Interpretation of the New High Resolution Model LMK

Heike Hoffmann, Volker Renner and Susanne Theis

Deutscher Wetterdienst, P.O. Box 100465, 63004 Offenbach a. M., Germany

1 Overview

In the framework of the so-called *Aktionsprogramm 2003* at DWD a new high resolution model for the very short range is being developed that is based on the non-hydrostatic limited area model LM. It is called LM Kürzestfrist (LMK) and will have a mesh size of 2 to 3 km which allows a direct calculation of phenomena on the meso-γ-scale. This is especially important for warning purposes. However, there is a problem with the short predictability limit of small scale features. When increasing model resolution the deterministic forecast of a single grid point is often not reliable and the random forecast error can be large. Therefore, the direct model output (DMO) of the LMK has to be interpreted statistically.
Within this project postprocessing methods for the weather parameters of the LMK are being developed. The three aims of the project are:

- to transform the direct model output for point forecasts (smoothed fields),
- to derive probability information for given thresholds and warning events,
- to develop a new weather interpretation for the LMK.

To suppress essentially unpredictable small scale structures, a simple spatial 5×5 averaging will be applied, followed by a re-calibration of the distribution of the smoothed field to the distribution of the direct model output for some of the elements (e.g. precipitation, wind gusts).
Moreover, exceedance probabilities for certain thresholds will be derived, especially with respect to the occurence of severe weather. In a first step these exceedance probabilities will be derived from individual LMK-forecasts by applying the Neighbourhood Method (NM) by Theis et al., 2003. This method was originally developed for the postprocessing of the weather parameters of the LM. The NM transforms the model output into a probabilistic forecast at a given grid point by assuming that points in a spatiotemporal neighbourhood constitute a sample of the forecast at the central grid point.
For this purpose also parameters from the weather interpretation (thunderstorms, fog, etc.) are required. The general task of the weather interpretation is to derive elements that are not calculated by the model directly and to translate the model information into the WMO weather code. The weather interpretation is operational for the LM (Renner 2002). Transfering the method to the LMK is not trivial, because the LMK is a convection resolving model. Therefore, model output parameters originating from the LM convection scheme are no longer available and have to be replaced by other promising parameters like the new LMK graupel, maximum radar reflectivity and maximum vertical velocity for instance.
In the following sections, verification results for the deterministic and probabilistic products as well as a short introduction to the weather interpretation are given.

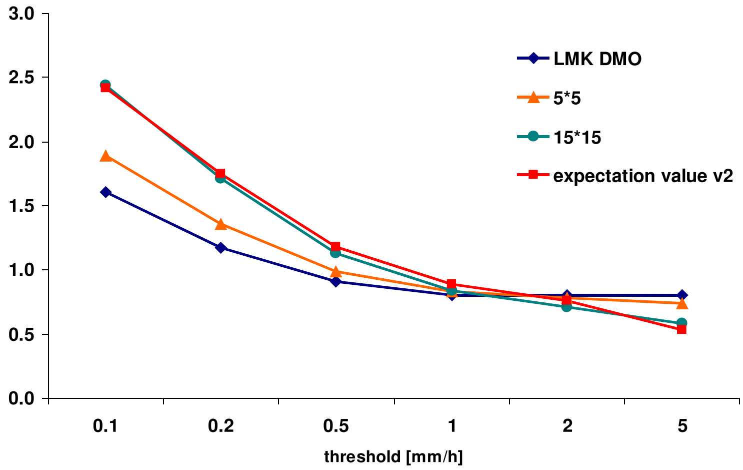

Figure 1: Frequency Bias (FBI) for different precipitation thresholds for the LMK DMO, for 5×5 and 15×15 spatial averaging and the expectation value of the NM version 2 in July 2004, 00 UTC forecasts.

2 Smoothed fields for deterministic point forecasts

High-resolution numerical weather predictions include noticeable stochastic elements even in the short range. In order to suppress essentially unpredictable small scale structures different smoothing techniques have been compared. Figure 1 shows the Frequency Biases (FBI) for the DMO, for simple spatial averaging over quadratic grid boxes of different size as well as the results for the expectation value of Version 2 (see chapter 3) of the Neighbourhood Method. Already for the DMO there is an overestimation of low precipitation amounts (FBI > 1) and an underestimation of high precipitation amounts (FBI < 1). This effect is additionally strengthened by the averaging. In extreme cases the FBI for the highest threshold of 5 mm/h can decrease to zero.
Figure 2 shows the Heidke Skill Scores for the same period. Here only for the highest threshold a degradation of the score due to the averaging is visible. There is however no overall improvement by using the NM instead of simple spatial averaging. Therefore we decided to apply the 5×5 averaging. As it is shown by the FBI, smoothing changes the distribution of the original field. We get more grid points with low precipitation and extreme values are more or less smoothed away. To revoke this change of the distribution a re-calibration algorithm was implemented that reconstitutes the distribution of the DMO also in the smoothed field. With this re-calibration method the obtained frequency bias is nearly the same as for the DMO (see Fig. 3). At this stage we only reconstitute the FBI of the DMO and abandon a re-calibration towards the real 'climate', because the LMK model is still in its development phase.

3 Probabilistic forecasts for weather warnings

A main goal of the LMK-project is the development of a model-based NWP system for very short range forecasts of severe weather especially related to deep moist convection and interactions with fine-scale topography.
Our forecasters have prepared a list of warning criteria that consists of threshold values. Whenever a certain threshold is exceeded, a warning is issued. Our aim is the derivation of

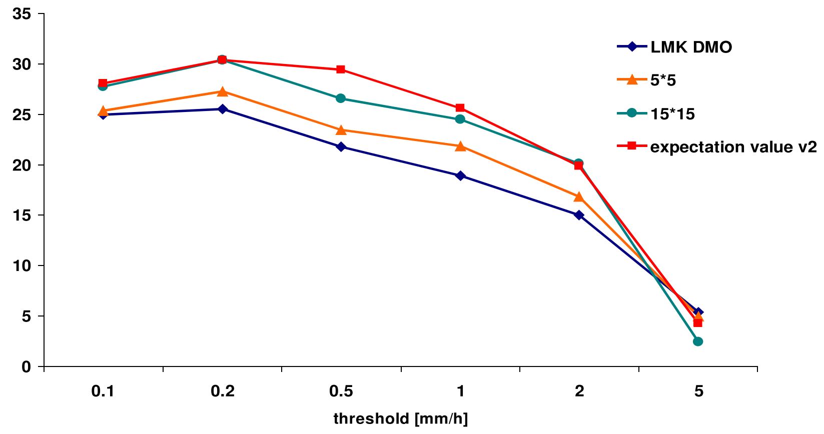

Figure 2: Heidke Skill Score (HSS) for different precipitation thresholds for the LMK DMO, for 5×5 and 15×15 spatial averaging and the expectation value of the NM in July 2004, 00 UTC forecasts.

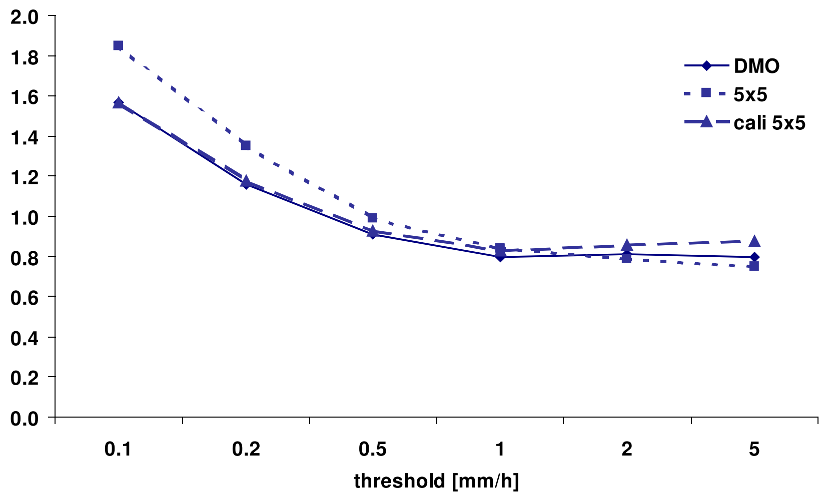

Figure 3: Frequency Bias (FBI) for different precipitation thresholds for the LMK DMO, for the 5×5 spatial averaging and the 5×5 smoothed and calibrated fields in July 2004, 00 UTC forecasts

probabilities for the exceedance of these thresholds.
We plan a two step approach to transform the deterministic LMK forecasts into probabilistic forecasts. In a first step we apply the Neighbourhood Method that uses the information from a spatiotemporal neighbourhood of a single model forecast. In a second step we use the information from the LMK forecasts that will be started every three hours - the so-called lagged average forecast ensemble (LAF).
Current work focusses on the neighbourhood approach. The method has originally been developed for the LM and is now applied to the LMK. To be able to compare the results obtained with the Neighbourhood Method for the LM and for the LMK, the forecasts of a two week period in January 2004 were processed with the NM with similar parameter settings. Figure 4 shows the Equitable Threat Score (ETS) of the 00 UTC forecasts. The dashed lines represent the results for the LM and the solid lines represent the LMK results. In addition to the direct model output, the expectation value and the median are drawn. The results are very similar with slightly better results for the LMK. Due to the critical issue

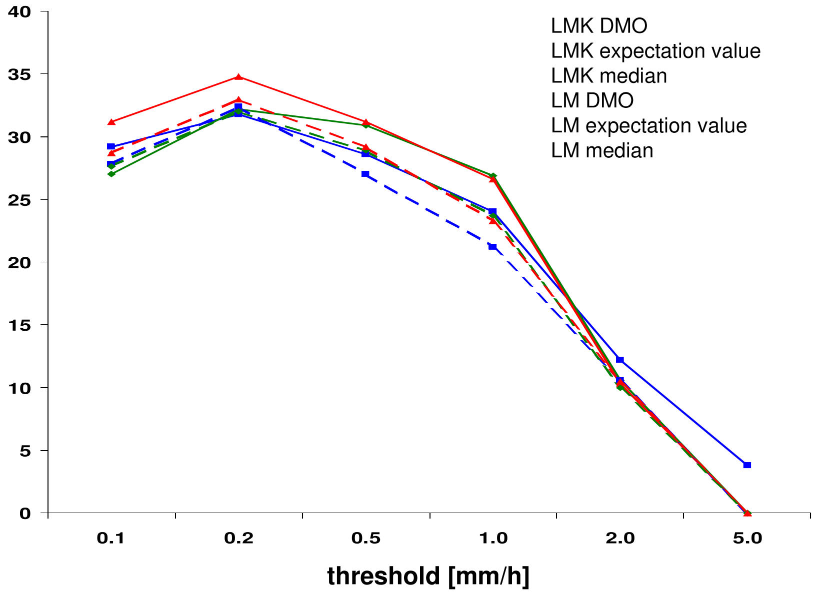

Figure 4: Equitable Threat Score (ETS) for different precipitation thresholds for the LM (dashed lines) and the LMK (solid lines) in January 2004, 00 UTC forecasts.

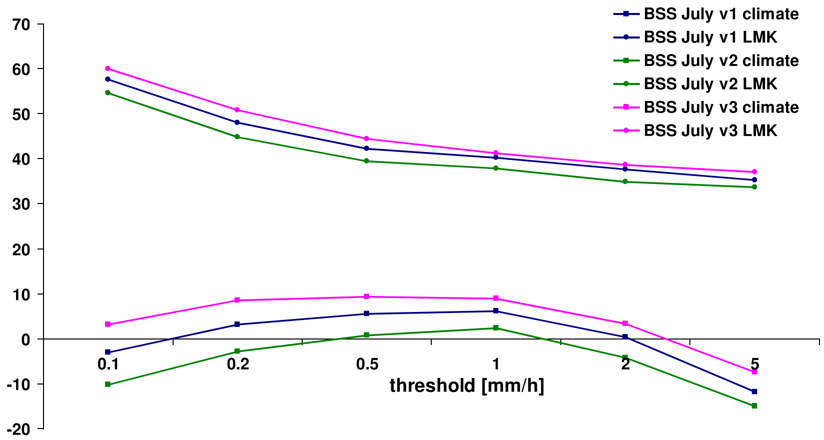

Figure 5: Brier Skill Scores (BSS) for different precipitation thresholds for different versions of the Neigbourhood Method, with 'climate' as reference forecast (lower lines) and with the LMK DMO as reference forecast (upper lines) in July 2004, 00 UTC forecasts.

of the double penalty for higher resolving models, the NM is expected to improve the LMK-DMO to larger extent than the LM-DMO. A higher resolution model predicts an observed small scale structure more realistically but often misplaced in space and time. The model is penalized twice, once for missing the actual feature and again for forecasting it where it does not occur. The NM aims at an alleviation of this problem.

The Brier Skill Score (see Fig. 5) is calculated for several versions of the Neighbourhood Method. The versions differ in the size of the temporal and spatial neighbourhood. The parameters of the used versions were:
vers_01: 3 time levels, radius of 10 grid increments (=28 km)
vers_02: 3 time levels, radius of 5 grid increments (=14 km)
vers_03: 3 time levels, radius of 15 grid increments (=42 km)

The BSS is calculated once with the 'climate' of the respective period as reference forecast and once with the DMO as a reference. However, the 'climate' is not known, so that we have to estimate it from the short verification period itself. In comparison with the real 'climate', better Brier Skill Scores would be achieved, because the estimated 'climate' reference contains too much specific information about the period. We also calculated the BSS with the DMO as reference forecast which leads to a significant improvement with BSS in the range of 0.4 to 0.6.

4 Weather Interpretation

Table 1: WMO code of weather

ww	Description
38	Drifting snow, slight or moderate
39	Drifting snow, heavy
45	Fog
48	Fog, despositing rime
50	Drizzle
56	Drizzle, freezing
60	Rain, sligth
63	Rain, moderate
65	Rain, heavy
66	Rain, freezing, slight
67	Rain, freezing, moderate or heavy
70	Snowfall, slight
73	Snowfall, moderate
75	Snowfall heavy
80	Rain shower(s), slight
81	Rain shower(s), moderate or heavy
82	Rain shower(s), violent
85	Snow shower(s), slight
86	Snow shower(s), moderate or heavy
95	Thunderstorm, slight or moderate
96	Thunderstorm, strong, wiht hail or gusts > 18 m/s or precipitation > 10 mm/h
99	Thunderstorm, heavy, with hail > 2 cm or gusts > 29 m/s or precipitation > 25 mm/h

The interpretation of model forecasts aims at the derivation of quantities that are not calculated by the model itself. The model information is translated into the WMO code of weather. The derived elements are given in Table 1. For the LMK there are a few more elements than for the LM, resulting from the list of warning criteria. The ww codes for strong and heavy thunderstorms (96 and 99) are not exactly the same as those from the WMO list but include the warning criteria for hail, gusts and precipitation. In the case of the LMK, which is a convection resolving model, the parameters produced by the convective parametrization scheme (convective precipitation, height of convective clouds, temperature at their upper limit) from the LM are missing and should be replaced by other promising parameters like graupel, radar reflectivity or maximum vertical wind velocity.
The weather interpretation is ready for pre-operational tests, but not tuned yet. Tuning is

set aside for the moment, because there is still a problem with the precipitation amount from the LMK in convective cases which is much too low compared to observations.

5 Conclusions and outlook

This study develops new methods to post-process the DMO of the LMK. Three aims are pursued: smoothing, probabilities and weather interpretation.
In terms of smoothing, a simple averaging over a 5×5 domain will be applied followed by a re-calibration of the distributions of the smoothed fields towards the distribution of the original field. Simple averaging atains roughly the same improvement as the NM with the same number of points in the neighbourhood.
In terms of probabilities, the BSS shows a significant improvement of the post-processed fields when compared to the deterministic DMO. The quality of the products improves with increasing size of the spatiotemporal neighbourhood. Only small improvements are achieved when compared to a 'climatological' forecast. However, this might be due to the 'climatology' which potentially leads to an unfair comparison.
In terms of weather interpretation, an operative version has been set up for the LMK.
Future work will deal with the fine-tuning of the weather interpretation and the derivation of probabilities for the full range of the above mentioned list of warning events (precipitation, gusts, thunderstorms, fog, etc.).

References

Renner, V., 2002: Interpretation. *Promet*, Jahrgang 28, Heft 1/2, Die neue Modellkette des DWD, pp 1-7.

Theis, S., Hense, A., Damrath U. and V. Renner, 2002: Ensemble Prediction and Statistical Postprocessing of Weather Parameters for the LM. *COSMO Newsletter*, No. 2, pp 152-161.

Theis, S., Hense, A., Damrath U. and V. Renner, 2003: Deriving Probabilistic Precipitation Forecasts from LM Simulations. *COSMO Newsletter*, No. 3, pp 209-220.

Theis, S.E., Hense, A. and U. Damrath, 2005: Probabilistic precipitation forecasts from a deterministic model: a pragmatic approach. *Meteorological Applications*, Vol. 12, No. 3, pp 257-268.