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MetClock cloud initialisation in HIRLAM

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1. Introduction

In Numerical Weather Prediction Models cloud liquid water is seldomly analysed because this parameter is very difficult (if not impossible) to observe directly.
This is quite unfortunate because clouds play a key role in both radiation and precipitation processes, and they influence dynamics as well.

Although attempts have been made to assimilate clouds (and also precipitation) in NWP models through the use of e.g. infrared and/or microwave observations of satellites in 3-D var and 4-D var procedures, we have chosen a more direct approach:

A 3-D cloud cover field is computed from a combination of Meteosat cloud top temperatures and Meteosat cloud cover on the one hand, and synoptic observations of cloud base heights of one or more cloud layers on the other hand.

The Meteosat cloud cover and cloud top temperatures are detected automatically by the 'MetClock' scheme (see (1)), which has been developed at the KNMI.

The 3-D cloud cover is then translated to water vapour and liquid water fields of the Hirlam model, in such a way that these fields match the degree of cloud cover detected by MetClock.
The vapour fields are then inserted into the Hirlam model, after the model initialisation.

In 5 case studies it is shown that the rms errors in forecasts of the amount of total cloud cover (measured in oktas), as well as the bias of these errors reduced markedly compared to reference runs, at least for the first 6 hours.

2. Cloud initialisation procedure

Clouds have been initialised for 2 different cloud physics schemes of the Hirlam model, namely Kain-Fritsch (in combination with Rasch-Kristjansson) and the Straco scheme.

First of all, the 3-D cloud cover field N is obtained from MetClock and synoptic observations as follows:
Cloud top temperatures and total cloud cover are computed by the MetClock scheme from Meteosat infrared and visual channels. Combination of these cloud top temperatures with vertical temperature profiles from Hirlam forecasts yields the cloud top heights.
Cloud base heights and cloud cover of one or more cloud layers are interpolated from synoptic observations, provided that these observations are not further away than 220 km. The weighting factor used in these interpolations is proportional to minus the sixth power of the distance to the synoptic station. If no sufficiently close synoptic observations are available cloud base heights are obtained from the Hirlam model, and cloud cover is from MetClock.
The amount of cover of the highest (or the only) cloud layer is always obtained from MetClock; if additional cloud layers are present underneath, their degree of cover is interpolated from synoptic observations.
Cloud tops of the highest (or the only) cloud layer are provided by MetClock, cloud tops of underlying layers are arbitrarily set at the cloud base plus 20% of the distance between cloud base and the base of the cloud layer above.

The translation of N to specific humidities is for the Straco scheme:

$$q_t = \min(q_t, \frac{q_s}{1+A})$$ (if N=0) (1a)

$$q_t = \frac{q_s}{A+1-2AN}$$ (if N > 0 and N < 1) (1b)

$$q_t = \max(q_t, \frac{q_s}{1-A})$$ (if N=1) (1c)

The equations above refer to stratiform clouds in the Straco scheme. Under convective conditions other relations between specific humidity and N are used. But in the present MetClock cloud initialisation the stratiform equations are applied to all meteorological conditions.

For Rasch-Kristjansson we have chosen the following translation:

$$q_m = \min(q_m, rh_{\min} * q_s)$$ (if N=0) (2a)

$$q_m = q_s[(1-rh_{\min})\sqrt{N} + rh_{\min}]$$ (if N > 0 and N < 1) (2b)

$$q_m = q_s$$ (if N=1) (2c)

The equations (2) do not exactly reflect the depence of N on all model parameters, because N also depends on vertical stability and on (large scale) vertical velocities, and these latter model parameters were not altered because they cannot be changed without affecting the model dynamics. Yet, the formulations above generally improve the initial N fields.

In equations (1) and (2) symbols have the following meaning: q_m: water vapour specific humidity, q_s: water vapour saturation specific humidity, q_t: total specific humidity, $rh_{\min}$: relative humidity (80%), A: constant depending on pressure and model resolution, N: cloud cover (between 0 and 1).

In the current MetClock initialisation procedure liquid water specific humidities are neglected and left unchanged.

3. Verification of case studies

We have verified the predicted total cloud cover for the following five case studies (typical weather types over the Netherlands are indicated between parentheses):

- December 9, 1998 (fog and very low clouds)
- May 10, 1999 (thunderstorms and heavy precipitation)
- August 23, 1999 (passage of a front)
- March 1, 2001 (snowfall, both stratiform and convective)
- April 19, 2001 (snow and rain showers, very unstable atmosphere)

All runs started at 12 UTC. Results of one case study (10 May 1999) are shown in figure 1 (only Kain-Fritsch) as an illustration. The left panel shows cloud cover of a reference run, and the right panel shows cloud cover predictions when clouds are initialised with MetClock at 12 UTC. It is seen that MetClock increases initial cloudiness considerably, compared to the reference run. This increase is probably realistic, because visual inspection of Meteosat images clearly indicated more clouds than were present in the Hirlam reference run. Yet, after one hour the two runs already are much more alike, presumably due to rain out of what the model perceives as an excess of water vapour. After 3 hours the two runs look even more alike, though clear differences are still visible. After 6 hours differences have really become small and both runs seem to underestimate cloudiness somewhat. Also the other Kain-Fritsch cases exhibited this negative bias for cloudiness, see table 1.

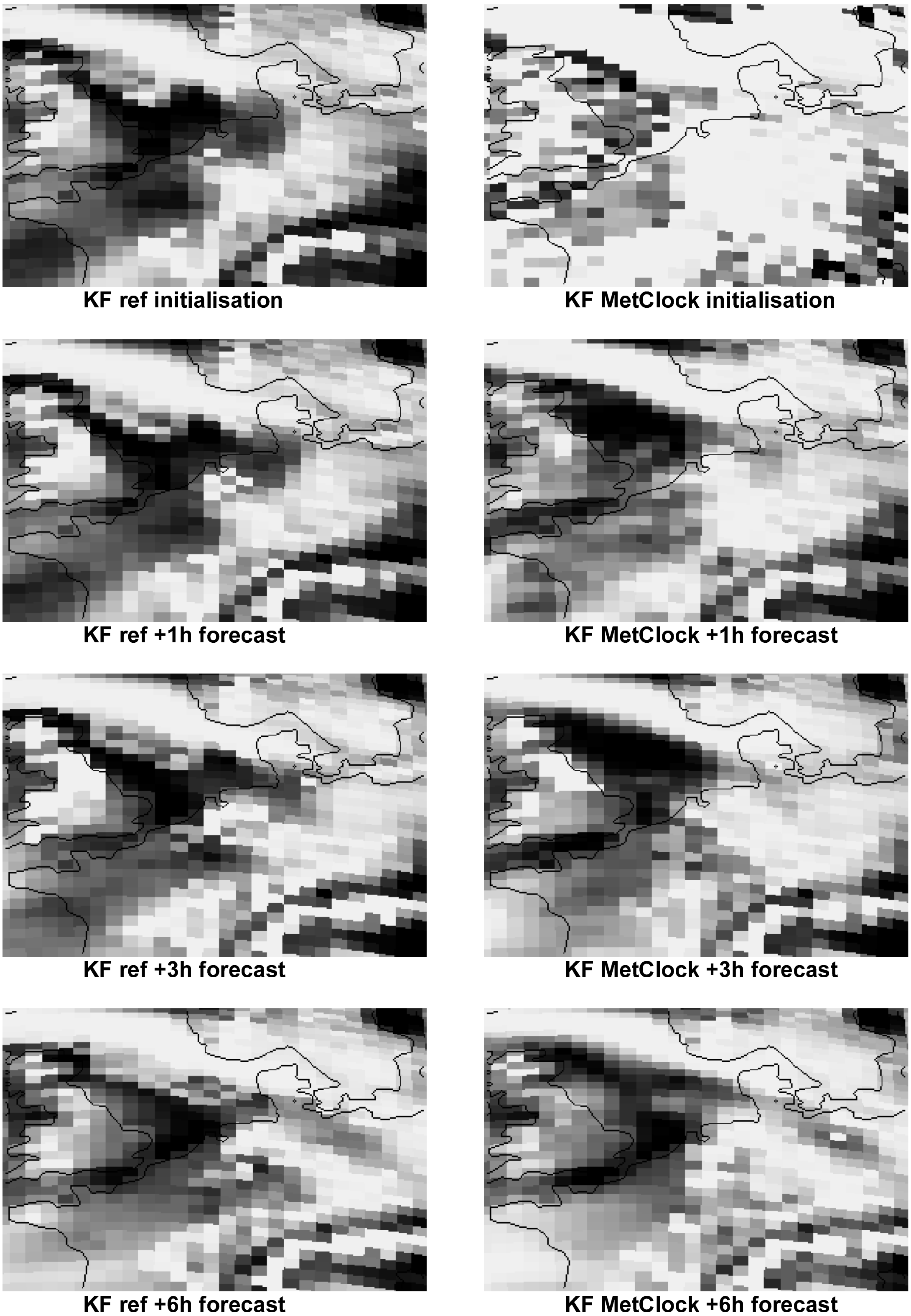

Figure 1 Total cloud cover of predicted cloudiness in oktas (KF: Kain-Fritsch / Rasch-Kristjansson, forecast length is indicated in hours) for 10 May 1999. Black: clear sky, white: 8 oktas.

We have verified the quality of the total cloud cover (root mean square and mean errors) by comparing model output to synoptic observations in the 'rectangular' area bounded by $-2°$ and $12°$ East and $48°$ and $58°$ North.

	REF bias (S)	REF rms (S)	MetCl bias (S)	MetCl rms (S)	REF bias (R)	REF rms (R)	MetCl bias (R)	MetCl rms (R)
+0	-1.0	2.8	0.1	2.5	-2.5	3.4	-0.4	2.2
+1	-0.6	2.7	-0.4	2.5	-2.1	3.1	-1.9	2.8
+2	-0.4	2.7	-0.3	2.6	-1.6	2.7	-1.5	2.6
+3	-0.4	2.8	-0.1	2.6	-1.4	2.6	-1.4	2.5
+6	0.4	2.7	0.6	2.7	-0.8	2.4	-0.6	2.3
+9	1.2	2.9	1.3	3.0	-0.1	2.4	-0.1	2.5
+12	1.5	3.3	1.6	3.4	0.5	3.0	0.5	3.0

Table 1: bias and rms errors of predicted total cloud cover (in oktas) for the Straco scheme (S), and for the Kain-Fritsch/Rasch-Kristjansson schemes (R).

4. Conclusions and final remarks

The preliminary results of the experiments indicate that the Hirlam model does not become unstable due to changing the initial water vapour field. This conclusion implies that variational methods seem not to be required for assimilating MetClock clouds. Of course this does not mean that it would be unwise to do so.
Experiments have also pointed out that the reaction of the dynamics to changing the cloud field enhances the influence of this change, though this influence is weak (not shown is this paper).
The most important conclusion is that cloud cover predictions are improved during the first 6 hours of the model forecast. After that time no improvement is seen, probably because most of the added water vapour is rained out, at least in these 5 cases. It was also seen that MetClock caused an increase of (model domain averaged) rainfall rates (in the order of 20%) during the first hours of the forecast.
In one additional experiment the air was dried (unrealistically), and in this case even after 12 hours a large difference between reference and 'dry' run was visible.
The 5 cases suggested that maybe too much water was added by using the MetClock initialisation. It would be worthwhile trying to add less water vapour, while keeping the same total cloud cover. This is possible by e.g. decreasing cloud layer depths, and keep the degree of cloud cover unchanged.
Furthermore, the Kain-Fritsch scheme shows a negative bias for cloudiness in both the reference runs, and the MetClock runs (after initialisation). This feature suggests that precipitation is formed too easily in this scheme.

Furthermore, we should point out that improvement of cloud initialisation in the Straco scheme is still possible, in particular in convective regions. In the Rasch-Kristjansson scheme more principal problems arise because e.g. vertical velocities determine cloud cover and you cannot simply change these velocities after the model initialisation.

Apart from that, it is important to perform a number of additional Hirlam runs, in order to obtain more statistically reliable verification results.

5. References

(1) 'Cloud detection using Meteosat imagery and Numerical Weather Prediction model data', Arnout Feijt, Paul de Valk and Sibbo van der Veen, *Journal of Applied Meteorology, July 2000, 1017-1030.*