QUANTITATIVE PRECIPITATION FORECASTING IN MOUNTAINOUS REGIONS - PUSHED AHEAD BY MAP

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Abstract: The improvement of Quantitative Precipitation Forecast (QPF) in mountainous area was the central supporting objective of the MAP project P1 devoted to the study of orographic precipitation. This paper attempts to review the main MAP-related achievements towards QPF improvement and to highlight the MAP-impact for developing QPF research and operational strategies.

***Keywords** – Quantitative precipitation forecast, MAP*

1. INTRODUCTION

Within the MAP project devoted to the study of orographic precipitation (P1), one of the key issues was the improvement of Quantitative Precipitation Forecasts over complex terrain. Back to mid 90's, i.e. during the very early stage of MAP, the expectation in that domain had been considerably raised by the emergence or consolidation of new high-resolution numerical tools, able to explicitly resolve moist convection. The impressive amount and the high quality of the data collected during the MAP special observing period (70 days of observations in 1999, among which nearly 40% are of special interest for QPF) offer a unique opportunity to test, validate and improve different new high-resolution modelling and assimilation systems. This paper summarizes the MAP-related achievements towards QPF improvement.

2. QUANTITATIVE EVALUATION OF PRECIPITATION FORECAST

2.1 MAP SOP studies

Within MAP, a lot of effort was put on the evaluation of the precipitation forecasts but, surprisingly, only very few studies were devoted to a systematic evaluation over the whole SOP. In Keil and Cardinali (2004), ECMWF 24h areal precipitation forecasts were compared with the observations over the Po catchment. The agreement was quite remarkable for the operational runs and was even slightly improved for the later runs based upon the MAP reanalysis. But of course, the real challenge was more focused on higher-resolution precipitation. In Benoit et al. (2002), it was shown than the MC2 real time forecasts (with horizontal resolution of 3km) captured quite well the timing of the precipitation events but under-predicted the magnitude of the precipitation by a factor of 2. From this data set, no final conclusion could be drawn regarding the merit of high-resolution models to circumvent using parameterized convection.

More recently, Buzzi et al. (2003, Brig MAP meeting) performed an extensive comparison involving hydrostatic models (ECMWF, BOLAM, SM, ALADIN, LILAM) and non-hydrostatic models (MC2 and LM), using exclusively operational SOP data. At the beta-mesoscale, an increase in the resolution yields an increase of the precipitation and a better performance for intense precipitation (i.e. above 25mm/12h).

Higher resolution hydrostatic models (ALADIN and BOLAM seemed somehow the best especially in terms of coincidence scores as Heidke) outperformed the few non-hydrostatic (NH) models, but probably because the NH models involved in this comparison were quite "young".

The SOP period was also chosen, due to the great amount of precipitation recorded, as the test period for the objective verification of the probabilistic mesoscale system LEPS (developed by ARPA-SIM). Results (Tibaldi et al., 2003) indicate that LEPS scores better than the global ensemble for high precipitation thresholds.

2.2 Case studies

Many case studies (including IOPs 2a, 2b, 3, 5, 8, 10, 14, 15) performed with non-hydrostatic models (MM5, MESO-NH, COAMPS, MOLOCH) appeared to have rather good precipitation results (with some exceptions, e.g. IOP14, Asencio and Stein, unpublished). In particular only the NH models could forecast the formation convective cells (e.g. over small orography like the Apennines) and their propagation, essential to get correct QPF (e.g. Asencio et al, 2003; Chiao and Lin 2003; Lin et al. 2005). However, no real effort was made to compare the results with the operational forecast.

The IOP2b case was used to intercompare the results of different non-hydrostatic models (MM5, MOLOCH, MESO-NH, MC2) at very-high resolution (2 to 3km). Even for this case, which has a good predictability (Walser et al., 2004), the spread between the models is quite large in terms of rain intensity (Richard et al., 2002).

3. MODEL IMPROVEMENT RESULTING FROM MAP

The examination of MAP results raised questions regarding the representation of the model orography. The MC2 and, to some extent, BOLAM orography representations were found too smooth and were modified to better preserve crest height (e.g. Buzzi et al., 2003).

Different MAP cases evidenced errors arising from the use of numerical diffusion on terrain following coordinate. A modified diffusion scheme applied on horizontal surfaces was implemented in MM5 and MESO-NH (Zängl, 2004, IOP10). Coordinate transformation errors were also better identified and eventually significantly reduced by use of the so-called SLEVE coordinate (Schär et al., 2002, MC2, IOP2b, Zängl, 2004, MM5, IOP10).

The MAP data were profusely used to tune or improve the explicit microphysical schemes of the models. The precipitation under-prediction in MC2 (operational SOP setup) could be partly ascribed to a too slow conversion from cloud water to rain (Smith et al., 2003). Some improvement was also achieved by refining the microphysical schemes (e.g. inclusion of a hail category, Richard et al., 2003; Lascaux and Richard, 2004; MESO-NH, IOP2a, IOP3, IOP8).

4. MAIN SOURCES OF ERROR

Simulated precipitation appeared sometime to be more sensitive to the numerical set up of the models than to the details of their physical parameterizations. Experiments carried out with the different microphysical schemes and PBL formulations available in MM5 showed a weak sensitivity to the parameterizations whereas a better numerical diffusion had a larger impact (Zängl, 2004, IOP10) but for IOP2b an ongoing study showed only a weak sensitivity to diffusion (may be due to a less complex topography). Another puzzling result, not fully understood but reported in different MM5 studies, is a large sensitivity to the choice of the convection scheme in the coarse resolution domain.

For some specific cases (IOP2a, IOP3, IOP15), precipitation fields were found extremely sensitive to the initial conditions. This was shown first by using different operational analysis systems (e.g. ECMWF versus ARPEGE) and/or confirmed later on with the use of the MAP reanalyses performed at ECMWF (MESO-NH, Asencio and Stein, Lascaux et al., 2004; BOLAM and MOLOCH, Buzzi et al., 2004). These results can be linked to Walser et al. (2004) findings regarding the low predictability of IOP3 and IOP15 events. Larger scale (synoptic) errors are still very important especially for the "chronology" of the event and cannot be corrected by fine scale modelling.

With convection resolving models, it is difficult to distinguish between model deficiencies and initial (and boundary) conditions errors with respect to error growth. Regarding QPF, position errors related to development and movement of convective systems are of major relevance.

5. IMPACT OF THE MAP REANALYSIS

Only the ECMWF model was used to systematically assess the impact of the reanalysis. Over the whole SOP, this impact was minor but constantly positive. Different case studies carried out with higher resolution models lead to more mitigated conclusions: mostly a weak - positive or negative - impact (IOP2b, IOP8, IOP14, MESO-NH, Asencio and Stein, IOP10, MM5, Zângl), a significant improvement in the case of IOP15 (BOLAM and MOLOCH, Buzzi et al., 2004) and a strong negative impact in the case of IOP2a (MESO-NH, Lascaux et al., 2004). Further analysis of this latter case allowed to identify or confirm some weakness in the humidity assimilation algorithm in ECMWF/IFS system.

Wang and Bazile (2004) studied with ALADIN the impact of the different ECMWF reanalyses on the IOP2b precipitation forecast. The reanalysis in which all the wind profilers are denied leads to a better precipitation forecast over the Central Po valley area.

6. DATA ASSIMILATION

The strong sensitivity to initial conditions together with the mixed results obtained with the MAP reanalysis triggered a series of experiments aiming at assimilating mesoscale structures instead of entirely relying on the large-scale analysis to initialize high-resolution models. These experiments were based upon optimal analysis methods (MM5, BOLAM, MESO-NH) or 3D Var (MM5). Some significant improvement was obtained for IOP2b (Ferretti and Faccani, 2005), IOP15 (Buzzi et al., 2004), and may be to a lesser extent IOP14 (Nuret, 2005) though it is not clear whether the best initial conditions always provide the best forecast (Faccani and Ferretti, 2005; Feretti and Faccani, 2005).

7. PREDICTABILITY ISSUES AND ENSEMBLE FORECASTS

Using MAP cases, two kinds of predictability study were conducted. The first aims at downscaling the global ECMWF ensemble prediction (EPS), using the a Limited Area Model (LEPS methodology). Results on four map cases (Molteni et al. 2001, Marsigli et al. 2001) show the usefulness of this mesoscale ensemble system in the forecast of intense precipitation events. This lead to the quasi-operational implementation at ECMWF of the COSMO-LEPS system, where the LM model of the COSMO consortium is used with the LEPS methodology at a resolution of 10 km.

The second approach assumes perfect predictability on the synoptic-scale to isolate the role of small-scale error growth (Walser et al. 2004, Walser and Schär 2004). Here a convection-resolving LAM (the MC2 in the same set-up as in Benoit et al. 2002) is used to address the role of small-scale perturbations that may grow within the LAM. It is found that small-scale predictability strongly differs from case to case. The occurrence of convection alone does not necessarily limit predictability. In IOP2b, individual convective cells (or the model's representation thereof) were found to be rather predictable. In contrast, for IOP3 uncertainties due to model-internal error growth prohibit the application of deterministic QPF-based approaches to hydrological forecasting (Walser and Schär 2004), even for intermediate-size catchments. An intercomparison of the MC2 and LM model in convection-resolving ensemble mode further indicates that normalized spread measures are less model-dependent than simulated precipitation amounts (Hohenegger et al. 2003).

8. CONCLUSION

In general, the evaluation of QPF based on different MAP case studies have corroborated the idea that the use of convection-resolving models is a pre-requisite to obtain realistic precipitation amounts and distributions in cases in which convective activity plays an important role. Convection implies the occurrence of complex microphysical processes that need to be modelled to simulate correct QPF, especially in relationship with precipitation efficiency.

As a general conclusion we advocate increased efforts for truly mesoscale assimilation of the initial data for high-resolution numerical weather prediction and intensified studies into the predictability of convection and precipitation. Part of these efforts will be continued within the forecast demonstration project D-PHASE.

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