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Some characteristics of the wind flow in the lower Urban Boundary Layer

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Abstract

The characteristics of the wind flow at low levels in the urban environment (Roughness Sublayer (RS)) are quite different from, and to some extent independent of the characteristics of the flow in the upper part of the Urban Boundary Layer. In the RS, in fact, the flow is influenced more by the local geometry, than by a homogeneous energy transfer between horizontal layers. In this paper, the results of wind tunnel flow measurements in and above a regular urban geometry pattern, with street canyons parallel and orthogonal to the oncoming wind, are reported. The statistics and the spectral characteristics of the flow in the RS are discussed. The influence of the oncoming turbulence on the RS flow is analysed, and the differences between the flow in transversal and longitudinal street canyons are evidenced.

Keywords: Wind fields; Urban Boundary Layer; Roughness Sublayer; Canopy Layer; Street canyons; Wind tunnel testing; Wind statistics; Wind spectra

1. The Urban Boundary Layer (UBL)

The characteristics of the wind flow in the urban environment are known to be quite different from those of a Turbulent Boundary Layer (TBL) naturally developed over a homogeneous rough surface. The boundary layer over a city centre is made of an External Layer (EL), in which the characteristics of the flow are not influenced by the change in roughness occurring in the city, and an UBL, in which the characteristics of the flow are

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associated with the large scale, inhomogeneous roughness which characterises the city centre, and in which the hypotheses of the Monin-Obukhov Similarity (MOS) (Venkatram, 1980) theory is not met (Fig. 1). The lower portion of the UBL is termed Internal Layer or Surface Layer (SL), which extends up to an elevation of approximately 10% the total depth of the boundary layer. In the SL the flow is strongly affected by the local geometry, i.e. the one-point characteristics of the flow can be quite different from their spatially averaged values. The SL can be further separated into a Inertial Sublayer (IS) and a Roughness Sublayer (RS), with the separation ranging between an elevation of twice to five times the average height of the buildings (the lower bound being the most common value in the literature). This is also the elevation where the Reynolds stresses take their maximum values. The characteristics of the flow in the RS is strongly dependant on the building arrangement, and relevant parameters are the uniformity of the building height and the building aspect ratio (ratio of the average building height to the average street width, H/W). Depending on the latter parameter, three different types of behaviour can be found; isolated roughness flow ($H/W<0.3$), for which the aerodynamics of the isolated building dominates; wake interference flow ($0.3<H/W<0.65$), for which aerodynamic interference between the buildings takes place; and skimming flow ($H/W>0.65$), which is the case of densely distributed, medium- to high-rise buildings. In the latter case, that of densely built city centres, a well defined average canopy height h_{mean} can be found, which separates the SL into an upper part and a lower part, termed Canopy Layer (CL). In the case of a skimming flow, a displacement height d_{u} is found, which is the elevation at which the mean wind speed profile tends to zero. The value of d_{u} is considered to be in the range of 2/3 h_{mean} to 3/4 h_{mean}, even though larger values of 0.92 h_{mean} have been found from full-scale measurements.

Experimental studies of the turbulent and heat fluxes in the UBL are available in the literature, aimed at the characterisation of the urban climate. Feigenwinter and co-workers

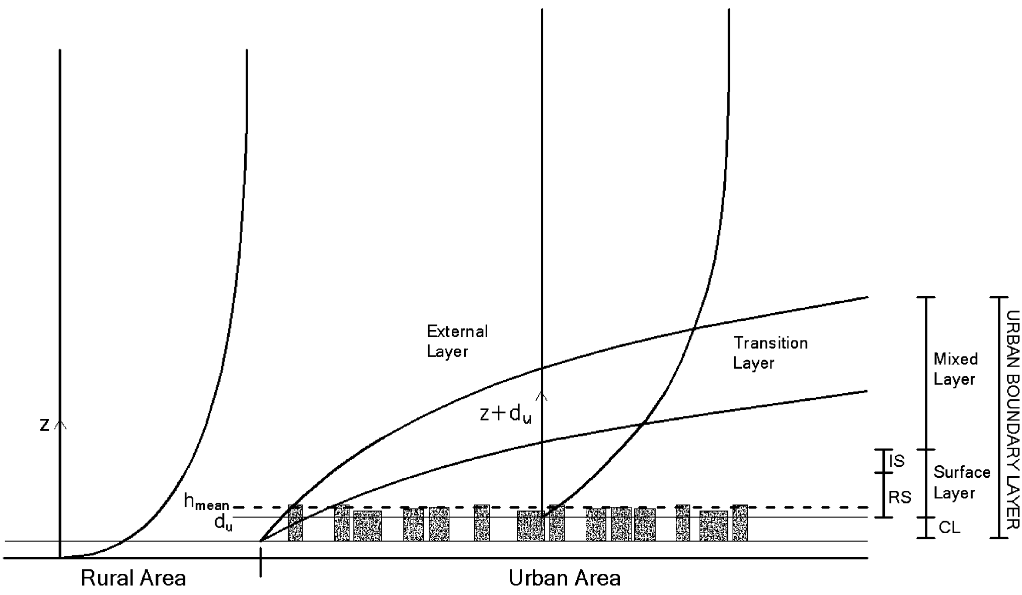

Fig. 1. Wind flow layers in the Urban Boundary Layer.