Experimentation with a modified surface stress

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7th May 2004

1 Introduction

The negative bias in HIRLAM surface pressure (and mean-sea-level pressure, p_{msl}) forecasts has been a long-lasting problem. The problem in February 2004 was again prominent as documented by Järvenoja (2004). What makes it still more embarrassing is the fact that the bias was worse in the new operational RCR at FMI, based on HIRLAM 6.2.1 version, than in the old FMI operational ATX system, based on HIRLAM 5.1.4. Another problem has been the positive bias in 10-metre wind speed (V_{10m}), as also reported in Järvenoja (2004).

In the HIRLAM All Staff Meeting (Madrid, 1-3 March 2004), Sass and Nielsen (2004) presented an idea of turning the surface stress vector ($\vec{\tau}_s$) clockwise (in NH) relative to the lowest model level wind (see also, Tijm, 2003). This write-up documents some test runs using the HIRLAM Reference version 6.1.2 and the same version with modifications for turning the surface stress by Sass and Nielsen (2004).

2 Parallel runs

Parallel test runs have been carried out using the HIRLAM Reference version 6.1.2. The runs have been conducted on the IBM at CSC (Center for Scientific Computing). The parallel experiments are as follows:

- REF : Reference HIRLAM version 6.1.2, with the bug in diagnosis of the ice cover from the analysed SST field corrected (Järvenoja, 2004)
- TAU : as REF, but the surface stress vector ($\vec{\tau}_s$) turned as described by Sass and Nielsen (2004)

The common features for the experiments are:

- Domain: Area corresponding to the old FMI operational suite (ATX) with a 0.3° horizontal resolution; model domain shown in Fig. 1
- 256 × 186 grid points; 40 levels in the vertical
- Semi-Lagrangian advection, time step 450 s
- Each suite with its own data assimilation (3D-Var, 6 h cycling)
- ISBA surface scheme with the related surface analysis package

- Lateral boundary conditions: ECMWF frames with horizontal resolution of 0.4°, as received operationally
- 48 h forecasts from 00 UTC analyses only
- Period: 30 January 2004 - 29 February 2004

3 Results

The experiments were carried out for the month of February 2004, when the HIRLAM RCR at FMI suffered from a large negative p_{msl} bias over continental Europe (Järvenoja, 2004). Fig. 1, showing the average p_{msl} (00 UTC analyses from REF) for February, demonstrates that the month of February was characterized with a high pressure in southern Europe, and two separate low pressure centres in northern latitudes, one over the Atlantic south of Greenland and the other over the Arctic north of Scandinavia.

In the following, some verification results from REF and TAU experiments will be presented.

3.1 Observation verification

Figure 2 demonstrates the observation verification (EWGLAM stations) scores of p_{msl} (upper row) and V_{10m} (lower row), for REF (left) and TAU (right) experiments. The p_{msl} scores indicate that the REF run has a bias of the order of -0.5 hPa in long forecasts, while the TAU run is only slightly negatively biased in terms of p_{msl}. This clearly points out that the modified surface stress has helped to reduce the negative p_{msl} bias. The TAU run also shows a smaller rms error in p_{msl} compared to REF, especially in longer forecasts, mainly due to the smaller bias.

The V_{10m} verification scores show that the REF run has a positive bias of almost 1 m/s. The bias curve also reveals a clear diurnal cycle: bias is larger in the nighttime (24 and 48 h) than in the daytime (12 and 36 h). This feature was seen also in pre-RCR tests at FMI as reported by Järvenoja (2004). The V_{10m} bias is much smaller in the TAU experiment: 0.5 m/s at night and only slightly positive in the daytime. This means the the modified surface stress helps to reduce the V_{10m} bias by about 0.5 m/s. Due to the smaller bias, also the V_{10m} rms error of TAU is smaller than that of REF. Scores of the two-metre temperature (T_{2m}) are similar for REF and TAU and are therefore not shown.

Observation verification scores for upper-air parameters (not shown) indicate the same kind of features as seen in connection of the surface parameters. The negative bias in geopotential heights (850, 500 and 250 hPa) is smaller in TAU than in REF. The practically unbiased upper-air winds (REF) become slightly negatively biased when introducing the surface stress modifications (TAU).

3.2 Field verification

Figures 3 and 4 demonstrate the geographical distribution of the p_{msl} bias in the 48 h forecasts for February 2004, for REF and TAU experiments, respectively. The negative bias in the REF run (Fig. 3) over continental Europe is similar to that seen in the old operational ATX system (5.1.4) at FMI, as documented in Järvenoja (2004), but the bias is smaller than that in the new RCR system at FMI. The largest negative bias, more than 3 hPa, is seen over the Baltic states. The negative bias (more than 2 hPa) over the Atlantic west of Europe is larger than that in the ATX system. This difference may be due to different HIRLAM versions and due the fact that 48 h forecasts were run from 00 UTC only in the REF run. Figure 4, depicting the p_{msl} bias for the TAU run, reveals that the negative bias is clearly smaller than that in the REF run. The bias values, e.g. over the Baltic states are somewhat over 1 hPa, while the values in the REF run exceeded 3 hPa. One drawback in the TAU run may be the larger positive bias in high latitudes compared to the REF run: over 2 hPa in TAU west of Greenland (above 1 hPa in REF) and over 2 hPa over Spitzbergen and Novaya Zemlya (less than 1 hPa in REF). As a whole, the modified surface stress (TAU) helps to reduce the negative p_{msl} bias over Europe, which is a welcome result.

Figures 5 and 6 show the distribution of the rms error of p_{msl} in the 48 h forecasts for February 2004, for REF and TAU experiments, respectively. Large values, as much as 6 hPa at maximum, can be seen over the North Atlantic and northern Europe in both REF and TAU runs. The rms error is somewhat smaller in the TAU run compared to the REF run, e.g. over Russia north of the Black Sea, over the Baltic states and Scandinavia, i.e., over areas where TAU also showed a smaller bias. As a whole the TAU run is somewhat better than the REF run in terms of the p_{msl} rms error.

3.3 Systematic differences

Next, some systematic differences between TAU and REF experiments for a few parameters are shown.

Figure 7 shows the systematic difference in the 48 h p_{msl} forecasts between TAU and REF (TAU-REF) experiments for February 2004. The TAU run has higher p_{msl} values than the REF run over large areas in high latitudes, in low pressure areas (see, Fig. 1), with the largest p_{msl} difference being 3.5 hPa over the Arctic between Spitzbergen and Novaya Zemlya. On the other hand, the pressure difference over Russia north of the Black Sea and over the Baltic states, in the area of the largest p_{msl} bias in the REF run, is smaller, being only 0.5-1.5 hPa. It seems that the p_{msl} increase through introduction of the modified surface stress is larger on the northern (cold) side of the low pressure area than on the southern (warm) side of the low pressure area. Consequently, some (1-2 hPa) of the negative p_{msl} bias is left over Russia north of the Black Sea in the TAU run, while some positive p_{msl} bias is generated over the Arctic. A small negative difference in p_{msl} is seen over the Atlantic west of the British Isles, in the area of a ridge of high pressure.

The large positive systematic differences between TAU and REF p_{msl} forecasts over the Arctic north of Scandinavia coincide with negative differences in the 1000 hPa temperature (T_{1000}), as shown in Fig. 8. Negative differences can be seen also over the Greenland coastal slopes. The differences are small elsewhere.

Figures 9 and 10 show systematic differences in the 48 h geopotential height forecasts between TAU and REF runs for 500 and 300 hPa, respectively. Figure 9 demonstrates that the TAU run results in higher 500 geopotential height (Z_{500}) values than REF in the low pressure areas (Fig. 1). A similar feature is seen also at 300 hPa (Fig. 10), although the differences are somewhat smaller.

Finally, Figs. 11 and 12 demonstrate the systematic differences in the predicted winds between TAU and REF, near the surface (V_{10m}) and at 700 hPa (V_{700}), respectively. Figure 11 reveals that the TAU run results in lower V_{10m} values than REF over almost the whole model domain. The predicted TAU wind speeds are at least 0.5 m/s lower than those of REF, except in the boundary zone and over Greenland. Over sea areas, over the Atlantic and the Arctic, the TAU wind speeds can be as much as 1.5-2 m/s lower than those of REF at some places. The systematic differences in V_{10m} between TAU and REF support the observation verification results presented in Section 3.1. The positive V_{10m} bias seen in the REF run is reduced through introduction of the modified surface stress (TAU).

The systematic differences in the predicted V_{700} between TAU and REF experiments (Fig. 12) demonstrate that the modified surface stress reduces the wind speed also in the upper atmosphere. The reduction can be as much as 2 m/s. The same type of reduction, though smaller, can be seen also higher in the atmosphere (not shown). The appearance of the difference fields (Figs. 11 and 12) is slightly worrying because of cellular, small-scale structures, which might indicate that one of the wind fields, that of TAU or REF, would have a noisy structure (not studied).

4 Summary and concluding remarks

Parallel runs have been carried out to demonstrate the impact of the modified (turned) surface stress introduced by Sass and Nielsen (2004). The results indicate that the modified surface stress helps to reduce the negative p_{msl} bias seen in the HIRLAM forecasts. The impact is seen also in the upper-air fields as a reduced geopotential height bias. The modified surface stress also results in lower V_{10m} values, thus reducing the positive bias that has been a problem in the HIRLAM forecasts for some time. The impact is seen also in the upper-air winds that have become slightly negatively biased due to the modified surface stress. As a whole, the modified surface stress clearly improves the p_{msl} and V_{10m} scores. A deeper study might be needed to find out possible side effects of the modified surface stress as the dubious structures in the difference fields of the winds might suggest.

A lot of work has been devoted to solving the negative p_{msl} bias and the positive V_{10m} bias in HIRLAM forecasts recently. Rontu (2004) has carried out experiments trying to find out the impact of e.g. modified roughness length(s), new orographic turbulence and meso-scale orography parameterizations. Her experiments reveal that the modified vegetation roughness (de Rooy, 2003) helps to half the positive bias in V_{10m}. Some bias reduction is also achieved through introduction of new orographic turbulence and meso-scale orography parameterizations. However, none of her experiments showed any significant reduction in the p_{msl} bias. The results in this write-up demonstrate that turning of the surface stress vector has a positive impact on both V_{10m} and p_{msl}.

References

Järvenoja, S., 2004: Towards the operational RCR system - results from pre-operational runs. *HIRLAM Newsletter*, **45**, (in this issue).

de Rooy, W., 2003: Modified roughness in ISBA and validation of CBR updates. *HIRLAM Newsletter*, **44**, 61-73.

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Sass, B.H. and N. W. Nielsen, 2004: Modelling of the HIRLAM surface stress direction. *HIRLAM Newsletter*, **45**, (in this issue).

Tijm, S., 2003: Different aspects of CBR/CLJ. *HIRLAM Newsletter*, **44**, 49-60.

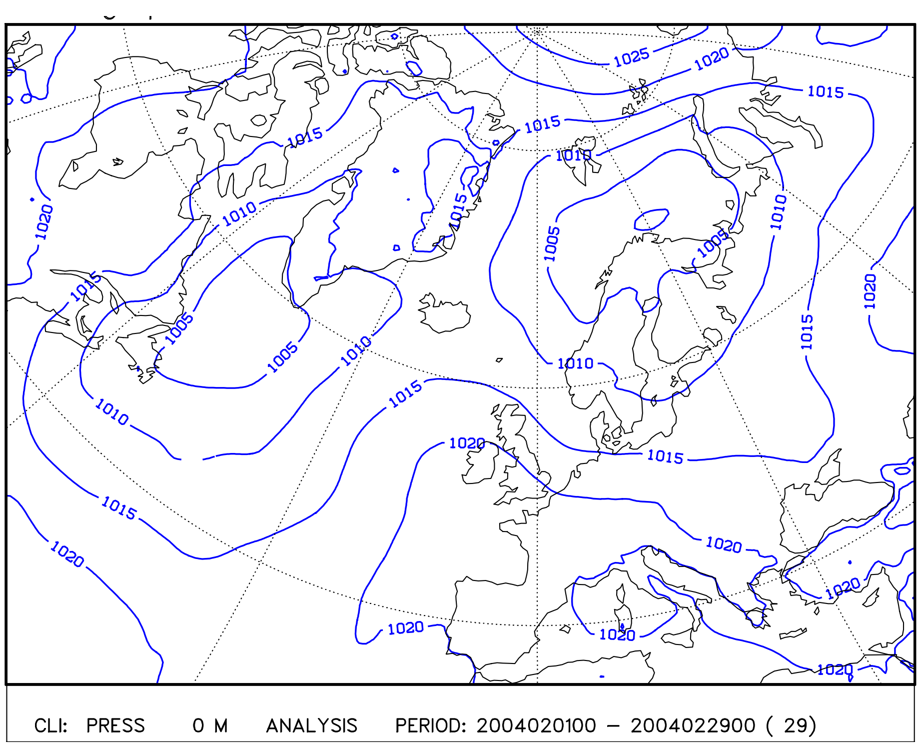

Figure 1: *Average* p_{msl} *for February 2004 as calculated from REF 00 UTC analyses. Contour interval: 5 hPa.*

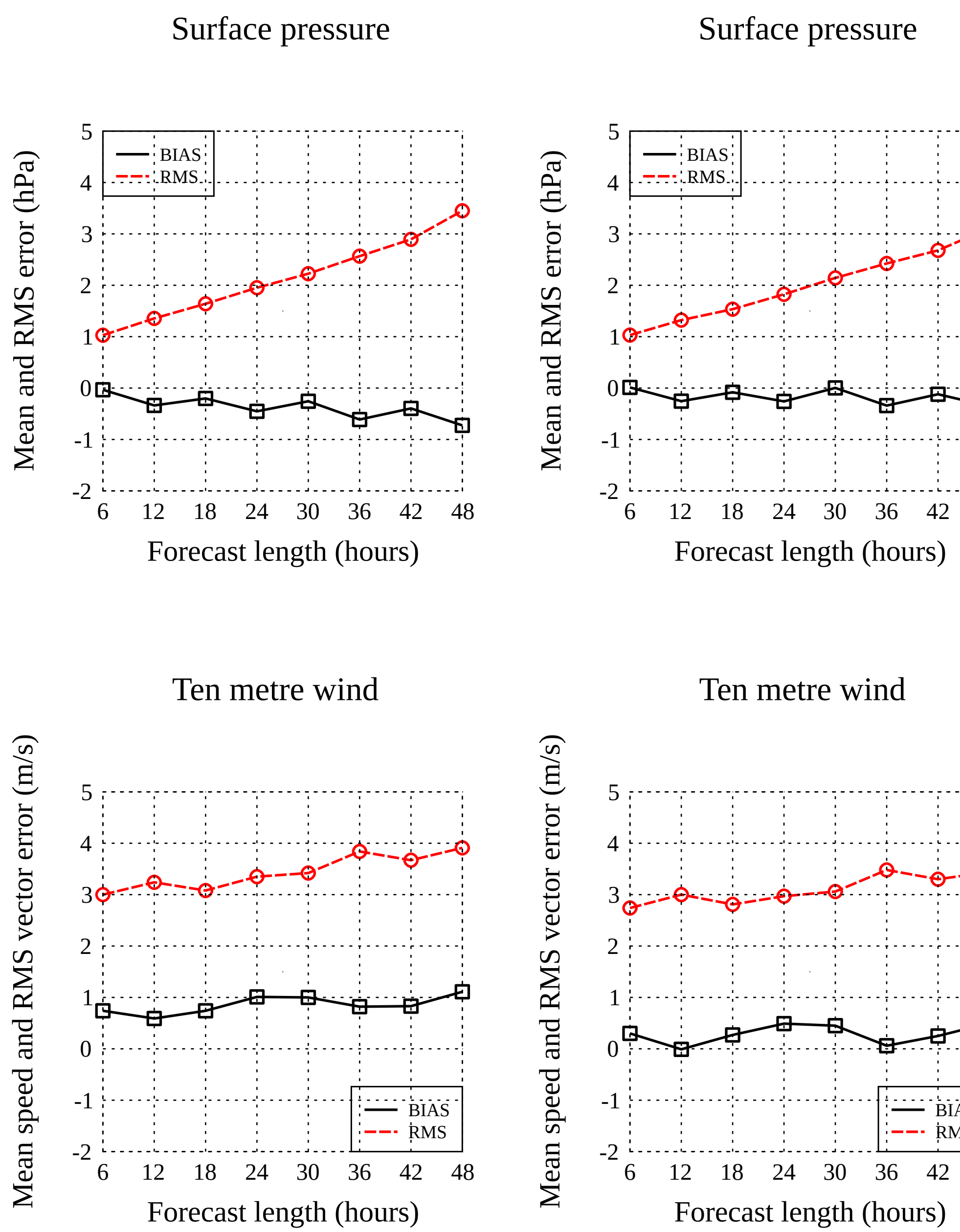

Figure 2: *Observation verification scores (EWGLAM stations) of* p_{msl} *(upper row) and* V_{10m} *(lower row) for REF (left) and TAU (right), for February 2004. Bias is indicated with squares and rms error with circles.*

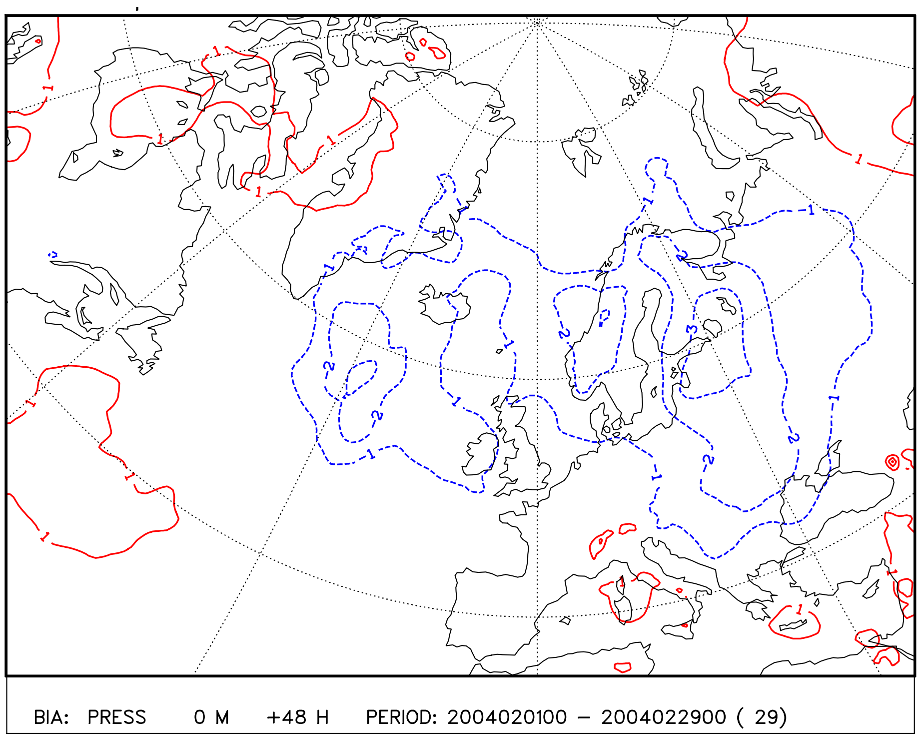

Figure 3: P_{msl} *bias in REF 48 h forecasts starting from 00 UTC, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

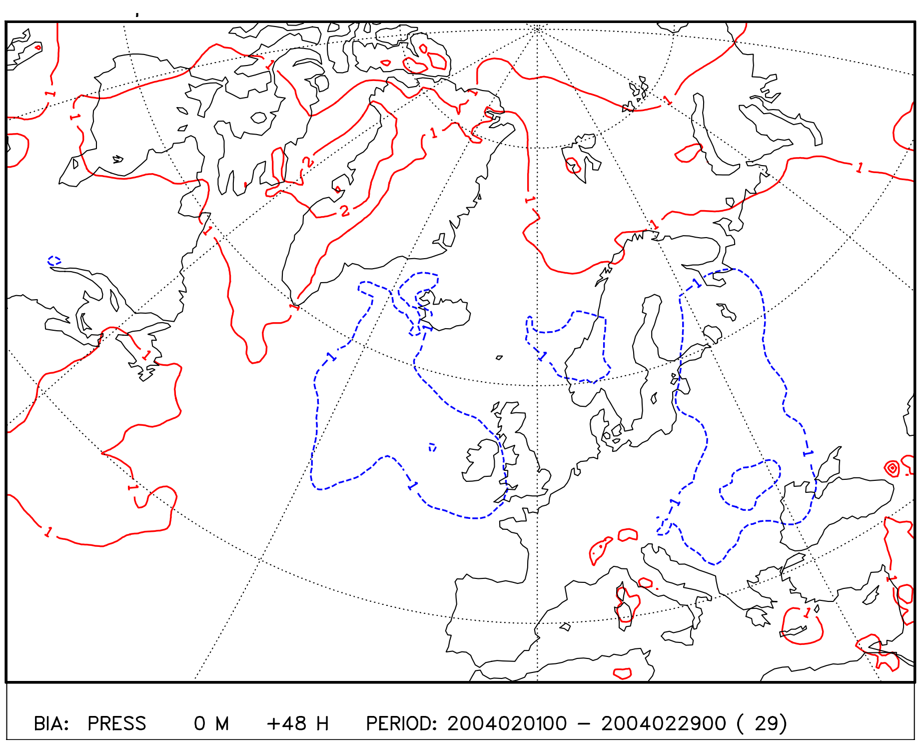

Figure 4: P_{msl} *bias in TAU 48 h forecasts starting from 00 UTC, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

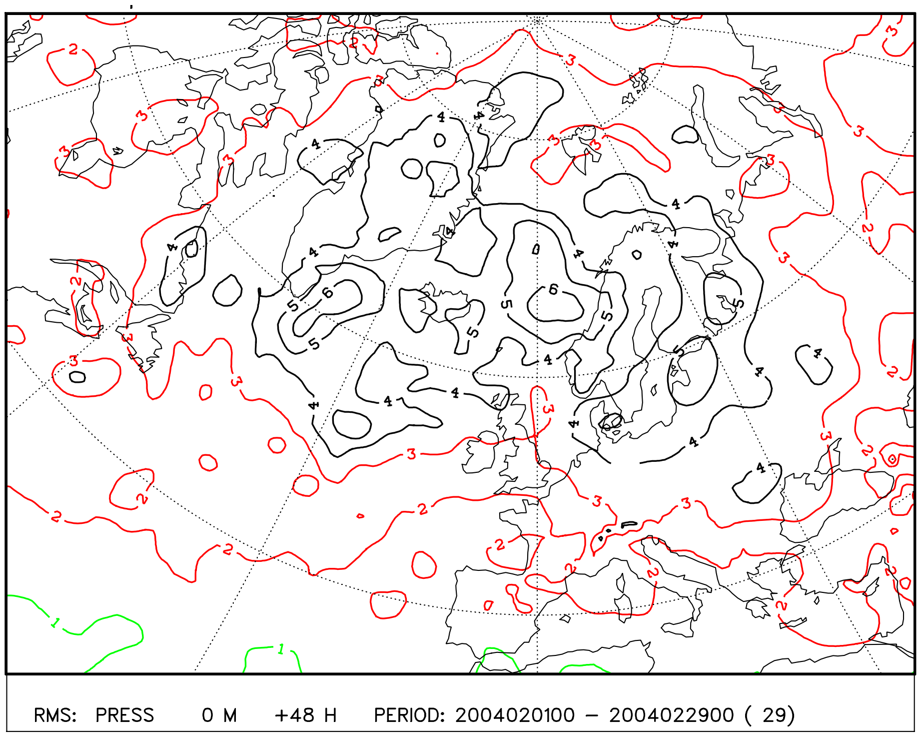

Figure 5: P_{msl} *rms error in REF 48 h forecasts starting from 00 UTC, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

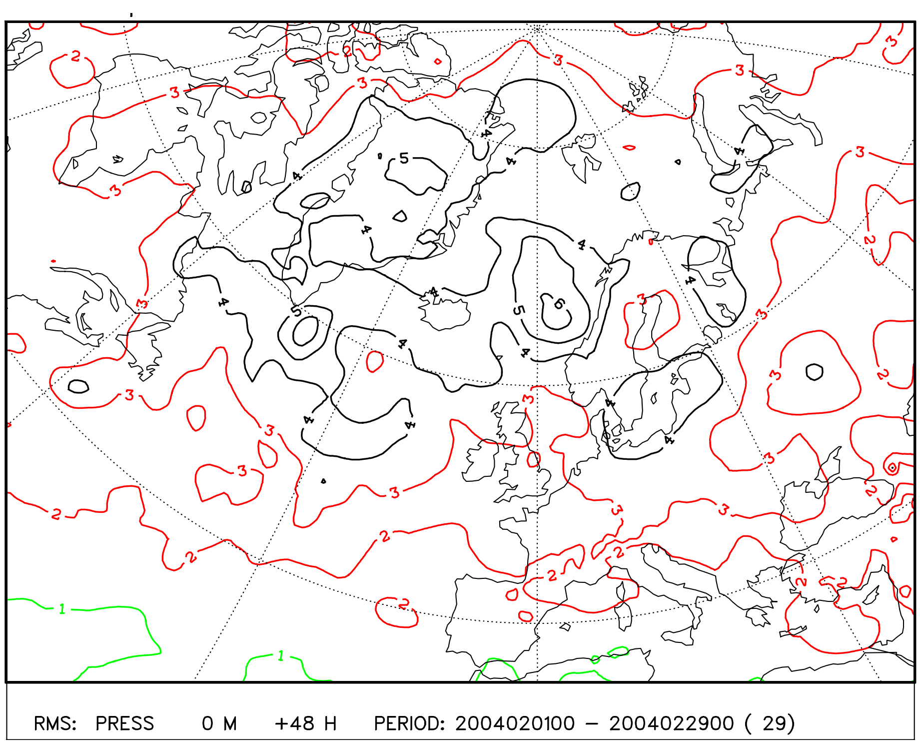

Figure 6: P_{msl} *rms error in TAU 48 h forecasts starting from 00 UTC, for February 2004. Contour interval: 1 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

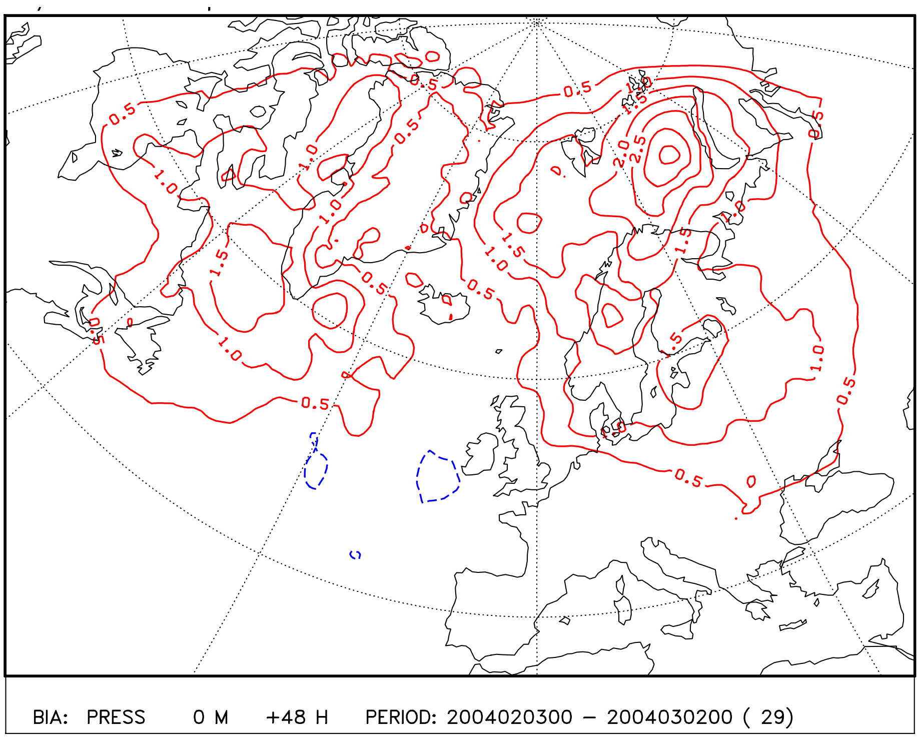

Figure 7: *Systematic difference in 48 h* p_{msl} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 0.5 hPa. The zero isoline not plotted, negative values indicated with dashed lines.*

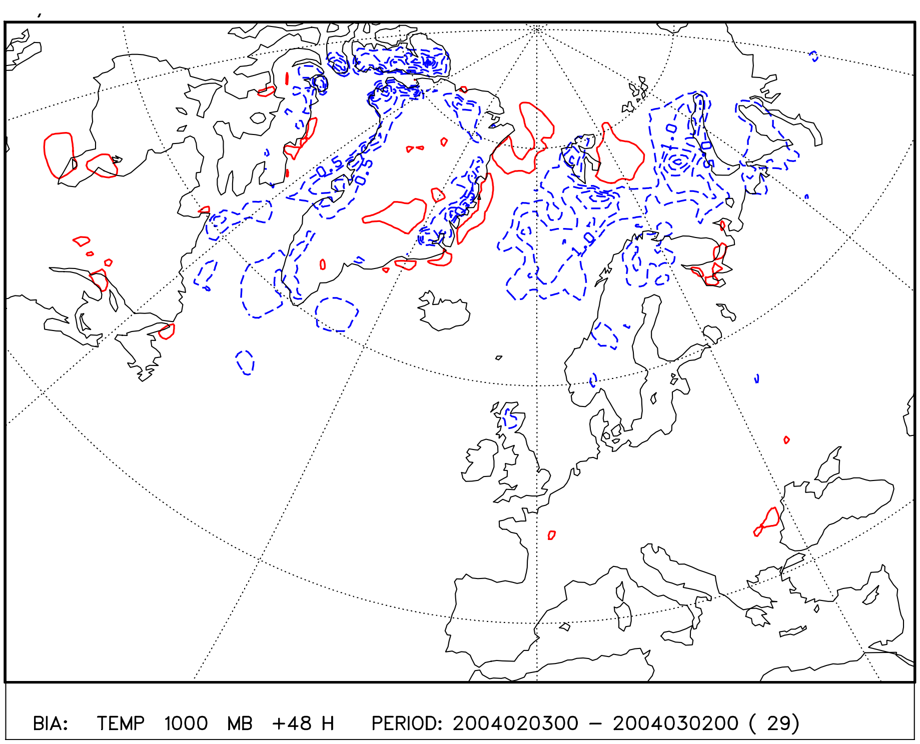

Figure 8: *Systematic difference in 48 h* T_{1000} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 0.5° C. The zero isoline not plotted, negative values indicated with dashed lines.*

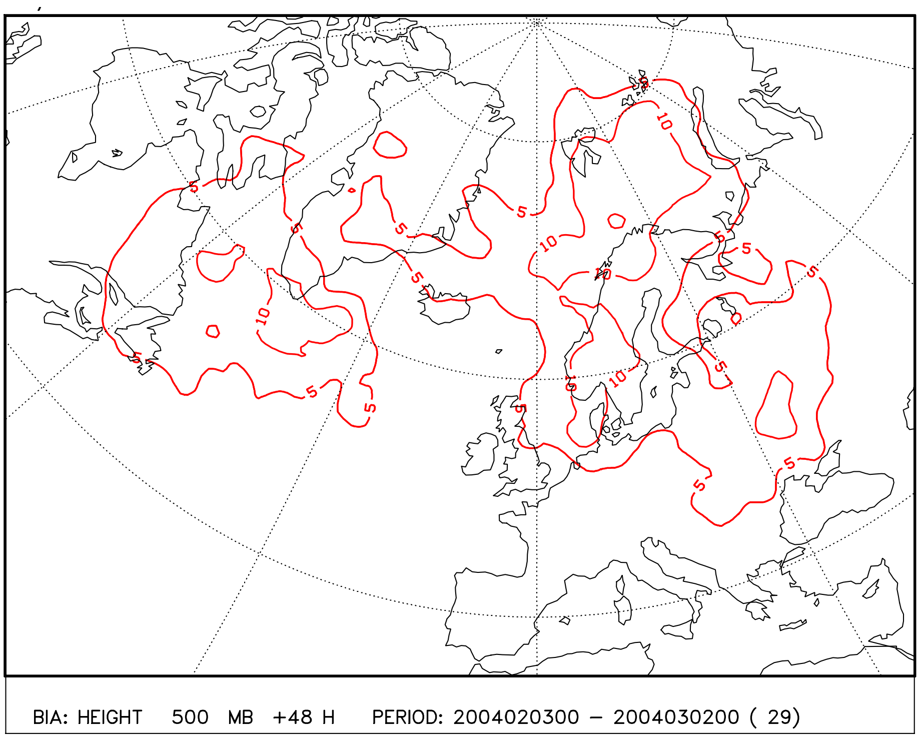

Figure 9: *Systematic difference in 48 h* Z_{500} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 5 m. The zero isoline not plotted, negative values indicated with dashed lines.*

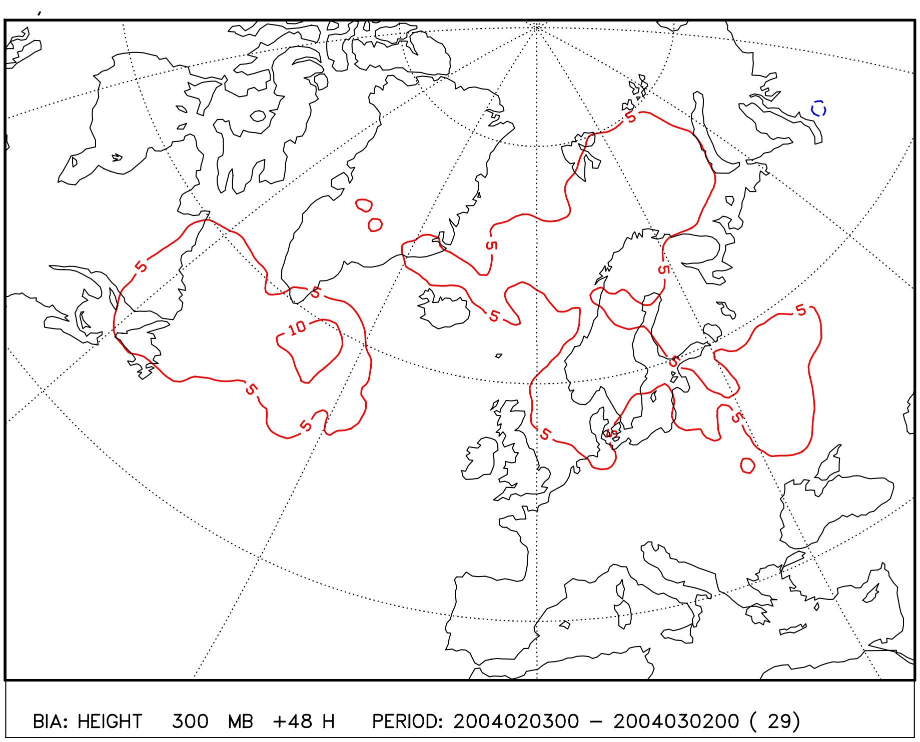

Figure 10: *Systematic difference in 48 h* Z_{300} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 5 m. The zero isoline not plotted, negative values indicated with dashed lines.*

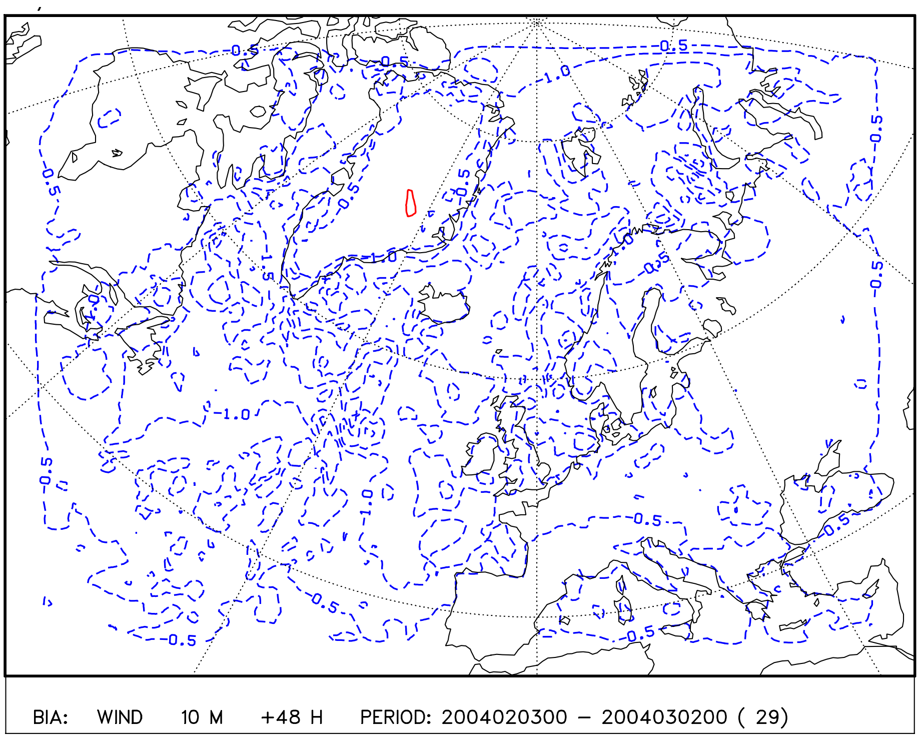

Figure 11: *Systematic difference in 48 h* V_{10m} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 0.5 m/s. The zero isoline not plotted, negative values indicated with dashed lines.*

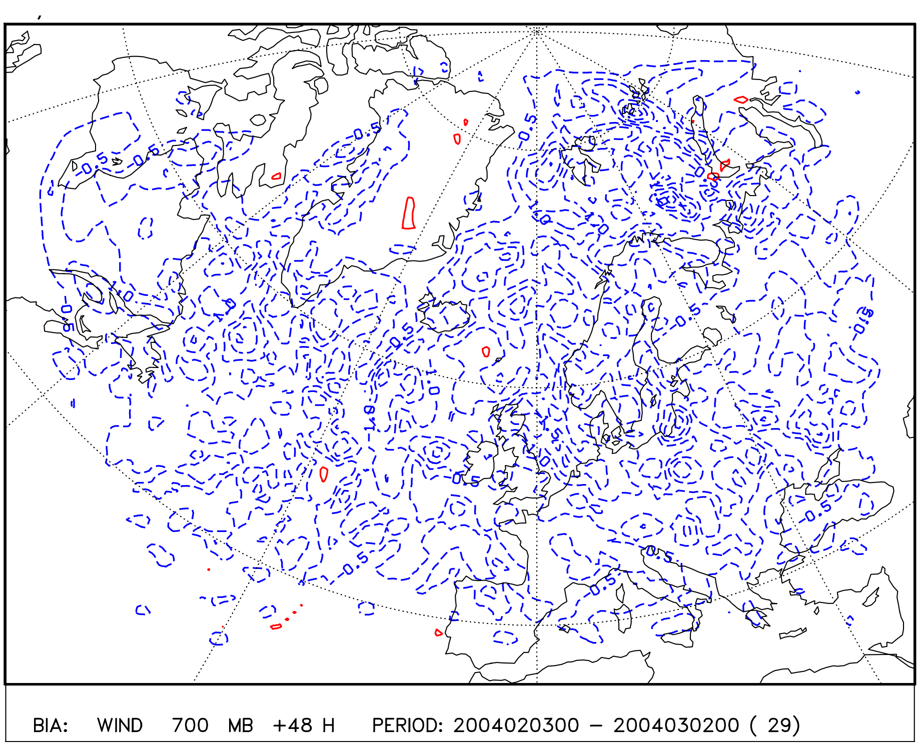

Figure 12: *Systematic difference in 48 h* V_{700} *forecasts between TAU and REF experiments (TAU-REF) for Februry 2004. Contour interval: 0.5 m/s. The zero isoline not plotted, negative values indicated with dashed lines.*