A model using the pseudo-incompressible equations with implicit LES for simulating gravity waves

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1. Introduction

We investigate the propagation and breaking of gravity waves in altitudes ranging from the ground to the upper mesosphere. We specially focus on turbulence production – with the aim of validating and improving the parametrization schemes in today's weather and climate models. To achieve this goal we developed a model with the following key features:

1) We integrate the *pseudo-incompressible* equations (Durran, 1989)
2) in a *finite-volume* discretization (FVM)
3) with the *adaptive local deconvolution method* (ALDM) (Hickel et al., 2006) as SGS turbulence model.

We present the model and discuss the properties and the interplay of the ingredients mentioned in point 1) to 3).

2. Governing Equations

A major advantage of the *pseudo-incompressible* equations is that they are *sound proof*, i. e. there is no severe time step restriction from the CFL stability condition. Different to standard anelastic equations, the pseudo-incompressible equations are asymptotically consistent with the Euler equations (Achatz et al., 2010) and allow for baroclinic vorticity production. The model reduction seems to be minimal: by defining a pseudo-incompressible density that only depends on entropy (potential temperature) and not on the pressure, the elasticity of the medium is removed without touching the relevant dynamic equations of continuity and momentum. The energy transport equation gives rise to a divergence constraint on the velocity field.

3. Finite-Volume Discretization

We use the pseudo-incompressible equations in *flux form,* which enables us to discretize the equations with finite-volumes – a discretization which conserves mass and momentum. To overcome the decoupling of pressure and velocity, we use a C-grid. The flux formulation allows us to implement a modern turbulence model: the adaptive local deconvolution method (ALDM).

4. Turbulence Model

In classical LES schemes the filtered LES equations and the SGS model have to be discretized accurately – with a numerical truncation error small enough not to interfere with the explicit SGS model. The basic idea of ALDM is that the *truncation error* of the numerical fluxes is tuned such that turbulence characteristics (e. g. the spectrum of decaying turbulence) fit DNS data. The free parameters enter the model in two ways:

1) The flux function consists of a high-order central difference part and a viscous part with a free parameter.
2) The values at the cell faces are obtained from a Weighted-Essentially-Non-Oscillatory (WENO) type reconstruction of the filtered values. Unlike WENO, where only one type of polynomials is used to achieve maximum order of accuracy, in ALDM all polynomials of degree 0 to 2 (constant, linear, quadratic) are blended. The different weights of the

polynomials include additional tuning parameters.

5. Numerical Results

First numerical results (e.g. hot and cold air bubble) show agreement with the literature.

References

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