DOCTORAL SCHOOL IN ENVIRONMENTAL ENGINEERING

XXIV CYCLE

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Urban scale phenomena and boundary layer processes in mountain valleys

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Abstract

The urban climate of the city of Trento, adopted as a representative case study of urban weather and climate phenomena in a mid-sized city lying in a mountain valley, is investigated using different methods and on different spatial scales.
First the intensity of the Urban Heat Island (UHI) is analyzed evaluating the differences ΔT_{u-r} between air temperatures measured at an urban automated weather station on a tower, over mean rooftop level (T_u), and at five suburban/rural weather stations (T_r), located few kilometers around the city boundaries. It is found that the extra-urban weather stations, being affected by different local-scale climatic conditions, display different temperature contrasts compared to the urban site. However the diurnal cycle of the UHI is characterized by similar behaviors at all the extra-urban weather stations: the UHI intensity is stronger at night, while during the central hours of the day an "urban cool island" is likely to occur. The diurnal maximum UHI intensity turns out to be typically of order 3°C, but under particularly favorable conditions it may be higher than 6°C. Wind speed and cloud cover are the weather factors which most affect UHI intensity, making it weaker with stronger winds and cloudier skies.
The investigation of the urban climate of Trento focuses then on a smaller spatial scale, analyzing in detail the thermal field inside an urban canyon located in the city center, by means of two experimental campaigns and the use of a simple model. This simple model simulates the energy balance of the different surfaces composing the urban canyon, calculating both surface and air temperatures inside the canopy. During the two field measurements, carried out in the summer 2007 and in the winter 2008-2009, temperature sensors were placed at various levels near the walls flanking the canyon and on a traffic light in the center of the street. It is found that the air temperature near the walls, both in summer and in winter, is strongly influenced by direct solar radiation, thus inducing a quite strong imbalance within the canyon: during sunny days an overheating of the east-facing sensors is found in the morning, while in the afternoon west-facing sensors are the warmest. On the other hand, when solar radiation is weak or absent, the temperature field inside the canyon is homogeneous. Moreover air temperature inside the canyon is generally higher than above roof level, the differences being larger during summertime, when solar radiation is stronger and can penetrate for longer inside the street. The measurements performed during the field campaigns, along with observations of wall surface temperatures taken from the literature, allow to validate the results of the urban canyon model. A good agreement between experimental measurements and

numerical results is found for both surface and air temperatures, in different seasons and under different weather conditions.
The urban area of Trento, being located in the Alpine Adige Valley, interacts with the atmospheric phenomena typical of these contexts, in particular thermally driven local circulation systems. Moreover the city is located at a point where various narrow tributary valleys or gullies join the Adige Valley, and, as a consequence, complex interactions of local circulation systems are present in the area of Trento. In order to study these phenomena, first the main features of local circulation systems developing in the Adige, Sarca and Lakes valleys, which directly influence the climate of the city, are investigated by means of the analysis of a dataset from surface weather stations covering the period 2004-2011. After that, high-resolution (500 m) numerical simulations with the mesoscale meteorological WRF model, coupled with the multi-layer Building Environment Parameterization (BEP) scheme, are utilized to study the urban climate of Trento in the Adige Valley context. Suitable datasets of land use, urban morphology and anthropogenic heat flux have been specifically prepared for these numerical simulations.
Both methods highlight the substantial differences occurring between the local circulation system developing in the Adige Valley, and that blowing in the Sarca and Lakes valleys. The former is a typical valley wind, while the latter is a combination of a lake breeze and a valley wind. The along-valley wind developing in the Adige Valley is mainly determined by the local geometry of the valley, which controls the penetration of solar radiation and the heating of the valley slopes. The lake breeze, the so-called Ora del Garda, starts to blow from the shores of Lake Garda in the morning and then propagates with its cooler air towards north in the Sarca and Lakes valleys, outbreaking into the Adige Valley north of Trento in the first part of the afternoon. In some days the lake breeze is even able to reach the central part of the urban area of Trento, thus lowering the temperature in the city in hot summer afternoons.
Focusing on the urban effects, the model is able to simulate correctly the daily cycle of the UHI, with high intensities during the night and negligible values in the central part of the day. Numerical results suggest that at night the temperature sharply increases at the city boundaries, while the thermal field is quite homogeneous inside the urban area, with only slightly higher temperatures where the urban morphology is more compact. Finally it is found that the presence of the city influences considerably also the wind field, due to the high roughness of the urban area.