NUMERICAL SIMULATIONS OF THE ELBE FLOOD CASE: SENSITIVITY TO INITIAL AND BOUNDARY DATA

G. Hartjenstein[1], G. Zängl[1], G. Doms[2]†, H. Frank[2], U. Schättler[2]

[1]Meteorological Institute, University of Munich
[2]Deutscher Wetterdienst, Offenbach
E-mail: *gisela.hartjenstein@lrz.uni-muenchen.de*

Abstract: Numerical experiments with the model chain of the German Weather Service are conducted to find the reasons for the bad performance of the operational precipitation forecast in the case of the Elbe flood in August 2002. The sensitivity to initial and to boundary data as well as to a new precipitation scheme and the horizontal model resolution is inspected. The greatest improvement concerning the amount and location of the predicted precipitation field is achieved by using ECMWF analysis data as initial fields. Also, the implementation of a precipitation scheme that allows the rain to be advected with the wind exhibits a positive effect. Last, the better resolution of the global model improves the rainfall forecast, whereas the better resolution of the regional model produces worse results.

Keywords *– precipitation forecast, Elbe flood 2002*

1. INTRODUCTION

In August 2002 heavy precipitation led to a catastrophic flooding of the river Elbe in eastern Germany. Most of the rainfall occurred during the 36 hour period from 12 August, 00 UTC to 13 August, 12 UTC with a peak of 394 mm at a little village in the Erzgebirge, a mountain range at the Czech border. Most of the operational precipitation forecasts were very poor. Although the models indicated a Vb cyclone track six days in advance, the amount and the location of the heavy rainfall associated with the cyclone were not well predicted. Even the high-resolution Lokalmodell (LM) of the German Weather Service (DWD) failed in this respect. The operational forecast of DWD started at 12 UTC on August 11 yielded a wrong position of the precipitation maximum (about 150 km too far east; see Fig. 2a), implying that most of the rain should have fallen outside the Elbe river catchment. The forecast initialized 12 hours later predicted the position much better, but the intensity of the rainfall was still severely underestimated.
In this study we test to which extent the initial and boundary data as well as model physics and model resolution play a role in predicting the heavy precipitation in the case of the Elbe flood.

2. OBSERVATION VERSUS OPERATIONAL FORECAST

Fig. 1 shows the observed accumulated rainfall from 00UTC, 12 August to 12 UTC, 13 August (taken from Zängl, 2004). The field has been generated by interpolating rainfall data from 530 weather stations to a regular grid with a spacing of 3 km (see Zängl, 2004). The region shown covers about 200 km by 200 km, and the Erzgebirge mountain range is indicated by the 300m, 600m and 900m height contours. The maximum with more than 300 mm is located at the northern slope of the Erzgebirge. Fig. 2 shows the corresponding 36h rainfall predicted by LM based on the operational forecasts started a) 12 UTC, 11 August and b) 00 UTC, 12 August. In these figures the background geography is indicated by rivers (blue) and political borders (black). The border between Germany and Czechia is oriented along the ridge of the Erzgebirge from SW to NE. Comparison with the observed field shows that the earlier forecast grossly underestimates the precipitation in the Erzgebirge region, and that the whole precipitation field is located too far east. The 00 UTC forecast is significantly closer to the observations, but the rainfall maximum is still 40-50 km too far east.

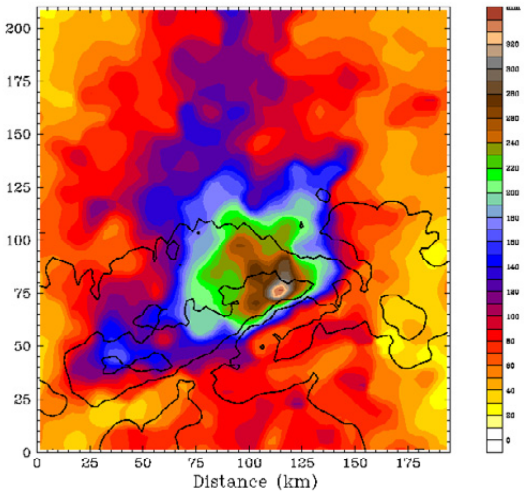

Figure 1. Observed accumulated rainfall from 00 UTC, 12 August to 12 UTC, 13 August (Zängl, 2004)

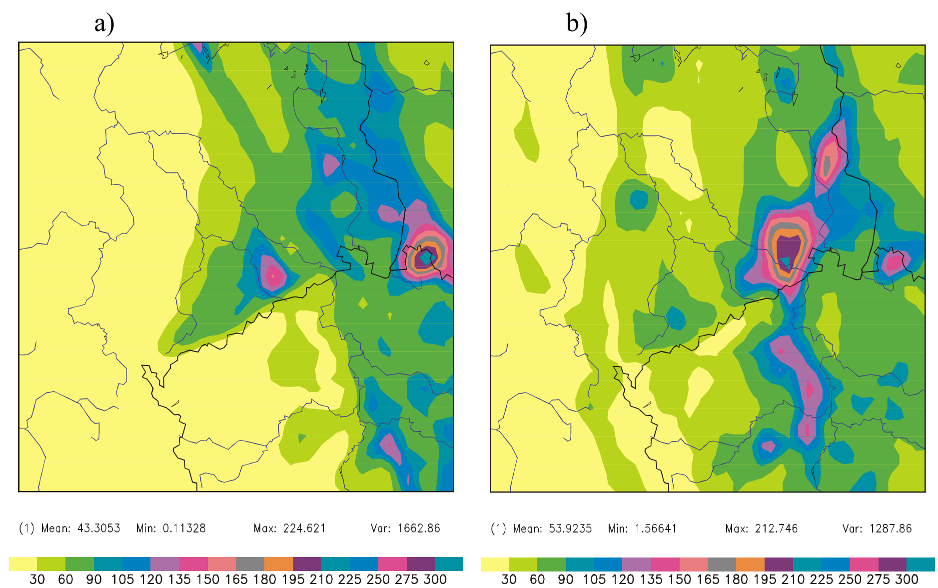

Figure 2. Operational 36h rainfall forecasts of LM. a) run started 12 UTC, 11 August and b) run started 00 UTC, 12 August.

3. SENSITIVITY TESTS

Several series of sensitivity experiments have been conducted in order to test the influence of the initial and boundary data, the initialization date, the horizontal resolution and the precipitation physics. The results are evaluated statistically in reference to the observations by calculating the station-averaged mean precipitation, the correlation coefficient, and the root mean square (rms) error of the 36 hour rainfall. Table 1 summarizes the results of all experiments which are discussed in the following. Obviously, the initialization of the LM has a large impact on the accuracy of the forecast.

3.1 Sensitivity to initial and boundary data

In general, all experiments started at 00 UTC on August 12 (denoted by: 1200 in Table 1) show a better performance than those started 12 hours earlier (in Table 1 denoted by: 1112). This is not surprising as the forecast accuracy generally tends to decrease with increasing lead time.
Operationally LM is driven by the GME, the global model of the DWD. Taking instead the forecasts from the ECMWF-model to drive the LM give much better results (EC-LM). In particular, the rainfall maximum which was situated too far east in the operational 1112 run moves close to the right position. Fig. 3 shows what we found to be the best of all experimental forecasts (EC-LMp-1200).
Our results suggest that it is mainly the 4DVAR data assimilation of ECMWF that accounts for this improvement, indicating that the 4DVAR scheme is superior to the initialization of the GME. A series of experiments in which the LM is driven by the GME model but the GME itself is initialized with the ECMWF analysis performs much better than the operational runs (denoted as EC-GME in Table 1). In particular, the EC-GME runs come close to the EC runs if the GME is operated at a horizontal resolution of 40 km (denoted as GME40), which is the operational resolution since 2004. The other GME experiments were conducted with a resolution of 60 km, which was the previous operational value.
Another test investigates the impact of the operational LM nudging analysis. We repeat the operational runs (OP-1112 and OP-1200), but omit the special initialization of LM (GME-LM series). Surprisingly, the more recent forecast (GME-LM-1200) shows a better performance than OP-1200, whereas run GME-LM-1112 is even worse than OP-1112. In the latter case, the correlation coefficient is even slightly negative. These results corroborate that the ECMWF analysis is clearly superior, at least in this particular case.

3.2 Sensitivity to precipitation scheme

In the LM version that was operational in 2002 the rain just falls down at that place where it is generated. We also conducted some experiments with a new precipitation scheme of LM. In this scheme the precipitation is advected by the wind (runs denoted by: LMp). Thanks to the new scheme, the location of the precipitation field shifts downwind into a better position, i.e. nearer to the crest line of the Erzgebirge. Although the total amount of the precipitation decreases with this scheme (implying a negative bias), the correlation with the observations is improved compared to runs with the old scheme, and the rms error is reduced (compare in Table 1 the EC-LM and the EC-GME-LM runs).

Table 1: Results of the statistical model validation

Experiment	average precipitation	correlation coefficient	rms error
Observation	93.3	---	---
OP-1112	51.5	0. 29	71.6
OP-1200	69.1	0.22	65.5
EC-LM-1112	84.1	0.65	45.4
EC-LM-1200	92.4	0.80	35.5
EC-LMp-1112	72.3	0.74	43.6
EC-LMp-1200	81.5	0.86	31.5
GME-LM-1112	67.1	-0.03	75.1
GME-LM-1200	76.8	0.42	59.7
LMK-1112	63.3	0.71	50.5
LMK-1200	71.5	0.77	42.3
EC-GME-LM-1112	73.9	0.51	54.3
EC-GME-LM-1200	106.6	0.71	46.3
EC-GME-LMp-1112	59.6	0.65	55.1
EC-GME-LMp-1200	89.7	0.78	36.7
EC-GME40-LMp-1112	66.2	0.78	45.1
EC-GME40-LMp-1200	82.5	0.85	32.5

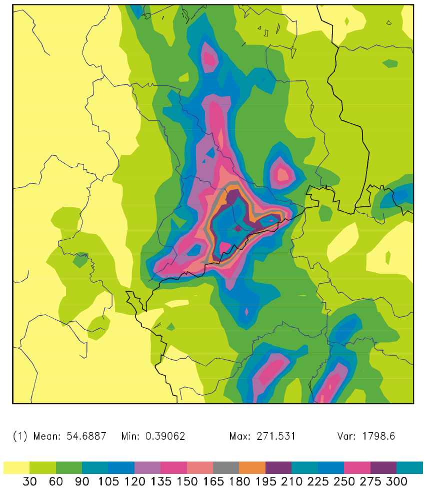

Figure 3. 36h rainfall forecast of LM driven by ECMWF forecast. The run started 00UTC, 12 August.

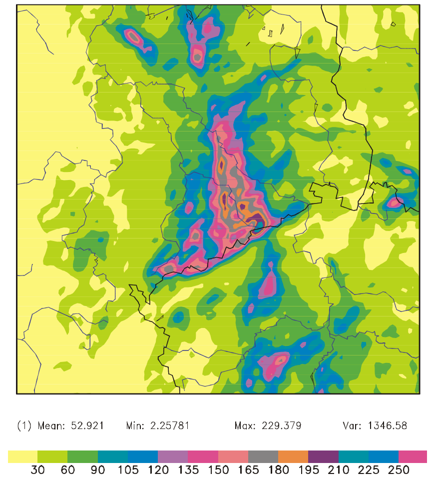

Figure 4. Same as Fig. 3, but for LMK-1200.

3.3 Sensitivity to horizontal resolution

Finally, we test the impact of refining the horizontal resolution of the LM to 2.8 km,which is envisaged as future operational resolution (referred to as LMK). The following experiments are driven by ECMWF analysis, which yielded the best results at 7 km resolution. In these runs, the parameterization of the convection is switched off. Obviously, the rain field now exhibits more small-scale structures (Fig. 4), but the overall precipitation amount is less than that of the corresponding EC-LM runs. This implies a larger negative bias (Table 1). Moreover, the correlation coefficient and the rms error are worse than for the corresponding 7-km experiments, indicating that a higher resolution does not necessarily mean a better performance. This is opposite to the results obtained by Zängl (2004) with the MM5 model. The reason for this behaviour may be found in the fact that the convection scheme used in LM tends to produce substantially more convective rain than the MM5 schemes. This compensates the tendency for under-predicting the precipitation at 7 km resolution but enhances the negative bias in the nested 2.8-km domain in which the convection scheme is deactivated.

4. CONCLUSIONS

We made a series of numerical experiments with the model chain of DWD to find the reason for the bad performance of the operational precipitation forecasts for the Elbe flood case in 2002. Most importantly, a pronounced improvement of the precipitation forecast is achieved when using ECMWF analysis data instead of the GME/LM analysis. On the other hand, the global model driving the LM does not seem to have a major impact, provided that its horizontal resolution is high enough. The implementation of the new precipitation scheme in LM, which allows the rain to be advected with the wind field, also generates improvements. In contrast, increasing the resolution of the LM produces worse results, which is probably due to the concomitant suppression of the convection parameterization.

REFERENCE

Zängl, G, 2004: Numerical simulations of the 12-13 August 2002 flooding event in eastern Germany, *Q.J.R.Meteorol.Soc.* **130**, 1921 - 1940.