SHORT RANGE ENSEMBLE FORECASTING OF CONVECTIVE PRECIPITATION

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KNMI, September 2003

1: Introduction

Model forecast errors are caused by two kinds of errors: small errors in the analysis, which grow exponentially and dominate the errors after three or more days in the forecast, and uncertainties in the assumptions, approximations and parameters of the physics, which are more important on the short term. By running a model a number of times, with small changes in the initial conditions in every run, an ensemble of forecasts is created that gives an estimate of the uncertainty on the medium range. Changing the initial conditions will not give a good estimate of the uncertainties on the short term, as the model error also is important for these forecasts. A different approach therefore has to be taken to make ensemble forecasts for the short-term forecasts. Model errors can be taken into account by using different models, different parameterisation schemes or by changing the parameters that represent important assumptions in the parameterisations. In this study we do the latter and focus on the forecast of convective precipitation with the Kain Fritsch convection scheme. The question we try to answer is: can we create a realistic spread in forecasted precipitation by means of changing parameters in the Kain Fritsch scheme?

2: Method

In the short term, forecasting clouds and precipitation is the most difficult. To get a first impression of the possibility of SREF (Short Range Ensemble Forecasting) we use the convection scheme of Kain Fritsch (1990). The Kain Fritsch convection scheme consists of two parts. The scheme starts with the trigger functions. These functions calculate the possibility of convection. If the conditions for cloud formation with the triggers are met, the scheme goes on with the mass-flux calculations. The updraught and downdraught will be calculated and from that the size of the cloud and the precipitation amount. The entrainment and detrainment fluxes are included in the calculations. The scheme calculates one cloud per grid box (which is in this study 22 by 22 km).

To create (mini) ensemble forecasts we change the magnitude of some parameters in the Kain Fritsch scheme. We choose to change four parameters: two in the trigger functions (two constants from the equation of the temperature perturbation caused by the vertical wind speed and the relative humidity, equations 3.36 and 3.39 in Unden et al., 2002) and two in the mass flux calculations (the initial radius of the cloud and the constant from the equation of the mass flux entrainment of the environmental air, equations 3.48 and 3.50 in Unden et al., 2002).

We started with changes of 20% in the parameters, but this did not lead to clear changes in the precipitation amount and precipitation distribution. So, we increased the changes to 50%. By running the model once with each of the parameters 50% increased and once with 50% reduced, we got eight experiments with different precipitation outputs. We investigated two cases to see if the changes in the parameters achieve a range in the precipitation outputs. In this study we have not looked if the range of model outputs gives a good estimate of the uncertainties, but only if a distribution with realistic properties can be achieved by this procedure.

3: 1D study

We first studied the impact of changes in the Kain Fritsch scheme in a 1D version of the Hirlam model. For this study we took the case of 29 July, 2000, a day with strong convection over the Netherlands and initialized the model with the radiosounding of 06 UTC of De Bilt. In the 1D study we changed the parameters in the convection scheme by 20%. The precipitation time series (figure 1) show the impact of these changes.

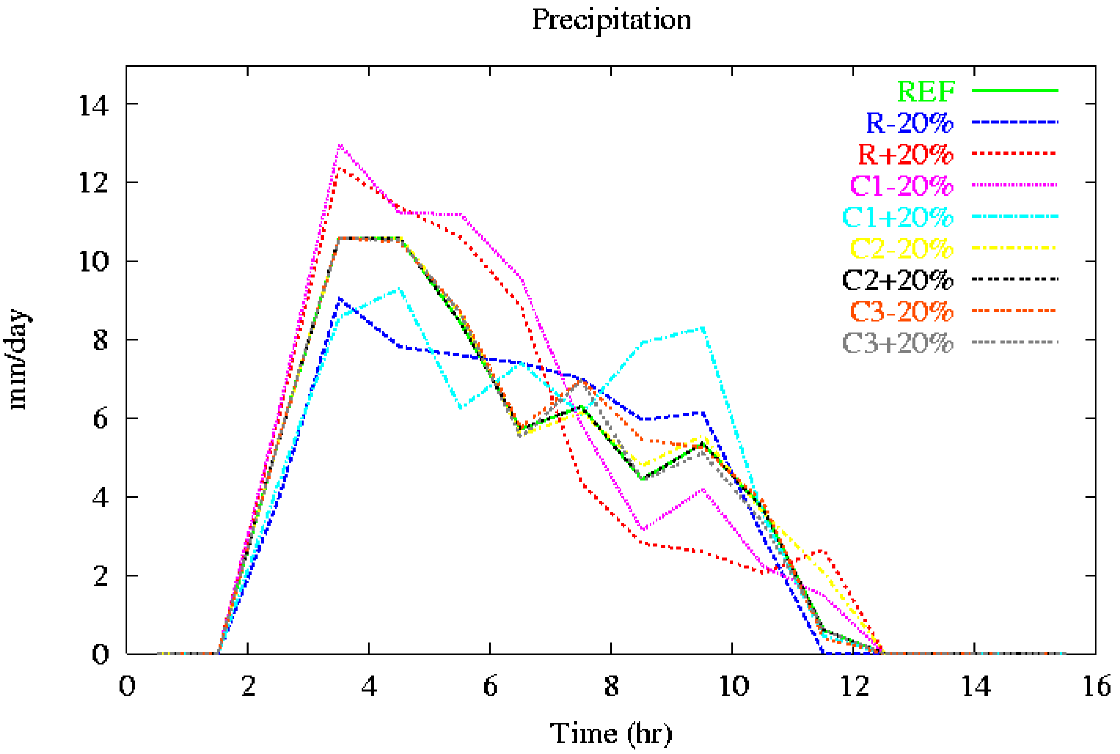

Figure 1: The amount of precipitation (mm/day) of the nine different 1D model runs. R denotes the changes in the radius of the cloud, C1 the changes in the entrainment parameter, C2 the temperature perturbation due to the vertical winds and C3 the temperature perturbation due to the relative humidity.

Figure 1 shows that the time of onset (in this case) is not very sensitive to the changes in the trigger functions. Overall, the changes of the trigger functions (C2 and C3) have almost zero impact in this case. The changes in the parameters of the mass flux calculations have a larger impact. Increasing the radius of the initial updraft has the largest impact and causes the maximum precipitation rate. Further in the experiment, however, the impact of increasing the radius of the initial updraft reverses and less precipitation is produced when the initial updraft radius is increased. This results from a quicker consumption of the convective available potential energy (CAPE) in this experiment, causing less energy to be available for shower development towards the end of the experiment. Decreasing the entrainment into the cloud has a similar impact as increasing the radius of the initial updraft. This is not strange as they both decrease the importance of entrainment processes that can dampen the vertical extent of clouds (impact of dry layers in the middle troposphere).

The 1D study looks at the impact of the changes in only one column of air. In a 3D model many more columns are convectively active and can influence the behaviour of adjacent columns. Many more feedbacks therefore are possible in a 3D experiment. Also, in a 3D study the trigger functions may be more important than in the 1D study, as there will always be columns that need only a little extra perturbation in the temperature to enable the development of clouds. The small impact of the changes in the trigger functions in the 1D study may therefore not be representative for the impact in 3D.

4: 3D case studies

In the 3D case studies the parameters in the Kain Fritsch scheme are changed by 50% (see table 1). This may have a significant impact on the average precipitation amounts that are forecasted in the different experiments. Looking at the domain averages of the precipitation we can conclude that this is not the case. The differences in domain-averaged precipitation are less than a few percent so the precipitation will not differ too much in the sensitivity experiments from the climate in the reference run.

Table 1: description of the 3D sensitivity experiments.

REF:	reference run		
EX1:	entrainment – 33%	EX5:	T-perturbation + 50%
EX2:	entrainment + 33%	EX6:	T-perturbation – 50%
EX3:	updraft radius + 50%	EX7:	RH-T-perturbation + 50%
EX4:	updraft radius – 50%	EX8:	RH-T-perturbation – 50%

30 July 2002

The first case study consists of a pure convective weather situation. In this situation thunderstorms developed that were not forecasted well by our operational model. It was important to forecast these showers correctly as these showers were accompanied by strong winds that were dangerous for people recreating on rivers and lakes. Figures of the hourly precipitation amounts (not shown here) reveal that the general image of the eight experiments is the same, but the details are different. The experiments 1 to 4 (the two parameters from the mass flux calculations) cause clear changes in the precipitation, while the experiments 5 to 8 (the two parameters from the trigger functions) show almost no difference. So, the parameters of the mass flux calculations have more influence on the precipitation than the parameters of the trigger function.

Theoretically, a change of the parameter of the trigger functions must lead to a change in the precipitation starting time. This effect should be visible most clearly in time series of one geographic point. Figure 2 is the time series of Kortijk (Belgium). This is a position where some experiments produce a lot of precipitation and some do not. The experiments 5 to 8 show neither much difference in the precipitation starting time, nor in the precipitation amount. But the range in precipitation amount between all eight experiments is about 14 mm, again showing that the mass flux calculations have the largest impact on the precipitation. The changes in the parameters determining the mass flux in the Kain Fritsch scheme cause a broad distribution in precipitation amounts. Differences in the time of onset and the sensitivity of this situation over the Netherlands (do showers develop or not) can be found in the output from this situation. Ensemble forecasting therefore seems to be feasible through changing parameters in the parameterisation scheme of interest.

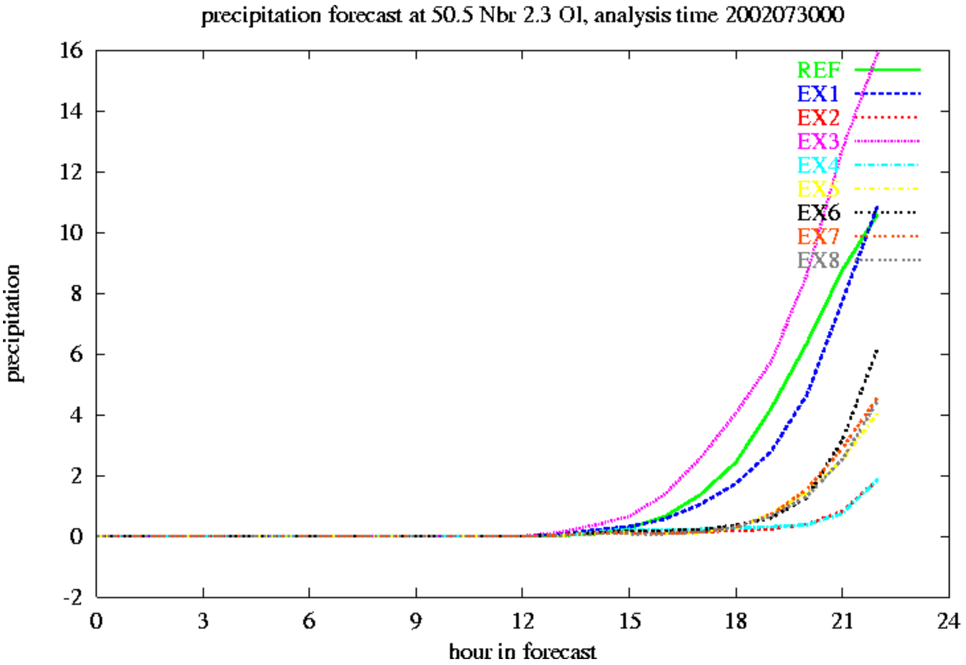

Figure 2: Time series of the precipitation in Kortrijk (Belgium) in the reference run and the 8 sensitivity experiments.

2 June 2003

In the second case study a cold front approaches the Netherlands from the west. Ahead of the cold front a convergence line exists. The convergence line triggers thunderstorms that lead to more precipitation than the cold front. The strong thunderstorms on the convergence line locally produced very large precipitation sums of more than 100 mm in the east of the Netherlands. In this case, Hirlam did not forecast the large precipitation sums correctly. We therefore hoped that the sensitivity experiments would show us large differences in precipitation sums or large differences in the geographical distribution of the precipitation.

The precipitation patterns in this experiment show a remarkable lack of differences between the different experiments. Somehow, the changes in the parameters have almost no impact on the development of convective precipitation in the model. This can be seen in the hourly precipitation figures (not shown here), and also in the precipitation time series.
Figure 3 shows the time series of the west coast of Belgium. The difference in precipitation amount is only 3 mm. The start time of the precipitation is the same in all experiments while the precipitation amounts also differ only 5 to 10 %. This is the case at almost all points for which time series were extracted. For this case the changes in the Kain Fritsch parameters do not result in a broad precipitation distribution and a probability forecast cannot be achieved through changing the parameters in the Kain Fritsch scheme only. As the convection in the model is mainly forced by the convergence, a probability forecast may be achieved through the parameters in the schemes that have impact on the convergence (turbulence, surface exchanges, initial conditions).

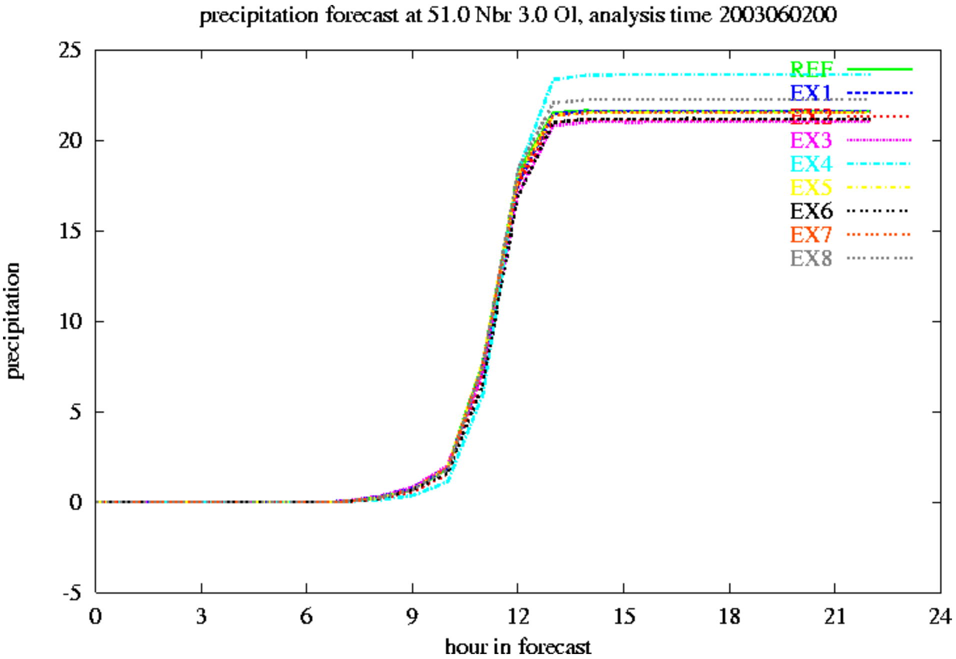

Figure 3: Time series of the precipitation at the Belgian coast in the reference run and the 8 sensitivity experiments.

Summary and discussion

The first weather situation leads to clear visible changes in the precipitation amount, especially in the time series of some locations. The parameters of the mass flux calculations are more sensitive than those of the trigger functions. The trigger functions seem to play only a small role in the Kain Fritsch scheme. The changes in the parameters in the second weather situation cause only small differences in the precipitation for the second case.

The differences between the two weather situations probably are the cause for the different impact of the changes in the Kain Fritsch scheme. In the first situation (almost) no large-scale forcing is present over the Netherlands when the showers develop. In the second case the thunderstorms develop on a convergence line. This forced convection clearly is much less sensitive for changes in the Kain Fritsch parameters than the freely developing showers of the first case.We therefore conclude that for certain weather situations significant differences in convective precipitation are achieved by changing certain parameters in the Kain Fritsch convection scheme. However the changes in the parameters in the convection scheme have to be quite large to get significant differences in the forecasted precipitation amounts and places. The differences that are found are not by itself an indication of realistic spread, which is what you really want to know.

There are two points that must be investigated further: the magnitude of the changes and for which weather situations changes in the Kain Fritsch parameters are useful. The origin of most of the parameters in the Kain Fritsch scheme is not clear to us. Knowing this origin is important for choosing the size of the changes. If one knows the origin of these parameters plus the uncertainty in these parameters, the perturbations can be chosen on a more physical basis. Also, these changes have to be tuned to give the correct probabilities. This can be done only by performing experiments over a longer period or by running a SREF system parallel to the operational forecasts and develop the tuning of the system based on this dataset.

References

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