11.6 VARIATIONAL ASSIMILATION OF CONVECTIVE PRECIPITATION FOR MESOSCALE FORECASTING

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1. INTRODUCTION

During the Mesoscale Alpine Programme (MAP) Special Observing Period (SOP), the Canadian Mesoscale Compressible Community Model (MC2) was run operationally to provide high resolution forecasts (up to 3 km). An overall performance of the MC2 has been documented by Benoit et al. (2002). It was found that MC2 under-predicted the precipitation, in particular the convective precipitation. The objective of this study is to evaluate the sensitivity of the model forecasts on the assimilation of convective precipitation in a 1D-Var context. An adjoint of the Kain-Fritsch convective parameterization scheme has been developed and inserted in MC2 for this purpose. The methodology and some preliminary results will be presented.

2. THE EVENT AND THE DATA USED

A strong convective case (IOP2a, Sep. 17, 1999) during the MAP SOP was chosen for this study. The rain rate from the Alpine Radar Composite was, in the first step, used as the observed rate since it provides a quasi-uniform spatial coverage, and a good indication for the location where the convection takes place. This data set (Hagen, personal communication) covers an extended alpine region at a spatial resolution of about 2 - 4 km and a time sampling of every 30 minutes. The data (not the graphical format) are available to us for the following days: 17, 18, 24, and 25 of Sep., and 3 and 4 of Oct., 1999. The accuracy of the radar rain rate is evaluated, in the first step, using daily precipitation from an analysis of Alpine high-resolution rain-gauge observations (Frei and Häller, 2001), keeping in mind that the hourly rain rate would be more suitable for the radar rain rate evaluation. Ultimately, this study will be extended to the use of the combined radar and rain-gauge measurements in the assimilation procedure when rain-gauge data becomes completely available.

The radar rain rate is accumulated over 24 hours (from 06 to 06 UTC), and then spatially aggregated to the analyzed rain grid, a regular latitude-longitude grid with a resolution of 0.3 x 0.22 degrees (corresponding to a grid-spacing of about 25 km). The evaluation of radar precipitation is based on four parameters: mean difference ($\frac{100}{n}\sum((R_i - G_i)/R_i)$), absolute difference ($\frac{100}{n}\sum(|R_i - G_i|/R_i)$), bias ($\frac{100}{n}\sum G_i/R_i$), and correlation

a) b) c)

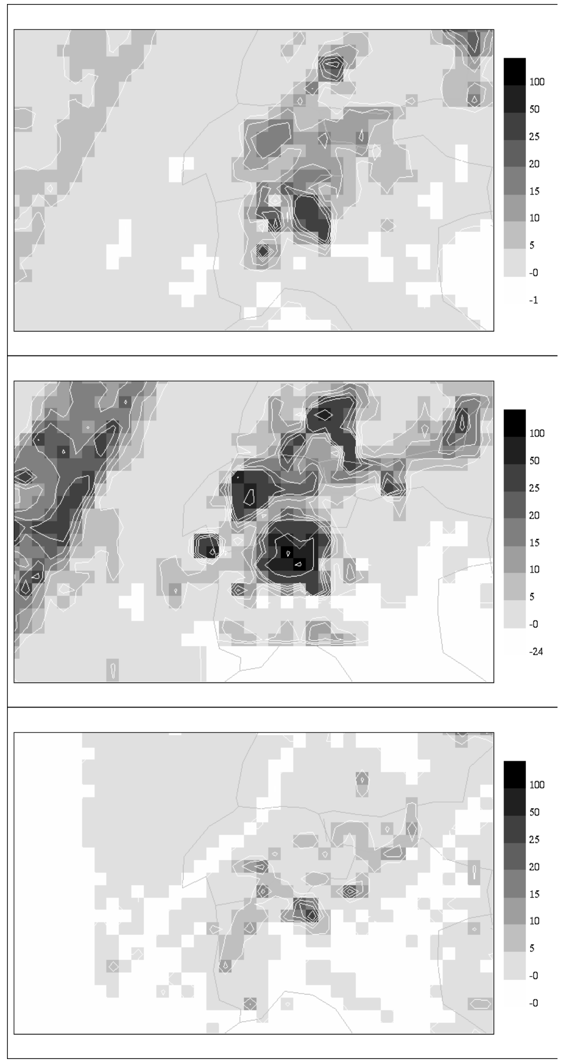

Figure 1. 24-h precipitation (in mm) respectively from a) analysis, b) radar observation, and c) MC2 simulation during the MAP SOP for the IOP 2a (Sep. 17, 1999). Negative values indicate no data available.

coefficient between R_i and G_i, with R_i and G_i denoting respectively the radar and rain-gauge measurements for the same grid point *i*, and *n* the total number of grid points considered in the calculation. The evaluation was done over a period of six days when the radar data are available to us (as previously mentioned). A threshold of 15 mm/day for precipitation is set for the evaluation purpose since only the convective precipitation is used in the assimilation procedure. These two data sets are

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correlated well (Table 1). The analyzed rain rate represents only 76% of the radar estimates. The radar may still overestimate the rain rate by an order of 10%, considering the underestimation in the analysis which is in the order of 4 - 10% (Frei and Häller, 2001). Figure 1 shows the 24-h precipitation respectively from analysis (Fig. 1a), radar observation (Fig. 1b) and MC2 simulation during the MAP SOP (Fig. 1c) for the IOP 2a (Sep. 17, 1999). MC2 under-predicted the precipitation during the experiment.

Table 1. Evaluation results

Mean diff.(%)	Abs. Diff (%)	Bias (%)	Cor. Coef.
24	40	76	0.65

3. THE MC2 MODEL AND THE 1D-VAR SCHEME

The MC2 is a compressible non-hydrostatic Limited Area Model (LAM). It is based on the Euler equations with a semi-implicit, semi-Lagrangian discretisation (Tanguay et al., 1990; Benoit et al., 1997). Detailed descriptions of the model dynamics and physics used in the MAP experiment can be found in Benoit et al. (2002), and will not be repeated here. In this study, the convection is parameterized with Kain-Fritsch (KF) scheme.

The 1D-Var scheme is based on the same formulation as used by Fillion & Errico (1997) except that the KF moist-convective parameterization scheme is used. An efficient and accurate approximation of the Tangent-Linear scheme for KF has been constructed recently by Fillion and Belair (2002) in view of operational applications at the Canadian Meteorological Center (CMC) for regional data assimilation and forecasting. The 1D-Var scheme uses the adjoint variational approach. Background error statistics for temperature and specific-humidity are derived from CMC operational 3D-VAR analysis system interpolated to the 46 vertical levels used in this study. Observational error statistics for rain rate are specified simply as a fixed percentage of the background rain rate. As in Fillion & Errico (1997), two or three iterations are enough to achieve convergence of the minimization scheme with preconditioning. Moist-convection is the only moist process used by 1D-Var, thus we assume pre-treatment of observed rain-rate is done in order to keep only the convective rain-rate contribution. This is only a first step towards the full and coherent introduction of moist-physical processes in variational data assimilation.

4. SIMULATION AND ASSIMILATION STRATEGY

In this study, MC2 was run in a one-way nesting mode: first at a horizontal resolution of 14 km with 147x147 grid points, and then at 3 km with 350x300 grid points (Fig. 2). There are 46 vertical levels with a lid at 25 km above sea level for both model grids. In order to compare the results with those obtained during the MAP SOP, the model configurations and grids were kept as close to those used in MAP SOP as possible. The MC2-14km simulation was initiated with the Swiss Model (SM) 1200 UTC +6-h forecast (or at 1800 UTC). The lateral boundary conditions were also from SM forecast. As soon as the radars detect a convective precipitation (> 10 mm/h, or 40 dbZ in reflectivity), the radar estimates will be used as the observed rain rate, and the MC2 output valid at the same time as the trial field (or background). An off-line 1D-Var analysis is performed with the adjoint of KF scheme. A new mesoscale analysis is then generated. This analysis procedure can be repeated as many times as the data available, and until the point when a higher resolution (3 km in this study) forecast will be started (Fig. 3).

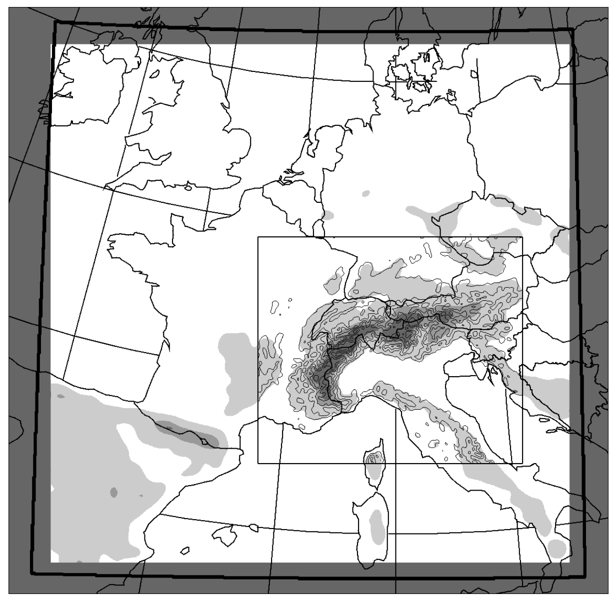

Figure 2: The computational domain of the SM-14km, MC2-14km, and MC2-3km. Heavy curvilinear black rectangle is the actual boundary of the Swiss Model (SM). The MC2-14km domain boundary is plotted in medium black rectangle, and the MC2-3km in thin black rectangle. Topography is plotted in gray shading and contours respectively used in MC2-14km and MC2-3km (filtered over 4 grid points). The political boundaries are also plotted in black lines.

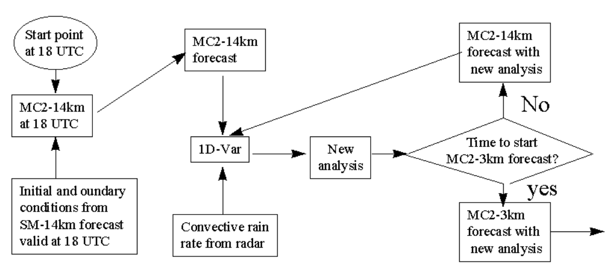

Figure 3. 1D-Var analysis procedure.

5. SUMMARY

An 1D-Var scheme has been developed. This scheme combined with the MC2 model was applied to a strong convective case. The objective of this study is to evaluate the impact of mesoscale analysis (at 14 km resolution) on model forecasts at higher resolution (3 km in this study). The preliminary results will be presented in the conference

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