Revision of the Turbulent Gust Diagnostics in the COSMO Model

Jan-Peter Schulz

Deutscher Wetterdienst, Offenbach a. M., Germany

1 Introduction

Verification has shown that the gusts in analyses and forecasts of the COSMO-EU model are systematically overestimated (e.g. Göber 2007). This is most obvious in storm systems during the winter season. COSMO-EU, formerly known as LME (see e.g. Schulz 2006), is an operational implementation of the COSMO model (Doms and Schättler 2002) at the German Weather Service (DWD), covering almost all Europe using a mesh size of 7 km.

The gust formulation of COSMO consists of two components: turbulent gusts and convective gusts (Schulz and Heise 2003). An analysis has shown that the turbulent gusts are responsible for the overestimation in the cases considered here. A revised formulation of the turbulent gust diagnostics is presented here which considerable reduces the bias in a number of case studies as well as in a numerical experiment with a length of a few weeks.

2 Diagnosing near-surface turbulent gusts

In the COSMO model the maximum turbulent gusts at 10 m above the ground are derived from the turbulence state in the atmospheric boundary layer, using the absolute speed of the near-surface mean wind V_m and its standard deviation σ:

$$V_\mathrm{turb} = V_\mathrm{m} + \alpha\ \sigma \tag{1}$$

$$V_\mathrm{turb} = V_\mathrm{m} + \alpha\ 2.4\, u_* \tag{2}$$

$$V_\mathrm{turb} = V_\mathrm{m} + \alpha\ 2.4\, \sqrt{C_\mathrm{D}}\, V_\mathrm{m} \tag{3}$$

The step from (1) to (2) uses an empirical relation between σ and the friction velocity u_*. The value 2.4 is given for instance in Panofsky and Dutton (1984), it is a mean empirical value derived from several observation campaigns. C_D is the drag coefficient for momentum. The parameter α has been estimated to $\alpha = 3$.

In the original version of the COSMO model (Doms and Schättler 2002) as of 1999 (35 levels, lowest one about 30 m above the ground) the absolute mean wind speed at the lowest level was taken for V_m in (3). When introducing the 40 vertical levels (Schulz 2006) in 2005 (lowest one about 10 m above the ground) the formulation was adapted, in order to keep the tuning, by interpolating V_m at 30 m from the two lowest model levels (while computing the friction velocity by definition from the speed at the lowest model level). The same procedure had been done in the global model GME before when changing to the 40 level version, and it was repeated here in order to stay consistent with the driving model. But this formulation leads to the overestimation of the gusts in COSMO-EU.

In the revised version presented here the wind speed at 10 m above the ground is taken for V_m, while an effort was made to keep this 10-m wind independent of the vertical discretisation. α is kept at a value of 3.

3 Case studies

Six storm cases in the first half of 2007 were identified from the reports of the DWD department issuing the weather warnings. In all cases COSMO-EU has overestimated the gusts. They have all been tested with the revised version of the model, four cases are presented here.

When testing the gust diagnostics the problem arises that the COSMO model also shows a tendency to overestimate the intensity of low pressure systems in terms of core pressure and pressure gradient. This could already explain the overestimation of the gusts. In order to exclude this additional uncertainty only cases are considered where the simulated pressure field is very close to the observed one, which is usually the case for the analyses and the very first forecast hours. It turned out that in all six cases the overestimation of the gusts already appears in the first forecast hour.

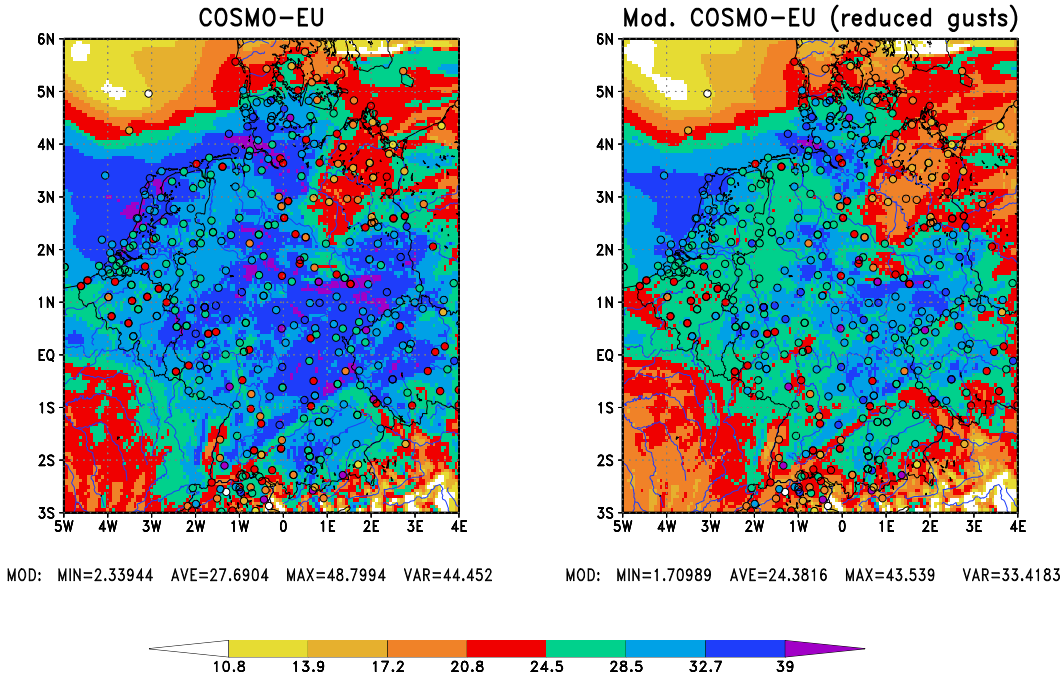

Figure 1: Comparison of 10-m gusts (m/s) on 18 Jan. 2007, 18 UTC + 01h, as forecasted by the operational COSMO-EU and by the modified COSMO-EU using the revised diagnostics for turbulent gusts. The circles in the maps are observations.

The first case presented here occured on 18 Jan. 2007. It got the name “Kyrill” and received probably the highest attention in German media of all storms during this winter season due to its wind speeds, the spatial extent and the destructions it caused. Figure 1 shows the 10-m gusts from the operational forecast of COSMO-EU and compares them to the gusts predicted by the revised model version. The forecasts on 18 Jan. 2007 at 18 UTC + 01h were selected, this was the time when the gusts reached their peak values in some parts of southern and western Germany. The reference period for the maximum gusts which are reported at this hour is the preceding hour, this means the period 18–19 UTC. The operational forecast shows wide areas in Germany and the surrounding countries with gusts of 12 Bft (dark blue and purple) or 11 Bft (blue). In the revised model version these gusts are reduced by about 1 Bft, turning dark blue areas into blue, and blue areas into green. In the other speed intervals we find a similar behaviour.

The overestimation of the gusts in the operational forecast becomes very obvious when comparing it to the observations, indicated by coloured circles in the maps. All available

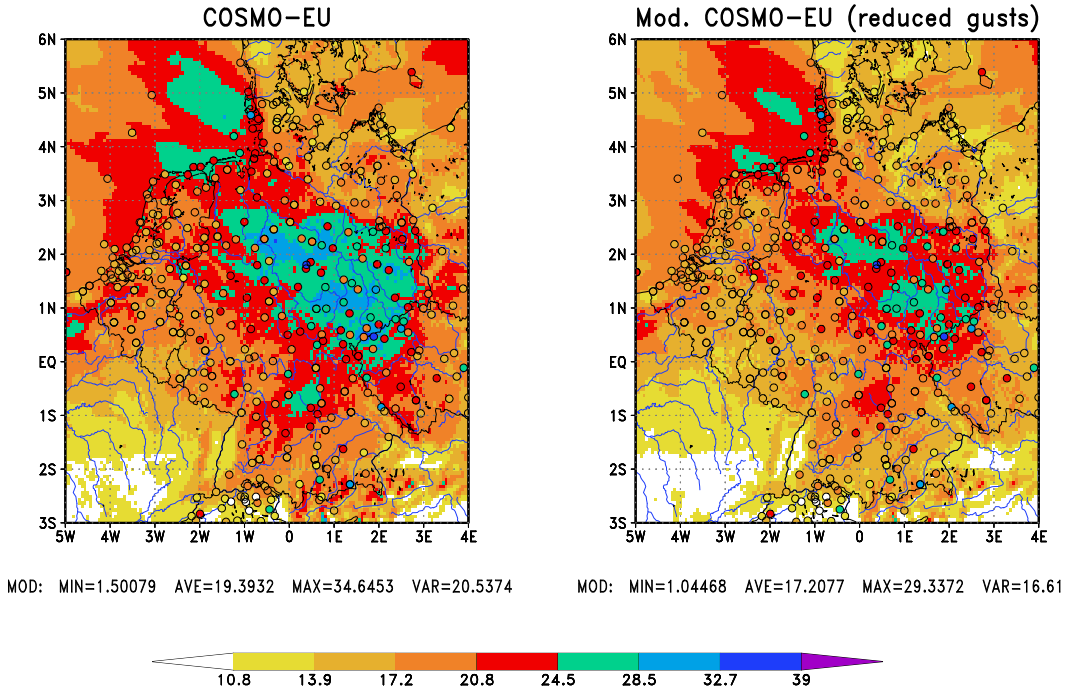

Figure 2: Comparison of 10-m gusts (m/s) on 21 Jan. 2007, 12 UTC + 01h, as forecasted by the operational COSMO-EU and by the modified COSMO-EU using the revised diagnostics for turbulent gusts. The circles in the maps are observations.

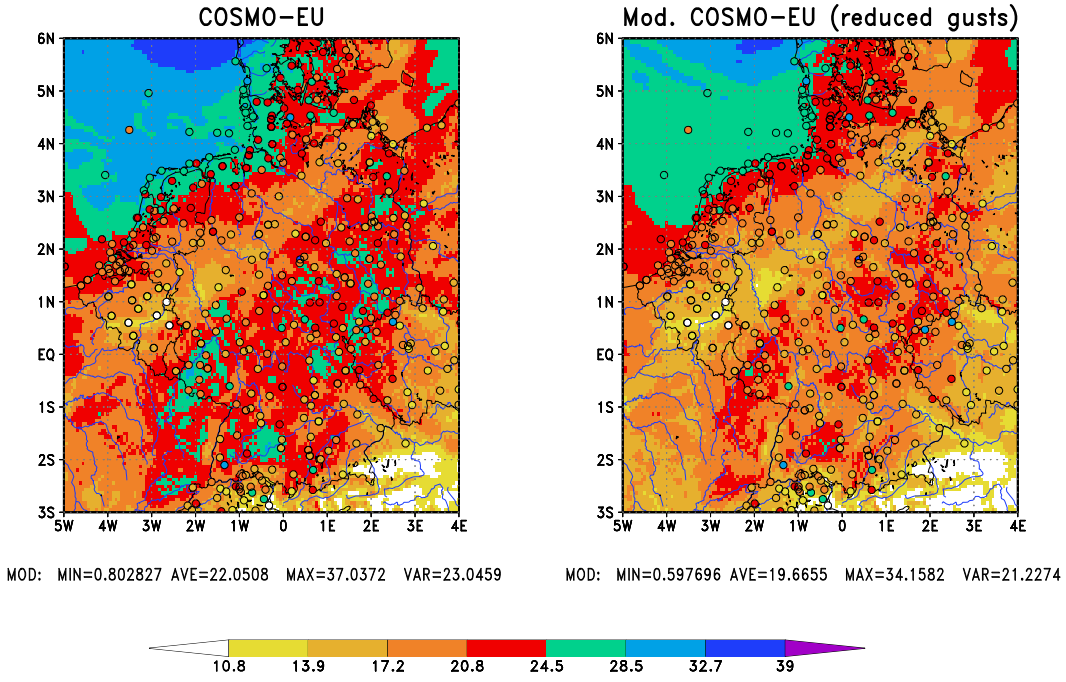

Figure 3: Comparison of 10-m gusts (m/s) on 18 Mar. 2007, 12 UTC + 01h, as forecasted by the operational COSMO-EU and by the modified COSMO-EU using the revised diagnostics for turbulent gusts. The circles in the maps are observations.

SYNOP observations were used here. The overestimation reaches from 1 Bft (e.g. green circles on blue shading) up to 3 Bft (red circles on dark blue shading). In the revised model version the gusts are reduced which leads to a considerable improvement, model and observations match much better at most places.

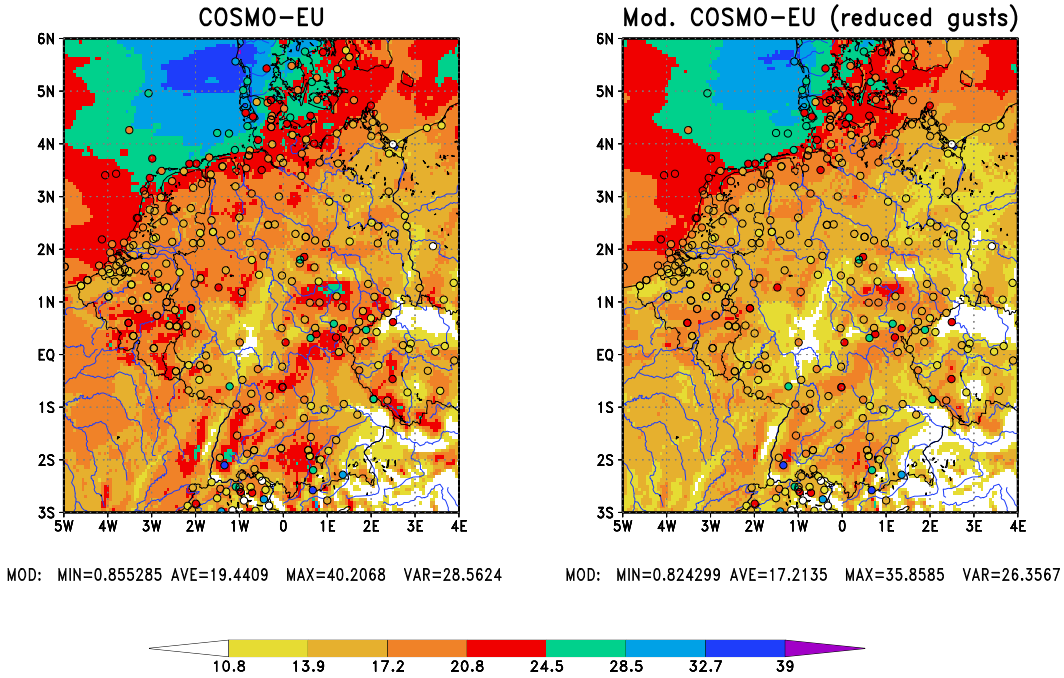

Figure 4: Comparison of 10-m gusts (m/s) on 01 Jan. 2007, 06 UTC + 01h, as forecasted by the operational COSMO-EU and by the modified COSMO-EU using the revised diagnostics for turbulent gusts. The circles in the maps are observations.

The three other cases (Figs. 2-4) show generally a similar behaviour. The operational forecasts were overestimating the gusts, although less pronounced than for the Kyrill case, while the reduced gusts of the revised model are in better agreement with the observations at most places. There are a few stations in mountainous areas which report much higher gust values than forecasted by both model versions. The reason is that these observations do most likely not fulfill the standards for measuring 10-m gusts, which would mean that they were representative for an undisturbed area of at least a few squarekilometers, providing an open flat terrain causing only minor alterations due to topographic effects. If this not the case it can not be expected that the COSMO-EU gusts which are computed on a 7 km $\times$ 7 km grid are comparable to this kind of observations.

4 Numerical parallel experiment

Besides the case studies the new formulation was also tested in a continuous numerical parallel experiment, repeating the operational forecasts. The period was 10 – 25 Jan. 2007. Figure 5 shows the observed mean gusts and also the observed ratio of mean gusts divided by mean wind speed, both versus mean wind speed. In this figure all available reports from 192 sites in Germany at heights between 0 and 500 m were used. Furthermore, the figure shows a systematic overestimation of the gusts by the operational COSMO-EU, as known from the case studies. On the other hand, the revised model version is almost free of bias.

There seems to be a little drawback for the high gusts which appear to be slightly underestimated in the revised model version. This behaviour seems to be caused by a few mountainous stations as discussed in the section before. Returning to the argument of representativeness, gust reports from airports would be expected to be of highest quality and most representative for an undisturbed area of at least a few squarekilometers and therefore best to be compared to a mesoscale model. This is done in Fig. 6 which shows the same as Fig. 5,

but only for observations at 17 German airports. With regard to these observations also the revised diagnostics still slightly overestimates the gusts. This is favourable in terms of the warning process which usually prefers a slight overwarning by the model.

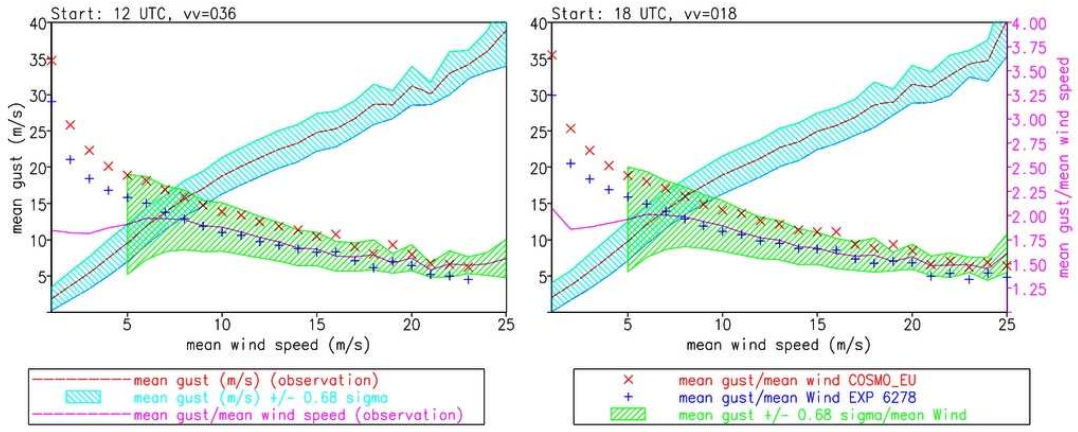

Figure 5: Observed mean gusts versus mean wind speed (blue shading, scale at left ordinate), observed ratio of mean gusts divided by mean wind speed, also versus mean wind speed (green shading, scale at right ordinate), both for the period 10 – 25 Jan. 2007. All available reports from 192 sites in Germany at heights between 0 and 500 m were used here. The red x-signs indicate the ratio of mean gusts devided by mean wind speed in the forecasts of the operational COSMO-EU, showing a systematic overestimation of the gusts. The blue plus-signs show the same ratio but for the COSMO-EU version with revised turbulent gust diagnostics. The latter is almost free of bias. This figure was provided by U. Damrath, DWD.

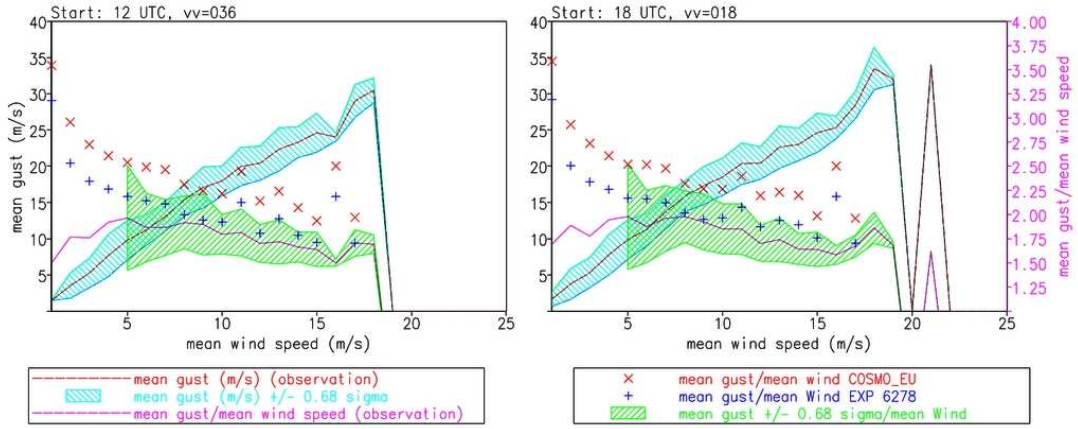

Figure 6: Same as Fig. 5, but only for observations at 17 German airports (below 500 m). With regard to these observations also the revised diagnostics still slightly overestimates the gusts, which is favourable in terms of the warning process. This figure was provided by U. Damrath, DWD.

5 Conclusions

Six storm cases were identified in the first half of 2007 in which COSMO-EU has overestimated the gusts. In two cases the overestimation is low (up to 1 Bft), in the four other cases it is higher (up to 2-3 Bft). In all cases the overestimation of the gusts already appears in the very first forecast hours when the pressure field is still in very good agreement with the

analysis. Hence, the overestimation is not simply a consequence of a systematic deviation from the real pressure field which may occur during the course of the forecast.

A revised formulation for diagnosing near-surface turbulent gusts for use in the COSMO model has been presented. It has been successfully tested with the selected six cases. The verification of a continuous numerical experiment of a few weeks length shows a good improvement as well.

References

Doms, G. and U. Schättler, 2002: A description of the nonhydrostatic regional model LM. Part I: Dynamics and Numerics. *Deutscher Wetterdienst*, Offenbach, 134 pp. (Available at: www.cosmo-model.org).

Göber, M., 2007: Comparing peaches and apples – on the accuracy of weather warning issued by forecasters and the accuracy of the model guidance. Presentation at the 3rd International Verification Methods Workshop, 31 Jan. – 2 Feb. 2007, Reading. (Available at: http://www.ecmwf.int/newsevents/meetings/workshops/2007/jwgv/workshop_presentations/-M_Goeber.pdf)

Panofsky, H. A. and J. A. Dutton, 1984: *Atmospheric turbulence – models and methods for engineering applications*. Wiley Interscience, New York, 397 pp.

Schulz, J.-P., 2006: The new Lokal-Modell LME of the German Weather Service. *COSMO Newsletter*, **6**, 210–212. (Available at: www.cosmo-model.org).

Schulz, J.-P. and E. Heise, 2003: A new scheme for diagnosing near-surface convective gusts. *COSMO Newsletter*, **3**, 221–225. (Available at: www.cosmo-model.org).