Modified roughness in ISBA and validation of CBR updates

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1. Introduction

Hirlam reference version 6.1.1. includes an update (developed by Colin Jones) of the CBR turbulence scheme, which showed promising results on especially the synoptic scale developments. However, the 10m-wind speed bias increased with the latter update (here referred to as IS6) and was therefore withdrawn in the next Hirlam version. Part of this note describes how this bias is strongly reduced by the use of more realistic model roughnesses (this experiment is referred to as ISV). Verification of the updated CBR scheme against Cabauw tower data (also presented in this note) showed an overestimation of the mixing of momentum near the surface, especially for atmospheric stable conditions. Therefore, Colin Jones made a new update of CBR that reduces this mixing, but (hopefully) maintains the synoptic improvements. Also this version in combination with the modified roughnesses (referred to as COL) is validated in this note.
Because some of the results presented here became available just before the deadline for this newsletter, not all results are fully analyzed.

2. Roughness in ISBA

In ISBA, z_0 values (set in INI_VEG.f) are based on homogeneous surfaces. For example, tiles with short grassland have a z_0 ranging from 1.2cm in winter to 2cm in summer. However, homogeneous grassland on a substantial part of the grid box area hardly exists in the European Hirlam model regions. Normally, grassland is alternated with tree lines, dikes etc., which has a large impact on the effective roughness length. Therefore we adjusted the model roughnesses for low vegetation grassland tiles to 20cm in winter and 25cm in summer. Similar adjustments are made for cropland, tundra, tall grass, etc.. For forests we made no adjustments although areas with a homogeneous forest also have a smaller roughness than heterogeneous landscapes with (small) open areas between the trees. However, this effect is probably less important because the impact on the roughness is relatively not as large as for low vegetation. As far as roughness concerns, it might be a good idea to extend ISBA to make a distinction between heterogeneous and homogeneous tiles possible.

In the current ISBA version (more precisely in PUTH3C.f), the surface parameters of some tile types are overwritten with the surface parameters of another tile type (INM is working on the solution of this problem). For example, urban is set to desert, which is no problem as far as the surface resistance (and therewith the latent heat flux) concerns, but the albedo and roughness of desert and urban are very different. Because we focus on the results for Western Europe, we decided to give desert and urban, urban surface parameters.

Although the new z_0 values are certainly more realistic for typical heterogeneous landscapes (checked with Bart van den Hurk), they should be considered as a first guess to test the impact on the model results.

3. Data

The validation period covers two months. August 2002 represents a summer month with convective rain days and October 2002 is a month with high wind speeds. Verification is shown against Cabauw tower data, EWGLAM and Nt+ (Netherlands and surroundings) synop stations, and radiosonds.

All Hirlam runs are made at 22km resolution and 306x251 points with 40 levels in the vertical. Model levels 40, 39 and 38, at about 32, 100, and 185m height respectively, can be compared with (vertically interpolated) Cabauw observations.

The experiments are:

IS6: Hirlam versions 6.1.1 (so including an update of CBR by Colin Jones). This version is only validated for August

ISV: As IS6 but with modified roughnesses as described in section 2.

COL: As ISV but with Colin's latest CBR update to decrease the mixing in stable conditions near the surface

4. Results

4a. Wind

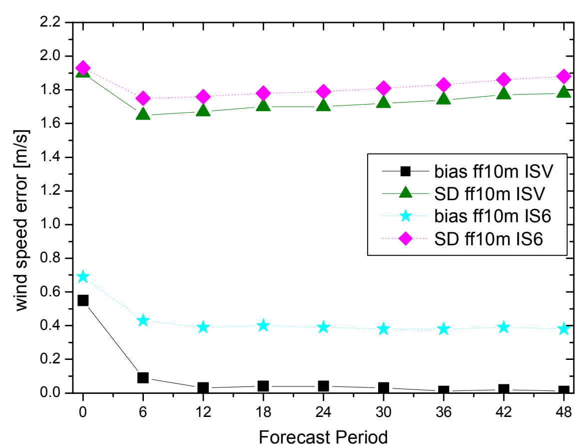
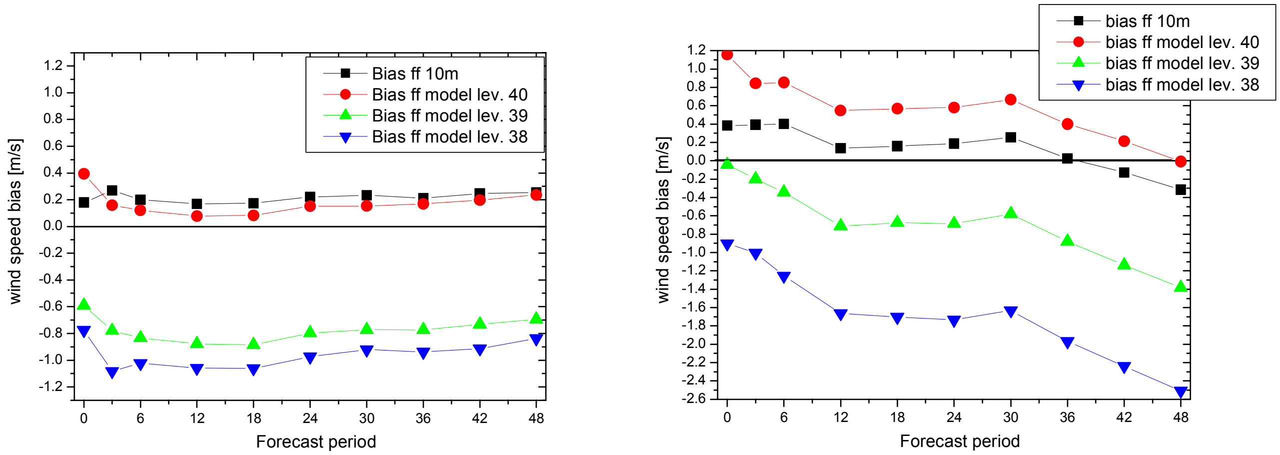


Fig. 1 Verification of 10m-wind speed (IS6 and ISV) [m/s] against EWGLAM stations for August 2002

Fig.1 shows that for August 2002, the bias in the 10m-wind speed against EWGLAM stations is practically eliminated when using the modified roughness (ISV). Also the SD decreases somewhat but this might be associated with the lower wind speeds. However, wind speed biases of large areas are difficult to interpret because we do not know the overall effect of the representation mismatches between observations and model output (Note that a representation mismatch can not be ascribed to a model error). For wind speed, the representation mismatch is primarily determined by the difference in roughness between the model and the observation site (De Rooy and Kok, 2003). EWGLAM stations include mountainous/coastal stations with possibly large representation mismatches. Therefore, verification scores as in Fig. 1 are useless to decide whether the roughness modifications should be included. Fig. 1 mainly shows the impact of the modified roughnesses. Nevertheless, we believe that the modified roughnesses should be included because it is likely that they better describe the actual friction for the model at the surface. These larger roughnesses are also welcome for other reasons. It is well known (see e.g. Lenderink, 2002) that the skill of NWP models for the prediction of synoptic developments (or the prediction of surface pressure) increases if the drag is increased. However, as an unwanted side effect this increased mixing leads to overestimations of the 10m-wind speed. Above land, the suggested, much larger, roughnesses compensate this bias substantially.

A similar plot as Fig. 1 for the Nt+ region (not presented) shows a 10m-wind speed bias of +0.2 for IS6 and -0.4 m/s for ISV (influence of coastal stations?). Fortunately, the results for Cabauw are easier to interpret. In experiment ISV, the z_0 of the corresponding grid box for Cabauw is 0.25cm. This grid box consists for 100% of low vegetation, grassland. For most wind directions the model z_0 is just slightly too high compared to the local situation. So in Cabauw, the representation mismatch is small and most of the bias can be ascribed to a model error. In Cabauw, the bias reduces from +1m/s with IS6 to +0.2 m/s with ISV (not shown). Considering the results for Cabauw and the above-mentioned arguments, incorporating the modified roughnesses seems beneficial. Hence, from hereon we concentrate on the differences between the turbulence scheme updates (ISV and COL).

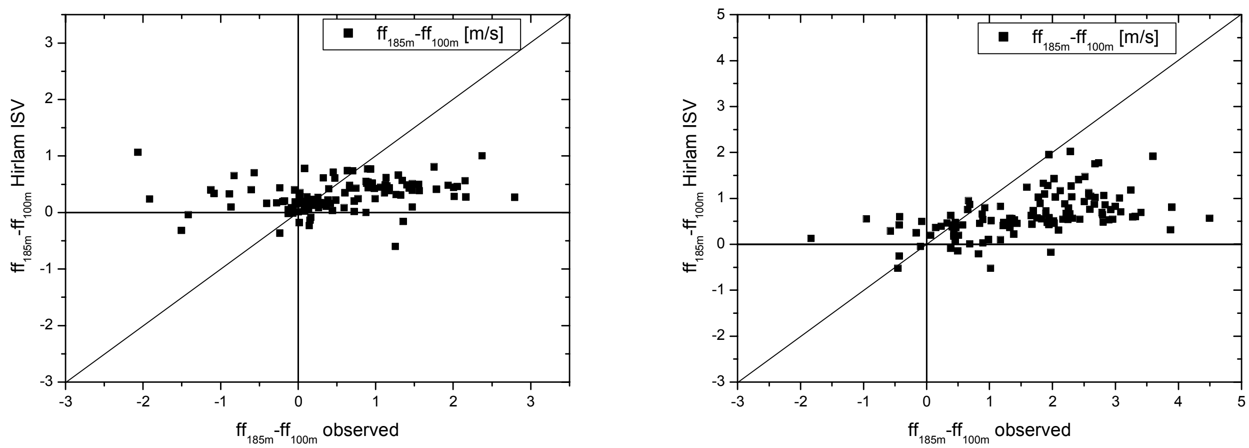


Figs.2a (left panel) and 2b (right panel). Hirlam (ISV) wind speed biases [m/s] at 10m and the lowest model levels, in Cabauw, for August 2002 (Fig. 2a) and October 2002 (Fig. 2b).

Figs. 2a and b shows the wind speed bias in Cabauw at different levels for ISV for August and October 2002 respectively. Biases at 10m and the lowest model level are small but quite large negative biases are found at 100 and 185m. Apparently, the turbulence scheme mixes momentum too much. A closer look (not presented) reveals that these overestimations of the vertical mixing occur mainly during nighttime (stable) conditions.

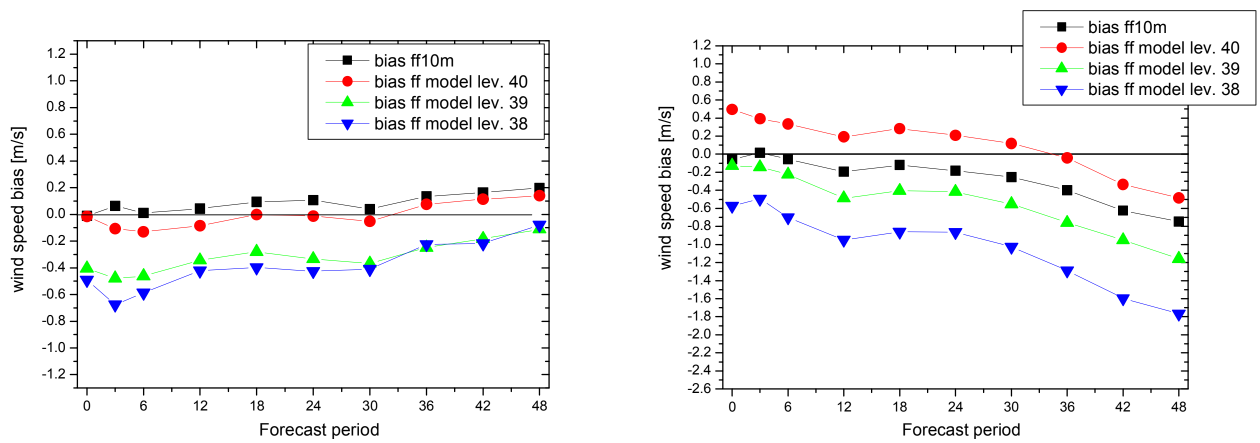
In contrast with the results for August, we see a decrease in the wind speed bias during the forecast period for October. This can probably be explained by the generally high wind speeds during October. If the observed wind speeds are high, a longer forecast will generally have the tendency to produce larger underestimations.

In Figs. 3a and b the observed and estimated (ISV, +12h forecasts) wind speed difference between 185 and 100m is plotted. Because of the high wind speeds in October, low level jets (negative values) are rare (Fig. 3b). For August, low-level jets are more commonly observed, but hardly forecasted. These results confirm the excessive mixing of momentum with ISV.



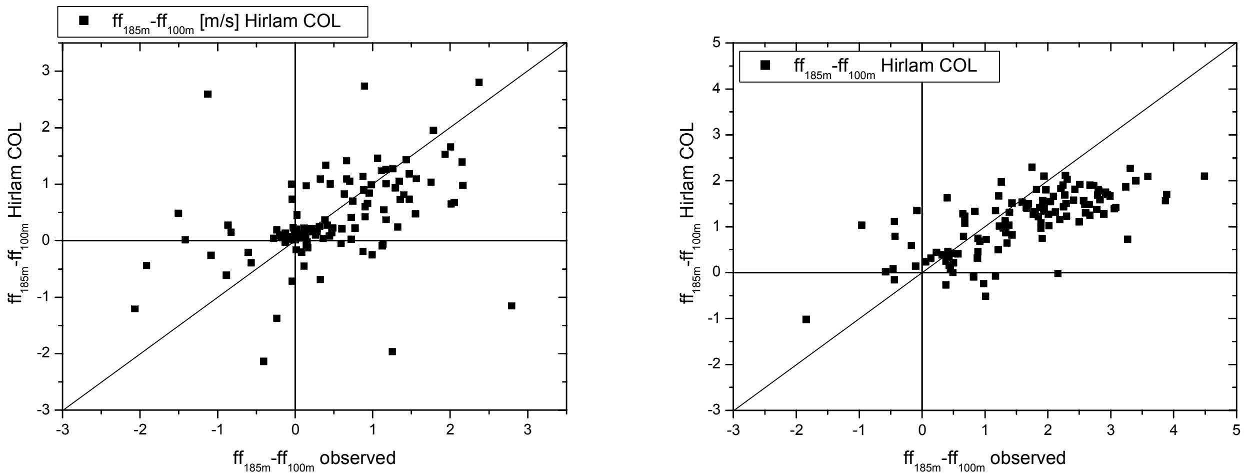
Figs.3a (left panel) and 3b (right panel). Hirlam (ISV) +12h forecast of ff_{185m}-ff_{100m} [m/s], in Cabauw, for August 2002 (Fig. 3a) and October 2002 (Fig. 3b).

To what extent, are the above-mentioned problems reduced with the new update of the turbulence scheme (COL)?



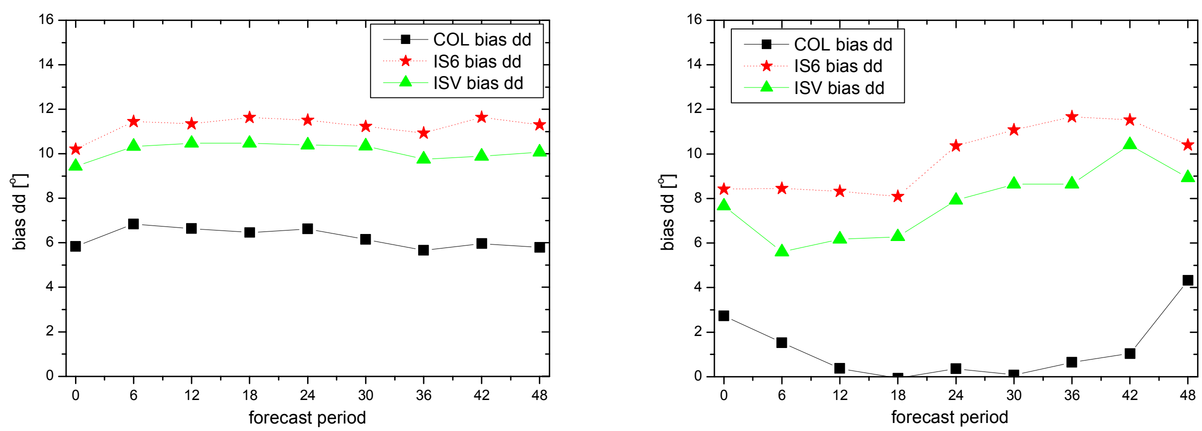
Figs.4a (left panel) and 4b (right panel). Hirlam (COL) wind speed biases [m/s] at 10m and the lowest model levels, in Cabauw, for August 2002 (Fig. 4a) and October 2002 (Fig. 4b).

Figs. 4a and b show that experiment COL substantially reduces the differences between the wind speed biases at different levels, indicating a more realistic mixing of momentum. This is also confirmed if we look at the wind speed difference scatter plots (Figs. 5a and b).



Figs.5a (left panel) and 5b (right panel). Hirlam (COL) +12h forecast of ff_{185m}-ff_{100m} [m/s], in Cabauw, for August 2002 (Fig. 5a) and October 2002 (Fig. 5b).

Fig. 5a reveals that in COL, low-level jets are produced, although not always on the right time. Also for October (Fig. 5b), the wind profile improves with COL instead of ISV.



Figs.6a (left panel) and 6b (right panel). Hirlam (IS6,ISV,and COL) wind direction [°]verification , for August 2002, against EWGLAM stations (Fig. 6a), and Nt+ stations (Fig. 6b).

Figs. 6a and b show that IS6 forecasts of the wind direction are improved with ISV but especially with COL. The higher roughness in ISV and the decreased mixing near the surface during stable conditions in COL lead to lower wind speeds, a relatively larger ageostrophic component of the wind, and therewith improved wind direction forecasts. Similar improvements in wind direction are found for October. We found no significant differences in SD of the wind direction.

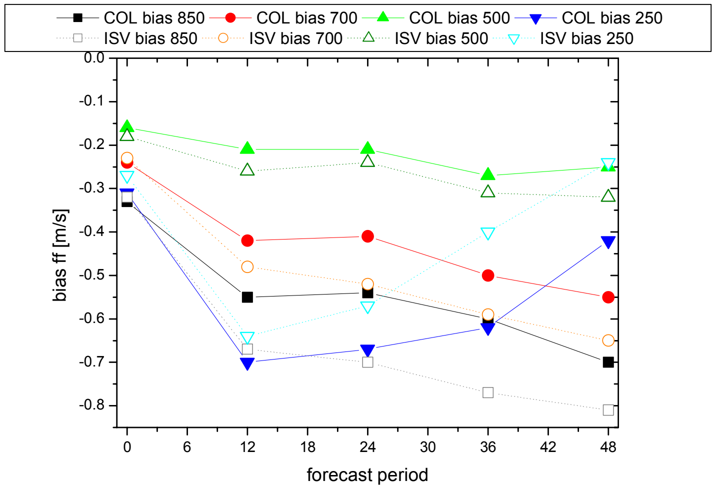
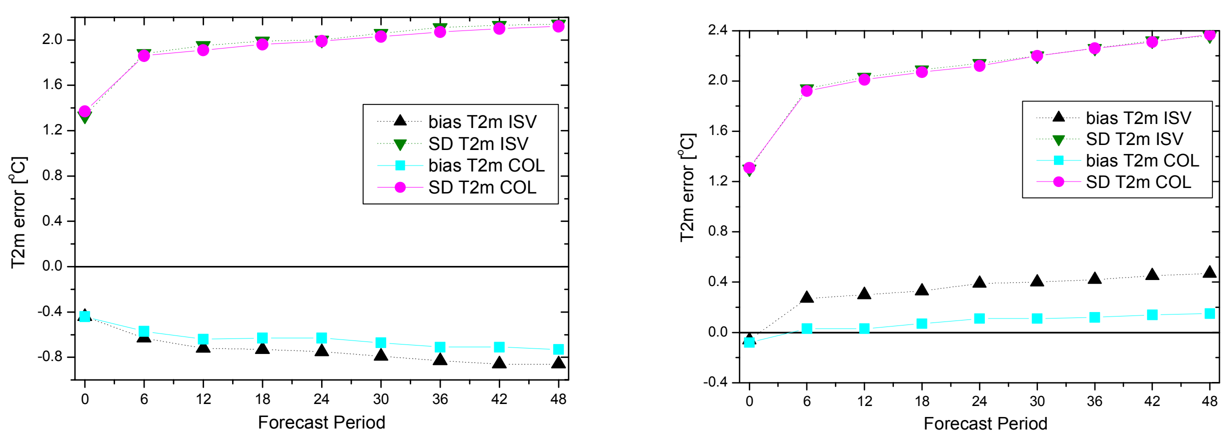


Fig. 7. Hirlam (ISV, COL) wind speed biases [m/s] against EWGLAM radiosonds for August 2002. Levels are given in [hPa].

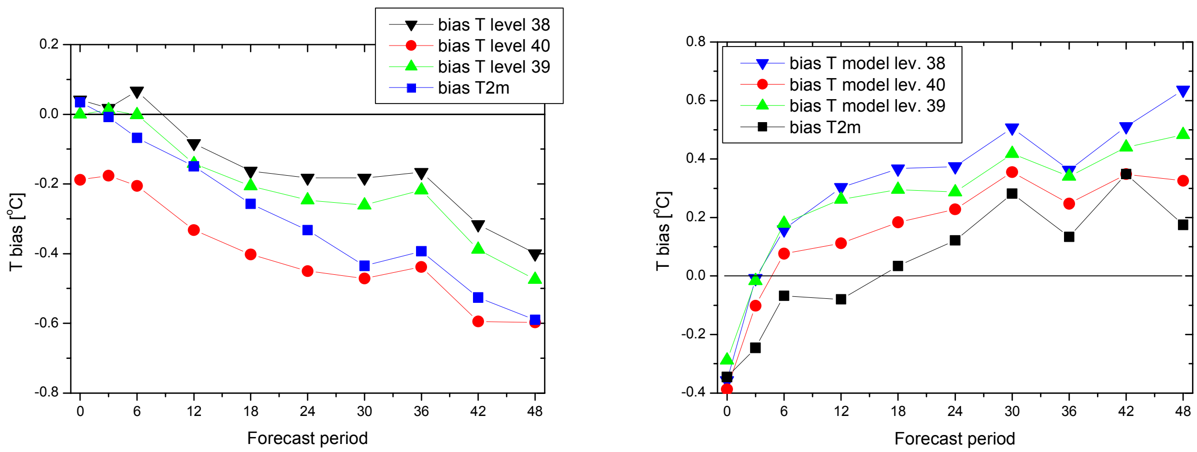
Fig. 7 presents wind speed biases against EWGLAM radiosonds for COL and ISV for August (results for October are very similar). While the small negative biases decrease at levels below 250 hPa with COL instead of ISV, COL produces somewhat larger biases at 250 hPa. We still do not have an explanation for this.

4b. Temperature

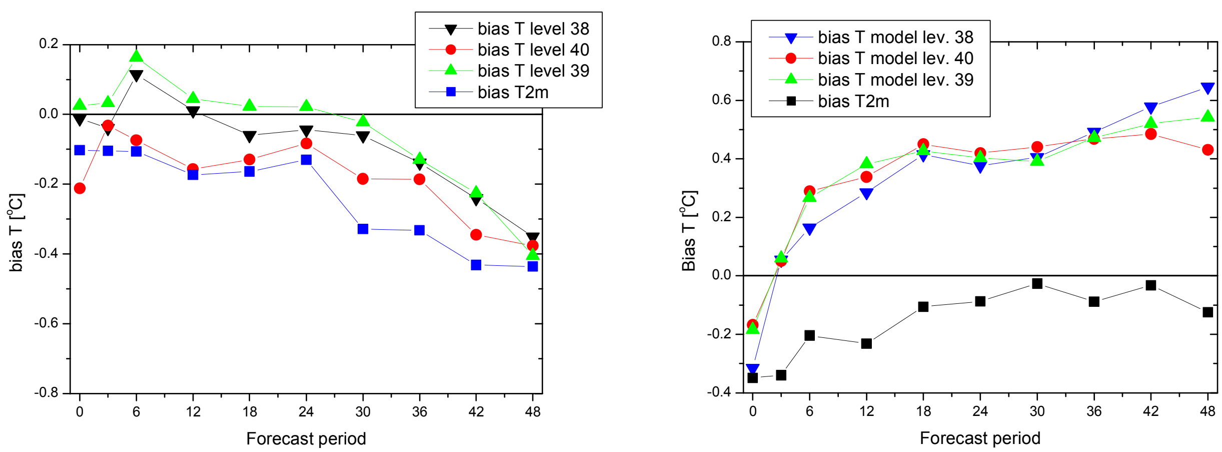


Figs. 8a (left panel) and 8b (right panel). Verification of T_{2m} (ISV and COL) against EWGLAM stations for August 2002 (Fig. 8a) and October 2002 (Fig. 8b)

For the same reasons as mentioned for wind speed (Fig. 1), the T_{2m} results against EWGLAM stations in Figs. 8a and b only give an indication of the impact of the different turbulence schemes. More interesting are the temperature results against Cabauw tower measurements.

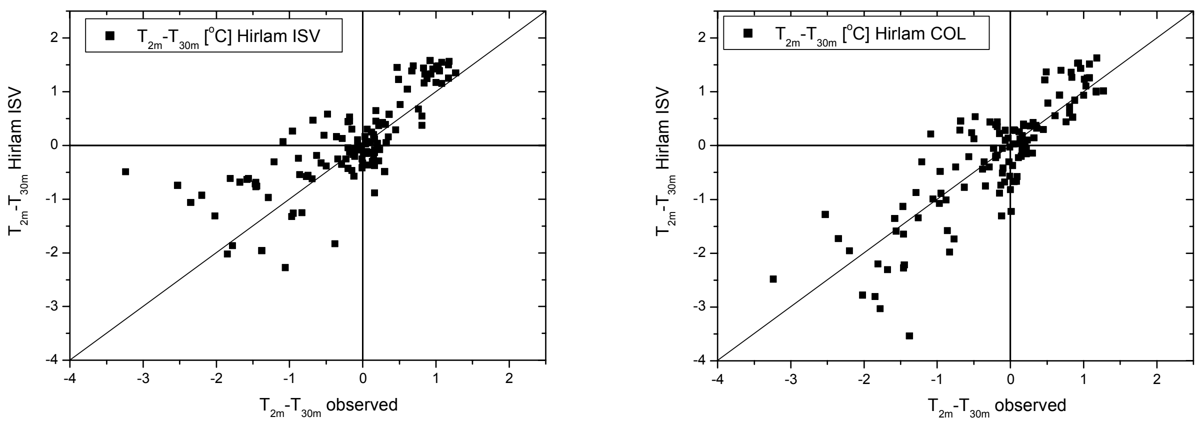


Figs.9a (left panel) and 9b (right panel). Hirlam (ISV) temperature biases [°C] at 2m and the lowest model levels, in Cabauw, for August 2002 (Fig. 9a) and October 2002 (Fig. 9b).

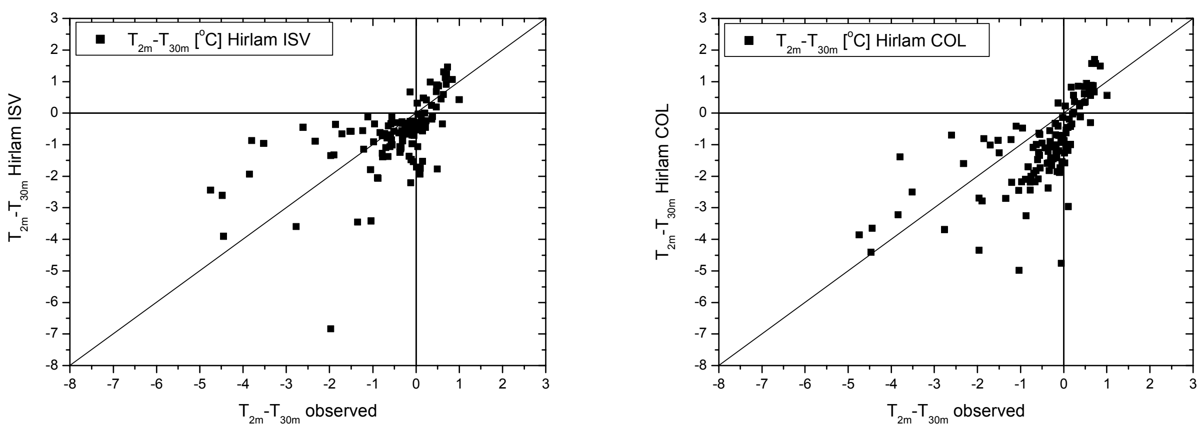


Figs.10a (left panel) and 10b (right panel). Hirlam (COL) temperature biases [°C] at 2m and the lowest model levels, in Cabauw, for August 2002 (Fig. 10a) and October 2002 (Fig. 10b).

Figs. 9a and 10a for August 2002 indicate a small improvement in the temperature profile with COL. Also Fig. 10b shows the better temperature profile with COL but with the exception of the peculiar (decoupled?) behavior of T_{2m} with COL.



Figs.11a (left panel) and 11b (right panel). Hirlam +12h forecast of T_{2m}-T_{30m} [^oC], in Cabauw, for August 2002, for ISV (Fig. 11a) and COL (Fig. 11b).

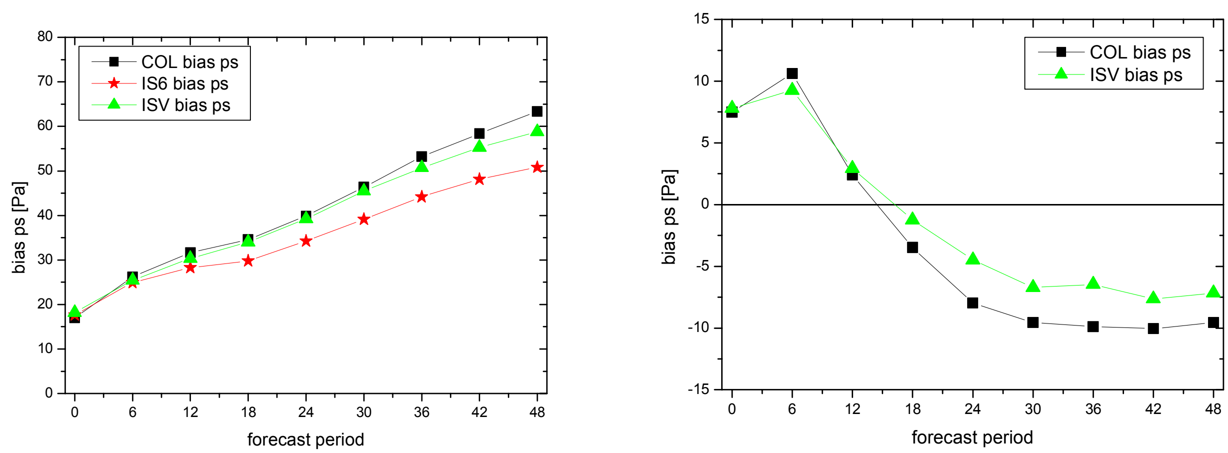


Figs.12a (left panel) and 12b (right panel). Hirlam +12h forecast of T_{2m}-T_{30m} [^oC], in Cabauw, for October 2002, for ISV (Fig. 12a) and COL (Fig. 12b).

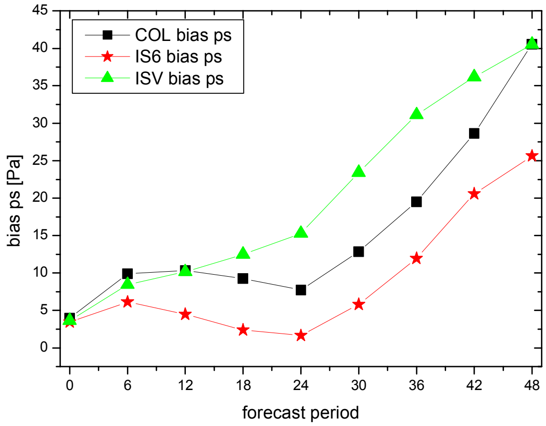
This phenomenon can also be recognized in Fig. 12b, where COL shows more too stable temperature differences in the moderately stable regime than ISV (Fig. 12a), and this also led to more underestimations of T_{2m} during nighttime, moderately stable conditions (not presented). However, during very stable conditions both versions overestimate T_{2m} (a well-known problem). Due to the earlier mentioned lack of time, the reason for the relatively cold T_{2m} with COL is not yet clear. More verification is necessary to find out if COL can lead to decoupled layers with much too cold near surface temperatures. Anyhow, for August, Figs. 11a and b show nicely improved temperature profiles near the surface with COL.

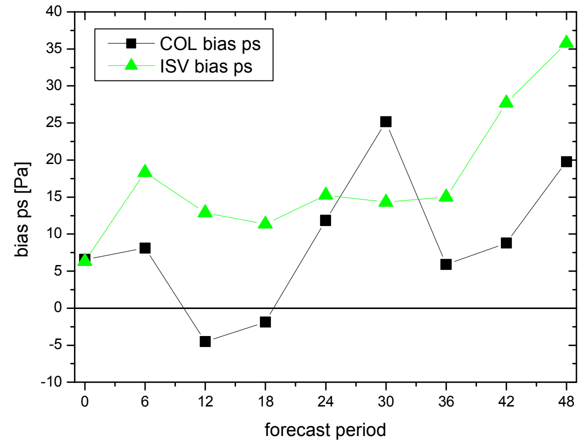
4c. Surface pressure

So far, we mainly investigated the mixing and the verification of near surface parameters. Also important is the question: Does COL maintain the good results of ISV for synoptic scale developments? This question is mostly beyond the scope of this note but maybe we can get a glimpse of the answer by looking at the surface pressure (ps) results.
SD of ps (not shown) is slightly larger with COL than with ISV or IS6. This can be explained by the stronger mixing of ISV and IS6, which leads to more smooth ps fields and therewith generally smaller SD. The ps bias against EWGLAM stations (Figs. 13a and 13b) is somewhat better with ISV instead of COL, but somewhat worse against Nt+ stations (Figs. 14a and 14b). Maybe representation mismatches associated with mountainous EWGLAM stations have a notable influence on the surface pressure results (although less than for temperature or wind speed). Therefore, also for pressure, caution should be taken in making conclusions about the skill of the model. Note that the biases are in [Pa] and therefore all presented errors can be considered small. Figs. 13a and 14a also reveals that larger roughnesses (ISV instead of IS6) generally lead to higher ps. A very speculative reason for this could be that wind coming from sea is slowed down more due to the higher roughness, leading to an increase of "accumulation" of air above land, thus leading to higher surface pressure. For winter months, with generally negative ps biases, this increased ps would be beneficial.



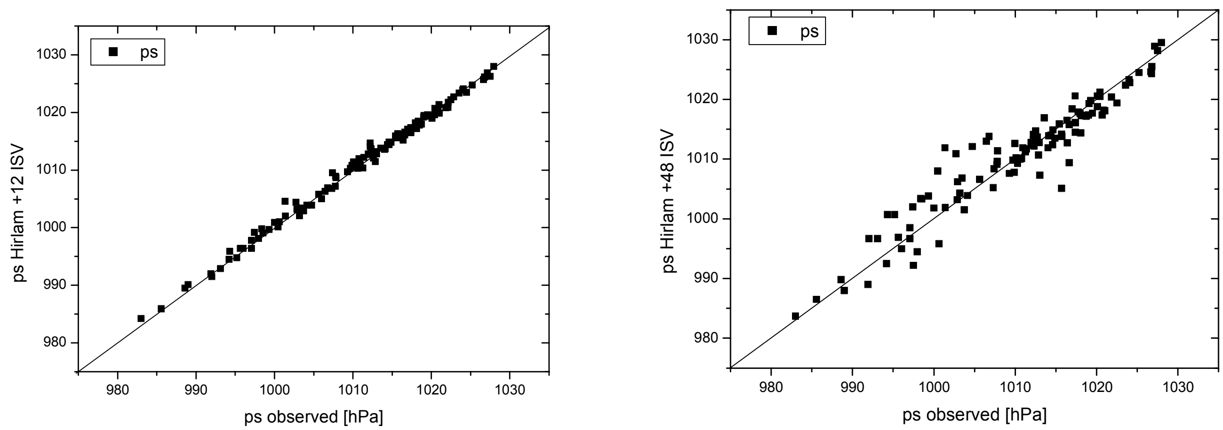
Figs.13a (left panel) and 13b (right panel). Hirlam (IS6, ISV, and COL) surface pressure (ps) biases [Pa] against EWGLAM stations, for August 2002 (Fig. 13a), and October 2002 (Fig. 13b).



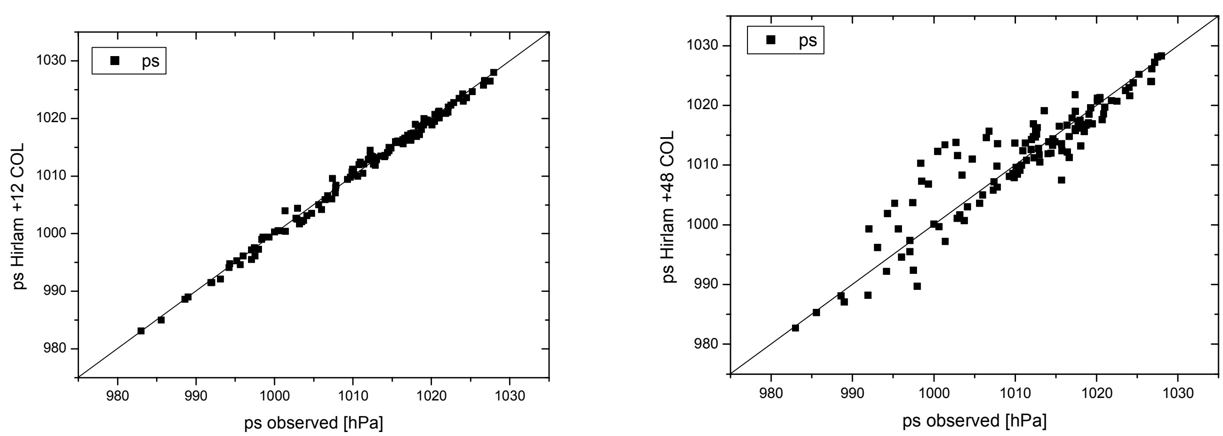


Figs.14a (left panel) and 14b (right panel). Hirlam (IS6, ISV, and COL) surface pressure (ps) biases [Pa] against Nt+ stations, for August 2002 (Fig. 14a), and October 2002 (Fig. 14b).

De Rooy (2001a) showed with an older CBR version, surface pressure scatter plots for Cabauw, for February 2001. He found that during the forecast, low pressures were increasingly underestimated, possibly due to not enough drag in the model. However, increasing the roughness turned out to have no impact on the underestimations of the low pressures (De Rooy 2001b). Comparing the +48h ps scatter plots for ISV and IS6 (not shown) confirm that there is no visible impact on the ps results (in contrast with Figs. 13a and 14a). Surface pressure scatter plots for August and October with all versions do not show underestimations of low pressures (possibly due to enhanced mixing in CBR, or because neither months are real winter months?). Unfortunately we do not have results with the older (less mixing) CBR version to see if low pressures are underestimated for these months. For August (not shown) no significant difference can be found between COL and ISV, but for October +48h forecasts (Figs. 15b and 16b) COL gives larger overestimations in the 995-1010 hPa range. Considering the decreased mixing in COL, these larger overestimations seem unexpected.



Figs.15a (left panel) and 15b (right panel). Hirlam (ISV) surface pressure forecasts [hPa] against Cabauw observations, for October 2002. The left panel shows +12h forecasts and the right panel +48h forecasts.



Figs.16a (left panel) and 16b (right panel). Hirlam (COL) surface pressure forecasts [hPa] against Cabauw observations, for October 2002. The left panel shows +12h forecasts and the right panel +48h forecasts.

5. Conclusions and discussion

In ISBA, large parts of the Hirlam model region are covered by low vegetation tiles, with very low z_0 values corresponding with homogeneous land use. However, such ideal homogeneous landscapes hardly exist. The usually apparent small-scale obstacles like tree lines, hedges and dikes, often have a dominating influence on the effective roughness. Therefore we suggest to increase the roughnesses for these low vegetation types to values corresponding with typical heterogeneous landscapes. A more thorough analysis about the proper z_0 values should still be made.

Hirlam version 6.1.1. includes an update of CBR (developed by Colin Jones) with increased mixing of momentum. As often observed, this increased mixing led to a better prediction of synoptic developments but the already positive bias in the 10m-wind speed further increased. The combination of the updated CBR scheme and the modified (larger) roughnesses results in small 10m-wind speed biases against EWGLAM stations and Cabauw. When using the modified roughnesses, the difference between the model roughness and the local roughness is small for the Cabauw site. Therefore, wind speed verification results against Cabauw can mostly be ascribed to the model performance. Verification of the lowest model levels against Cabauw shows the excessive mixing of momentum near the surface during especially stable conditions, leading to strong negative wind speed biases at 100 and 185m. This excessive mixing also results in the total absence of low-level jets. Hence, Colin Jones made a new update of CBR to reduce the mixing of momentum near the surface during stable conditions. This last update results in much better wind profiles near the surface. Also the temperature profiles seem better, with the exception of a peculiar difference in temperature bias between 2m and the lowest model levels during moderately stable conditions in October. Therefore, more temperature verification is necessary to find out if this update can lead to decoupling with much too low near surface temperatures. Verification of the surface pressure gives no clear indication if the improvements in synoptic development are maintained with the last CBR update. Also for that, more verification is necessary.

Acknowledgements
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