A new Method for T2M Forecast in Complex Orography Areas

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1 Introduction

Meteorological parameter forecast is a quite challenging task in the Alpine region, due to complex geography and orography and to inexact parametrization of several physical processes. Limited area models also can show strong systematic and random errors in the parameter forecast, compared to the values observed by ground stations. As an example, consider the Figures 1 and 3, showing the mean temperature values in Piedmont observed in January and June 2004 respectively, compared with limited area models forecasts: errors up to 8°C can be observed.

Many post-processing methods are available for parameter forecast correction, see Kalman (1960) for instance, but usually they impose some hypothesis on parameter behaviour, such as Gaussian error distribution or no-correlation between errors. Krishnamurti (1999) introduced the so-called Multimodel technique, a post-processing method using several model outputs to obtain parameter forecasts. The Multimodel SuperEnsemble technique (see also Krishnamurti, 2000) takes into account the different model outputs, weighted by parameters calculated in a training period.

In this study we apply for the first time the SuperEnsemble technique on the operational model runs (00 UTC runs) of the 7 km resolution version of LM. We consider the outputs of Local Area Model Italy by UGM, ARPA-SIM, ARPA Piemonte (nud00), Lokal Modell by Deutscher Wetterdienst (lkd00) and Alpine Model (aLMo) by MeteoSwiss (alm00). We evaluate the model performances with respect to our regional high resolution network. Here presented are the results of 2 m temperature forecasts, compared with the measurements of 201 stations, divided in altitude classes ($< 700\ m$, $700 - 1500\ m$, $> 1500\ m$).

2 Multimodel Theory

As suggested by the name, the Multimodel SuperEnsemble method requires several model outputs, which are weighted with an adequate set of weights calculated during the so-called training period. The simple ensemble method with biased (Eq. 1) or bias-corrected (Eq. 2) data respectively, is given by

$$S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}(F_i - \overline{F_i}) \tag{1}$$

and

$$S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}(F_i - \overline{O}) \tag{2}$$

The conventional superensemble forecast (Krishnamurti, 2000) constructed with bias-corrected data is given by

$$S = \overline{O} + \sum_{i=1}^{N} a_i (F_i - \overline{O}) \qquad (3)$$

where N is the number of models, F_i is the i^{th} forecast by the model, $\overline{F_i}$ and $\overline{O}$ are the mean forecasts and the mean observation during the training period T.

The calculation of the parameters a_i is given by the minimization of the mean square deviation

$$G = \sum_{k=1}^{T} (S_k - O_k)^2 \qquad (4)$$

by derivation $\left(\frac{\partial G}{\partial a_i} = 0\right)$ we obtain a set of N equations, where N is the number of models involved $(i, j = 1, N)$:

$$\left(\sum_{k=1}^{T} \left(F_{i_k} - \overline{F_i}\right)\left(F_{j_k} - \overline{F_j}\right)\right) \cdot (a_i) = \left(\sum_{k=1}^{T} \left(F_{j_k} - \overline{F_j}\right)\left(O_k - \overline{O}\right)\right) \qquad (5)$$

We then solve these equations using the Gauss-Jordan method (see Press et.al., 1992).

3 Results

3.1 Multimodel post-processing results: JANUARY 2004

We calculated Multimodel Ensemble and SuperEnsemble forecast using the three LM versions for the month of January 2004. Instead of using a fixed long training period, as in Krishnamurti (2000), we preferred to use a dynamic training period to take into account the seasonal variation of model performances. Then for each forecast day, forecast time and station we considered the 90 days before as training period, we calculated the forecast and observation means and the Multimodel weights and then we obtained Ensemble and SuperEnsemble forecast.

We evaluated the forecast improvement by comparison with observed values in the given period. Figure 1 shows the mean value confrontation. It has to be pointed out the strong systematic error of the direct model outputs, mainly in the medium mountain area ($700\ m < height < 1500\ m$). More details can be found in Fig. 2, where Root Mean Square Error (RMSE) and Mean Error (or Bias) are shown. The model systematic error is about 6-8°C on the mountains, with significant increase around noon (+12 hr and +36 hr forecast time). Multimodel Ensemble and SuperEnsemble strongly reduce this bias, and RMSE shows the better performance of SuperEnsemble.

3.2 Multimodel post-processing results: JUNE 2004

We repeated the same procedure for the month of June 2004. The mean values of Fig. 3 do not show a strong systematic error, as they did in January, but the diurnal cycle is not well described by direct model outputs. Multimodel SuperEnsemble and Ensemble again perform better, as shown in Fig. 4. The RMSE shows again a better performance of SuperEnsemble with respect to Ensemble.

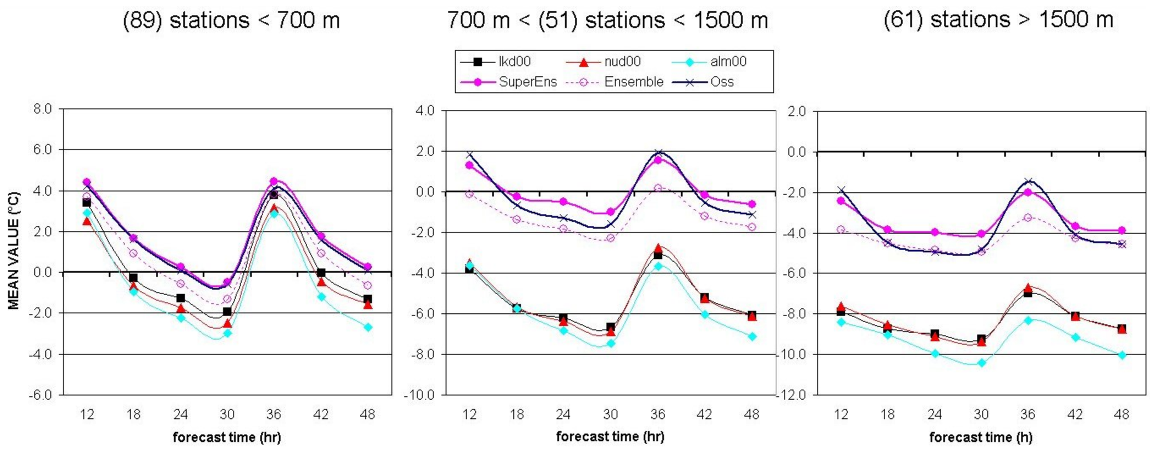

Figure 1: Mean temperatures for 201 Piedmontese weather stations: observed values (obs), SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, LM forecast (alm00, nud00, lkd00), JANUARY 2004

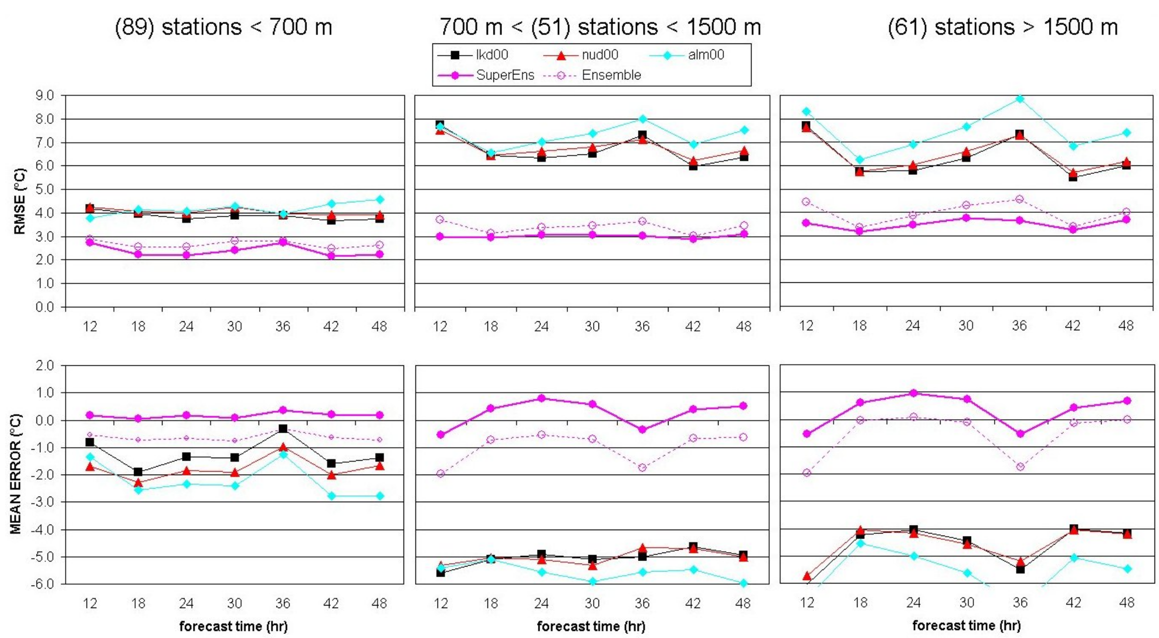

Figure 2: Root Mean Square Error (top) and Mean Error (bottom) for 201 Piedmontese weather stations: SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, LM forecast (alm00, nud00, lkd00), JANUARY 2004

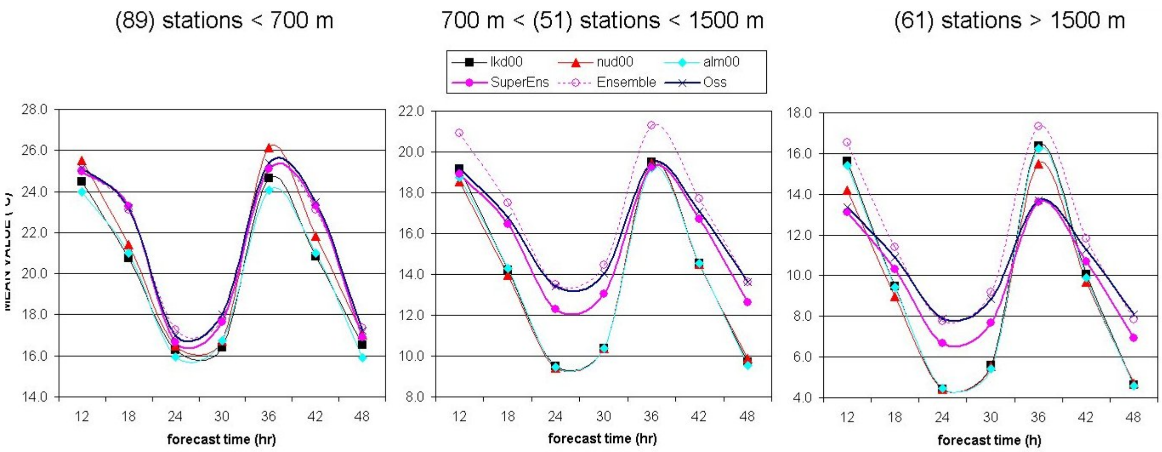

Figure 3: Mean temperatures for 201 Piedmontese weather stations: observed values (obs), SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, LM forecast (alm00, nud00, lkd00), JUNE 2004

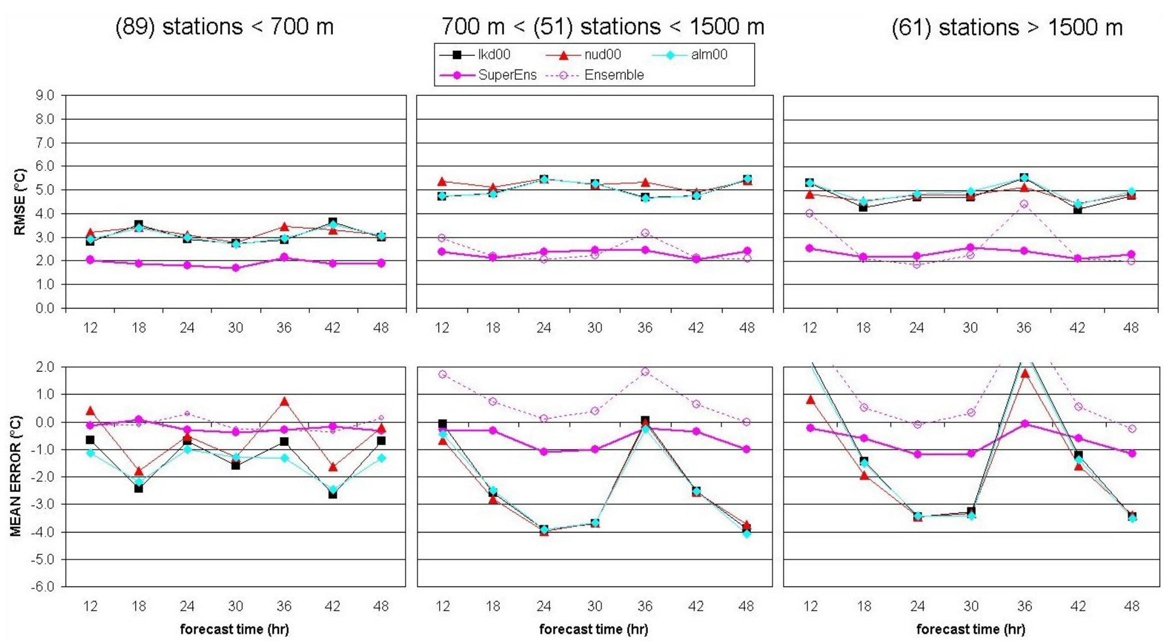

Figure 4: Root Mean Square Error (top) and Mean Error (bottom) for 201 Piedmontese weather stations: SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, LM forecast (alm00, nud00, lkd00), JUNE 2004

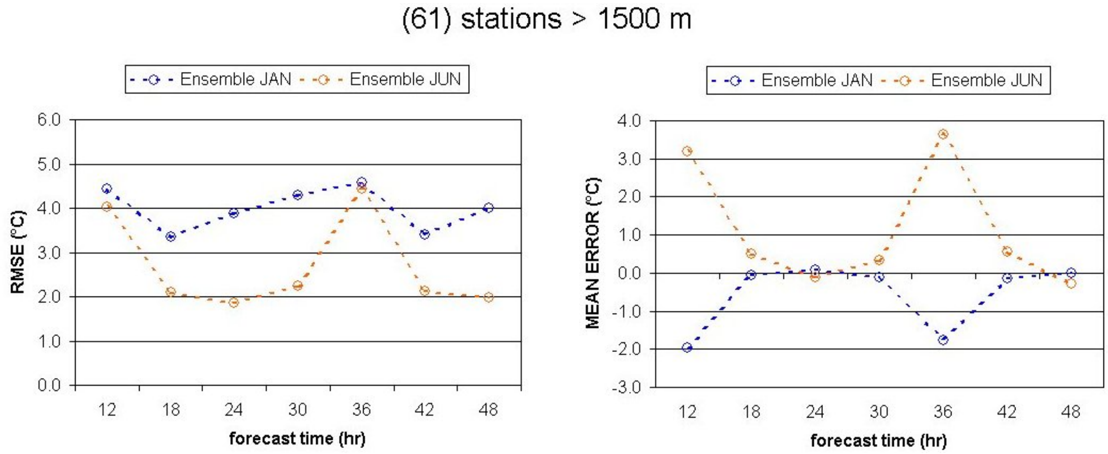

Figure 5: Root Mean Square Error (left) and Mean Error (right) for higher (> $1500m$) weather stations: confrontation between Multimodel Ensemble January - June forecast

Actually Multimodel Ensemble is nothing but an unbiased mean of the direct model outputs, so it is quite interesting the comparison of 2m temperature RMSE for higher stations (> 1500 m). As shown before, it is worse during daytime hours (+12 hr and +36 hr forecasts), and the bias is opposite during winter (models underestimate the observed values) with respect to summer (models overestimate). A possible explanation is the uncorrect parametrization of the presence of snow on the ground, with its influence on heat flux calculation (see Fig. 5).

4 A comparison with Kalman filter results

A version of the Kalman filter (Kalman, 1960) post-processing on the direct output of ECMWF run at 12UTC is currently used every day for the 2m temperature forecasts over the entire Piedmont, but we register a degradation of the predicted values with increasing height of the weather stations. The same problem is evident also in the filtering of the limited area model outputs. The reason for this degradation can be found in the strong variability of the performances of the models day by day in the alpine region. In fact Kalman filter is very good in reducing the strong systematic errors, but fails when the difference between predicted and observed values varies strongly from one day to the next one.

Here we present the comparison between a test run of Kalman filter post-processing method on LM-DWD and the Multimodel method results. Figure 6 and 7 show the results for January 2004 and June 2004 respectively. Kalman filter and Multimodel SuperEnsemble give similar results, both in bias and RMSE.

5 Conclusions and perspectives

Direct Model Output 2m temperature forecasts show a noticeable degradation in the Alpine region, with strong systematic and random errors in any version of LM. Consequently, a new approach named Multimodel technique has been tested for the first time on limited area

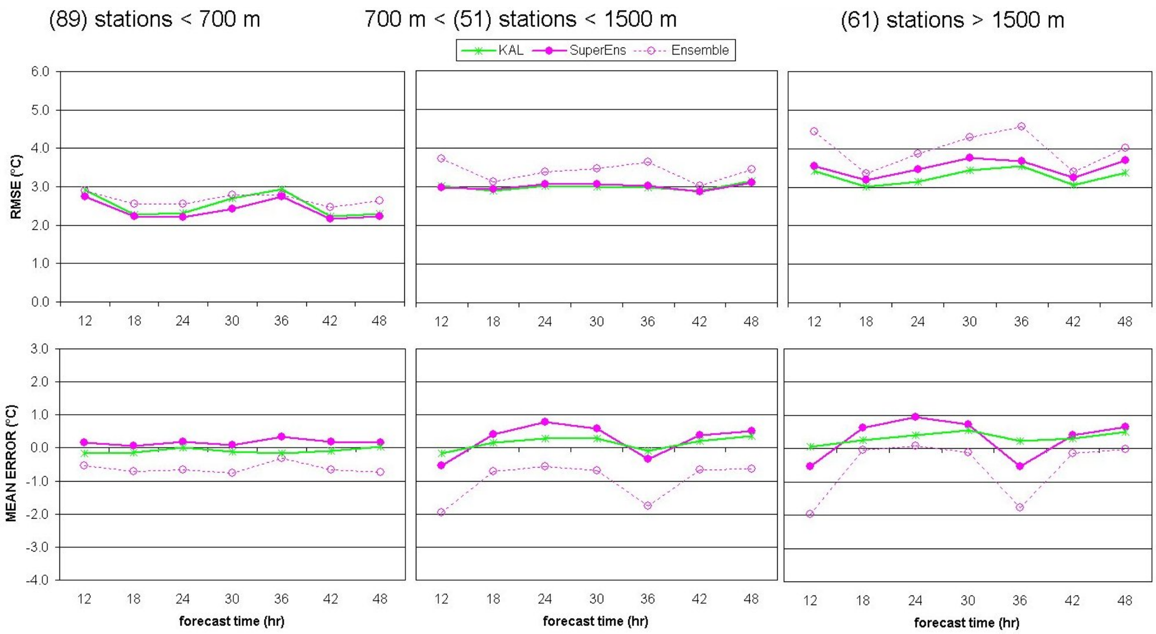

Figure 6: Root Mean Square Error (top) and Mean Error (bottom) for 201 Piedmontese weather stations: SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, Kalman filter based on LM-DWD (KAL), JANUARY 2004

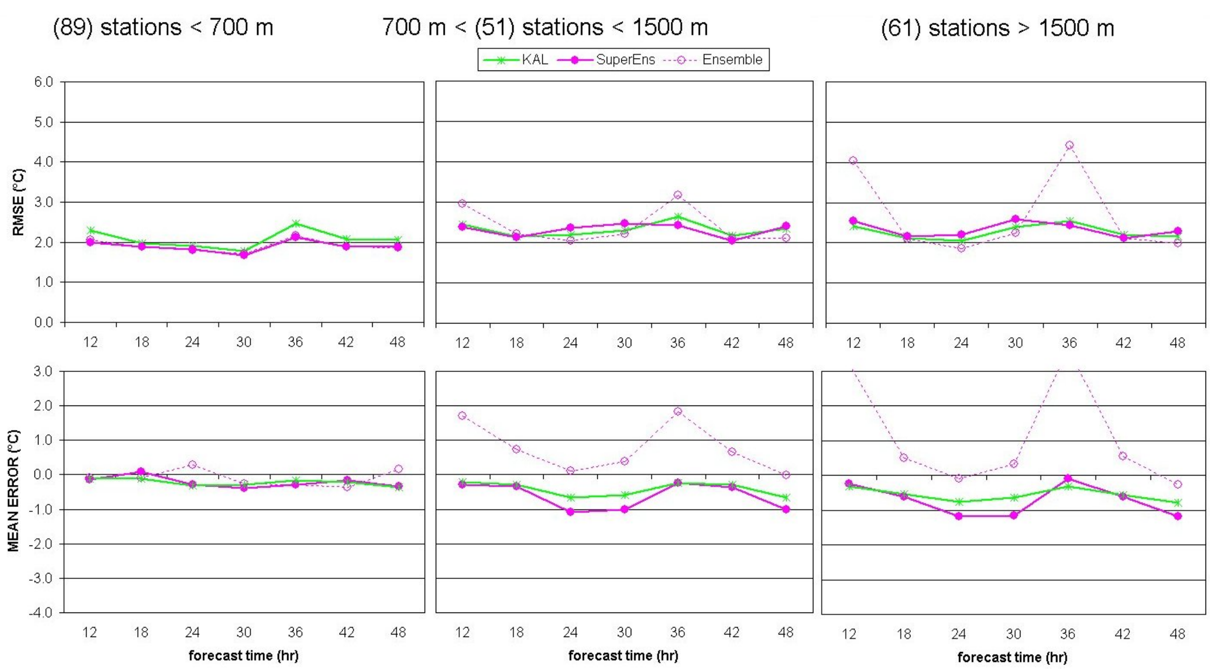

Figure 7: Root Mean Square Error (top) and Mean Error (bottom) for 201 Piedmontese weather stations: SuperEnsemble (SuperEns) and Ensemble (Ensemble) forecast, Kalman filter based on LM-DWD (KAL), JUNE 2004

models. The Multimodel SuperEnsemble improves the forecasts in high mountains locations, both in bias and RMSE and its performances are similar to those from Kalman filter, the latter being a much more complex technique, not suitable for all kind of variables. The hope is to obtain also good results in extending the Multimodel method to other parameters such as humidity and precipitation.

Acknowledgements

We wish to thank the Deutscher Wetterdienst and MeteoSwiss for providing the model outputs for this research work.

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