# Idealised Tests of the very short range Forecast Model LMK

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At the Deutscher Wetterdienst (DWD) the NWP model LMK ('LM Kürzestfrist') is under development since the end of 2003 with the goal to deliver weather forecasts for a very short time range (up to 18 h) with a spatial resolution lying in the meso-$\gamma$-scale (about 2.5-3 km). We expect at this resolution that the very coarse scale structures of convective cells can be resolved and severe weather events, connected e.g. with super- and multi cell thunderstorms can be simulated by the model to a certain extent. Additionally effects of more fine scaled topography (severe downslope winds, Föhn storms, ...) can be considered (Doms and Förstner 2004).

The starting point for this development is the nonhydrostatic, compressible model LM ('Lokal-Modell') (Schär et al. 2002), which is in operational use since end of 1999 and which was extended to handle with the higher resolution by several steps. As mentioned, at a resolution of 2.8 km the LMK partly can develop deep convection explicitly. Consequently a full parameterisation of deep convection is not longer needed. But one still needs again a mechanism to transport humidity out of the boundary layer, therefore a parameterisaton for this 'shallow convection' by a simplification of the Tiedtke-scheme is used. Furthermore besides the humidity variables water vapour, cloud water, cloud ice, rain and snow a new ice phase (graupel) with higher sedimentation velocities than snow is needed for the explicit simulation of deep convection (Reinhardt 2005).

In this article we want to concentrate on the improvements of the dynamical core. Instead of the Leapfrog-time-splitting method used in LM a 2-timestep TVD-Runge-Kutta-method of 3rd order was used (Förstner and Doms 2004). This allows the use of advection schemes of higher spatial order (here: upwind 5th order) at relatively high Courant numbers. This dynamical core was tested in several studies.

The test case of a non-linear 2-dim. density current, generated by a falling cold bubble, was proposed 1990 at the 'Workshop on Numerical Methods for solving linear flow problems' and is e.g. described in Straka et al. (1993). In a steady, dry adiabatic stratified atmosphere with $\Theta = 300$ K, an elliptic cold bubble is set with a maximum extension of 8 km horizontally and 4 km vertically, centered in 3 km height and up to 15 K colder than the surrounding atmosphere. The generation of arbitrary small structures is suppressed by an artificial diffusion ($K = 75$ m$^2$/s). By this scale-limiting diffusion a grid-convergent solution can be found which was calculated by Straka et al. (1993) based on an ongoing reduction of the grid resolution with an elementary solver. This reference solution is shown after 900 s in figure 1 (left, above). One recognizes especially the propagation of a bow front and the generation of Kelvin-Helmholtz-instabilities connected with the density current. In figure 1 (left, below) the comparison with the Runge-Kutta 3rd order time-integration scheme and a resolution of $\Delta x = 50$ m is presented.

A further test with a 2-dimensional flow over a bell-shaped mountain of 100 m height and a half width of 4 grid spacings was performed and compared to the analytic solution. In figure 1, right, an isothermal stratification with $T_0 = 285.15$ K, an incoming flow with $U = 10$ m/s and a resolution of $\Delta x = 7$ km was used. In the simulation with the new dynamic core a considerably bigger time step of 72 s is used compared to the Leapfrog-scheme used in LM (40 s) and the solution compares at least equally well with the analytical one as the results for the Leapfrog core. This is especially the case in the lower half of the domain. The discrepancies in the upper half are mainly due to the upper boundary condition where a damping layer is used.

In a third idealized study the flow over a bell-shaped mountain with superimposed variations

$$h(x) = h_0 \exp\left[-\left(\frac{x}{a}\right)^2\right] \cos^2\left(\frac{\pi x}{\lambda}\right)$$

with $h_0 = 250$ m, $a = 5$ km and $\lambda = 3$ km is simulated. The results for two different height coordinates — SLEVE (Schär et al. 2002) and the normal Gal-Chen formulation — are shown in figure 2. This is a good test of the formulation of the metric terms in terrain-following coordinates (Klemp et al. 2003)

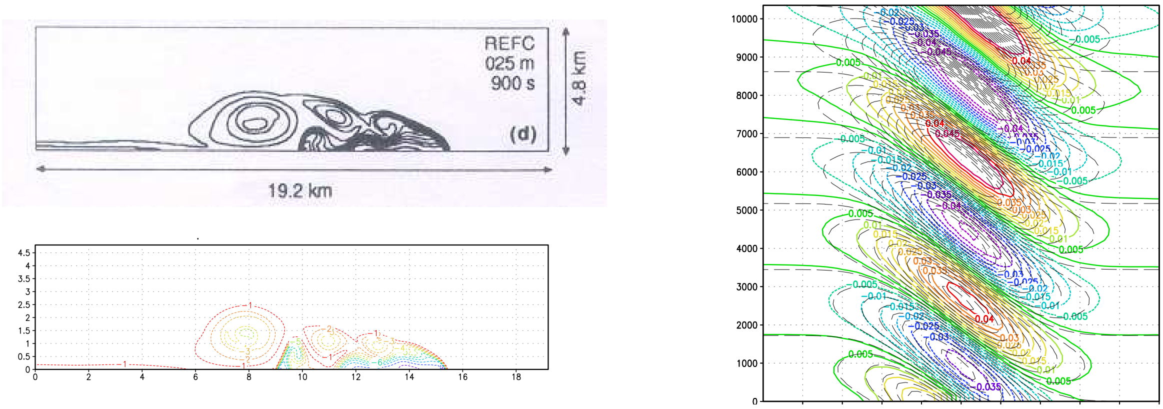
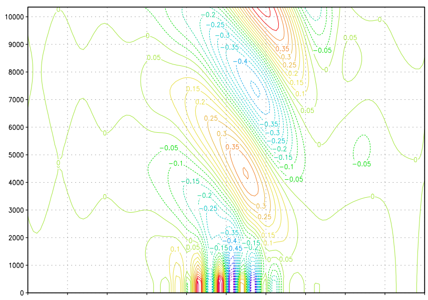
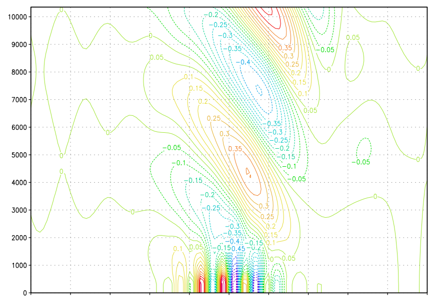



**Figure 1:** *Vertical cross sections for:*
*Left side:* $\Theta' = \Theta - \Theta_0$ *for the density current test after 900 s. above: reference solution by Straka et al. (1993), below: LMK solution. It is only shown the right half of this symmetric flow.*
*Right side: vertical wind velocity* $w$ *for a 2D isothermal flow over a mountain after a simulation time of 30 h. The analytic solution is given in thin dashed contours.*

especially at the lower boundary, since inconsistent treatment would lead to small scale distortions of the wave structure higher up in the atmosphere.



(a) SLEVE coordinate.



(b) Gal-Chen coordinate.

**Figure 2:** *Vertical cross section of* $w$ *for a 2D flow after a simulation time of 24 h. Incoming flow:* $U = 10$ $m/s$*; stratification:* $N = 0.01\ s^{-1}$ – $T_0 = 285.15$ $K$. $\Delta x, \Delta y = 500$ $m$.

## References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