Ensemble activities at ARPA-SIM: the COSMO-LEPS and COSMO-SREPS systems

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Abstract: The most recent results of the two main activities on limited-area ensemble systems carried out at ARPA-SIM, namely the COSMO-LEPS and COSMO-SREPS projects, are shown. Both systems have 16 members and 10km of horizontal resolution but, while COSMO-LEPS is operationally running since 2002 and it has been designed for the early medium range, COSMO-SREPS is being developed as a short-range ensemble and it has been run for a 1-month test period in autumn 2006. Results are presented for some selected events, comparing the performance of the two system in terms of precipitation in the overlapping forecast range (first 72 hours). The spread-skill relation of the two systems is analysed over the Alpine area in terms of 2m temperature, focusing on the role of the different sources of uncertainty in producing the spread.

Keywords: *ensemble, precipitation, model perturbations*

1. The ARPA-SIM ensemble systems.

COSMO-LEPS is the limited-area ensemble prediction system based on the non-hydrostatic "COSMO-model" (formerly known as “LM”), developed within the COSMO consortium since 2002 (Montani et al. (2003)). This system aims at improving upon the early and medium-range predictability of extreme and localised weather events, especially when orographic and mesoscale-related processes play a crucial role. The integration domain is shown in Figure 1.

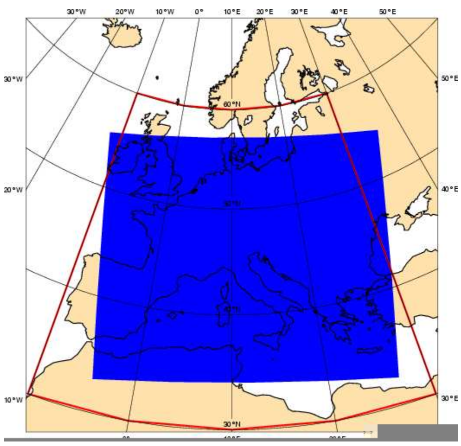

Figure 1: Domain of the two limited-area ensembles (blue area).

COSMO-SREPS (Short-Range Ensemble Prediction System) is being developed by ARPA-SIM within a Priority Project of the COSMO Consortium, with the collaboration of a number of COSMO scientists. The project deals with the development and implementation of a short-range ensemble based on the COSMO model. This system 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 EELKM (Experimental Ensemble LM-K) of DWD.

The strategy to generate the mesoscale ensemble members proposed by this project tries to take into account several possible sources of uncertainty and then to model many of the possible causes of forecast error. The proposed system would benefit of: perturbations of the initial conditions, perturbations of the boundary conditions, perturbations of the limited-area model.

In the COSMO-LEPS system, the perturbations are ingested mainly through the boundary conditions, which are provided by some selected members of the operational ECMWF EPS (Molteni et al. (2001); Marsigli et al. (2001)). Being the COSMO-LEPS perturbations derived from the EPS ones, the system is useful especially in the early medium range (day 3-5). Furthermore, a random choice of the scheme to be used for the parameterisation of the deep convection (either Tiedtke or Kain-Fritsch) is allowed in the LM runs. A preliminary study (Marsigli et al. (2005)) suggested that the perturbations applied in this way play a minor role with respect to the perturbations at the boundaries, which explain the major amount of the spread.

The necessity of using a probabilistic approach also for the short-range and for the smaller scales can be understood in the light of the recent model developments. Despite the possibility to explore the scale of the order of few kilometres, the capability of numerical models to correctly forecast local and intense precipitation is still nowadays limited. This is true even at short time-range, up to 48 hours, due to the loss of atmospheric predictability going down to small spatial and temporal scales. At this scales (1 to 10 km), it is not completely satisfactory just to reproduce precipitating structures, but a correct localisation in space and time is required together with realistic peak values. These considerations introduce the need of a quantification of the predictability associated with a forecast which has been until now considered better provided by a deterministic very high resolution model. The scales at which the uncertainty needs to be quantified are influenced by phenomena which are only marginally considered in the generation of the perturbations for the global ensemble. In order to design an ensemble system for these purposes, the use of perturbations which can generate a reasonable spread in the short-range and of perturbations that act on a more local scale and is explored. Within the project, it has been planned to apply three different techniques for the model perturbations: (1) use of different parameterisation schemes, due to the difficulty to establish which scheme is better able to parameterise a particular physical processes (2) perturbation of the parameters of the schemes, (3) perturbation of the surface fields. The reasons leading to the choice of the perturbation type (1) are . As for perturbation type (2), a number of parameters are included in the Lokal Modell formulation, especially in the schemes used for the parameterisations of the physics. Generally, these parameters are assigned a fixed value chosen within a range, describing the uncertainty around the best estimate of the parameter. Therefore, model perturbations are added by varying, in the different model runs, the value assigned to the parameter within its range.

In order to take into account the error of the global model that comes from the boundaries, a multi-model approach is adopted for COSMO-SREPS. A MUlti-Model MUlti-Boundaries ensemble system is currently run by INM, where five different limited-area models (UM, HIRLAM, HRM, MM5, LM) are driven by the four global models (IFS, GME, UM, NCEP) which provide both initial and boundary conditions. The four LM runs nested on the four different global models are provided to the COSMO partners by INM. The four INM-LM runs are used in the SREPS project to drive 16 LM runs at higher resolution (10 km). Each of the 25 km LM runs provides initial and boundary conditions to 4 higher resolution LM runs, differentiated by the use of 4 different model perturbations (see Table 1).

Table 1: Perturbations applied to each of the 16 ensemble members. The members of each row are differentiated only by the model perturbations but have the same initial and boundary conditions, while the reverse is true for the members of each column.

	model perturbations			
ic and bc	p1=ctrl	p2=kainfri	p3=turlen	p4=patlen
COSMO25km on IFS	m1	m2	m3	m4
COSMO25km on GME	m5	m6	m7	m8
COSMO25km on NCEP	m9	m10	m11	m12
COSMO25km on UM	m13	m14	m15	m16

The system has been run in the described configuration over a 21-day test period in autumn 2006. The selected days, from 13/09/06 to 27/11/06, are characterised by moderate to intense precipitation affecting an area including northern Italy, Switzerland and Germany. COSMO-SREPS is run over the same area of the COSMO-LEPS system, with the same horizontal (10km) and vertical resolution (40 levels). The considered forecast range is 72 hours.

2. Results.

2.1 The 13/05/2006 event.

The first run of the COSMO-SREPS system was performed for the 13 May 2006 event, when precipitation of moderate intensity have affected northern Italy and Switzerland. The run has started at 00 UTC of the 13 May 2006.

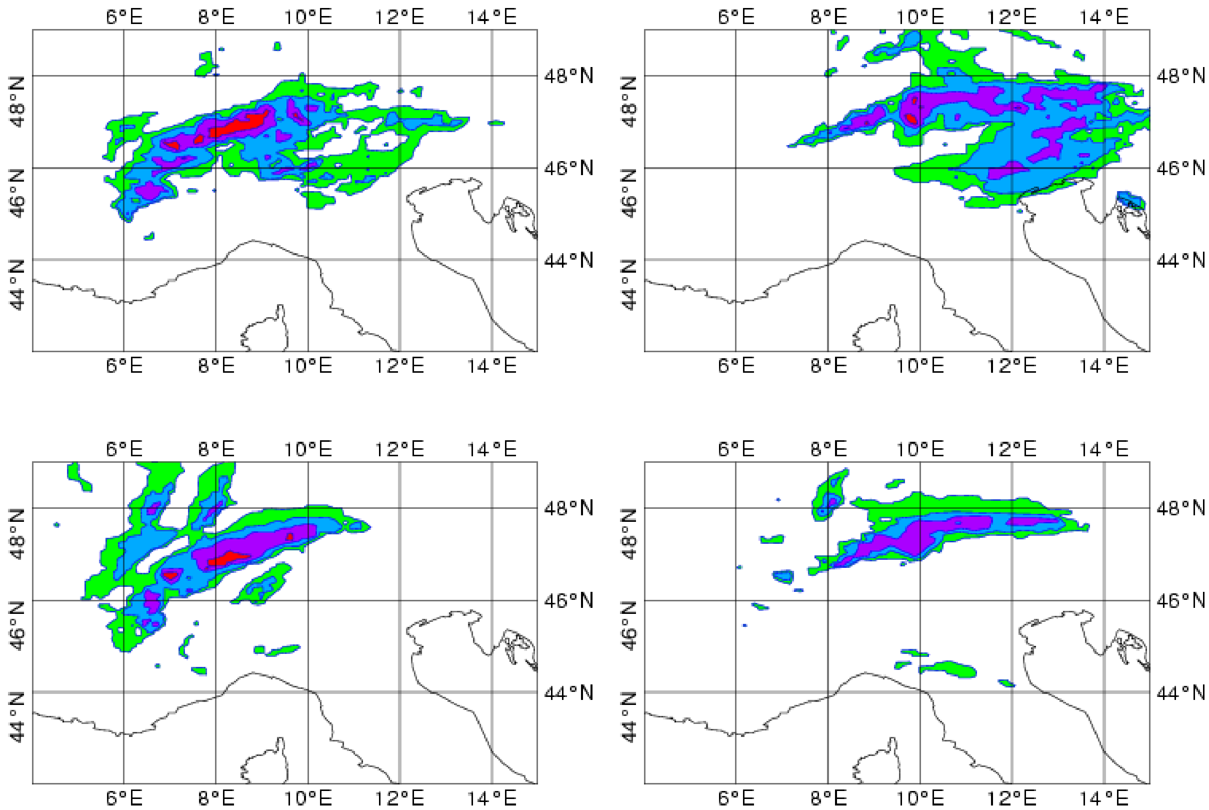

Figure 2: COSMO–SREPS (top) and COSMO–LEPS (bottom) probability maps for the 10mm/6h threshold, for the periods 18-24 UTC of the 13 May (left) and 00-06 UTC of the 14 May (right). Isolines are relative to 10 (green), 30 (blue), 60 (violet) and 90 (red) %.

The COSMO-SREPS probability maps relative to the event “precipitation exceeding 10mm/6h” for the two 6-hour periods 18-24 UTC of the 13 May (18-24 h forecast range) and 00-06 UTC of the 14 May (24-30 h forecast range) are shown in the two top panels of Figure 2. In the two bottom panels are shown the COSMO-LEPS probability maps for the same period, relative to the run started at 12UTC of the 13 May, the forecast range being respectively 06-12 h and 12-18 h. In the first 6-hour period precipitation was observed mainly on the north-western Alps, in the Ticino and Lago Maggiore area (not shown). Both probabilistic systems indicate as likely to be interested by precipitation exceeding 10mm/6h an area including the one where precipitation was actually observed. In the second 6-hour period, heavy precipitation was occurring over the plain of the Veneto region, approximately around 12ÂřE - 46ÂřN, with moderate precipitation spreading over the central part of the Alps (not shown). For this period, only the COSMO–SREPS forecasts assign a probability exceeding 30%

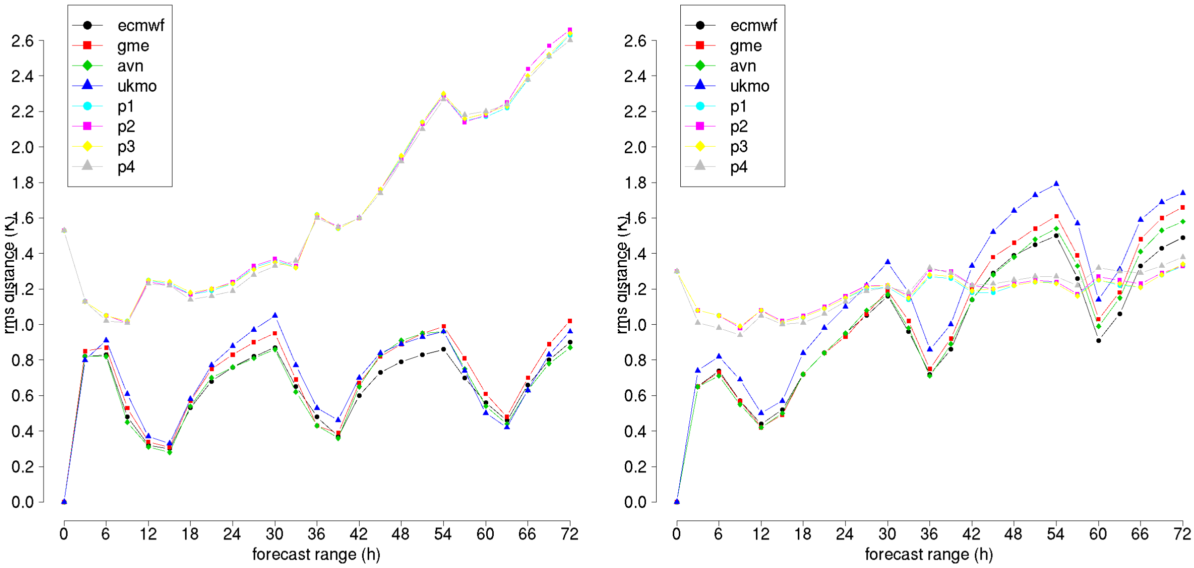

Figure 3: Root-mean-square distance, in terms of 2m temperature, among 8 different groups of ensemble members: the 4 members with the same IFS father in black, the 4 members with the same GME father in red, the 4 members with the same NCEP father in green, the 4 members with the same UM father in blue, 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. The left panel is for the 28/10/06 run, the right panel is for the 24/11/06 run.

to the occurrence of precipitation over the plain, while COSMO-LEPS maps indicate as likely to be affected by rainfall the central Alps area only.

2.2 The autumn test period.

In Figure 3 it is shown how the spread, computed in terms of 2m temperature, among ensemble members varies according to the criterion used to group the members. Two different runs have been selected in the test period, in order to show the day-to-day variability of the contributions to the total spread.

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