On the Excessive Low Cloudiness in the DMR Runs: A Case Study

Xiaohua Yang and Bent Hansen Sass
Danish Meteorological Institute

Abstract

In a case study of a problematic DMR (Delayed Mode Run using reference HIRLAM model) forecast, it is found that the forecasts feature an extensive and persistent low cloud cover over larger part of Finland and middle of Sweden, as are grossly unrealistic compared to observations. The forecasts also under-predict severely the 2m temperature during daytime. The case is believed to exemplify the problems often seen in the quasi-operational DMR runs. By examining the archived DMR output and performing parallel tests it is concluded that the direct cause of the forecast failure is in input field. The rather cold soil surface over Nordic area may be directly related to the formation and persistence of the cloud at the lowest model levels. In light of findings from the case study, comments on future improvement on various aspects of the forecast system are made.

1 Background

Since last spring the quasi-operational Delayed Mode Run (DMR) has been running almost non-stop using the ECMWF computer facilities, with the HIRLAM reference version 4.7.3. The main features of the forecast system includes OI scheme for upper air analysis and NASU for surface analyses over water surface, digital filter initialization, Eulerian time integration, CBR turbulence closure and STRACO condensation scheme.

During the monitoring of the DMR forecast runs, it has been observed by many HIRLAM colleagues that the forecasted fields seem to suffer rather frequent and unrealistically extensive low cloud coverage. The situation is most obvious in winter and spring time over Scandinavian area. Another likely related feature in the DMR runs is the significant negative bias in T2m (a couple of degree for the Nordic area), which can be seen clearly from those daily and monthly observation verification curves displayed at the HIRLAM webpage on HexNet.

This note examines such a typical problem case from an archived DMR forecast. The forecast was started at March 20 2001, 00 UTC. Synoptic chart (Figure 1, valid at 12 UTC) shows several low pressure areas with snow situated over the Norwegian Sea, Poland (near the border to Bela-Russia) and east of Finland, respectively. In between these low pressure systems, parts of Sweden and Finland are influenced by a weak high pressure ridge, with generally calm condition and clear skies. However, the DMR forecasts show rather extensive and persistent low cloud cover over larger part of Finland and middle part of Sweden, as is exemplified in Figure 2 a, for the +12hr forecast valid at 12 UTC. The predicted cloud cover is completely unrealistic compared to observations. At the same time, the predicted 2m temperature at 12 UTC (Figure 2 b) shows an overall negative bias of around 2-6 degrees for the area. A further examination of the model output indicates that the unrealisticly extensive low cloudiness and

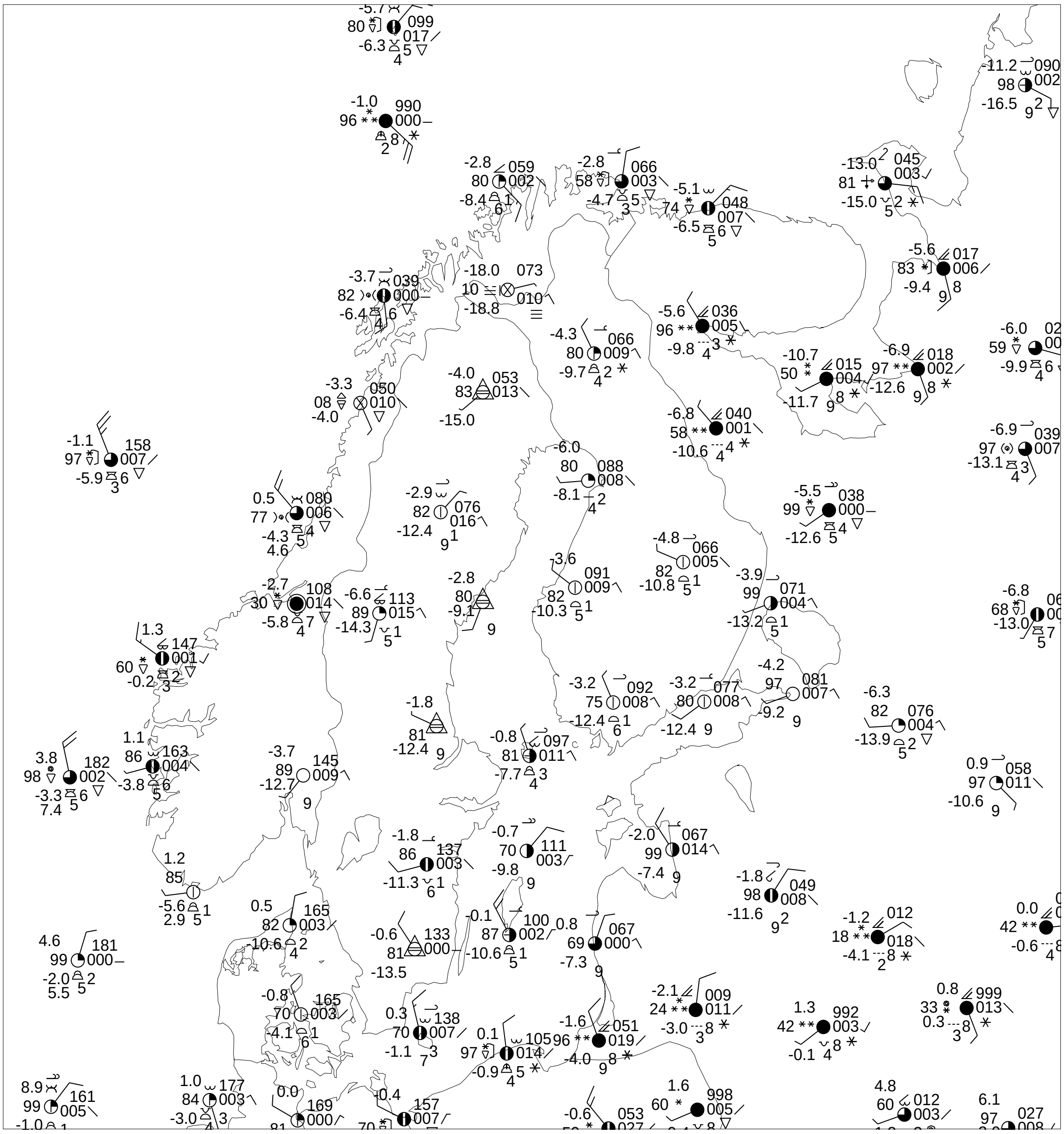

Figure 1: Surface observation on March 20, 2001, 1200 UTC.

cold temperature over Finnish and Swedish area are found throughout the forecast period. Also, the predicted amount of low cloud covers are mainly in the lowest model levels, while the medium and upper level clouds seem to be generally realistic.

2 Experiments

Obviously, the direct cause of the failed short range forecast must be in the forecast model and/or the input field. To identify the main cause of the failure, a series of parallel experiments have been made to examine impact of changing input analysis, forecast model and data assimilation setup. We first compare the corresponding comparable operational forecasts (G45) at Danish Meteorological Institute (DMI), which has a similar resolution (0.45 degree) to DMR. The forecast model for G45 is rather similar to that of the current reference HIRLAM version, especially in terms of physical parameterization package, which is essentially the same. Other aspects of difference between the setup of the reference HIRLAM and DMI's operational forecast system will be further discussed later.

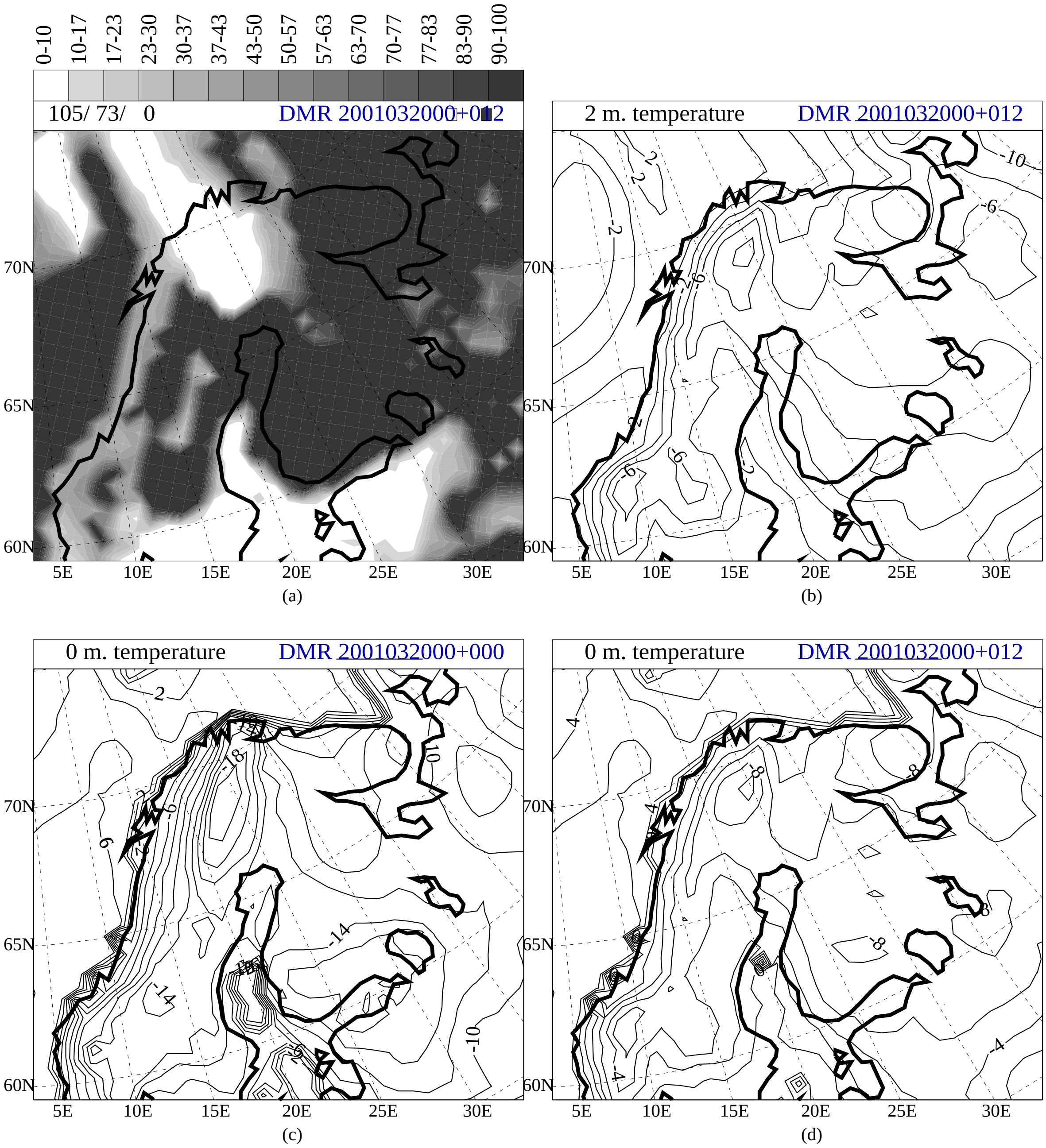

Figure 2: Analysis and forecast from DMR run: (a) 12 hr forecast of low cloud cover, (b) 12 hr forecast of 2m Temperature, (c) input surface temperature at 00 UTC,(d) 12 hr forecast of surface temperature.

Figure 3 a presents the corresponding low cloud cover prediction from the G45 model. It is rather clear that the forecast by G45 is much more realistic in comparison to the verifying observation in Figure 1. The predicted T2m (Figure 3 b) is also in good agreement with the observations.

Our next exercise is to design an experiment REF, in which the analysis from G45 (valid at 2001032000) is used to replace the DMR analysis and a 12 hour forecast is made using the

DMR setup with the reference HIRLAM. The resulted forecasts are seen to be very similar to those from the original G45 run, see, e.g., the plotted low cloud cover forecast in Figure 4 a. We thus may conclude that the forecast failure in DMR is unlikely to be caused DIRECTLY by the problems in the forecast model. Instead, the main causes have to be in the input field to the forecast model.

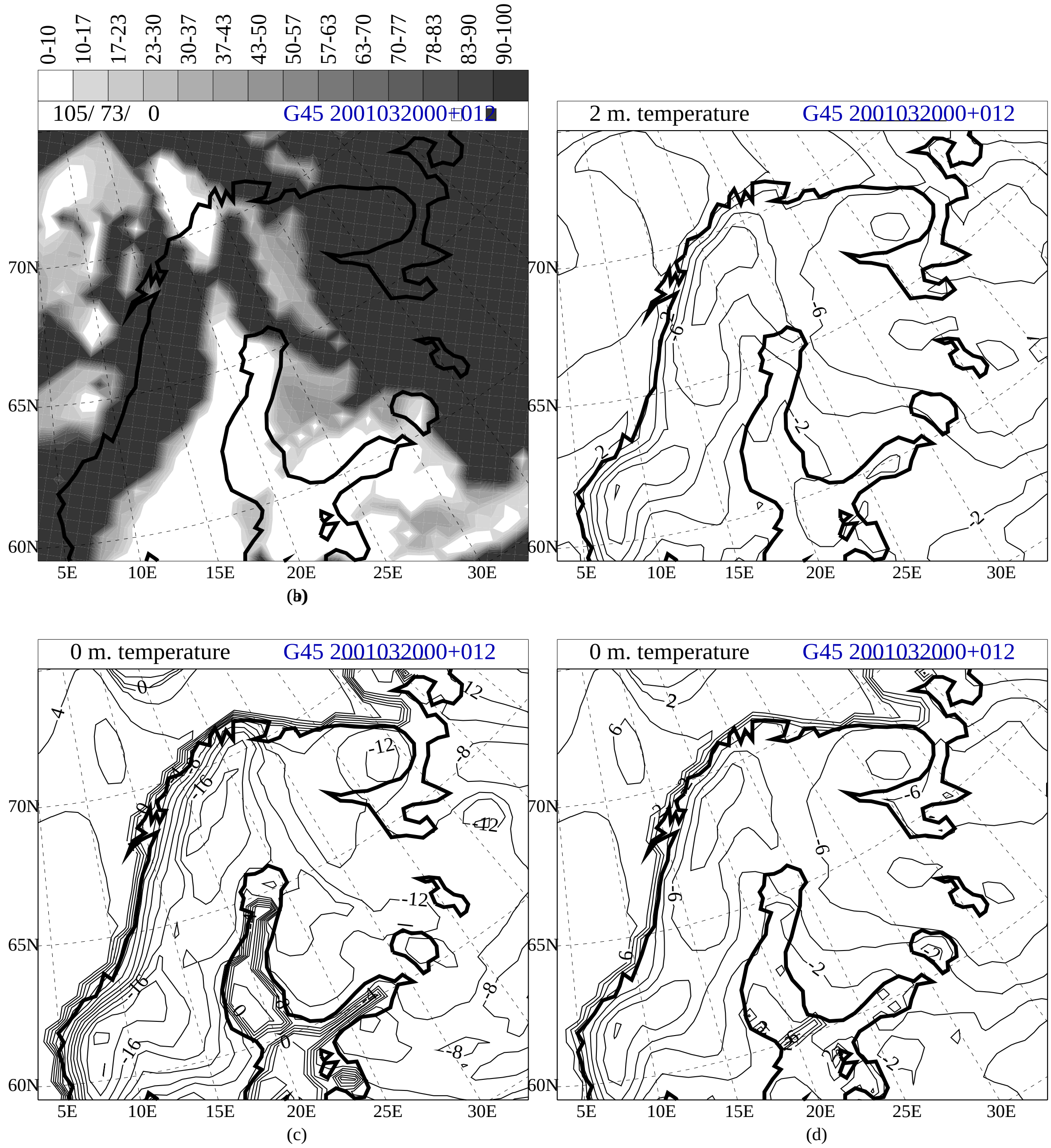

Figure 3: Same as in Figure 2 but from DMI's operational G45 runs.

Comparisons have hence been made to the input fields to DMR and G45, which contain both analysed upper air dynamic fields and unanalysed fields. The unanalysed fields include both prescribed climatological fields and quantities over water surface, such as SST and fraction of ice cover, etc., and also the prognostic land surface variables such as soil temperatures, wetness and snow cover. No strikingly different upper air fields, including those of the humidity analyses, have been found. Relatively large differences are found between the SST and fraction of ice cover in DMR and G45 input (not shown here). On the other hand, such differences in conditions over water surfaces do not seem to explain the remarkably different short range cloud cover forecast over land area as seen here. The difference in initial soil temperature over land area between DMR and G45 input fields are, however, worth attention. Figure 2 c and Figure 3 c show the land surface temperature at initial time in the DMR and G45 input, respectively. Apparently, the DMR soil surface is colder than in G45 by more than 2 degrees in most areas over Finland and Sweden. Over south Finland, the temperature difference is as much as 5-8 degrees. The difference in the surface temperature may have directly contributed to the different atmospheric response in these two models. In DMR, clouds are formed in the lowest model levels and persistent during the forecast, resulting in substantially larger cold surface bias after sunrise, shown in the predicted T2m (Figure 2 b) and Ts (Figure 2 d) at 1200 UTC, as compared to those in the G45 runs (Figure 3 b for T2m and Figure 3 d for Ts).

The importance of initial surface fields is also demonstrated in experiment DFH. In DFH, data assimilation cycles are set up in an attempt to 'repeat' DMR runs, with all conditions being equal to the DMR runs, except that the assimilation cycle is initiated 12 hours earlier at 2001031912 as a 'cold start'. With the standard 'cold-start' setup in HIRLAM, ECMWF analysis or forecast is used as first guess for upper-air analysis. However, at the start of the subsequent forecast, the surface fields from the (ECMWF) first guess is basically ignored and instead, climate fields are used. Hence the first guess used in data assimilation for 2001032000 in DFH is rather different from the real DMR runs, especially in the surface prognostic fields carried over from previous forecast cycles. In fact, the surface temperature fields at 2001032000 for DFH runs are significantly warmer than in the DMR runs and not surprisingly, the resulted 12 hr forecast show no problems either in cloud cover (Figure 4 b) or in T2m (not shown here). Similar results are also seen from another experiment ECH (Figure 4 c), in which the ECMWF analysis is used directly as initial input to make 12 hr forecast. Again, with the standard HIRLAM setting, the prognostic land surface fields are started from the climate fields, causing the forecast to be quite different from the runs in both DMR and G45. The results from DFH and ECH here are not really surprising. In data assimilation cycles, un-analysed surface fields may often require long 'spin-up' time to reach a stable state from a 'cold start'. This factor should be taken into account in applications such as design of experiments for validation purpose.

Although the input fields to the forecast model, in particular the cold soil surface, have been shown to be the direct cause for the failed DMR forecast, the impact of physical parameterization in forecast model has also been briefly examined. In fact, in terms of excessive low cloud cover in DMR runs, lack of parameterization in STRACO for the shallow convection process at the interface of the boundary layer cloud top and overlaying stable layer has been seen as an important contributing factor, causing the model to be less accurate in simulating evolution of boundary layer cloud cycle. Recently, modification in the STRACO scheme which takes into account of the shallow convection process have been tested in data assimilation as well as 1D experiments and the resulted forecasts indeed show a generally reduced low cloud cover. The update has also been tested in this study. However, the difference in resulted 12 hour forecast do not differ substantially from the control DMR runs (not shown here), which is not surprising considering the severely biased initial surface features in the input. On the other hand, the alternative physical parameterization schemes may indeed results in wildly different forecasts. In experiment HSU, we replace the turbulence and condensation schemes in the reference HIRLAM model by Holtslag vertical diffusion and Sundqvist condensation schemes as have been used in previous reference versions. The resulted low cloud cover forecast (Figure 4d)

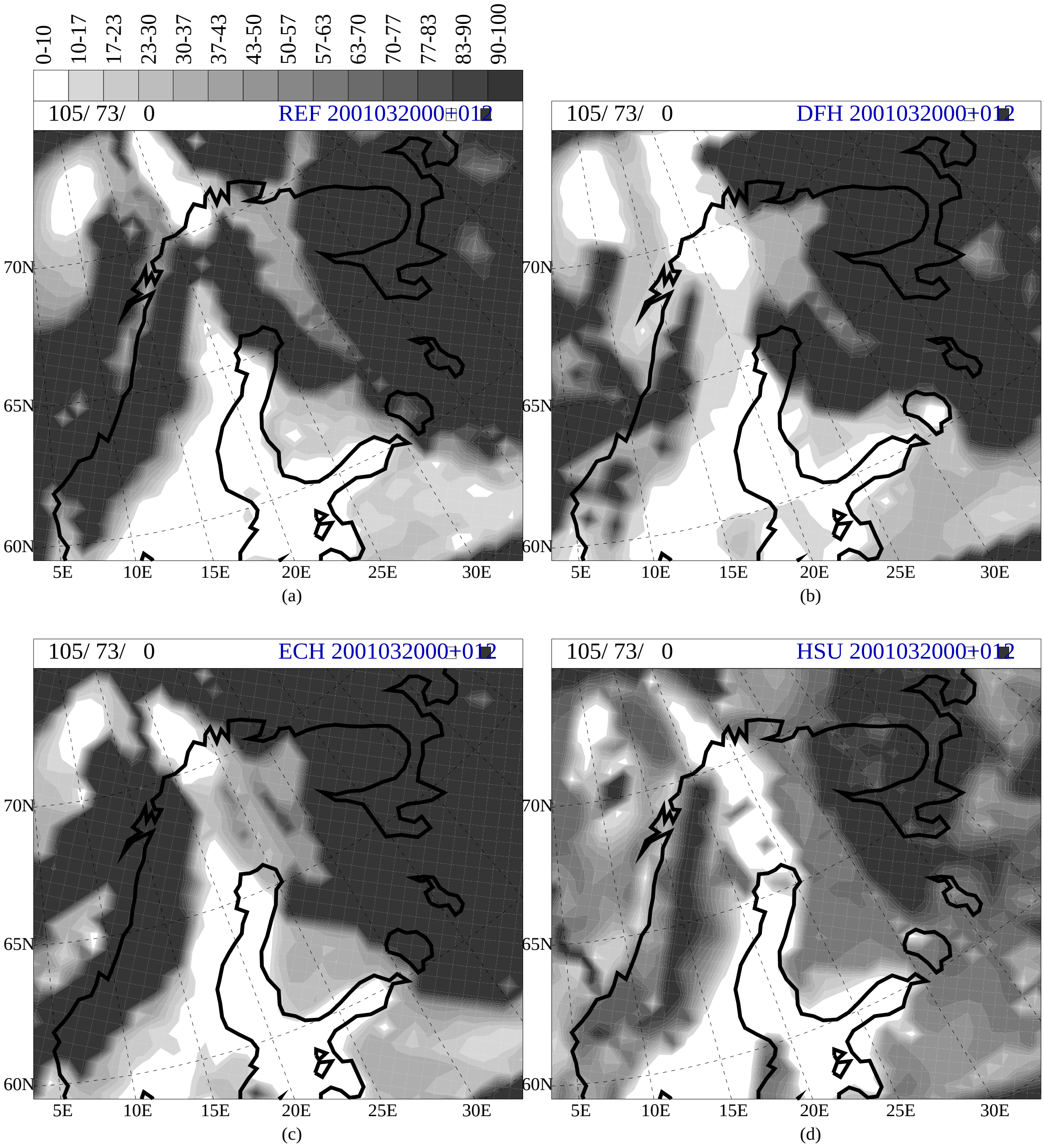

Figure 4: 12hr forecast of low cloud cover valid at 20010320 12 UTC for (a) REF: DMR forecast using G45 analysis; (b) DFH: DMR forecast with cold start 12 hr earlier; (c) ECH: DMR forecast using ECMWF analysis; (d) HSU: DMR forecast with turbulence and condensation schemes replaced by Holtslag and Sundqvist schemes.

becomes remarkably different from the DMR runs. In fact, one can no longer observe the extensive cloud cover over the Nordic area at the 1200 UTC forecast. It is, however, not obvious that the tested alternative parameterization schemes have indeed been superior than the current reference schemes, in view of the questionable initial surface fields as discussed earlier.

3 Discussions

Interestingly, so far in the corresponding comparable operational forecasts at DMI that applies similar physical parameterization as in the reference HIRLAM, there has been little evidence which indicate similar general problems, as observed in DMR runs, with excessive low cloud cover and large negative surface temperature bias. Taking into account various aspects of the differences between setup in the forecast system in DMI and the reference HIRLAM, one may speculate that one likely contributing factor to the better performance in DMI's HIRLAM runs may be associated with the 're-start' procedure. With 're-start', upper-air ECMWF analysis (which is assumed to resolve better large scale features) is combined with G45 analysis to derive analysis increment and thereafter used in producing first guess fields for later assimilation cycles. It is possible that such practice may, over long period of time, help to overcome potential systematic bias in HIRLAM forecasts at lower boundary layer, e.g., through gradual correction of low level temperatures and relative humidities.

In the present HIRLAM system, prognostic surface variables such as land surface soil temperature, soil moisture and snow cover etc. are not assimilated. This implies that the forecasted surface features are carried forward directly through data assimilation cycles in form of unanalysed first guess quantities. Bias in the surface fields may gradually develop, directly or indirectly influenced by the system bias in the analysis and forecast of upper air quantities. It is not obvious that the upper air analysis could be effective to correct such a surface tendency. On the other hand, the forecast model has potential to enhance bias trend through positive feedback. This may have been the case for the increasing cold bias in the soil temperature as well as the T2m temperature over the winter and spring periods in DMR runs, which is manifested by the excessive low cloud cover. Obviously, improvement in physical parameterization such as the enhanced treatment of shallow convection by STRACO, can alleviate some of the systematic model bias, because, ultimately, the shortcomings in forecast model are the main sources of systematic forecast bias. Also, in view of the dramatically different forecast response to the different parameterization schemes as shown in experiment HSU, for operational practice, it might be a feasible approach to try to use alternative schemes occasionally to 'shoot off' the accumulated bias problem, if the scheme happens to have opposite bias characteristics, (granted that this is not a scientific approach to solve forecast problem!). Similar remarks may also be said about the cold start data assimilation procedure. One may use it periodically to help overcoming systematic bias accumulation. Finally, a fundamental cure of the accumulated bias problem in surface fields would be through direct data assimilation of surface properties (such as the assimilation scheme in ISBA). At surface analysis step, prognostic surface fields are constantly relaxed to observations and gradual drift in prediction of surface features may thus be avoided.

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