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Numerical simulations of the precipitation event observed during the MAP IOP2a: Sensitivity to the initial conditions

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ABSTRACT

Numerical simulations of the convective system observed during the MAP IOP2a have been performed with Meso-NH, using a threefold nesting technique with horizontal mesh-sizes of 32, 8 and 2km. The reference experiment initialized from the operational ECMWF analysis of 17 September 1999 12 UTC succeeds reasonably well in initiating the convective line over the Alpine foothills and reproducing its propagation towards the East. The sensitivity of these results to the reanalysis products is investigated. In the ECMWF MAP reanalysis, the lower atmosphere above Northern Italy is found considerably drier than in the operational analysis. As a consequence, convection is almost entirely inhibited in the mesoscale simulations based upon the reanalysis.

1. Introduction

The Intensive Observing Period (IOP) number 2a of the Mesoscale Alpine Programme (MAP, Bougeault et al., 2001), took place on 17 September 1999. Between 12 UTC and 24 UTC, a deep convective system developed over the southfacing slopes of the Alps, in the Lago Maggiore area. In the late afternoon a convective line formed over the Alpine foothills. During the early night, it propagated towards the south-east over the plain where it intensified and evolved into a more complex three-dimensional system.

Different simulations of this event have been performed using the French non-hydrostatic model Meso-NH (Lafore et al., 1998). In a former study, Richard (2001) showed the sensitivity of the results to the initial conditions. A simulation initialized with the French analysis (ARPEGE) failed to reproduce the system whereas the same simulation based upon the operational analysis of the European Center Medium-range Weather Forecast (ECMWF) was quite successful (Richard et al, 2003). Hereafter, this later simulation is used as a control run and is referred to as ECM-OD.

Recently, ECMWF has produced a reanalysis of the MAP period. This reanalysis includes a lot of additional data collected during the field experiment and was also performed with a more recent version of the assimilation system (Keil and Cardinali, 2003). Therefore, the IOP2a simulation has been reconducted, based upon this reanalysis. However and quite unexpectedly, the new experiment (ECM-MI hereafter) significantly departs from the control run. Different features of the reanalysis (upper-level cooling, low-level wind convergence, low-level moisture) could explain this contrasted behaviour of the mesoscale simulations.

All the simulations were run at high resolution with a 2-way interactive grid-nesting method for horizontal grid-sizes of 32, 8 and 2 km. In the innermost domain, cloud and precipitation are explicitly resolved with the standard microphysical scheme of the model which predicts the mixing ratio evolution of 6 water species, including a 3-class ice scheme : pristine ice, snow/aggregates and graupel. All three simulations start on 17 September 1999, 12 UTC and were integrated for 12 hours.

2. Synoptic situation

On 17 September 1999, at 12 UTC, a 982 hPa surface low is located 15^o west of Ireland, whereas, a secondary low (1004 hPa) stands over the Italian Peninsula and induces a southeasterly flow of 10 m/s over the Adriatic sea towards north-western Italy. At 500 hPa, a ridge is extending from Hungary to Scandinavia, and a trough from Ireland to the western Spain. Between these two features, a short-wave trough is located over southern France. During its progression towards the East, the atmosphere above northern Italy is destabilized by advection of cold moist air in the upper levels.

3. Evolution of the control simulation

The IOP 2a convective system was well observed with three ground-based Doppler radars (S-Pol, Ronsard and Monte-Lema) located in the Lago Maggiore area. The observed reflectivity fields at 2000m are shown in the left row of Fig.1 at 18 UTC, 21 UTC and 00 UTC, and are used to assess the model results shown in the second row. The control simulation (ECM-OD) succeeds reasonably well in initiating the convective line, and depicting its propagation toward the south-east and its later evolution in a more complex convective cluster, even though a weak time delay can be observed.

The precipitation field deduced from the Swiss radar composite is reproduced in Fig.2a and can be compared with the model field shown in Fig.2b. The narrow precipitation band occurring in the north-west of the domain is not present in the simulation but the location and intensity of the main precipitation core over Italy are quite consistent with the observations.

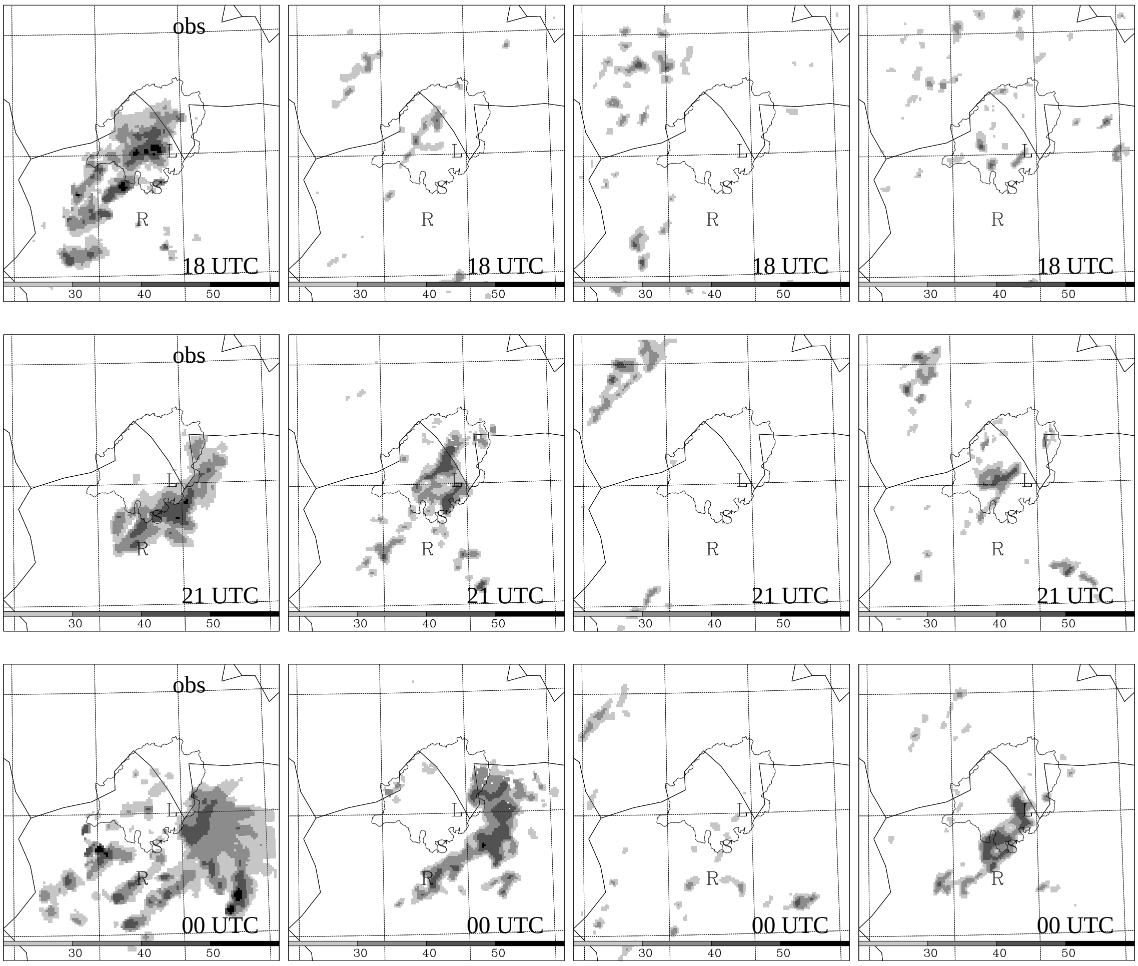

Figure 1: Reflectivity fields at 2000 m at 18 UTC, 21 UTC and 00 UTC. From left to right: observed radar reflectivities, equivalent reflectivities computed in the ECM-OD, ECM-MI and ECM-MI2 experiments (units in dBZ). The letters R , S and L designate the locations of the Doppler radars (respectively, Ronsard, S-Pol and Monte-Lema).

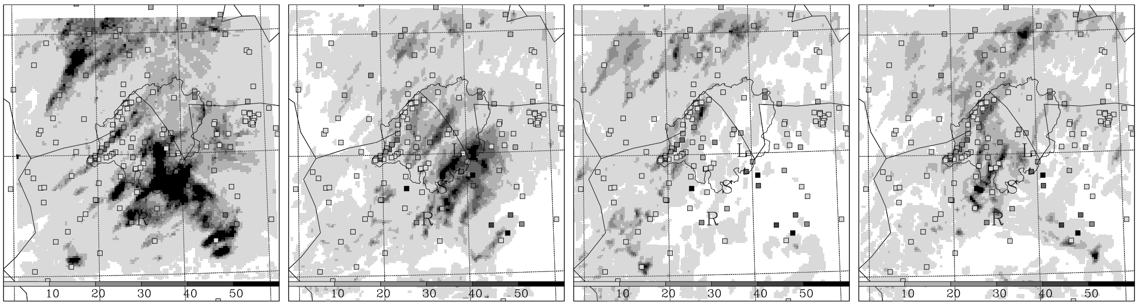

Figure 2: 12h accumulated precipitation field (in mm) from 17 September, 12 UTC to 18 September, 00 UTC. From left to right: radar deduced observations (a), results of the ECM-OD (b), ECM-MI (c), and ECM-MI2 (d) experiments. Rain gauge measurements, represented by squares, are superimposed.

4. Evolution of the simulation initialized with the reanalysis

The ECM-MI simulation is strictly identical to ECM-OD except it was initialized and forced with the MAP reanalysis. The computed reflectivity fields are shown in the third row of Fig.1, and the accumulated precipitation in Fig.2c. Some light precipitation now occurs over Switzerland, in the north-east of the domain. This precipitation (not seen by the Doppler radar network but visible in the Swiss composite) was not depicted by the control run. But the most striking departure from the control experiment is the quasi absence of convection over Italy. A few cells develop over the Alpine slopes but do not assemble in any organized system. Precipitation remains quite weak and is concentrated in the mountainous area.

5. Where do the differences come from?

The mid-level cooling

The most intense phase of the system was associated with the passage of an eastward-moving small-scale trough at the mid levels. This feature is present in both the analysis and the reanalysis. However the resulting cooling which contributes to destabilize the atmosphere is less pronounced in the reanalysis and remains localized over the plain (Fig.3). The hypothesis that the convection intensification was the result of a phasing between the orographic forcing and the small scale trough becomes less valid with the reanalysis.

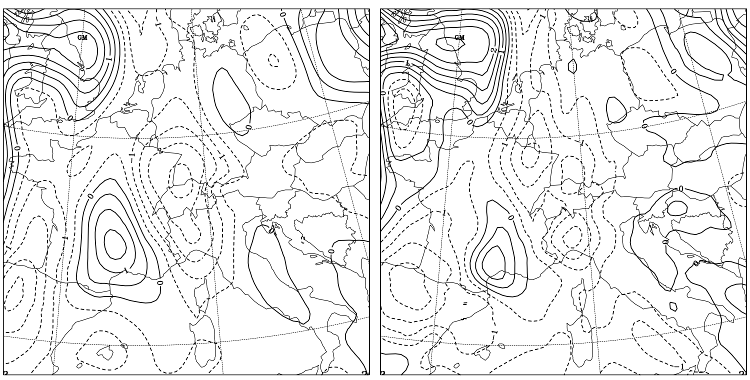

Figure 3: Difference in the temperature fields at 7km between 17 September 12 UTC and 18 UTC for the operational analyses (left) and the reanalyses (right).

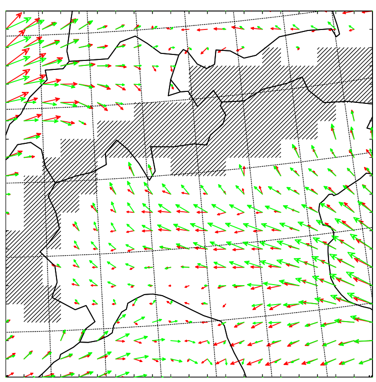

Figure 4: Horizontal wind field at the 1km height on 17 September 12 UTC, in the operational analysis (green vectors) and in the reanalysis (red vectors).

The low-level wind

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Some differences between the analysis and the reanalysis are also present in the low level wind shown in Fig.4 for the 1km height. In the reanalysis the Adriatic flow is 2 m/s weaker. Furthermore, the south component of the Ligurian flow is so weak that a convergence between the two flows is now unlikely to occur.

The low-level moisture

Another major discrepancy between the analysis and the reanalysis is found in the low level moisture represented in Fig.5. This figure evidences that the lower layers of the atmosphere are considerably drier in the reanalysis. Compared to the Milano Linate sounding, the operational analysis was too moist but the reanalysis is too dry. This dry bias is also confirmed by the GPS data. Such a difference might be sufficient in itself to explain why convection is almost entirely inhibited in the ECM-MI simulation.

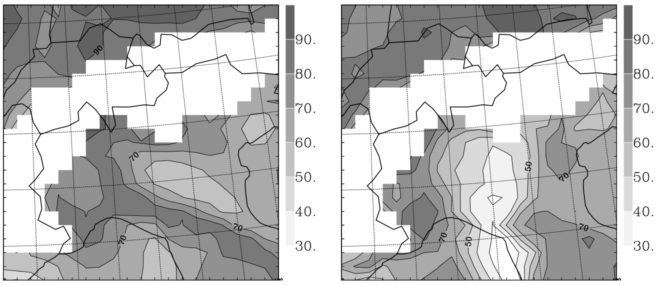

Figure 5: Relative humidity fields on 17 September 12 UTC, at 850 hPa, in the operational analysis (left) and the reanalysis (right). Units are in %.

6. Sensitivity to the the moisture field

To specifically evaluate the impact of the humidity field on the mesoscale simulation, a third experiment was performed (referred to as ECM-MI2). This last simulation was initialized from the reanalysis just as ECM-MI but the vapor mixing ratio field was replaced by the one of the operational analysis. The results in the equivalent reflectivity field are presented in the last row of Fig.1, and the accumulated precipitation in Fig.2d. Contrary to ECM-MI, an organized convective system develops over the plain and moves eastward. However this system, appears later and is much weaker than in the control experiment ECM-OD. Its efficiency in term of precipitation is weak.

7. Conclusions

Different high-resolution simulations of the MAP IOP2a convective system have been conducted with the MESO-NH model. Using different sets of initial conditions lead to contrasted results. The simulation based upon the operational ECMWF analysis produces fairly realistic results whereas the simulations based either on the operational French analysis or on the MAP ECMWF reanalysis completely fail. A sensitivity experiment shows that this different behaviour should not be only ascribed to the moisture field. The strong sensitivity of the mesoscale simulations to the initial conditions stresses out the low predictability of the IOP2a convective event.

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