Relaxing the HIRLAM orography in the boundary zone - a preliminary test

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1 Introduction

Several improvements for the HIRLAM boundary treatment were recommended at the HIRLAM-5 Workshop in Dublin in October 2002 (HIRLAM, 2003) and many of these improvements were also included in the HIRLAM-6 Scientific Plan. One of the recommended modifications, the MC2 boundary treatment, has already been introduced into the HIRLAM Reference System version 6.1.2 (McDonald, 2003; Järvenoja, 2003).

Another recommended item was to relax the HIRLAM orography towards the orography of the boundary dataset in the boundary zone. The HIRLAM orography can differ rather much from the orography of the boundary dataset, e.g. the ECMWF orography, especially over high terrain. If the HIRLAM orography and the orography of the boundary dataset differ much in the boundary zone, some imbalance is generated in the boundary fields even though the vertical profiles are adjusted in the vertical interpolation scheme. Introduction of the relaxed orography might result in more balanced boundary fields and thus have positive impact on forecasts.

This note first describes the method of relaxing the HIRLAM orography and then reports the results from two 2-week parallel tests using the reference HIRLAM orography and the relaxed orography.

2 Method

A preliminary test to relax the HIRLAM orography towards the orography of the boundary dataset was carried out as a separate task outside of the actual HIRLAM system. This separate task consists of two steps: 1) interpolation of the orography of the boundary dataset into the HIRLAM grid, if the resolutions do not match or the grid points do not overlap - otherwise picking the orography for the HIRLAM area from the boundary dataset and 2) relaxing the HIRLAM orography towards the orography of the boundary dataset. Step (1) is straightforward and is needed in order to have the HIRLAM orography and that of the boundary dataset in the same grid. In step (2), the weights used in the relaxation are first defined in the same manner as in the actual boundary relaxation scheme in the forecast model. Then the relaxed HIRLAM orography is computed as a weighted mean of the HIRLAM orography and that of the boundary dataset, using the calculated weights. Finally, a new climate file is created, where this relaxed orography replaces the original one.

3 Parallel tests

Parallel test runs have been carried out using the present HIRLAM reference boundary treatment with reference orography and relaxed orography. The runs have been conducted on the IBM at CSC using the HIRLAM 6.1.2 system. The parallel experiments are as follows:

- REF : reference HIRLAM boundary treatment as in HIRLAM 6.1.2
- REL : as REF, but the HIRLAM orography relaxed towards the orography of the boundary dataset in the boundary zone

The common features of the experiments are:

- Domain: Area corresponding to the FMI operational suite (ATX) with a 0.3° horizontal resolution; model domain shown in Fig. 1
- 256 × 186 grid points; 40 levels in the vertical
- Semi-Lagrangian advection, time step 6 min
- Each suite with its own data assimilation (3D-Var, 6 h cycling)
- ISBA surface scheme with the related surface analysis package
- Lateral boundary conditions: ECMWF frames with horizontal resolution of 0.4°, as received operationally
- 48 h forecasts from 00 UTC analyses only
- Periods: 12-27 January 2003 and 16-31 July 2003

Another set of experiments was set up to test the case where the western (inflow) boundary is over a mountain area. The characteristics of these experiments, nested inside REF and REL domains, are:

- RNF : as REF, but nested
- RNL : as REL, but nested
- Domain: Inside REF/REL, with the western boundary over Scandinavian mountains; model domain shown in Fig. 2
- Horizontal resolution of 0.15°
- 166 × 140 grid points; 40 levels in the vertical
- Semi-Lagrangian advection, time step 4 min
- Each suite with its own data assimilation (3D-Var, 6 h cycling)
- ISBA surface scheme with the related surface analysis package
- Lateral boundary conditions: REF/REL forecasts from the same cycle
- 48 h forecasts from 00 UTC analyses only
- Periods: 12-27 January 2003 and 16-31 July 2003

4 Results

4.1 Relaxed orography

The relaxed orography for experiment REL is calculated from the ECMWF orography included in the boundary dataset. These boundaries (operational frames) are received with a horizontal resolution of 0.4°, which means that the horizontal interpolation into the HIRLAM grid is needed before relaxation. The same applies to the nested experiment RNL, where boundaries from REL experiment are used: the RNL orography (0.15°) is relaxed towards the REL orography (in 0.3° resolution). Figures 1 and 2 show the differences between the relaxed orography and the original orography between experiments REL and REF (REL-REF) and between RNF and RNL (RNL-RNF), respectively. In Fig. 1 (REL-REF), maximum and minimum differences are +383 and -576 m and Fig. 2 (RNL-RNF) +406 and -631 m, respectively. The differences are rather large, but concentrated on a rather small geographical area. In Fig.1 (REL-REF), the largest values are seen over the Caucasus mountains (east of the Black Sea) and east of the Mediterranean. In Fig 2. (RNL-RNF) largest differences are north of the Black Sea and over the Scandinavian mountains. The structure of the differences consists of small negative and positive cells. Unfortunately, in a black-and-white plot the solid and dashed lines cannot be distinguished.

4.2 Impact on forecasts

In the following, some results from the parallel tests are presented by looking at systematic differences between REL and REF experiments as well as between RNL and RNF.

Figure 3 shows the systematic difference in 48 h mean-sea-level pressure (p_{msl}) forecasts between REL and REF (REL-REF) for the winter period of 12-27 January 2003. Differences are small, being ±1 hPa over the Caucasus mountains. Cells of ±0.5 hPa can be seen in northern Europe. Differences in the 300 hPa geopotential height (Fig. 4) are small as well: of the order -10 m at most at the eastern boundary and ±5 m over northern Russia.

Figure 5 demonstrates differences in the 36 h two-metre temperature (T_{2m}) forecasts (valid at daytime) between REL and REF experiments for the summer period of 16-31 July 2003. Differences of a couple of degrees can be seen at the eastern boundary, and differences of the order of ±0.5°C can be seen in some areas in Europe and Russia. Differences in the 48 h T_{2m} forecasts are comparable to those of 36 h forecasts (not shown). Figure 6 shows differences in the total cloud cover in the 36 h forecasts between REL and REF. In the previous figures the differences were mainly in the boundary zone, but in this parameter differences of the order of ±0.1 (fraction) can be seen in large parts of the model domain. The differences in the accumulated 48 h total precipitation between REL and REF experiments are shown in Fig. 7. Experiment REL gives about 10 mm less precipitation than REF over the Caucasus mountains at the eastern boundary. Elsewhere the differences are of the order of ±2 mm at the largest.

The differences in the relaxed orography (REL) and the original orography (REF) are very small at the western (inflow) boundary. This may explain the fact that differences between experiments REL and REF are small as shown in Figs. 3-7. The impact study was extended by a set of nested experiments, RNF and RNL, inside the REF and REL areas. Now the western (inflow) boundary was placed over the Scandinavian mountains (see Fig. 2). The same two 2-week periods were run as in case of REL and REF experiments.

Figure 8 shows systematic differences in 48 h p_{msl} forecasts between RNL and RNF (RNL-RNF) for the winter period of January 2003. Note the contour interval of 0.25 hPa. Differences are really small except in the SE corner of the area over mountains. The inner area remains practically unaffected. The differences do not spread from the boundary, even though in this case it could have been expected due to the westerly or southwesterly flow over the Scandinavian mountains.

Figs. 9 and 10 demonstrate the average 48 h accumulated total precipitation for the summer period of 16-31 July 2003 for RNF and RNL experiments, respectively. The striking feature in these figures is small precipitation amounts in the boundary zone. This feature comes from the MC2 boundary treatment, which reduces especially convective precipitation in the boundary zone (Järvenoja, 2003). However, there are still left some spots with higher precipitation amounts in the boundary zone in the RNF experiment (Fig. 9). These spots coincide areas where the relaxed and original orography differ, i.e., where the original orography of the experiment and that of the boundary dataset differ. The largest average 48 h accumulated precipitation in the SE corner of the area (north of the Black Sea) reaches 140 mm. There are some other spots with more than 15 mm, e.g., in the western boundary zone over Scandinavian mountains. Introduction of the relaxed orography (RNL) removes these spots of larger precipitation amounts in the boundary zone as demonstrated by Fig 10. Closer examination of Figs. 9 and 10 reveals that there are differences in the precipitation amounts also in the inner area, not only in the boundary zone. Precipitation, or more accurately convection in this summer case, seems to be “somewhat” sensitive to relaxation of orography.

The observation verification scores, using observations from EWGLAM stations, do not reveal any difference in the forecast skill between REL and REF experiments, either in winter or in summer. The same applies to the skill between RNL and RNF forecasts for the winter period. Just minor differences between RNL and RNF scores can be seen for the summer period, but overall superiority cannot be concluded either way.

5 Concluding remarks

A preliminary test to relax the HIRLAM orography towards the orography of the boundary dataset in the boundary zone has been carried out and the impact of the relaxed orography on the forecasts has been studied with the aid of parallel experiments.

The impact of the relaxed orography on forecasts is rather small and concentrated mainly in the boundary zone, as revealed by the parallel experiments. Practically no difference in verification scores between forecasts using the relaxed and original orography can be found.

In this preliminary test the relaxed orography has been created outside of the HIRLAM system with the original orography only being replaced by the relaxed one in the climate file. This means, e.g., that the surface temperature in the climate file is not adjusted to the new relaxed orography. The work is going on to carry out the orography relaxation in a proper way in the climate generation phase of the HIRLAM system.

References

HIRLAM, 2003: HIRLAM Workshop on Mesoscale Modelling, Dublin, 14-16 October 2002, *HIRLAM Workshop Report*, p. 64.

Järvenoja, S., 2003: Testing of the MC2 boundary treatment in HIRLAM. *HIRLAM Newsletter*, **43**, 143-153.

McDonald, A., 2003: MC2 boundary treatment in HIRLAM. *HIRLAM Newsletter*, **43**, 140-142.

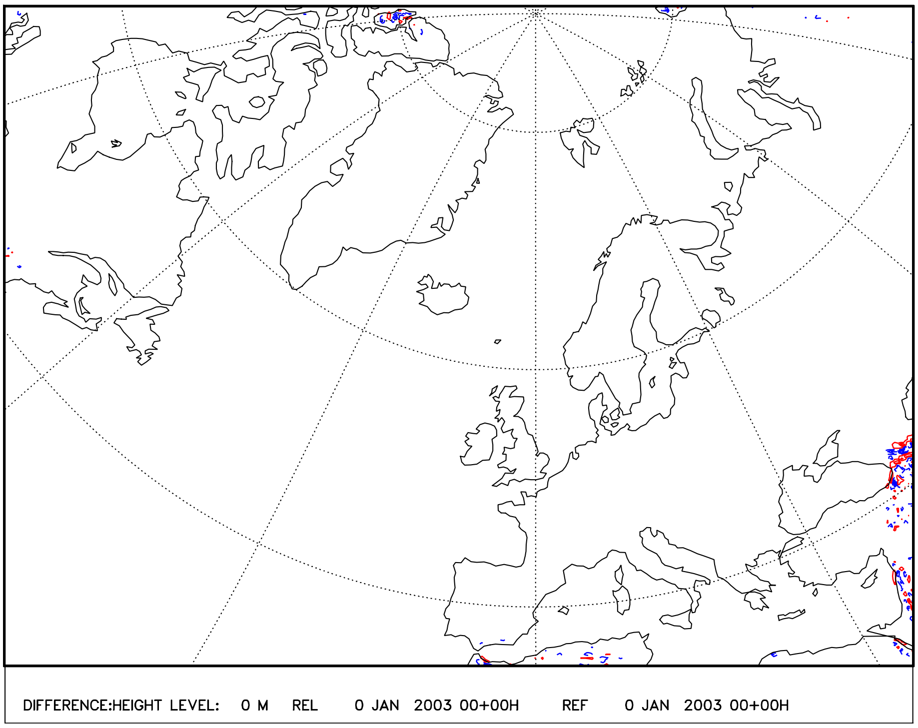

Figure 1: *Difference between the relaxed (REL) and the original (REF) orography (REL-REF). Contour interval: 100 m. The zero isoline not plotted, negative values indicated with dashed lines.*

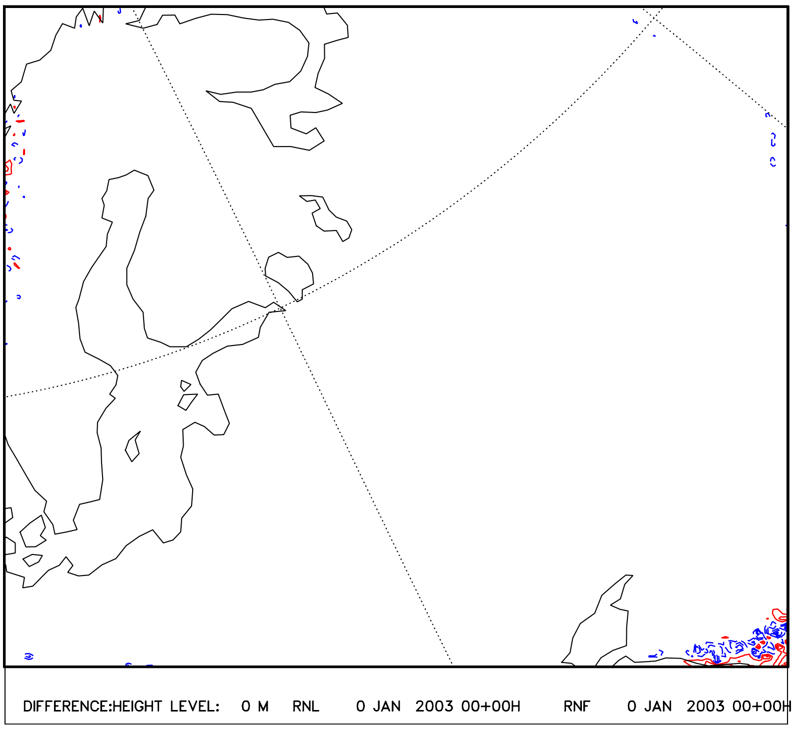

Figure 2: *Difference between the relaxed (RNL) and the original (RNF) orography (RNL-RNF) for the nested system. Contour interval: 100 m. The zero isoline not plotted, negative values indicated with dashed lines.*

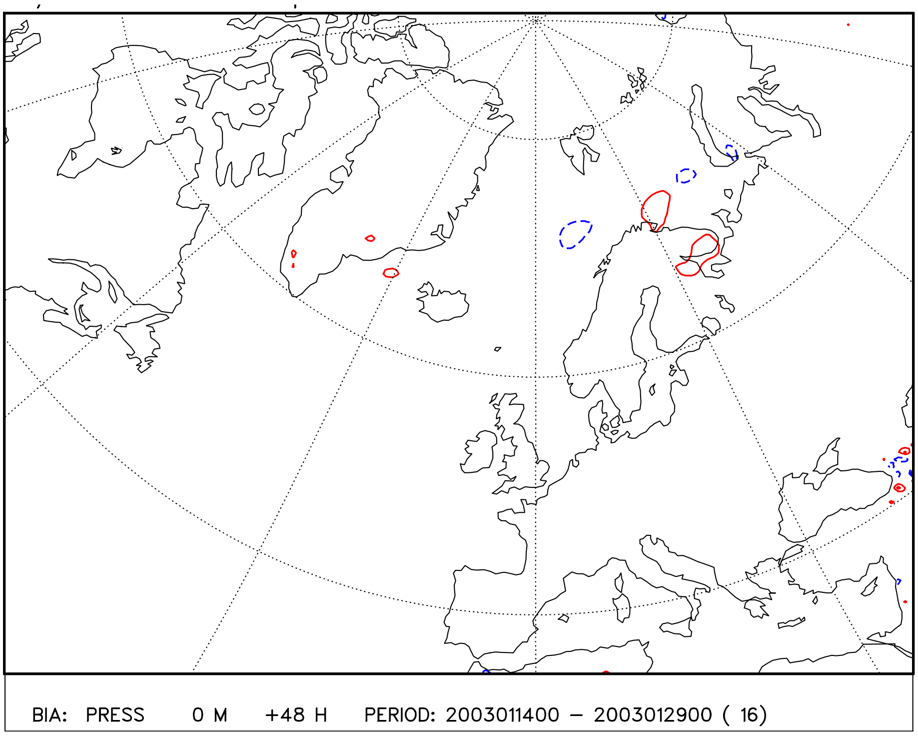

Figure 3: *Systematic difference in 48 h* p_{msl} *forecasts between REL and REF experiments (REL-REF) for the period 12-27 January 2003. Contour interval: 0.5 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

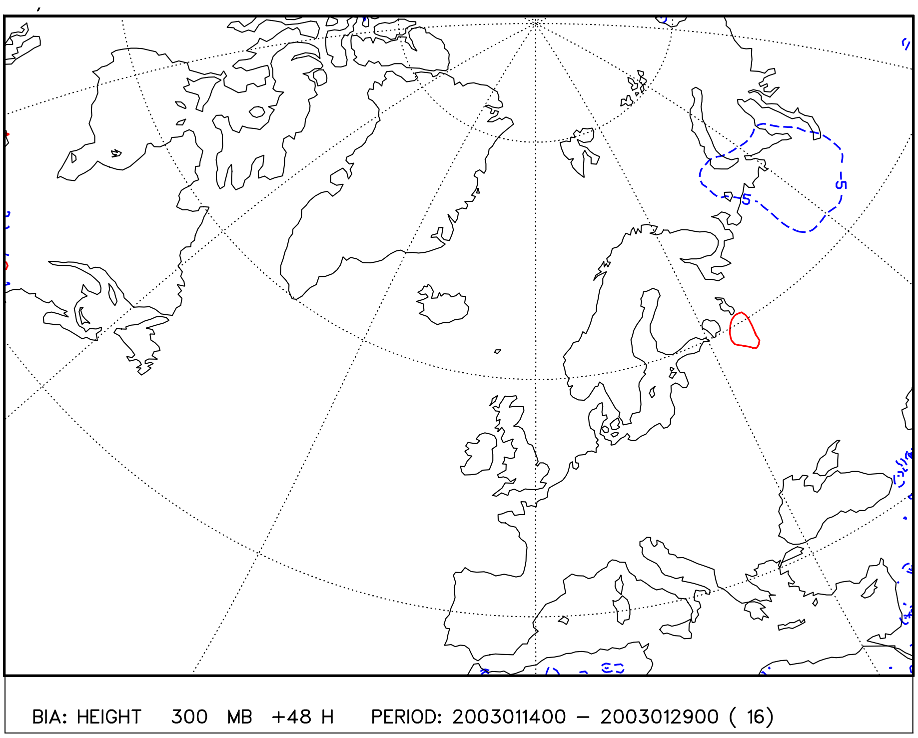

Figure 4: *Systematic difference in 48 h 300 hPa geopotential height forecasts between REL and REF experiments (REL-REF) for the period 12-27 January 2003. Contour interval: 5 m. The zero isoline not plotted, negative values indicated with dashed lines.*

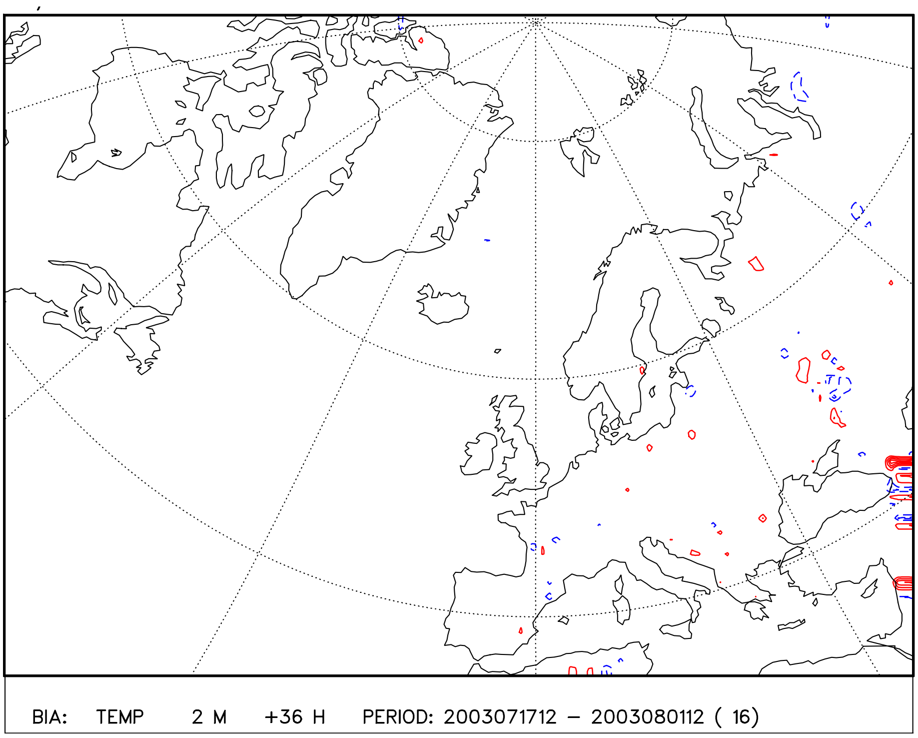

Figure 5: *Systematic difference in 36 h* T_{2m} *forecasts between REL and REF experiments (REL-REF) for the period 16-31 July 2003. Contour interval: 0.5° C. The zero isoline not plotted, negative values indicated with dashed lines.*

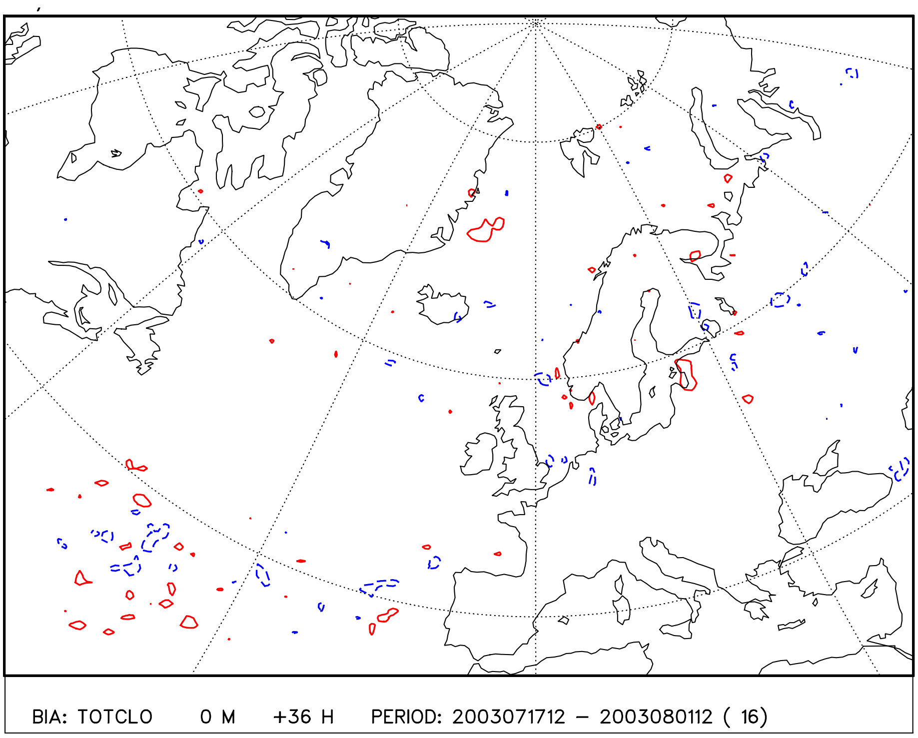

Figure 6: *Systematic difference in 36 h total cloud cover forecasts between REL and REF experiments (REL-REF) for the period 16-31 July 2003. Contour interval: 0.1 (fraction). The zero isoline not plotted, negative values indicated with dashed lines.*

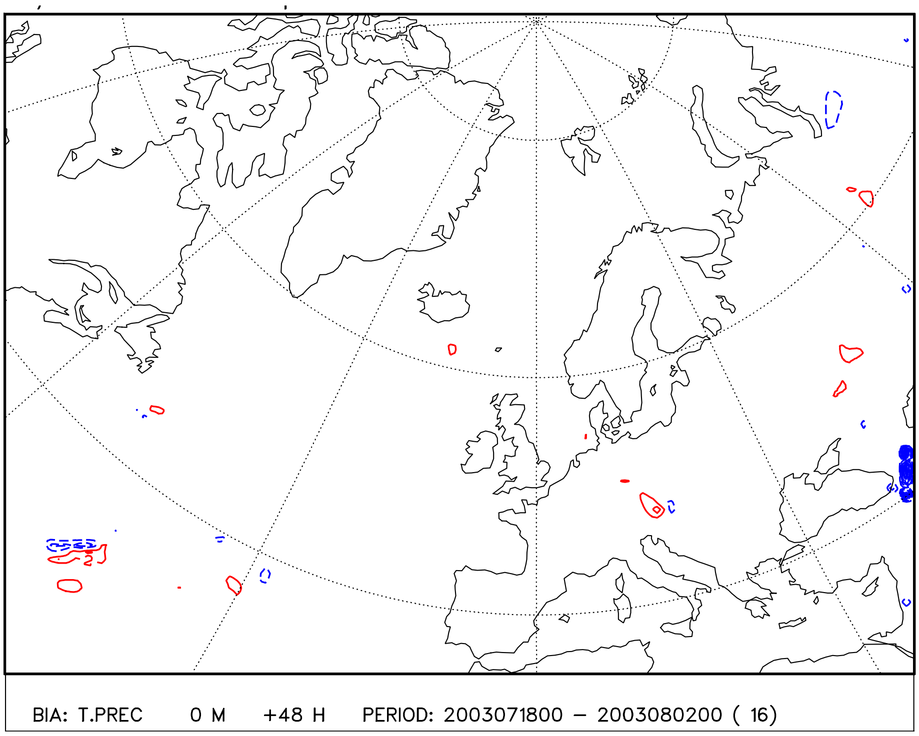

Figure 7: *Systematic difference in 48 h accumulated total precipitation between REL and REF forecasts (REL-REF) for the period 16-31 July 2003. Contour interval: 2 mm. The zero isoline not plotted, negative values indicated with dashed lines.*

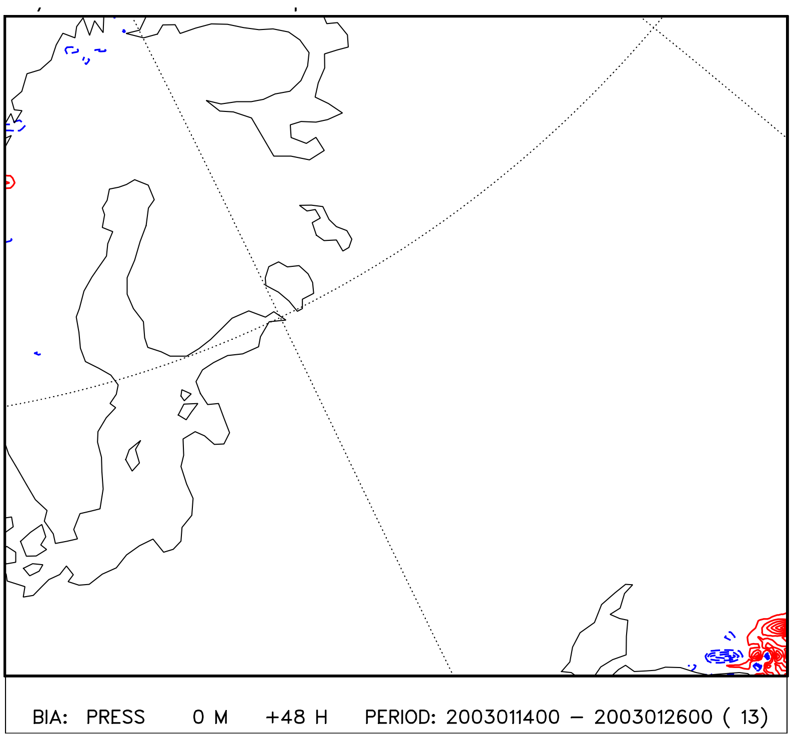

Figure 8: *Systematic difference in 48 h p_{msl} forecasts between RNL and RNF experiments (RNL-RNF) for the period 12-24 January 2003. Contour interval: 0.25 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

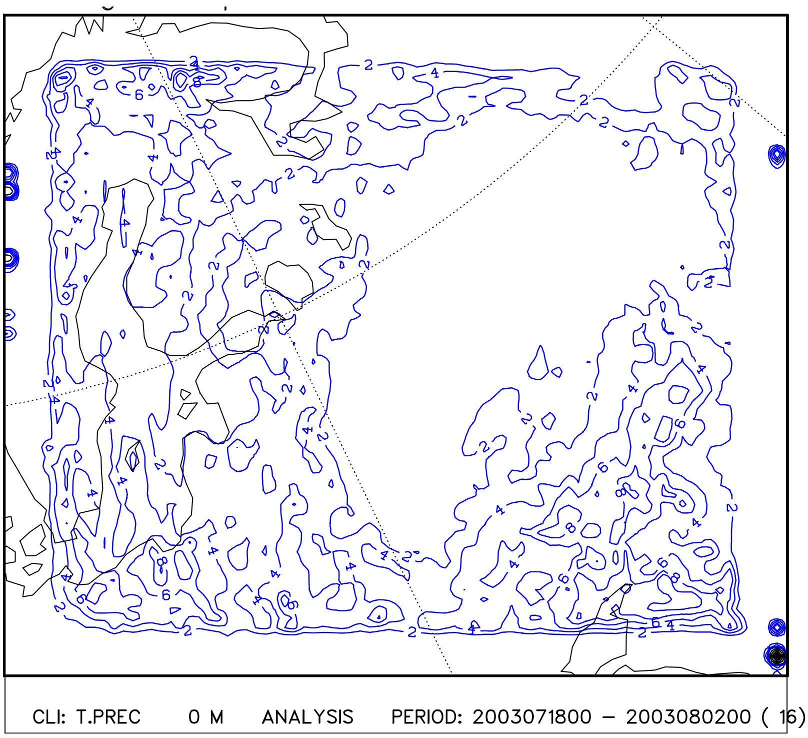

Figure 9: *Average 48 h accumulated total precipitation in RNF forecasts for the summer period 16-31 July 2003. Contour interval: 2 mm for values 2-10 mm, 15 mm for values 15 mm or more.*

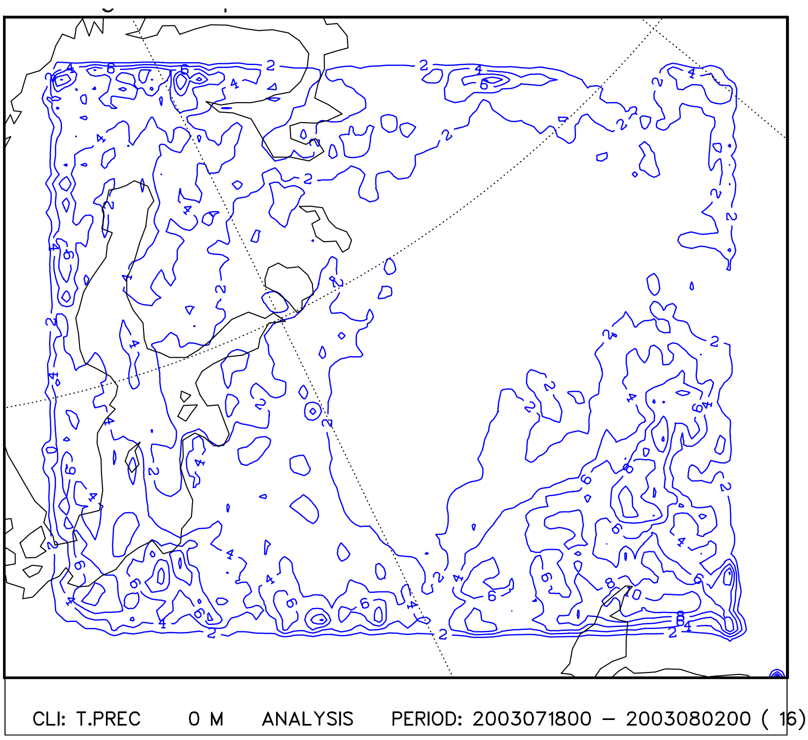

Figure 10: *Average 48 h accumulated total precipitation in RNL forecasts for the summer period 16-31 July 2003. Contour interval: 2 mm for values 2-10 mm, 15 mm for values 15 mm or more.*