Introduction and validation of a simplistic method to represent vehicle-induced turbulence in high-resolution large-eddy simulations

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Vehicle-induced effects (VIE) and exhaust fumes interacting with turbulent flow has become known to be a critical factor when investigating the wind flow and the transport of pollutants in urban street canyons. Up to now, mainly the Reynolds-Averaged-Navier-Stokes (RANS) technique has been applied for CFD studies of the processes within urban street canyons; research studies using turbulence-resolving Large-Eddy Simulations (LES), however, were rather rare. As LES models explicitly resolve the dominant turbulent motions, whose knowledge is needed to fully understand the processes, the incorporation of moving objects into a turbulence-resolving model is essential for the accurate simulation of pollutant dispersion in urban environments. In this paper we outline our effort to account for VIE in the LES model PALM. For this purpose, an innovative and easy to implement method was realised to represent a common car shape within the environmental LES setup: the so-called \textit{air-block method}. Its concept is based on an object (representing the vehicle) in which a fixed velocity is prescribed to the objects grid volumes that equals the driving speed of the vehicle. Control of its movement, however, is achieved via a Lagrangian particle located at its center of gravity. This approach is significantly different from conventional consideration of solid objects as obstacles, since the air-block representation assumes that frictional drag is much smaller (and can thus be neglected) than form drag. By the same token the implementation is much easier to achieve in a complex LES model such as PALM.

In this talk we will outline the newly-developed simplistic method to represent driving vehicles in an LES model and show its performance based on a validation study for the turbulent wake flow and dispersion of exhaust fumes. For this purpose we employ existing wind tunnel data and comparative PALM simulations using the conventional solid-obstacle approach (Carpentieri et al. 2012, Atmospheric Environment, 62:9-25, DOI:10.1016/j.atmosenv.2012.08.019; Kastner-Klein et al. 2001, J. Wind Eng Ind Aerodyn, 89:849-861, DOI:10.1016/S0167-6105(01)0074-5).