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Multiscale modelling of atmospheric flows with EULAG

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Flows in the atmosphere are characterised by the interaction of different spatial and temporal scales. A simple example is a stratified large-scale flow over a mountain exciting upward propagating mesoscale gravity waves and - due to their breaking - even small-scale turbulence.

Numerical modelling of atmospheric processes on different spatial and time scales (so-called multi-scale modelling) is a challenge. In general, simulations of atmospheric flows are performed on a fixed spatial grid. The governing equations for momentum, pressure and temperature are discretisized and solved numerically; here we use the anelastic non-hydrostatic approximations for the general Navier-Stokes equations. The numerical solver simulates dynamic and thermodynamic processes, which are resolved by the grid (spatial and temporal). However, processes on scales smaller than the spatial/temporal grid resolution must be parameterized. It is often not clear, if and how processes on larger scales impact and initiate processes on smaller scales.

We apply a new concept for multi-scale modelling in mesoscale models: The basic equations for momentum and potential temperature are solved in the perturbation form, i.e. only deviations from a prescribed ambient state are regarded. In general, the ambient states represent a (known) solution of the equations of motion. Usually, these ambient states are assummed to be constant in time and an vary only in vertical direction in space.

This approach extends the classical set-up of simulations with the anelastic equations significantly by considering the temporal evolution of the larger scale flow, i.e. the ambient wind fields are now time dependent. Because of the possibility to control the large-scale flow very accurately it is now possible to investigate the impact of large-scale processes on smaller-scale processes. Furthermore, the change in flow regimes (e.g. the initiation of convection in a surface heated valley flow under the influence of oscillating up- and down-valley wind) can be studied easily.

In this contribution, we outline our approach and present some first application results. The formation of mesoscale gravity waves excited by a flow over a mountain with temporal changes in wind shear and direction is investigated. This is a scenario, which occurs every day in nature, but for simplicity usually the case of a steady flow over a mountain is investigated.