A comparison of DMO and statistically adapted quantitative areal precipitation forecasts from different NWP models

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1. INTRODUCTION

There is an increasing demand for quantitative precipitation forecasts (QPFs) especially within the water management and power generation sectors. QPF forecasts are often taken as input for hydrological models to provide improved runoff forecasts.

It is well known that QPF errors are generally large, especially in cases of moderate to heavy precipitation. In mountainous areas, global models (GMs) and limited area models (LAMs) show quite different precipitation characteristics, due mostly to their different grid resolution. Global models have a tendency to underestimate peak orographic precipitation amounts, while for LAMs peak value overestimation is a common characteristic especially in mountainous areas. Attempts were made to improve forecast quality by using statistical methods such as model output statistics (MOS), the perfect prog method (PPM), and simple linear combination of forecasts from two different NWP-models.

2. BASIS

For this study the GM of the ECMWF and the LAM ALADIN-LACE were chosen. The ECMWF-model is well suited for statistical adaptation methods, because a long time series is available which is necessary in order to apply MOS or PPM methods successfully.

For the abovementioned reasons it seems possible that a statistical combination of the forecast values could be a step towards a more precise forecast of precipitation amounts.

For the purpose of this study, Austria was divided into 26 regions, which were chosen according to hydrological criteria and correspond to river catchment areas.

Due to the fact that Austria has a large number of different landscapes like flat areas, alpine rim (=upslope precipitation) areas, and inner-alpine areas, different types of orographic effects on the precipitation fields can be expected.

3. COMBINATION OF MODELS

For combining the two forecasts a simple weighing method was used.

$$RR = w * rrecm + (1 - w) * rrala \qquad (1)$$

with:

RR .... Combined forecast

rrecm ..... ECMWF forecast

rrala ..... ALADIN-LACE forecast

w .... Weighing factor

It should be noted that the constraint on the coefficients of $rrecm$ and $rrala$ to add up to 1 was not imposed a priori. However, during the analysis it turned out that this sum was frequently near the value 1, so this additional degree of freedom was dropped in the final formulation. The dataset used in the study consists of 6-hour precipitation forecasts from January 1997 to March 2000 from both models. The forecast range reaches from +06 to +48 hours for ALADIN-LACE and from +18 to +64hours for the ECMWF model.

The optimal weighing factor was calculated from the dataset by requiring that the mean absolute error of the 6-hour forecast be a minimum. The weighing factor itself is a function of the forecast precipitation category (3 different categories for each model). This means that for different amounts of forecast precipitation, different weighing factors are used.

As a final result one obtains 9 different weighing factors for each catchment area. For one specific forecast, linear interpolation between these 9 values takes place.

The following table lists weighing factors (values for w) for different regions and all possible combinations of precipitation categories:

prec. categ.	A1	A2	A3	A4	A5
$\alpha 1$	0.8	0.4	0.6	0.7	0.5
$\alpha 2$	0.9	1.0	1.0	0.8	1.0
$\alpha 3$	1.0	1.0	1.0	0.9	1.0
$\beta 1$	0.1	0.1	0.0	0.1	0.2
$\beta 2$	0.2	0.1	0.0	0.1	0.2
$\beta 3$	0.2	0.1	0.0	0.1	0.2
$\gamma 1$	0.1	0.2	0.2	0.2	0.2
$\gamma 2$	0.1	0.2	0.2	0.1	0.3
$\gamma 3$	0.9	1.0	0.9	0.7	0.8

A1 .... average over northern upslope areas
A2 .... average over hilly areas
A3 .... average over southern upslope areas
A4 .... average over inneralpine areas
A5 .... average over flat areas

$\alpha 1$ .... ECM$\leq$2mm / ALA$\leq$3mm
$\alpha 2$ .... ECM$\leq$2mm / 3mm$<$ALA$\leq$6mm
$\alpha 3$ .... ECM$\leq$2mm / ALA$>$6mm
$\beta 1$ .... 2mm$<$ECM$\leq$4mm / ALA$\leq$3mm
$\beta 2$ .... 2mm$<$ECM$\leq$4mm / 3mm$<$ALA$\leq$6mm
$\beta 3$ .... 2mm$<$ECM$\leq$4mm / ALA$>$6mm
$\gamma 1$ .... ECM$>$4mm / ALA$\leq$3mm
$\gamma 2$ .... ECM$>$4mm / 3mm$<$ALA$\leq$6mm
$\gamma 3$ .... ECM$>$4mm / ALA$>$6mm

In Figures 1-4 some verification results are presented for the combined forecast compared to the forecasts of the individual models for different regions.

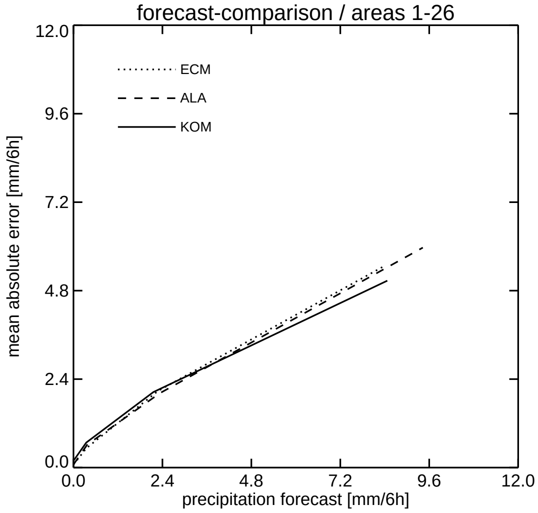

Figure 1: Mean absolute error of ECMWF, ALADIN-LACE, and the combined model for 6-hour precipitation ... average over all areas

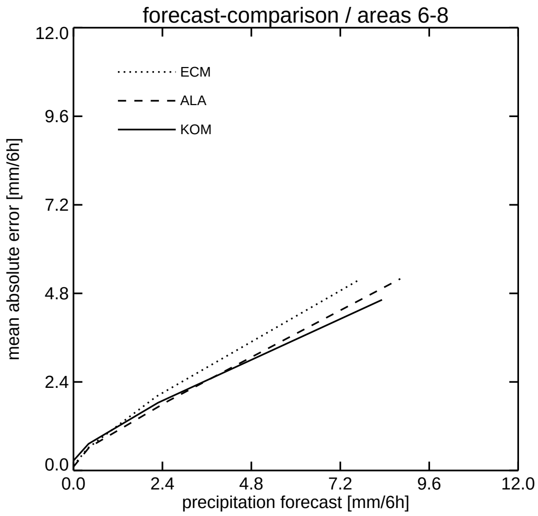

Figure 2: Mean absolute error of ECMWF, ALADIN-LACE, and the combined model for 6-hour precipitation ... average over northern upslope precipitation areas

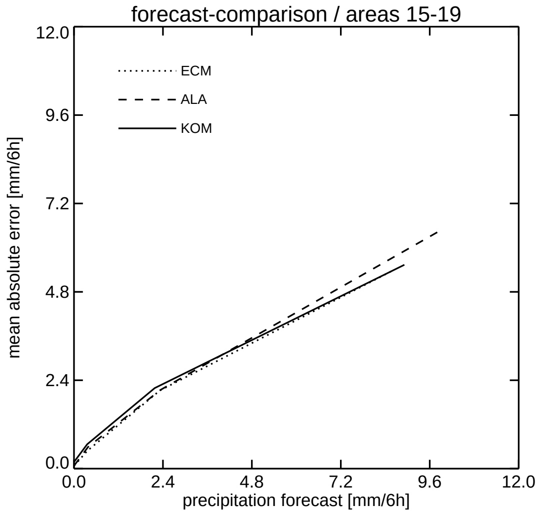

Figure 3: Mean absolute error of ECMWF, ALADIN-LACE, and the combined model for 6-hour precipitation ... average over southern upslope precipitation areas

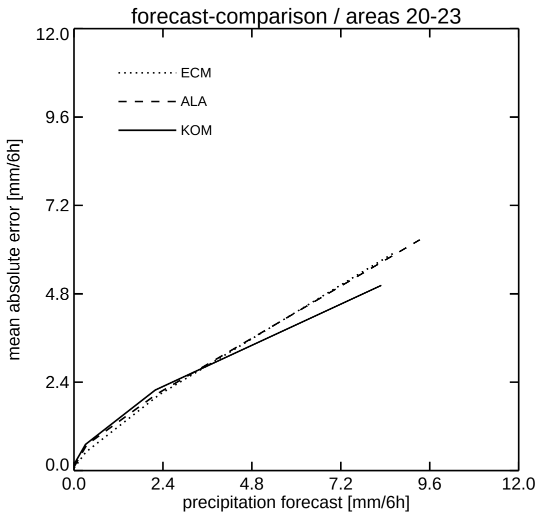

Figure 4: Mean absolute error of ECMWF, ALADIN-LACE, and the combined model for 6-hour precipitation ... average over flat/hilly regions in the north east

It can be seen from Figures 1-4 that the improvement of the combined forecast is significant only for higher precipitation amounts ($\geq$5mm/6h). The reason for this can be explained as follows. The statistical method, based on minimizing the mean absolute error, gives more weight to the model that forecasts smaller amounts. Consequently, the number of cases in which high precipitation amounts are predicted is reduced. In other words, high precipitation amounts are predicted by the combined model only if both models give significant precipitation for the same time period. The number of cases in the smaller categories is increased in the combined model as compared to the individual models, i.e. many events 'shift to the left' in Figures 1-4, taking their relatively high error (resulting from underestimation) with them.

It was assumed that especially in mountainous areas the complementary behaviour of the two models would allow for improvements by model combination, but this turned out to be only partially true. In cases where both models forecast comparable precipitation amounts with a similar temporal and spatial pattern, the method works quite good, but the number of these situations is too small to compensate for those where differences between the models are very large.

4. MOS and PPM- TECHNIQUE

In addition to the simple method described in Section 3. it was tried to improve the forecasted precipitation amounts with standard MOS-technique. This method is successfully used in many NWP centers to improve forecasts of a large number of meteorological variables, including probability of precipitation (see Glahn and Lowry, 1972; Haiden and Hermann, 2000) However it is also known that with regard to precipitation amounts, MOS results may not provide much improvement over DMO, in particular when applied to point forecasts.

Here the MOS method is applied to areal precipitation, which might be expected to give better results than application to point values. For the forecast of 6-hour precipitation, predictors such as temperature, wind, and relative humidity on different vertical levels were used. Finally one equation is obtained for each forecast range and each area

$$RRopt(6h) = q0 + q1 * PR1 + q2 * PR2 + ... \quad (2)$$

where the q's denote the weighing factors and the PR's the forecasted values of the predictors.The equation does not necessarily include the same predictors at different forecast ranges and in different areas since only those 5 predictors that explain most of the variance are retained.

The PPM is similar to MOS except that the statistics are not calculated from model forecasts but from model analyses (Brunet et al., 1988; Seidl, 2000). The method is of practical value only if the forecasts are sufficiently close to reality. On the other hand any improvement in the DMO directly results in an improvement of the PPM results, which is not necessarily the case with MOS.

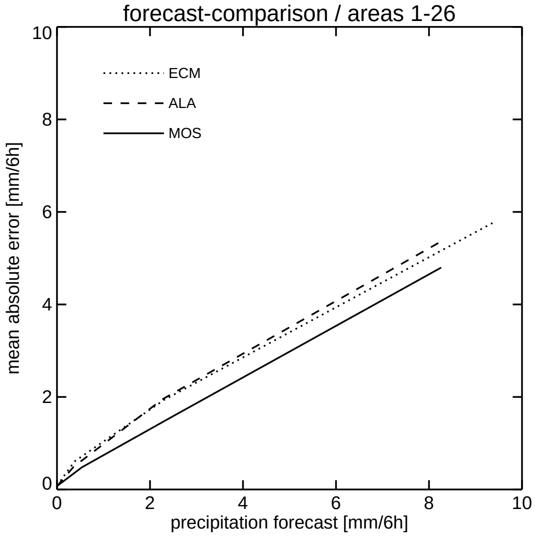

Figure 5: Mean absolute error of ECMWF, ALADIN-LACE, and MOS for 6-hour precipitation ... average over all areas

In Figures 5-7 some results are presented for MOS compared to the basic models for different regions.

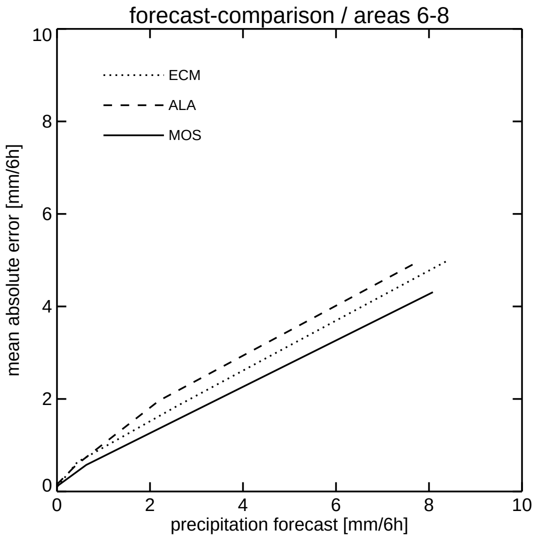

Figure 6: Mean absolute error of ECMWF, ALADIN-LACE, and MOS for 6-hour precipitation ... average over northern upslope precipitation areas

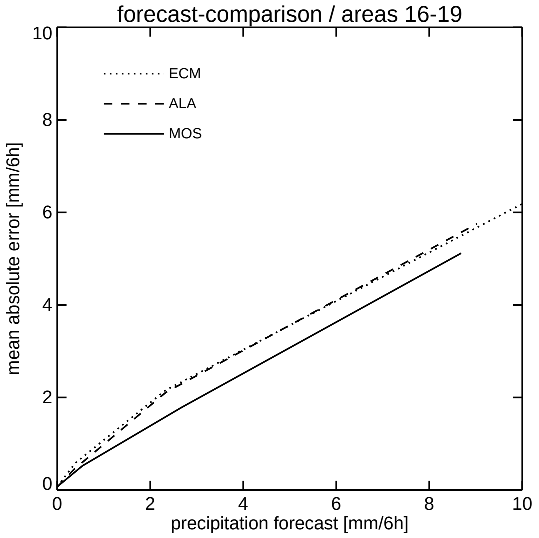

Figure 7: Mean absolute error of ECMWF, ALADIN-LACE, and MOS for 6-hour precipitation ... average over southern upslope precipitation areas

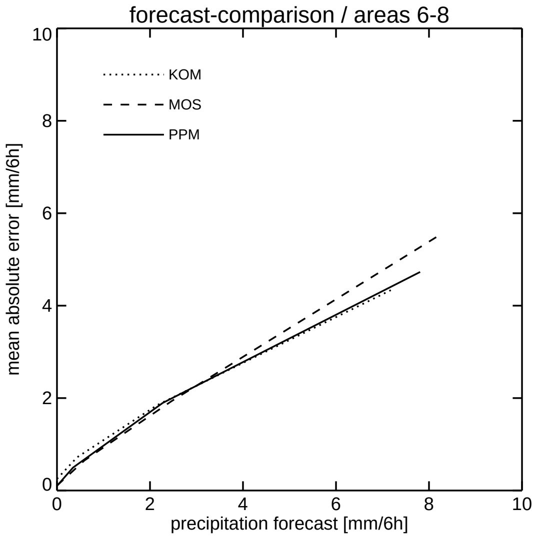

Figure 8: Mean absolute error of model combination, PPM, and MOS for 6-hour precipitation ... average over northern upslope precipitation areas

Figures 5-7 show that in trying to improve DMO by MOS technique one can be partly successful, although MAE is just one of many ways to measure the quality of forecasts. If the MOS is tuned in the sense that it should focus mainly on the heavy precipitation events one obtains a higher probability of detection but the false alarm rate increases as well. This could be regarded as a 'risky' MOS, which is good for detecting most of the heavy events. If we compare the MAE's, then we find that a conservative MOS is better suited to keep the MAE low.

Figures 8 and 9 show a comparison of the MAE for the different statistical methods.

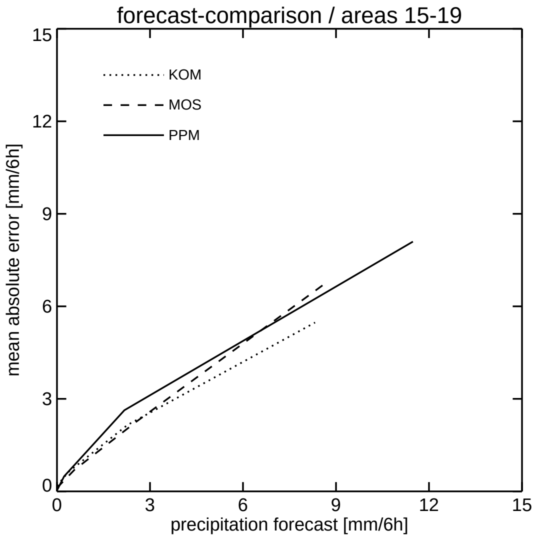

Figure 9: comparison of the mean absolute error for model combination, PPM and MOS for 6-hour precipitation ... average over southern upslope precipitation areas

The last figures show, that the differences in MAE between the statistical adaptation methods are not that large. They can for the most part be explained by the fact that the more frequently high amounts are forecasted, the higher the MAE. It means that for the combined model, which is the most conservative one, the MAE is slightly lower than for the other two methods. The MAE of the two latter models is dependent on their tuning, which either can be designed for detecting a high percentage of heavy events or for reducing the number of false alarms.

5. Conclusions

The statistical combination method described in this paper gives weak to moderate improvements of quantitative precipitation forecasts in cases of moderate to heavy precipitation. However, this gain is largely a result of a more conservative behaviour of the combined model (compared to the individual models) in such cases. This means that the FAR is being reduced, but at the cost of a decrease of the POD.

For the common statistical adaptation methods MOS and PPM the results show that slight improvements can be achieved but it is not possible to significantly reduce the forecast errors with either of the two methods. On the plus side this confirms that the precipitation given by the DMO does not contain a large systematic error.

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