Increase of COSMO–LEPS horizontal resolution and its impact on the probabilistic prediction of precipitation events

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1. Introduction

One of the main challenges for numerical weather prediction (NWP) is still recognised as quantitative precipitation forecasting. The use of the probabilistic approach via the ensemble forecasting has now become commonplace to tackle the chaotic behaviour of the atmosphere and to support forecasters in the management of alert procedures for events with little deterministic predictability. In the framework of limited–area ensemble forecasting, the COSMO–LEPS system (Montani et al., 2003) was the first mesoscale ensemble application running on a daily basis in Europe since November 2002. A number of system upgrades had a positive impact on COSMO–LEPS forecast skill of precipitation in the short and early medium–range, documented by Montani et al. (2010).
As computer power resources increase, it was investigated the extent to which an increase in horizontal resolution of COSMO–LEPS runs could have a benefit on the probabilistic prediction of those surface fields, like precipitation and 2–metre temperature, heavily affected by orography and mesoscale processes. For this reason, a number of system upgrades were tested and their impact was studied, focusing the attention to the performance of COSMO–LEPS for heavy precipitation events.

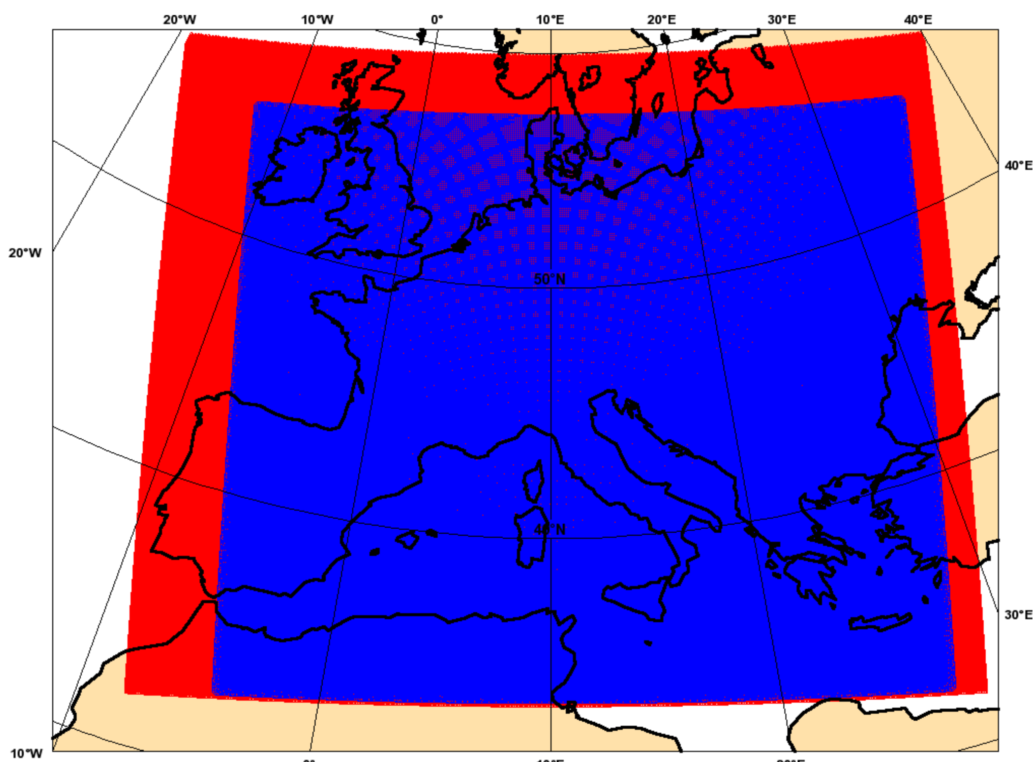

Figure 1: Integration domain for COSMO–LEPS "oper" (blue) and "test" (red).

Table 1: Main features of the “oper” and “test” COSMO–LEPS.

	“oper”	“test”
EnsembleSize	16 members	16 members
ForecastLength	132h	132h
InitialTime	12 UTC	12 UTC
HorizontalResolution	10 km	7 km
VerticalResolution	40 ML	40 ML
Time–step	90 s	60 s
NumberofGridPoints	306x258x40= 3.157.920	511x415x40= 8.482.600
Subgrib–scale Orography	FALSE	TRUE
Use of external database for vegetation cover	FALSE	TRUE
ModelVersion	4.7	4.8
Perturbations:	convect. scheme (TD or KF)	convect. scheme (TD or KF)
	tur_len (500 or 1000)	tur_len (150 or 500 or 1000)
	pat_len (500 or 10000)	pat_len (500 or 2000 or 10000)
		crsmin (50 or 150 or 200)
		rat_sea (1 or 20 or 40)
		rlam_heat (0.1 or 1 or 5)

More precisely, the following modifications were introduced:

- increase of the horizontal resolution from 10 to 7 km;
- enlargement of the integration domain so as cover completely Central and Southern Europe (see Fig. 1);
- introduction of new “stochastic” perturbations in COSMO–LEPS runs.

From June to November 2009, both the operational system (referred to as “oper”) as well as the new one (referred to as “test”) were run in parallel. Afterwards, the relative merits/shortcomings of the systems were assessed on the basis of a number of probabilistic indices (Marsigli et al., 2008). Table 1 summarises the main properties of “oper” and “test”, indicating the common features as well as the innovations of the new system.

2. Methodology of verification

The performance of COSMO–LEPS (both “oper” and “test”) is analysed considering the probabilistic prediction of 12–hour accumulated precipitation exceeding a number of thresholds for several forecast ranges. As for observations, it has been decided to use the data obtained from the SYNOP reports available on the Global Telecommunication System (GTS), since this is recognised to be a homogeneous and stable dataset throughout the verification period (June to November 2009).

In order to assess the skill of the system over complex topography, verification is first performed in the domain ranging from 43N to 50N and from 2E to 18E. This domain, sometimes referred to as MAP D-PHASE area (Mesoscale Alpine Programme, Demonstration of Probabilistic Hydrological and Atmospheric Simulation of flood Events in the alpine region), is the common terrain of investigation for the Forecast Demonstration Project which took place during the Operation Period of D-PHASE (Zappa et al., 2008; Rotach et al., 2009). Within

Table 2: Main features of the verification configuration.

variable:	12–hour accumulated precipitation (18–06, 06–18 UTC);
period:	from June to November 2009;
region 1:	43–50N, 2E–18E (mapdom);
region 2:	35–58N, 10W–30E (fulldom);
method:	nearest grid–point;
observations:	SYNOP reports;
fcst ranges (h):	6-18, 18-30, 30-42, 42-54, 54-66, 66-78, 78-90, 90-102, 102-114, 114-126;
thresholds:	1, 5, 10, 15, 25, 50 mm/12h;
scores:	ROC area, BSS, RPSS, OUTL;

this domain (referred to as "mapdom"), a fixed list of 412 SYNOP stations is considered and the relative reports in terms of total precipitation are used to evaluate the COSMO–LEPS skill. In addition to this, it has been also considered a second (larger) domain, which includes approximately the full COSMO–LEPS domain, ranging from 35N to 58N and from 10W to 30E. Within this further domain (referred to as "fulldom"), a list of 1542 stations is taken and the performance of "oper" and "test" is also assessed.

The SYNOP reports have undergone a simple quality control firstly based on the "surpassing" of a confidence level (provided in the data retrieved by ECMWF archive) for the full report. In addition to this, for cases of very high precipitation records, the values are compared, whenever possible, to those taken from nearby non–GTS stations. In case of discrepancy between non–GTS and SYNOP reports, the latter is discarded and the relative data not used in the computation of the scores.

As for the comparison of model forecasts against SYNOP reports, we select the grid point closest to the observation. Little sensitivity to the results is found when, instead of the nearest grid point, a bi-linear interpolation using the 4 nearest points to the station location, is used to generate the model forecasts. Therefore, the results shown hereafter will be relative only to the nearest grid-point method.

The performance of COSMO–LEPS is examined for 6 different thresholds: 1, 5, 10, 15, 25 and 50 mm/12h.

As already mentioned, verification was performed over a 6–month period, from June to November 2009. For the full period, the following probabilistic scores are computed: the Brier Skill Score (BSS), the Ranked Probability Skill Score (RPSS), the Relative Operating Characteristic Curve (ROC) area and the Percentage of Outliers (OUTL). For a description of these scores, the reader is referred to Wilks (1995) and to Marsigli et al. (2008). The main features of the verification exercise are summarised in Table 2.

3. Performance of the systems

As already mentioned, both "oper" and "test" COSMO-LEPS were run continuously once a day from June to November 2009. Afterwards, both systems were verified against the precipitation observed by a network of about 412 (1542) SYNOP stations covering the so–called "mapdom " ("fulldom"). The skill of the two systems in terms of prediction of 12–hour accumulated precipitation is summarised in Fig. 2, where the Ranked Probability Skill Score (RPSS) is plotted against the forecast range for both "oper" and "test" configurations.

It can be noticed that "test" COSMO-LEPS has higher RPSS for all forecast ranges. The difference between the two systems is consistent throughout the full forecast range, up to day 5, with a larger gap in favour of "test" COSMO-LEPS more evident for the first two days

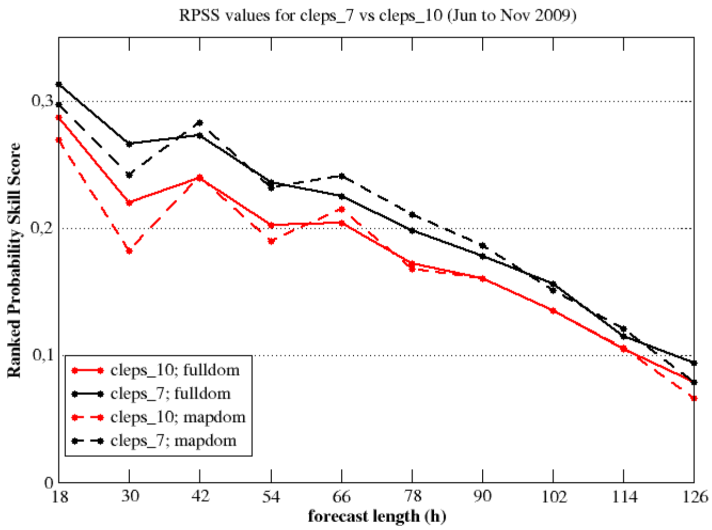

Figure 2: Ranked Probability Skill Score for “oper” (red) and “test” (black) COSMO–LEPS, calculated over the 6–month period from June to November 2009. Solid (dashed) lines refer to scores over the “fulldom” (“mapdom”).

of integrations. This holds when verification is performed either in the Alpine area (dashed lines, relative to “mapdom”) or over the entire integration domain (solid lines, relative to “fulldom”).

If the attention is now focused on the performance of both systems for a specific event, many of the above comments still hold. Fig. 3 shows the scores of “oper” and “test” in terms of ROC area and BSS for the event “12–hour accumulated precipitation exceeding 10 mm”.

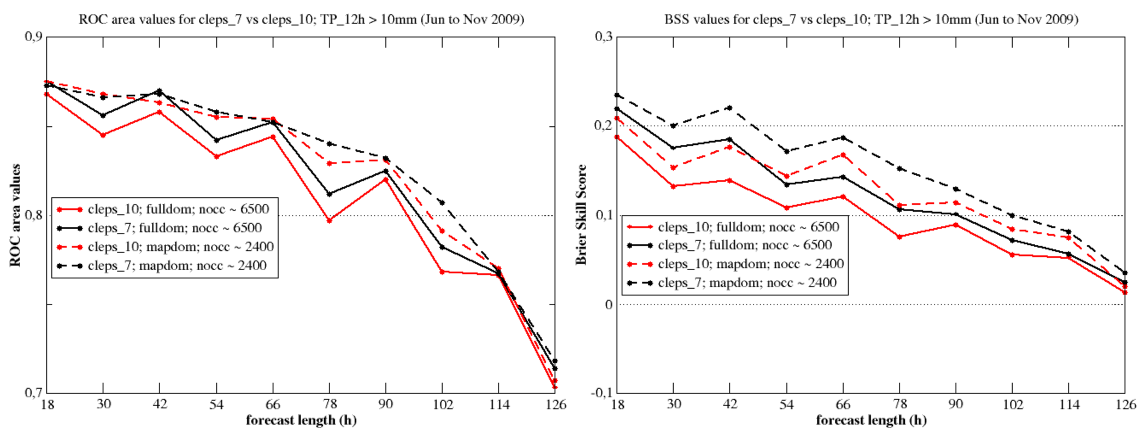

Figure 3: ROC area values (left panel) and BSS (right panel) for “oper” (red) and “test” (black) COSMO–LEPS relative to the event “precipitation exceeding 10mm in 12 hours” for the forecast ranges of Table 2. Both scores are calculated over the 6–month period from June to November 2009. Solid (dashed) lines refer to scores over the “fulldom” (“mapdom”).

As for the ROC area (left panel), it can be noticed that the impact of enhanced resolution in “test” runs is almost negligible for short forecast ranges, if the verification is performed over the “mapdom”. Instead, a larger and positive impact is noticeable for verification over the “fulldom”, up to fc+102h. As for the BSS, the performances of “oper” and “test” COSMO–LEPS indicates a clear margin in favour of the higher–resolution system. This latter result holds for both verification domains.

Finally, the attention is focused on the ability of the “test” system to reduce the number of outliers with respect to “oper”, thanks to the higher resolution as well as to the introduction

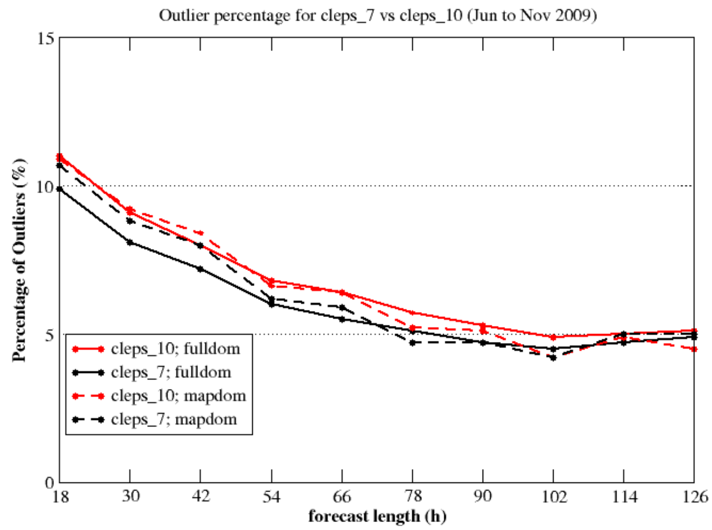

Figure 4: Percentage of Outliers for "oper" (red) and "test" (black) COSMO–LEPS, calculated over the 6–month period from June to November 2009. Solid (dashed) lines refer to scores over the "fulldom" ("mapdom").

of new perturbations which should ensure a larger spread among "test" forecasts. Fig. 4 shows that, in the 7–km system (black lines), the number of outliers is reduced for all forecast ranges, except the longest one, with respect to the operational system. The impact is more evident over the "fulldom", where the higher–resolution system outperforms "oper' with a 12–hour gain in predictability. It can also be noticed that, for all configuration and verification networks, there is a sort of "plateau" at about 5% of outliers, which seems, at the moment, a limit for the number of outliers in COSMO–LEPS systems.

4. Summary and Outlook

The results presented in the previous sections are based on a long and statistically significant sample (6–month period and several hundreds of SYNOP stations). They show the potential of the higher–resolution COSMO–LEPS, which can provide more accurate rainfall forecasts, thanks to a better description of orographic and mesoscale–related processes. In addition to this, the introduction of new model perturbations proved to have a positive effect on the forecast skill of the ensemble system.

Following the indications provided by different probabilistic scores, the 7–km COSMO–LEPS was implemented operationally in December 2009 and has been running on a daily basis since then. As for the future, it is envisaged to continue the systematic verification of the system, to monitor the added value of the higher resolution in the ensemble runs and to study new possible ameliorations.

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