Romanian Reports in Physics, Vol. 63, No. 1, P. 208–219, 2011

PRELIMINARY RESULTS OF COSMO MODEL FORECAST FOR THE ROMANIAN TERRITORY CASE STUDIES*

R. DUMITRACHE, L. VELEA, C. D. BARBU, I. IBANESCU, A. LUPASCU

National Meteorological Administration, Bucharest, Romania
E-mail: rodica.dumitrache@meteoromania.ro

Received July 30, 2009

Abstract. The aim of this paper is to analyze the performance of COSMO (Consortium for small Scale Modeling) model in situation with severe weather cases (strong atmospheric instability, observed heavy precipitation) and made a statistical inter-comparison between COSMO and HRM (High Resolution Model) models. The period of statistical evaluation is February-August 2005, corresponding to first pre-operational COSMO model runs at the National Meteorological Administration, in Bucharest. The statistical scores were made using the surface observations from 160 meteorological stations on the Romanian territory. The experiments for the severe weather situation was realized using two different precipitation schemes for COSMO model at two horizontal resolutions (7 km and 2.8 km). The results show an improvement of quality forecast for COSMO model, most evident for summer months and the ability of the model to realistically simulate small-scale features in experiments at fine resolution. Also, the experiments for cases with heavy precipitations showed the model capability to simulate well the spatial distribution of the precipitation field.

Key words: numerical modeling, evaluation.

1. INTRODUCTION

Weather forecasting is more and more based on numerical simulations. The use of a numerical model requires good knowledge of the model's capabilities.

The aim of this paper is to analyze the performance of COSMO (Consortium for small Scale Modeling) model in situation with severe weather cases (strong atmospheric instability, observed heavy precipitation) and made a statistical inter-comparison between COSMO and HRM (High Resolution Model) [5] models.

* Paper presented at the Annual Scientific Session of Faculty of Physics, University of Bucharest, June 5, 2009, Bucharest-Magurele, Romania.

The evaluation of model performances may be done through objective methods, using the score skills, which emphasize some characteristics of model behavior. Additional information can be obtained through subjective analysis, especially by investigating special cases where certain model features are enhanced. Combinations of these methods facilitate the understanding of the model's limits and its capacity to simulate realistically physical processes on the integration domain and suggest directions of improvement of model performances.

Starting from March 2005, the non-hydrostatic limited–area model COSMO [1, 2], developed at DWD (Deutscher Wetterdienst) Germany, have been implemented on a Linux Cluster and run in a pre-operational regime in National Meteorological Administration. In order to use it in the operational forecast activity a thorough analysis of model results is necessary.

For statistical evaluation, different scores were computed for the period February-August 2005 using the difference between COSMO and HRM outputs and surface observations. The next step was inter-comparison of the scores obtained for both models.

The two models used for this analysis, COSMO and HRM, present some similarities with regard to the physical parameterization, having common parameterization schemes for the radiative transfer [7], the mass-flux convection scheme [9], the soil model [3], and the same type of horizontal and vertical coordinates: horizontal – rotated latitude/longitude coordinates; vertical – sigma pressure coordinates [1]. However, there are significant differences, both in the numerical and in the physical representations packages. Some of the most noticeable differences with respect to physical parameterization refer to the parameterization of surface layer processes, vertical turbulent transport and grid-scale clouds and precipitation. In the COSMO model, for the first two schemes an approach based on prognostic TKE (Turbulent Kinetic Energy) equation is used, while in HRM, similarity theory-based surface transfer scheme [4] and level-2 scheme [6] of vertical diffusion in the atmosphere are employed. For grid-scale clouds, COSMO uses a scheme including ice clouds as prognostic variable, which leads to a function describing the fraction of cloudiness which differs from that used in HRM, where the clouds are formed only by liquid water and vapors. Precipitation formation is treated in HRM using a bulk microphysics parameterization with column equilibrium for the precipitating phases. With COSMO, this equilibrium approach leads to the diagnostic version of precipitation scheme and there is also available, a prognostic version which includes the tri-dimensional transport of precipitation. A more detailed description of the two models can be found in [10].

The verification was applied for four parameters: sea-level pressure, 2 m temperature, 10 m wind speed and 6 hours cumulated precipitations. The data and methods used are described in section 2.

The model behavior was also investigated for some severe weather events, like heavy-precipitation cases and situations of strong atmospheric instability. The results of these verifications and analyses are presented in section 3.

The paper ends with summary and some conclusion remarks.

2. INPUT DATA AND STATISTICAL PARAMETERS

COSMO model is integrated at horizontal resolutions of 7 km (161×145 grid points) and 2.8 km (301×231 grid points) respectively. HRM model is integrated on 28 km resolution (14×37 grid points).

For the initial and lateral boundary conditions, COSMO (7 km resolution) and HRM (28 km resolution) use data from global model GME (Global Model), at the horizontal resolution of 40 km and a frequency of updating lateral boundary conditions of 3 hours. The COSMO (2.8 km) use data from COSMO (7 km resolution) for initial and boundary conditions, at 1 hour.

The statistical evaluation is made using the COSMO (7 km resolution) and HRM (28 km resolution) models outputs, and synoptic surface observations at 160 meteorological stations on the Romanian territory. The forecasted values are extracted from the models output in the closest neighboring grid point with respect to the station location. Four surface parameters are considered for this analysis: sea level pressure, 2 m temperature, 10 m wind speed and 6 hours cumulated precipitations, for 12 hours and 36 hours anticipations respectively.

For the first two parameters the following statistical scores are used: mean error (ME) and mean square root error (RMSE). Precipitation model forecasts were analyzed using the following scores: frequency bias (FBI), false alarm ratio (FAR), probability of detection (POD), percent correct (PC), true skill score (TSS), threat score critical success index, (CSI) [8]. FBI measures the ability of the model to forecast events at the same frequency as found in the sample, disregarding forecast accuracy. FAR is calculated as number of non-realization of an event over the total number of forecasts of that event, therefore it is sensitive to false predictions of the event, not to missed events. POD is a score that measures the ability to correctly forecast a certain category, so it is sensitive to missed events, not to false alarm, and in an ideal situation it has the value one. PC is a measure of forecast accuracy, calculated as the ratio of correct forecasts over the total number of forecasts, expressed as percent. A more complete score is the TSS, that uses all the relevant information contained in the observation and forecast, allows an estimation of the probability that the observation/forecast association is real and has value in the fixed range –1 to +1. The last score used for the verification of precipitation is CSI, which is a measure of relative accuracy and has the advantage that it is sensitive to both false alarms and missed events [8].

The categories for the current analysis of precipitation forecast were obtained using the threshold measured value of 0.2 mm over the last 6 hours: for measured amount of precipitation smaller than this value, it is considered that no precipitation occurred. Thus, there are 2 categories/classes used for the statistical evaluation of forecast accuracy for the precipitation: class 1 refers to non-occurrence of the event; class 2 is related to the occurrence of precipitation. Using only these two classes, no reference to the forecasted and observed amount of precipitation is made. The present procedure follows the operational verification procedure used in NMA Bucharest.

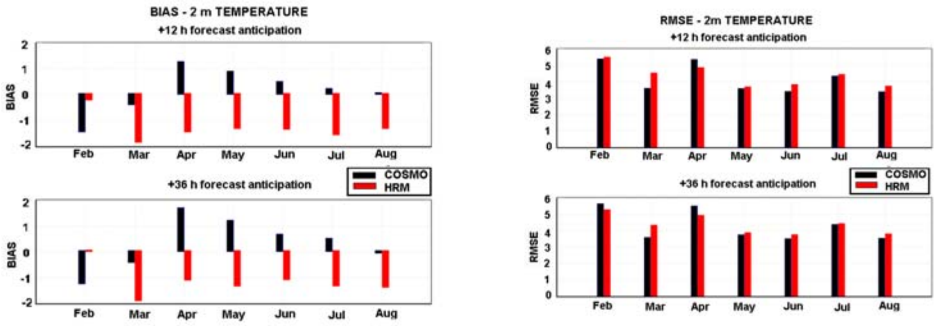
For the 10 m wind speed, the errors were computed only for cases when the observed values were at least 4 m/s. This condition is in agreement with the standard used in the operational verification in National Meteorological Administration for this parameter, where the winds with speed weaker then this threshold are not subject to statistical verification.

The second part of this study presents the result of COSMO model behavior in some special weather situations characterized by strong winds and heavy precipitation in May – July 2005. In the following, only some of the results are presented, namely for the situations of 7 May and 23 July 2005. For these cases, COSMO model results from pre-operational runs and results from numerical experiments at horizontal resolution of 2.8 km were qualitatively compared with observations. At a fine resolution, convection is represented explicitly in the model, while for the resolution of 7 km, the Tiedke mass-flux scheme [9] was used to parameterize this process. Due to increased computational costs, the fine-scale simulations were realized for integration domains chosen such as the phenomena of interest to be in the center of the domain and thus less affected by the lateral boundary conditions treatment. Initial and boundary conditions for these experiments were obtained by interpolating the results of COSMO model integrated at a 7 km horizontal resolution, with a frequency of updating the lateral boundary conditions of 1 hour.

3. RESULTS OF ASSESSMENT AND DISCUSSIONS

3.1. Statistical Evaluation and inter-comparison

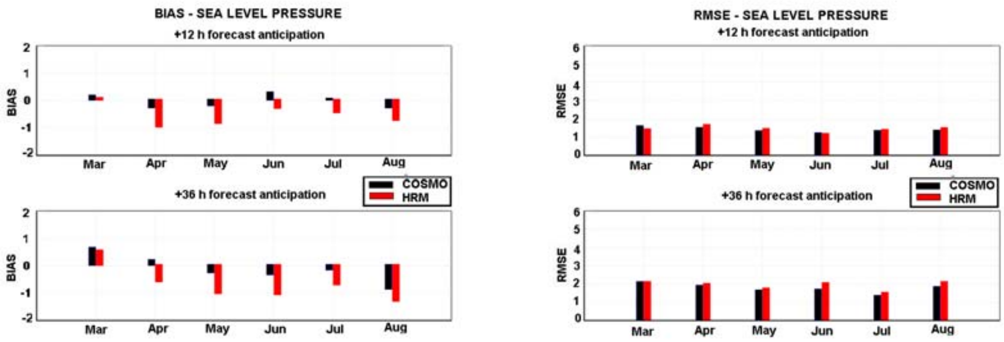
Analyzing the monthly scores computed for 2 m temperature (Fig. 1), there can be seen an enhancement of forecast quality in case of the COSMO model, except for February where, even if both models underestimate this parameter, the HRM forecast has smaller errors. The average amplitude of COSMO errors is less than 2.5^{o}C, while for HRM it is around the value of 3^{o} C. A clear improvement of COSMO forecast is evident for the summer months, for both anticipations.



a) b)

Fig. 1 – Inter-comparison of score skills between COSMO and HRM models, for 2m temperature; February – August 2005: a) mean error ºC; b) root mean square error ºC.

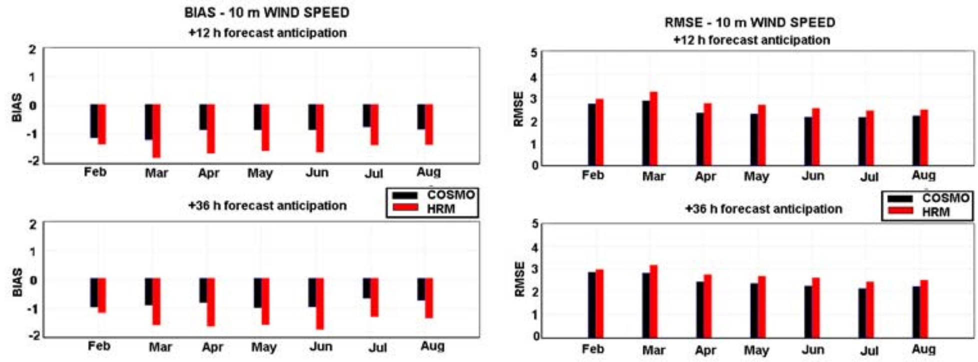
In case of sea level pressure (Fig. 2), for most of the months in the considered interval, the forecasts of both models are overestimated. An improvement of the COSMO forecast can be seen. The errors average amplitude for the 12 hours anticipation is around 1 hPa for both models. For the 36 hours anticipation it is of 1.5 hPa for COSMO and around 2 hPa for HRM.



a) b)

Fig. 2 – Inter-comparison of score skills between COSMO and HRM models for sea-level pressure; February – August 2005: a) mean error (hPa); b) root mean square error (hPa).

Looking at the skill scores for 10 m wind speed, shown in Fig. 3, it is evident that for the entire period considered both models underestimate this parameter. That suggest it might be a systematic error in the models and it could be improved by tuning the parameters in physical representations (*e.g.* roughness length). From Fig. 3, the enhancement of COSMO forecast for 10 m wind speed is also apparent. The difference between the two models errors is at least 1 m/s. Again, toward the end of the interval the improvement of forecast quality is more evident.



a) b)

Fig. 3 – Inter-comparison of score skills between COSMO and HRM models for 10m wind speed; February – August 2005: a) mean error (m/s); b) root mean square error (m/s).

For precipitation, the procedure was made only for classes Occurrence / Non-Occurrence of the event and there is no reference to the amount of precipitation forecasted/produced.

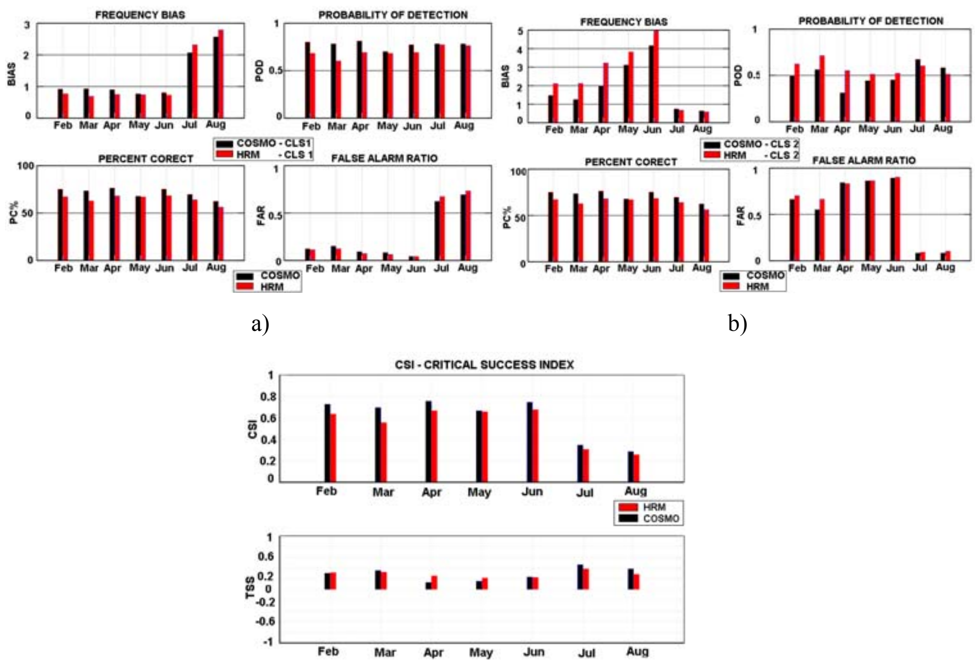
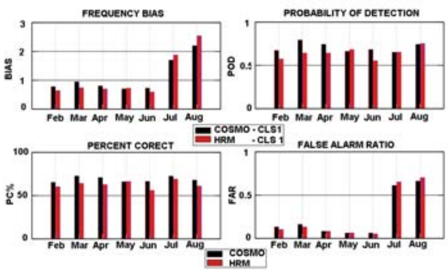


Fig. 4 – Inter-comparison of score skills between COSMO and HRM models for 6 hours cumulated precipitations; February-August 2005, 12 hours anticipation: a) class 1: frequency bias, FAR, POD, PC; b) class 2: frequency bias, FAR, POD, PC; c) CSI and TSS.

The plots in Figs. 4 and 5 show that in general, for both classes, COSMO has a better percent of realization of the forecasts. For class 2 (occurrence of precipitation), HRM has a larger probability of detection than COSMO and also a smaller FAR, which indicates that this model overestimates the producing of this phenomenon more than COSMO. TSS shows a clear improvement of COSMO forecast, even if there are some intervals where the forecast quality is comparable for both models.



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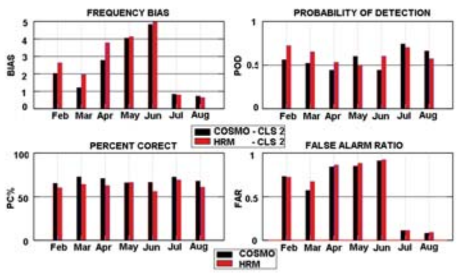

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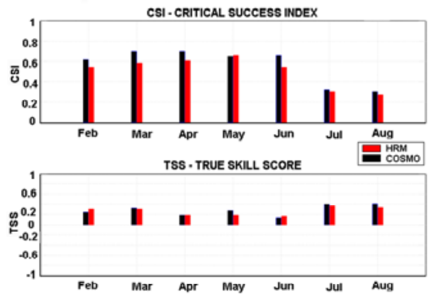


c)

Fig. 5 – Inter-comparison of score skills between COSMO and HRM models for 6 hours cumulated precipitations; February-August 2005, 36 hours anticipation: a) class 1: frequency bias, FAR, POD, PC; b) class 2: frequency bias, FAR, POD, PC; c) CSI and TSS.

3.2. Case studies

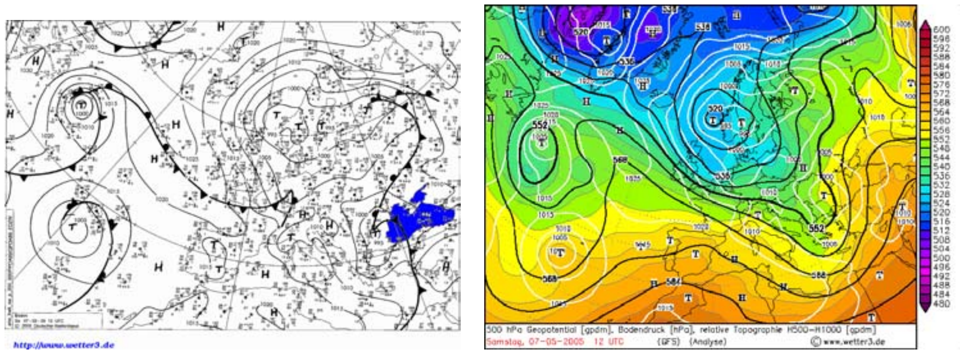
COSMO model was used in a number of numerical simulations of special meteorological situations observed in May – July 2005, characterized by wind intensifications or heavy precipitations, in order to evaluate model's ability to realistically simulate them.

The analyzed cases are:

– 7 May 2005 – strong atmospheric instability in the south of the country.

– 23 June 2005 – heavy precipitation observed

For the first situation, the cyclonic activity in the Romanian area was intense (Fig. 6a), and the frontal system associated with the atmospheric low generated violent phenomena in the southern part of the country (Romanian Plain). The altitude structure (Fig. 6b) favored cold air advection on the entire tropospheric column. The polar air mass increased its moisture over the Mediterranean Sea, thus becoming highly unstable. In the south of Romania, important amounts of precipitation were observed as well as violent wind gusts near the Movilita (Ialomita county) and Buftea (Ilfov county) localities.

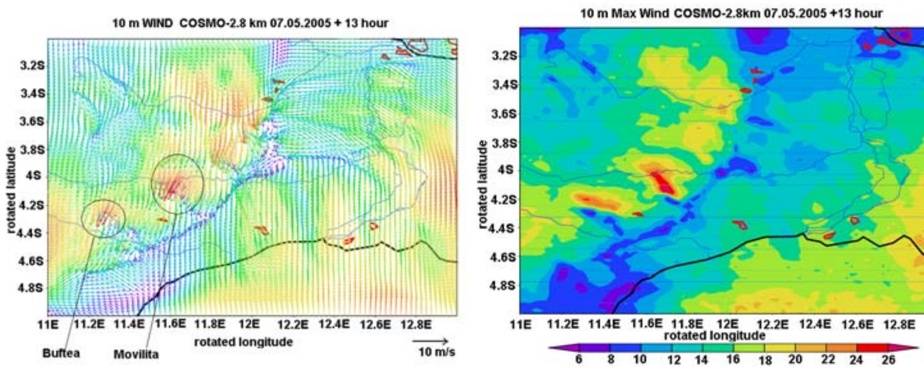


a) b)

Fig. 6 – Synoptic situation for 7 May 2005, 12 UTC: a) Global model GME analysis for surface pressure; b) Analysis for absolute topography at the level of 500 hPa [11].

In order to investigate the COSMO model behavior this model was integrated at the 2.8 km horizontal resolution, on a domain centered on the area where these phenomena occurred.

The simulated 10 m wind field shows the convergence zone in the central-southern part of Baragan (Fig. 7a), as well as sudden variations in the wind direction and intensity. The model indicates gust winds of 24 m/s behind the maximum convergence zone – which can be associated with the frontal area – but also wind rotations, suggesting strong convective activity (Fig. 7b). Taken into account the relatively large anticipation (13 h), it may be said that the simulation had a good accuracy.



a) b)

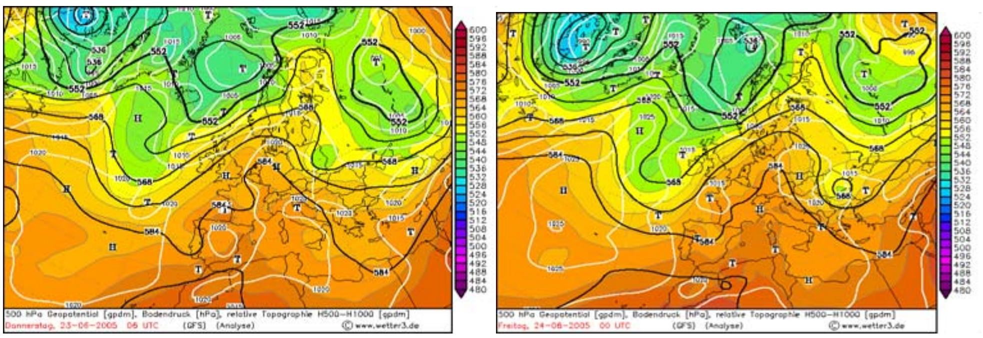
Fig. 7 – COSMO wind field for 7 May 2005, 13 UTC: a) wind vector field;
b) maximum wind speed at 10m, over the latest one-hour interval. Units are m/s.

Features of wind intensifications and rotations, like in this case, are present only in experiments at a high resolution. Other tests for similar weather events showed that, in general, the instability associated with atmospheric fronts is better simulated by the model than cases with only convective instability, which seems to be underestimated.

The model's ability to correctly forecast heavy precipitation events was studied for five such cases observed in the eastern and south-eastern part of the country in June-July 2005. The model was integrated at two horizontal resolutions, of 7 km and at 2.8 km respectively, using diagnostic and prognostic versions of large-scale precipitation parameterization scheme. The integration domain for a coarser resolution is that used in the operational and pre-operational runs of HRM and COSMO, respectively, while for finer resolution it covers only the Romanian territory.

The numerical experiments realized for these cases show the model capability to simulate well the spatial distribution of precipitation field, even if the amounts are overestimated. The most realistic results are obtained for the combination between the 7 km resolution and the prognostic version of large scale parameterization scheme, this also being part of the present configuration of the pre-operational run.

As an example the case of 23 June 2005 is presented here. The synoptic situation for this date is characterized, in the middle troposphere, by the development, toward the central and southern part of the continent, of the trough associated to the baric low over Russian Plain which favored the penetration of cold air mass over the Romanian region (Fig. 8). In the second part of the day and during night the axis of the trough was located over Romania, the closed nucleus enhancing the ascending motion in the eastern and southeastern regions. In the lower troposphere, the mass separation was apparent through a cold atmospheric front, which crossed Romania from NW to SE. There were quite important precipitations in most part of the country. In some regions in Subcarpathian areas hail was observed and wind intensifications were recorded in the eastern part of the country.

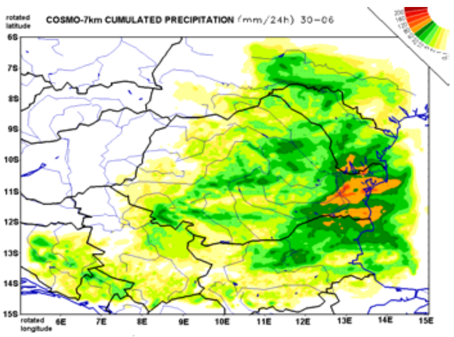


a) b)

Fig. 8 – Synoptic situation (analysis) for 23.06.2005: a) 06 UTC; b) 24 UTC.

The numerical simulations at the 7 km resolution (Fig. 9 a, b) are in a quite good agreement with the observed precipitation field (Fig. 10), the spatial distribution pattern being well simulated, but the amounts of precipitation are overestimated. In both experiments, the model shows a false maximum in the SW of the country (about 40 l/m2 in the model, no observed precipitation). The eastern part of the country is in generally overestimated, more specifically in the SE (Dobrogea region) there is a strong overestimation in the model (about 80–120l/m2), while in the observed field, the values are around 15–20 l/m2. In this region, convection seems to play an important role in the model, leading to about 55 l/m2 in 24h (not shown). In fact, the overestimation in all regions seems to be determined by convective processes, in the model. Using the prognostic version, the areas with significant precipitations are smaller, thus being more realistic.

In both experiments at the 2.8 km resolution (Fig. 9 c, d), the maximum in south-eastern part of the country has values two times smaller than at a coarser resolution, the localization of this maximum being the same. Instead, a new maximum occurs in the Danube Delta (about 80 l/m2) which is not present in experiments at the 7 km resolution. Using the diagnostic version at 2.8 km, results show more intense maxima, situated in the same regions as in experiments with prognostic version.



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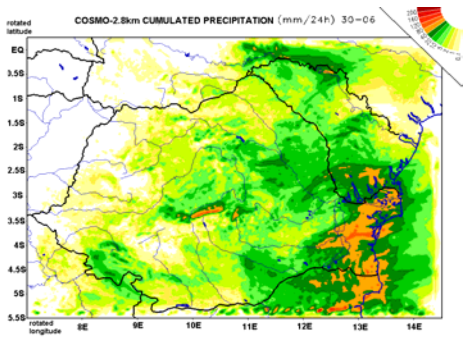

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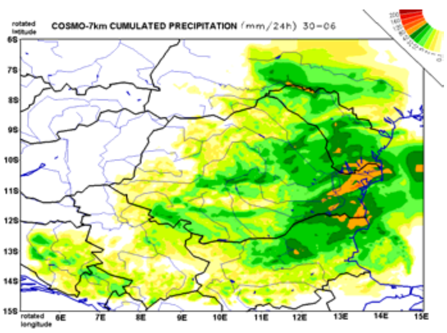

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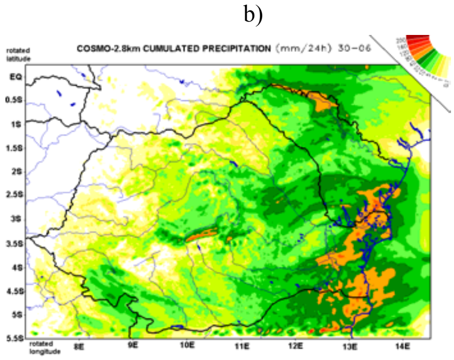

d)

Fig. 9 – Simulated total precipitation field for 23 June 2005 using different resolutions and versions of the large-scale precipitation parameterization scheme: a) 7 km horizontal resolution, diagnostic version; b) 7 km horizontal resolution, prognostic version; c) 2.8 km horizontal resolution, diagnostic version; d) 2.8 km horizontal resolution, prognostic version. Units are mm.

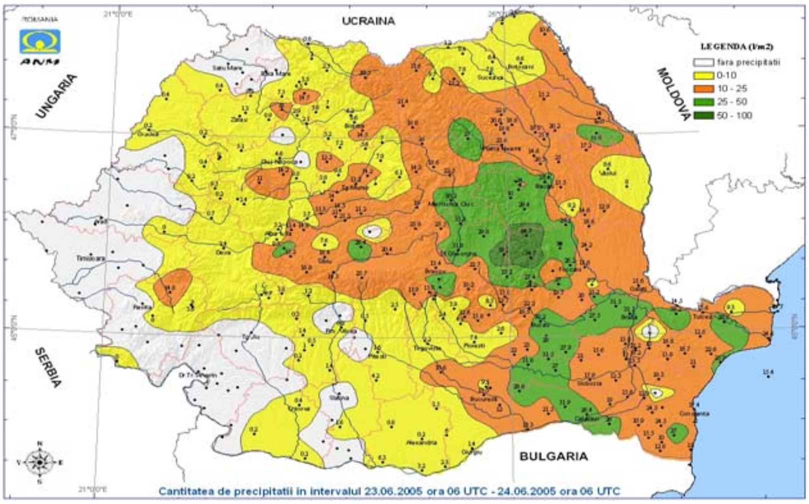

Fig. 10 – Map of observed precipitation, cumulated for a 24 h interval, for 23.06.2005.

3. SUMMARY AND CONCLUDING REMARKS

The performances of non-hydrostatic model COSMO was evaluated using statistical score skills. These scores were also compared with the same scores obtained for HRM model. The evaluated parameters were: 2m temperature, 10 m wind speed, sea level pressure and 6 hour cumulated precipitations for the forecast anticipation of 12 hours and 36 hours for February–August 2005 period.

The monthly skill scores show an improvement of quality forecast for COSMO, most evident for summer months. The occurrence of precipitation is overestimated by both models, slightly better scores being obtained for COSMO model.

Numerical simulations for situations with strong atmospheric instability realized for horizontal resolutions of 7 km and 2.8 km showed that the model displays good ability to simulate realistically small-scale features like wind intensifications, these characteristics being present only in fine-scale experiments. Tests also denote that, in general, the instability associated with atmospheric fronts is better simulated by the model than cases with only convective instability, which seems to be underestimated.

For the cases with heavy precipitations the model simulates well the spatial distribution of precipitation field, even if the amounts are overestimated. The most realistic results are obtained for the combination between 7 km resolution and the prognostic version of large scale parameterization scheme, this being also part of the present configuration of the pre-operational run.

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