Inner-urban air flow simulations to predict fine dust pollution of anthropogenic sources using LES-LBM on multiple GPGPUs

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ABSTRACT

The UNO predicts that in 2030 over 60% of the world population will live in urban environments. This percentage will increase to up to 70% in the year 2050. With that said, more than ever it is essential that we protect the living conditions in inner-urban regions. In this regard the air quality is of particular importance. The microclimatic implications of the densely built-up area mainly influence the dispersal dynamics of pollutants in ambient air. These are in particular fine dust particles and nitrogen oxides [1, 2]. According to the UN as of today only 12% of the world wide urban population are exposed to an air quality that remains under the level set by WHO. According to this survey half of the urban population is exposed to more than two and a half times of the fine dust limit [3].

Major anthropogenic sources of these pollutants are motorized and private transport, the manufacturing industry, power plants and heating systems in private households. Wind field and pollutant dispersion simulations in the urban near-field on the scale of individual buildings or streets have been used for several decades both in science and practice [4]. Here primarily Reynolds Averaged Navier-Stokes (RANS) models are used to give answers to environmental and urban planning questions. However with these models only mean wind fields are represented and the important turbulent exchanges in the near-surface area are fully parameterized.

Nowadays the computing power of high-performance computing (HPC) systems allow for more detailed turbulence modelling using Large Eddy Simulation (LES) [5, 6, 7] covering whole city districts with resolutions of up to 1m [8, 9]. On the one hand LES simulations show much better mean flow and concentration distribution and on the other hand provide a reliable prediction of the turbulent fluctuations of the flow characteristics. Vegetation influences are currently considered using simple inventory models covering the leaf area index [10].

In this work we present a LES-LBM based simulation environment using multiple General Purpose GPUs that allows for detailed predictions of the pollutant dispersion in city districts on the micro scale. Also the model respects dynamic traffic loads and local industrial sources of pollution on the building scale. In addition, micro scale partial models describe the influence of the vegetation (e.g. trees) on the pollutant dispersion.

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