Current situation with the NH HIRLAM

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1. Introduction

During the past year the non-hydrostatic HIRLAM has mainly been technically improved, although a number of results of scientific interest have been obtained as well. The non-hydrostatic code has been brought closer to the reference system and it has achieved the same portability as the hydrostatic HIRLAM. Although several questions are still open in the non-hydrostatic code, the code has proved to be usable and it is ready for wider adoption by the HIRLAM community.

2. Technical developments

Both implementations of the Eulerian integration schemes have become available for the non-hydrostatic model. The technical report on the semi-implicit Eulerian scheme is in the process of being reviewed and it should soon be made available to the HIRLAM community.

The stability of the code has also been significantly improved. This has been achieved due to the port of the non-hydrostatic code to the HIRLAM reference version 5.0.0, and due to an important bug-fix in the calculation of the gradients. Several minor bug-fixes have also had their part in securing the implementation of the non-hydrostatic model.

The reimplementation of the parallelization design has been an essential development in the non-hydrostatic code. A meeting was held at SMHI in February 2002, where a group of specialists interested in the development of the non-hydrostatic code decided to redesign the parallel implementation. The new design conforms much better with the reference HIRLAM. As a side-effect of the reimplementation, the port of the non-hydrostatic code to the SHMEM libraries on T3E was created. Now, the non-hydrostatic code should run on every platform supported by the reference HIRLAM.

To facilitate communication in the community of users of the non-hydrostatic HIRLAM, a web page has been created that is available at the location http://www.physic.ut.ee/~aarnem/nhhirlam. The code of the non-hydrostatic model can be downloaded from the website; versions 0.8.1 and 0.7.4 are available. Version 0.8.x contains the code with reimplemented parallelization design. The version 0.7.4 can efficiently be employed on systems with a small number of processors.

3. Modeling results

Due to the improved stability of the 5.0.0 reference system, and due to the bug-fixing, the non-hydrostatic model has been able to show the quality inaccessible before. On Figure 1, the results of the modeling of a small scale cyclone are presented. The plots show the surface pressure contours of a 24-hour forecast for the hydrostatic and non-hydrostatic models. As it can be seen from the Figure, the patterns of the contours are very similar. The resolution in the experiments is 11 km with the 114x100x31 grid. The non-hydrostatic model gives a slightly deeper cyclone, but this should probably not be treated as a non-hydrostatic effect. The effect has most likely been caused by a different treatment of the surface pressure in the compared models. In the non-hydrostatic model the surface pressure is adjusted.

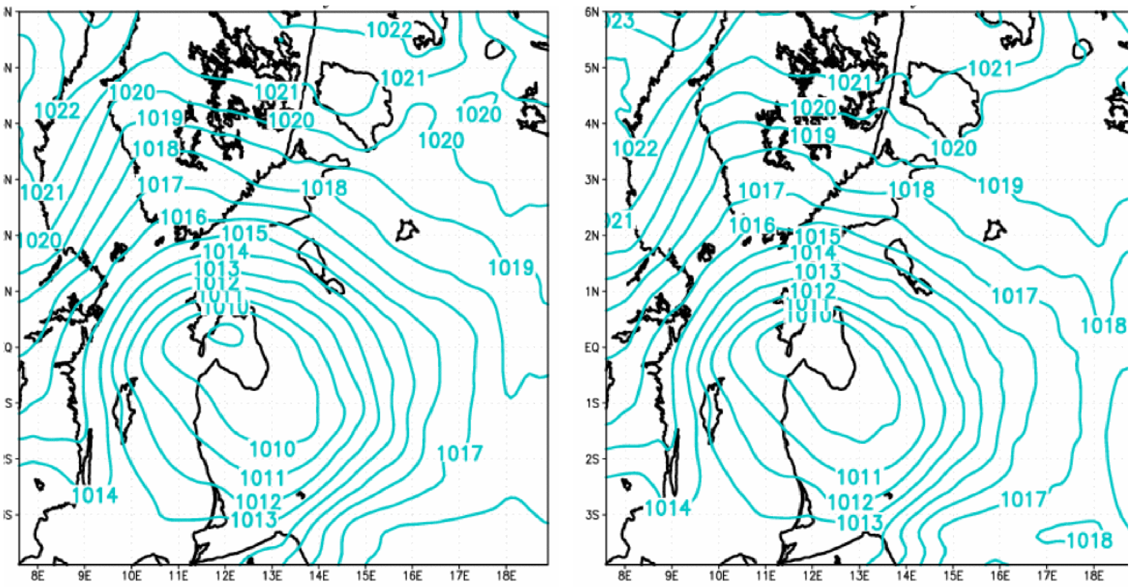

Figure 1. 24 hour forecasts of the surface pressure for the non-hydrostatic (first pane) and hydrostatic (second pane) models. The resolution is 11 km and grid size is 114x100x31.

It is generally thought that the semi-implicit integration scheme in the model allows significantly longer time-steps. The statement is true in case of low resolutions, but with finer resolutions, the difference between the explicit filtered model and the semi-implicit model diminishes. Table 1 represents the time-steps of the explicit and semi-implicit non-hydrostatic models. The models are compared at different resolutions with different flow profiles characterized by the half-width a_0 and the maximum wind U_{max}.

As it is seen from the Table, the difference in the time-steps is significant at lower resolutions, while diminishing at higher resolutions. As the semi-implicit integration scheme tends to distort the wave structures, the explicit scheme might be preferred when a correct representation of the buoyancy waves is important. It must be emphasized that the explicit scheme is applied to the filtered model. Without filtering the explicit scheme would never achieve so large time-steps.

Δx (m)	A_0 (km)	U_{max} (m/s)	$\Delta x/U_{max}$ (s)	explicit NH (s)	semi-implicit NH (s)
11000	30	30	366.7	60	340
5500	10	30	183	40	180
550	10	30	18.3	14	17
550	2.5	30	18.3	16	18

Table 1. Time-steps of explicit and semi-implicit non-hydrostatic models on different resolutions Δx and for different characteristic mountain half-widths a_0. U_{max} is the maximum wind speed.

4. Open questions with the non-hydrostatic model

Despite a significant technical progress, several important issues still have to be investigated, before it can be claimed that the development of the non-hydrostatic model is finished.

One of such issues is the problem of reversed recurrence in the dynamic routine HSDYN.f.

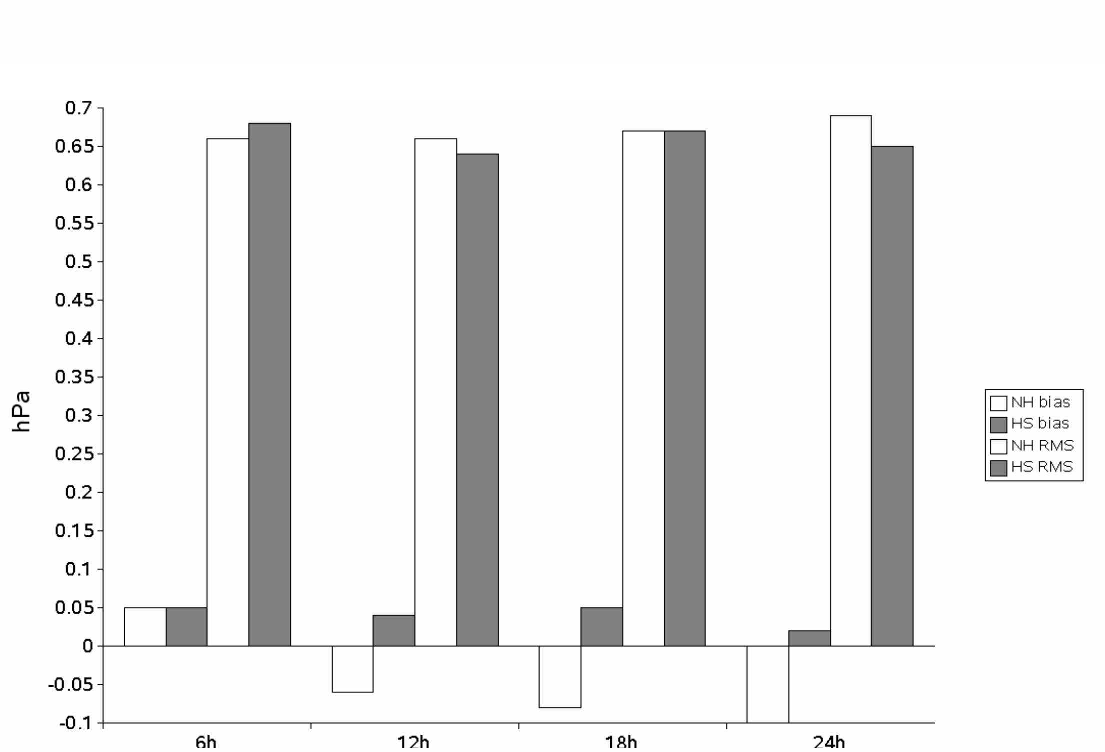

Figure 2. RMS errors and biases of surface pressure for different forecast lengths on the 11 km resolution with the reversed recurrence

In the original reference code the recurrence of the continuity equation is computed from the bottom to the top:

$$\left(\dot{\eta}\frac{\partial p}{\partial \eta}\right)_{k-1/2} = \left(\dot{\eta}\frac{\partial p}{\partial \eta}\right)_{k+1/2} + \Delta B_k \frac{\partial \overline{p}_s}{\partial t} + \nabla \cdot \vec{V}_k .$$

$\overline{p}_s$ is reference pressure. Experiments have shown that the reversed direction of recurrence would increase the stability of the model.

Still, an unpleasant side-effect seems to occur. As it can be seen from the Figs 2 and 3, the bias of the surface pressure has a significant drift under the reversed recurrence scheme. A slight negative drift of the bias can be observed even in case of original recurrence, but it becomes much larger in the reversed scheme. The causes of the drift are still unclear and need further investigation.

An important question about the application of the non-hydrostatic model concerns the adequate initialization and nesting. The non-hydrostatic model uses the assumption of the adjusted surface pressure and consequently, the wind field must satisfy the vertically integrated mass balance condition. This is not the case with the current initialization schemes and boundary fields. To clarify the situation, more investigation is needed.

So far the computations with real forecasts have been carried out at resolutions, where significant non-hydrostatic effects cannot be observed. Thus the results have not yet shown a clear evidence of the benefit of the application of the non-hydrostatic model. A good set of experiments in the real forecasting conditions is urgently needed, which could justify the benefit of the non-hydrostatic modeling for the numerical weather prediction purposes.

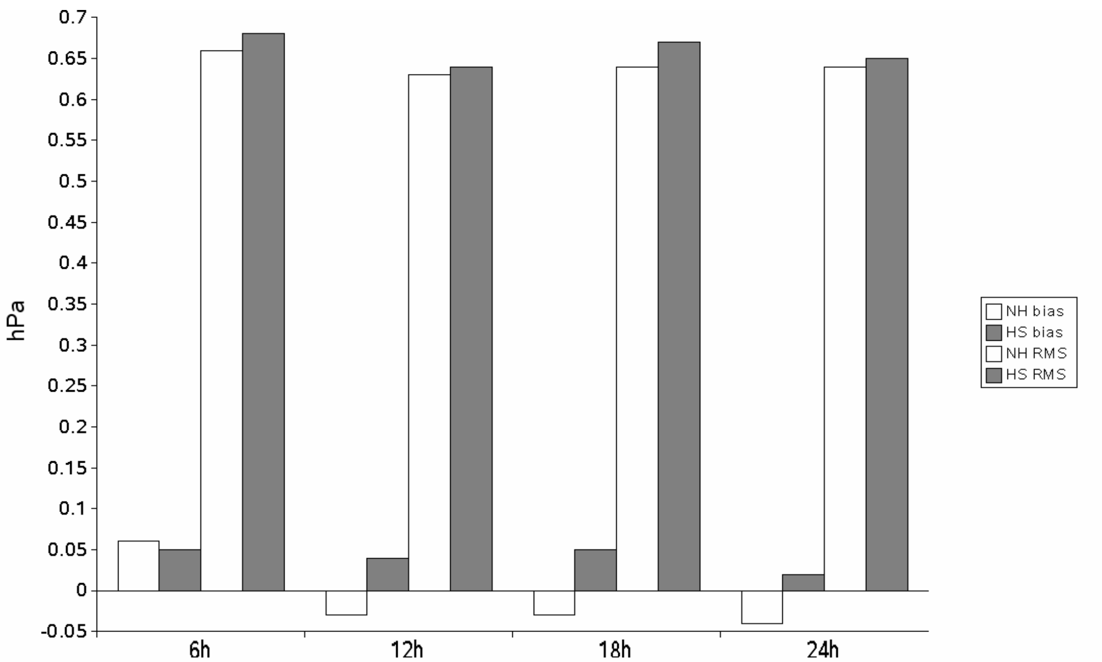

Figure 3. RMS errors and biases of surface pressure for different forecast lengths on the 11 km resolution with the original recurrence

5. Conclusions

The non-hydrostatic model has reached the state where it can effectively be employed for the research and modeling problems at high resolutions. Several questions are still open, but they are rather attributed to the polishing of the adiabatic core. There exists an urgent need for model experiments at very high resolutions (~1-2 km), accompanied with the need for a suitable physical package.