Impact of the topography and LBC on the ALADIN precipitation forecast

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1. Motivation

Because of strong influence of mountain on weather processes, ALADIN have some specific problems over complex mountainous areas, especially the precipitation forecast. The aim of the work is to improve the ALADIN precipitation forecast. Special attentions are paid to investigating the impact of the model topography and LBC's on the ALADIN precipitation forecast.

2. Domains, data and meteorological situation

The domains used for the numerical simulations are shown in Fig. 1 (Ahrens *et al.*, 2001). The coarse-grid domain LACE (12.2 km horizontal resolution, 37 level in vertical, hydrostatic) is centred over Central Europe and coupled to ARPEGE. The intermediate domain VIENNA (9.6 km horizontal resolution, hydrostatic) is for the studies over the Alps and coupled to ALADIN/LACE; ALADIN/VIENNA is taken as the control run. The domain LMTA is positioned so as to include the Lago Maggiore Target Area, our most interest target area for investigation.

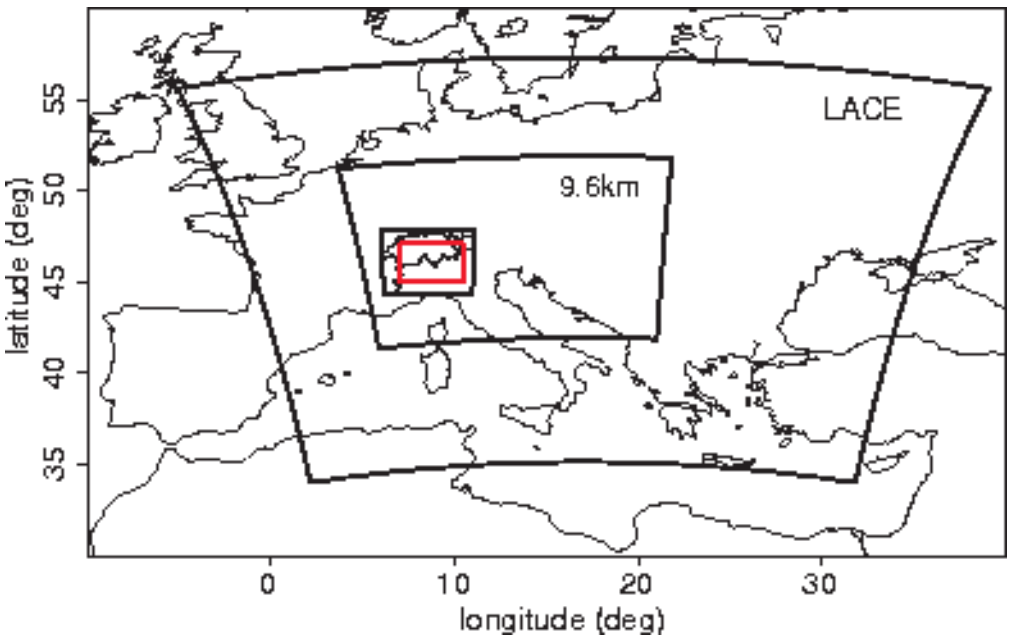

Figure 1. ALADIN domains for the numerical simulations. ***LACE*** : over central Europe, 12.2 km horizontal resolution; ***VIENNA*** : over the Alps, 9.6 km horizontal resolution; ***LMTA*** : Lago Maggiore Target Area; the sub-domain in red is used for the detailed investigation.

Heavy rainfall over the Alps occurs very often in autumn on the southern slopes of the Alps (Frei and Schär, 1998). The LMTA domain belongs to these maximums and was chosen for studying the mechanisms of persistent rain. This area is well investigated and observed within the Mesoscale Alpine Programme, MAP (Binder *et al.*, 1996, Bougeault *et al.,* 2001) and the EU Project RAPHAEL (Bacchi and Ranzi, 2000). The dense operational observation network in the Alpine region was complemented during the special observation period (autumn 1999) by research instruments: ground-based and airborne radars, supplementary radio-soundings,... The dataset collected during the Intensive Observation Periods (IOPs) allows the direct study of heavy rain and

the validation of fine-scale research and operational models over a mountainous area. One of the most intense rainfall episodes, IOP2b (19 and 20 September 1999), is used here for the study.

The synoptic situation of IOP2b is characterized by (details in Asencio *et al.,* 2002) : a deep cyclone located to the West of Ireland at 00 UTC on 19th Sept., and moving to France at 12 UTC on 20th Sept.; a strong stationary anticyclone over Russia, which extends by a ridge even to South of the Mediterranean Sea East of 20°E. In North Africa, a second cyclone moves from Morocco to Tunisia during the IOP2b.

An active cold front is associated with the Atlantic cyclone. At 00 UTC, it extends along an approximately North-South axis from the British Islands to Portugal. It crosses France on 19th Sept. and reaches the Alpine orography during the night. The eastwards evolution across the Po Valley during the 20th Sept. is slowed down by the stationary high pressure over Eastern Europe.

This is a typical synoptic situation for heavy rainfall over the Alps because the cold front movement will intensify the West-East pressure gradient and therefore the low-level jet ahead of it. Moreover, warm air originating from Africa crosses the Mediterranean Sea and this leads to the formation of a conditionally unstable air mass.

3. Results

For investigation of the ALADIN precipitation forecast over the complex mountainous area, the precipitation analysis (version 2.0, 25 km resolution) from ETH, Zürich, (Frei and Häller, 2001); and radar precipitation analysis provided by the MAP Data Center, Zürich, and M. Hagen, DLR, are used, which are shown in Fig. 2.

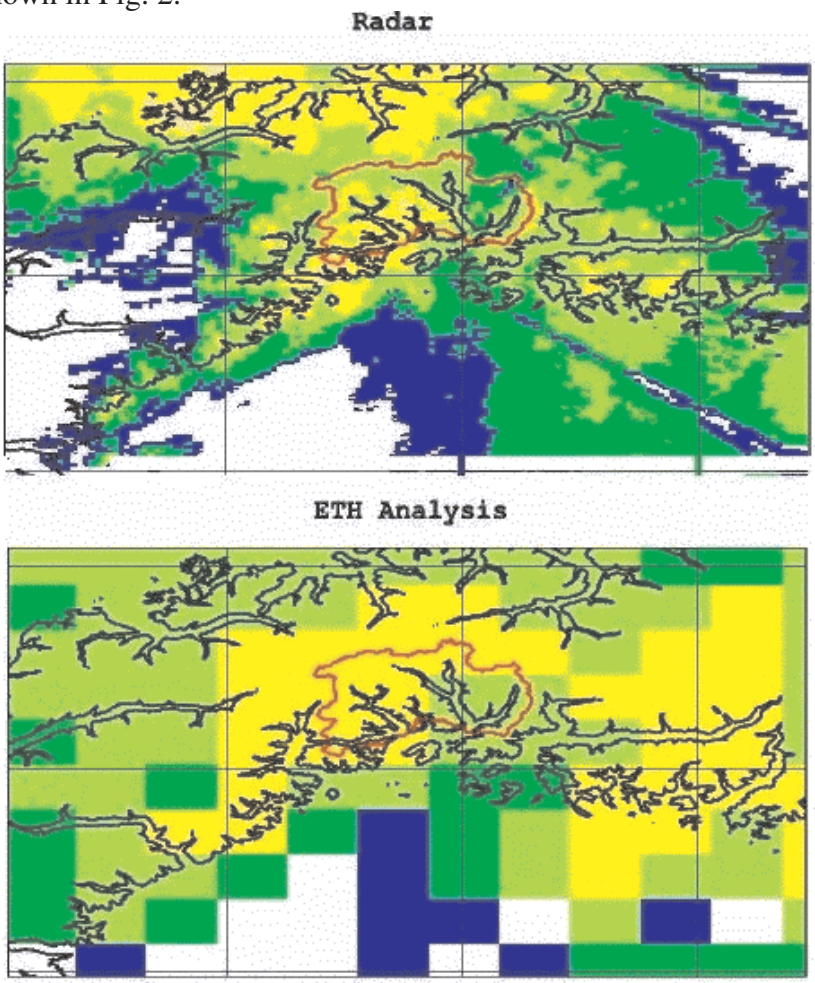

Figure 2. 24 h mean precipitation rate, in mm/h, from 06 UTC 20.09.1999 to 06 UTC 21.09.1999.

3.1 Model orography

The representation of the orography in the model plays a crucial role in the precipitation forecast. For having more knowledge about the influence of the model orography on the precipitation forecast we simulate the IOP2b case by using different model orographies in the ALADIN/VIENNA, i.e. 9.6 km horizontal resolution, coupled to ALADIN/LACE. The model orographies we have chosen are:

1) envelope orography
2) mean orography (without envelope)
3) semi-envelope orography, which is based on the variational method (Bouteloup, 1994). The underlying idea is to keep close to mean orography at the largest scales and to the usual, enhanced, envelope orography at the small scales. This is achieved simply through a modification of the cost function $\boldsymbol{J}$ minimized in the computation of the spectral orography:

$$\boldsymbol{J}^{new} = \boldsymbol{J}^{old} + \boldsymbol{P}\sum_{n,m}\left|\boldsymbol{R}_n^m - \boldsymbol{S}_n^m\right|^2 / \left(\sqrt{m^2+n^2}+0.5\right)^{\boldsymbol{a}}$$

$\boldsymbol{J}^{old}$ is computed in gridpoint space so as to minimize Gibbs oscillations over sea. $\boldsymbol{R}$ and $\boldsymbol{S}$ are the spectral components of the final and mean (before any minimization) orography. $\boldsymbol{a}$ and $\boldsymbol{P}$ are tuning parameters.

The height-latitude cross-sections of the different model orographies and the original input data at longitudes 7.1°E, 8.5°E and 9.0°E are shown in Fig. 3. The mean orography is closer to the reality than the envelope and the semi-envelope ones, which increase the mass of the mountain. The comparison of the precipitation forecasts using envelope and mean orography is presented in Fig. 4. The impact of using the mean orography is positive, it reduces the precipitation maximum on the top of the mountain, and the forecast is closer to the analyses, but the other problem is still there, e.g. too dry in the lee side of the mountain. We have also compared the forecasts using full envelope and semi-envelope orographies in the model, there is indeed an improvement on the precipitation maximum, but not so evident.

One may be afraid that by introducing no envelope orography the wind forecast will be deteriorated. For this a comparison between the wind forecast with and without the envelope orography is presented in Fig. 5. This is the time-height cross-section of the averaged wind intensity. The result is very similar, and we can't conclude to any deterioration in the wind forecast by using no envelope orography. The validation of the wind intensity with the radar observations (see Asencio *et al.,* 2002) shows that the forecasted upper-level jet is weaker in intensity and few hours earlier than observed, and in the low levels the wind intensity is overestimated a bit in the period 06 UTC to 12 UTC 20.09.1999. In this period, the cold front is over the area.

3.2 Lateral boundary conditions (LBCs)

An experiment was done for investigating the impact of the coupling LBCs on the model precipitation forecast. In the simulation, the initial conditions and lateral boundary conditions, linearly interpolated in time between 6 hourly analyses (not as in the control run with a forecast), are given by the ARPEGE operational analyses. To analyse the impact, we focus on the western side of the Po Valley, and divide it into 3 areas. For the definition of those three areas, please see Asencio *et al.* (2002). The temporal evolution of the rain averaged over each area (Fig. 6) shows that the simulation with forecast as coupling overestimates the rain over Alpine slopes and Piedmont area, and is quite reasonable over central Po Valley. All of them exhibit a temporal shift. The experimental simulation is close to the radar observation in intensity over the Alpine slopes and Piedmont area, but underestimates the rain over central Po Valley. As in the control one, the temporal shift is still there.

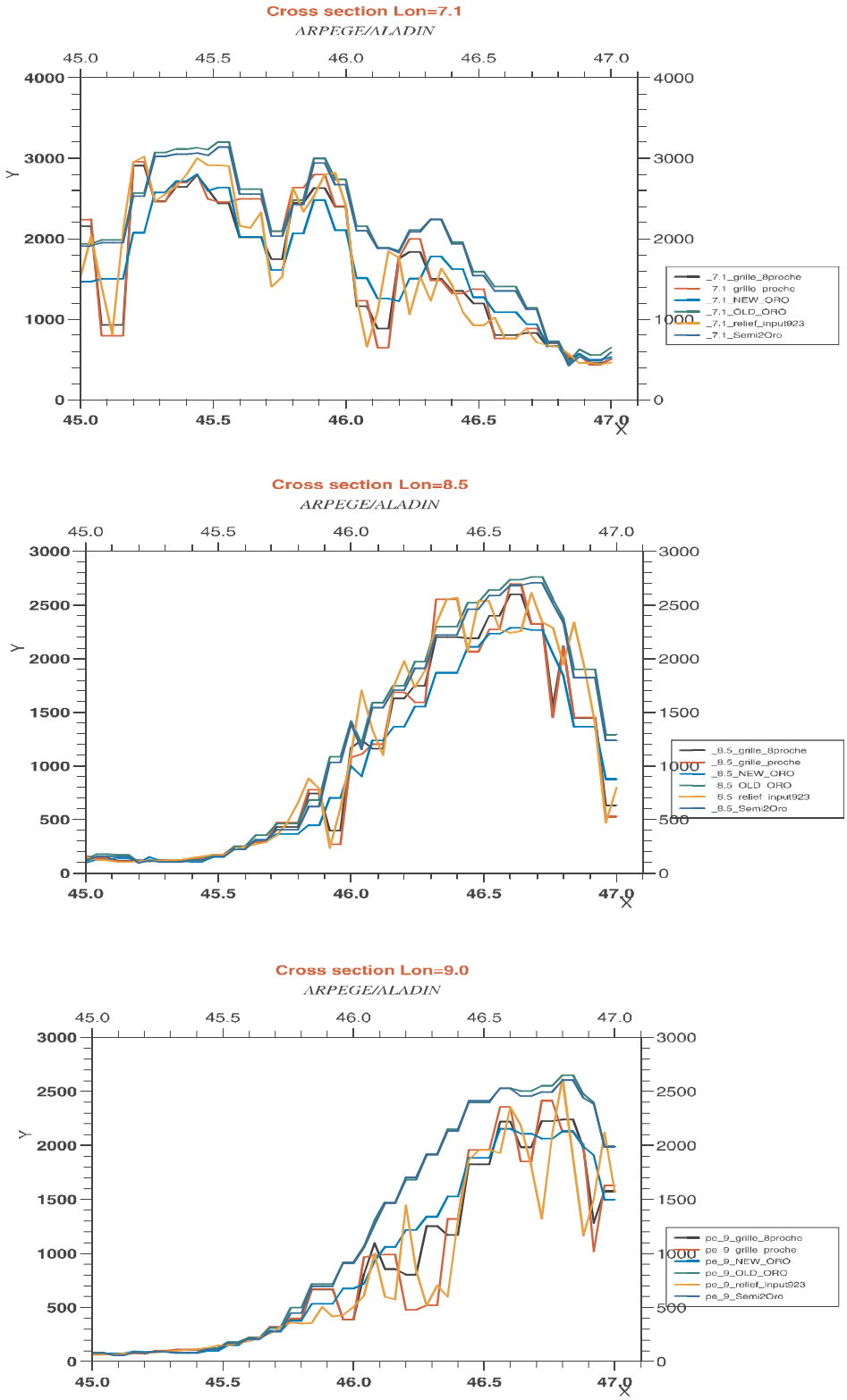

Figure 3. South-North cross-sections of the orography used in the simulations, at 7.1°E, 8.5°E and 9°E. **Grille_8proche** : average of the 8 surrounding gridpoints. **Grille_proche** : average of the 4 surrounding gridpoints. **NEW_ORO** : without envelope. **OLD_ORO** : envelope. **Relief_input923** : original input data. **Semi2Oro** : semi-envelope.