The COSMO–SREPS Priority Project: The Autumn 2006 Testing Period

Chiara Marsigli, Andrea Montani and Tiziana Paccagnella

ARPA-SIM, Bologna, Italy

Flora Gofa and Petroula Louka

HNMS, Athens, Greece

1 Introduction

The development of COSMO–SREPS (COSMO Short-Range Ensemble Prediction System) is carried out within a Priority Project of the COSMO Consortium (the project description can be found at http://cosmo-model.cscs.ch/content/tasks/priorityProjects/sreps/default.htm). COSMO-SREPS is built to fulfil some needs that have recently arisen in the COSMO community:

- to have a short–range mesoscale ensemble to improve the support to the forecasters, especially in situations of high impact weather;
- to have a very short-range ensemble for variational data assimilation purposes (1D-Var), to estimate a flow–dependent error covariance matrix;
- to provide initial and boundary conditions to the very high resolution ensemble COSMO-DE-EPS under developement at DWD.

In order to accomplish these purposes, ensemble perturbations are required to generate a reasonable spread in the short–range and to act on the spatial scales which are more affected by errors in the short–range predictions. The strategy to generate mesoscale ensemble members proposed by this project tries to take into account several possible sources of uncertainty and thus to model many of the possible causes of forecast error (Marsigli et al., 2006).

In order to take into account the error of the global model on which the mesoscale one is nested, a multi–model approach is adopted. The MUlti–Model MUlti–Boundaries (MUM-MUB) ensemble system currently run by INM (Garcia–Moya et al., 2006), where five different limited–area models (UM, HIRLAM, HRM, MM5, COSMO) are driven by four global models (IFS, GME, UM, NCEP) having different assimilation cycles, is used to provide both initial and boundary conditions. In particular, INM provides to the COSMO partners the four 25-km COSMO runs nested on the four different global models.

In the current COSMO–SREPS setup, the four INM–COSMO runs are then used to drive 16 COSMO runs at higher resolution (10 km). Each of the 25-km COSMO runs provides initial and boundary conditions to four 10-km COSMO runs, differentiated by four different model perturbations (Fig. 1). Perturbations to the model are applied in two ways: (1) using different parameterisation schemes and (2) perturbating the parameters of the schemes. The reasons leading to the choice of the perturbation of type (1) are based on the difficulty to establish which scheme is better able to parameterise a particular physical process or to approximate the true solution. As for perturbation type (2), this choice is due to the fact that a number of parameters are included in the COSMO formulation, especially in the schemes used for

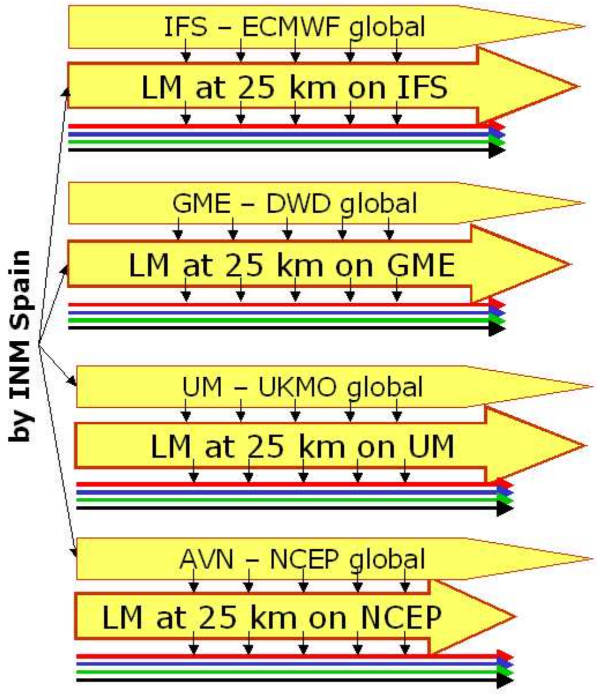

Figure 1: Scheme describing the COSMO–SREPS setup.

Table 1: Model perturbations used in COSMO–SREPS.

Name	Description	Parameter range	Default value	Used value
T	scheme for the parametrisation of the deep convection	T, KF, KFB	Tiedtke	Tiedtke
KF	scheme for the parametrisation of the deep convection	T, KF, KFB	Tiedtke	Kain–Fritsch
pat_len	length scale of thermal surface patterns	[0,10000]m	500	10000
tur_len	maximal turbulent length scale	[100,1000]m	500	1000

the parameterisations of the unresolved physical processes. Generally, these parameters are assigned a fixed value chosen within a range, which describes the uncertainty around the best estimate of the parameter. Therefore, model perturbations can be applied by varying within its range the value assigned to the parameter in the different model runs. For this purpose, the range of variability needs to be carefully specified and it is made available by the scientists involved in the development of the schemes.

The model perturbations applied to the present configuration of COSMO–SREPS are described in Table 1.

Each 25–km COSMO integration drives four 10–km COSMO runs, each of them with a different setup of the physics, i.e. the first using the Tiedtke scheme for the parametrisation of the deep convection and the default value for each of the other parameters, the second using the Kain–Fritsch scheme and the default value for each of the other parameters, the third using the default Tiedtke scheme but using the value 10000 for the pat_len parameter and the default value for the tur_len parameter, the fourth using the default Tiedtke scheme, the default value for the pat_len parameter, but using the value 1000 for the tur_len parameter. Therefore, each run is perturbed only in one parameter or scheme. This allows to have four runs for each model perturbation, driven by all possible global models.

The system has been built in this way in order to permit an evaluation of the performance of the different global models as driving models and of the different physics setup. In principle, all the model perturbations have to be equivalent from a statistical point of view. A model setup which is always performing better or worse than the others should be always or never used into the model and not considered as a possible perturbation. Whether this equivalence holds, is being checked on the basis of the system runs on the testing periods.

COSMO–SREPS has been run in the described configuration over 21 cases of moderate and intense precipitation occuring over either Italy or Germany during Autumn 2006. The runs have started either at 00 or at 12 UTC, depending on the boundary conditions availability. The system runs over the same area as the COSMO–LEPS system, at a horizontal resolution of about 10 km and with 40 vertical levels. The considered forecast range is 72 hours.

A preliminary analysis of the system performace is presented here, based on this testing period.

The involvement of the Hellenic National Meteorological Service (HNMS) in Task 6 of COSMO–SREPS focused on the verification of COSMO ensemble forecasts for autumn 2006. In particular, the 21 cases of 72-hour forecast horizon and 16 members were used for verification over Greece using the available SYNOP data. The parameters verified were the 2m air temperature, the mean sea-level pressure (MSLP) and the precipitation.

2 Spread-Error Relationship

In order to evaluate if the perturbations applied to the ensemble are appropriate for the short–range and for the description of the uncertainty affecting the forecast of surface variables, the spread of the COSMO–SREPS system is analysed.

In Fig. 2 the COSMO–SREPS spread and error (root-mean-square), computed in terms of 2m temperature over a set of about 900 stations covering northern Italy, are compared with COSMO–LEPS one. The observations on station points are compared with the values forecasted on the nearest grid points.

Only the COSMO–SREPS runs starting at 12 UTC (7 days) have been used for this analysis, since only these runs permit a clean comparison with COSMO–LEPS, which runs every day at 12 UTC. A comparison of the 00 UTC COSMO–SREPS with the 12 UTC COSMO–LEPS seemed not to be advisable due to (1) the dependence of the spread and of the error of the time of the day and (2) the different performances of the COSMO model when driven by the 00 or the 12 UTC IFS runs.

It appears from the plot that COSMO–SREPS spread is greater than COSMO–LEPS one for the considered forecast range, being almost double during the first 24 hours and then approaching the other with increasing forecast range. This indicates that the short–range ensemble can really benefit of a source of uncertainty which plays a role in the short range. Furthermore, the errors of the two systems are quite close, suggesting that the greater amount of spread shown by COSMO–SREPS is not worsening the forecast, but permits to describe part of the uncertainty affecting the forecast, at least for the first two days.

It has to be pointed out that the error is, for both systems, higher than the spread, suggesting that both systems are underdispersive for all the forecast ranges. This is probably indicative

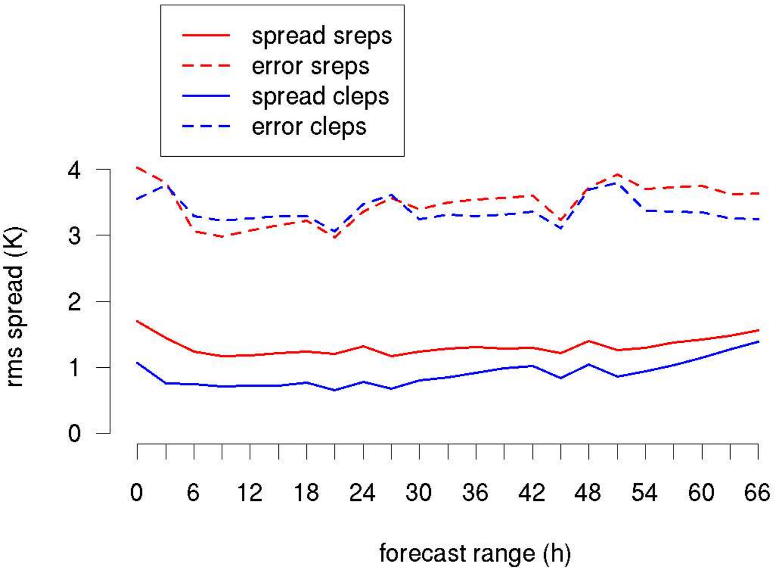

Figure 2: Root–mean–square error (dashed lines) and Root–mean–square spread (solid lines) relative to COSMO–SREPS (red lines) and COSMO–LEPS (blue lines) in terms of 2m temperature with increasing forecast range.

of the fact that the COSMO model systematic error plays a significant role, the model perturbations applied to COSMO–SREPS being probably not enough, in terms of processes described, to take it into account.

In order to address the problem of understanding how the different perturbations applied to COSMO–SREPS contribute to determine its spread, the spread has been computed also for eight different grouping of the 16 ensemble members, containing 4 members each. The members can be distinguished either on the basis of the driving run, which permits to create 4 groups labelled with the name of the driving model (ecmwf, gme, avn, ukmo), or on the basis of the COSMO model perturbation, which permits to create 4 groups labelled with p1 (T, see Table 1), p2 (KF), p3 (pat_len) and p4 (tur_len). The spread so obtained are plotted in Fig. 3.

For this plot, only the COSMO–SREPS runs staring at 00 UTC (14 days) have been used, due to the dependence of the spread on the time of the day.

The black line is relative to the root–mean–square distance among the 4 ensemble members which have received initial and boundary conditions from the ECMWF–COSMO run. Hence, the differences among these 4 members come only from the perturbations applied to 4 model parameters. On the other hand, the magenta line is relative to the root–mean–square distance among the 4 ensemble members which have the same model formulation, the model having been perturbed by selecting the parametrisation p2 (Kain–Fritsch) in all the 4 runs. It is clear that the spread among members having different values of physics parameters but the same driving model is always lower (almost a half) than the spread among members having different driving models but the same COSMO formulation. Therefore, the major contribution to the spread is given by the different initial and boundary conditions, as expected, on average over the whole sample. Over specific point of the domain and for specific days, the situation can be quite different and even reversed (not shown).

An evaluation of the influence of the different kind of perturbations on the error affecting

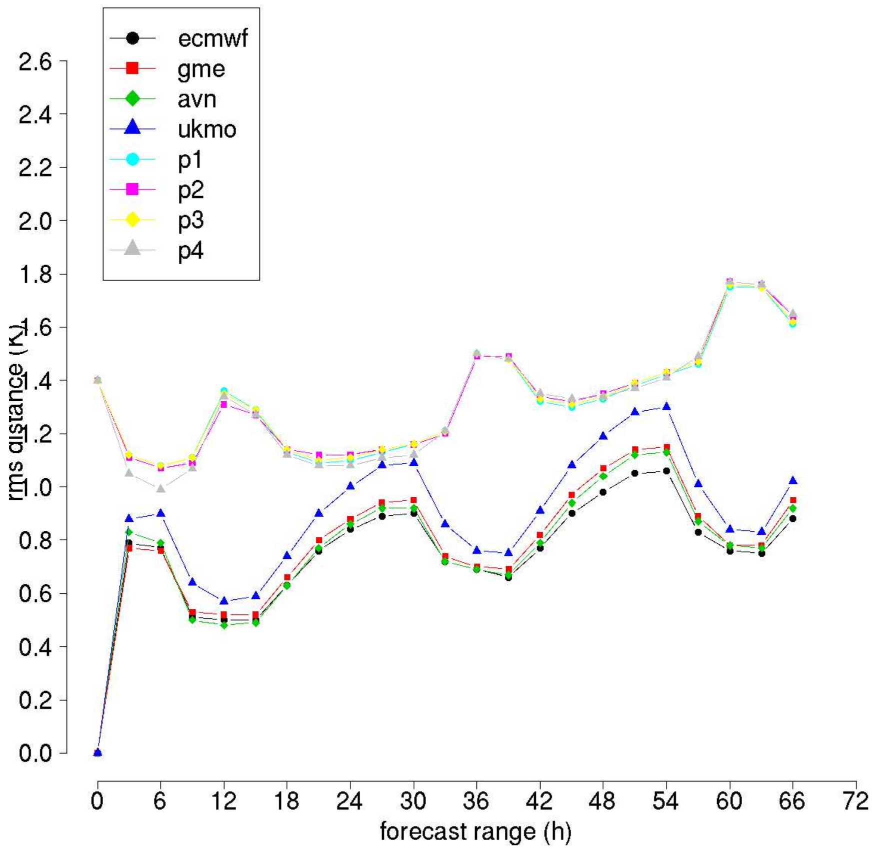

Figure 3: Root–mean–square distance, in terms of 2m temperature, among 8 different groups of ensemble members: the 4 members with the same ECMWF father in black, the 4 members with the same GME father in red, the 4 members with the same NCEP father in green, the 4 members with the same UKMO father in blue, the 4 members with the same p1 model perturbation in violet, the 4 members with the same p2 model perturbation in orange, the 4 members with the same p3 model perturbation in magenta and the 4 members with the same p4 model perturbation in cyan.

precipitation forecasts is complicated by the difficulty in defining a spread measure in terms of this parameter. In order to evaluate how the different perturbations affect precipitation forecasts, an objective verification in terms of this variable has been carried out. The skill of the COSMO–SREPS ensemble is thus compared with the skill of the eight sub–ensembles which can be built by grouping the members on the basis either of their driving model or of their physics perturbation. The ROC area values obtained for 24-h precipitation, computed by averaging both forecasted and observed values over boxes of 0.5×0.5 degrees, are shown in Fig. 4.

Observations are provided by a dense network of raingauges covering northern Italy and Switzerland (about 1400 stations).

The two plots in the upper row show how the ROC area changes from the whole ensemble (cyan line) to each of the 4 member ensembles made up by the COSMO runs with the same driving model (blue line for ECMWF, red line for GME, green line for AVN, black line for UKMO). The reduction in score due to the difference in the number of ensemble members is evident for every sub–ensemble. Furthermore, the ROC area varies of a considerable amount

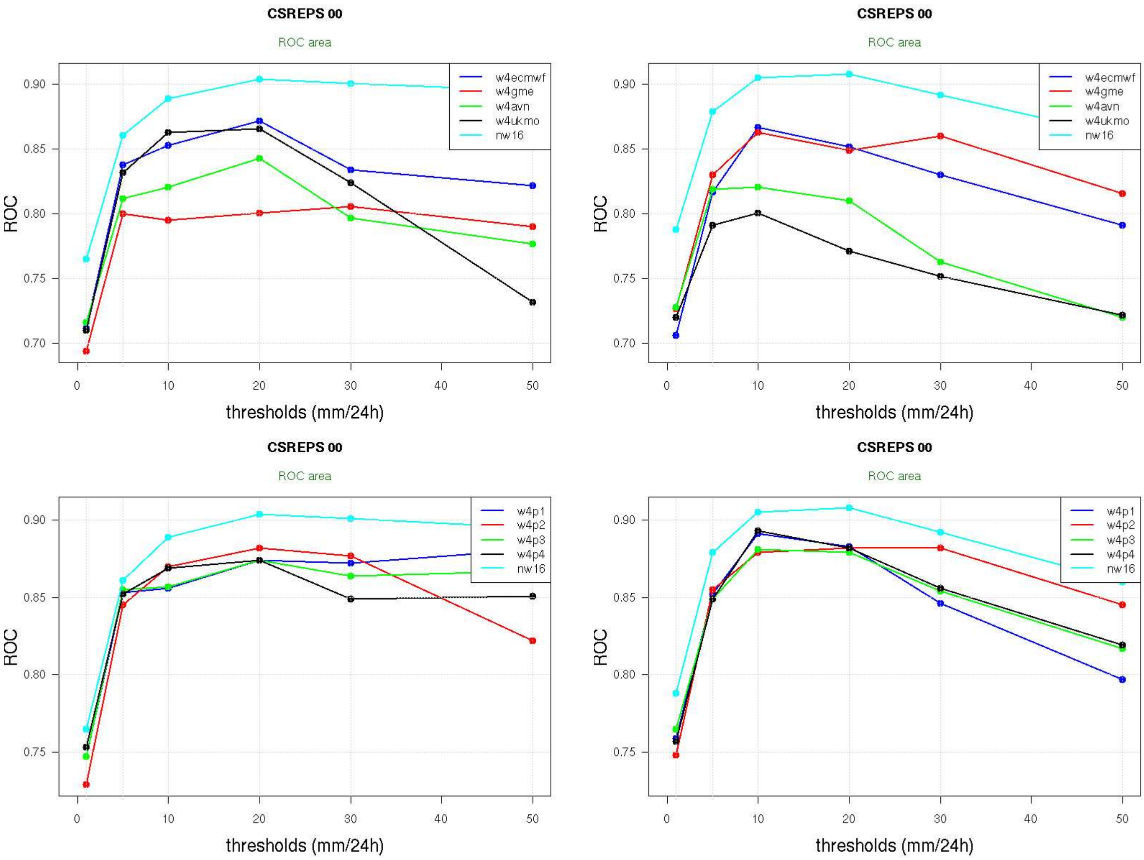

Figure 4: ROC area relative to the 24-h precipitation forecasts issued by COSMO–SREPS (cyan line) and by four sub–sets of it. In the upper panels the four sub–sets of 4 members each are made up by grouping the members with the same father, while in the lower panels by grouping the members with the same physics perturbation. The forecast range in 18-42 h in the left column and 42-66 h in the right column. Verification is performed in terms of average values over boxes of 0.5×0.5 degrees.

from one sub–ensemble to another, the ECMWF and UKMO members performing better at the 18–42 h forecast range (left panel) while at the 42–66 h forecast range the best score is obtained by the ECMWF and GME members. These variations can also be due to the smallness of the available sample, hence, on the basis of this preliminary analysis, it is not possible to draw general conclusions about which driving model provides the best performance.

As for the 4 member ensembles made up by the COSMO runs with the same physics perturbations (lower row), the ROC area values are generally higher than those exhibited by the ensembles with the same driving model, indicating that the diversity in terms of driving model (which characterises the ensembles in the lower row) guarantees higher skill with respect to the diversity in terms of physics parametrisations alone (which characterises the ensembles is the upper row). Furthermore, the ROC areas of the 4 sub–ensembles are quite similar, indicating that all the physics perturbations are equivalent from the skill point of view.

3 Verification

Within the COSMO cooperation, objective verification of the COSMO–SREPS system has been carried out at HNMS (Greek National Meteorological Service), evaluating the system performance in terms of surface variables (2m temperature, precipitation, mean sea level pressure, 10m wind) over Greece. This aims also at assessing the extent to which the 16 members have different skill, depending on the driving model or on the parameter set up.

The involvement of the Hellenic National Meteorological Service (HNMS) in Task 6 of COSMO–SREPS focused on the verification of the ensemble forecasts for autumn 2006. In particular, the 21 cases of 72-hour forecast horizon and 16 members were used for verification over Greece using the available SYNOP data. The parameters verified were the 2m air temperature, the mean sea–level pressure (MSLP) and the precipitation.

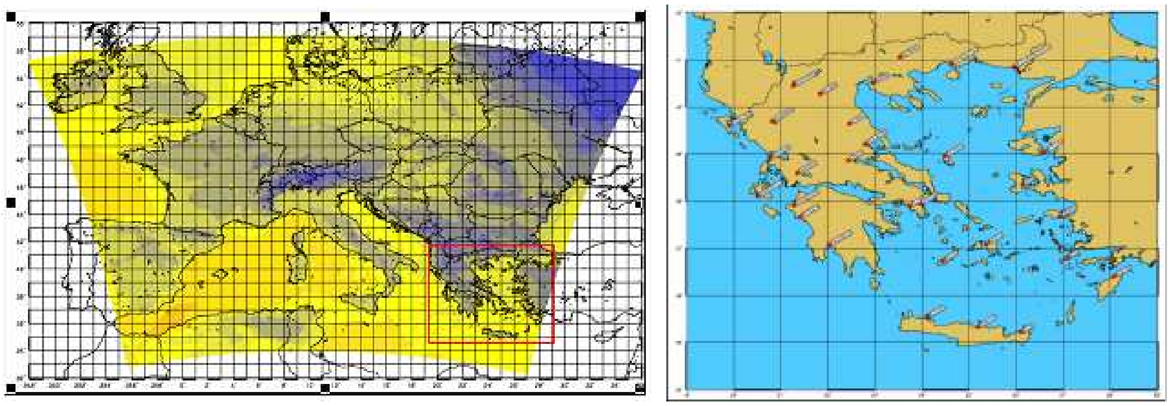

Figure 5: Left panel: the red square indicates the verification domain used for Greece. Right Panel: the SYNOP stations.

Greece is located at the very southeast part of the domain implemented (Fig. 5, left panel), therefore some SYNOP data may be influenced by the boundaries. 30 stations were used for the verification as shown in the right panel of Fig. 5. Due to the complexity of Greece's topography the grid points closest to the location of the stations were used.

For the continuous parameters of temperature and MSLP the statistical analysis was based on the calculation of Bias and Root Mean Square Error (RMSE) averaged over all forecast members and stations. Fig. 6 shows the results of the statistical analysis for all forecast members. In general, averaged BIAS and RMSE values showed a small overestimation of MSLP (not shown) and statistically acceptable values, namely, approximately 2C for 2m temperature and less than 5 mb for MSLP (Fig. 6), apart from a few specific forecasts in November for which RMSE was large compared to the mean value (Fig. 7).

The verification of the 6-hour precipitation, being a non–continuous parameter, was based on the deterministic approach, namely, the production of contingency tables, the calculation of the Probability Of Detection (POD), the False Alarm Rate (FAR) and other statistical scores. The threshold ranges used for these quantities were: 0-0.1 mm, 0.1-4.0 mm, 4.0-9.0 mm, >9.0 mm. These values were lower than those conventionally used in SREPS due to the limited precipitation amounts existing during the selected period.

The sample used was statistically small for extracting conclusive information on precipitation forecast. Figure 8 shows the evolution with forecasting period of POD and FAR grouped according to the different initial conditions for the two first threshold ranges. Figure 9 shows the same results but grouped according to the different convective scheme parameterizations.

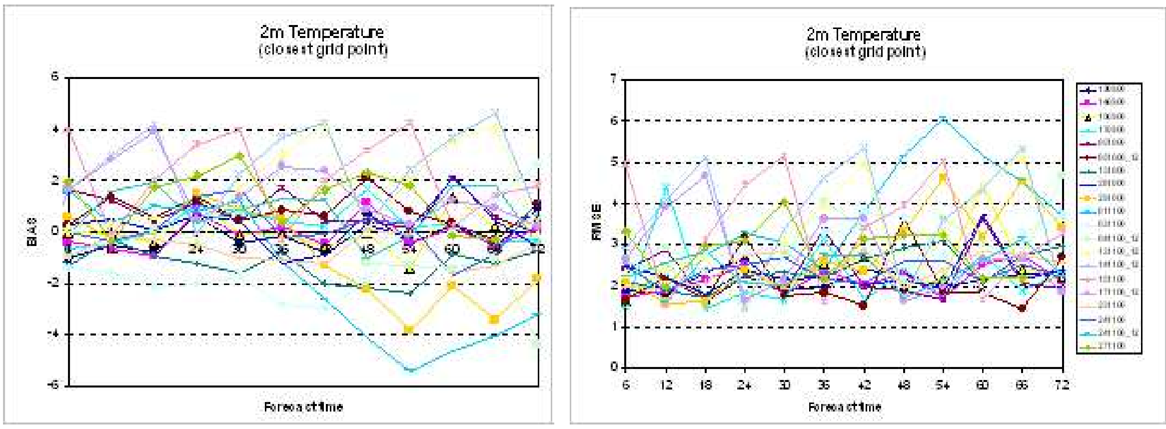

Figure 6: Bias (left panel) and RMSE (right panel) for 2m air temperature for all forecast members.

The available results suggested that the precipitation amounts were generally overestimated. The influence of the different initial conditions on the forecasted precipitation field was evident. The influence of the convective scheme and turbulent length scale is important mainly on forecasting accurately the presence of a precipitation event as indicated by the POD value.

4 Summary and Outlook

The analysis of the COSMO–SREPS performances for the Autumn 2006 testing period permits to draw positive conclusions on the usefulness of the system in describing the short–range forecast error affecting surface parameters, thought the system results to be underdispersive. The verification over Greece carried out by HNMS indicates that the forecast error in terms of 2m temperature and MSLP is in agreement with the error of the deterministic implementation of the model.

It has to be underlined that all these results are very preliminary, being based on a very small sample of 21 days, so it is not possible to draw robust conclusions on their basis.

In order to allow an extensive evaluation of the system, COSMO–SREPS was run during the whole DOP (June to November 2007) of the MAP D-PHASE project. The ensemble was run at the 00 UTC of each day for which the initial and boundary conditions provided by INM were available, ending in 107 runs which cover unevenly the 6 month period.

An evaluation of the spread of the system, also in relation to the forecast error, is being carried out in terms of both surface and upper air parameters (2m temperature, MSLP, Z500).

Furthermore, a study on the physics perturbations is being carried out, in order to select the most promising physics perturbations to be applied to COSMO–SREPS in the future. Since the COSMO–SREPS system has proved to be underdispersive in the first testing period, the possibility of adding more and more different physics perturbations is being explored. For this purpose, a 16 member ensemble has been running, taking initial and boundary conditions for each run from the operational IFS deterministic run and applying 16 different physics perturbations to the model. This is being done for the whole Autumn 2007 (91 runs), with the same model version and domain used for COSMO–SREPS.

Finally, the future plans of HNMS within COSMO–SREPS are:

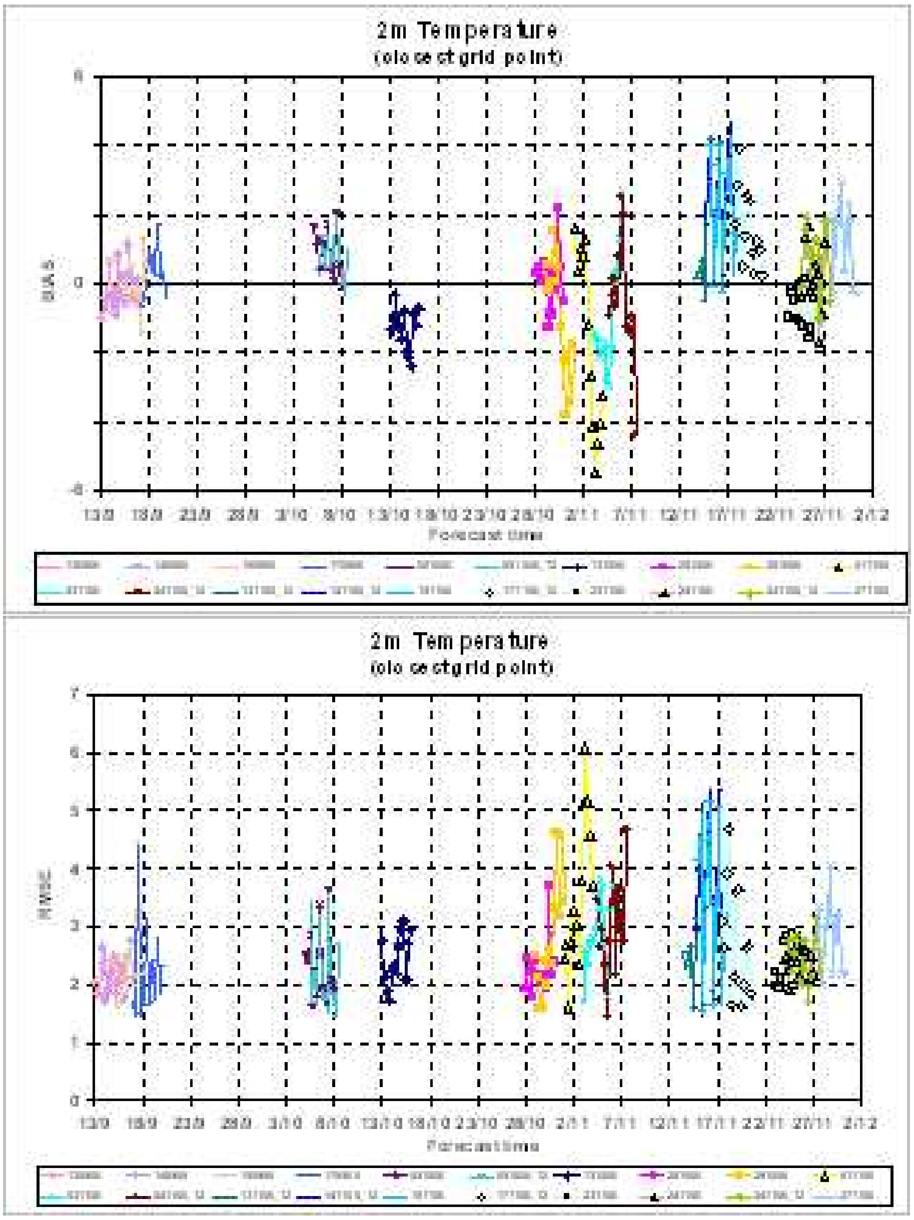

Figure 7: Bias (left panel) and RMSE (right panel) for 2m air temperature for all forecast members during the testing period.

- Application of the existing statistical methods to a larger sample (MAP D-PHASE period)
- Extend the statistics to include other meteorological parameters (wind where available)
- Investigation of precipitation ensemble forecasts using probabilistic approach (ROC diagrams, etc)

References

Garcia-Moya, J.A., A. Callado, C. Santos, D. Santos, J. Simarro and B. Orfila, 2006: Recent Experiences with the INM Multi-model EPS scheme. *Newsletter of the 28th EWGLAM and 13th SRNWP meetings*, 9-12 October 2006, Zürich, Switzerland, 267-276.

Marsigli, C., A. Montani and T. Paccagnella, 2006: The COSMO-SREPS project. *Newsletter*

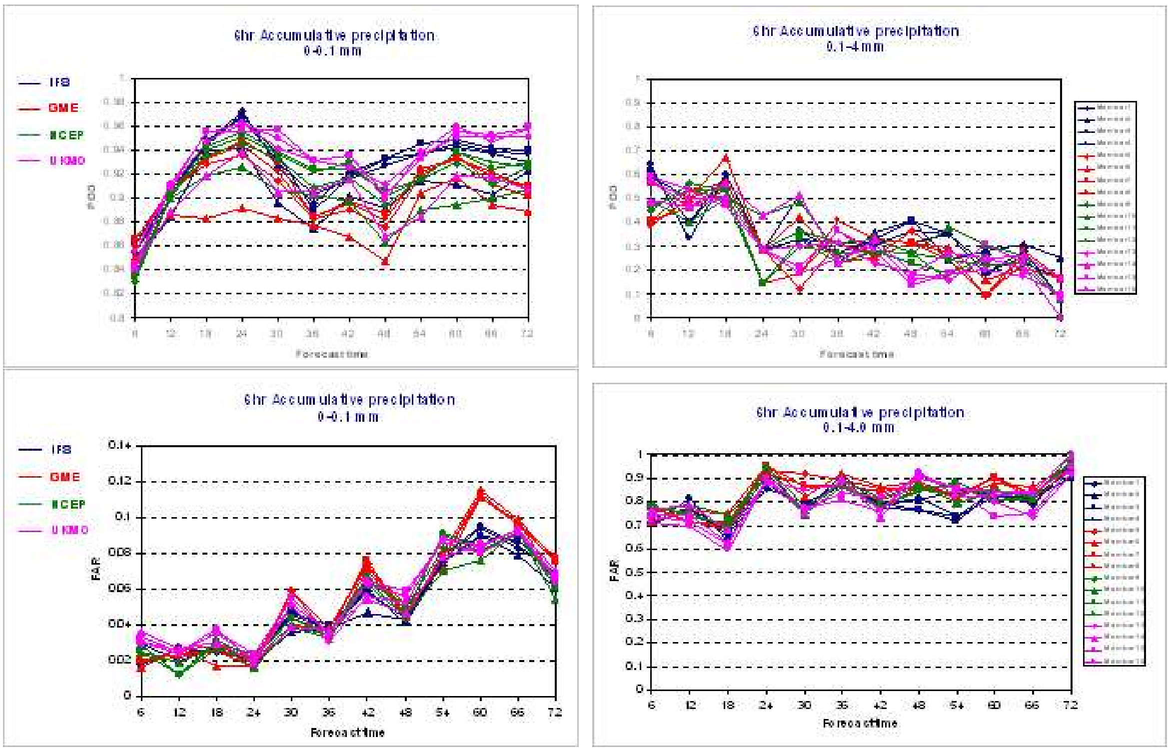

Figure 8: Values of POD and FAR grouped on different initial conditions.

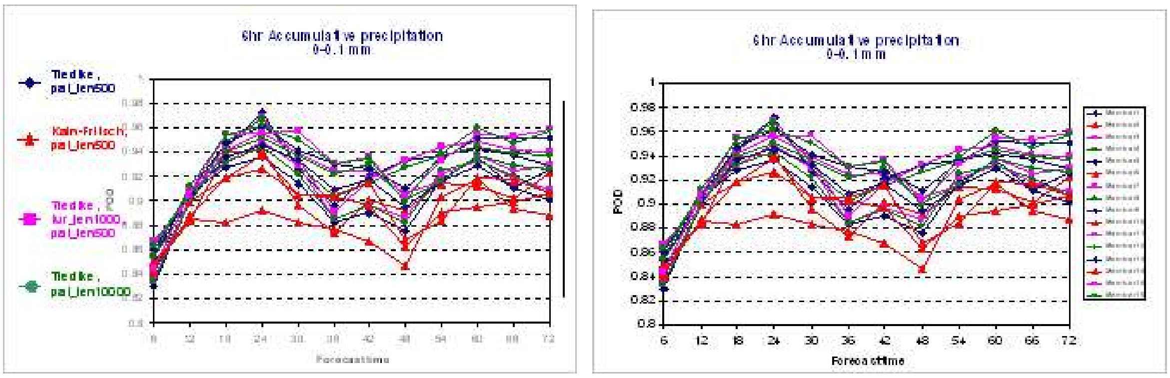

Figure 9: Values of POD and FAR grouped on different convective scheme.

of the 28th EWGLAM and 13th SRNWP meetings, 9-12 October 2006, Zürich, Switzerland, 277-283.