Implementation of a 3D-Turbulence Parameterization for the Very Short Range Forecast Model LMK

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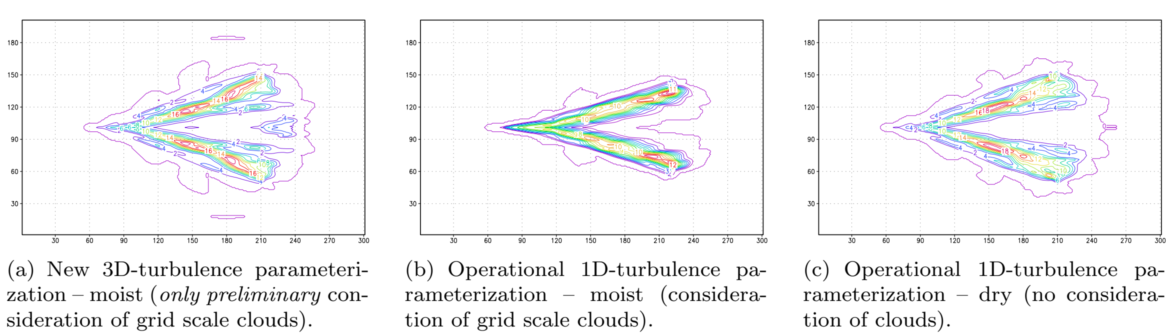
The model LMK ('LM Kürzestfrist') which aims at very short range weather forecasts in the meso-γ-scale (about 2.5-3 km) is currently developed at the Deutscher Wetterdienst (DWD) (Doms and Förstner 2004; Baldauf et al. 2005). This development includes the introduction of a new dynamical core (Förstner and Doms 2004) and new physical parameterizations for cloud microphysics (Reinhardt 2005) and 3-dimensional turbulence into the framework of the LM (Doms and Schättler 2002). In the operational 7 km version of the LM only vertical diffusion is taken into account, but as we go to higher and higher resolutions the inclusion of horizontal diffusion will become relevant. If this is already the case at a spatial resolution about 3 km is still open for discussion.

The 3D-turbulence scheme was originally developed for the LITFASS project of the DWD (Herzog et al. 2002) with a Smagorinski-type scheme and was used for LES simulations. To be applicable at the planned resolution of the LMK a Mellor-Yamada-type parameterization was added. Implementation of this scheme for LMK mainly consisted in the adaption to the new 2-timelevel Runge-Kutta core. In particular the inclusion of the horizontal diffusion terms for momentum, heat and moisture, as well as the integration of the prognostic TKE equation. Up to now several metric terms related to the coordinate transformations are neglected in the formulation of the horizontal terms and it will be further investigated if this approximation is justified. The advection and diffusion of TKE is solved in a way equivalent to the other scalar prognostic quantities. We use the following parameterized version of the TKE equation:

$$\begin{aligned}\frac{\partial \overline{e}}{\partial t} + \overline{u}_j \frac{\partial \overline{e}}{\partial x_j} = &+2\left(\frac{\partial}{\partial x_1}\left(K_m^H \frac{\partial \overline{e}}{\partial x_1}\right) + \frac{\partial}{\partial x_2}\left(K_m^H \frac{\partial \overline{e}}{\partial x_2}\right) + \frac{\partial}{\partial x_3}\left(K_m^V \frac{\partial \overline{e}}{\partial x_3}\right)\right) \\ &+ K_m^H S_H^2 + K_m^V S_V^2 - K_h^V N^2 - c_\epsilon \frac{\overline{e}^{\frac{3}{2}}}{l}.\end{aligned} \tag{1}$$

Here we introduce a distinction between K^H and K^V where the horizontal diffusion coefficients are determined from the vertical ones by use of an anisotropy factor proportional to the aspect ratio of the mesh. This is done for the sake of simplicity and will be replaced by more sophisticated methods in the near future. Compared to the operational parameterization of the LM (Raschendorfer 2001) the one used in the 3D scheme misses a number of features. Most important only a preliminary treatment of moist turbulence is included where for example only grid scale cloudiness is taken into account. Also missing is a parameterization for subscale thermal circulations. Therefore it is planned to combine the straightforward implementation of the horizontal diffusion terms and integration of the TKE in the new dynamical core described above with the more sophisticated parameterizations of the operational scheme in the beginning of 2005.



(a) New 3D-turbulence parameterization – moist (*only preliminary* consideration of grid scale clouds).

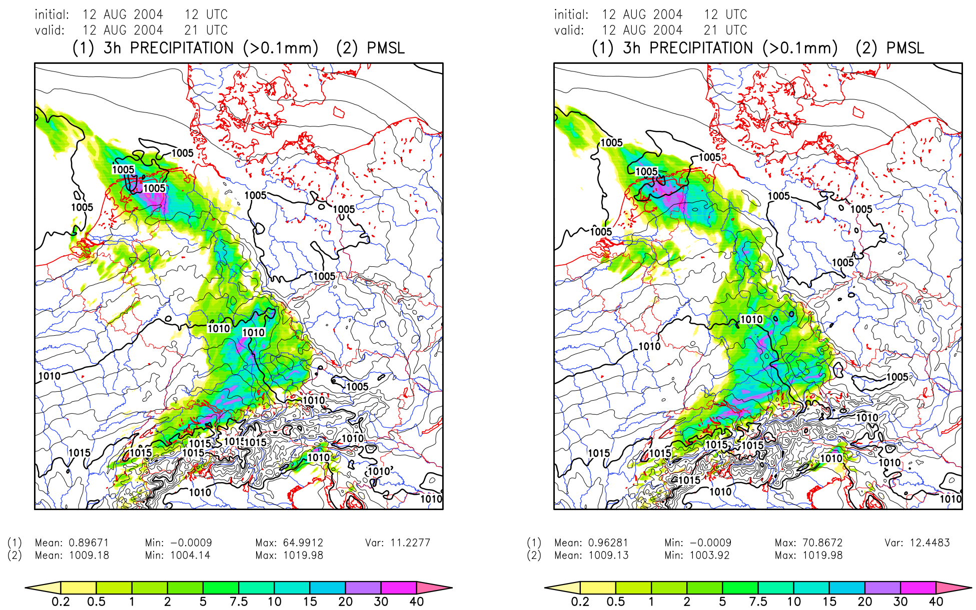
(b) Operational 1D-turbulence parameterization – moist (consideration of grid scale clouds).

(c) Operational 1D-turbulence parameterization – dry (no consideration of clouds).

Figure 1: *Accumulated Precipitation in colored contour lines. Results of LMK simulations with TVD-RK-3rd / UP-5th dynamics after a simulation time of 192 min – $\Delta t = 6$ s; $\Delta x, \Delta y = 1$ km.*

An idealized study reveals the relevance of the advanced moist turbulence formulation in the operational scheme. Figure 1 shows the accumulated precipitation for a storm splitting test case (Weisman and Klemp 1982) with $U_{max} = 25$ m/s and $q_{max} = 14$ g/kg.

In spite of the restrictions mentioned, the new scheme runs stable and produces realistic results. As an example Figure 2 shows a comparison of a precipitation forecast using the two different schemes. At least in this real case study the two schemes produce very similar results with only a bit less precipitation when the new 3D scheme is used.



(a) New 3D-turbulence parameterization. (b) Operational 1D-turbulence parameterization.

Figure 2: *Forecast for 12 August 2004, 21 UTC. Shown in shaded colors is the 3 h accumulated precipitation and the pressure at mean sea level in black contour lines. Results of LMK simulations with TVD-RK-3rd / UP-5th dynamics after a simulation time of 9 h –* $\Delta t = 30$ *s*; $\Delta x, \Delta y = 2.8$ *km.*

References

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