# USE OF MULTIMODEL SUPERENSEMBLE TECHNIQUE FOR MOUNTAIN-AREA WEATHER FORECAST IN THE OLYMPIC AREA OF TORINO 2006

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**Abstract**: The XX Olympic Winter Games will be held in Torino, Italy, on February 10-26, 2006 and the IX Paralympic Winter Games on March 10-19, 2006. The Olympic mountain venues are set in middle-, high- and very high-mountain places in the Susa and Chisone Valleys in Piedmont (up to 2600 m above sea level), therefore weather forecasts are strongly dependent on the complex geography and orography of these valleys. Direct model outputs, even from high-resolution limited area models, show many strong systematic and random errors in the forecast, compared to the values observed by our high-density non-GTS network. We present some results of the Multimodel SuperEnsemble technique (Krishnamurti et al. 2000) applied on both global circulation models and on non-hydrostatic limited-area models. The Multimodel SuperEnsemble technique takes into account various model outputs, weighted by parameters calculated in a training period. This is one of the first applications of this technique with limited-area models and in a narrow mountain area and results show a good improvement of meteorological parameter forecasts such as temperature and precipitation.

***Keywords -*** *ICAM, MAP, Croatia, Multimodel, Post-processing, Ensemble, SuperEnsemble*

## 1. INTRODUCTION

Multimodel SuperEnsemble technique (Krishnamurti *et al.*, 2000) is a powerful post-processing method able to reduce direct model output errors. Several model outputs are put together with adequate weights to obtain a combined estimation of meteorological parameters. Weights are calculated by square error minimization in a so-called training period.

In a previous paper (Cane and Milelli, 2005) we applied the Multimodel technique on the operational 00 UTC runs of Local Area Model Italy by UGM, ARPA-SIM, ARPA Piemonte (nud00), Lokal Modell by Deutscher Wetterdienst (lkd00) and aLpine Model by MeteoSwiss (alm00). This was one of the first implementations of Multimodel technique on limited-area models (in this case of 0.0625° resolution) and we obtained a strong improvement in temperature forecasts in Piedmont region.

In this paper we focus on the Olympic Area where the XX Olympic Winter Games and the IX Paralympic Winter Games will be held on 2006. The Multimodel technique is applied also on the operational 12 UTC run of the ECMFW global model. Temperature and precipitation results are shown.

## 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 bias-corrected or biased data respectively, is given by

$$S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}\left(F_i - \overline{F_i}\right) \quad (1) \qquad \text{or} \qquad S = \overline{O} + \frac{1}{N}\sum_{i=1}^{N}\left(F_i - \overline{O}\right) \quad (2)$$

The conventional SuperEnsemble forecast (Krishnamurti et. al., 2000) constructed with bias-corrected data is given by

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

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

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

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

$$\begin{pmatrix} \sum_{k=1}^{T}\left(F_{1_k}-\overline{F}_1\right)^2 & \sum_{k=1}^{T}\left(F_{1_k}-\overline{F}_1\right)\left(F_{2_k}-\overline{F}_2\right) & \cdots & \sum_{k=1}^{T}\left(F_{1_k}-\overline{F}_1\right)\left(F_{N_k}-\overline{F}_N\right) \\ \sum_{k=1}^{T}\left(F_{2_k}-\overline{F}_2\right)\left(F_{1_k}-\overline{F}_1\right) & \sum_{k=1}^{T}\left(F_{2_k}-\overline{F}_2\right)^2 & & \vdots \\ \vdots & & \ddots & \vdots \\ \sum_{k=1}^{T}\left(F_{N_k}-\overline{F}_N\right)\left(F_{1_k}-\overline{F}_1\right) & \cdots & \cdots & \sum_{k=1}^{T}\left(F_{N_k}-\overline{F}_N\right)^2 \end{pmatrix} \bullet \begin{pmatrix} a_1 \\ \vdots \\ \vdots \\ \vdots \\ a_N \end{pmatrix} = \begin{pmatrix} \sum_{k=1}^{T}\left(F_{1_k}-\overline{F}_1\right)\left(O_k-\overline{O}\right) \\ \vdots \\ \vdots \\ \sum_{k=1}^{T}\left(F_{N_k}-\overline{F}_N\right)\left(O_k-\overline{O}\right) \end{pmatrix} \tag{5}$$

We then solve these equations using Gauss-Jordan method.

## 3. RESULTS

The Olympic Area is monitored by ARPA Piemonte with a very-dense automatic weather station network. We used the data from this non-GTS network for the calculation of the weights in the training period and for validation purposes.

### 3.1. Temperature: February 2004

We calculated Multimodel Ensemble and SuperEnsemble forecast using the four models for the month of February 2004 (Olympic period). Instead of using a fixed long training period, as in Krishnamurti *et al.*, 2000, we preferred to use a dynamic short training period to take into account the seasonal variation of model performances. Then for each forecast day, forecast time and station we

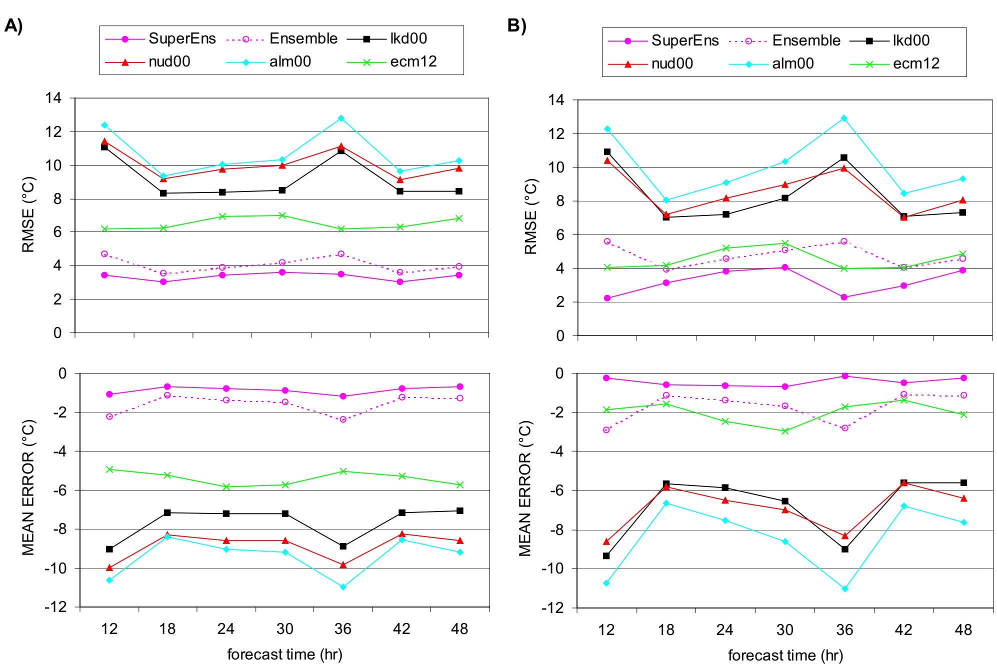


**Figure 1.** Temperature results. Root Mean Square Error (top) and Mean Error (bottom) of forecast vs observations for SuperEnsemble (SuperEns), Ensemble, German LM (lkd00), Italian LM (nud00), Swiss LM (alm00) and ECMWF (ecm12). A) 700 m < station height < 1500 m B) station height > 1500 m.

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 Root Mean Square Error and the Mean Error (or bias) of Multimodel SuperEnsemble, Ensemble and the four models interpolated at the station location. Stations are grouped by height: 10 middle-mountain stations (700 m < height < 1500) and 21 high-mountain stations (height > 1500 m).

It has to be pointed out the strong systematic error of the direct model outputs, reaching a bias of the order of 10 °C, with significant increase around noon (+12 hr and +36 hr forecast time). Multimodel Ensemble, which is simply an unbiased model combination, reduces this bias, but the RMSE is still around 4 °C. Multimodel SuperEnsemble reduces the bias and also improves the RMSE with values of 2-3 °C and similar performances for all the forecast times.

### 3.2. Precipitation: January-December 2004

33 raingauges are available in the Olympic Area, thus giving a good coverage of the two valleys. We applied Multimodel Ensemble and SuperEnsemble technique on the average and maximum values of this network, considering the whole 2004, in order to achieve a good statistics with at least 20 events for each precipitation threshold. Average and maximum values were also calculated for each model, taking into account the grid points covering the given area.

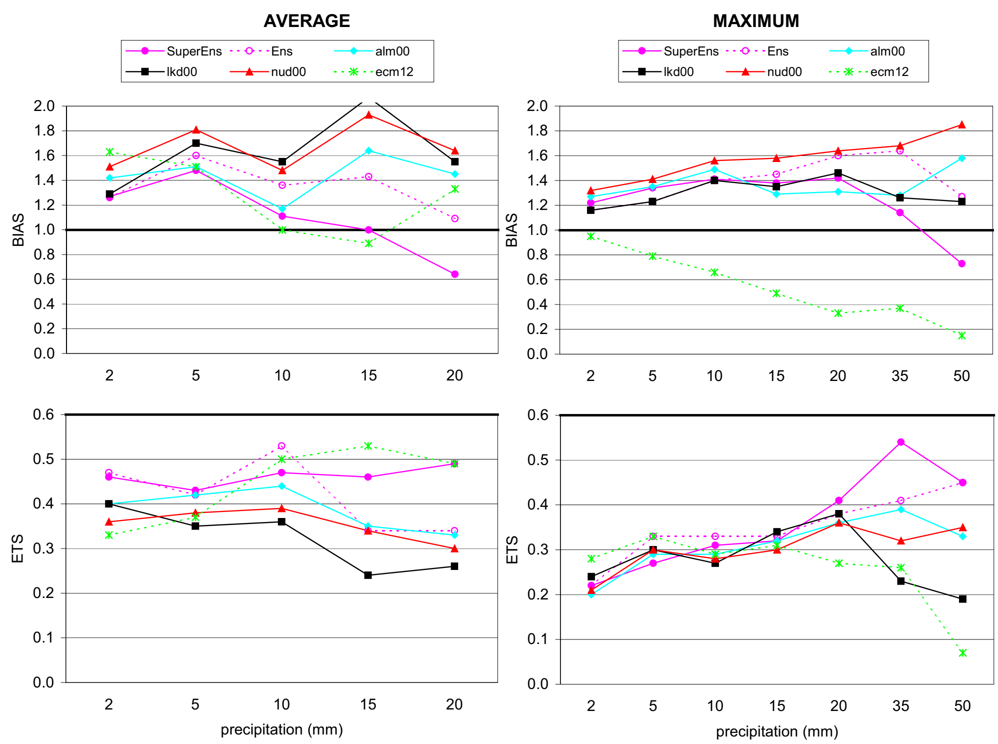


**Figure 2.** Precipitation results. Normalized Bias (top) and Equitable Threat Score (bottom) of forecast vs observations for SuperEnsemble (SuperEns), Ensemble, German LM (lkd00), Italian LM (nud00), Swiss LM (alm00) and ECMWF IFS (ecm12).

Ordinary SuperEnsemble technique was applied, using a fixed training period of 180 days before the forecast period. We compared the models and Multimodel results by Normalized Bias and Equitable Threat Score (ETS). Results are shown in Fig. 2.

In the Olympic area the models usually overestimate average precipitation, as we can see by the BIAS values higher than 1. Multimodel SuperEnsemble gives a good BIAS reduction. The best improvement is obtained in the spatio-temporal localization of the precipitation events, as described by ETS: Multimodel SuperEnsemble shows the highest values.

Multimodel improvement in the maximum values is less significant, but Multimodel results are still comparable with the best model, both in BIAS and ETS.

## 4. CONCLUSION

Multimodel Ensemble and SuperEnsemble technique are applied for the first time on three versions of the LM limited area model together with the ECMWF IFS global model in the Area of the XX Olympic Winter Games.

Multimodel SuperEnsemble gives a good improvement of temperature forecast, with BIAS and RMSE reduction.

We obtained an improvement also in average precipitation forecast, while in maximum precipitation forecast Multimodel SuperEnsemble gives results comparable with the best model.

This study will be extended to the whole Piedmont region, taking into account also other parameters.

In the framework of the Interreg IIIB-Medocc project Amphore the Multimodel technique will be applied on really different models: LAMI, Aladin, MM5, RAMS, Bolam, ECMWF.

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