Geophysical Research Abstracts, Vol. 9, 01550, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-01550

An LES driven Lagrangian stochastic particle model used for footprint evaluations

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Recent review papers on footprint modeling have pointed out that the large-eddy simulation (LES) technique is a potentially powerful tool for the validation and further development of currently used footprint evaluation methods. LES-derived turbulence statistics might be invaluable especially under complex conditions, where self-similar profiles fail to describe the flow and turbulence field properly, as e.g. at forest edges or in inhomogeneously heated areas. The great advantage of the LES method is that both, the turbulence statistics as well as the resulting scalar concentration and scalar flux field, are evaluated explicitly, while some exterior turbulence statistics have to be provided to run standard footprint models.

In spite of the great potential of the LES method for footprint evaluations only a few studies on LES derived footprints, using an Eulerian approach for the calculation of the dispersion of a scalar constituent, have been published so far. Recently, several authors have presented their suggestions how to implement a Lagrangian stochastic particle model in the framework of an LES model.

Here, we present how the coupling of the parallelized large-eddy simulation model PALM with a Lagrangian stochastic particle model in forward mode has been realized. We show the basic validity of the approach by comparing the results of a dispersion simulation in the convective boundary layer with the results from a prior numerical study and a tank experiment. Moreover, we point out that the approach can be applied successfully to the evaluation of footprints of scalar concentration and scalar fluxes. This is shown by a comparison with the footprint results of another LES model, a Lagrangian stochastic footprint model, an analytical footprint model and experimental results for a convective boundary layer.

Furthermore, we present results for footprint evaluations in the stably stratified boundary layer of the GABLS study, where it becomes evident that the Ekman spiral has an impact on the shape of the footprint. The footprint function is not longer symmetric around the axis defined by the direction of the boundary-layer mean wind.

Finally, we show results of first footprint evaluations under idealized inhomogeneous conditions prescribed by a sinusodial heat flux variation. They point out that the footprint is considerably influenced by the inhomogeneity. E.g. the location of the sensor with respect to the heat flux maximum is essential for the alongwind extension of the footprint area and the relative importance of cross-wind dispersion. This is due to the structure of the thermally induced mesoscale circulation caused by the surface inhomogeneity.