A New Scheme for Diagnosing Near-Surface Convective Gusts

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1 Introduction

A new parameterization for diagnosing near-surface gusts generated by convection for use in the forecast models of the Deutscher Wetterdienst is presented. In the current formulation of the operational models the peak gusts are derived from the turbulence state in the atmospheric boundary layer. This works quite well in most winter situations in Central Europe, but in convective situations, mostly in summer, it fails. In the new scheme the maximum possible near-surface gusts generated by convection are estimated from the wind speed which is transported by the downdraft from higher levels to the ground and the wind speed associated to the downdraft itself.

2 iagnosing Near-Surface Convective Gusts

In the operational LM (Doms and Schättler 1999) the maximum gusts at 10 m above the ground are derived from the turbulence state in the atmospheric boundary layer:

$$V_{\mathrm{turb}} = (1 + \alpha\sqrt{C_{\mathrm{m}}})V_{\mathrm{KE}} \tag{1}$$

Here, C_{m} is the drag coefficient for momentum and V_{KE} the absolute wind speed at the lowest model level. The parameter α has been estimated by Majewski (pers. comm. 2002) from METAR gust reports from german airports. Reports from airports are expected to be of highest quality and most representative for an undisturbed area of at least a few squarekilometers because there is usually an open flat terrain available and therefore only minor alterations due to topographic effects are expected. For this reason, LM winds and gusts which are computed on a 7 km $\times$ 7 km grid are best to be compared to this kind of observations. α was estimated to $\alpha = 7.2$.

In order to capture 10-m gusts generated by convection, a new parameterization has been developed. It is based on the downdraft formulation of the convection scheme (Tiedtke 1989) in LM. Following Nakamura et al. (1996) in a slightly simplified way, the maximum possible 10-m gusts in convective situations in the model are estimated from the wind speed which is transported by the downdraft from higher levels to the ground and the wind speed associated to the downdraft itself:

$$V_{\mathrm{conv}} = \sqrt{\beta \int_0^H 2g\frac{\Delta\Theta}{\Theta}\mathrm{dz} + V(H)^2} \tag{2}$$

Here, $\Delta\Theta$ is the potential temperature deficit in the downdraft, Θ is the potential temperature of the surroundings, $V(H)$ is the wind speed at height H where the downdraft starts and g is the acceleration of gravity. We estimated the parameter β in a number of case studies to $\beta = 0.2$.

Now, the new maximum possible 10-m gusts in LM are computed as the maximum of these two components:

$$V_{\mathrm{gust}} = \max(V_{\mathrm{turb}}, V_{\mathrm{conv}}) \tag{3}$$

3 The Berlin Storm

The new parameterization has been tested in a number of case studies. An extreme case is presented here, the Berlin storm which occured on 10 July 2002.

The weather situation in Germany on this day was dominated by a broad front of thunderstorms moving across the country in northeastern direction, reaching Brandenburg and Berlin in the evening hours. The Figures 1–4 show the 10-m gusts from the operational forecast of LM and compare them to the gusts predicted by the new parameterization. Both forecasts were started on 09 July 2002 at 00 UTC, hence the event took place on the second forecast day.

Figure 1 compares the forecasts of the two model versions on 09 July 2002 at 00 UTC + 41h, i. e. 17 UTC on 10 July 2002. The reference period for the maximum gusts which are reported at this hour is the preceding hour, this means the period 16–17 UTC. The front which extends from north to south across Germany is clearly visible in both simulations. But in most parts of Eastern Germany not very high wind peaks of up to about 10 m/s were operationally forecasted. In contrast to this, the forecast with the modified model version shows significant stronger gusts of at least 15 m/s. In large regions of Eastern Europe even higher gusts of partly more than 20 m/s are forecasted. These are convective gusts that are diagnosed by the new parameterization in regions of convective activity in the model, here in the pre-frontal region. The differences between the two model versions are shown in Fig. 2 (right panel).

In order to get an idea of the forecast quality, SYNOP observations have been printed into the maps in Fig. 1. Only stations at german airports were used. The operational forecast shows a reasonable agreement with the observations in the region of the front, in the pre-

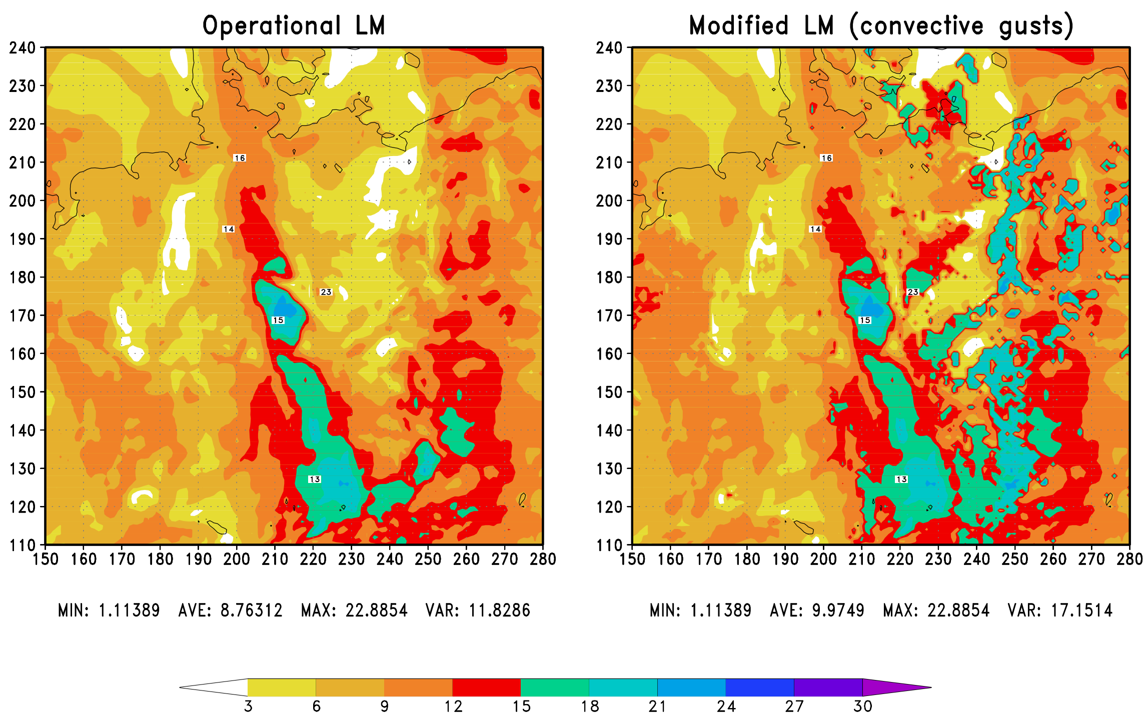

Figure 1: Comparison of 10-m gusts (m/s) on 9 July 2002, 00 UTC + 41h, as forecasted by the operational LM and by the modified LM using the new parameterization of convective gusts. The numbers in the maps are observations.

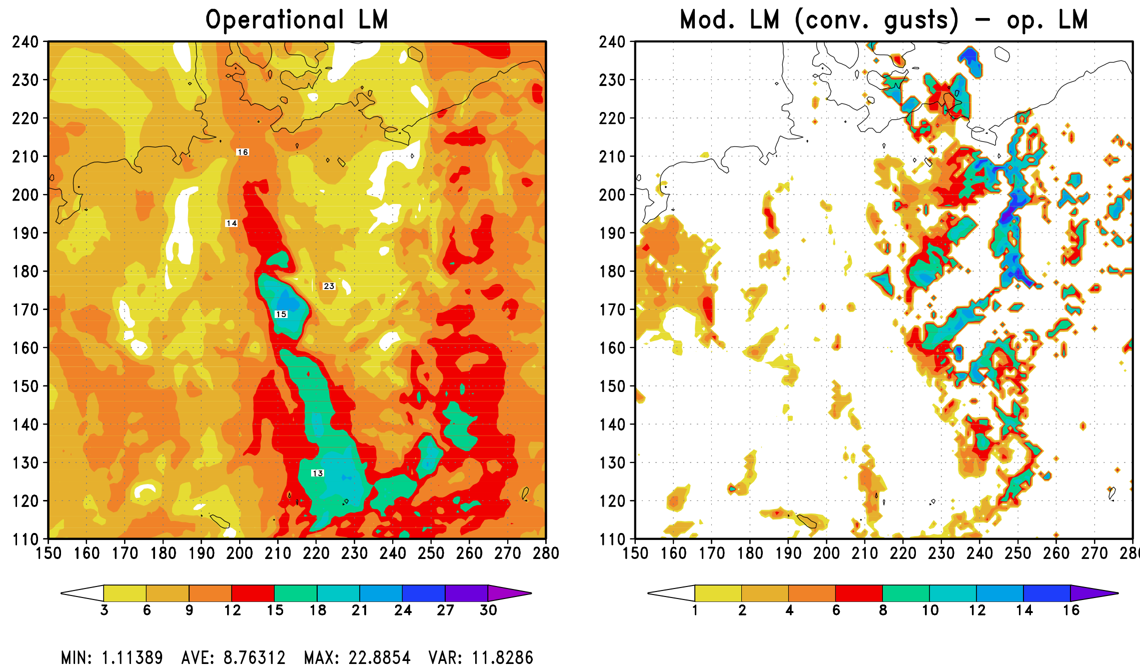

Figure 2: 10-m gusts (m/s) on 9 July 2002, 00 UTC + 41h, as forecasted by the operational LM (left) and the difference between the modified and the operational LM (right). The numbers in the left map are observations.

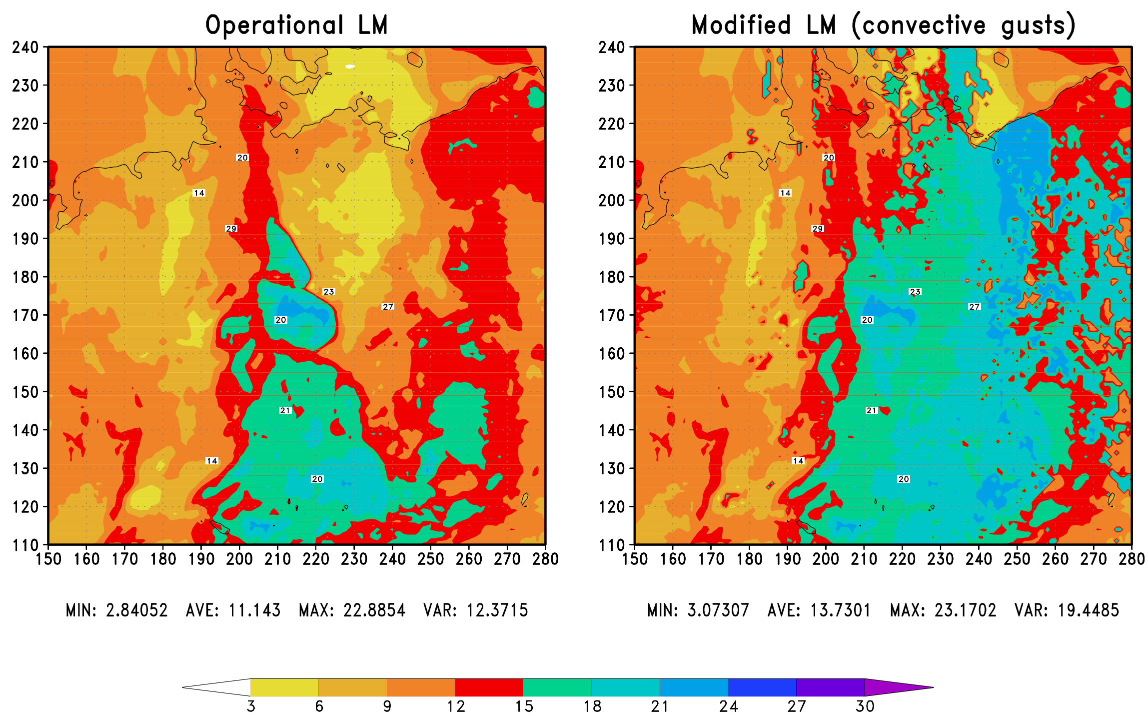

Figure 3: Comparison of 10-m gusts (m/s) on 9 July 2002, 00 UTC + 37h-42h, as forecasted by the operational LM and by the modified LM using the new parameterization of convective gusts. The numbers in the maps are observations.

frontal region the model underestimates the gusts. For instance, in Leipzig 23 m/s were observed, but only about 9 m/s were forecasted. The new gust parameterization predicts 15–18 m/s which is much closer to the observation.

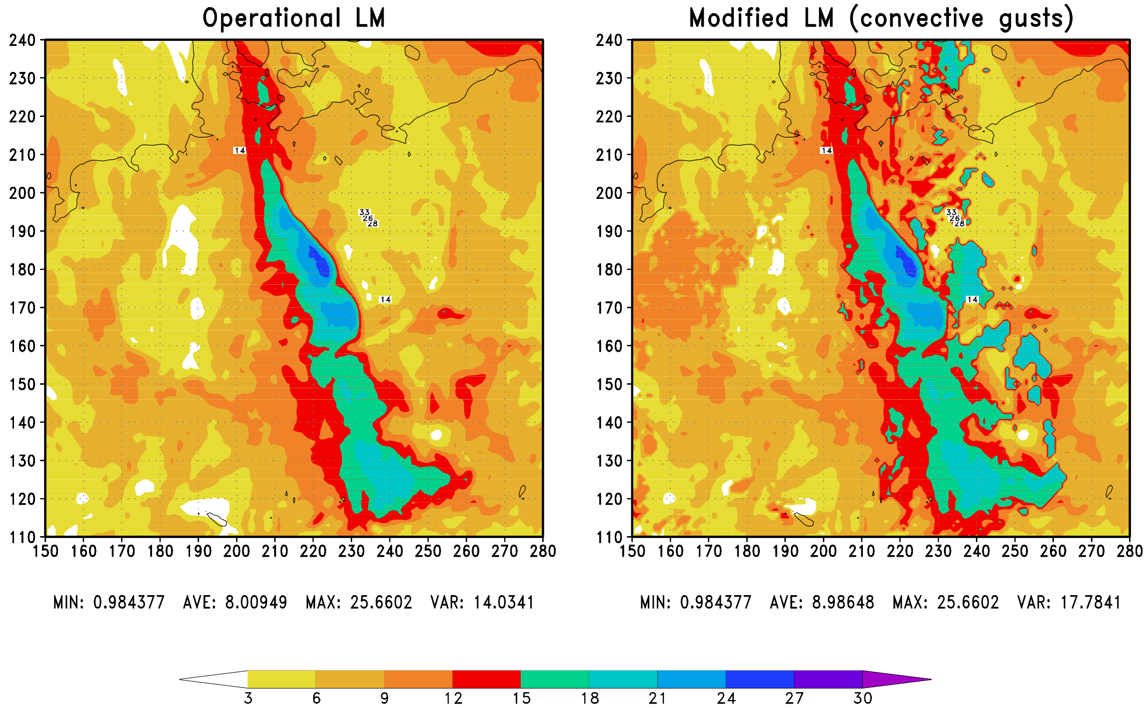

Figure 4: Comparison of 10-m gusts (m/s) on 9 July 2002, 00 UTC + 43h, as forecasted by the operational LM and by the modified LM using the new parameterization of convective gusts. The numbers in the maps are observations.

Figure 3 shows the gusts on 10 July 2002 at 18 UTC. SYNOP gust observations which are reported at this hour refer to the preceding 6 hours, i. e. 12–18 UTC. Again, the operational forecast is satisfying in the front, east of it the gusts are underestimated. The new model version is significantly closer to the observations, this is particularly obvious for the observed gusts of 23 m/s and 27 m/s in Leipzig and Dresden.

During the following hour, 18–19 UTC, the gusts in Berlin reached their peak values on this day. Berlin-Tegel reported 33 m/s, the two other Berlin airports Tempelhof and Schönefeld reported 26 m/s and 28 m/s, respectively. As Fig. 4 shows there were no hints at all for these peak values in the operational forecast. The new parameterization at least provides clear signals for convective gusts in this region. In the context of gust forecasts in the preceding hours one would expect that the new formulation would allow for a more precise warning by the forecasters.

4 Conclusions

A new parameterization for diagnosing near-surface gusts generated by convection for use in the forecast models of the Deutscher Wetterdienst has been presented. In this new scheme the maximum possible near-surface gusts generated by convection are estimated from the wind speed which is transported by the downdraft from higher levels to the ground and the wind speed associated to the downdraft itself.

We conclude that the new scheme appears to be promising diagnostic allowing for improved gust forecasts. As soon as the forecasters got some experiences with this new kind of information, it should allow them to much more reliably detect near-surface gusts in convective situations.

References

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