Verification of updates of the CBR scheme in Hirlam?

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Introduction

Perhaps this note concerns more with pitfalls of verification than with the verification results itself. These pitfalls arise whenever you try to validate a certain scheme, in this case a turbulence scheme, by comparing results of 3D Hirlam simulations with observations. As such, the description of verification problems can be important for everyone who is involved in verification. Nevertheless, results are presented. The two investigated updates of the reference CBR scheme, CBR_KNMI and CBR_INM, are described by the paper of Lenderink & Sanchez (elsewhere in this Newsletter, from hereon LS). Results are shown for July 1996 (both schemes) and February 2001 (only CBR_KNMI, for the reason see LS). For both months Cabauw tower measurements are used. For February we also used synops stations and a radiosonde.

Results

July 1996

In Cabauw in the Netherlands we have a 200m high meteorological tower. So model output at the lowest two model levels can be directly compared with hourly observations. Because we want to evaluate a turbulence scheme, of which the purpose is to do the vertical mixing, it is interesting to look at differences of wind speed and temperature between the lowest two model levels (at about 140 and 30m).

Figure 1 Observed and modelled wind speed difference between the lowest two model levels for July 1996

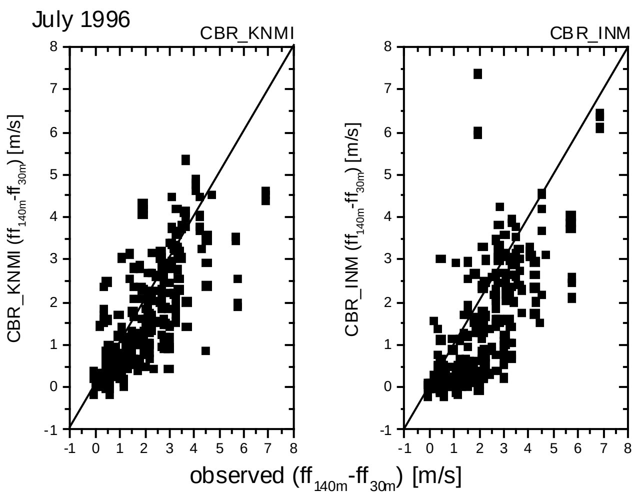
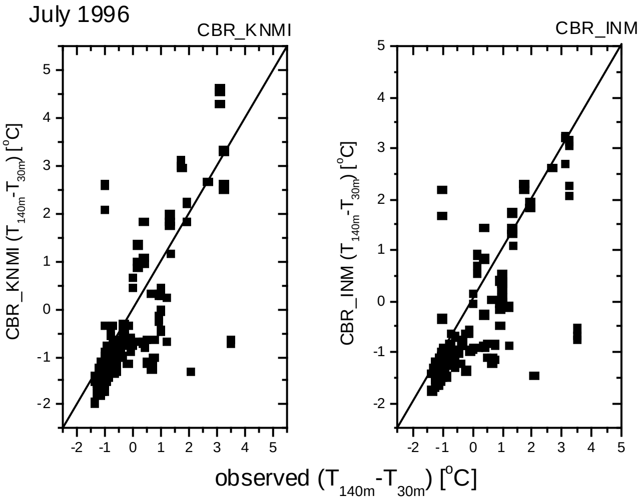


Figure 1 clearly shows the much more realistic momentum mixing with both updates in comparison with the reference CBR scheme (see LS). The scatterplot of CBR_KNMI looks somewhat better, e.g. for the prediction of small wind speed differences. This also results in a wind speed difference RMSE 0.3 m/s lower with the CBR_KNMI than with the CBR_INM version

Figure 2 Observed and modelled temperature difference between the lowest two model levels for July 1996



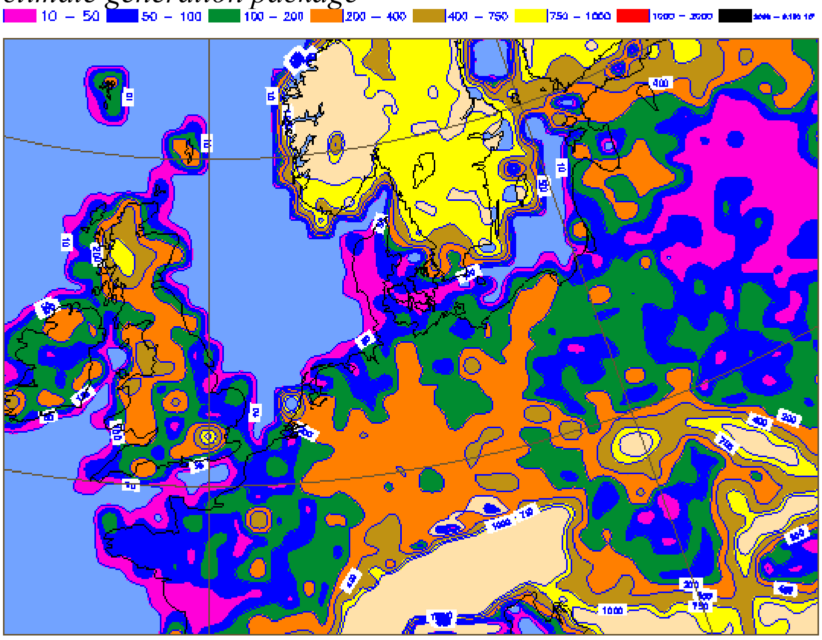
Also for the temperature difference (Figure 2), both updates of the CBR scheme behave comparable. This time the scatterplot of the INM version seems somewhat better (not leading to a significant improvement of the RMSE (< 0.1 ^{o}C)).

Looking at the results for temperature and wind speed for different levels separately, the differences between both schemes are small but considerably better than the reference CBR scheme.

February 2001

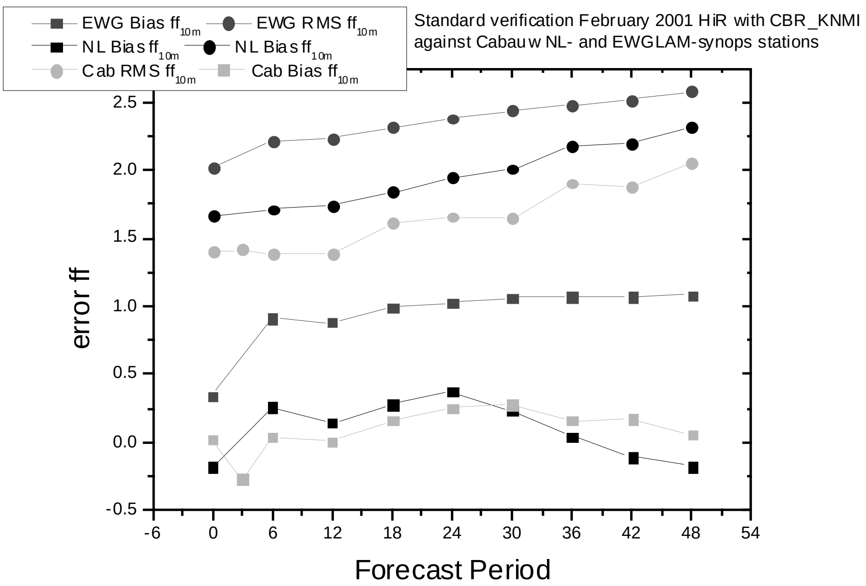
Before we discuss the results of February let us have a look at the roughness length map as produced by the new climate generation package.

Figure 3 Roughness length [mm] (vegetation + orographic) as produced by the new climate generation package



Striking are the large areas with too low z_0, like e.g. in Danmark and large parts of France and England. Many of these areas are defined as open fields/woods with a z_0 of only a few centimetres. In the new climate package of Han The, this problem can easily be reduced. In the Netherlands a special high resolution land use map is applied, leading to relatively high (but realistic) z_0. For example the gridpoint nearest to Cabauw has a roughness length of 0.34 m which is realistic as gridbox mean but larger than the local z_0 in Cabauw.

Figure 4 10m wind speed verification results against EWGLAM synop stations, synop stations in the Netherlands, and Cabauw

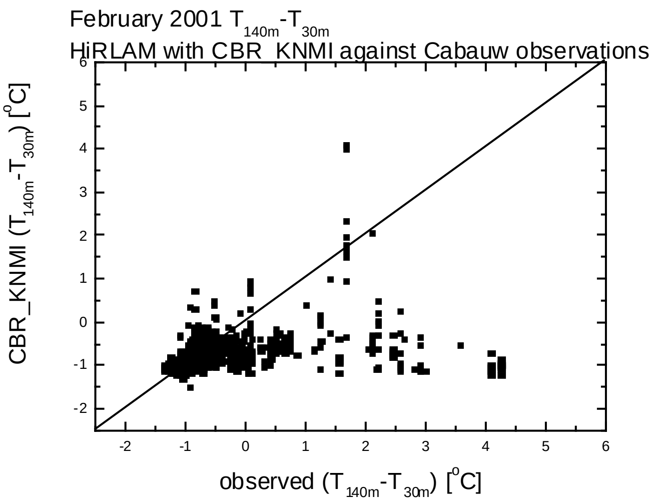


In Figure 4 we see that the bias in the 10m wind speed verified against EWGLAM stations (all over Europe) is +1 m/s. It is not surprising that this bias is positive if we

remember the large areas in Europe with too low roughness length. Consistent with the relatively large z_0 in the Netherlands, we see that the bias in the Netherlands is much lower (about 0.2 m/s). The results for Cabauw (not exactly the same hours) also show a small bias. A perhaps trivial but very important result is that there is a clear correlation between the error in the 10m wind speed and the wind direction. In the south to south/west direction the local z_0 in Cabauw is particularly low (about 0.07m instead of Hirlam's 0.34m). Especially in this direction we see a significant underestimation of the wind speed.
Considering these results it seems plausible that in this verification the bias in the 10m wind speed is dominated by the roughness effect and not by the turbulence scheme. A turbulence scheme which has not enough vertical momentum mixing will undoubtedly improve the ff_{10m} bias against EWGLAM stations!

We remain with the question why the bias in f_{10m} is roughly 0 whereas the local roughness length in Cabauw is lower than in Hirlam. This can be explained if we look at Figure 5. Here we see that almost all hours in the model are unstable while in reality many stable hours occur. As a result, there is too much mixing in the model (normally leading to an overestimation of the 10m wind speed). Here we see a fine example of a representation problem (the relatively high z_0 in Hirlam) which is cancelled by a compensating error (too much mixing) leading to a zero bias.

Figure 5 Observed and modelled temperature difference between the lowest two model levels for February 2001



How can we explain these erroneous unstable hours?
As Figure 6a and 6b illustrate (they are typical for a long period in February) the notorious Hirlam problem of too much and too persistent low-level clouds during a winter period is to blame. While the model has an unstable profile in the lowest model levels due to radiative cooling at the cloud top, we see a stable profile in reality. This problem was also apparent in our operational model which uses the Holtslag vertical diffusion scheme. It is not yet completely clear what is the main cause of these low level clouds but a possible solution can be found in the representation of shallow convection with the new Kain-Fritsch convection scheme or in a turbulence scheme with moist conservative variables.

Figure 6a

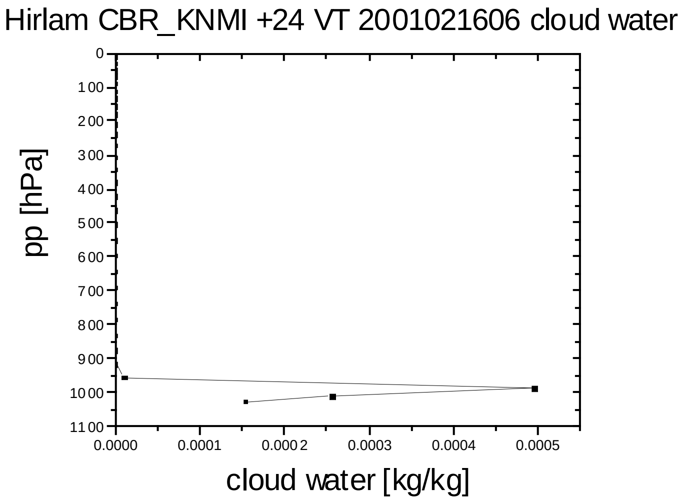
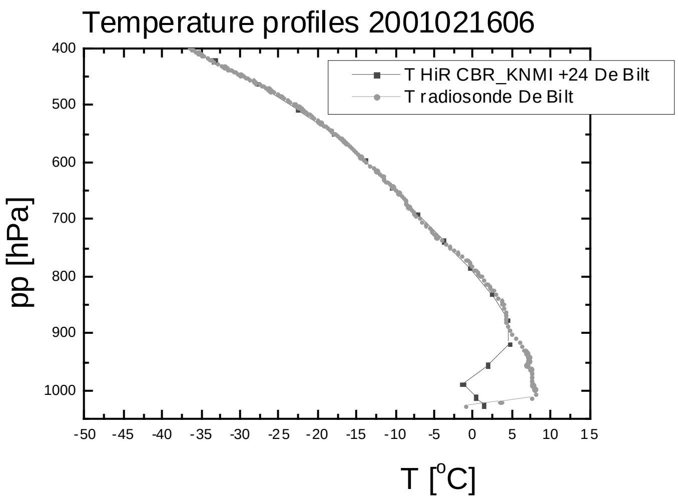
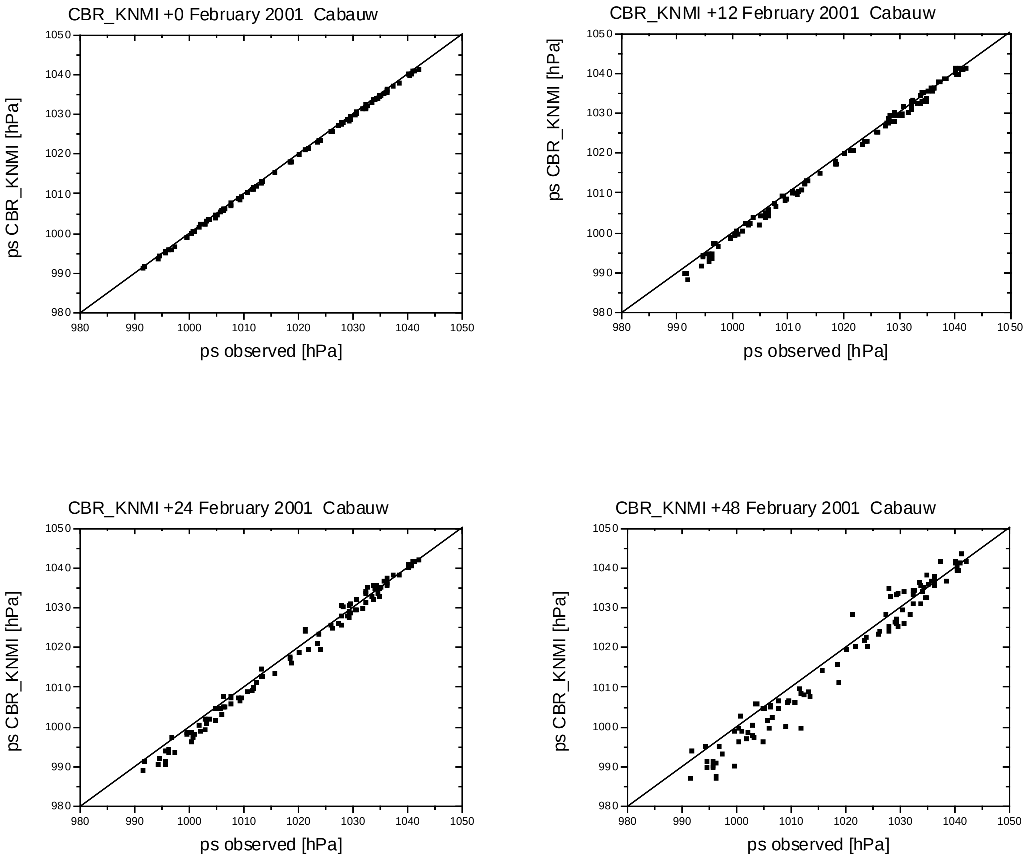


Figure 6b



Finally, results are shown of a parameter, which does not suffer from representation problems, the surface pressure. As shown in the first picture of Fig 7 the analysed pressure for Cabauw is almost perfect. During the forecast we see that for high pressures the bias stays virtually zero, whereas for low pressures a negative bias develops. This might seem surprising because we found too many unstable hours with too much mixing for February. Too much mixing results in too much filling up of depressions which is in contradiction with Figure 7. However pressure is a parameter with a large footprint. Although we are looking at the results for one point (Cabauw), the results tell us something of the performance of Hirlam on a large scale. It is speculative but the development of a negative bias during the forecast might be the result of not enough drag in the model (again the too low z_0 field!). Due to the too low roughness lengths there is not enough vertical momentum mixing and as a result depressions become too deep as shown in Figure 7.

Figure 7 Surface pressure scatterplots for different forecastperiods



Conclusions and remarks

- Both proposed updates of the reference CBR scheme show much better vertical mixing characteristics than the original CBR scheme. As such it is advisable to replace the reference turbulence scheme with one of the updates on a short term. The differences between the updates are rather small and some additional verification (a winter period) is preferable to make a choice.
- The roughness length map has a significant impact on the 10m wind speed verification and possibly also on surface pressure. The current roughness length map has large areas with too low values and should be optimised! However this does not mean that the z_0 field should be tuned on the ff_{10m} bias because this bias is strongly influenced by the representation problem which should be handled only in the post processing (De Rooy, 1999). Hopefully the problem of the increasing negative pressure bias is reduced by choosing reasonable vegetation roughness lengths.
- Do not primarily use validation of diagnostic output parameters to decide on the implementation of a scheme or Hirlam can never make progress on the longer term! An example of pitfalls with ff_{10m} bias (and thus RMSE) against EWGLAM stations is given in this report. One should be even more careful with verification of T_{2m}. It is not very wise to choose a turbulence scheme based on e.g. T_{2m} bias improvement against EWGLAM stations. What now looks beneficial might make

things worse if ISBA is implemented (which will undoubtedly have a large impact on the T_{2m} results). Near surface output parameters are extremely sensitive to compensating model errors and representations problems.
After specific case studies with detailed observations, a scheme should be tested in 3D tests by concentrating on parameters that are directly influenced by the scheme.

Acknowledgements

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References

De Rooy, Wim, 1999: Hirlam Near surface output: Error sources and possible improvements in T2m and V10m forecasts, Hirlam Newsletter No.33 May