A Revised Cloud Microphysical Parameterization for COSMO-LME

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1 Introduction

Quantitative precipitation forecasting (QPF) is one of the major applications of limited-area numerical weather prediction (NWP) models. With a limited-area NWP model, like the 7-km COSMO-LME at DWD, the detailed orography and the explicit simulation of mesoscale dynamical structures should lead to an increased forecasting skill compared to global models with coarser horizontal resolution.

Unfortunately, the last years have shown some problems with the precipitation forecasts of COSMO-LME. For example, an overestimation of orographic precipitation, a too frequent occurence of very light precipitation (drizzle) and a general overestimation of the wintertime precipitation amounts.

One possible cause for some of these problems on the meso-β-scale are simplifications within the cloud microphysical parameterization. Therefore a revised version of the COSMO-LME microphysics scheme has been developed and brought into operations.

2 Microphysics of COSMO-LME

The grid-scale microphysics parameterization of COSMO-LME predicts the four hydrometeor species cloud droplets, raindrops, cloud ice and snowflakes using the mixing ratio of each hydrometeor type as prognostic variable and includes horizontal and vertical advection for all species. For most cloud microphysical processes the scheme follows the work of Rutledge and Hobbs (1983) and a detailed description is given in Doms and Schättler (2004). At DWD this scheme has been operational since 16 September 2003.

As an attempt to improve the mesoscale precipitation structures predicted by COSMO-LME several modification have been made recently:

- The Kessler-type autoconversion/accretion scheme has been replaced by the parameterization of Seifert and Beheng (2001) assuming a constant cloud droplet number concentration of 5×10^8 m^{-3}.
- Based on measurements of Field et al. (2005) a new parameterization of the intercept parameter $N_{0,s}$ of the exponential snow size distribution

  $$f(D) = N_{0,s} \exp(-\lambda D),$$

  is introduced, replacing the constant $N_{0,s} = 8 \times 10^5$ m^{-4} in COSMO-LME. In the revised scheme the intercept parameter is parameterized as a function of temperature T and snow mixing ration q_s by:

  $$N_{0,s} = \frac{27}{2} a(3,T) \left(\frac{q_s}{\alpha}\right)^{4-3b(3,T)}$$

  with $\alpha = 0.069$. The functions $a(3,T)$ and $b(3,T)$ are given by Table 2 of Field et al. (2005).

Especially at cold temperatures this leads to a higher intercept parameter, i.e. smaller snowflakes which fall out much slower.

- For the autoconversion of cloud ice and the aggregation of cloud ice by snow a temperature dependent sticking efficiency has been introduced similar to Lin et al. (1983):

$$e_i(T) = \max(0.2, \min(\exp(0.09(T - T_0)), 1.0))$$

with $T_0 = 273.15$ K.

- The geometry of snow has been changed to a mass-diameter relation of $m = \alpha\, D^2$ with $\alpha = 0.069$ and a terminal fall velocity of $v = 15\, D^{1/2}$ with D in m, m in kg and v in m/s.

Overall these changes lead to a slower formation of rain and snow as well as a reduced sedimentation velocity of snow. The terminal fall velocity of snow of $v = 15\, D^{1/2}$ is somewhat lower than usually assumed based on observations or labratory measurements. This 'tuning' can be justified by the fact that a 7-km model cannot yet fully resolve the updraft structures of mesoscale orography, as e.g. shown by Garvert et al. (2005) who compare simulations with 4 km and 1.3 km resolution with observations.

3 Results

Figure 1 shows two example forecasts of 11 January 07 and 22 December 06. For 11 Jan COSMO-LME overestimates the orographic precipitation in the mountainous regions of Germany. This effect is reduced with the new version of the cloud microphysics scheme (LMEp). The COSMO-LME forecast of 22 Dec 06 shows widespread light precipitation in Brandenburg and Sachsen (East Germany) which was not observed. The LMEp with the new microphysics does not show this problem. In a test period of 6 weeks the new version showed a significant improvement in the TSS and FBI of surface precipitation (not shown).

4 Summary and Conclusions

The new version of the COSMO-LME microphysical scheme has been tested in an operational setup including data assimilation over several weeks in December 2005 and December/January 2007. The results show a better representation of orographic precipitation, e.g. reducing the common overestimation over the Black Forest mountains, and a reduction of drizzle events. Both leads to an improved QPF skill during wintertime and demonstrates the importance of cloud microphysics on the mesoscale. Unfortunately, but not unexpected, the general overestimation of wintertime precipitation cannot be cured by this change of the microphysical parameterization. The revised microphysics scheme is now in operation in the 7-km COSMO-LME at DWD since 31 January 2007 9 UTC.

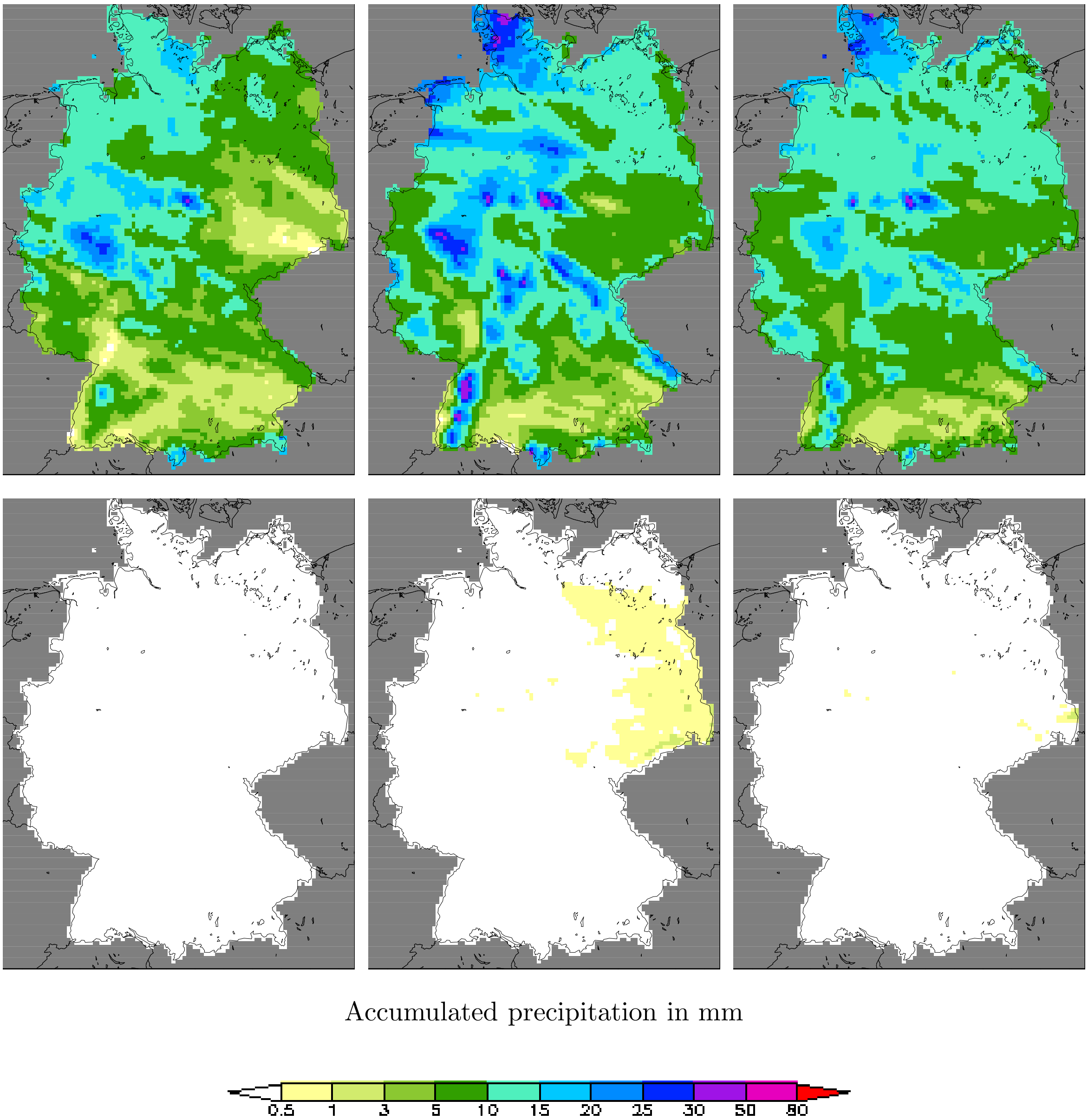

Figure 1: Accumulated precipitation 06-06 UTC from 00 UTC forecasts of 11 Jan 07 (top) and 22 Dec 06 (bottom). Shown are observations (left), LME: old microphysics (middle), LMEp: revised microphysics (right)

References

Rutledge, S.A., P.V. Hobbs, 1983: The Mesoscale and Microscale Structure and Organization of Clouds and Precipitation in Midlatitude Cyclones. VIII: A Model for the 'Seeder-Feeder' Process in Warm-Frontal Rainbands, *J. Atmos. Sci.*, **40**, 1185-1206.

Doms G., J. Förstner, E. Heise., H.-J. Herzog, M. Raschendorfer, R. Schrodin, T. Reinhardt, G. Vogel, 2005: A Description of the Nonhydrostatic Regional Model LM. Part II: Physical Parameterizations, *Deutscher Wetterdienst*, Offenbach, 139 pages. Available at: www.cosmo-model.org.

Seifert, A., K. D. Beheng, 2001: A double-moment parameterization for simulating autoconversion, accretion and selfcollection, *Atmos. Res.*, **59-60**, 265–281.

Field P.R., R.J. Hogan, P.R.A. Brown, A.J. Illingworth, T.W. Choulartona, R.J. Cotton, 2005: Parametrization of ice-particle size distributions for mid-latitude stratiform cloud, *Quart. J. Roy. Met. Soc.* **131**, 1997–2017.

Lin Y.-L., R.D. Farley, H.D. Orville, 1983: Bulk parameterization of the snow field in a cloud model, *J. Clim. Appl. Meteorol.*, **22**, 1065–1092.

Garvert M.F., B.A. Colle, C.F. Mass, 2005: The 13-14 December 2001 IMPROVE-2 Event. Part I: Synoptic and Mesoscale Evolution and Comparison with a Mesoscale Model Simulation, *J. Atmos. Sci.*, **62**, 3474–3492.