A study on the spread/error relationship of the COSMO-LEPS ensemble

M. Salmi, C. Marsigli, A. Montani, T. Paccagnella

ARPA-SIMC, HydroMeteoClimate Service of Emilia-Romagna, Bologna (Italy)

1 Introduction

This work aims at providing an evaluation of some statistical properties of the COSMO-LEPS ensemble. In particular, the relationship between the spread and the forecast error of the COSMO-LEPS ensemble is here evaluated, with the purpose of quantifying the capability of the ensemble of representing the forecast error, in a statistical sense. The analysis is performed for two upper-air meteorological variables: geopotential height at 700 hPa and temperature at 850 hPa. The dependence of this relation from the forecast range, from the season, and from the spatial location is also assessed.

2 Assessing the spread/skill relationship

The operational mesoscale ensemble COSMO-LEPS (COSMO Limited-area Ensemble Prediction System) runs over large part of Central and Southern Europe, with a spatial resolution of 7 km (from Dec 2009). COSMO-LEPS has been designed to provide probabilistic predictions of surface parameters, especially for severe weather, in late-short to early-medium range (up to day 5.5). COSMO-LEPS is a downscaling of the ECMWF EPS, where 16 EPS members are selected and used to provide initial and boundary conditions to the COSMO runs. A set of COSMO model physics parameters are also perturbed, following the results of the SREPS and CONSENS Priority Projects.

In general, an ensemble should provide, among other kinds of information, an estimation of the reliability of the forecast: if the ensemble forecasts are quite different from each other, it is clear that at least some of them are wrong, whereas if there is good agreement among the forecasts, there is more reason to be confident about the forecast (Kalnay, 2002). That is, the spread (which is a measure of atmospheres predictability) can be used as a predictive variable to forecast the forecast error. In order to assess the COSMO-LEPS spread/skill relationship, here the COSMO-LEPS ensemble spread is computed and compared against the error of the ensemble mean (calculated with respect to a reference analysis).

The ensemble spread is defined as the ensemble standard deviation, the RMS distance of each member from the ensemble mean, while the forecast error is the RMS error of the ensemble mean with respect to the ECMWF analysis.

For this work, the COSMO-LEPS forecasts in terms of geopotential height at 700 hPa and temperature at 850 hPa have been considered, for two different seasons: summer (JJA) and autumn (SON) 2009. ECMWF operational analyses (horizontal resolution of approx. 25 km) are extracted over a regular lat-lon grid (0.25x0.25 deg) and used as the reference analyses. The 10-km COSMO-LEPS runs are interpolated on the same 0.25x0.25 deg regular lat-lon grid of the ECMWF data.

In order to express the spread/skill relationship, ensemble spread and error of the ensemble mean have been computed (separatley for each meteorological parameter, for each season and for each forecast range) for each point of the domain over the whole period. Hence, each grid point of the domain is characterized by a couple of numbers: a value of spread and a value of error. Following Wang and Bishop (2003), spread values are then split into 10 subgroups of equal population: each error value is therefore assigned to the group of its corresponding spread value. For each class, an average spread value is computed, together with the corresponding average error value. Finally, the average values are plotted in a graph. The slope of the resulting line expresses how the two quantities are correlated. If the line lies above the bisector, then the spread is underestimated and the system simulates too little uncertainty. On the contrary, if the line lies below the bisector, then the effective error committed by the ensemble mean is smaller than the one simulated by the spread.

3 Results

The results of the present work are presented in a comprehensive manner in Salmi (2010). Here, only the main outcomes are briefly described.

Dependence on season and forecast range.

The spread/error relationship is shown in Fig. 1 for the two meteorological parameters and for the two seasons. In the computation of the ensemble spread and error, an orography mask is applied, in order to reduce the spurious error due to mountains. The effect of the mask is to eliminate from the computations all the points of the forecast fields in which orography value is greater than 1000 m.

For what concerns the Z700 fields (top row), there is generally a good relationship between error and spread, especially in summer. In autumn a poor correlation is evident between the two quantities for the +24 h forecast range. Spread values are generally overestimated after day 2.

In terms of T850, spread and error are well correlated during summer, while they have an evident non-linear relation in autumn. During both seasons, values of spread are slightly underestimated. Short-term forecast ranges present worse slopes than those of the medium-range. In autumn the correlation is quite poor for the +24h forecast range and improves clearly only from day 4.

The curved form of the spread/skill lines for the T850 indicates that, in the central spread categories, the error and the spread are uncorrelated, since a wide range of error values correspond to specific spread values.

Geographical dependence.

In order to highlight possible dependencies of the spread-skill relationship upon the geographical position and also to help to comprehend the reason of the un-correlation seen in the previous section, the domain is divided into 4 sub-areas. Each area is identified with a specific colour, as shown in Fig. 2.

Then, all the 10965 grid points of the domain are drawn on scatter-plots, without grouping them. Each point is coloured according to its geographical position as described by Fig. 2.

Results for T850 for the last three forecast ranges (+72 h in the top row, +96 h in the middle row and + 120h in the bottom row) during summer (left column) and autumn (right column) are shown in Fig. 3.

In the summer season, the relation is reasonably good over the whole domain at the +96 h and +120 h forecast ranges, while at +72 h the points of the blue and black areas (respectively

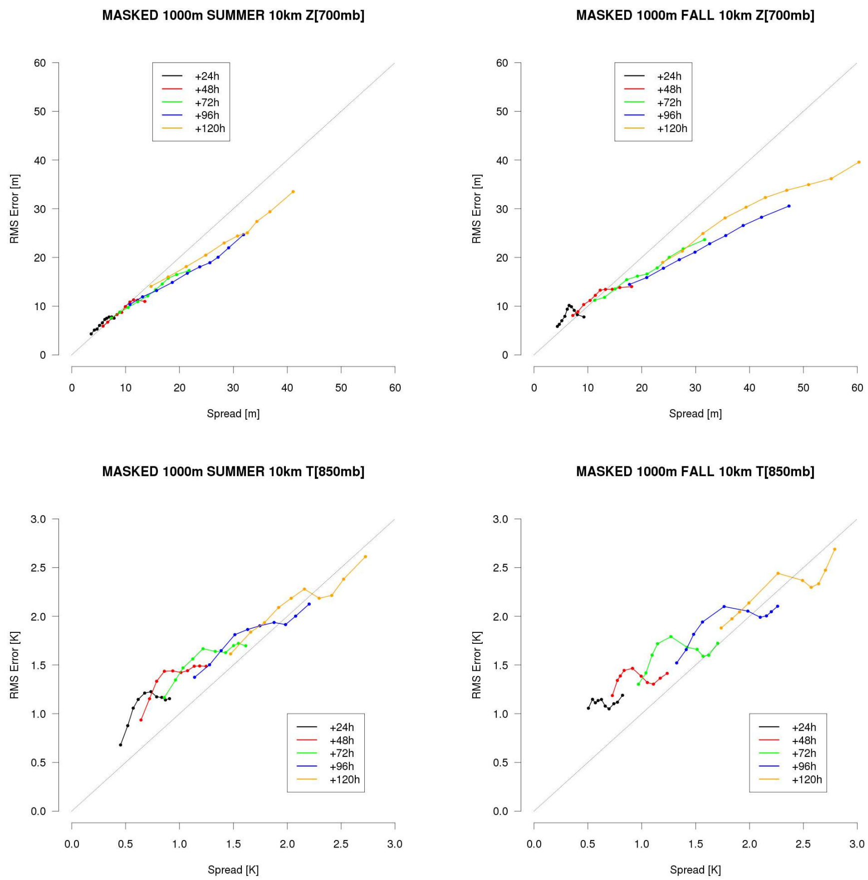

Figure 1: Spread/skill relationship of the COSMO-LEPS forecasts for Z700 (top row) and T850 (bottom row) and for 2 seasons (summer in the left column and autumn in the right column). The different colours are relative to the 5 considered forecast ranges.

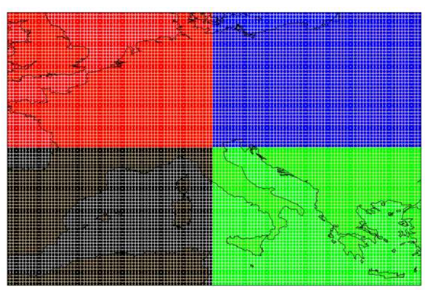

Figure 2: Subdivision of the domain in 4 areas.

north-east and southe-west areas) are markedly not distributed along the diagonal.

On the contrary, the scatter-plots for the autumn season show clouds of points not distributed along the diagonal, with the exception of the green dots (south-east area) for the longer forecast ranges. In each plot there are two very distinct groups of points with different trends, depending on the position: in the southern belt (green and black areas) or in the northern one (red and black areas). Spread and skill seem here to be uncorrelated, even though in the eastern Mediterranean Basin the relation is slightly better. In general, it can be underlined that both spread and error rise when rising the latitude and that the relationship appears to be slightly better over the eastern Mediterranean Basin.

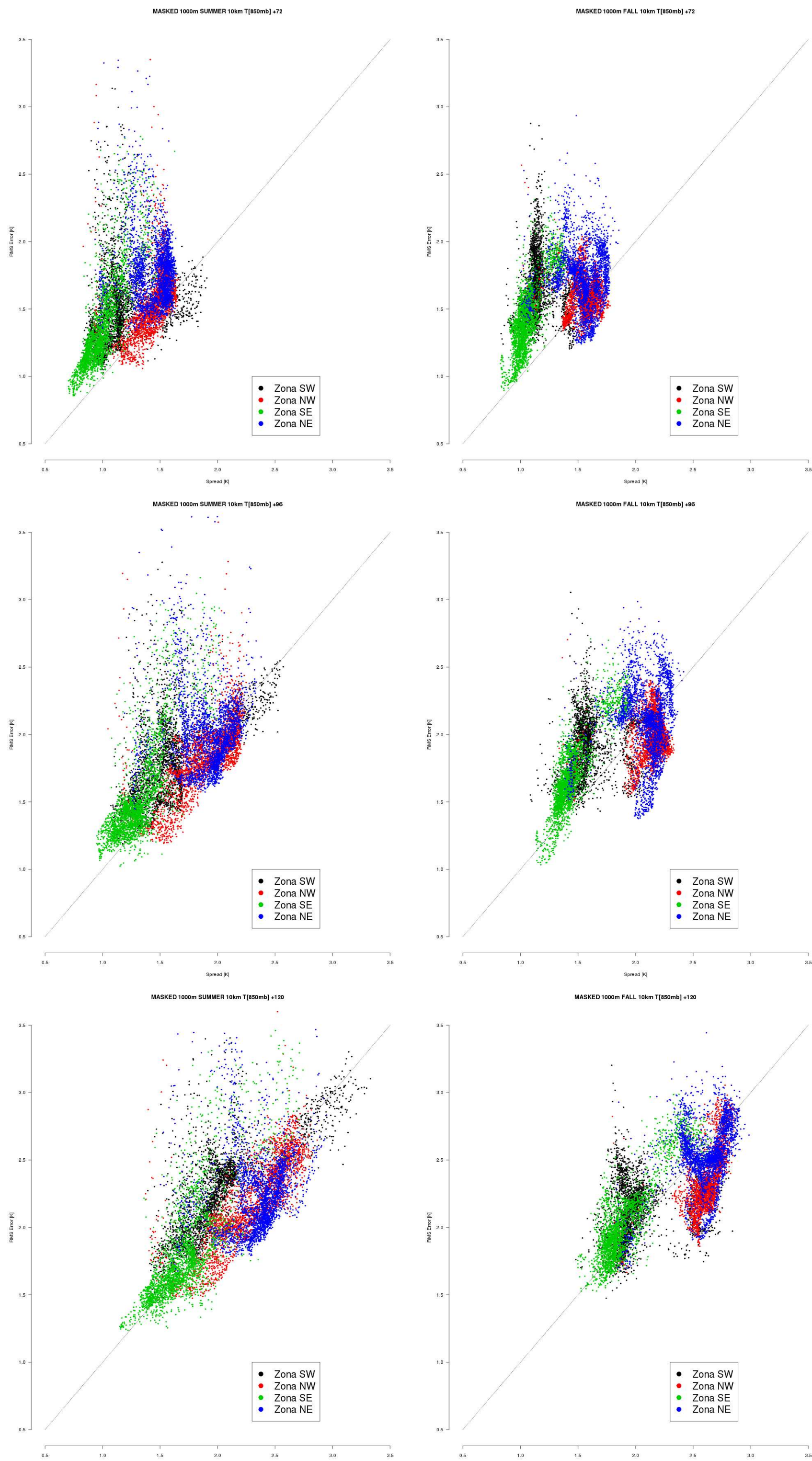

Figure 3: Scatter plots of the spread and skill values of the COSMO-LEPS forecasts of T850. The plots are relative to the 2 seasons (summer in the left column and autumn in the right column) and are for 3 different forecast ranges (+72 h in the top row, +96 h in the middle row and + 120h in the bottom row). The different colours are relative to the 4 areas in which the domain has been divided.

The scatter-plots regarding the 700hPa geopotential height (not shown) are far more regular, showing a good linear relationship between spread and error, for all areas.

4 Conclusions

In general, the spatial distribution of the ensemble spread and of the ensemble mean error for the considered variables are generally correlated, especially after the second forecast-day. This means that the spread plays a predictive role in the geographical distribution of the forecast skill.

The spread tends to underestimate the error in T850 field, particularly in the short-term forecasts. On the contrary, for what concerns the Z700, the spread tends to slightly overestimate the error, especially for medium-range forecasts. The spread-error spatial correlation is generally better for the Z700 than for the T850.

Furthermore, the COSMO-LEPS spread-error spatial relationship over Europe strongly depends on geographical position and season. The correlation is better during summer rather than in autumn, especially over Central Europe.

In general, the Mediterranean Basin (compared to Central Europe) presents a better correlation between spread and skill, along with lower values for both. This means that it is an area characterized by smaller uncertainty of the atmosphere and that perturbations applied to the system grow proportionally to this uncertainty.

This is a preliminary study, which needs to be extended to other variables, such as precipitation and 2-meters air temperature.

References

[1] Kalnay, E, 2002: Atmospheric Modeling, Data Assimilation and Predictability. *Cambridge University Press*, pp. **364**.

[2] Wang, X., C. H. Bishop, 2003: A comparison of Breeding and Ensemble Transform Kalman Filter Ensemble Forecast Schemes. *Journal of Atm. Sci.*, 60, p. **1140-1158**.

[3] Salmi, M., 2010: The spread/error relationship on the COSMO-LEPS limted-area ensemble predicition system. Graduation thesis, *University of Bologna*, pp. 41.