Recent developments of the Rasch-Kristjansson scheme in Hirlam

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1 Introduction

The Rasch-Kristjansson stratiform condensation scheme (RK-scheme) was introduced as an option in the HIRLAM system for about 6 years ago. It has been used together with the Kain-Fritsch convection scheme for the operational forecasts in Sweden since 2003. It is also intended to be the reference version in new Hirlam releases.

Significant developments of the RK-scheme have been done lately, both in Spain and in Sweden. The result is a new version, called RK-03 here, after Zhang et al (2003). This new RK-scheme is based on the code in the NCAR CAM3 model (Community Atmospheric Model version 3.1) It is now used operational at SMHI since the beginning of February 2008 and with a separate prognostic treatment of cloud water and -ice. The new stratiform condensation scheme is also in a version with the new surface scheme (often called “newsnow”), see https://hirlam.org/trac/wiki/newsnow20080508. There is an even newer IFS-coded version which is going to be tested during summer.

Here, a short summary of the problems related to the old version of the scheme is presented in section 2, followed by a description of the new RK-scheme in section 3. A short description of a parameterization for using separate prognostic cloud water and ice is in section 4, followed by some verification results in section 5 and a short summary in section 6.

2 Problems with the Hirlam 7.1.2 RK-scheme

This version is based on the work of Rasch and Kristjansson, (1998). It will be called RK-98 here. Here, the change of cloud condensate where based on tendencies of temperature, cloud condensate, humidity and cloud cover. Although it works mainly good, there have been some characteristic of the forecasts that are not satisfactory. Those characteristic may be summarised in the following way:

- Small amounts of precipitation occur too frequent.
- Middle level cloud amounts near 4 octas are too frequent. (This gives a good RMS error, but duty forecasters complain about the too “thin” middle level cloud field.)
- In case of strong jet-streams, there might be a “noisy” cirrus cloud field.
- Too small amount of low clouds in the new 7.1.2 reference set up. (This was not a big problem in reference version 6.3.5, so it has partly to do with differences between those two reference versions.)

Both the over-forecasting of small amounts of precipitation and the “noisy” cirrus clouds may be related to numeric noise in RK-98.

3 Short presentation of the new RK-version (RK-03)

The main difference is that the tendency of cloud cover is not used anymore for the calculation of the change of cloud condensate. Instead the cloud cover variation with the relative humidity is used. The
noise is significantly reduced and because of that, small precipitation does not occur that often. It is also possible to get rid of the noise of the cirrus cloud field.

The most significant change of the forecast behaviour with RK-03 is the reduction of the areas of small precipitation amounts. One example of this is present in figure 1.

One other important thing is that low clouds become less scattered and the cloud condensate amount is higher so the radiative cooling from the ground gets lower in wintertime which has a positive impact especially when the new surface scheme is used.

4 The prognostic cloud ice scheme

The work on using separate prognostic treatment of cloud water and ice has been going on for quite a long period. In the present version it is possible to choose between using no separation (and let the ice fraction of the cloud condensate be a function of temperature, as in the present reference Hirlam) and a separate prognostic treatment. Presently, this is just done by change the number of passive scalars (NSVAR) from one (=diagnostic) to two (=prognostic).

With prognostic treatment of cloud ice, newly formed clouds contain mainly supercooled water if the temperature is between 0°C and -40 °C. After some time ice crystals grow and if they become big enough they will fall out as precipitation. Between 0°C and -32 °C the main source for new ice crystals is a process called heterogeneous freezing. This means that drops of supercooled water collide with some usually solid material which triggers a freezing process. Below about -32 °C another process, homogeneous freezing becomes important. Here, supercooled water freezes

![Figure 1: 12 hours precipitation for December 10, 2007 with the reference 7.1.2 RK-scheme to the left and with the CAM3 RK-scheme to the right. red number are observed precipitation.](image-url)
spontaneously. Below -40 °C this is more or less the only freezing process and is also very fast, but also at such low temperatures there may be supercooled water, often as a solution of sulphur acid in the very beginning.

The most important part of the parameterization is the growth of cloud ice crystals by water deposition. It closely follows the one suggested by Rotstayn et al, (2000) for spherical ice crystals, and is presently the parameterization of heterogeneous freezing. The parameterization of homogeneous freezing is very simple and is based on a study by Heymsfield et al (1993). For temperatures below -40 °C the relative humidity must be higher than the ice-saturation before condensation starts. There is some uncertainty about what the ice supersaturation should be. Presently, the assumed ice-supersaturation follows a parameterization suggested by Kärcher and Lohmann, (2002). It is used regardless if separate prognostic cloud ice is chosen or not.

The gravitational sedimentation of cloud water and cloud ice is also introduced by using the code from the CAM3 model. For more details about the new parameterizations used, see Ivarsson (2007). The difference between using or not using separate prognostic treatment of cloud water and ice can be illustrated by the figures 2 and 3.

Figure 2: Cloud evolution with the 1D-Hirlam and using a diagnostic treatment of the evolution of cloud ice. On the y-axis is the geometric height in metres and on the x-axis the time in hours. Red dots are isolines for cloud water kg/kg x 100000 and blue dots are similar isolines for cloud ice. The cloud fraction is pictured with different grey shadings, the temperature in Celsius with blue isolines and the relative humidity with respect to ice with green isolines.
If the ice fraction of cloud condensate is only dependent on the temperature, the ice content will gradually rise as the temperature inside the cloud gets lower as in figure 2, but with a prognostic treatment, all the cloud condensate is supercooled water in the beginning, and after some time some of it will turn to cloud ice. Since the cloud ice has a higher sedimentation speed, there will be more cloud ice in the lower part of the cloud than near cloud top as seen in figure 3. This distribution of cloud water and cloud ice is often found in mixed-phase clouds.

5 Verification results

Many of the tests with the new RK-scheme has been done together with the new surface scheme (often just called “newsnow”). One important test case is January 2006, when some problems occurred with the RK-98 causing too much cooling at the surface. The following plots show the results for the SMHI operational 11km domain, which is rather small and covers northern Europe and northwestern Russia. 60 levels in the vertical are used.

The precipitation forecast verification is shown in figures 5 and 6 (12 hours precipitation). In figure 5 the small precipitation amounts are verified.

The number of forecasted cases with no precipitation or less than 0.1 mm is significantly reduced with the new version. Also the overall over-forecasting of precipitation is reduced. For larger amount of precipitation there is no big differences. Those that are present may be coincidental due to the low number of events with large precipitation. The RMS-error for 2-metre temperature and dew-
Figure 4: The bias and RMS error for some surface parameters. RK98 (red) is the reference RK-scheme, RK03 (green) is the scheme with RK-03 and prognostic ice.

Figure 5: To the left: Kuipers skill score, which is the difference between hit rate and false alarm rate, and the frequency distribution of forecasts and observations. RK98 (red) is the reference RK-scheme, RK03 (green) is the scheme with RK-03 and prognostic ice. The observed frequencies are in grey. To the right at the top: The mean amount of precipitation. To the right at the bottom: The ratio between the forecasted amount of precipitation and the observed amount for different precipitation intervals.

Figure 6: To the left: Kuipers skill score for different precipitation thresholds. RK98 (red) is the reference RK-scheme, RK03 (green) is the scheme with RK-03 and prognostic ice. The statistical uncertainty is marked with thin green bars. To the right at the top: The ratio between the forecast amount of precipitation and the observed amount for different precipitation intervals. To the right at the bottom: The number of cases with forecasted or observed precipitation (y-axis) for different thresholds of precipitation amounts (x-axis). In grey the observed number of cases.
point, cloud cover and mean sea level pressure are also better with the new scheme, but not for the 10-metre wind since the positive bias is increased. The reduced negative bias of 2-metre temperature is to a large extent due to a reduced negative bias of low clouds and thus the cooling of the surface is reduced.

6 Summary

A new version of the Rasch-Kristjansson stratiform condensation scheme has been introduced in Hirlam, together with sedimentation of cloud condensate and a separate prognostic treatment of cloud water and cloud ice. The results of those changes may be summarised as follows:

- The problems with small amounts of precipitation occurring often seems not to be present anymore.
- The middle level cloud which earlier was near 4 octas too frequent, have now a distribution that is more well spread. Perhaps it is somewhat too often near 0 and 8 octas instead. The same is seen for high clouds. Low clouds are generally better predicted with the new scheme, since there is too less low clouds with the old version.
- The problem with “noisy” cirrus cloud field in case of strong winds are either not present anymore or at least very rare.

References


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