Status Kain Fritsch Rasch Kristjansson and Hirlam 22 km experiences

Sander Tijm, with contributions from Roy Wichink Kruit, Oscar van de Velde, Ben Wichers Schreur, Toon Moene

1 Introduction

Kain Fritsch Rasch Kristjansson (KF-RK) developments currently are moving fast. In February 2002, a meeting was held in Norrkøping to decide on the path toward the possible introduction of KF-RK into the Hirlam reference system. In Norrkøping the model version that is used in the comparison with STRACO was decided on. In section 2 we will describe what was agreed on.

Different aspects of KF-RK are tested at KNMI. One of these aspects is the resolution dependence of the KF-RK scheme. With increasing resolution the triggers that set of convection in the scheme also become stronger, resulting in larger precipitation amounts. In section 3 we will show some preliminary results of an experiment checking the resolution dependence of the scheme. We will also show results of a longer time integration.

As nowcasting with Hirlam becomes increasingly important at the high resolution that is currently used in Hirlam, it is important to know the behaviour of the system in the first few hours of the forecast. A large model spinup makes the model less suitable for nowcasting. In section 4 we will describe the behaviour of the model with KF-RK and DFI.

The last subject of this contribution deals with the first experiences we have with the new Hirlam system at KNMI. On March 5, 2002, this new version has become operational. With the introduction the resolution jumped from 0.5 to 0.2° and the model now runs with Hirlam version 5.0.6 whereas the old model was based on Hirlam version 4.3.4. The introduction did get a mixed reception. The new model version clearly solved a few old problems, but they have been replaced by new ones. In section 3.1 and 4 we will show some of our experiences with the new model version.

2 Status of KF-RK

Before KF-RK can be introduced in the reference Hirlam a few steps have to be taken. First, the scheme must prove its value by being at least as good as STRACO. Second, the scheme must work in a recent reference version of Hirlam and third, the scheme must not be too time-consuming which means that optimization is necessary, especially for the use on vector machines.

In the Norrkøping meeting it has been agreed that the scheme first must show that it at least equals the scores of the current reference scheme STRACO before a large effort is put in the optimization of the scheme. As a number of institutes are involved in the comparison of the two schemes, it was necessary to agree upon the exact version and settings that are used in the comparison. Table 1 shows the settings of the parameters that are used.

Model version	5.1.4 + STRACO update
Resolution	0.2°
Area	at least Europe + part N-Atlantic
Horizontal diffusion	6^{th} order
Boundaries	Analyses (operational does not work)
Orography	Filtered
Vertical levels	40
Time step	360 s.

Table 1: *The model version plus settings that are to be used in the comparison between KF-RK and STRACO.*

Originally it was agreed upon to use the boundary strategy 'operational' for the scheme comparison. Tests with this strategy revealed that it does not work properly (it uses 'today' instead of the DTG of the experiment). It also increases the amount of boundary data that has to be retrieved from MARS by a factor of 2. We therefore now run with analyses as boundaries. This has the drawback that the scores from the experiments cannot be compared with operational scores, but this drawback is not so large that it is deemed worthy to put effort in making the operational strategy work again.

The scores of the two schemes will be taken from the standard verification package available in Hirlam. Using Hirlam version 5.1.4 has the additional advantage that it is one of the first versions that includes the precipitation verification. This will give some insight into the performance of the two schemes e.g. concerning the erroneous production of small precipitation amounts and the underprediction of large amounts, although it will be difficult to get statistically significant results for this last problem. In addition, the precipitation forecasts can be compared to local data, e.g. extended rain gauge network data or verified radar sums. As this data usually is not available outside the country of interest, this kind of verification has to take place in the participating centres.

The results of the comparison have to be available around mid-june 2002. Preliminary results are shown on:
http://www.knmi.nl/~tijm/KF.html

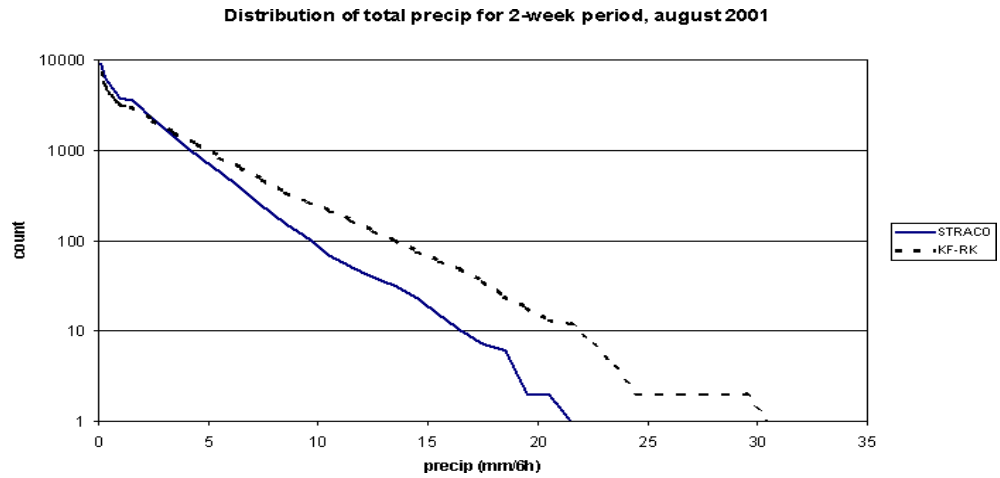

Figure 1: *The precipitation distributions (mm per 6 hours) over the Netherlands and surroundings of STRACO and KF-RK for a 16-day period in august 2002, both in Hirlam version 5.0.5. Note that these experiments are performed with 'old' versions of STRACO and Kain Fritsch.*

With older versions of KF-RK and STRACO than the ones that are used in the comparison, a comparison has been made between KF-RK and STRACO to see if the precipitation distributions of KF-RK and STRACO are different. One of the main problems of the old STRACO versions was an overprediction of small precipitation amounts and an underprediction of the large precipitation amounts. Figure 1 shows the precipitation distributions of STRACO and KF-RK for a 16 day period in August 2001. In this period heavy showers frequently occurred. The figure clearly shows the differences in the distributions of the two schemes. In comparison with STRACO the distribution of KF-RK shows less small amounts and more large amounts, changes in the direction that are necessary to get better verification results. Looking at these distributions one has to keep in mind that the versions of the schemes that are used are old. The STRACO and KF-RK schemes that are used in the comparison both are the most recent versions of the schemes that are available.

3 Resolution dependence of KF-RK

Convection schemes usually produce results that depend on the resolution, with increasing precipitation amounts as the resolution increases (see e.g. Woetman Nielsen, 1999). In the 2001 version of STRACO, this resolution dependence has been corrected by introducing a scaling factor that is dependent on the depth of the clouds and on the horizontal resolution. At a resolution of 0.15° the decoupling of the convection starts and this decoupling is complete at a (theoretical) resolution of 0°.

The resolution dependence of KF-RK has not been studied systematically in detail yet. In the literature, some results are available that show the increasing precipitation with increasing resolution. However, there is also some evidence that this increase stops when the resolution goes below 0.1°.

So far, only one experiment has been performed to check the resolution dependence of KF-RK in Hirlam. The case concerns a strongly convective situation on 29 July 2000. On this day a cold upper air provided excellent conditions for thunderstorm development over the Netherlands and its surroundings. In onshore winds the thunderstorms repeatedly developed on a line about 30-40 km inland, causing some places to receive much precipitation from 3 or 4 thunderstorms.

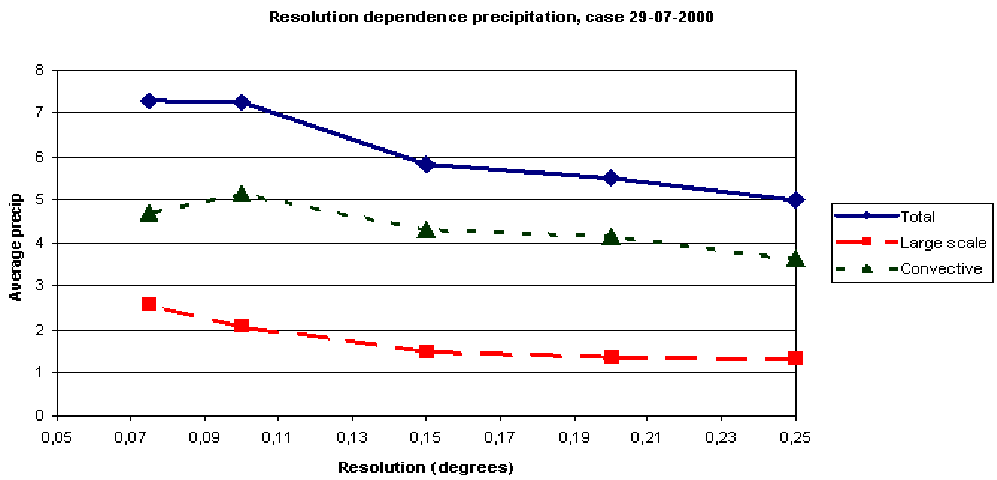

Figure 2: *The resolution dependence of the total, large scale and convective precipitation on 29-07-2000 for 5 horizontal resolutions and averaged over the Netherlands and its surroundings.*

This case has been run from an ECMWF first guess on 5 different resolutions. The resolution decreases from 0.25 to 0.1° in steps of 0.05° while the last run was performed on a resolution of 0.075°. Figure 2 shows the dependence of the precipitation on the resolution over the same area for all different resolutions. It clearly shows an increase in total precipitation with increasing resolution (smaller grid point distances) until it reaches 0.1°. Increasing the resolution further to 0.075° does not result in an increase in total precipitation, which is the kind of behaviour you want to get from a tuned, resolution independent scheme over the entire range of resolutions. The major part of the increase in precipitation when the resolution is increased to less than 0.25° is caused by an increase of the convective precipitation. However, increasing the resolution beyond 0.1° in this case results in a decrease of the convective precipitation. The large-scale precipitation steadily increases, keeping the total precipitation at the same level between 0.1 and 0.075° resolution.

In general, the large-scale precipitation behaves as expected, steadily increasing with resolution, as more and more of the precipitation producing processes are resolved by the model. The convective precipitation however, is also expected to increase with increasing resolution, as the forcings that trigger the convection in the KF-scheme become stronger with increasing resolution. This only happens up to the 0.1° resolution. The 0.075° run shows a significant drop in convective precipitation that probably is caused by the resolution dependence in the trigger representing the vertical velocity variance. This trigger becomes zero or negative for the very high resolutions depending on the magnitude of the vertical velocity. However, it can not be concluded that this is general behaviour for the KF-RK scheme on the basis of this case study alone.

An experiment with older versions of STRACO and Kain Fritsch using resolutions of 0.1 and 0.2° shows that the resolution dependence of Kain Fritsch is not so large (an increase of 5% going from 0.2 to 0.1°) in an autumn period, a period where convection is less important than the purely convective case described above, probably reducing the resolution dependence that is mostly caused by the convective part of the scheme.

3.1 STRACO resolution dependence

The resolution dependence in STRACO-schemes, that were the reference from Hirlam versions 4.6.3 up till now, has been reduced by including a decoupling factor in the convective part of the scheme. This decoupling factor starts working at a resolution of 0.15° and the convection is completely decoupled at very high resolution. The limit of 0.15° degrees for the decoupling parameter implies that there is no resolution dependence of STRACO at resolutions between 0.15 and 0.5°.

The parallel running of the 22 km Hirlam 5.0.6 system and 55 km Hirlam 4.3.4 at KNMI enabled us to check this assumption. The period of comparison is January 24 to February 15 2002. During this period there was a lively depression activity. To enable the comparison of the two different resolutions, the 0.5° resolution precipitation sums are interpolated to the 0.2° grid.

Figure 3 shows the precipitation distribution over an area covering the Netherlands and the North Sea (no strong orographic forcing) for this three week period. There is no difference for the small precipitation amounts, but the 0.2° run clearly produces more large precipitation sums. A part of this difference can be explained by the interpolation. The 0.5° run will not produce the same high maxima as the higher resolution run. This effect can be seen in the cut off of the 0.5° distribution beyond about 25 mm. There is however a significant increase in precipitation sums of 5 to 25 mm in the 0.2° run. This increases the total precipitation in

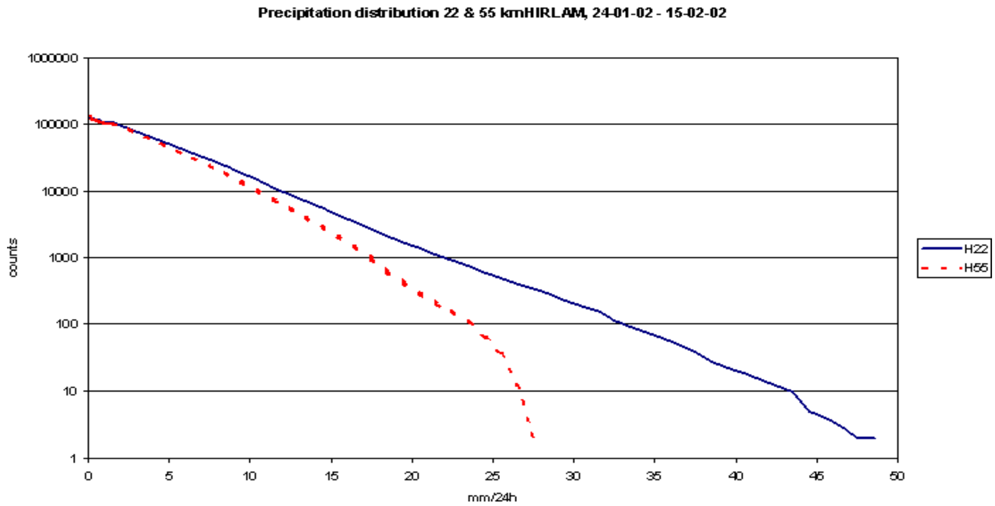

Figure 3: *The precipitation distributions over the Netherlands and the North Sea for the period January 24 to February 15 2002 in the 0.2 and 0.5° runs.*

the new KNMI Hirlam system, an effect you have to take into account when interpreting the results from the new run. From these distributions it can be concluded that the STRACO scheme does have a resolution dependence in the resolution range from 0.2 to 0.5°, something that is not taken into account in the decoupling parameter in the STRACO scheme.

On average, the precipitation did not show a clear bias in the 55 km run. Verification against two years of observations shows that the overprediction of small precipitation sums was compensated by an underprediction of large sums. As the 22 km run increases the number of large precipitation sums and leaves the small sums untouched, the total precipitation is increased. Therefore, the new 22 km system has a wet bias which is about 15 to 20% for the months March and April 2002.

4 Spinup and consistency of forecasts

At KNMI, the impact of digital filtering initialization (DFI) and incremental DFI (IDFI) on meteorological parameters has been studied. In this study Hirlam was run at 0.25 and 0.1° resolution and for the convection/condensation the Kain Fritsch Rasch Kristjansson scheme was used. This study was triggered by the observation that the wind speed near the surface is reduced by about 10 % directly after the initialization and also the observation that a low-level jet, although in the observations, was removed after the initialization. Phenomena such as low-level jets can be quite important in the triggering of convection and in nowcasting for aviation forecasts.

In addition, the output of the new KNMI operational Hirlam system has been studied quite intensively. Several unwanted characteristics of the system have been found, some of them already known, but some also new. Model spindown by the initialization and the following spinup in the forecast are unwanted because they can impact the subsequent analysis and climatological model parameters, such as the soil wetness, that are not adjusted by the analysis. It also reduces the usability of the model in the nowcasting and reduces the confidence of the meteorologists in the model output.

First we will discuss the results of the study with DFI and IDFI. It was found that the precipitation showed a negative bias in the first few hours after the initialization when DFI was used. IDFI did not show this bias. At a resolution of 0.25° neither DFI nor IDFI has proved to deliver the most consistent precipitation forecasts over all forecast hours, but DFI seems to show the best position accuracy in three of four thunderstorm cases. At 0.1° resolution DFI or IDFI behave practically the same. Precipitation structures come out much better in some cases that at 0.25° resolution. We can therefore conclude that resolution makes more difference for the details of location and intensity of precipitation than the method of initialization.

The largest increments are made in the wind speed, with especially low level wind speed being most affected. IDFI results in a zero bias whereas DFI produces a negative bias in low level wind speeds. Also, maximum and minimum increments usually are about two times larger in DFI with analyzed high wind speeds erased in some places. DFI increment fields also suffer from higher increments near the boundaries of the domain.

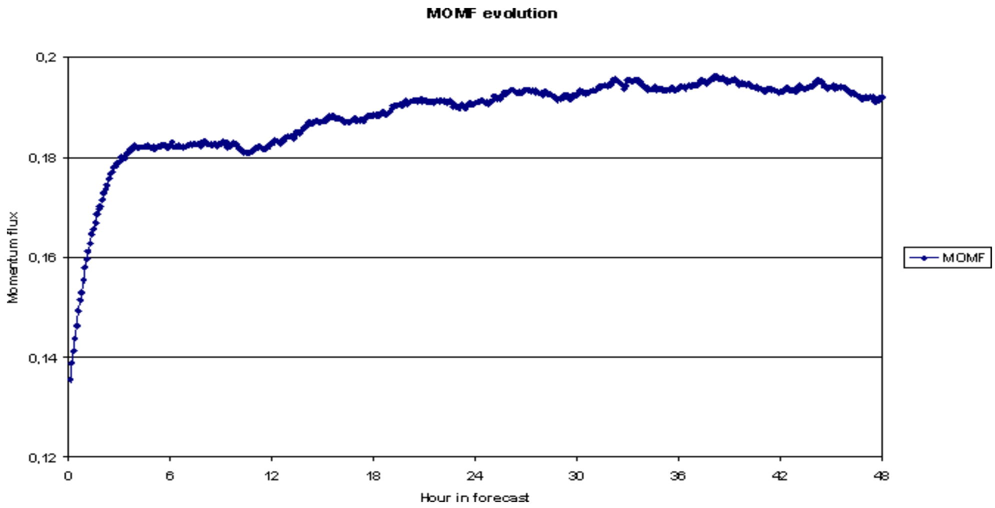

Figure 4: *The average statistics for the new operational KNMI Hirlam for the momentum flux.*

The new operational KNMI Hirlam system shows some spindown and spinup features that were previously known (e.g. the in the wind, see figure 4, clouds and precipitation) but some new features were found also. The spindown due to the initialization and the subsequent spinup by the model may have a negative impact on the analysis cycle as the spinup is not complete after three hours, at the time of a new analysis. The spinup in the momentum flux takes about 4 hours to complete (see figure 4). This can result in larger, erroneous analysis increments, resulting in a degradation of the forecast quality. The main additional problem that has been found is a damped wave in the surface pressure, even when this surface pressure is averaged over the entire model domain. Figure 5 shows the evolution of the surface pressure averaged over 20 days taken from the time step statistics of Hirlam. This figure clearly shows a bump in the surface pressure in the first 6 hours of the forecast. It also seems that a wave still is present later in the forecast, even though this figure is compiled of 80 forecasts that have different start times. This bump in the surface pressure is most visible in single point time series under high pressure conditions. Under these conditions the first maximum in surface pressure can be more than 1 hPa whereas the pressure jump in the average statistics is about 0.2 hPa. Where this pressure jump comes from is not clear at this moment.

The second line in figure 5 is the average evolution of the amount of water vapour in the model domain. It does not show a wave-like solution like the surface pressure, but that is not the interesting feature of this line. The water vapour content of the atmosphere shows a similar trend as the surface pressure. The amount of water vapour that is lost during the forecast is about $0.15 kg/m^2$, which amounts to about 0.15 hPa pressure loss during a forecast. The

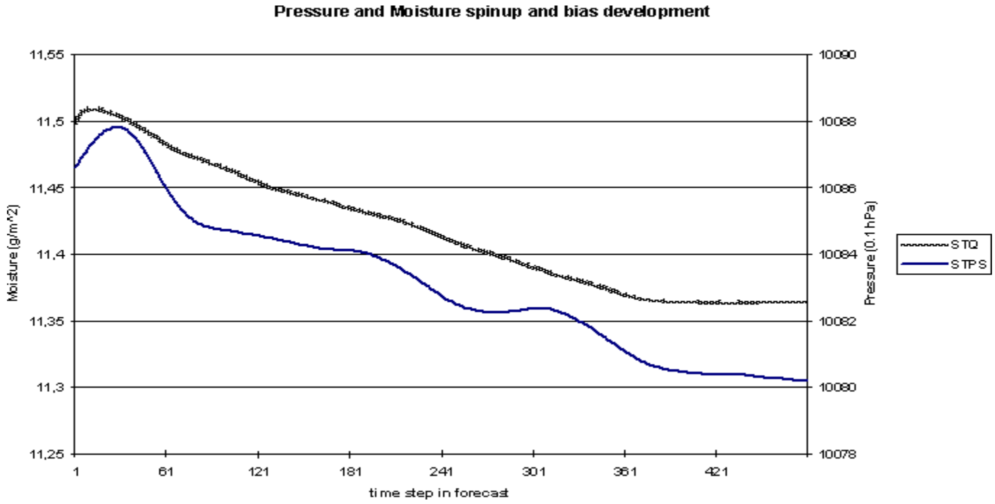

Figure 5: *The average statistics for the new operational KNMI Hirlam for the surface pressure and the water vapour content of the atmosphere.*

actual loss in surface pressure is more in the order of 0.6 hPa, so the loss in water vapour accounts for only 25% of the mass loss during an average forecast. However, the most likely process that causes the mass loss, convection and condensation, causes the release of heat in the atmosphere. As a consequence the heated air expands and the mass will be redistributed. This redistribution (over the boundary?) may result in the additional mass loss. Also, the moisture removed through condensation may be compensated by additional evaporation, fueling the heat release mechanism.

5 Conclusions

The introduction of KF-RK in Hirlam as the reference is at a critical stage. Several institutes are performing comparisons between KF-RK and STRACO. When KF-RK showes at least equal scores compared to the latest STRACO version it can be incorporated in a beta release of Hirlam. The results of these comparisons must be available around the middle of June. Before KF-RK can be incorporated in a beta release of Hirlam the scheme will require a considerable effort, however, to improve the computational performance on vector machines.

One of the features of the KF-RK scheme that has not been researched extensively is the resolution dependence of this scheme. A single case study with strong convective activity shows that the convective and large-scale precipitation increase with increasing resolution until the resolution is 0.1°. Increasing the resolution further to 0.075° results in a decrease in the convective precipitation and a continuing increase in large-scale precipitation, keeping the total precipitation at the same level. Further research is necessary to determine the resolution dependence of KF-RK and to find a solution for this effect.

The operationalization of the new KNMI Hirlam system (22 km resolution) has resulted in an increase in precipitation. Comparisons with other models and with the old 55 km run show that the new Hirlam run produces most precipitation of all models. The model version is 5.0.6, which means that we run without the STRACO update for shallow convection. Also the orography is not filtered which sometimes may result in spurious precipitation over mountainous areas.

A study of the statistics output of Hirlam clearly shows the spinup of the model in the first few hour of the forecast (actually the problem is spindown of the model that is caused by the initialization). The reduction of clouds, precipitation and wind already is known, but the wave in the pressure that is most visible in first hours of the pressure evolution is a phenomenon that has not been reported before. After the initial pressure maximum a damped wave seems to be present in the model. The cause of this wave is presently being studied at KNMI.

A second phenomenon that can be seen in the model statistics is the negative trend in the surface pressure in the model. The negative trend in the surface pressure correlates strongly with a negative trend in the water vapour content of the model. However, this negative trend in the water vapour can only explain 25% of the total pressure trend. The other 75% may come from the release of too much latent heat in the atmosphere as the negative trend in the water vapour probably is caused by too much condensation.

Reference

Niels Woetman-Nielsen, 1999: Sensitivity of precipitation forecasts to horizontal resolution using the STRACO scheme. Hirlam Newsletter 33.