Urban Climate 23 (2018) 114–130

Contents lists available at ScienceDirect

Urban Climate

journal homepage: http://www.elsevier.com/locate/uclim

High resolution unsteady RANS simulation of wind, thermal effects and pollution dispersion for studying urban renewal scenarios in a neighborhood of Toulouse

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ARTICLE INFO

Article history:
Received 30 May 2016
Received in revised form 26 October 2016
Accepted 5 November 2016

Keywords:
Urban pollution
Numerical simulation

ABSTRACT

Detailed, high resolution, unsteady RANS simulations are used to study short episodes of local pollution dispersion in the neighborhood of Bordelongue in Toulouse in the framework of the French ANR project EUREQUA (Haoues-Jouve et al. 2015). These urban areas consist of various types of buildings and obstacles: small houses, tower blocks, highway, local streets, vegetation areas, etc. The 3D geometry of this urban area was constructed with an in house tool developed around the open-source geometry and mesh generator *SALOME*, based on the available geophysical data from the French geographical institute (IGN). The open-source computational fluid dynamics (CFD) code *Code_Saturne*, with the atmospheric option developed at CEREA, was used to carry out the simulations. The vegetation composed of tall trees is considered as a porous volume which induces a drag force to the air flowing through it. The pollutants of the local traffic emissions are considered as passive scalars (no chemical reaction). The global meteorology, including stratification conditions, is taken into account using boundary conditions obtained from mesoscale simulations performed over the region, with a zoom over the city by the Meso-NH code and the TEB urban parameterization. The simulation results of the air flow and pollution dispersion are compared with measurements obtained with fixed stations especially set up in the area during the campaigns. A good agreement is found between the measurements and simulations in terms of wind velocity and air temperature. For the wind direction the agreement is only fair with a Mean Bias of nearly 25° but nevertheless we

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http://dx.doi.org/10.1016/j.uclim.2016.11.002

find a good agreement with the NO_x concentration time series at a local measuring station inside the neighborhood. This good agreement is explained partly by the adjustment of the unknown local emission factor but also by the configuration of the ring road surrounding in part the neighborhood, making it less sensitive to wind direction errors.
Two urban renewal scenarios proposed by architects and local inhabitants are simulated under the same meteorological conditions. Increasing the height of anti-noise walls (from 3 to 6 m) does not improve the neighborhood air quality (except very locally) and the suppression of a big building block next to the ring road has a mixed effect, displacing the pollution (concentration increased in some area, decreased in some others).

1. Introduction

For several decades, the computational fluid dynamics (CFD) techniques have been used to carry out studies of the atmospheric environment which covers research fields such as the heat island effects, the air quality in urban areas, the wind safety assessment of urban renewal projects (Ashie and Kono, 2011; Jakeman et al., 2006; Gousseau et al., 2011). Although large advances in CFD techniques and high performance computing (HPC) have been achieved, the accurate modeling and prediction of air quality in urban areas remains still a huge challenge. It is mainly due to the complexity of the whole urban system, especially in the areas composed of various types of buildings, from small houses to skyscrapers and other urban features, such as highway, local streets, and vegetation areas. Buildings of different types have different thermal effects on the air flow since different construction materials have various heat exchange and radiative properties. In addition urban databases are fragmented, incomplete and not well suited for these applications. The human activities such as heating, traffic and industries also alter the air flow pattern in the urban canopy. All these factors can in principle be included in the CFD models but due to the limitation of computational resources, some choices must be made as to the most relevant ones. If one wants the details at the neighborhood level, the CFD simulation involves various parameter choices such as the simulation domain extent, the level of detail of the obstacles geometrical representation, the turbulent modeling method and the corresponding coefficients or parameters, the numerical discretization schemes, so as to keep only key factors and to neglect other factors considered as “less relevant”. Best practice guidelines (Franke et al., 2011; Tominaga et al., 2008) were published to facilitate the set-up of such numerical simulations. It is important to point out that the CFD technique was adopted by the Dutch Wind Nuisance Standard (MEN, 2006) to evaluate the urban wind comfort and wind safety besides the traditional wind tunnel experimentation. It can be considered as a milestone for the acceptance of CFD as a relatively reliable tool in urban micro-meteorology studies.

In the present study, we address the following question: can we accurately simulate with high resolution CFD actual meteorological and pollution conditions observed in a neighborhood of Toulouse over several days? *We* want to check the accuracy by comparison with data from the EUREQUA field measurements campaign (described below) and then, confident with this accuracy, use additional simulations to study the effect of proposed urban renewal scenario for the area.

The Reynolds-Averaged Navier–Stokes equations (RANS) and Large Eddy Simulation (LES) are the two approaches widely used today for the atmospheric simulation at microscale. Most of the previous studies were focused on idealized and very small scale urban model, such as street canyons or buildings of simplified geometry. Gromke et al., 2008 studied the pollutant dispersion in a street canyon with trees using both wind tunnel measurement and simulation carried out by the software FLUENT using the standard $k-\epsilon$ and Rij-ε turbulence closure. Their study showed that the in-canyon air quality can be significantly altered by introducing trees at the urban planning stage. Moonen et al., 2011 ran both RANS and LES simulation and proposed the ventilation potential as an indicator to characterize the pollution dispersion in a street canyon. Their LES simulations showed higher scalar exchange fluxes as compared to RANS. Since no corresponding experimental study was available, no decisive conclusion was made with respect to the reality. Solazzo et al. (2009)