Development of a NWP System for Very Short-Range Forecasts

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For very detailed short range forecasts, the Deutscher Wetterdienst (DWD) has started the development of a meso-γ version of the operational nonhydrostatic regional model LM. This new version, called LMK, will utilize a grid-spacing of 2-3 km with about 50 vertical layers and an integration domain of about 1300 x 1300 km^2 (see Fig.1). LMK is aiming at the explicit prediction of deep convection and will provide 18-h forecasts for Germany eight times per day based on all observations available, including satellite and radar data. The development work is organized by an internal 3-years project from end 2003 to end 2006, with the operational implementation of the LMK system scheduled for late 2006.

With the new system, it is intended to fill the gap between traditional nowcasting methods for severe weather events (up to 3-6 hrs) and current short-range NWP with grid spacings of about 10 km and forecast ranges up to 48-72 hrs. In the time range of 18 hrs severe weather often forms in context with deep moist convection (such as super- and multi-cell thunderstorms, squall-lines, mesoscale convective complexes and mesocyclones) or due to interactions with fine-scale topography (such as fog, severe downslope winds, Föhn-storms, flash-floodings, etc.). As these events cannot be resolved with the resolution of present models, their prediction is in general very poor. However, there is a strong public demand for improved weather forecasts at finer scales and shorter ranges. An accurate prediction of extreme rainfall events or severe wind gusts in both time and space is especially required for hydrological, civil protection and environmental agencies to issue adequate warnings.

We expect a number of potential benefits of running a forecasts model routinely with a grid spacing better than 3 km on a quite large domain (to keep some internal predictability), since many more mesoscale weather systems and their scale interactions including local topographical effects can be properly resolved. Such a resolution will allow to simulate deep convective clouds directly and many deficiencies introduced by parameterized convection are removed. This means that the life-cycle of individual clouds can be represented in detail together with dynamic interactions and organization, resulting in features like supercell and squall-line formation or storm-cell initiation by gust fronts. It is expected that this will allow for much more realistic and hopefully more accurate forecasts of severe weather events. Deriving the convective-scale LMK from the LM requires a not only an adjustment of the existing schemes but also a development of new components within data assimilation, dynamics and numerics, physical parameterization, verification and validation. The project structure is organized along these points.

With respect to numerics, current work focuses on the the implementation of a TVD-variant of the 3rd-order in time Runge-Kutta time integration. The scheme can easily be combined with the standard time-split forward-backward methods to integrate fast compression waves and furthermore allows for flexible use of high-order spatial advection operators. From the latter, we expect noticeable benefits for simulating processes such as deep convective cloud evolution which is at or close to the grid-scale. Using a 5th-order advection scheme, the new scheme allows for a time step almost twice as large as with the standard Leapfrog/2nd-order centered differencing scheme of LM. This advantage is somewhat reduced since the advection operator has to be calculated three times. The main reason for applying the new time scheme, however, is not to save CPU-time but to achieve a more accurate and thus much better converged numerical solution at neutral computational costs. For first results from the RK3 time integration see the paper by Förstner and Doms in this volume.

The equations for the hydrological cycle have also to be reconsidered for very high spatial resolution, since advective transport of precipitation particles (like rain and snow) may no longer be neglected as it is done in current schemes. Hence, the present diagnostic treatment of precipitation has to be replaced by an algorithm based on the full 3-d budget equations for rain and snow. For LMK, a numerical algorithm to solve these prognostic equations has been constructed by combining a 3-d semi-Lagrangian advection scheme with an implicit treatment of precipitation fallout (see paper by Baldauf, this volume). Tests of the scheme indicate that the horizontal transport of snow is essential for correcting an erroneous spatial distribution of precipitation of orographically forced rainfall in case of stable stratification. In case of high-resolution applications, the vertical advective transport of precipitation will be of crucial importance for describing the life-cycle of deep convective storms correctly.

Considering physical processes on the meso-γ scale, parameterization issues related to deep convection and gravity waved drag will disappear due to a direct simulation of these processes. Shallow convection, however, will still remain sub-grid scale and can play a significant role for initiating deep convection. At present, it is not clear if standard global-scale convection schemes based on steady-state plume cloud models with a moisture- or moist static energy convergence closure can cope with shallow convection at very high resolution. We plan to develop a shallow-convection scheme based on a dynamic cloud model, which allows for an explicit calculation of entrainment and detrainment, and a closure based on PBL turbulent kinetic energy. Remaining parameterized physical processes are turbulent mixing, microphysics, radiation and surface fluxes. For the latter two, we initially rely on the standard parameterization used in LM. Turbulent transport becomes essentially 3-d at very high resolution, e.g. lateral exchange across cloud boundaries will be important for the evolution and organization of deep convection. A new 3-d turbulence scheme based on turbulent kinetic energy using a non-isotropic closure for fluxes has been developed and is currently implemented. A more comprehensive treatment of the ice-phase is also important when simulating deep clouds directly. In this aspect, we will upgrade the present microphysics scheme to include graupel (and later on hail) as an additional precipitation category.

It is planned to run the LMK every 3 hours from a continuous data assimilation stream based on the LM observational nudging technique (Fig.1). Such a rapid update cycle will require a short data cut-off (less than 30 min) and the successful use of available non-synoptic remote sensing data. In this respect, the assimilation of radar reflectivities using the latent heat nudging (LHN) technique is under evaluation and satellite data will be assimilated by using profiles obtained with 1-D var retrievals. The LHN will be based on 5-min reflectivities, which requires the development of corresponding data correction algorithms and data quality control methods as well as the development of a European composite.

Verification and validation of high-resolution model forecasts is very difficult as representativity errors, spatial and temporal variability, and lack of suitable data become important - resulting in a less meaningful applicability of traditional quantitative scores. In the LMK project, we will focus on the use of a radar simulation model (to compare directly with radar measurements) and pseudo satellite imaginary in various channels, combined with new verification tools such as pattern recognition methods. These activities go along with the development of appropriate diagnostic tools and derivation of necessary products for customers.

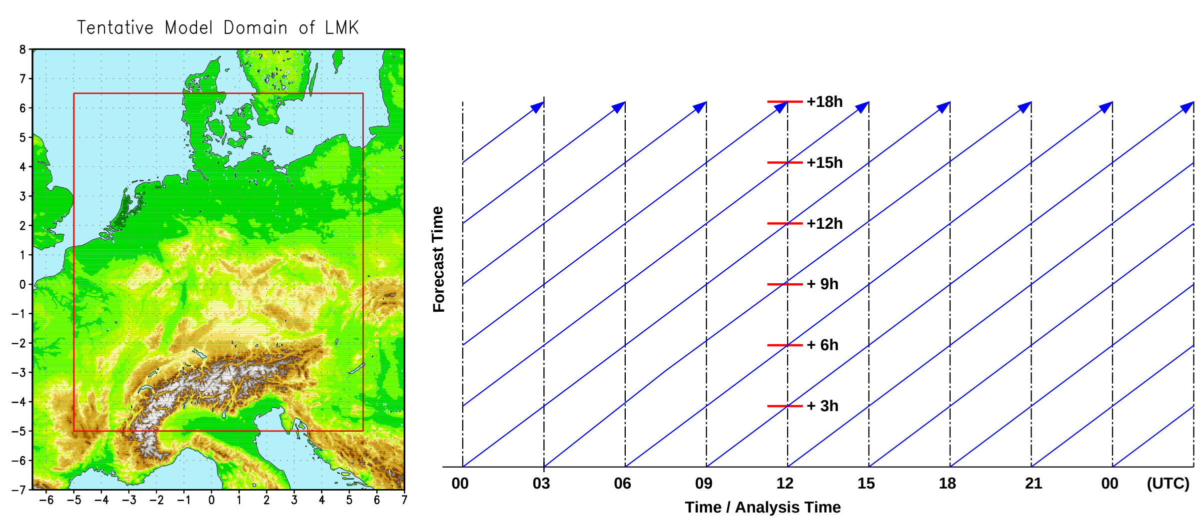

Figure 1: Tentative integration domain for LMK (left) and planned update cycle with forecasts every 3 hours (right). At a given time, 6 forecasts are available, allowing to generate some lagged averaging ensemble products.