Operational Implementation of Ensemble Forecasts using Lokal-Modell

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1 Introduction

The increase of computer power resources has recently enabled a marked development of numerical weather prediction (NWP) models as concerns not only the possibility to afford higher horizontal and vertical resolution but also a more detailed description of the physical processes related to atmospheric instability. As a consequence, the average performance of NWP models has noticeably improved and the operational use of sophisticated global–model ensemble prediction systems is more and more widespread. Nevertheless, the forecast of localised and severe weather events (e.g. heavy rainfall, strong winds, cold temperature anomalies) is still nowadays a challenging problem, despite the more and more careful detection of precursors, developments and mature phase of this kind of events. The key role played by mesoscale and orographic–related processes can seriously limit the predictability of intense and localised events. Although the use of high–resolution limited–area models (LAMs), nested on the fields predicted by the global runs, has definitely improved the short–range prediction of locally intense events, it is sometimes difficult to forecast accurately their spatio–temporal evolution for ranges longer than 48 hours. Therefore, several methodologies have recently been implemented and experimented to tackle the problem and improve upon the short to medium–range prediction of those surface fields heavily affected by local processes, the attention being often focused on quantitative precipitation forecast (QPF). Thanks to the generation of ensemble systems, many weather centres have given more and more emphasis to the probabilistic approach, which enable to estimate the predictability of the atmospheric flow and assess the reliability of the deterministic forecast beyond the very short range.

As concerns the use of limited–area models, the Regional Meteorological Service of Emilia–Romagna ARPA–SMR (in Bologna, Italy) developed the Limited–area Ensemble Prediction System (LEPS). By means of a clustering–selection technique, ECMWF members are first grouped into five clusters, then a representative member (RM) is selected within each cluster (Marsigli et al., 2001; Molteni et al., 2001; Montani et al., 2001). The RMs provide both initial and boundary conditions for the integrations with a limited–area model, which is run five times (once per RM), so generating a small–size high–resolution ensemble for forecast ranges up to 120 hours. Hence, the probabilistic products typically generated at ECMWF (e.g. probability maps for rainfall rates or wind intensity exceeding particular thresholds) can be produced on the basis of the information provided by LAM integrations, each run being weighted according to the population of the cluster where the RM is selected. It is worth mentioning that the experimentation was carried out using LAMBO (Limited Area Model BOlogna), the hydrostatic limited-area model in operational use at ARPA-SMR. LAMBO is based on the NCEP ETA model and has an operational horizontal resolution of 20 km with 32 vertical levels. Another important feature of the ARPA–SMR methodology is the use of the concept of "super–ensemble" (Montani et al., 2003). Rather than using only one ECMWF EPS set, more (up to three) consecutive daily EPS sets, progressively lagged in time, are used, providing initial sets of up to 153 individual members. From preliminary evaluations, the use of the super–ensemble technique increases the reliability of the computed a–priory probability of occurrence of the predicted event (surpassing of a precipitation threshold).

The results obtained so far indicate that LEPS methodology allows to combine the benefits gained by the probabilistic approach (a set of different evolution scenarios is highlighted) with the high–resolution detail of LAM integrations, without having to pay too much in terms of computer power. It has been shown that, over a number of test cases and for several forecast ranges (48–120 hours), LEPS performs better than EPS as concerns the estimate of precipitation intensity as well as the detection of the regions most likely affected by heavy rain.

2 COSMO–LEPS Project

Following the above–mentioned encouraging results, the generation of a limited–area ensemble prediction system based on Lokal Modell (LM), the COSMO–LEPS project, has recently started. This project aims at the operational implementation of "short to medium–range"

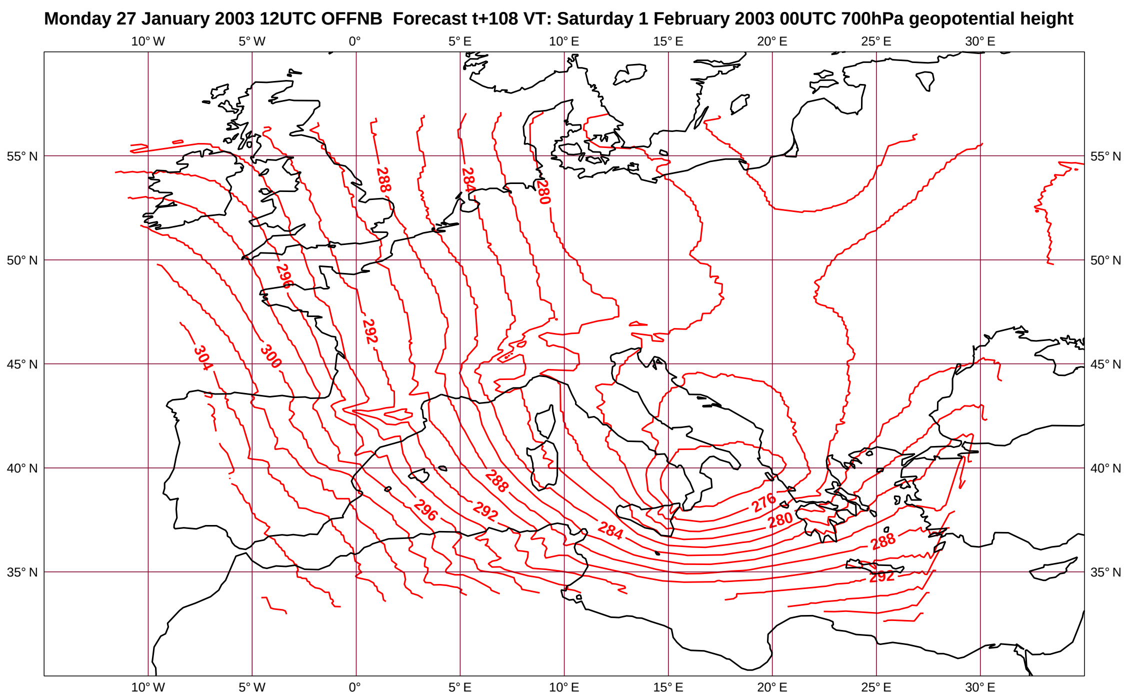

Figure 1: Operational COSMO–LEPS domain.

(48–120 hours) probabilistic forecasts over a large domain (see fig. 1) covering all countries involved in COSMO. Therefore, an "experimental–operational" COSMO–LEPS suite was set–up at ECMWF so as to produce in real time probabilistic forecasts (based on LM nested on EPS members) to be disseminated to the COSMO community.

Thanks to the experience gained during the experimentation phase, it was decided for the time–being to set–up the suite as follows:

- three successive 12–hour–lagged EPS runs (started at 12 UTC of day *N–2*, at 00 and 12 UTC of day *N–1*) are grouped together so as to generate a 153–member super–ensemble; the three ensembles are denoted as "oldest", "middle" and "youngest" EPS, respectively (see fig. 2);

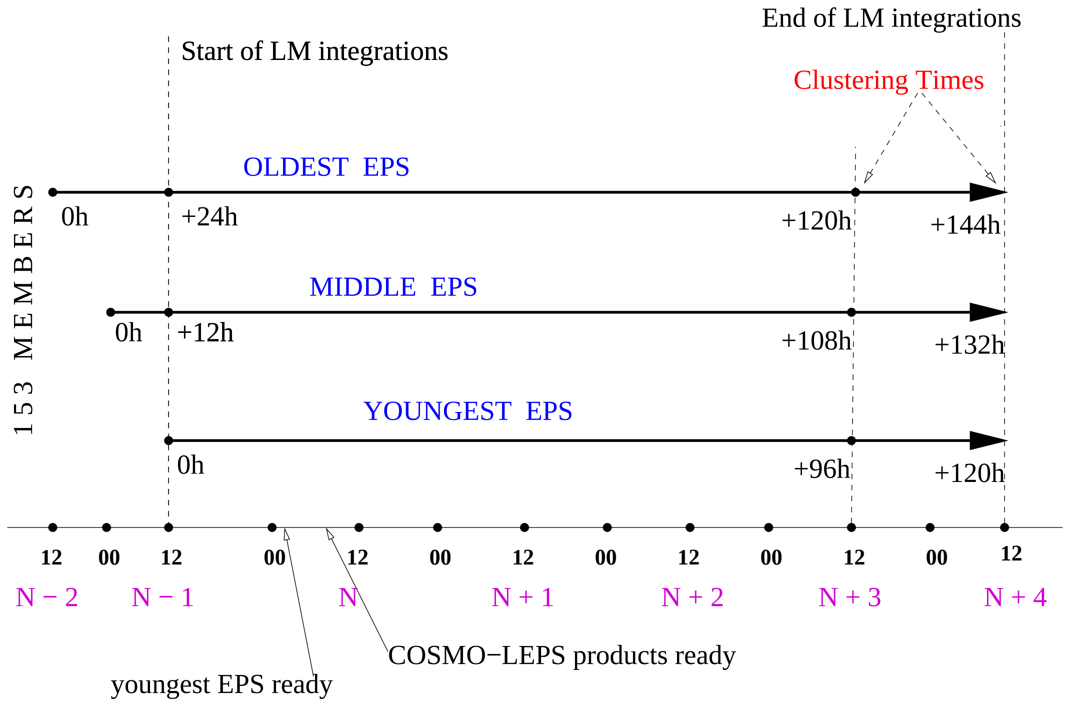

Figure 2: Details of COSMO–LEPS suite.

- a hierarchical cluster analysis is performed on the 153 members so as to group all elements into 5 clusters (of different populations); the Complete–Linkage method (Wilks, 1995) is used to construct the clusters; the clustering variables are Z, U, V and Q (specific humidity) at three pressure levels (500, 700, 850 hPa) and at two forecast times (fc+96 and fc+120 for the "youngest" EPS, corresponding to fc+108 and fc+132 for the "middle" and to fc+120 and fc+144 for the "oldest" EPS); the cluster domain covers the region 30N–60N, 20W–40E;

- within each cluster, one representative member (RM) is selected according to the following criteria: the RM is that element closest to the members of its own clusters and most distant from the members of the other clusters; distances are calculated using the same variables as for the cluster analysis; hence, 5 RMs are selected;

- each RM provides initial and boundary conditions for the integrations with LM, which is run 5 times for 120 hours, always starting at 12UTC of day *N–1* and ending at 12UTC of day $N + 4$;

- LM domain has a horizontal resolution $\Delta x \simeq 10$ km ($306 \times 258 = 78948$ grid points), 32 vertical levels and the time–step used for the integrations is 60 sec;

- probability maps based on LM runs are generated by assigning to each LM integration a weight proportional to the population of the cluster where the RM (providing initial and boundary conditions) was selected; deterministic products (that is, the 5 LM scenarios in terms of surface and upper–level fields) are also produced;

- LM grib–files are disseminated to the COSMO community;

- a limited number of LM output fields is archived at ECMWF.

Since the "youngest" EPS (started at 12UTC of day *d-1*) is available at ECMWF in the first hours of day *d*, LM runs can start in the very early morning and COSMO–LEPS products are usually available by 9UTC of day *d*, well in time to be used for operational forecasts. COSMO–LEPS dissemination started during November 2002 and, at the time of writing (February 2003), the system is still being tested to assess its usefulness in met–ops rooms. In particular, the assistance given to forecasters in cases of extreme events and the forecast accuracy of COSMO–LEPS products need to be assessed.

3 Dissemination and Archiving

At the Warsaw meeting of September 2002, a preliminary list of LM output to be disseminated to the COSMO community was agreed as follows:

probabilistic products
(fc +48–72, fc+72–96, fc+96–120):

- prob of 24h rainfall above 20, 50, 100, 150 mm;
- prob of 72h rainfall above 50, 100, 150, 250 mm;
- prob of 24h $Tmax_{2m}$ above 20, 30, 35, 40 C;
- prob of 24h $Tmin_{2m}$ below -10, -5, 0, +5 C;
- prob of 24h $UVMAX_{10m}$ above 10, 15, 20, 25 m/s;
- prob of 24h snow above 1, 5, 10, 20 cm;

deterministic products
per each LM run (fc+36; fc+60, fc+84, fc+108):

- rainfall (and MSLP);
- Z700 e T850;

As concerns the archiving of LM forecasts at ECMWF, at the moment the following fields are saved (for each LM run):

- rainfall (c6, c12, c18, ..., c120)[5];
- $Tmax_{2m}$ (fc+6, fc+12, fc+18, ..., fc+120);
- $Tmin_{2m}$ (fc+6, fc+12, fc+18, ..., fc+120);
- $UVmax_{10m}$ (fc+6, fc+12, fc+18, ..., fc+120);
- MSLP (fc+0, fc+6, fc+12, ..., fc+120);
- Z500 (fc+0, fc+6, fc+12, ..., fc+120);
- Z700 (fc+0, fc+6, fc+12, ..., fc+120);
- T850 (fc+0, fc+6, fc+12, ..., fc+120);

The usefulness of these products (as concerns both dissemination and archiving) as well as the possibility to add (and/or remove) other products will be discussed at the joint meeting of WG4 and WG5 to be held in Geneva (26–27 May 2003).

[5] "c" means cumulated from the beginning of the run: therefore "c12" means "forecast rainfall cumulated from the beginnnig of the run up to fc+12h"

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