VERIFICATION AND INTERCOMPARISON OF PRECIPITATION FIELDS MODELLED BY LAMS IN THE ALPINE AREA: TWO FORALPS CASE STUDIES

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Abstract: Sharing knowledge and experience about NWP verification among forecasting and research centres, and environmental agencies in the alpine area is one of the main goals of the EU FORALPS project - INTERREG IIIB Alpine Space. In this framework, employed state-of-the-art verification techniques have been shared and applied to numerical simulations of specific case studies of rainfall events on the northeastern alpine area. These techniques will be also applied in the frame of the APAT participation to MAP D-PHASE. In this work, simulations of two events with three LAMs are discussed and verified with traditional and more innovative techniques. Models include two high-resolution non-hydrostatic models - WRF running at the Regional Meteorological Observatory (OSMER) of Friuli-Venezia Giulia (Italy) and ALADIN operational at the Environmental Agency of the Republic of Slovenia (EARS) - and the hydrostatic 10-km QBOLAM operational over the Mediterranean basin at APAT. All models are forced by ECMWF analyses and forecasts, used as a basis for verification together with rain gauges and satellite. Verification techniques include traditional eyeball methods and non-parametric skill scores along with up-to-date object-oriented techniques as the Continuous Rain Area (CRA) analysis. Besides, simulation of satellite observed fields (METEOSAT-7 WV channel) are also employed. Both events are connected with the passage of small Mediterranean cyclones. The quality of the ECMWF forecast of these cyclones' evolutions (trajectory and details) seems to depend on the model initialisation. In addition, space-time shift in the LAMs' predicted precipitation is found. Such a displacement varies among models. Object-oriented techniques - such as CRA - are employed to provide a quantitative basis to these results. This is done with the aim of studying how the model error propagates from global model to LAMs, in connection with the configuration differences among LAMs.

Keywords: *Forecast verification, NWP model intercomparison, Alpine area, FORALPS*

1. INTRODUCTION

In the frame of the EU project FORALPS - INTERREG IIIB Alpine Space (*http://www.foralps.net*), it has been decided to conduct an annual survey on the project partners' (PPs) forecast and verification activities. From the first survey, a report about different verification methods used by PPs, both in an operational and in a research framework, was produced. The report includes, among others, eyeball verification, graphical summary techniques, parametric and non-parametric skill scores, spatial verification techniques, etc., along with information on meteorological models run at the PPs' own centres. In order to share knowledge about verification techniques, and compare and evaluate the suitability of the different methods in describing the model forecast quality, a common verification activity on selected case studies has been planned.

Since this is a work in progress, only some of the preliminary verification results related to two significant rainfall events - 16–20 Nov. 2002 and 08–10 Sep. 2005 - mainly occurred over the Friuli-Venezia Giulia region (northeastern Italy) are presented. Before 0000 UTC Nov. 17 2002, a big cyclone approaching Europe from the Atlantic evolves in a northeasterly elongated trough, spanning from Denmark to Gibraltar, due to the blocking effect of a stationary high on Eastern Mediterranean. In the following 48h the trough tip evolves in a small-scale cyclone, travelling along the curved path Gibraltar - Algerian coast - Sardinia - northwestern Italy. The cyclone reaches its maximum depth on day 18 Nov. and decays in the following days. Rainfall over the Alps seems to be linked to the southwesterly moist advection from the elongated trough on day 17, and to the cyclone dynamics during the following two days. The second event is linked to the passage of a cold-core, small cyclone, north-westerly approaching Spain on 7 Sep. 2005. In the following 48h the cyclone moves on the western Mediterranean basin, rotating around the Pyrenees and losing its strength: the minimum 500 hPa GPH passes from about 5610 m at 0000 UTC 7 Sep. to about 5700 m at 0000 UTC 9 Sep. During this time, southwesterly moist advection, associated to precipitation, is present on the alpine area.

Forecast and observed data are described in sect. 2. Few examples from subjective verification techniques are presented in sect. 3. Section 4 discusses the preliminary results of the QPF verification. Final remarks and future work are addressed in sect. 5.

2. NWP MODELS AND OBSERVATIONS

Forecasts were modelled by: the 9.5 km ALADIN model (*http://www.cnrm.meteo.fr/aladin/*) operational at the Environmental Agency of the Republic of Slovenia (EARS); the 0.1° QBOLAM model (Speranza et al., 2004; Mariani et al., 2005) operational at APAT, which is a parallel version of the BOLAM model developed at the CNR-ISAC (Buzzi et al., 1994); the 10 km WRF model running in a research configuration at the Regional Meteorological Observatory (OSMER) of Friuli-Venezia Giulia; and the 0.5° ECMWF model (*http://www.ecmwf.int*). Models have a different domain size, covering from the alpine area (ALADIN and WRF) to the Mediterranean Basin (QBOLAM). They also differ for the parameterization schemes employed, and about the ECMWF initial and boundary conditions: 1200 UTC for QBOLAM and WRF; 0000 UTC for ALADIN. For the precipitation comparison, forecast data have been post-processed on two common verification grids[1] by means of a simple nearest-neighbor average method, also know as remapping (Accadia et al., 2003) and accumulated at 24h, staring from 0000 UTC. Forecast fields have been subjectively analyzed on the native grid at different time intervals.

Two different rain gauge data set have been considered for the two events. For the November 2002 event (left panel in Fig. 1), precipitation data have been obtained by the working rain gauges belonging to the networks of APAT[2] (407 gauges over the northern Italy), ARPA Emilia-Romagna[3] (147 gauges over Emilia-Romagna region), ARPA Liguria (24 gauges over Liguria region), OSMER (25 gauges over Friuli-Venezia Giulia region), EARS (18 gauges over Slovenia), and ZAMG (145 gauges over Austria). For the September 2005 event (right panel in Fig. 1), precipitations have been collected from the working rain gauges of APAT (147 gauges only over the northeastern Italy), ARPA Emilia-Romagna (240 gauges), ARPA Liguria (119 gauges), ARPA Lombardia (67 gauges over Lombardia region), OSMER (25 gauges), EARS (21 gauges), and ZAMG (162 gauges).

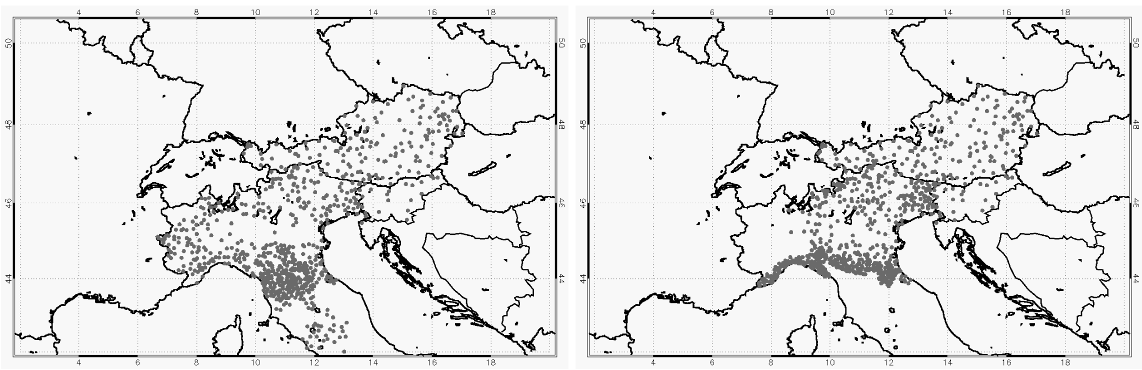

Figure 1: Geographical distribution of working rain gauges. Left: for the November 2002 event. Right: for the September 2005 event.

In order to produce an adequate (i.e., less sensitive to grid box size) observed rainfall gridded analysis over the two common verification grids, a two-pass Barnes objective analysis scheme has been used (Barnes, 1964; Koch et al., 1983). This technique assigns to each gauge observation a Gaussian weight as a function of the distance between the gauge and the grid box centre. Gridded fields have been accumulated on a daily basis.

Moreover, ECMWF analyses, the METEOSAT-7 water vapor channel imagery and the lightning observations have been considered for a subjective sub-synoptic verification.

[1] One with grid box size of 0.1° and the other with 0.5° (Lat: 42.5–49.4 °N; Lon: 2.5–19.4 °E)

[2] Former Italian National Hydrographic and Marigraphic Service (SIMN) network.

[3] Available online via the web-based DEXTER system.

3. SUBJECTIVE VERIFICATION

3..1 ECMWF forecast quality check

A comparative check of differences between subsequent ECMWF forecasts has been performed on the 2002 event. This can provide some hint about the ability of the global model to represent the involved phenomena. In a similar case subject of a previous study (Casaioli et al., 2006), some indications have been found about the sensitivity of forecast quality on the analysis detail. Up to 17 Nov., 500 hPa GPH relative differences between subsequent forecasts are localized on the trough tip and the south-westerly jet over western Mediterranean (not shown) while, later, they seem to correspond to the localization of the center of the developing cyclone; this is somewhat evident also in the MSLP difference fields (not shown).

3..2 Precipitation fields

A comprehensive inspection of forecast and observed daily precipitation fields for the 2002 event, evidences a good forecasting skill for all the models skill during days 16 Nov. and 19 Nov. (when, indeed, large-scale synoptic forcing is prevailing), whereas both on day 17 Nov. (when the Mediterranean cyclone is developing) and on 18 Nov. (when it is passing over the Alpine space) the LAMs' predicted patterns markedly differ among them and with the observations. For instance, on day 18 Nov. a strong rainfall peak on the eastern Alps is caught by all the models, but a meridional rain belt is predicted by each LAM at a different longitude. Looking also at the MSLP forecast pattern, this seems to be connected to the different cyclone evolutions predicted by the models. Despite the absence of observations on the Adriatic sea (where is located the band in WRF forecast), it is possible to assess that the ALADIN forecast is the more realistic one. This is possibly associated with the fact that this model's run is initialized 12h later than the other.

3..3 Satellite water vapor comparison

A more advanced subjective technique has been also employed in order to verify the forecast dynamics sub-synoptic details. Indeed, the METEOSAT-7 WV channel image is qualitatively comparable (in cloud-free areas) with the temperature pattern over the 75 mg/kg specific humidity iso-surface (reckoned from above). Thus, it is possible to verify forecast dynamical features, monitoring the cyclone evolution. For instance, Fig. 2 evidences that QBOLAM "misses" the secondary structures of the cyclone, as the vorticity centre pointed by an arrow in the left panel of Fig. 2, which is associated with strong convection occurred 24h earlier along the Algerian coast (not shown). This may eventually result in an overestimate by QBOLAM of the cyclone minimum depth.

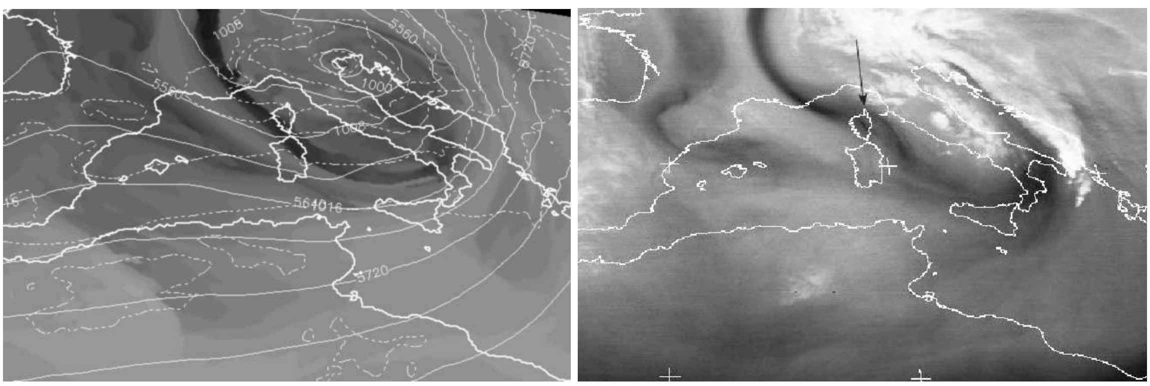

Figure 2: Left: QBOLAM forecast at 0000 UTC 19 Nov. 2002 , initialized at 1200 UTC 17 Nov 2002. 500 hPa GPH is indicated with solid line, whilst MSLP is indicated with dashed line. Right: METEOSAT-7 WV image at 0000 UTC 19 Nov. 2002.

4. QPF verification

Forecast precipitation verification has been performed by means of both standard methods, such as the contingency table-based non-parametric skill scores[4] (Wilks, 1995), and the diagnostic contiguous rain area analysis (CRA, Ebert and McBride, 2000), suitable to quantify the spatial forecast error in terms of displacement, pattern and volume error. Unfortunately, given the short time period of the two events, it is not possible to assess the uncertainties on skill score differences employing the bootstrap technique (Hamill, 1999; Accadia et al., 2003).

In the 2002 event, the models show an HK score between 0.4 to 0.6 for thresholds up to 20 mm/24h with a BIA close to 1. Above 20 mm/24h, models overforecast the event and, as a consequence, skill scores decrease. For the two days with observed intense precipitations (16 and 18 Nov.), the CRA results show small displacement, especially when using as CRA pattern-matching the correlation maximization. In general pattern error is the main source of error. In the 2005 event, ALADIN tends to underforecast the event (BIA < 1.0). WRF and QBOLAM show, instead, a BIA close to 1 for the lower thresholds and between 1.5 and 2 for the medium-high thresholds. The overforecasting models could have too many false alarms so that the skill scores could be negatively affected compared with the model with a lower BIA. Thus, at this stage is not possible to assess which model gives, in terms of skill scores, the best forecast. A possible solution may be the application of the BIA adjustment procedure (see, e.g., Accadia et al., 2003), which assess whether the skill score differences between two models are the result of an actual different forecast capability, or are simply explained by the differing BIA scores. For QBOLAM, CRA results using the correlation criterion show a small displacement.

5. Final remarks

In the present paper, authors make an overview of the verification study under development in the framework of the FORALPS project. The experience gained in this verification study over the alpine area will be applied to the APAT participation to the MAP D-PHASE.

However, these are only partial results. This study will be completed through a systematic application of the described methods to both the two cases. Results will be then employed in order to give a coherent picture of the different models' prediction, especially looking for physical explanations of their different behavior.

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REFERENCES

Accadia, C., S. Mariani, M. Casaioli, A. Lavagnini, and A. Speranza, 2003: Sensitivity of precipitation forecast skill scores to bilinear and a simple nearest neighbour average method on high resolution verification grids. *Wea. Forecasting*, **18**, 918–932.

Buzzi, A., M. Fantini, P. Malguzzi, and F. Nerozzi, 1994: Validation of a limited area model in cases of Mediterranean cyclogenesis: Surface fields and precipitation scores. *Meteorol. Atmos. Phys.*, **53**, 53–67.

Barnes, S. L., 1964: A technique for maximizing details in numerical weather map analysis. *J. Appl. Meteor.*, **3**, 396–409.

Casaioli, M., S. Mariani, C. Accadia, N. Tartaglione, A. Speranza, A. Lavagnini, and M. Bolliger, 2006: Unsatisfying forecast of a Mediterranean cyclone: a verification study employing state-of-the-art techniques. *Adv. Geosci.*, **7**, 379–386.

Ebert, E. E., and J. L. McBride, 2000: Verification of precipitation in weather systems: determination of systematic errors. *J. Hydrol.*, **239**, 179–202.

Hamill, T. M., 1999: Hypothesis tests for evaluating numerical precipitation forecasts. *Wea. Forecasting*, **14**, 155-Ű167.

Koch, S. E., M. Desjardins, and P. J. Kocin, 1983: An interactive Barnes objective map analysis scheme for use with satellite and conventional data. *J. Climate Appl. Meteor.*, **22**, 1487–1503.

Mariani, S., M. Casaioli, A. Accadia, M. C. Llasat, F. Pasi, S. Davolio, M. Elementi, G. Ficca, and R. Romero, 2005: A limited area model intercomparison on the "Montserrat-2000" flash-flood event using statistical and deterministic methods. *Natural Hazards and Earth System Sciences*, **5**, 565–581.

Speranza, A., C. Accadia, M. Casaioli, S. Mariani, G. Monacelli, R. Inglesi, N. Tartaglione, P. M. Ruti, A. Carillo, A. Bargagli, G. Pisacane, F. Valentinotti, and A. Lavagnini, 2004: POSEIDON: An integrated system for analysis and forecast of hydrological, meteorological and surface marine fields in the Mediterranean area. *Nuovo Cimento C*, **27**, 329–345.

Wilks, D. S., 1995: *Statistical Methods in the Atmospheric Science*. Academic Press. 467 pp.

[4]Such as the frequency bias score (BIA), the equitable threat score (ETS), the Hanssen-Kuipers score (HK) and the odd ratio skill score (ORSS).