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INTERCOMPARISON OF THE SIMULATED PRECIPITATION FIELDS OF THE MAP/IOP2B WITH DIFFERENT HIGH-RESOLUTION MODELS

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1. INTRODUCTION

Among the different precipitating events that were observed during the MAP field experiment (Bougeault et al., 2001), the case of IOP2b (19/20 September 1999) was the most intense and produced in the Lago Maggiore area local precipitation maxima exceeding 300 mm in less than 30h. This heavy precipitation occurred as a baroclinic trough was approaching the Alps from the west and as low-level moist Mediterranean air was advected toward the Lago Maggiore region.

This case has been selected for an intercomparison exercise of different numerical models run at very high-resolution (2 to 3km). All the models were initialized and forced with the same operational analyses of ECMWF. All the simulations start on September 19, 12 UTC and were carried out for a 30h time period.

2. THE DIFFERENT MODELS AND THEIR NUMERICAL SETUP

Four different numerical models have been used for this study: MESONH, MOLOCH, MM5 and MC2. All the four are non-hydrostatic.

MESONH, developed in the French community is a research-oriented model, based upon an anelastic system of equations (Lafore et al., 1998; Stein et al., 2000, http://www.aero.obs-mip.fr/~ mesonh/). The MESONH simulations were carried out over two nested domains of horizontal resolutions of 10 and 2.5 km and with a two-way interactive nesting procedure. The convection scheme, adapted from Kain and Frisch (1993) was activated only in the coarse grid simulation. The explicit microphysical scheme integrates the prognostic equations of water vapor, cloud water, rainwater, pristine ice, snow agregates and graupel.

MOLOCH, developed at the ISAC-CNR of Bologna for research purposes is based on the fully compressible set of primitive equations written in terrain-following coordinates. The model 'dry' physics is presently based on the BOLAM parameterization, while a new microphysical scheme, partly based on the Rutledge and Hobbs (1983) formulation is implemented. No sub-grid convection is taken into account. MOLOCH, which has been used here for the first time with complete physical parameterization, has been run on a 2 km grid nested in a 10 km simulation of the BOLAM model.

MM5 (MM5V3) is the widely used model of PSU-NCAR. In this study it has been run by two research groups with a different setup. The experiment referred to as MM5-RE (provided by the university of L'Aquila) was performed using three domains, two-way nested, with resolution of 27, 9, and 3 km. The MRF (Song and Pan, 1996) parameterization has been used for the boundary layer. The convection parameterization (Kain and Fritsch, 1990) was activated only in the coarse resolution domains and associated with the explicit computation of cloud and rain water. The experiments referred to as MM5-E1 and as MM5-E2 (provided by the University of Munich) are based on the standard MM5 version. They were also performed using three domains, but with resolution of 18, 6 and 2 km. These two experiments differ only by their treatment of the numerical diffusion.

MC2 is the Mesoscale Compressible Community model developed at RPN in Canada. It is based on the Euler equations with a semi-implicit, semi-Lagrangian discretization. This model was used very successfully in real time during MAP (Benoit et al., 2001). The MC2 simulations were carried out over three nested domains of horizontal resolutions of 40km, 10km and 2km.

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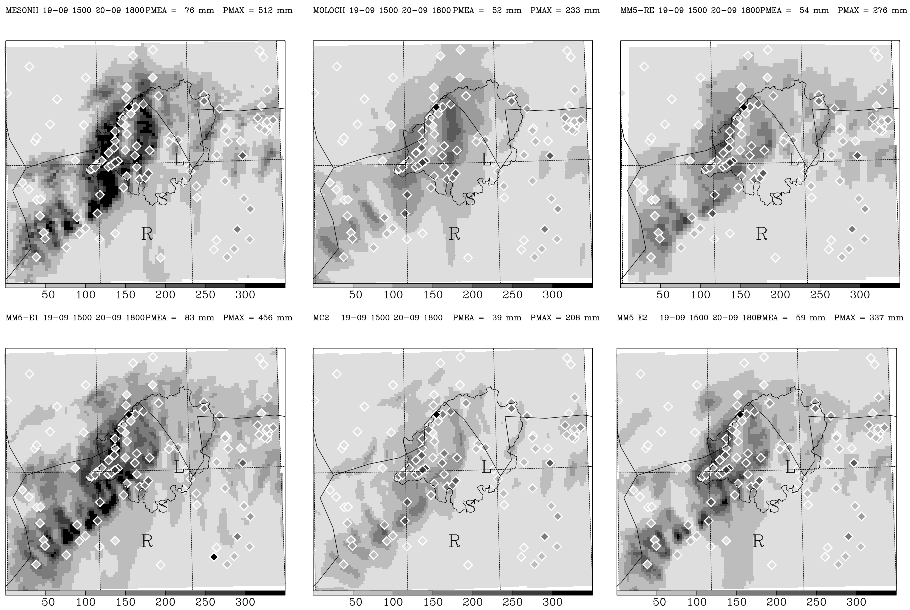

Figure 1: 27h accumulated precipitation (grey shading, in mm), computed in the different numerical experiments. The available rain gauge measurements (small diamonds) are superimposed with the same grey coding. The thin black lines refer to the Toce-Ticino watershed location, parallels and meridians (46^{o}N, 8^{o}E and 9^{o}E), and political borders between France, Switzerland and Italy. The letters R, S, L indicate the location of the radars.

3. COMPARISON WITH SURFACE MEASUREMENTS

The comparison is performed over an area of 250 km x 220 km centered over the Lago Maggiore. It roughly corresponds to the computational domain of the innermost models. Over this area, 117 ground stations provided hourly surface precipitation measurements.

Fig.1 compares the accumulated precipitation fields computed with the different models. The available surface observations are superimposed on each plot. The 27 h accumulation period spans from September 19, 15UTC to September 20, 18UTC and excludes the first 3 hours of simulation that could be affected by model spin-up. Between the six experiments there is a remarkable consistency in the precipitation pattern. All the computations show two elongated main bands of precipitation north-south oriented, located at 8^{o}E and 8.5^{o}E. Weaker additional bands, northwest-southeast oriented close to French border, or north-south oriented east of the Ticino-Toce watershed are also present in all experiments. However, the fields markedly differ in the intensity of the computed precipitation. The domain areal average varies in the range of 1 to 2, from 83mm (for MM5-E1) to 39mm (for MC2).

Many arguments may be invoked to explain this large difference in the precipitation amount (different model numerics, physics, numerical setup, ...) but the most straigthforward explanation can probably be found in the representation of the orographic forcing. All the models make use of an averaged orography which is then smoothed to avoid the generation of spurious numerical noise. Depending upon the filter properties, the final orogaphies and therefore the resulting orographic forcing may differ substantially from one model to another. This is evidenced in Fig.2 which shows the respective orographies of MM5-E1 and MC2. It is clear that the terrain slopes are quite steeper in MM5 than in MC2.

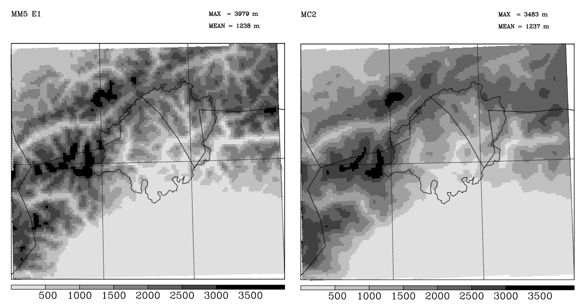

Figure 2: Topography (in m) used in MM5 and in MC2 for the 2km resolution simulations

	Cor. 1h	Cor. 6h	Cor. 27h	Mean Bias
MESONH	0.33	0.49	0.62	+28%
MOLOCH	0.31	0.47	0.62	-22%
MM5-RE	0.27	0.43	0.55	-16%
MM5-E1	0.37	0.53	0.63	+28%
MC2	0.30	0.47	0.63	-32%
MM5-E2	0.36	0.53	0.63	-10%

Table 1: Correlation coefficients between 1h, 6h, and 27h accumulated precipitation measured by the surface rain gauges and computed by the different models, and mean bias.

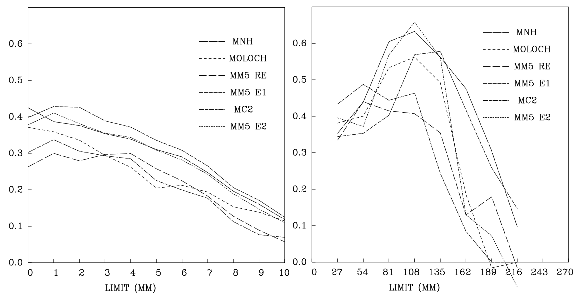

Figure 3: Heidke skill scores as a function of the precipitation threshold, computed for the different numerical experiments for the hourly precipitation (left) and fot the precipitation accumulated over 27h (right).

The comparison between MM5-E1 and MM5-E2 gives an idea of the sensitivity of the precipitation fields to some apects of the model numerics. A different scheme for the numerical diffusion, in this example, reduces the mean precipitation by a factor as large as 30%.

To get an objective comparison between surface observations and model output, different statistical parameters were computed: correlation coefficient, bias, and Heidke skill scores. These parameters were derived for different accumulation period 1h, 6h, and 27h. Table 1 summarizes the results. Between the different experiments, the over/under estimation of the computed precipitation ranges from -30% to +30%. In term of correlation, all experiments are quite close together. The correlation coefficients are weak for the hourly precipitation (around 0.3) but significantly increase when the accumulation period gets longer. For the 27h time period of the event, they reach 0.6.

Classically precipitation are evaluated by computing skill scores derived from contingency tables. In this study Heidke skill scores were computed on the basis of two-class tables (ie precipitation below or above some threshold). Results are presented in Fig.3 as a function of the class limit for the hourly precipitation and for the precipitation accumulated over the 27h. Consistently with the results obtained for the correlation, the scores get higher when the accumulation period is longer. Results obtained with MM5-E1, MM5-E2 and MESONH tend to be slightly better than the other results. It is interesting to note that the modification of the numerical diffusion (MM5-E2 versus MM5-E1) has improved the MM5 scores for the 27h precipitation for the low precipitation thresholds but has degraded them for the large ones.

4. COMPARISON WITH RADAR MEASUREMENTS

During the experiment the Lago Maggiore area was monitored by a network of three Doppler radars (see Fig.1 for their location). Precipitation estimates could be derived from the radar measurements (Georgis et al., 2002). These data are only available over a subdomain of 150km x 150km, and only for a shorter time period (15h, starting on September 19, 19UTC). In order to simultaneously compare rain gauge measurements, radar-derived precipitation, and model output the score computation was reconducted over this reduced time and space window. Only 61 of the previous 117 surface stations are included in this last domain. Results are presented in Fig.4. For hourly precipitation radar derived rainfall are in general slightly more accurate than the model rainfall. This is no longer the case for the 15h precipitation. For the radar data, the accumulated precipitation was computed by summing up each hour, the hourly rain rates derived over a 15mm mesurement period. Probably, better results could be obtained with a higher temporal frequency. Looking at the time evolution of the spatially averaged precipitation (not shown) it also appears that the radar derived rates are weaker by a factor 2 than the measured ones whereas they are quite accurate when the comparison is restricted to the 10 closest surface stations. This indicates that the quality of the radar rain estimates rapidly degrades when the distance to the radars increases.

Despite of the large similarity of the 27h accumulated precipitation fields shown in Fig.1, the time evolutions from one model to the other are quite different. This is illustrated in Fig.5 which shows the hourly precipitation rates at the beginning and at the end of the most intense precipitating phase. According to the radar data and surface observations, the maximum precipitation occurred during the night of September 20 between 00 and 08 UTC. All the models capture reasonably well the onset of heavy precipitation, except MOLOCH

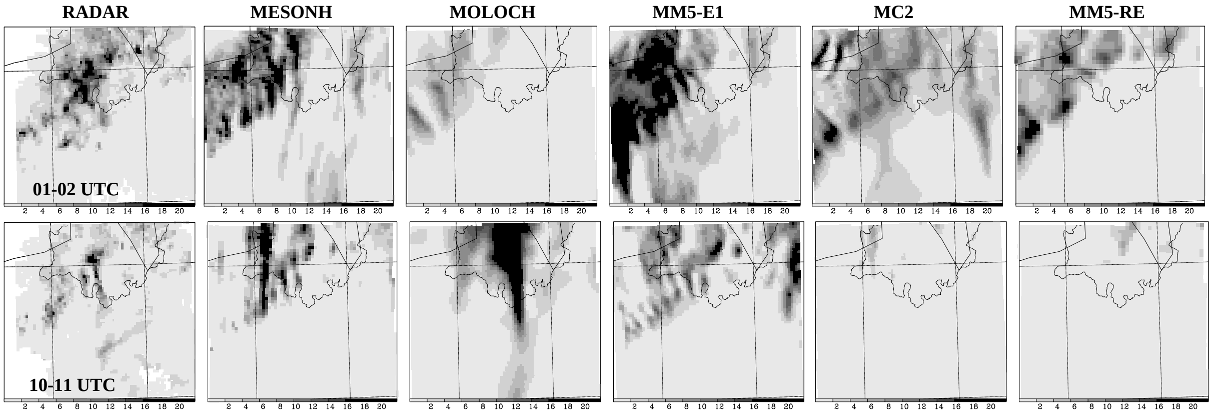

Figure 5: Hourly precipitation derived from the radar measurements and computed in the numerical experiments for September 20, 01-02 UTC (top) and 10-11 UTC (bottom).

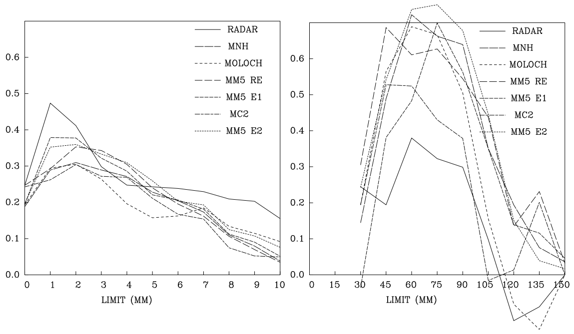

Figure 4: Same as Fig.3 but for the domain and time period corresponding to radar measurements.

which exhibits some time delay. More discrepancies are found in the decreasing phase after 08 UTC. At 10 UTC, precipitation is still quite intense in MOLOCH, whereas it has ceased an hour sooner in MM5-RE, and two hours sooner in MC2.

5. CONCLUSION

Using the data set collected during the MAP IOP2b, computed precipitation fields from six numerical high-resolution experiments have been compared with rain gauge measurements and radar derived precipitation. It was found that:

- Model results over/underestimate the total precipitation by a factor ranging from -30% to +30%

- At the first order, the model bias might be related to the level of smoothing applied to the model topography

- The accuracy of the model precipitation is rather weak for the hourly rainfall but is fairly reasonable for the precipitation accumulated over the 27h time period of the event.

- Conversely radar precipitation estimates are less accurate for the total precipitation than for the hourly precipitation rate.

- The accuracy of the radar derived precipitation rapidly degrades when the distance to the radars increases.

In a future work, these different meteorological model output will be used to feed hydrological models in order to assess the potential of a coupled hydro-meteorological modelling system for improving flashflood forecasting.

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