The importance of small-scale analysis on the forecasts of COSMO-DE

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1 Introduction

With respect to the development of a new assimilation method for COSMO (within the COSMO priority project KENDA) the question arises, which benefit can be expected from small-scale details in the analysis on the quality of COSMO-DE forecasts. To address this question three experiments were conducted for a 2-week-convective summer period in June 2007. This period was dominated by weak anti-cyclonic conditions with frequent air-mass convection in the afternoon. A convective period was chosen, small-scale features in the analysis are expected to be more relevant than in periods governed by large scale circulation.

2 Experimental Setup

Three experiments were conducted, each of them starting forecasts at 00, 06, 12 and 18 UTC (denoted hereafter as 00-UTC, 06-UTC, 12-UTC and 18-UTC runs) from different analyses:

1. starting from an interpolated COSMO-EU analysis,
2. starting from a COSMO-DE analysis with LHN of radar derived rain rates,
3. starting from a COSMO-DE analysis without LHN of radar derived rain rates.

All experiments were performed with COSMO model version 4.8, using the new setting of the PBL parameters suggested by Seifert et al. (2008). The boundary conditions for the forecasts are the one's of the operational setup, which means there were derived from 3 hour old COSMO-EU forecasts. To achieve the best comparability the soil moisture at the beginning of each forecast and analysis run was identical in all 3 experiments by setting equal to the first experiment (i.e. interpolated analysis). Furthermore all forecast were started from the respective analysis of the assimilation cycle in contrast to the operational setup, where a forecast starts from its time-critical analysis. This means that the data cut off is considerably larger than in the operational setup and the set of observations used in the three different analyses of this study are nearly the same.

3 Results

The model results were verified against different observation types, i.e. ground base SYNOP stations, radiosondes, radar derived precipitation rates and integrated water vapour measured by GPS. The verification results in general indicated that the more small-scale feautures are represented within the analysis the better are the forecasts. That means, model runs assimilating radar derived rain rates are the best ones followed by the runs starting from the small-scale analysis. Forecast starting from an interpolated analysis were found to have the lowest quality. In some situations the forecast quality is quite similar. But in cases where the weather conditions are dominated by small-scale phenomena the differences are biggest. This leads to the fact, that 00-UTC or 06-UTC runs are more comparable than 12-UTC or 18-UTC runs. This may be related to the fact, that more benefit is found from the small-scale analysis in 12-UTC or 18-UTC runs than for 00-UTC and 06-UTC runs.

- verification against SYNOP observations:
  Both experiments starting from small-scale analyses tend to improve the quality of the forecast. Especially in the first forecast hours the quality is generally better. Both, RMSE and BIAS are improved. The biggest improvement due to small-scale analyses is found for PMSL (see fig. 1) and 2m temperature. Then forecasts tend to be warmer in 2m temperature and lower in PMSL. The results suggest that the improvements are largest for 18-UTC and 00-UTC runs, whereas the improvements in 6-UTC or 12-UTC runs are smaller, but still present.

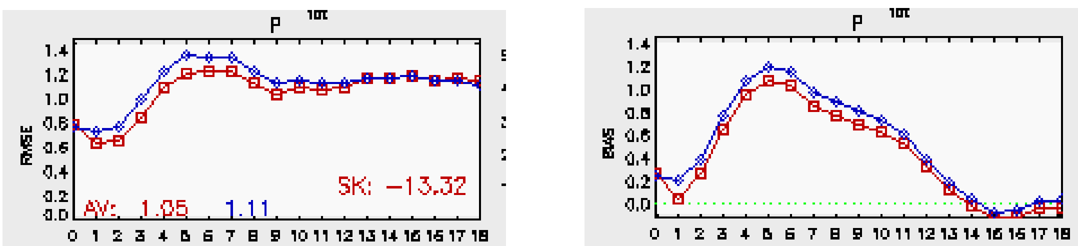

Figure 1: RMSE (left) and BIAS (right) in PMSL against SYNOP measurements over forecast time. 00 UTC forecasts starting from interpolated COSMO-EU analysis (blue) and COSMO-DE analysis (red).

- verification against radiosondes,
  The upper air verification (see fig. 2) depicts the largest difference between the small-scale analyses and the coarse-scale analysis within the mid troposphere. Here the coarse-scale analysis verifies worse and tends to be more cold and wet. This is more pronounced at 12 UTC than at 00 UTC. Also the vertical extent of the difference is greater at noon

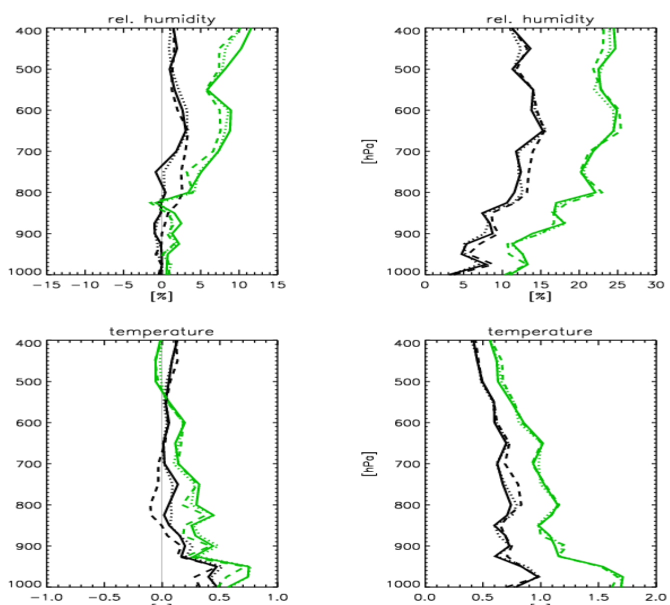

Figure 2: Verification against radio sondes at 12 UTC: Bias (left) and RMSE (right) for relative humidity (upper panels) and temperature (lower panels) at analysis time (black lines) and +12h forecast time (green): bold lines COSMO-DE analysis with LHN, dotted lines COSMO-DE analysis without LHN, dashed lines interpolated COSMO-EU analysis.

and includes the boundary layer. All differences have almost vanished after 12 hour forecast time.

- verification against radar derived rain rates:

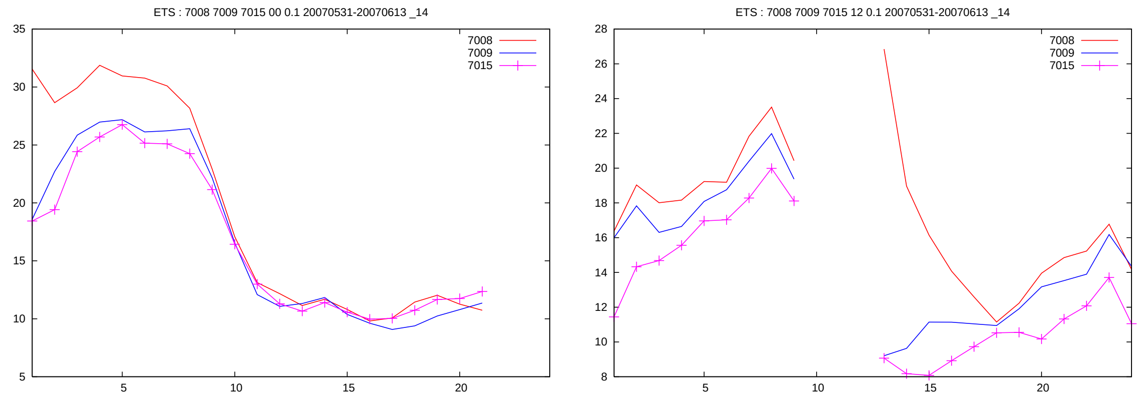

Figure 3: Equitable threat scores against radar observations (threshold of 0.1 mm/h) for 00-UTC runs (left) and 12-UTC runs (right): COSMO-DE analysis with LHN (red), COSMO-DE analysis without LHN (blue), interpolated COSMO-EU analysis (magenta plus sign).

Equitable threat score (fig. 3) show the ability of the LHN analysis to greatly improve the forecast within the first few hours (up to 6 hours, seefig. 3). This agrees well with the results from former studies (Stephan et al. (2008)). Even the small-scale analysis without LHN provides better forecast quality than the coarse-scale analysis. The quality is improved most in the 12-UTC and 18-UTC runs. Furthermore all experiments show a strong dependency of forecasting the diurnal cycle of precipitation on the starting time of the forecast (see fig. 4). 12-UTC runs are not able to produce an acceptable diurnal cycle and in particular they tend to miss the peak of convective precipitation in the afternoon. All other forecasts show better results and the older the forecast the more the modell seems to be able to simulate that peak.

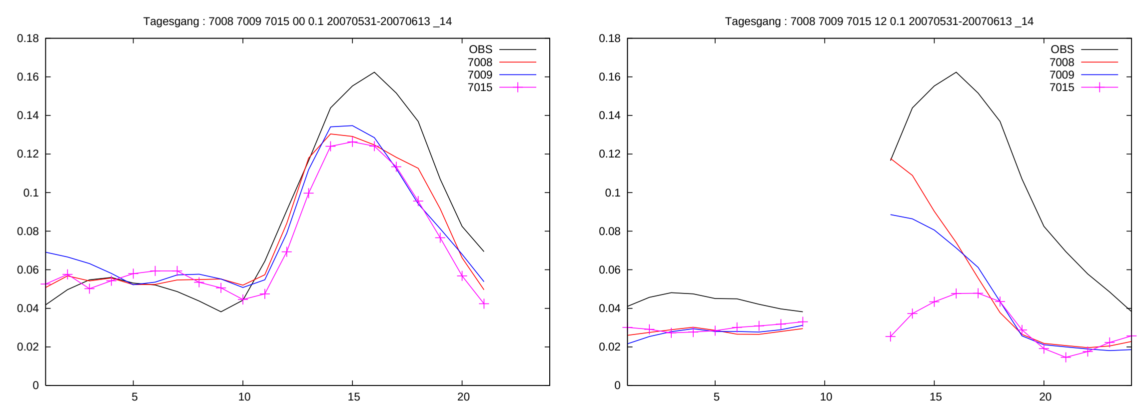

Figure 4: Averaged diurnal cycle of precipitation rate for 00-UTC runs (left) and the 12-UTC runs (right) starting on: COSMO-DE analysis with LHN (red), COSMO-DE analysis without LHN (blue), interpolated COSMO-EU analysis (magenta plus sign). The black line depicts the observations.

Also with respect to the diurnal cycle, the small-scale analysis, and especially the LHN analysis is most beneficial to the 12-UTC and 18-UTC runs, whereas the impact on 12-UTC runs is limited to the first 4-5 hours.

- verification against GPS derived integrated water vapouri (IWV):

Forecast starting from the small-scale analyses verify better against GPS derived IWV during night (see fig. 5). At daytime, and especially in the early afternoon the quality of all three experiments are comparable. At these hours the forecasts starting from the interpolated analysis tend to be even a bit better than the other forecasts. This result seems to be independent from the starting time of the forecast. Furthermore it reveals the fact that the forecasts starting from the interpolated analysis tend to be dryer than the others. The wettest forecasts are the ones which start from the LHN analysis. The differences are greater for 00-UTC runs than for 12-UTC runs.

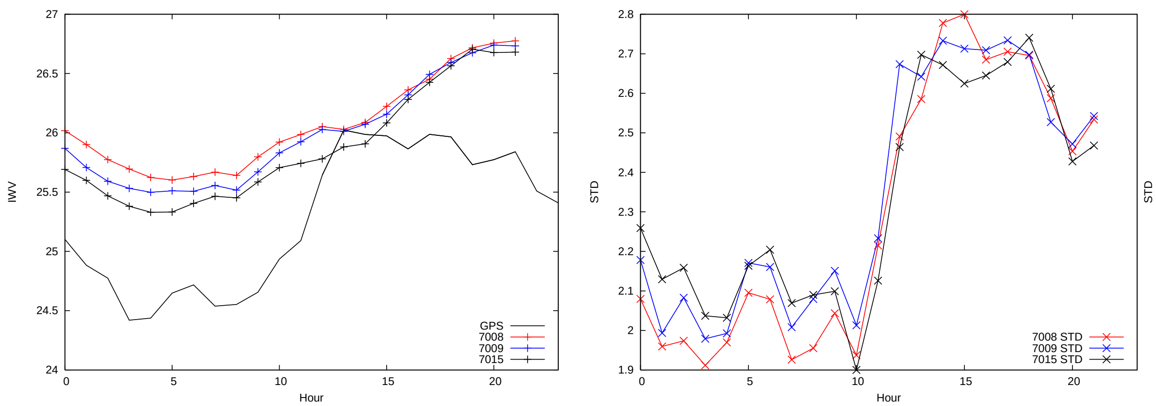

Figure 5: Averaged diurnal cycle of integrated water vapour (IWV, left) and standard diviation (right) of 00-UTC runs: GPS IWV measurements (black), COSMO-DE analysis with LHN (red), COSMO-DE analysis without LHN (blue), interpolated COSMO-EU analysis (black plus sign).

4 Conclusions

A study with the convection permitting model COSMO-DE has been made to indicate whether and how much small-scale detail in the analysis could improve QPF. For the selected two-week summer period dominated by weak anti-cyclonic weather conditions with air-mass convection, the local weather was expected to be clearly influenced by small-scale effects. It has been found that in some cases, the additional small-scale detail in the analysis significantly improved QPF, and statistically, the largest benefit has been found for the forecasts starting at 12 UTC (noon) or 18 UTC. This motivates further investments in high-resolution data assimilation, and namely in the development of an EnKF-based scheme for COSMO.

References

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[2] A. Seifert, M. Baldauf, K. Stephan, U. Blahak, K. Beheng, 2008: The challenge of convective-scale quantitative precipitation forecasting, *Proc. 15th Int. Conf. Clouds and Precip., Cancun, Mexico*, 2008