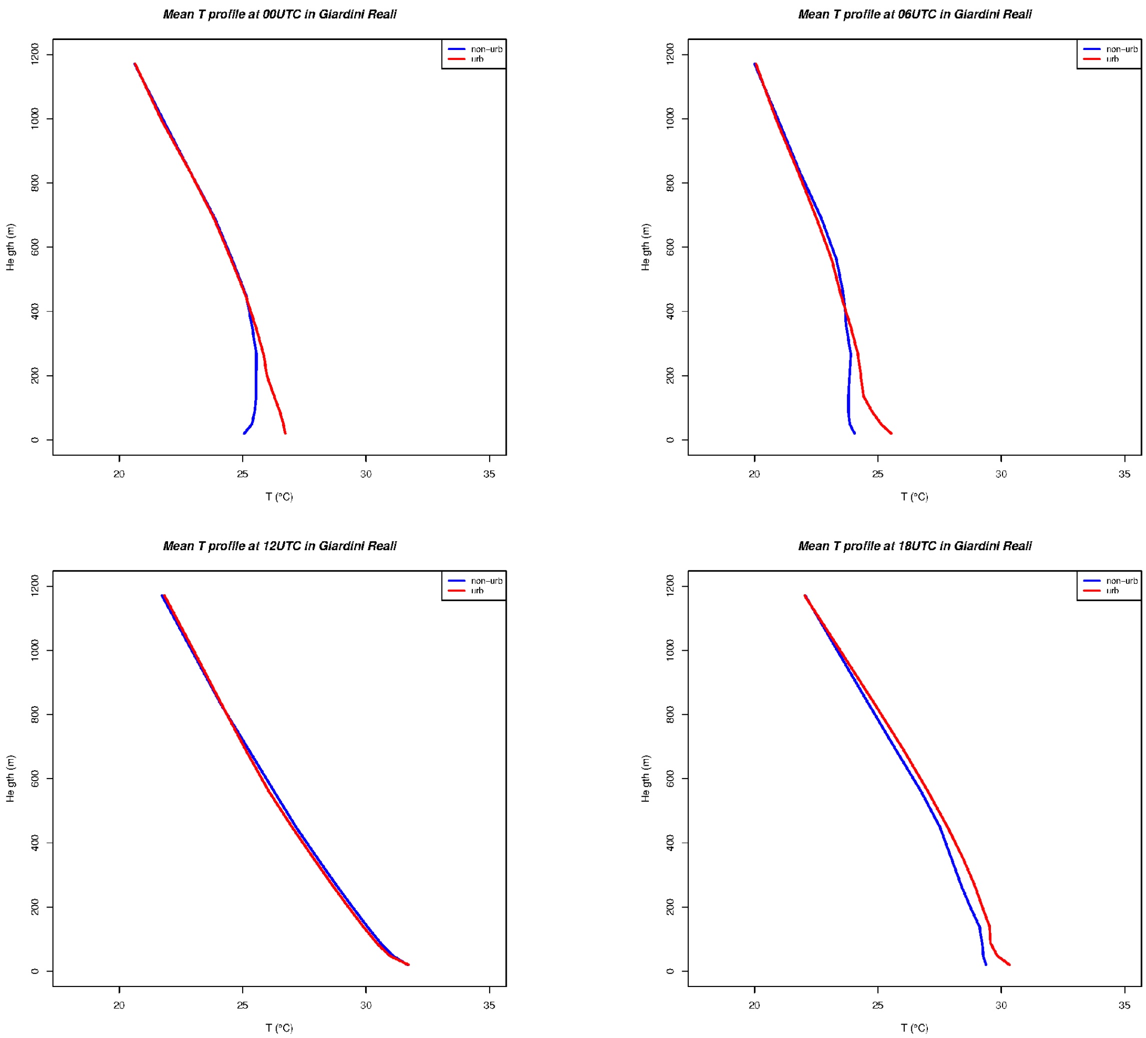

Figure 9: Mean vertical profile of T over Torino Giardini Reali at different hours.

The simulated vertical profiles of T are shown in Figs. 7-9. In Torino Consolata the difference between URB and NON-URB is limited to the lowest layers where URB has in general higher temperatures (except at 12UTC where the profiles are equivalent). Above 300-400 m the profiles collapse to a single curve. In Moncalieri (rural area) the differences are quite small as it could be expected. Torino Giardini Reali is quite similar to Consolata.

4 Summary and outlook

A set of simulations have been performed with COSMO over Torino area at very high resolutions (about 1 km), considering the period 1-7 July 2015. The bulk model TERRA-URB parameterizes the effects of buildings on the air flow using the externally calculated anthropogenic heat flux. The effects of the introduction of this urban parameterization on the quality of results have been quantified. TERRA-URB allows a better representation of the daily minimum temperature. This is a remarkable results, since it is the minimum temperature that determines the UHI (mainly). However, considerable work is still needed, especially for what concerns the optimization of the model configuration. This work has been performed with a private version of COSMO, modified with TERRA-URB, but once the scheme will be included in the official COSMO release (v5.6), a more structured project will start.

Hendrik Wouters (KU Leuven, Belgium) and Uli Blahak (DWD) are gratefully acknowledged for providing the COSMO/TERRA-URB software package and for the technical and scientific hints.

We would like to thank the Italian National Department of Civil Protection for the support given to this project.

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[3] Milelli, M., 2016: Urban heat island effects over Torino. *COSMO Newsletter*, 16, **1-10**.

[4] http://www.arpa.piemonte.gov.it/rischinaturali/tematismi/clima/confronti-storici/dati/dati.html