The new very short range forecast model COSMO-LMK for the convection-resolving scale

M. Baldauf, K. Stephan, S. Klink, C. Schraff, A. Seifert, J. Förstner, T. Reinhardt, C.-J. Lenz
Deutscher Wetterdienst, Kaiserleistr. 42, 63067 Offenbach, Germany
e-mail: michael.baldauf@dwd.de

1. Introduction

Up to now the model chain of the Deutscher Wetterdienst (German Weather Service, DWD) is built up by the global model GME with about 40 km resolution and the regional, meso-beta model LME (commonly developed in COSMO, `http://www.cosmo-model.org`) with 7 km resolution. Since August 2006, the newly developed numerical weather prediction system LMK ('LM-Kürzestfrist') for very short range forecasts (up to 18h) and with a resolution on the meso-gamma scale (dx=2.8km) is in a pre-operational trial at the DWD. This is the first time that a convection resolving model is used at the DWD. The emphasis of this model system lies in the prediction of severe weather events related to deep moist convection and to interactions of the flow with small scale topography.

The currently used LMK-configuration covers the domains of Germany, Switzerland and Austria and smaller parts of the other neighbouring countries with $421 \times 461 \times 50$ gridpoints and a horizontal resolution of 2.8 km.

The project LMK was established at the DWD in the mid of 2003 within the scope of the 'Aktionsprogramm 2003' and ended in December 2006. It was subdivided into four subprojects:

1. Supply of quality controlled radar-precipitation data.
2. The installation of an assimilation method for radar reflectivity using latent heat nudging to provide highly resolved initial fields, especially for the initiation of convection.
3. The advancement of the numerical model based on the currently used LM.
4. Finally the accompanying verification and the advancement of verification methods for horizontal model resolutions of about 2.8 km.

2. Latent heat nudging

A meso-γ-model has special requirements concerning data assimilation: at this scale highly resolved, rapidly updated data fields are needed, which can in principle be delivered by radar observations. The German radar network has a spatial resolution of radially 1 km and laterally 1° and a temporal resolution of 5 min. for the precipitation scan. The assimilation method should be fast and also relatively easy to implement. The latent heat nudging (LHN) approach fulfills these requirements. It uses the differences between (radar) measured and simulated precipitation rates and interpretes them as a lack or surplus of latent heat along the trajectory of a condensed particle. One basic assumption of the LHN is that this relation is valid in a vertical model column. This basic assumption stands in contradiction to the use of a prognostic precipitation scheme which drifts rain and snow by several grid lengths over several time steps. This leads to some sort of feedback problem, which can be solved partially by using an undelayed reference precipitation step additionally to the prognostic precipitation step. Another improvement can be obtained by using latent heating increments only in the growth stage of a convective cell. These modifications led to a more realistic assimilation of the precipitation pattern of convective events (Schraff et al. (2006)).

3. Numerical model development

The dynamical formulation of the LMK bases on the COSMO-Lokal Modell (LM) (Doms and Schättler (2002)): it is a non-hydrostatic, fully compressible model in advection form. But there are some differences in the numerical formulation. LMK now uses a two-timelevel integration scheme based on the Runge-Kutta-method of 3. order for the prediction of the 3 cartesian wind components u, v, w, the pressure perturbation p' from a hydrostatic base state, and the temperature perturbation T'. This allows the use of an upwind advection scheme of 5. order in the horizontal with Courant-numbers up to 1.4 (Wicker and Skamarock (2002)). For the 6 humidity variables (mass fractions of water vapour, cloud and rain water, cloud ice, snow and graupel) several Courant-number-independent Euler- and Semi-Lagrange-schemes can be used (Förstner et al. (2006)). Idealised tests of this new dynamical core with linear mountain flow and nonlinear density current simulations performed very well.

One of the most farreaching changes from LM is that LMK will not longer use a deep convection parameterisation. Instead of this, LMK aims to resolve moist convection explicitly. For the smaller scales of convection the sligthly modified shallow convection scheme of the Tiedtke Cumulus parameterization scheme is used. This parameterization especially takes care of the transport of moisture from the boundary layer to a height of about 3 km and therefore avoids the overestimation of low cloud coverage. Without a deep convection parameterization the need for a faster sedimenting ice phase seems to be necessary. Therefore the former 5-class microphysics scheme was extended by a new precipitation class 'graupel'. This new scheme was tested with the IMPROVE-2 data set and one day of the BAMEX field campeign. In

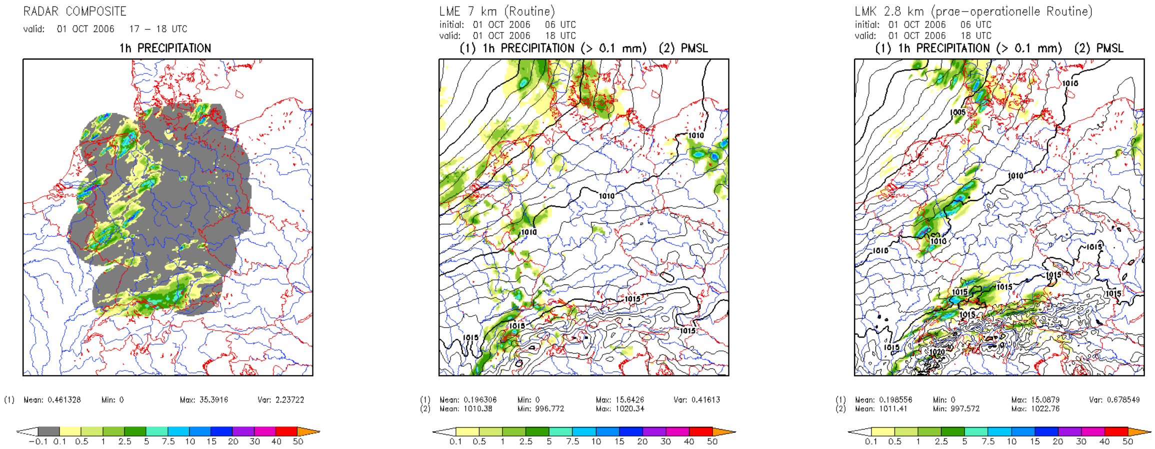

Figure 1: Radar observation (left), LME- (middle), and LMK- (right) simulations of convectively amplified frontal precipitation at 01.10.2006

the latter test case, the ability of the LM to resolve deep convection could also be shown. Further improvements of the physics packages are the introduction of 3-dimensional turbulence with full metrics (Baldauf (2006)) (but which is not used up to now in the pre-operational runs) and a new 7-layer soil model. For the problem of underestimation of precipitation in convective situations, the resolution of 2.8 km is not responsible, as could be shown by comparisons with 1km runs. Instead this problem could be cured by reducing the evaporation of rain below the cloud base and by making changes in the boundary layer parameterisation of subgrid scale clouds.

4. Experiences from the pre-operational test phase

In general, LMK has better scores for wind speed and gusts in 10 m above ground. The RMSE of the wind speed is reduced by about 5 to 10 % compared to LME. The RMSE of 2m temperature is mostly smaller in LMK, too, although no soil moisture analysis is used. The precipitation forecast had better true skill statistics (TSS) in the months September to November 2006. But in December, LMK had drawbacks compared to LME. This is partly due to the fact, that LHN is switched off in winter months due to bright bands in the radar data, which are up to now not corrected. The stratification of LMK is often slightly too unstable, which gives the hint, that convection is not efficiently enough resolved by the model. In contrary, LME produces too stable stratifications, an artefact of the parameterization.
The figures show an example ('01.10.2007'), where frontal precipitation is convectively increased. Whereas the parameterisation of LME does not initiate convection in western Germany, LMK is able to reproduce at least a bigger part of the rain area at the correct time, compared to radar observations.
In general LMK improves precipitation forecasts in situations, where convection is connected with a synoptic forcing, whereas it does not perform as well in free convection situations. Here, only the latent heat nudging can trigger precipitation events a few hours in advance.
LMK has clear advantages in more dynamically driven phenomena due to its better spatial resolution. Lee waves are often correctly forecasted, which gives an increased skill for aviation, especially for gliders. Strong downslope winds in stably stratified atmosphere are better forecasted too, an example was found at 05.11.2006 in the lee of the Erzgebirge, where a hydraulic jump could be simulated by LMK.
The operational usage is planned for April 2007.

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