17.4 A COMPARISON OF AN INTERACTIVE AND NON-INTERACTIVE APPROACH TO MESOSCALE FORECASTING USING THE IOP-2B OF MAP

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1. INTRODUCTION

Commonly, numerical simulations of mesoscale atmospheric flow are achieved using a non-interactive nested approach. In such an approach a coarse resolution model is used to specify time-dependent lateral boundary conditions for the high resolution limited area model covering the region of interest. The method is described as non-interactive since the solution over the inner domain does not affect the solution of the outer domain. The simplicity of this method is appealing, and is particularly well suited to hindcast studies where analyses can be used as initial and boundary conditions for the simulations.

The method is not however without its difficulties. Often the discrepancy between the temporal and spatial resolution of the coarse resolution simulation (or analyses) is such that several intermediate integrations, or cascades, are required before the desired simulation can be made. A more serious problem arises from the need to properly specify the lateral boundary conditions. Staniforth (1997) discusses the issue of the well-posedness for various implementations of lateral boundary conditions, and the difficulties of their use with sets of equations supporting multiple signal speeds (e.g. gravity, acoustic).

For its operational forecasting needs, the Meteorological Service of Canada has opted for an interactive approach to mesoscale modeling. The Global Multiscale Environmental (GEM) model (Côté et al, 1998) uses a global variable resolution mesh, with a high resolution uniform window over the area of interest, and a smoothly decaying resolution outside this window. The model being global, the initial-boundary problem is well posed for all flow types. The method is particularly well suited to the forecasting needs of Canada, where the area of interest is particularly large (~ 5.4×10^7 km^2). Besides its well-posedness, the method also has the advantage of only requiring an analysis at initial time, since no lateral conditions are required.

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Since a non-interactive nested version of GEM has recently become available, it is now possible to compare the two approaches in an otherwise identical framework. To do this comparison, the well documented IOP-2B of MAP was selected.

2. MODEL SETUP

The GEM model is an implicit semi-Lagrangian, finite-element model. A complete description of the hydrostatic formulation of the model can be found in Côté et al. (1998), and of the nonhydrostatic version in Yeh et al. (2002).

For the limited area experiment the control analyses of ECMWF available every 3 hours from the MAP website were used as initial and boundary conditions for a 25-km resolution 33-hour integration starting 19 September 1999 09UTC. The forecast valid 19 September 1999 12UTC was then used as initial conditions for a 10-km resolution, 30-hour integration over a smaller domain. The hourly outputs of the 25-km simulation were used to provide boundary conditions for the 10-km run. A final cascade to a 2-km resolution grid was made. The 27-hour forecast was initialized using the forecast valid 19 September 1999 15UTC of the 10-km run. The hourly outputs of the latter were used as boundary conditions for the 2-km forecast. Figure 1 illustrates the resolution cascade over the area of interest.

The variable resolution integration (GEM-VAR) was initialized using the control analysis of ECMWF valid 19 September 1999 12UTC. The results over the last 27 hours of the 30-hour integration are then compared to those obtained from the 2km GEM-LAM simulation. The global mesh of GEM-VAR has a high resolution window that covers precisely the same area as the 2-km resolution window of GEM-LAM (C in Fig. 1). Outside this area of interest the resolution in GEM-VAR decays smoothly, with the mesh intervals in both the latitudinal and longitudinal directions, increasing by approximately 10% away from the area. The integration is started 3 hours prior to the 2-km LAM, so that finer scale features which are absent from the ECMWF analysis, have had time to develop before the comparison between the two modeling approach is started. This is similar to the 3-hour lagtime between the various nesting in the LAM approach which allow each model to develop finer scales before it is used as initial and boundary conditions for the next run.

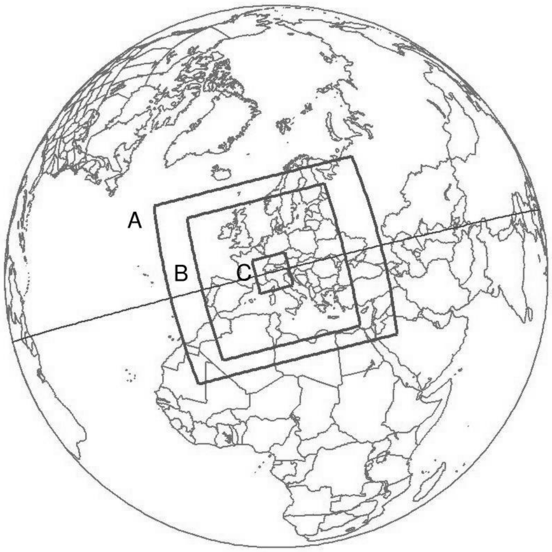

Figure 1: Extent of the 25-km (A), 10-km (B), and 2-km limited area model (C).

Table 1 summarizes the main characteristics of the various integrations. The cost of integrating the variable resolution model is approximately 55% higher than that of the LAM.

Model	Res	gridsize	Unif. grid	timestep	Hrs
LAM	25 km		210x177	720 s	33
LAM	10 km		350x350	225 s	30
LAM	2 km		400x400	40 s	27
VAR	2 km	537x522	400x400	40 s	30

Table1: Resolution, gridsize, timestep and leadtime for the 3 GEM-LAM and the GEM-VAR integration.

3. IOP-2B

The following observational summary of the IOP-2b event is taken from the notes of the MAP - Numerical modelling working group IOP-2b model intercomparison, MAP Science Director and the POC Science Co-ordinator available at http://www.aero.obs-mip.fr/map/MAP_wgnum; and Rotunno and Ferretti (2003). This event took place from 18 to 21 September, 1999 and is considered to be among the most intense precipitation events that occurred during the project. By the end of this period the rainfall amounts exceeded 300 mm locally over Lago Maggiore Target Area (LMTA) in northern Italy. The heaviest precipitation amounts occurred from 19 to 20 September. During this time in the synoptic scale, a deep upper trough approached from the Atlantic Ocean over the area. Ahead of the trough, at the lower levels, a southerly flow advected potentially unstable air from the Mediterranean Sea into the mountainous regions of northern Italy. The combination of mid level instability associated with the trough, the potentially unstable airmass and the rising slopes of the mountains produced the torrential rainfalls over the LMTA. Detailed radar observational analysis showed that the southerly flow became more southeasterly near the mountains, resulting in a flow more perpendicular to the southwest-northeast oriented mountains. This persistent moist flow caused the maximum precipitation centers to be along the sloping mountain ranges.

4. MODEL RESULTS

For the IOP-2b case the feature of interest, for comparison purposes, is the accumulated precipitation field and the main synoptic and mesoscale processes that lead to the maximum accumulations. Both GEM-VAR and GEM-LAM were initiated with an advancing 500 hPa trough (not shown). Their eastward evolutions were very similar in time and space. As shown in Figures 2(a) and (b) both models were generating southerly flow over the area of interest. In both cases the flow was situated a head of the 500 hPa trough at lower levels and were in agreement with the observations (above summary). This persisting southerly flow was advecting moisture from the south towards the mountains of northern Italy. It is interesting to note that both models were showing a more southeasterly flow near the mountainous regions showing a similar flow pattern to what was indicated by the observational analysis.

Figures 3(a) and (b) show the simulated 21hr precipitation accumulation valid at 1200 UTC 20 September, 1999 for the GEM-VAR and GEM-LAM respectively. These figures indicate that both models produced, even though not identical but, similar distribution of precipitation and intensity over the LMTA region. The maximum 21 hours accumulated centers over this region were 339 mm and 289 mm for the GEM-VAR and GEM-LAM respectively. The slight change in the precipitation maxima may be due to the different initial and boundary condition strategies employed for each model. These amounts however are in reasonable agreement with the actual observed precipitation maxima.

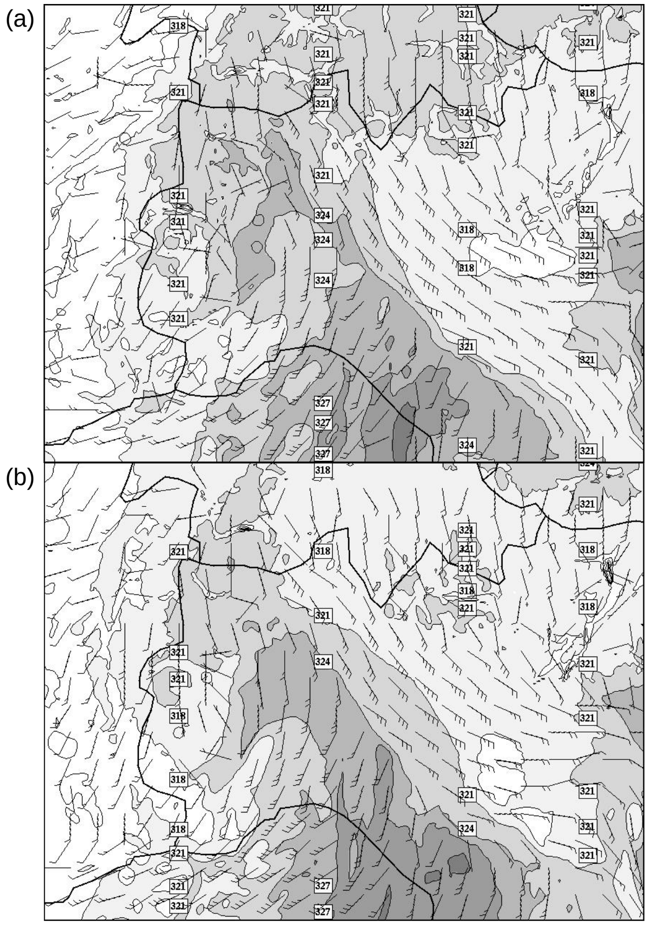

Figure 2:. (a) and (b) near surface wind barbs and contours of equivalent potential temperature (contour interval is 3º K) valid at 0900UTC 20 September 1999 for GEM-VAR and GEM-LAM respectively.

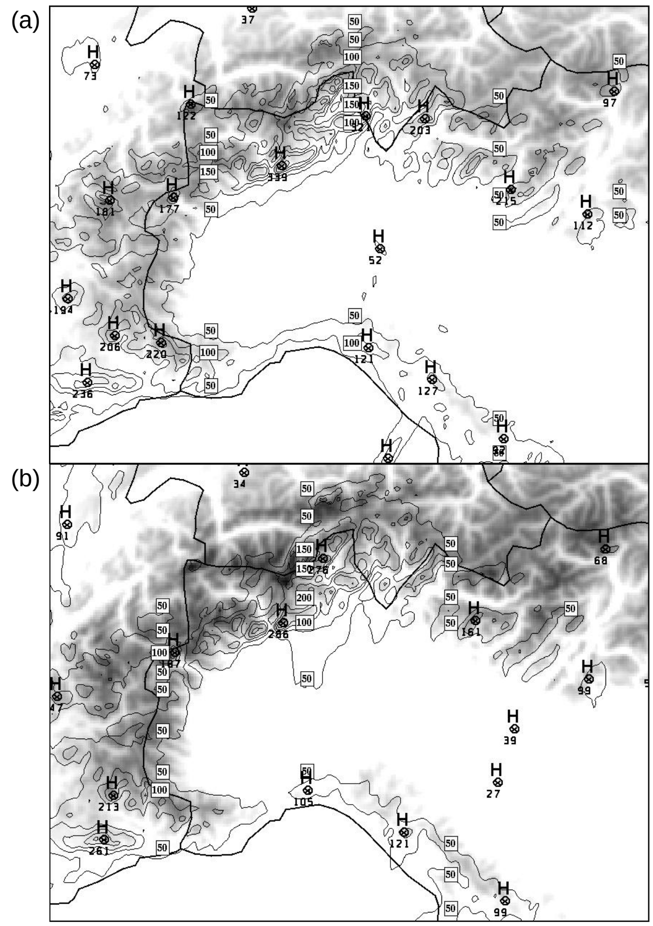

Figure 3. (a) and (b) contours of 21 hours accumulated precipitation (contour interval is 50 mm) and background topography (in grey) valid at 1200UTC 20 September 1999 for the GEM-VAR and GEM-LAM respectively.

5. CONCLUSIONS

The nested limited-area and variable-grid approaches provide in the case of IOP 2b similar results. The evolution of the large scale flow, as prescribed by the boundary conditions in the nested approach and by the GEM model in the variable mesh approach, are consistent, and the flow over the area of interest is primarily driven by the small scale topographic forcing which is identical in both models. The results are achieved at a significantly higher computational cost with GEM-VAR (~55%), but is obtained in a *true* forecast mode, starting from a single analysis.

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