Exploring and Validating LM Performance at Very High Resolution

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abstract: Numerical weather prediction models will in the near future be operationally run at resolutions of the order of 1-3km even at the Alpine scale. It is the purpose of this study to investigate the potential benefits and also the problems involved with this increase in resolution. To this end high resolution simulations (at 2km) with the Lokal Modell (LM) of the *COSMO*[1] are performed for selected MAP IOP cases and the results are examined in comparison with available high resolution datasets from the MAP campaign and with operational simulations at coarser resolution.The study develops in three directions: (i) study of meso-scale structures with help of a new modeling tool (Dynamics), (ii) with a systematical analysis of the model behavior for a selection of MAP IOP case studies with particular attention to model errors in precipitation field (Prediction) and (iii) experiments with the numerical set-up of the model (Numerics) investigating the influence of the domain size on the high resolution simulation and adapting the number of vertical levels of the model due to the increased horizontal resolution.

Keywords - ICAM, MAP, Croatia

1. INTRODUCTION

The new generation of supercomputers developed recently allows the use of more sophisticated numerical models able to better represent a mountain terrain and therefore improve forecasting precipitation and other mesoscale phenomena in the alpine region. In addition to that the Special Observing Period (SOP) of the Mesoscale Alpine Programme (MAP) that has taken place in autumn 1999 has among the scientific objectives to improve understanding of orographic precipitation, gap flows and foehn (Binder and Schär 1996) and to provide a useful database for validating numerical models (Bougeault et al. 2001). The use of MAP data has therefore been a suitable chance for testing the Lokal Model (LM) developed by COSMO at very high resolution. The case chosen for this validation study is MAP IOP 15 (5-10 November 1999), a case with moderate orographic precepitations on the southern side of the Alps.
The study is divided into two sections. Section 2 describes the influence of the outer domain size on the nested high resolution simulation. In section 3 the errors of the LM model with two different setups in the precipitation field are shown. A conclusion in drawn in section 4.

2. DOMAIN ISSUE

The aim of the first part of the study is to investigate how the large scale flow on the nested 2km simulation is influenced by the domain size of the coarser simulation. To this purpose three different domains have been arbitrary chosen along with an alpine domain for the high resolution simulation (fig. 1). Since for MAP cases ECMWF provides also Re-analysis data (RE, which include additional observations) it is a suitable chance to also have indications on the effects of initial data on

[1] Consortium for Small Scale Modeling

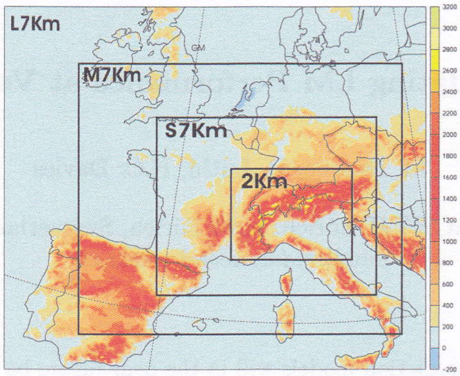


Figure 1: In this figure you can see the three selected domains for the 7Km Simulation (Large, Medium and Small domain) along with the alpine domain [2Km].

the model (and give some issues on the quality of ECMWF Analysis (AN) and RE). The procedure that has been followed is:

- Case Study: IOP15 (06/11/1999)
- Initial Conditions: ECMWF Analysis (AN)
- 7Km Simulation on L,M,S Domains initialized with AN
- 2Km Simulation nested on alpine area
- Low Pass Filter
- Difference beetween 7Km [2Km] and AN on alpine Domain
- Root Mean Square (RMS) of 7km [2Km] on Alpine Area
- The same also done with MAP RE data as initial conditions

Before going further to the results, some comments must be pointed out and discussed: ECMWF provides MAP RE data with 3hrs time resolution instead of the operational 6hrs, an important aspect that could contribute for better simulations. Since the model is operated with "perfect boundary conditions", the simulated large scale flow should follow the analysis closely. We therefore apply a low pass filter to both analysed and modeled fields and use the RMS difference of the geopotential as a measure for the deviation of the simulation from the analysis.
Beginning with the lower atmosphere (850hPa), we can see in fig. 2 (top left and right) the RMS for the 7Km run on the left and the 2Km run on the right. The first impression is that in both cases the RMS values are extremely low, show a good coherence and a stabilization of the RMS values with time and that the runs initialized with RE exhibit lower RMS, an indication that RE data could better reproduce the lower troposphere (along with 3hrs time resolution). Differences can be found in the divergence with time of RMS values for L,M and S (greater in 2km runs then in 7km).
The lower part of fig. 2 for the high troposphere shows a different behavior: The RMS values are still low with a remarkable coherence but it is evident that RE-initialized simulation values are not lower (at least in the first 12-15 hrs) than the AN-initialized, indicating that RE data are not better in the higher troposphere than the operational data. Another important difference visible in the lower part of fig. 2 is the exponential character of the RMS for AN-initialized simulations, while the RE-initialized runs seem to be more stable.
As can be seen from fig. 2 the RMS difference always decreases as we go from the large to the small domain. This can be interpreted as follows: in the larger domain the model has more freedom to develop its own flow structure, whereas in the smaller domain it is much more restricted by the lateral boundary conditions. This needs to be kept in mind when setting the outer domain size. Depending on the application of the model a balance between the freedom to develop and the correct representation of the large scale flow needs to be found.

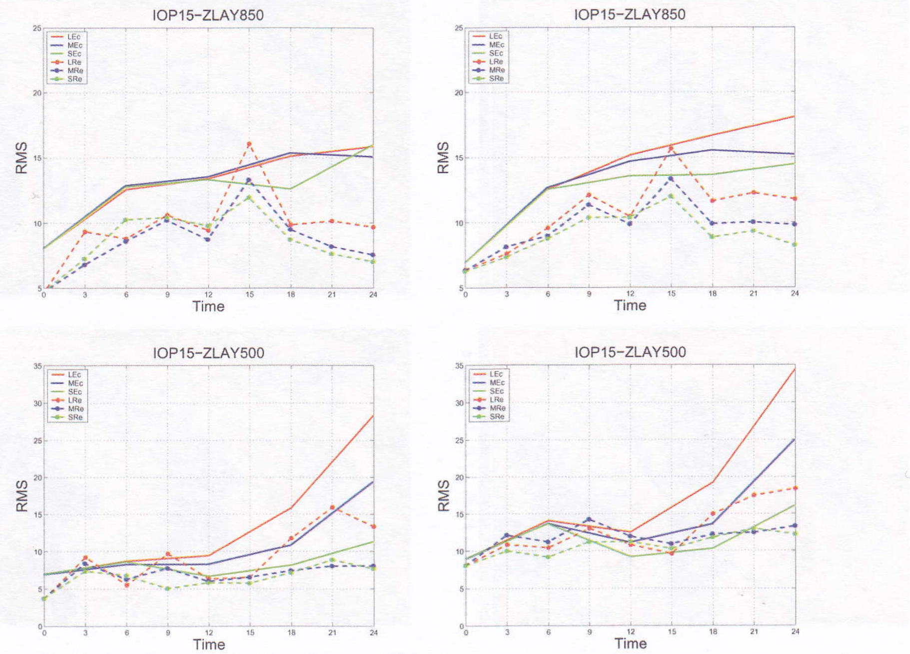
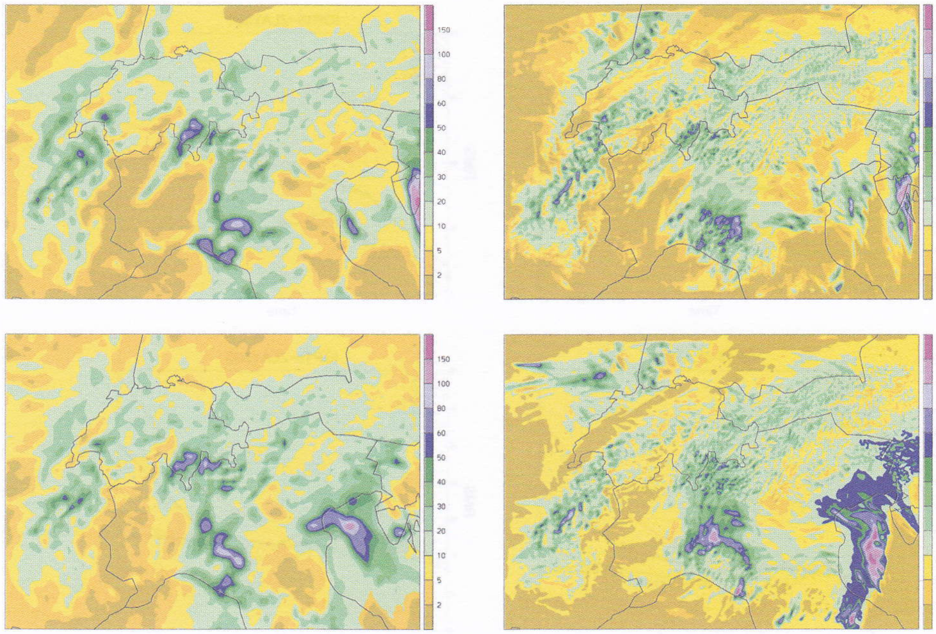


Figure 2: RMS of geopotential field at 850 hPa (top) and 500hPa (bottom) for 7km (left) and 2km (right) on alpine domain. Solid lines initialized with AN, dashed lines with RE.

3. MODEL ERROR IN PRECIPITATION FIELD

The reliability of a precipitation forecast is another issue of great importance when judging a high resolution model. In this second part of the study a comparison between real data and model simulation (initialized with ECMWF operational data and RE data) at two different horizontal resolution (7 and 2Km) for the MAP IOP15 case (06 November 1999) will be shown.
The Analysis of Alpine High-Resolution Rain-Gauge Observations for November 06 1999 (fig. 4 bottom left) shows a heavy precipitation event over the northern adriatic coast and Veneto region in Italy with daily precipitation amount up to 80mm, a secondary maximum over the central Po plain (near Milan) up to 60 mm, a local precipitation minimum over the extreme NW Italy and a regular distibution of about 20mm over the Alps. The simulation at 7km initialized with operational data (fig. 4 top left) does not show the adriatic precipitation maximum (but the very strong maximum present over Croatia could indicate an horizontal shift of about 200km). This forecast also pictures no precipitations over a large area of the Italian NW region. The nested 2Km run is very similar, with a peculiar difference over the Swiss Plateau, where little precipitation is properly predicted. More interesting are the results when the initialization is performed with RE data (fig. 4 middle left and right). The maxima over northern adriatic and over the Po valley are forecasted (sligthly to the south-east of the exact location) as well as the dry region over NW Italy. In particular the 2Km resolution run pictures precisely the two precipitation maxima (overestimating the amplitude) while the Swiss Plateau appears completely dry, which is not the case in the reality.
The use of RE data for the model initialization has an strong impact on precipitation forecasts, ameliorating significantly the precipitation distribution. The benefits from the use of the 2Km horizontal resolution instead are less evident (but present) in this November case, a period of low convection and the peculiarities of the model at very high resolution (convection scheme) may not be totally visualized.



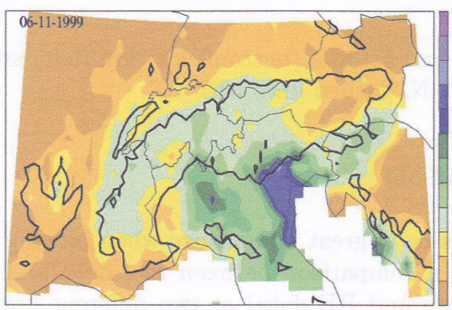


Figure 3: 24 hours precipitation on the 06 November 1999: LM Model at 7Km (top left) and at 2Km (top right) initialized with ECMWF data; at 7km (middle left) and at 2Km (middle right) initialized with MAP RE data and Analyses of Alpine High-Resolution Rain-Gauge Observations for the MAP Special Observing Period (left, Frei C. and Häller E., 2001).

4. CONCLUSIONS

The first aim of the study was to investigate how the large scale flow on the nested 2km simulation is influenced by the domain size of the coarser simulation. The RMS values of the geopotential field at 850hPa and 500hPa obtained are extremely low and always decrease from L to S-domain, since in a larger domain the model has more freedom to develop according to its physics, while if smaller the model is more forced by the boundary conditions.
In this case study we also had the possibility to test the quality of ECMWF operational and RE data. Simulations initialized with RE data show smaller RMS and much better precipitation forecasts both at 7 and 2Km horizontal resolution for this particular case. This last simulation in particular forecasts a daily precipitation distribution very close to the real data when compared with the operational run, whose skills in forcasting precipitations are often insufficient (fig.4). Even though the model performs quite well for the IOP15 case driven with analyses at the lateral boundaries further refinements are needed to yield even better results. The introduction of prognostic precipitation and a 3D-turbulence scheme might help to improve the results.

5. REFERENCES

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