Tests with different CBR versions

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1 Introduction

The CBR turbulence scheme by Cuxart et al. (2000) was introduced into the HIRLAM Reference system in September 1999 in version 4.6.2, and FMI and INM took this version into operations later in 1999. The operational use of the CBR scheme soon revealed two weaknesses: 1) a positive 10-metre wind bias of the order of 1 m/s; 2) a positive mean-sea-level pressure (p_{msl}) bias associated with areas of low pressure systems.

The origin of the 10-metre wind bias was shown by de Rooy (2000): too strong mixing of momentum in the lowest model levels. A coordinated work within the HIRLAM project was established in late 2000 to correct the problems of the CBR scheme. The aim of this note is to report the performance of the modified CBR schemes, developed at KNMI and INM, when compared to the reference scheme.

2 Parallel tests

2.1 Parallel suites

Improvements to the CBR scheme have been developed by Lenderink at KNMI and by Cuxart at INM. These modified schemes are described elsewhere in this issue of the HIRLAM Newsletter (Lenderink et al., 2001).

In order to evaluate the performance of these schemes against the reference CBR scheme, three different parallel runs were carried out. The experiments are as follows:

- CBR : reference CBR scheme
- CBN : modified CBR scheme by Lenderink (KNMI)
- CBM : modified CBR scheme by Cuxart (INM)

The common features for the three experiments are:

- Period: January 2000
- Domain: The FMI operational ATA (0.4°) area
- 194 * 140 grid points; 31 levels in the vertical
- Eulerian advection, dt = 3 min

- Each suite with its own data assimilation (OI, 6 h cycling)
- 48 h forecasts from 00 UTC analyses only

2.2 Test period and appearance of problems

January 2000 was a very active low pressure month in Northern Europe. Cyclones were developing frequently over the Atlantic and travelling towards Northern Europe and the Arctic Sea. Figure 1 shows the average p_{msl} pattern for January 2000. Figure 2 demonstrates the geographical distribution of the p_{msl} bias for the 48 h forecasts in January 2000, based on the reference CBR suite. This suite actually corresponds to the FMI operational ATA suite which was implemented in November 1999. The bias distribution in Fig. 2 is typical for the CBR scheme: there is a clear positive bias over Northern Europe (2 hPa) and over the Arctic Sea (4 hPa), coinciding with the (monthly mean) low pressure. A minor negative bias can be seen over the Atlantic, in the area of a high pressure. In contrast, the Louis scheme usually resulted in a negative p_{msl} bias in areas of a low pressure. Therefore, a clearly different behaviour of the HIRLAM model caused some confusion among duty forecasters at FMI, when the new model version with the CBR scheme was introduced into operations in late 1999.

Figure 6 demonstrates the bias and the RMS vector error (EWGLAM stations) of the 10-metre wind as a function of the forecast length for different experiments. As can be seen, the bias for the CBR suite (dotted line with triangles) is almost independent of the forecast length and is about 1 m/s. The p_{msl} bias together with this 10-metre wind bias are the problems that the modified CBR schemes try to solve, and the results from these schemes are presented in the following.

2.3 Results from parallel tests

The geographical distributions of the 48 h p_{msl} bias for CBN and CBM suites are shown in Figures 3 and 4 , respectively. The p_{msl} bias of the CBN and CBM suites are very similar. Compared with CBR (Fig. 1), both CBN and CBM reduce (remove) the positive bias over Northern Europe and over the Arctic Sea. The CBN and CBM schemes even introduce some negative bias over northern Russia, as does CBN over Finland. The negative bias over Russia north of the Black Sea is also increased by CBN and CBM when compared to that of CBR. The positive bias north of the British Isles remains in CBN and CBM as it is in CBR.

Figure 5 shows the bias and RMS error of p_{msl} as a function of the forecast length for the three different suites, as verified against observations from EWGLAM stations. The modified schemes reduce the small bias slightly, CBN more than CBM. Daily bias values, computed for the Scandinavian area (not shown), reveal that the modified schemes result in generally lowered p_{msl} values, i.e., a positive bias is reduced, but a negative bias becomes even more negative in 48 h forecasts. The RMS error of the modified schemes is slightly larger (with CBN largest) than that of the reference CBR. This results in an increased standard deviation (random error) for the modified schemes since also the bias has become smaller.

Figure 6 shows that both modified schemes, CBN and CBM, reduce the 10-metre wind bias to about 0.5 m/s, as it is 1 m/s for the reference CBR scheme. The CBN scheme reduces the bias a little bit more. Both modified schemes show smaller RMS vector error than the reference CBR scheme.

Finally, Figures 7 and 8 demonstrate the systematic difference in the 10-metre wind speed between CBN and CBR (CBN-CBR), and between CBM and CBR (CBM-CBR), respectively. It can be seen that the CBN scheme (Fig. 7) results in smaller wind speeds, about 0.5 m/s smaller, almost over the whole area, even though there are some small areas associated with larger wind speeds. The CBM scheme also gives smaller wind speeds than CBR (Fig. 8) over land areas, but the CBM scheme does not reduce the wind speed as much as CBN over sea areas.

3 Summary

Parallel tests with two modified CBR schemes and the reference CBR scheme have been carried out for the period of January 2000. The reference CBR scheme has two problems: a positive 10-metre wind bias of the order of 1 m/s and a positive p_{msl} bias in low pressure areas. Both modified schemes are able to reduce these biases. The 10-metre wind bias is halved, being about 0.5 m/s when using the modified schemes, and the positive p_{msl} bias associated with low pressure areas is also reduced.

References

Cuxart, J., Bougeault, P. and J.-L. Redelsperger, 2000: A turbulence scheme allowing for mesoscale and large-eddy simulations. *Q. J. R. Meteor. Soc.*, **126**, 1-30.

Lenderink, G., Sanchez, E. and J. Cuxart, 2001: Status of work on the turbulence modelling in the CBR scheme. *HIRLAM Newsletter*, **38**, in this issue.

de Rooy, W., 2000: Experiences with the Hirlam including the CBR scheme. *HIRLAM Newsletter*, **35**, 121-127.

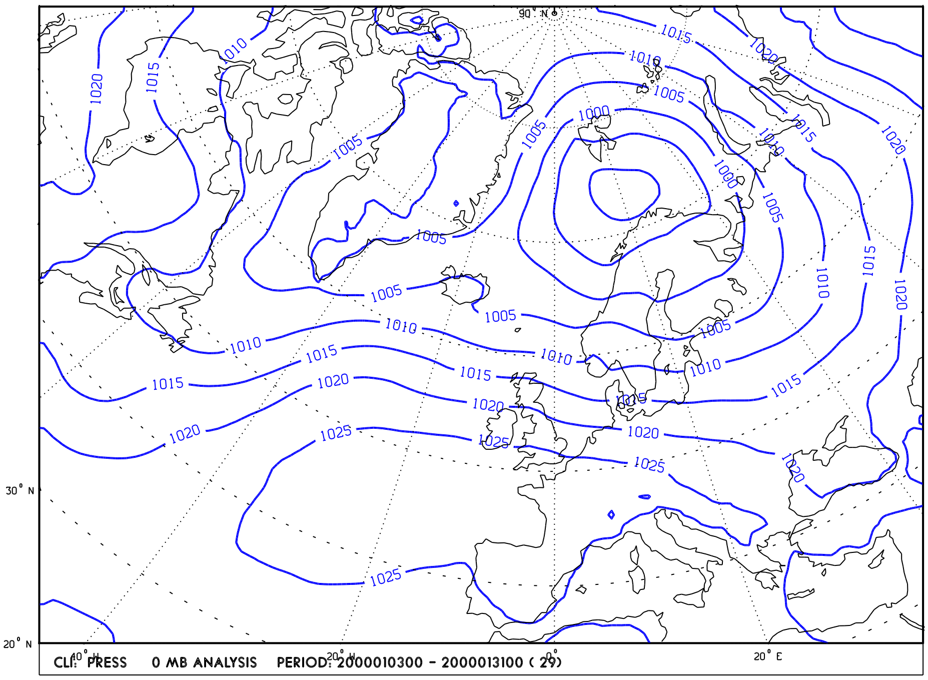

Figure 1: Average p_{msl} pattern, as computed from 00 UTC analyses 1-29 January 2000. Contour interval: 5 hPa.

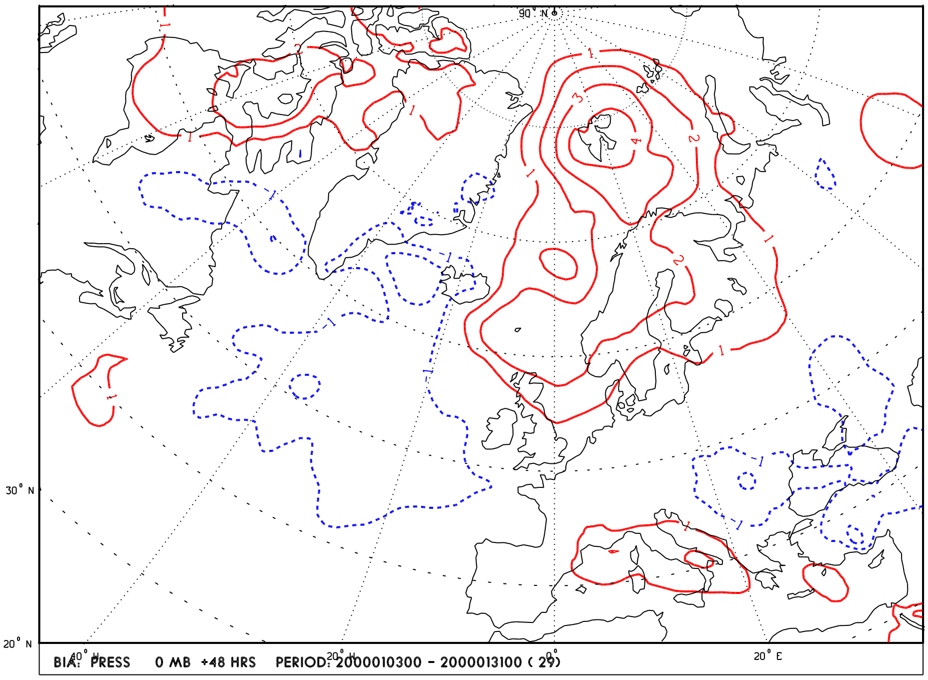

Figure 2: The p_{msl} bias of 48 h forecasts based 00 UTC analyses in January 2000 for the CBR suite. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.

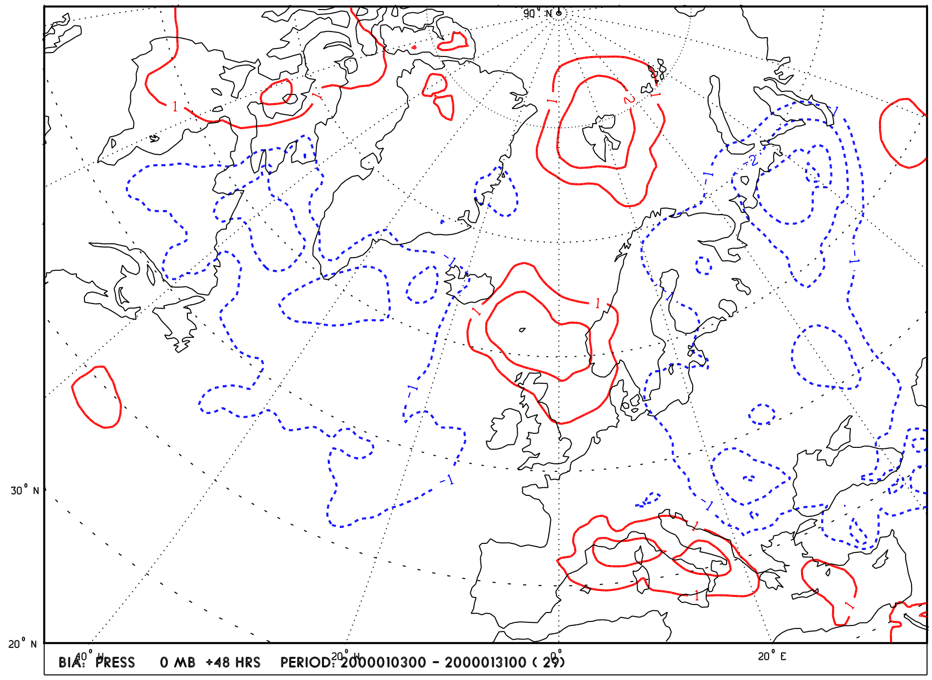

Figure 3: The p_{msl} bias of 48 h forecasts based 00 UTC analyses in January 2000 for the CBN suite. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.

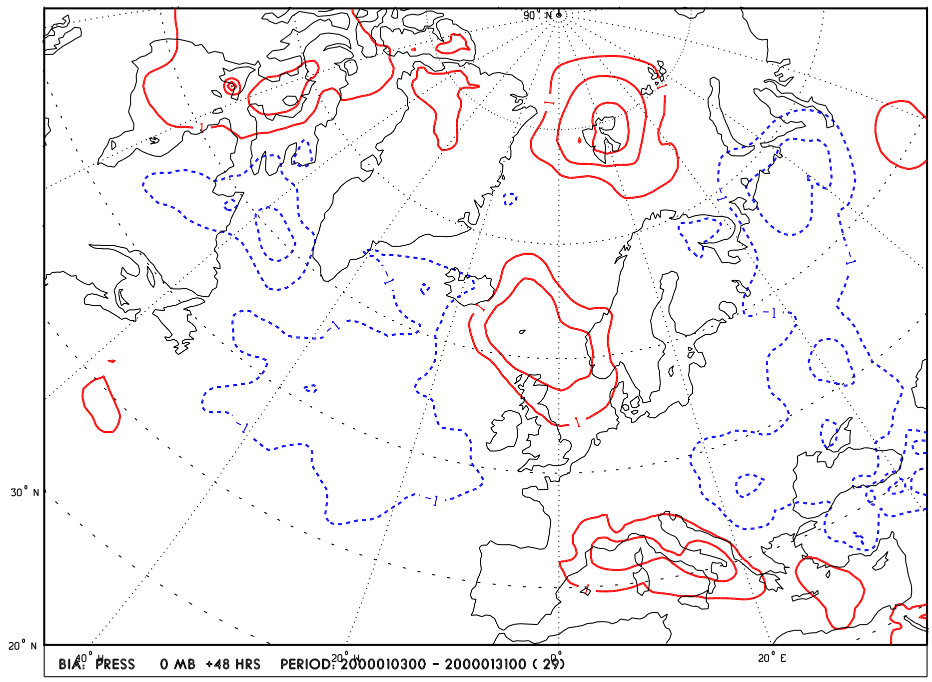

Figure 4: The p_{msl} bias of 48 h forecasts based 00 UTC analyses in January 2000 for the CBM suite. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.

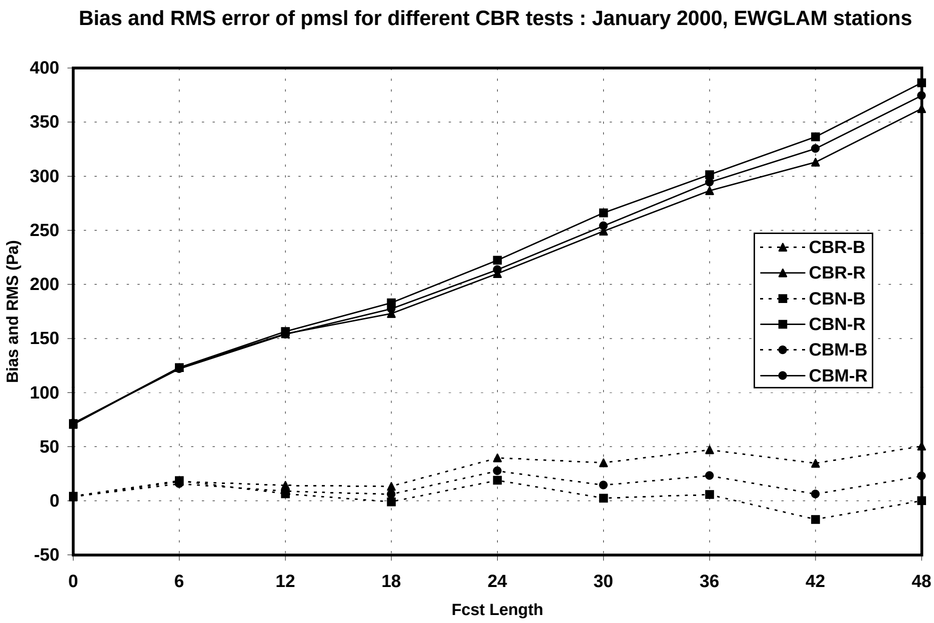

Figure 5: Bias (dotted lines) and RMS error (full lines) of p_{msl} as a function of forecast length for different CBR versions: CBR (triangle), CBN (square), CBM (circle).

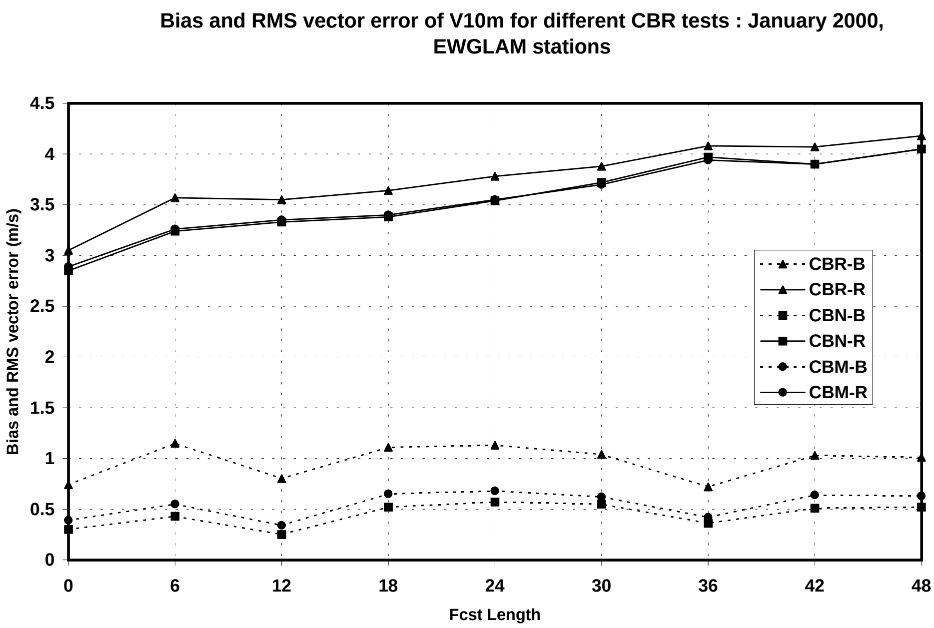

Figure 6: Bias (dotted lines) and RMS vector error (full lines) of V_{10m} as a function of forecast length for different CBR versions: CBR (triangle), CBN (square), CBM (circle).

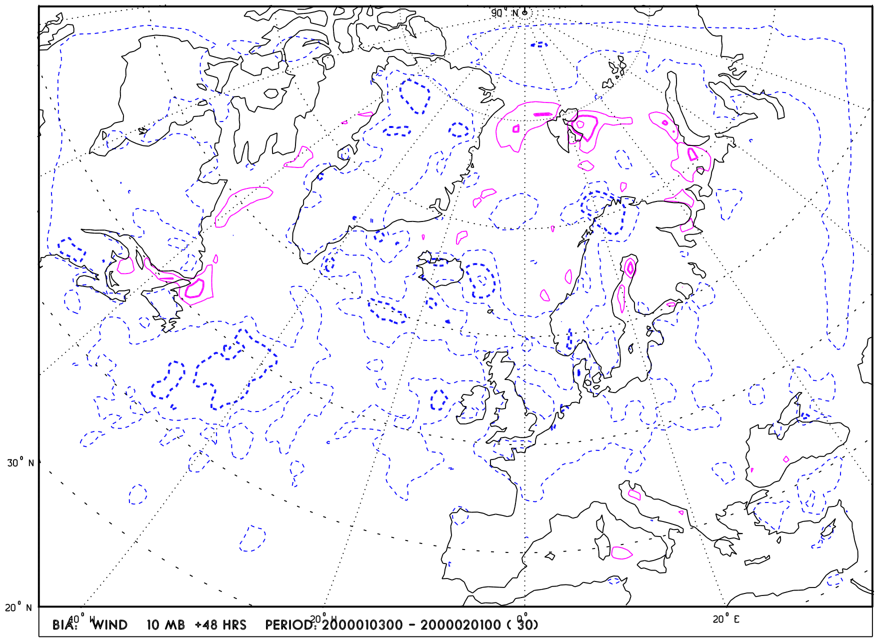

Figure 7: The systematic difference in the 10-metre wind speed between CBN and CBR (CBN-CBR) experiments for 48 h forecasts in January 2000. Contour interval: 0.5 m/s, thick lines indicate full m/s. The zero isoline not plotted, negative values indicated with dashed lines.

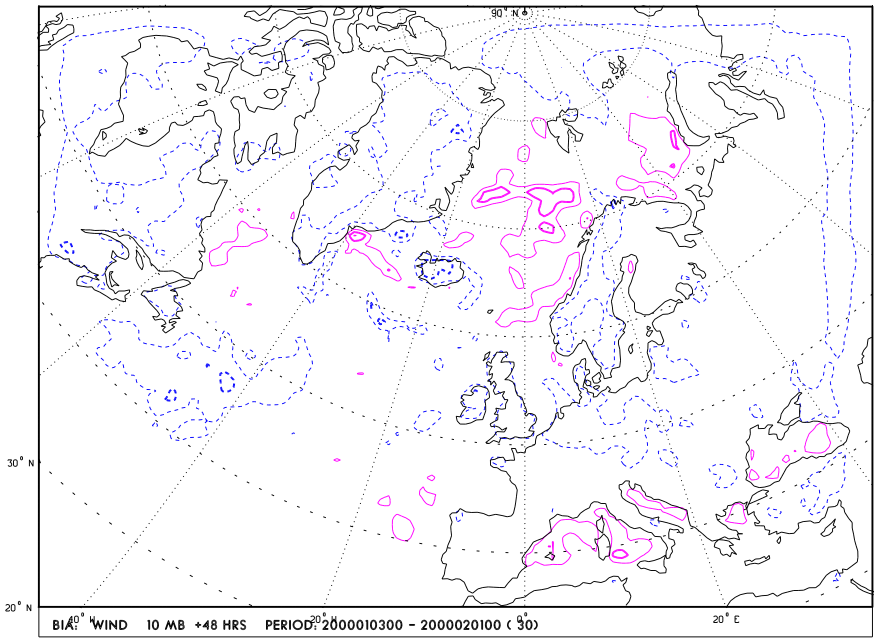

Figure 8: The systematic difference in the 10-metre wind speed between CBM and CBR (CBM-CBR) experiments for 48 h forecasts in January 2000. Contour interval: 0.5 m/s, thick lines indicate full m/s. The zero isoline not plotted, negative values indicated with dashed lines.