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Numerical dispersion of gravity waves

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In the atmosphere several types of waves are present. On the mesoscale internal gravity waves are especially important. These waves can be found throughout the atmosphere wherever it is stably stratified. As gravity waves influence the mesoscale flow, their accurate simulation is of great interest. One of the problems associated with the simulation of gravity waves are their dispersive properties. The physical dispersion is mainly influenced by the static stability of the air. However, in numerical models the type of grid spacing as well as grid size and the numerical methods used additionally influence the properties of waves.

When different grid sizes are used within one domain gravity waves that cannot be resolved on the coarse grid cannot leave the fine grid and are reflected at the internal boundary. This has also been found and analysed for simple wave types. Consequently, the stretching factor between fine and coarse grid is usually kept smaller than four which still leaves some reflection. For large domains atmospheric simulations on fine grids are still not feasible in terms of computational cost. Therefore, two-way nesting and adaptive grid methods are more and more frequently used.

In this work numerical dispersion relations are experimentally derived using the anelastic mesoscale model METRAS. The dependency of the group velocity on different grid sizes and numerical advection schemes (based on a central scheme and the essentially non-oscillatory (ENO) method) is presented showing a slow down of the waves with increasing grid sizes. The point of slow down is reached at smaller grid size with the central scheme than with the ENO method. A solution is presented to attenuate the reflected waves in order to avoid gravity waves being trapped within the domain of the fine grid. It is based on an internal sponge layer between coarse and fine grid with optimized damping coefficients depending on the local stratification. The method is successfully applied in an idealized two-dimensional test case with gravity waves of different wave lengths.