Precipitation Verification (Overestimation): A Common View of the Behaviour of the LM, aLMo and LAMI

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1 Introduction

The operational verification of precipitation over Germany and especially over Switzerland showed an increased overestimation during the last two winters (2003/04 and 2004/05) as compared to earlier winters (Sec. 2). The differences of mean monthly precipitation (24h-sums of LM +6 to +30h) to rain gauges in Germany and Switzerland showed a strong increase of the positive bias since the end of 2003 (C. Schraff, personal communication).

These two verification results were the starting point of this examination. The aim is to give some hints and information to the WG3-scientists for identifying the causes of possible precipitation overestimation in winter by looking more in detail into the verification of precipitation over the full domains of the operational model versions running in COSMO.

The relation between monthly sums of forecasted (by LM, aLMo and LAMI) and observed precipitation (SYNOP and rain gauges network) has been examined since January 2000 (Sec. 3 and 4). The bias (from monthly or seasonal sums) shows a different signal from season to season, region to region but also from year to year (for the same region). One part comes from the precipitation variability, another part could arise from model changes (namely the cloud ice scheme). The overestimation in winter seems more concentrated for the last two/three winters (and partly over the mountainous regions).

Further studies are necessary to identify possible causes of precipitation overestimation (Sec. 5): the problem is that precipitation is a very hard parameter not only in prediction but also in verification! Some few cases can "offset" a mean statistics based on biases. A first step was an examination of scatter plots of daily precipitation (Sec. 6): it shows that the overestimation is not only a problem of some isolated cases, but is visible on almost all days. The next steps (Sec. 7) will be studied in 2006 within the COSMO priority project "Tackle deficiencies in quantitative precipitation forecasts".

2 Verification of aLMo and LM with the hourly observations from the automatic network of MeteoSwiss during the four last winters and for the test chains at DWD and MeteoSwiss with the cloud ice scheme.

Fig. 1 shows the mean daily cycle of precipitation during the last winters (a) 2002/03, (b) 2003/04, (c) 2004/05 and (d) for a testsuite at MeteoSwiss with the cloud ice scheme in Spring 2004.

During winter 2002/03 LM and aLMo gave a similar overestimation: LM 25%, aLMo 30%. The slightly stronger overestimation in aLMo comes from the high amounts (10 mm/6h). The results from the earlier winter 2001/02 are similar (not shown): overestimation in both models, of the order of 20% in aLMo and 25% in LM. During these two winters, both models were driven by GME and run without cloud ice scheme.

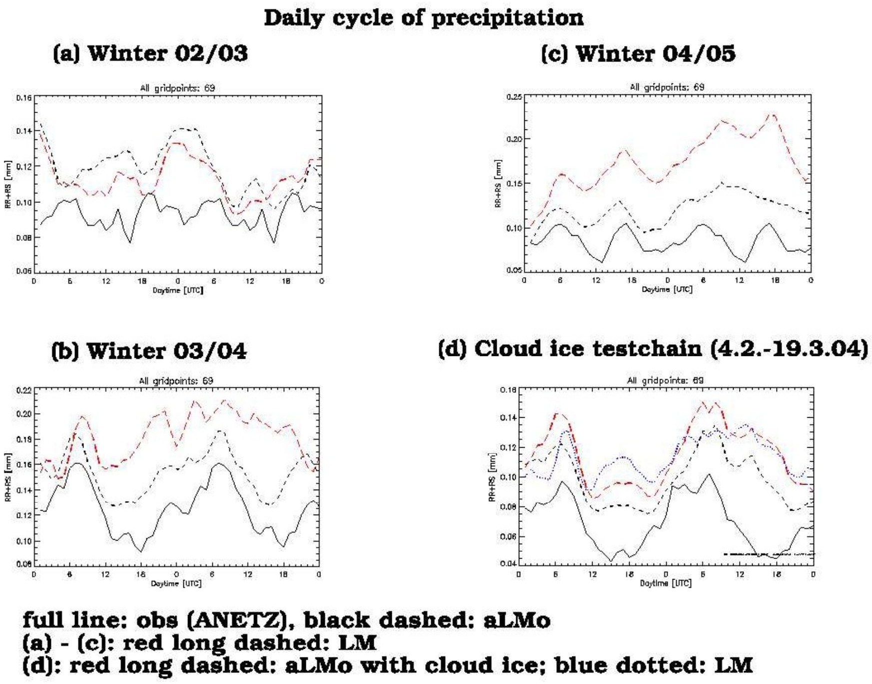

Figure 1: Verification of the daily cycle of precipitation for all 69 grid points corresponding to an ANETZ-station during the winters (a) 2002/03, (b) 2003/04, (c) 2004/05 and (d) for a test suite from 4/2-19/3/2004 with the cloud ice scheme. Observations (ANETZ): full line black. In (a)-(c): aLMo: black dashed line; LM: red long dashes. In (d): aLMo without cloud ice: black dashed line, aLMo with cloud ice: red long dashes, LM (also with cloud ice scheme; here just for comparison): blue dotted line.

During the winter 2003/04 LM run with cloud ice scheme, but aLMo still without the cloud ice scheme (see COSMO Newsletter No. 4, pp. 181-188 "Recent changes to the cloud-ice scheme"). aLMo shows an overestimation of $\backsim$20% and LM $\backsim$40%. aLMo captures better the mean daily cycle, possibly due to the lateral boundary conditions (LBC) from ECMWF (IFS-frames since 16.09.03), whereas LM takes the LBC from the GME (DWD). The frequency bias shows an overestimation for low amounts (0.1 mm/6h) in both models, of the order of 35-40% for grid points $<$ 800m and 55-65% for grid points $>$ 800 m. The high amounts (10 mm/6h) are underestimated with aLMo ($\backsim$10%) and overestimated with LM ($\backsim$35%) but in the range 800-1500 m both models show an overestimation, aLMo of 30% and LM of almost 100%.

A possible candidate for this stronger overestimation in LM as compared to aLMo could be the cloud ice scheme. DWD tested the cloud ice scheme in a test suite of LM during May 2003 (with an almost neutral impact) and with a revised version in September 2003 (with noticeable improvements) [see COSMO Newsletter No. 4, p. 187]. MeteoSwiss tested the cloud ice in a test suite from 4 February to 19 March 2004 (Fig. 1): the results over Switzerland showed an increase of $\backsim$15% in precipitation (but already the operational version gave an overestimation of $\backsim$20%). The frequency bias shows an overestimation for low amounts (0.1 mm/6h) in both versions, of the order of $\backsim$70-80%. The high amounts (10 mm/6h) are much more frequent in the cloud ice version: aLMo without cloud ice scheme gives an underestimation of $\backsim$20% and aLMo with cloud ice an overestimation of $\backsim$30%.

So the increased precipitation amount in LM as compared to aLMo during winter 2003/04 could come from the cloud ice scheme already operational in LM, but not yet in aLMo, where it was introduced in May 2004. During the year 2004 the prognostic precipitation scheme has been introduced operationally in LM (26/04/2004) and in aLMo (15/11/2004), so in winter 2004/05 both models run with the cloud ice scheme and with prognostic precipitation scheme. But LM run since 15.12.2004 with a bug correction in the numerical treatment of the prognostic precipitation: this correction gives a higher precipitation amount of ∽10-15% in the area mean. In aLMo this correction has been introduced only in July 2005.

During the winter 2004/05 LM gives about 35% more precipitation than aLMo over a domain of 57x39 grid points covering Switzerland, but already aLMo gives ∽20% too much precipitation as compared to all 69 ANETZ stations. In the first forecast hours the difference between both models is less pronounced. The frequency bias shows an overestimation for low amounts (0.1 mm/6h) in both models, for grid points $<$ 800m of ∽40% in aLMo and 65% in LM, for grid points $>$ 800 m of ∽70-90% in aLMo and even 20% more in LM. The high amounts (10 mm/6h) are slightly underestimated with aLMo (∽10%) but strongly overestimated with LM (∽230%). During this winter 2004/05 LM run with a bug correction in the prognostic precipitation scheme giving ∽10-15% more precipitation, so about a third of the higher precipitation amount in LM is explained by this fact.

Summarized we can say: especially during the last two winters LM and aLMo gave a strong overestimation in precipitation over the mountainous regions. A possible cause could be the introduction of the prognostic cloud ice scheme that was not enough tested during wintertime conditions.

3 Verification of LM with rain gauges over Germany and Switzerland and of aLMo with all European SYNOPS.

Fig. 2 shows the monthly evolution from January 2000 to December 2004 of the 24h precipitation sums from +6h to +30h (blue surface) and the mean bias (red line) of LM as compared to the 3300 rain gauge stations in Germany. It shows the increased positive bias during the last two winters. This increase comes mainly from the mountainous regions in the southern part of Germany (not shown). The verification with the 450 rain gauges over Switzerland (not shown) gave already an overestimation in winter 2001/02 when LM and aLMo run without the cloud ice scheme.

Fig. 3 shows the winter season precipitation bias of 12 hourly precipitation sums at all European SYNOP stations over the full domain of aLMo (from Portugal in South-West to Poland in North-East). The mean bias shows a decrease in the overestimation during the last winters. Fig. 4 shows the mean error of 12 hourly precipitation during Winter 2004/05 and confirms that the overestimation is mainly concentrated over the Alpine region. The behaviour over the Alpine region discussed in Sec. 2 (increase of the bias) is just reverse over the major part of Europe outside the mountainous regions!

4 Verification of LM, aLMo and LAMI with raingauges over Piedmont.

Fig. 5 show the seasonal cumulated precipitation maps from the three operational models LAMI, LM and aLMo and the rain gauge network over the Piedmont region. In particular winter 2003/04 (DJF'04) and winter 2004/05 (DJF'05) are remarkable both in term of wet/dry seasons and in term of different model versions performance. There is a general overestimation during both winters: in winter 2003/04 aLMo, that run without prognostic

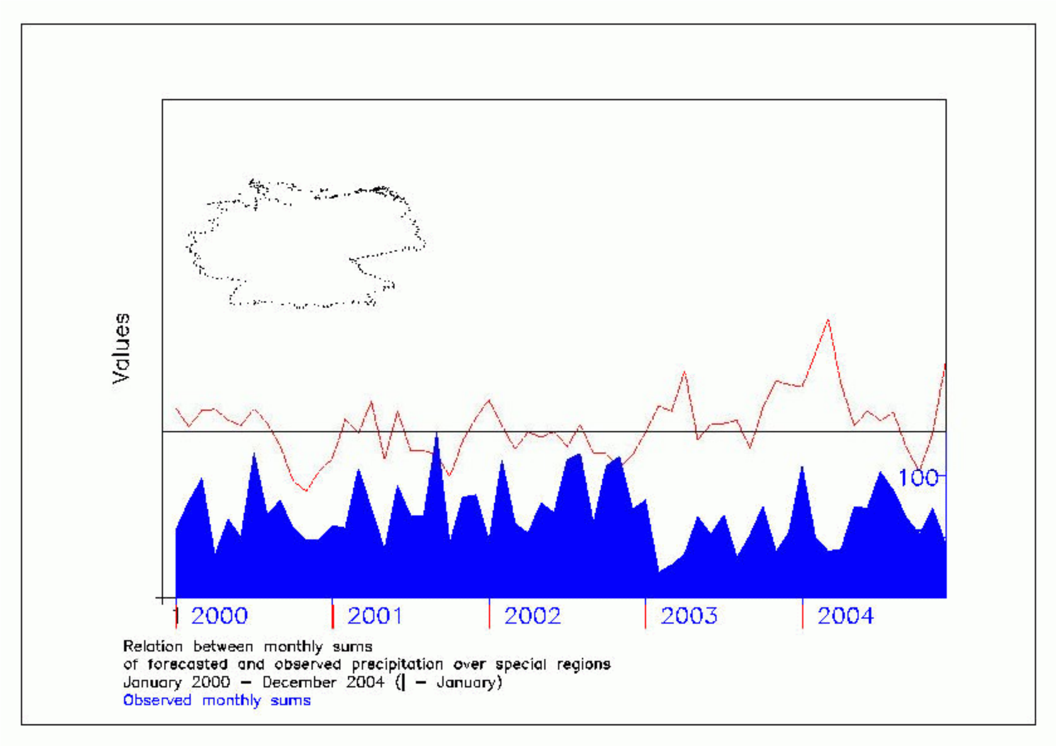

Figure 2: Monthly evolution from January 2000 to December 2004 of the 24h precipitation sums from +6h to +30h (blue surface) and the mean bias (red line) of LM as compared to the 3300 rain gauges stations in Germany.

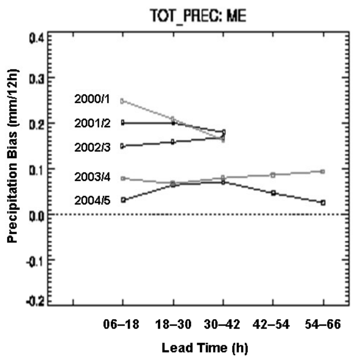

Figure 3: Precipitation bias for the winter seasons of 12 hourly precipitation sums at European SYNOP stations of all 00 UTC and 12 UTC aLMo-forecasts. Results are plotted for the different lead times.

cloud-ice scheme, performs slightly better with respect to the other ones (with cloud ice scheme): this is also visible on the frequency bias results. In winter 2004/05 all three models run with prognostic cloud ice scheme and LM and aLMo also with prognostic precipitation scheme (but not LAMI): in that last winter LAMI seems to overestimate less than aLMo and LM, but this winter was unfortunately very dry in Piedmont, so the results are difficult to interpret.

5 Preliminary conclusions.

A possible cause for the precipitation overestimation is the cloud ice scheme, but other causes (masked by the precipitation variability) are also possible, because

- already before the introduction of cloud ice scheme we had seasons with precipitation

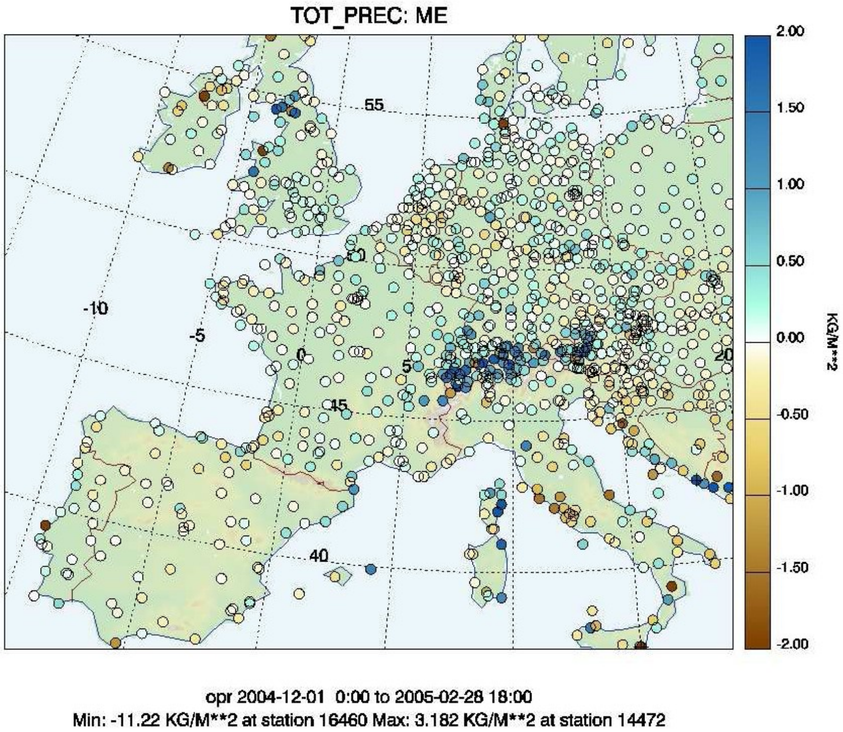

Figure 4: Mean error of 12 hourly precipitation sums from all 00 UTC and 12 UTC aLMo-forecasts (range +30h to +42h).

overestimation;

- we have great regions (especially in Southern Europe) with a decrease of the (seasonal) biases during the last winters.

Clearly, more work is necessary to find causes of the precipitation overestimation in mountainous regions.

6 Scatter plots of daily precipitations sums over Germany and Piedmont

Scatter plots of daily precipitation amounts can help to see if this overestimation is due to (some few) cases where the model gives (much) precipitation that is not observed, or whether overestimation of precipitation is a problem in all (or most) cases. Monthly scatter plots of the daily sums of LM vs rain gauges in Germany for three months are shown in Fig. 6-Fig. 8: August 2002 with the flooding events in Central Europe, December 2002 when LM run without cloud ice scheme and December 2004 when LM run with cloud ice scheme. The overestimation is not only a problem of some cases (i.e. days). In 2002 the observed strong precipitation (more than 10 mm in the areal mean) were underestimated. This behaviour is just reversed in December 2004, where almost all days show an overestimation. The last two winters (2003/04 and 2004/05) gave systematically overestimated daily sums whereas during the summer months there is no systematic over/underestimation (not shown).

Fig. 9 shows similar scatter plots over the Piedmont region for the two winters 2003/04 and 2004/05 for the three models aLMo, LM, and LAMI. Also here it is evident that the biases in the seasonal means is not a problem of isolated days. Figure 10 gives the results of the daily scatter plots of January 2005: during this month the overestimation of the three models is

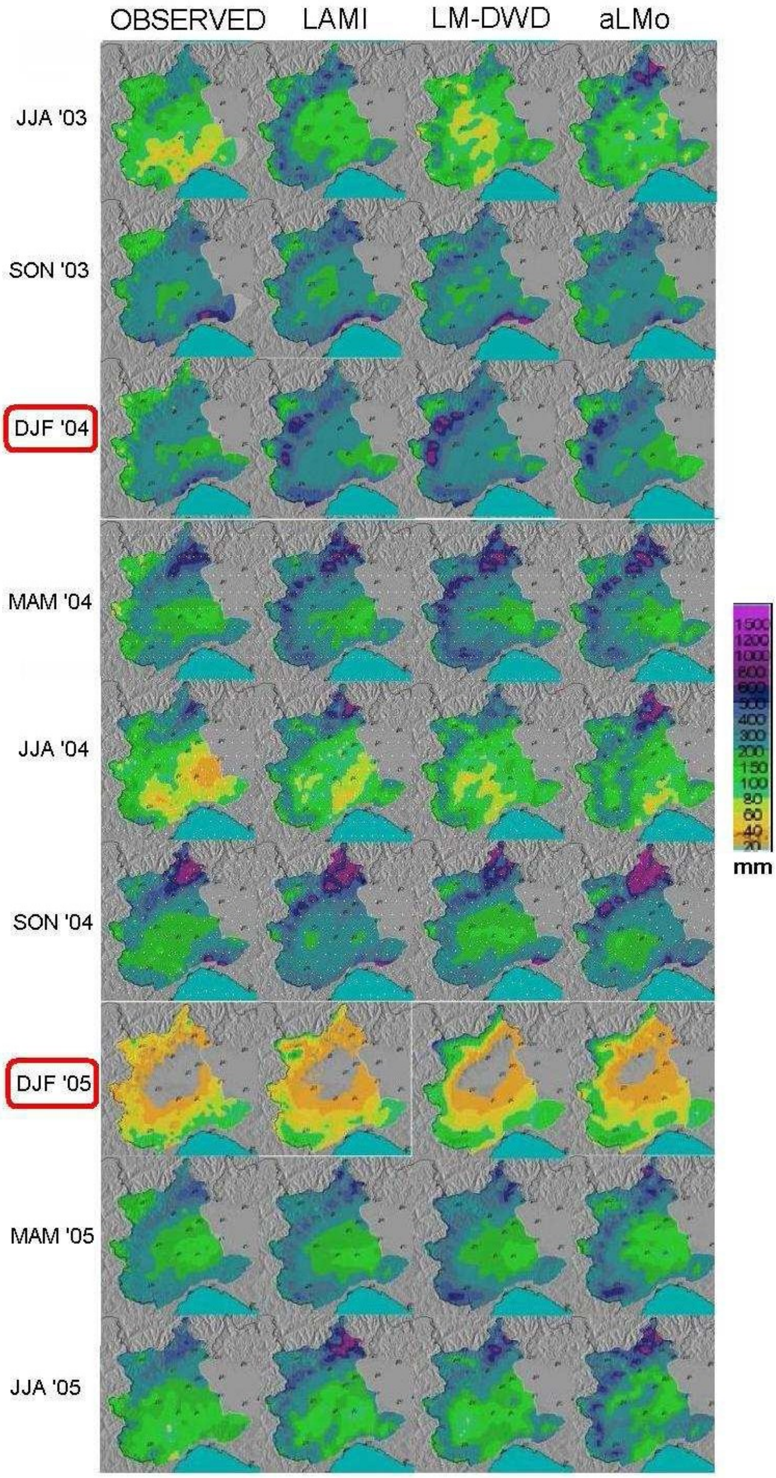

Figure 5: Seasonal cumulated precipitation maps from the 00 UTC operational forecasts (24h sums from +0h to +24h) of LAMI, LM and aLMo and observed from the rain gauges over the Piedmont region.

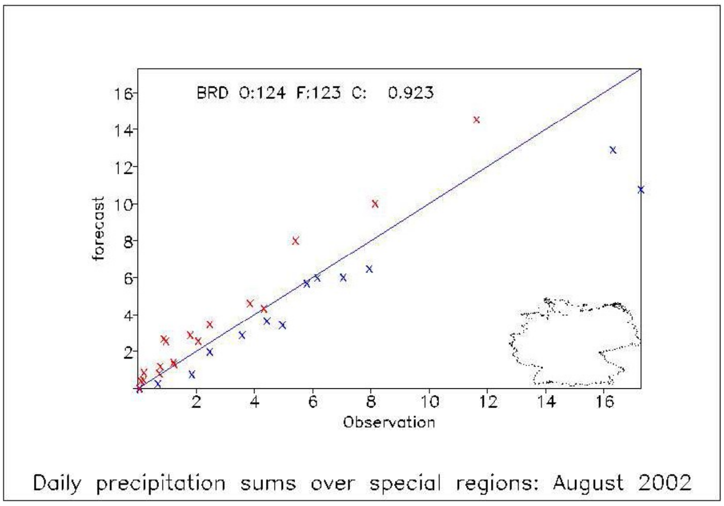

Figure 6: Monthly scatter plots of the daily sums of LM vs rain gauges in Germany for August 2002.

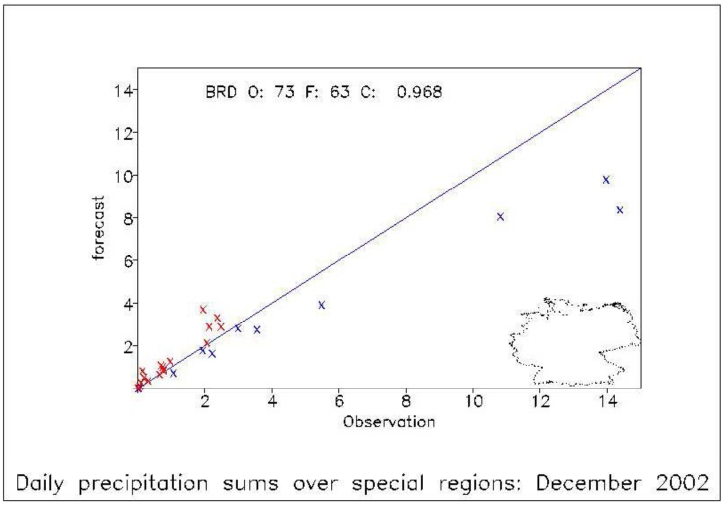

Figure 7: As in Fig. 6 but for December 2002.

very high for all days (Fig. 10 shows LM, but the results for LAMI and aLMo are similar). The overestimation is much higher in January 2005 than on the other two winter months: during this month the precipitation events were mainly due to a cold air outbreak and two days of strong northwesterly flow, i.e. they are connected to synoptic situations with cold air. It could be a hint that the overestimation is more pronounced during very cold precipitation events. This must be further investigated with a more systematic weather-type dependant verification of these wintertime precipitations.

7 Outlook.

Further systematic scatter plots of daily precipitation sums (also from radar areal mean estimates) can help to better identify the forecast failures. Alternatively simple conditional verifications by discriminating between events of different (observed) vertical stability (i.e., unstable/convective vs stable/stratiform) or with parameters such as 'convective/stratiform

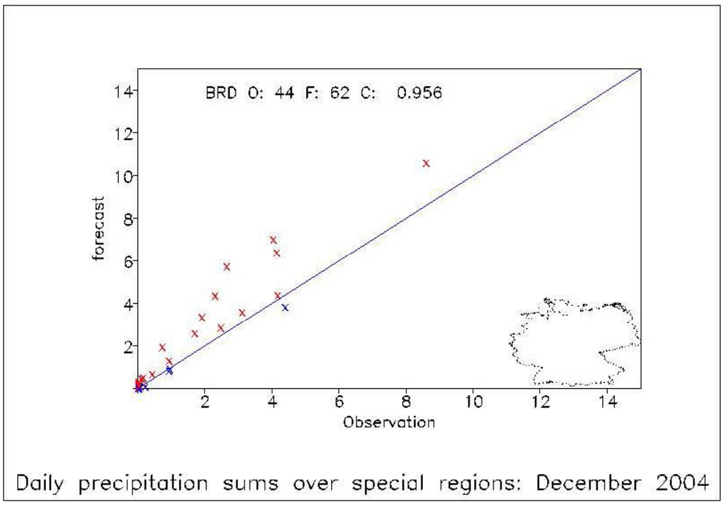

Figure 8: As in Fig. 6 but for December 2004.

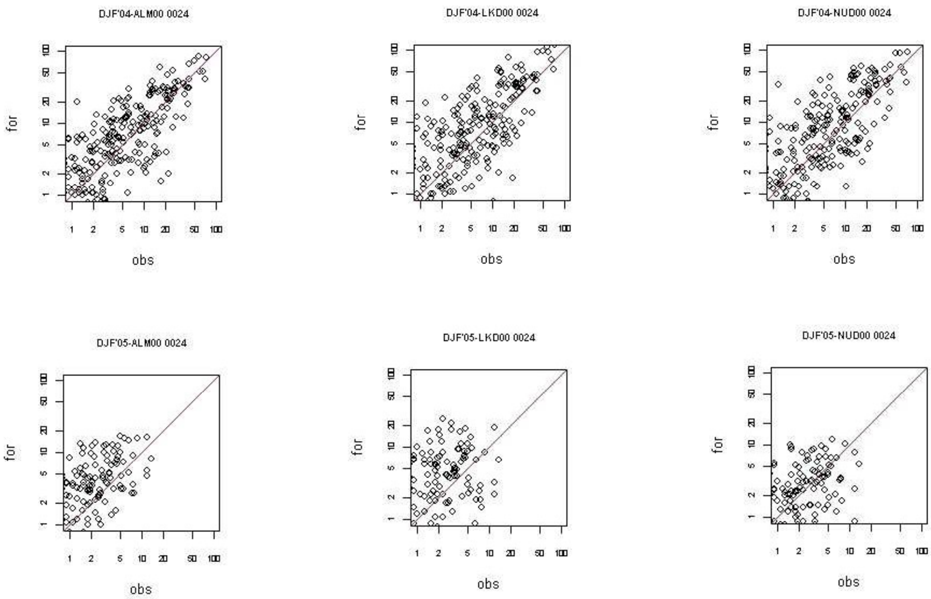

Figure 9: Scatter plots over the Piedmont region for the two winters 2003/04 (upper part) and 2004/05 (lower part) for the three models aLMo (left), LM (middle) and LAMI (right).

precipitation amounts in the model' would help to attribute the problem to specific parts of the physics parameterizations or other model properties.

The COSMO priority project "Tackle deficiencies in quantitative precipitation forecasts" will pursuit this study: a first task will be a consolidated report of forecast failures and verification findings.

References

COSMO Newsletter, No. 4, 2004.

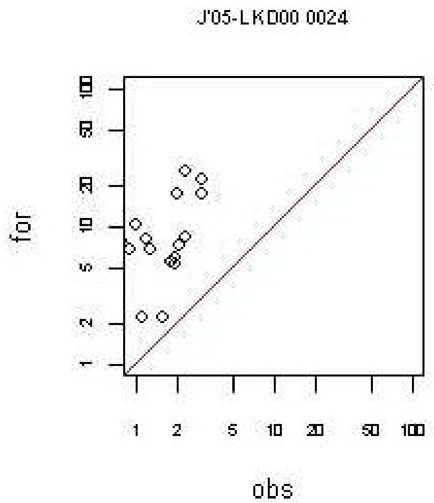

Figure 10: Scatter plots over the Piedmont region for LM in January 2005.