VERIFICATION OF LIMITED-AREA MODELS PRECIPITATION FORECASTS DURING THE MAP-SOP

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Abstract: This contribution presents an extensive study about the performances and forecast skills for rain precipitations of several limited area models operating during the Special Observing Period of the Mesoscale Alpine Programme (MAP-SOP, Autumn 1999). Verification is carried out using the updated version of the MAP dataset. Observed data are submitted to a further validation procedure aimed at pointing out defective gauges. As a result, more than 500 stations over a domain surrounding the Alps have been selected. Several statistical indexes widely used in literature are computed using the ECMWF global model as reference. The performances of the limited area models are discussed in detail, paying particular attention to their behavior as a function of rain threshold.

1. INTRODUCTION

Over the last decades a great effort has been devoted by the international atmospheric community to develop limited area models for numerical weather forecasting capable to simulate with increasing resolution short-term and small-scale phenomena. In this process, a branch of meteorology known as forecast verification has achieved the task to test model improvements as well as the development of new features using meteorological measurements (Anthes, 1989). The collection of a large dataset available to a wide community and suitable to advance the existing knowledge and prediction techniques relies among the aims of the Mesoscale Alpine Programme (MAP) started in 1994. Within this project a large field experiment over the Alps, the MAP Special Observing Period (SOP), has taken place from September 7 to November 15 1999 (Bougeault, 2001) . From then on, the MAP-SOP measurements have been widely used to validate numerical weather predictions in mountain areas and in particular to test the capability of the models in forecasting heavy precipitation fields (Arena, 2001; Richard, 2002). This contribution falls within this context and is aimed at presenting a comparison of the performances of most of the mesoscale models operating during the MAP-SOP for the rain precipitation variable. Particular attention is paid to their behavior as a function of rain threshold and forecast times.

2. THE MODELS

The operationally generated outputs of the daily runs of the LAMs operating during the MAP-SOP period have been considered in the verification. The global model of the European Center for Medium range Weather Forecasting (ECMWF) – with resolution of about 55km - has also been taken into account as a reference. A detailed description of the numerical models is beyond the goal of this contribution. Here we only provide a short summary of their main properties:

- Bolam (Nagata, 2001) : an hydrostatic model which daily runs using two different resolutions, i.e. 21 and 7km at the *Meteo-Hydrological Center of Liguria Region* (CMIRL) in collaboration with the *Physics Department of the University of Genova* (DIFI) and the *Institute of Atmospheric Sciences and Climate* of the *Italian National Research Council* (ISAC-CNR). The initial and boundary conditions are provided by the ECMWF model;
- Lilam: an older version of Bolam operational at CMIRL which run with a resolution of 10km. It is driven by Dalam, which runs at the *Central Office of Agriculture* (UCEA) and is and is further nested into the ECMWF;
- Lokal Modell (LM) (Thomas, 2000): a non-hydrostatic model developed at the *Deutscher Wetterdienst* (DWD) with a resolution of 7km. The boundary and initials conditions are provided by the Global-Modell (GME) at DWD. During the MAP SOP an earlier version was operating;

- Swiss Model SM (Binder, 1995): a hydrostatic model no longer used since 2001. During the MAP-SOP it was operational at the *Swiss Meteorological Institute* where it was daily run at a resolution of 14km. It was driven by the Europa-Modell of the DWD which was nested in an old version of the GME at DWD;
- MC2 (Benoit, 1997): a high-resolution (2km) non-hydrostatic model developed and operational at *Environment Canada*. During MAP-SOP a beta version nested in the Swiss Model was made available to compare the experiment with high-resolution forecasts;
- Aladin (Members, 1997): an hydrostatic model developed by *Météo France* in collaboration with ECMWF. It has a resolution of 12.2km and runs daily with initial and boundary conditions provided by ARPEGE, the global model of *Météo France*. The model implementation considered here is that of ALADIN-LACE, run in Vienna.

3. THE DATA SET AND THE ADOPTED METHODOLOGY

The verification of the numerical models has been performed using the most recent version of the MAP-SOP database (including the ITAMAP 2.0) dataset. In detail, the stations lying within the intersection of the domains of the considered models (coordinates in the range 43.5-47.0° latitude N and 6.5-12.5° longitude E) have been selected. The rain data have been submitted to a preliminary validation procedure which has evidenced some defective gauges and reduced to 512 the number of stations useful for the verification. For each station the precipitation values available as 1h accumulated rain have been further integrated to obtain the precipitation accumulated over 6h, hereafter named tp6.

Commonly adopted indexes have been used to perform the statistical analysis (Richard, 2003). *Bias* (B), *false alarm rate* (FAR) and *threat scores* (TS) are computed from the contingency table as described in Ref. (Wilks, 2000). Models' statistical outputs have also been compared with the *no skill* random forecast through the *Heidke Skill Score* (HSS).

4. STATISTICAL RESULTS AND DISCUSSION

In Fig.1 the maximum value of tp6 measured over the selected domain is reported versus time (blue line). The corresponding forecasted precipitation is shown as comparison using pink lines. In detail, the simulated data refer to the second forecast day, i.e. to a forecast time between 24 and 48h. However, since the MC2 forecast was limited to 24h, the results for the first forecast day are shown. Even this simple graphical intercomparison between observed and forecasted precipitation provides interesting indications on each model's strengths and weaknesses. It can be noted that the ECMWF model correctly provides the time position of the precipitation peaks. As expected considering its relatively low spatial resolution, the ECMWF forecasts often underestimate the rain peaks. Also MC2, i.e. the model with the highest spatial resolution, strongly underestimates heavy rains. The BOLAM chain shows capable of catching the intensity of the precipitation peaks, with clear dependency on the resolution. In fact, the 21km version still tends to underestimate the rain amount but the error is less systematic than for the ECMWF model and in a few cases the forecasted peak is even higher than the measured one. On increasing the BOLAM resolution up to 7km, the correspondence with observations further improves and the forecasted values are quite satisfactory. Very good results are also obtained by the ALADIN model, while LILAM, and especially the LM and SM tend to predict sharp precipitation peaks which are sometimes much higher than the corresponding measured rainfall.

Statistical indexes (precipitation scores) have been computed considering rain thresholds between 1 and 50mm/6h for the first, second and third forecast day. The results are shown in Fig.2. As expected, the ECMWF global model (yellow symbols) turns out to be a very good model in predicting light rains – which are slightly overestimated - but its scores become worse as the intensity of precipitation increases. A similar behavior is found for MC2 (black symbols), which appears as the driest among the considered models at almost all the precipitation thresholds. The BOLAM chain outperforms ECMWF in the moderate and high precipitation range, where both versions obtain good scores. In particular, BOLAM21 (blue symbols) slightly underestimates moderate-heavy rains the first and third day, while BOLAM7 (pink symbols) is generally positively biased and provides a considerable rate of false alarms. The behavior of LILAM (red symbols) is similar to BOLAM21 except during the first day where it provides an anomalous high FAR. There are several differences between LILAM and BOLAM: among these the use of different parameterization schemes for convection (Emanuel and Kain-Fritsch, respectively). The Emanuel scheme (but an earlier version was implemented) is known to overestimate precipitation peaks (Corazza, 2003 and references therein). Good and well balanced scores are obtained over the whole forecast time by ALADIN (green symbols). This model outperforms the other LAMs in the moderate-high precipitation range and gives satisfactory results – TS and

HSS only slightly below the ECMWF – also at low rain thresholds. We finally remark that the LM (cyan symbols) and the SM (gray symbols) models obtain values of TS and HSS lower then the global model for light-moderate rains and approach the yellow symbols only in the heavy precipitation range. In particular, the SM seems to be very wet while the LM appears dryer than the average of the other models at low threshold and becomes positively biased at high ones. Both models provides a very large amount of false alarms, especially during the first 24h forecast.

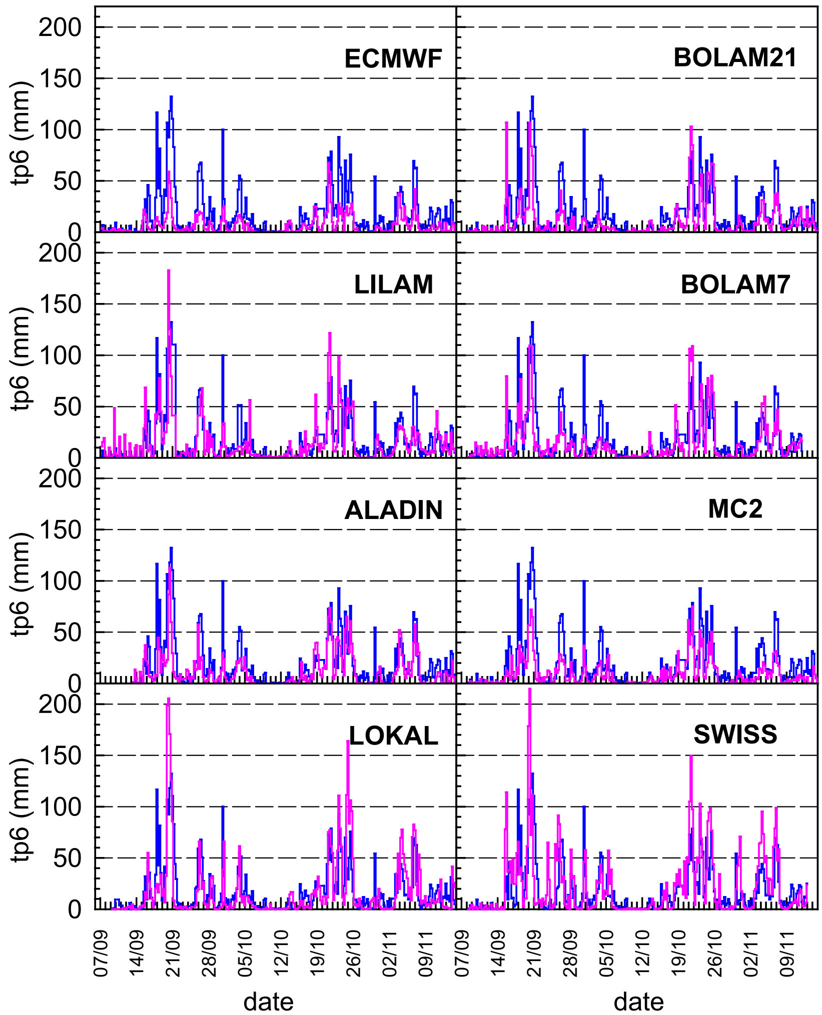

Figure 1. The blue lines show the time evolution of the maximum value of 6h cumulated precipitation (tp6) measured by the rain gauges; the pink lines report the corresponding maximum precipitation forecasted by the models during the second (first, in the case of MC2) forecast day. For each station the closest model grid point is considered.

4. CONCLUSION

In this contribution advantage has been taken of the unique opportunity provided by the MAP-SOP campaign to have a great amount of available meteorological data, both observations and numerical model simulations. The behavior in forecasting precipitation fields of the most advanced models running during the campaign has been evaluated using statistical indexes and some hints have been obtained. In detail, the ECMWF model is confirmed to be less effective in forecasting moderate and heavy rain. In this precipitation range, good scores are obtained by the BOLAM chain and especially by ALADIN. The high resolution MC2 model - developed during MAP-SOP in an experimental suite - has also been tested and results strongly dry. Finally, the LM and the SM seem to present some problems related to quantitative forecasting intense precipitation.

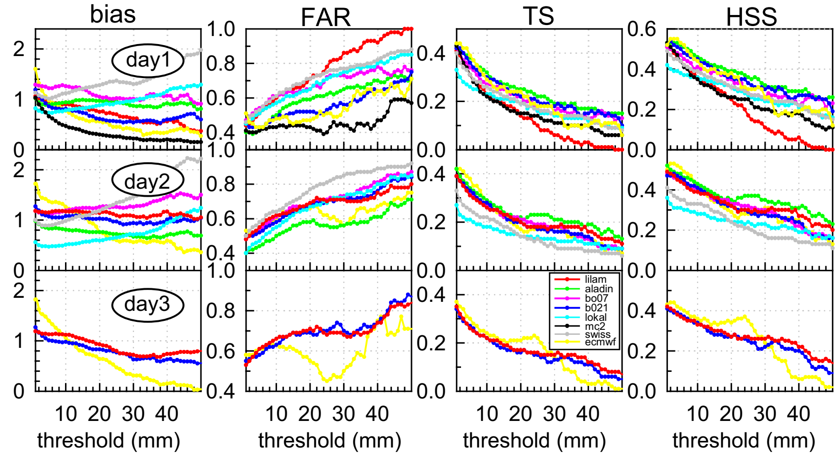

Figure 1. Statistical indexes – *Bias*, *False Alarm Rate* (FAR), *Threat Score* (TS) and *Heidke Skill Score* (HSS) – for 6h cumulated precipitation computed at increasing threshold and at different forecast days.

REFERENCES

Anthes R., Y.H. Kuo, E.Y. Hsie, S. Low-Nam, T.W. Bettge, 1989: Estimation of skill and uncertainty in regional numerical model, *Quarterly Journal of the Royal Meteorological societ*y, **115**, 763-806.

Arena N., R. Benoit, P. Binder, A. Buzzi, G. Contri, M. Corazza, R. Cresta, M. Damonte, S. Gallino, D. Sacchetti, N. Tescaro, E. Trovatore, 2001: Verification and intercomparison of limited area models operating during the MAP-SOP: some results, *MAP Newsletter*, **15**, 98-101.

Benoit, R., M. Desgagne, P. Pellerin, S. Pellerin, Y. Chartier, S. Desjardins, 1997: The canadian MC2: A semi-lagrangian, semi-implicit wide-band atmospheric model suited for fine-scale process studies and simulation, *Mon. Wea. Rev.*, Vol **125**.

Binder P., A. Rossa 1995: The Piedmont flood: operational prediction by the Swiss Model. *MAP newsletter*, **2**, 12-16.

Bougeault P., P. Binder, A. Buzzi, R. Dirks, R. Houze, J. Kuettner, R.B. Smith, R. Steinacker, H. Volkert , 2001: The MAP Special Observing Period. *Bulletin of the American Meteorological Society* , **82** , 433-462.

Corazza M., A. Buzzi, D. Sacchetti, E. Trovatore, C.F. Ratto, 2003: Simulating extreme precipitation with a mesoscale forecast model. *Meteorol Atmos Phys*, **83** , 131-143.

Members of the ALADIN International Team, 1997: The ALADIN Project - Mesoscale modelling seen as a basic tool for weather forecasting and atmospheric research, Bulletin of the World Meterological Organization, **46**, 317-324.

Nagata, M., L. Leslie, H. Kamahori, R. Nomura, H. Mino, Y. Kurihara, E. Rogers, R.L. Elsberry, B.K. Basu, A. Buzzi, J. Calvo, M. Desgagne, M. D'Isidoro, S.Y. Hong, J. Katzfey, D. Majewski, P. Malguzzi, J. McGregor, A. Murata, J. Nachamkin, M. Roch, C. Wilson, 2001: A Mesoscale Model Intercomparison: A Case of Explosive Development of a Tropical Cyclone (COMPARE III). *J. Meteorol. Soc. Japan*, **79**, 999-1033.

Richard E., N. Asencio, R. Benoit, A. Buzzi, R. Ferretti, P. Malguzzi, S. Serafin, G. Zangl, J.F. Georgis, 2002: Intercomparison of the simulated precipitation fields of the MAP/IOP2b with different high-resolution models. *Proceedings of the 10th Conference on Mountain Meteorology, Park City, 17-21 June 2002*.

Richard E., S. Cosma, R. Benoit, P. Binder, A. Buzzi, P. Kaufmann, 2003: Intercomparison of mesoscale meteorological models for precipitation forecasting. *Hydrol. Earth Sys. Sci* ,**7** , 799 – 811.

Thomas S., C. Girard, G. Doms, U. Schattler, 2000: Semi-Implicit Scheme for the DWD Lokal-Modell, *Meteorol. Atmos. Phys.*, **73**, 105-125.

Wilks D.S., 1995: Statistical methods in the atmospheric sciences: an introduction, Academic Press, S. Diego, 233.