High-resolution large-eddy simulation of urban atmospheric boundary layer

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Abstract

The main interests of our research group are Urban Atmospheric Boundary Layer (Urban ABL, UABL), wind flow, turbulence and various transport phenomena within the UABL, and application of high-resolution Large-Eddy Simulation (LES) to study these phenomena. We are motivated to study these problems both from the scientific and applied points of view. Our central modelling idea is as follows. We include the whole vertical extent of the ABL in a large LES domain in order to realistically resolve the large, strongly elongated turbulent structures of the ABL. While using a large domain, we also use high resolution in order to capture at least the most important part of the turbulent motion within street canyons and courtyards etc. in the urban canopy in the area of primary interest. These requirements together would lead to a huge number of grid nodes without the self nesting method which we have developed especially for urban LES (Hellsten et al., 2017). The nesting method allows us to use a large outer domain with a compromised resolution and a smaller higher-resolution nest-domain for the area of principal interest. Several nest domains can be set in a cascading chain or in parallel. We typically use set ups with two domains (root and nest) or three cascading domains (root, 1st nest and 2nd nest) to achieve a sufficiently large model domain and high resolution within the area of principal interest. The modelling system includes a realistic model for the urban geometry including terrain shape and buildings and also trees. Currently we are working e.g. on implementing aerosol physics modelling in PALM.

The PALM LES model (Maronga et al., 2015) forms the core of our modeling system. It is a highly versatile LES model for ABL and UABL problems with very effient parallelization based on the Message Passing Interface (MPI) scalable up to tens of thousands of processes.

We have so far applied the PALM system to the following UABL problems. We have developed a source-area estimation method for greenhouse-gas flux measurements in urban environment based on high-resolution LES with coupled Lagrangian-stochastic (LS) particle modelling (Auvinen et al., 2017). We have applied PALM to a practical air quality study for a certain city planning purpose in collaboration with the City of Helsinki (Kurppa et al., 2018). Currently we are studying UABL LES sensitivity to various modelling choices such as ABL depth (often unknown), details of tree modelling and grid resolution. Moreover, we are looking for an optimal layout of street canyon vegetation from the air quality point of view in collaboration with the City of Helsinki. We are also currently developing a new precomputed LES-LS based model for hazardous material release accidents.

References:

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