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Investigation of surface-layer parameterizations on the basis of the UTP experimental campaign in Turin city

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The study of the characteristics of the flow and turbulence in urban canopy, and of its connected dispersive conditions, is of increasing interest. The flow and turbulence structure of the Atmospheric Boundary Layer (ABL) above urban areas is significantly perturbed by the density and distribution of buildings and other obstacles, by the thermal effect of the so-called “urban heat island”, by the possible presence of topographical inhomogeneities. The overall interaction of the atmospheric flow with an urban canopy complicates the structure of the atmosphere near the surface, that is very sensible to the turbulent energy exchanges. The situation becomes even more complicated in case of calm conditions or low-wind regime, as for wind speed lower than 1.5 m/s, when, in general, it is not possible to define a precise mean wind direction. The surface layer in urban areas can be divided in two sub-layers, the roughness layer (RL), wherein the flow and turbulence are influenced by individual roughness elements, and the inertial layer (IL), which is the remaining part of the surface layer above the RL, where the influence of the individual roughness element is mixed up by turbulence. While in the IL it is expected that the Monin-Obukhov Similarity Theory applies, in general it does not hold in the RL.

The aim of this work is to thoroughly investigate the peculiarities of the surface layer flow and turbulence in a complex urban fabric and a frequent low-wind regime, which are the characteristic conditions in the city of Turin (North-West Italy). We refer to an observational campaign (Urban Turbulence Project, UTP) performed at one site in Turin, where a meteorological station is placed. It is equipped with a meteorological mast 25 m high where sonic anemometers were installed at three different levels, to obtain vertical profiles of the wind and temperature inside the ABL. Close to the mast, a station measuring solar radiation, humidity and temperature at ground level was also active. The availability of the observations at different levels allows investigating the vertical structure of the surface layer in the urban canopy and supports the evaluation of the limits in the applicability of the classical Monin-Obukhov similarity theory.

To interpret the peculiarities of the flow and turbulence in the conditions under consideration, a thorough analysis of the mean flow and of the surface layer and turbulence parameters, as functions of the wind regime and of the stability, is presented. Various formulations and parameterizations proposed in the literature for the analysed quantities have been evaluated and verified on the observed dataset and the results are compared to other studies. This study can represent the basis to possibly develop alternative surface-layer formulations to better account for the effects of low-wind conditions and of the urban canopy.